energy

[r]evolution

A SUSTAINABLE WORLD ENERGY OUTLOOK

GWEC
GLOBAL WIND ENERGY COUNCIL

EREC
EUROPEAN RENEWABLE ENERGY COUNCIL

GREENPEACE

report 4th edition 2012 world energy scenario

"will we look into the eyes of our children and confess

that we had the **opportunity**,
but lacked the **courage**?
that we had the **technology**,
but lacked the **vision**?"

partners

Greenpeace International, European Renewable Energy Council (EREC), Global Wind Energy Council (GWEC)

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image A WOMAN CARRIES HER DAUGHTER AS SHE WALKS THROUGH A FLOODED STREET NEAR BANGPA-IN INDUSTRIAL PARK IN AYUTTHAYA, THAILAND. OVER SEVEN MAJOR INDUSTRIAL PARKS IN BANGKOK AND THOUSANDS OF FACTORIES HAVE BEEN CLOSED IN THE CENTRAL THAI PROVINCE OF AYUTTHAYA AND NONTHABURI WITH MILLIONS OF TONNES OF RICE DAMAGED. THAILAND IS EXPERIENCING THE WORST FLOODING IN OVER 50 YEARS WHICH HAS AFFECTED MORE THAN NINE MILLION PEOPLE.

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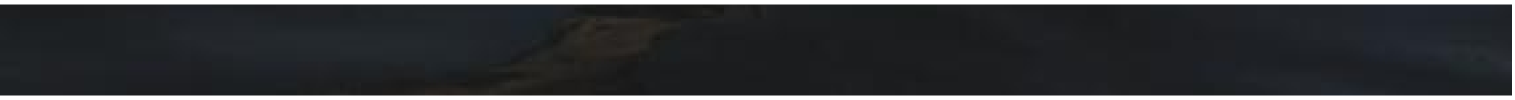

for further information about the global, regional and national scenarios please visit the Energy [R]evolution website: **www.energyblueprint.info/**

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foreword

The Global Energy [R]evolution series presents us with a compelling vision of an energy future for a sustainable world. The scenarios proposed by the Energy [R]evolution have gained a reputation for the insight and explanations they provide decision makers.

This fourth edition carries on this tradition, by outlining an updated and well-articulated pathway to achieve the transition to a global sustainable energy future. The International Renewable Energy Agency (IRENA) welcomes the recognition of the central role that renewable energy will play in this new energy paradigm.

contents at a glance

image LA DEHESA 50 MW PARABOLIC SOLAR THERMAL POWER PLANT. A WATER RESERVOIR AT LA DEHESA SOLAR POWER PLANT. LA DEHESA, 50 MW PARABOLIC THROUGH SOLAR THERMAL POWER PLANT WITH MOLTEN SALTS STORAGE. COMPLETED IN FEBRUARY 2011, IT IS LOCATED IN LA GAROVILLA AND IT IS OWNED BY RENOVABLES SAMCA. WITH AN ANNUAL PRODUCTION OF 160 MILLION KWH, LA DEHESA WILL BE ABLE TO COVER THE ELECTRICITY NEEDS OF MORE THAN 45,000 HOMES, PREVENTING THE EMISSION OF 160,000 TONNES OF CARBON. THE 220 H PLANT HAS 225,792 MIRRORS ARRANGED IN ROWS AND 672 SOLAR COLLECTORS WHICH OCCUPY A TOTAL LENGTH OF 100KM. BADAJOZ.

Achieving this transition relies on addressing key energy issues such as access to modern energy services, security of supply and the sustainability of the energy mix. Environmental degradation, increasing energy demand, and unsustainable resource use are critical challenges that must be addressed. Renewable energy will play an essential role in advancing sustainable development by improving the access of millions to energy, whilst helping ensure energy security, and mitigating the existential risk of climate change by reducing emissions.

The benefits associated with renewable energy are influencing how countries meet their energy needs, the increase in policies and investment globally attests to this. This growth in the uptake of renewable energy - the "Silent Revolution" - is playing out across the globe: over the last decade 430,000 MW of renewable energy capacity has been installed, with global total investment reaching a record $ 257 billion in 2011, a year in which renewable energy became a trillion dollar industry, and the cost of modern renewable energy technologies continued to fall.

Accelerating the "Silent Revolution" globally requires greater levels of commitment and cooperation to develop enabling policy, combined with practical business solutions. To enable this, policy makers, scientists and businesses require access to up-to-date, relevant and reliable data. Scenarios are a helpful aid for decision making, by mapping out the complex issues and information that must be considered. Through its investigation of issues surrounding the future of energy, the Global Energy [R]evolution 2012 makes an invaluable contribution to informing global decisions-makers.

The Global Energy [R]evolution publication provides an important complement to IRENA's efforts to provide knowledge and know-how, and to facilitate the flow of information encouraging the deployment of renewables. Therefore, it is with pleasure that IRENA welcomes this fourth edition of the Global Energy [R]evolution scenario, and the contribution the European Renewable Energy Council and Greenpeace have made to the vital debate on transitioning the world to a more secure and sustainable energy future.

Adnan Z. Amin
DIRECTOR-GENERAL
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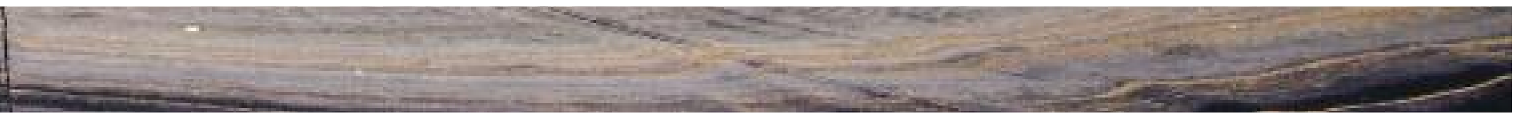
JULY 2012



contents

image A WOMAN IN FRONT OF HER FLOODED HOUSE IN SATJELLIA ISLAND. DUE TO THE REMOTENESS OF THE SUNDARBANS ISLANDS, SOLAR PANELS ARE USED BY MANY VILLAGERS. AS A HIGH TIDE INVADES THE ISLAND, PEOPLE REMAIN ISOLATED SURROUNDED BY THE FLOODS.

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image NORTH HOYLE WIND FARM, UK'S FIRST WIND FARM IN THE IRISH SEA WHICH WILL SUPPLY 50,000 HOMES WITH POWER.

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image A YOUNG INDIGENOUS NENET BOY PRACTICES WITH HIS REINDEER LASSO ROPE. THE INDIGENOUS NENETS PEOPLE MOVE EVERY 3 OR 4 DAYS SO THAT THEIR REINDEER DO NOT OVER GRAZE THE GROUND AND THEY DO NOT OVER FISH THE LAKES. THE YAMAL PENINSULA IS UNDER HEAVY THREAT FROM GLOBAL WARMING AS TEMPERATURES INCREASE AND RUSSIAS ANCIENT PERMAFROST MELTS.

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introduction

"FOR THE SAKE OF A SOUND ENVIRONMENT, POLITICAL STABILITY AND THRIVING ECONOMIES, NOW IS THE TIME TO COMMIT TO A TRULY SECURE AND SUSTAINABLE ENERGY FUTURE."

image DUST IS SEEN BLOWING ACROSS THE WEST COAST OF SOUTHERN AFRICA FROM ANGOLA TO SOUTH AFRICA.

The world's energy system has bestowed great benefits on society, but it has also come with high price tag: climate change, which is occurring due to a build of carbon dioxide and other greenhouse gases in the atmosphere caused by human activity; military and economic conflict due to uneven distribution of fossil resources; and millions of premature deaths and illness due to the air and water pollution inherent in fossil fuel production and consumption.

The largest proportion of global fossil fuel use is to generate power, for heating and lighting, and for transport. Business-as-usual growth of fossil-fuels is fundamentally unsustainable. Climate change threatens all continents, coastal cities, food production and ecosystems. It will mean more natural disasters such as fire and floods, disruption of agriculture and damage to property as sea levels rise.

The pursuit of energy security, while remaining dependent on fossil fuel will lead to increasing greenhouse gas emissions and more extreme climate impacts. Rising demand and rising prices drives the fossil fuel industry towards unconventional sources such as tar sands, shale gas and super-coal mines which destroy ecosystems and put water supplies in danger. The inherent volatility of fossil fuel prices puts more strain on an already stressed global economy.

According to the Intergovernmental Panel on Climate Change, global mean temperatures are expected to increase over the next hundred years by up to 6.4° C if no action is taken to reduce greenhouse gas emissions. This is much faster than anything experienced in human history. As average temperature increases approach 2°C or more, damage to ecosystems and disruption to the climate system increases dramatically, threatening millions of people with increased risk of hunger, disease, flooding and water shortage.

A certain amount of climate change is now "locked in", based on the amount of carbon dioxide and other greenhouse gases already emitted into the atmosphere since industrialisation began. No one knows how much warming is "safe" for life on the planet. However, what we know is that the effects of climate change are already being felt by populations and ecosystems. We can already see melting glaciers, disintegrating polar ice, thawing permafrost, dying coral reefs, rising sea levels, changing ecosystems and fatal heat waves that are made more severe by a changed climate.

Japan's major nuclear accident at Fukushima in March 2011 following a tsunami came 25 years after the disastrous explosion in the Chernobyl nuclear power plant in former Soviet Union, showing that nuclear energy is an inherently unsafe source of power. The Fukushima disaster triggered a surge in global renewable energy and energy efficiency deals. At the same time, the poor state of the global economy has resulted in decreasing carbon prices, some governments reducing support for renewables, and a stagnation of overall investment, particularly in the OECD.

image WIND TURBINES AT THE NAN WIND FARM IN NAN'AO. GUANGDONG PROVINCE HAS ONE OF THE BEST WIND RESOURCES IN CHINA AND IS ALREADY HOME TO SEVERAL INDUSTRIAL SCALE WIND FARMS.

Rising oil demand is putting pressure on supply causing prices to rise which make possible increased exploration for "marginal and unconventional" oil resources, such as regions of the Arctic newly accessible due to retreating polar ice, and the environmentally destructive tar sands project in Canada.

For almost a decade it looked as if nothing could halt the growth of the renewable industries and their markets. The only way was up. However the economic crisis in 2008/2009 and its continuing aftermath slowed growth and dampened demand. While the renewable industry is slowly recovering, increased competition, particularly in the solar PV and wind markets has driven down prices and shaved margins to the point where most manufacturers are struggling to survive. This is good news for the consumer, however, as the prices for solar PV fell more than 60% between 2010 and 2012, and wind turbine prices have also decreased substantially. This means that renewables are directly competitive with heavily subsidized conventional generation in an increasing number of markets, but for the industry to meet its full potential governments need to act to reduce the 600 billion USD/annum in subsidies to fossil fuels, and move ahead with pricing CO_2 emissions and other external costs of conventional generation.

As renewables play an increasing role in the energy system, one can no longer speak of 'integration' of renewables' but 'transformation', moving away from the reliance on a few large power plants, or single fuels to a flexible system based on a wide variety of renewable sources of supply, some of which are variable. Investments in new infrastructure, smarter grids, better storage technologies and a new energy policy which takes all these new technologies into account are required.

the new energy [r]evolution

The IPCC's Special Report on Renewable Energy and Climate Change (SRREN) chose the last Energy [R]evolution edition (published in 2010) as one of the four benchmark scenarios for climate mitigation energy scenarios. The Energy [R]evolution was the most ambitious, combining an uptake of renewable energy and rigorous energy efficiency measures to put forward the highest renewable energy share by 2050, although some other scenarios actually had higher total quantities of renewables. Following the publication of the SRREN in May 2011 in Abu Dhabi, the Energy [R]evolution has been widely quoted in the scientific literature.

The Energy [R]evolution 2012 takes into account the significant changes in the global energy sector debate over the past two years. In Japan, the Fukushima Nuclear disaster following the devastating tsunami triggered a faster phase-out of nuclear power in Germany, and raised the level of debate in many countries. The Deepwater Horizon disaster in the Gulf of Mexico in 2010 highlighted the damage that can be done to eco-systems and livelihoods, while oil companies started new oil exploration in ever-more sensitive environments such as the Arctic Circle. The Energy [R]evolution oil pathway is based on a detailed analysis of the global conventional oil resources, the current infrastructure of those industries, the estimated production capacities of existing oil wells in the light of projected production decline rates and the investment plans known by end 2011. To end our addiction to oil, financial resources must flow from 2012 onwards to developing new and larger markets for renewable energy technologies and energy efficiency to avoid "locking in" new fossil fuel infrastructure.

Rapid cost reductions in the renewable energy sector have made it possible to increase their share in power generation, heating and cooling and the transport sector faster than in previous editions. For the first time, this report takes a closer look at required investment costs for renewable heating technologies. The employment calculation has been expanded to the heating sector as well and the overall methodology of the employment calculation has been improved.

For the urgently needed access to energy for the almost 2 billion people who lack it at present, we have developed a new "bottom up" electrification concept in the North Indian state of Bihar (see chapter 2). New technology coupled with innovative finance may result in a new wave of rural electrification programs implemented by local people. A power plant market analysis of the past 40 years has been added to further develop the replacement strategy for old power plants. While the solar photovoltaic and wind installation have been increased, the use of bio-energy has been reduced due to environmental concerns (see page 212). Concentrated solar power stations and offshore wind remain cornerstones of the Energy [R]evolution, while we are aware that both technologies experience increasing difficulty raising finance than some other renewable technologies. Therefore we urge governments to introduce the required policy frameworks to lower the risks for investors. New storage technologies need to move from R&D to market implementation; again this requires long term policy decisions. Without those new storage technologies, e.g. methane produced from renewables (see chapter 9), a transition towards more efficient electric mobility will be more difficult.

Last but not least, the automobile industry needs to move towards smaller and lighter vehicles to bring down the energy demand and introduce new technologies. We urge car manufactures to finally move forward and repeat the huge successes of the renewable energy industry.

This fourth edition of the Energy [R]evolution shows that with only 1% of global GDP invested in renewable energy by 2050, 12 million jobs would be created in the renewable sector alone; and the fuel costs savings would cover the additional investment two times over. To conclude, there are no real technical or economic barriers to implementing the Energy [R]evolution. It is the lack of political will that is to blame for the slow progress to date.

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JUNE 2012

executive summary

"AT THE CORE OF THE ENERGY [R]EVOLUTION WILL BE A CHANGE IN THE WAY THAT ENERGY IS PRODUCED, DISTRIBUTED AND CONSUMED."

image GEMASOLAR, A 15 MWE SOLAR-ONLY POWER TOWER PLANT. IT'S 16-HOUR MOLTEN SALT STORAGE SYSTEM CAN DELIVER POWER AROUND THE CLOCK. IT RUNS THE EQUIVALENT OF 6,570 FULL HOURS OUT OF A 8,769 TOTAL. GEMASOLAR IS OWNED BY TORRESOL ENERGY AND HAS BEEN COMPLETED IN MAY 2011.

The Energy [R]evolution Scenario has became a well known and well respected energy analysis since it was first published for Europe in 2005. This is the fourth Global Energy [R]evolution scenario; earlier editions were published in 2007, 2008 and 2010.

The Energy [R]evolution 2012 provides a consistent fundamental pathway for how to protect our climate: getting the world from where we are now to where we need to be by phasing out fossil fuels and cutting CO_2 emissions while ensuring energy security.

The evolution of the scenarios has included a detailed employment analysis in 2010, and now this edition expands the research further to incorporate new demand and transport projections, new constraints for the oil and gas pathways and techno-economic aspects of renewable heating systems. While the 2010 edition had two scenarios – a basic and an advanced Energy [R]evolution, this edition puts forward only one; based on the previous 'advanced' case.

the fossil fuel dilemma

Raising energy demand is putting pressure on fossil fuel supply and now pushing oil exploration towards "unconventional" oil resources. Remote and sensitive environments such as the Arctic are under threat from increased drilling, while the environmentally destructive tar sands projects in Canada are being pursued to extract more marginal sources. However, scarcity of conventional oil is not the most pressing reason to phase-out fossil fuels: cutting back dramatically is essential to save the climate of our planet. Switching from fossil fuels to renewables also offers substantial benefits such as independence from world market fossil fuel prices and the creation of millions of new green jobs. It can also provide energy to the two billion people currently without access to energy services. The Energy [R]evolution 2012 took a closer look at the measures required to phase-out oil faster in order to save the Arctic from oil exploration, avoid dangerous deep sea drilling projects and to leave oil shale in the ground.

image SOVARANI KOYAL LIVES IN SATJELLIA ISLAND AND IS ONE OF THE MANY PEOPLE AFFECTED BY SEA LEVEL RISE: "NOWADAYS, HEAVY FLOODS ARE GOING ON HERE. THE WATER LEVEL IS INCREASING AND THE TEMPERATURE TOO. WE CANNOT LIVE HERE, THE HEAT IS BECOMING UNBEARABLE. WE HAVE RECEIVED A PLASTIC SHEET AND HAVE COVERED OUR HOME WITH IT. DURING THE COMING MONSOON WE SHALL WRAP OUR BODIES IN THE PLASTIC TO STAY DRY. WE HAVE ONLY A FEW GOATS BUT WE DO NOT KNOW WHERE THEY ARE. WE ALSO HAVE TWO CHILDREN AND WE CANNOT MANAGE TO FEED THEM."

climate change threats

The threat of climate change, caused by rising global temperatures, is the most significant environmental challenge facing the world at the beginning of the 21st century. It has major implications for the world's social and economic stability, its natural resources and in particular, the way we produce our energy.

In order to avoid the most catastrophic impacts of climate change, the global temperature increase must be kept as far below 2°C as possible. This is still possible, but time is running out. To stay within this limit, global greenhouse gas emissions will need to peak by 2015 and decline rapidly after that, reaching as close to zero as possible by the middle of the 21st century. The main greenhouse gas is carbon dioxide (CO_2) produced by using fossil fuels for energy and transport. Keeping the global temperature increase to 2°C is often referred to as a 'safe level' of warming, but this does not reflect the reality of the latest science. This shows that a warming of 2°C above pre-industrial levels would pose unacceptable risks to many of the world's key natural and human systems.[1] Even with a 1.5°C warming, increases in drought, heat waves and floods, along with other adverse impacts such as increased water stress for up to 1.7 billion people, wildfire frequency and flood risks, are projected in many regions. Neither does staying below 2°C rule out large-scale disasters such as melting ice sheets. Partial de-glaciation of the Greenland ice sheet, and possibly the West Antarctic ice sheet, could even occur from additional warming within a range of 0.8 – 3.8°C above current levels.[2] If rising temperatures are to be kept within acceptable limits then we need to significantly reduce our greenhouse gas emissions. This makes both environmental and economic sense.

global negotiation

Recognising the global threats of climate change, the signatories to the 1992 UN Framework Convention on Climate Change (UNFCCC) agreed to the Kyoto Protocol in 1997. The Protocol entered into force in early 2005 and its 193 members meet continuously to negotiate further refinement and development of the agreement. Only one major industrialised nation, the United States, has not ratified the protocol. In 2011, Canada announced its intention to withdraw from the protocol. In Copenhagen in 2009, the members of the UNFCCC were not able to deliver a new climate change agreement towards ambitious and fair emission reductions. At the 2012 Conference of the Parties in Durban, there was agreement to reach a new agreement by 2015 and to adopt a second commitment period at the end of 2012. However, the United Nations Environment Program's examination of the climate action pledges for 2020 shows a major gap between what the science demands to curb climate change and what the countries plan to do. The proposed mitigation pledges put forward by governments are likely to allow global warming to at least 2.5 to 5 degrees temperature increase above pre-industrial levels.[3]

the nuclear issue

The nuclear industry promises that nuclear energy can contribute to both climate protection and energy security, however their claims are not supported by data. The most recent Energy Technology Perspectives report published by the International Energy Agency includes a Blue Map scenario including a quadrupling of nuclear capacity between now and 2050. To achieve this, the report says that on average 32 large reactors (1,000 MWe each) would have to be built every year from now until 2050. According to the IEA's own scenario, such massive nuclear expansion would cut carbon emissions by less than 5%. More realistic analysis shows the past development history of nuclear power and the global production capacity make such expansion extremely unviable. Japan's major nuclear accident at Fukushima in March 2011 following a tsunami came 25 years after the disastrous explosion in the Chernobyl nuclear power plant in former Soviet Union, illustrating the inherent risks of nuclear energy. Nuclear energy is simply unsafe, expensive, has continuing waste disposal problems and can not reduce emissions by a large enough amount.

climate change and security of supply

Security of supply – both for access to supplies and financial stability – is now at the top of the energy policy agenda. Recent rapidly fluctuating oil prices are lined to a combination of many events, however one reason for these price fluctuations is that supplies of all proven resources of fossil fuels are becoming scarcer and more expensive to produce. Some 'non-conventional' resources such as shale oil have become economic, with devastating consequences for the local environment. The days of 'cheap oil and gas' are coming to an end. Uranium, the fuel for nuclear power, is also a finite resource. By contrast, the reserves of renewable energy that are technically accessible globally are large enough to provide more than 40 times more energy than the world currently consumes, forever, according to the latest IPCC Special report Renewables (SRREN). Renewable energy technologies are at different levels of technical and economic maturity, but a variety of sources offer increasingly attractive options. Cost reductions in just the past two years have changed the economic of renewables fundamentally, especially wind and solar photovoltaics. The common feature of all renewable energy sources, the wind, sun, earth's crust, and ocean is that they produce little or no greenhouse gases and are a virtually inexhaustible 'fuel'. Some technologies are already competitive; the solar and the wind industry have maintained double digit growth rates over 10 years now, leading to faster technology deployment world wide.

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2 JOEL B. SMITH, STEPHEN H. SCHNEIDER, MICHAEL OPPENHEIMER, GARY W. YOHE, WILLIAM HARE, MICHAEL D. MASTRANDREA, ANAND PATWARDHAN, IAN BURTON, JAN CORFEE-MORLOT, CHRIS H. D. MAGADZA, HANS-MARTIN FÜSSEL, A. BARRIE PITTOCK, ATIQ RAHMAN, AVELINO SUAREZ, AND JEAN-PASCAL VAN YPERSELE: ASSESSING DANGEROUS CLIMATE CHANGE THROUGH AN UPDATE OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) "REASONS FOR CONCERN". PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES. PUBLISHED ONLINE BEFORE PRINT FEBRUARY 26, 2009, DOI: 10.1073/PNAS.0812355106. THE ARTICLE IS FREELY AVAILABLE AT:HTTP://WWW.PNAS.ORG/CONTENT/EARLY/2009/02/25/0812355106.FULL.PDF. A COPY OF THE GRAPH CAN BE FOUND ON APPENDIX 1.

3 UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP): 'BRIDGING THE EMISSIONS GAP'. A UNEP SYNTHESIS REPORT, NOV. 2011.

Energy efficiency is a sleeping giant – offering the most cost competitive way to reform the energy sector. There is enormous potential for reducing our consumption of energy, while providing the same level of energy services. New business models to implement energy efficiency must be developed and must get more political support. This study details a series of energy efficiency measures which can substantially reduce demand across industry, homes, business and services as well as transport.

the energy [r]evolution key principles

The expert consensus is that this fundamental shift in the way we consume and generate energy must begin immediately and be well underway within the next ten years in order to avert the worst impacts of climate change.[4] The scale of the challenge requires a complete transformation of the way we produce, consume and distribute energy, while maintaining economic growth. The five key principles behind this Energy [R]evolution will be to:

- Implement renewable solutions, especially through decentralised energy systems and grid expansions
- Respect the natural limits of the environment
- Phase out dirty, unsustainable energy sources
- Create greater equity in the use of resources
- Decouple economic growth from the consumption of fossil fuels

Decentralised energy systems, where power and heat are produced close to the point of final use reduce grid loads and energy losses in distribution. Investments in 'climate infrastructure' such as smart interactive grids and transmission grids to transport large quantities of offshore wind and concentrating solar power are essential. Building up clusters of renewable micro grids, especially for people living in remote areas, will be a central tool in providing sustainable electricity to the almost two billion people around who currently don't have access to electricity.

projections to reality

Projection of global installed wind power capacity at the end of 2010 in the first Global Energy [R]evolution, published in January 2007.

>> 156 GW

Actual global installed wind capacity at the end of 2010.

>> 197 GW

While at the end of 2011 already 237 GW have been installed. More needs to be done.

the energy [r]evolution – key results

Renewable energy sources account for 13.5% of the world's primary energy demand in 2009. The main source is biomass, which is mostly used in the heat sector.

For electricity generation renewables contribute about 19.3% and for heat supply, around 25%, much of this is from traditional uses such as firewood. About 81% of the primary energy supply today still comes from fossil fuels and 5.5% from nuclear energy.

The Energy [R]evolution scenario describes development pathways to a sustainable energy supply, achieving the urgently needed CO_2 reduction target and a nuclear phase-out, without unconventional oil resources. The results of the Energy [R]evolution scenario which will be achieved through the following measures:

- **Curbing global energy demand:** The world's energy demand is projected by combining population development, GDP growth and energy intensity. Under the Reference scenario, total primary energy demand increases by 61% from about 500 EJ (Exajoules) per year in 2009 to 806 EJ per year in 2050. In the Energy [R]evolution scenario, demand increases by only 10% compared to current consumption until 2020 and decreases slightly afterwards to 2009 levels.
- **Controlling global power demand:** Under the Energy [R]evolution scenario, electricity demand is expected to increase disproportionately, the main growth in households and services. With adequate efficiency measures, however, a higher increase can be avoided, leading to electricity demand of around 41,000 TWh/a in 2050. Compared to the Reference scenario, efficiency measures avoid the generation of 12,800 TWh/a.
- **Reducing global heating demand:** Efficiency gains in the heat supply sector are even larger than in the electricity sector. Under the Energy [R]evolution scenario, final demand for heat supply can eventually be reduced significantly. Compared to the Reference scenario, consumption equivalent to 46,500 PJ/a is avoided through efficiency measures by 2050. The lower demand can be achieved by energy-related renovation of the existing stock of residential buildings, introduction of low energy standards; even 'energy-plus-houses' for new buildings, so people can enjoy the same comfort and energy services.

references
4 IPCC – SPECIAL REPORT RENEWABLES, CHAPTER 1, MAY 2011.

image THOUSANDS OF FISH DIE AT THE DRY RIVER BED OF MANAQUIRI LAKE, 150 KILOMETERS FROM AMAZONAS STATE CAPITOL MANAUS, BRAZIL.

- **Development of global industry energy demand:** The energy demand in the industry sector will grow in both scenarios. While the economic growth rates in the Reference and the Energy [R]evolution scenario are identical, the growth of the overall energy demand is different due to a faster increase of the energy intensity in the alternative case. Decoupling economic growth with the energy demand is key to reach a sustainable energy supply by 2050, the Energy [R]evolution scenario saves 40% less energy per $ GDP than the Reference case.
- **Electricity generation:** A dynamically growing renewable energy market compensates for phasing out nuclear energy and fewer fossil fuel-fired power plants. By 2050, 94% of the electricity produced worldwide will come from renewable energy sources. 'New' renewables – mainly wind, PV and geothermal energy – will contribute 60% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 37% already by 2020 and 61% by 2030. The installed capacity of renewables will reach almost 7,400 GW in 2030 and 15,100 GW by 2050.
- **Future costs of electricity generation:** Under the Energy [R]evolution scenario the costs of electricity generation increase slightly compared to the Reference scenario. This difference will be on average less than 0.6 $cent/kWh up to 2020. However, if fossil fuel prices go any higher than the model assumes, this gap will decrease. Electricity generation costs will become economically favourable under the Energy [R]evolution scenario by 2025 and by 2050, costs will be significantly lower: about 8 $cents/kWh – or 45% below those in the Reference version
- **The future electricity bill:** Under the Reference scenario, the unchecked growth in demand, results in total electricity supply costs rising from today's $ 2,364 billion per year to more than $ 8,830 billion in 2050. The Energy [R]evolution scenario helps to stabilise energy costs, increasing energy efficiency and shifting to renewable energy supply means long term costs for electricity supply are 22% lower in 2050 than in the Reference scenario (including estimated costs for efficiency measures).
- **Future investment in power generation:** The overall global level of investment required in new power plants up to 2020 will be in the region of $ 11.5 trillion in the Reference case and $ 20.1 trillion in the Energy [R]evolution. The need to replace the ageing fleet of power plants in OECD countries and to install new power plants in developing countries will be the major investment drivers. Depending on the local resources, renewable energy resources (for example wind in a high wind area) can produce electricity at the same cost levels as coal or gas power plants. Solar photovoltaic already reach 'grid parity' in many industrialised countries. For the Energy [R]evolution scenario until 2050 to become reality would require about $ 50,400 billion in investment in the power sector (including investments for replacement after the economic lifetime of the plants). Under the Reference scenario, total investment would be split 48% to 52% between conventional power plants and renewable energy plus cogeneration (CHP) up to 2050. Under the Energy [R]evolution scenario 95% of global investment would be in renewables and cogeneration. Up to 2030, the power sector investment that does go to fossil fuels would be focused mainly on cogeneration plants. The average annual investment in the power sector under the Energy [R]evolution scenario from today to 2050 would be $ 1,260 billion, compared to $ 555 billion in the Reference case.
- **Fuel costs savings:** Because renewable energy, except biomass, has no fuel costs, the fuel cost savings in the Energy [R]evolution scenario reach a total of $ 52,800 billion up to 2050, or $ 1320 billion per year. The total fuel cost savings therefore would cover more than two times the total additional investments compared to the Reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.
- **Heating supply:** Renewables currently provide 25% of the global energy demand for heat supply, the main contribution coming from the use of biomass. In the Energy [R]evolution scenario, renewables provide more than 50% of the world's total heat demand in 2030 and more than 90% in 2050. Energy efficiency measures can decrease the current demand for heat supply by 10 %, and still support improving living standards of a growing population.
- **Future investments in the heat sector:** The heat sector in the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. In particular enormous increases in installations are required to realise the potential of the not yet common solar and geothermal technologies and heat pumps. Installed capacity needs to increase by a factor of 60 for solar thermal and by a factor of over 3,000 for geothermal and heat pumps. Because the level of technological complexity in this sector is extremely variable, the Energy [R]evolution scenario can only be roughly calculated, to require around $ 27 trillion investment in renewable heating technologies up to 2050. This includes investments for replacement after the economic lifetime of the plant and is approximately $ 670 billion per year.

- Future employment in the energy sector: The Energy [R]evolution scenario results in more global energy sector jobs at every stage of the projection.

  There are 23.3 million energy sector jobs in the Energy [R]evolution in 2015, and 18.7 million in the Reference scenario.

  In 2020, there are 22.6 million jobs in the Energy [R]evolution scenario, and 17.8 million in the Reference scenario.

  In 2030, there are 18.3 million jobs in the Energy [R]evolution scenario and 15.7 million in the Reference scenario.

  There is a decline in overall job numbers under both scenarios between 2010 and 2030. Jobs in the coal sector decline significantly in both scenarios, leading to a drop of 6.8 million energy jobs in the Reference scenario by 2030. Strong growth in the renewable sector leads to an increase of 4% in total energy sector jobs in the Energy [R]evolution scenario by 2015. Job numbers fall after 2020, so jobs in the Energy [R]evolution are 19% below 2010 levels at 2030. However, this is 2.5 million more jobs than in the Reference scenario. Renewable energy accounts for 65% of energy jobs by 2030, with the majority spread over wind, solar PV, solar heating, and biomass.

- **Global transport**: In the transport sector it is assumed that, energy consumption will continue to increase under the Energy [R]evolution scenario up to 2020 due to fast growing demand for services. After that it falls back to the level of the current demand by 2050. Compared to the Reference scenario, transport energy demand is reduced overall by 60% or about 90,000 PJ/a by 2050. Energy demand for transport under the Energy [R]evolution scenario will therefore increase between 2009 and 2050 by only 26% to about 60,500 PJ/a. Significant savings are made from a shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains – together with reducing vehicle kilometres travelled per year. In 2030, electricity will provide 12% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 44%.

- **Primary energy consumption**: Under the Energy [R]evolution scenario the overall primary energy demand will be reduced by 40% in 2050 compared to the Reference scenario. In this projection almost the entire global electricity supply, including the majority of the energy used in buildings and industry, would come from renewable energy sources. The transport sector, in particular aviation and shipping, would be the last sector to become fossil fuel free.

- **Development of CO_2 emissions:** Worldwide CO_2 emissions in the Reference case will increase by 62% while under the Energy [R]evolution scenario they will decrease from 27,925 million tons in 2009 to 3,076 million t in 2050. Annual per capita emissions will drop from 4.1 tonne CO2 to 2.4 tonne CO_2 in 2030 and 0.3 tonne CO_2 in 2050. Even with a phase out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long term, efficiency gains and greater use of renewable electricity for vehicles will also reduce emissions in the transport sector. With a share of 33% of CO_2 emissions in 2050, the transport sector will be the main source of emissions ahead of the industry and power generation. By 2050 the Global Energy related CO_2 emissions are 85% under 1990 levels.

policy changes

To make the Energy [R]evolution real and to avoid dangerous climate change, Greenpeace, GWEC and EREC demand that the following policies and actions are implemented in the energy sector:

1. Phase out all subsidies for fossil fuels and nuclear energy.
2. Internalise the external (social and environmental) costs of energy production through 'cap and trade' emissions trading.
3. Mandate strict efficiency standards for all energy consuming appliances, buildings and vehicles.
4. Establish legally binding targets for renewable energy and combined heat and power generation.
5. Reform the electricity markets by guaranteeing priority access to the grid for renewable power generators.
6. Provide defined and stable returns for investors, for example by feed-in tariff programmes.
7. Implement better labelling and disclosure mechanisms to provide more environmental product information.
8. Increase research and development budgets for renewable energy and energy efficiency.

climate and energy policy

image HURRICANE BUD FORMING OVER THE EASTERN PACIFIC OCEAN, MAY 2012.

If we do not take urgent and immediate action to protect the climate, the threats from climate change could become irreversible.

The goal of climate policy should be to keep the global mean temperature rise to less than 2°C above pre-industrial levels. We have very little time within which we can change our energy system to meet these targets. This means that global emissions will have to peak and start to decline by the end of the next decade at the latest.

The only way forwards is a rapid reduction in the emission of greenhouse gases into the atmosphere.

1.1 the UNFCCC and the kyoto protocol

Recognising the global threats of climate change, the signatories to the 1992 UN Framework Convention on Climate Change (UNFCCC) agreed the Kyoto Protocol in 1997. The Protocol entered into force in early 2005 and its 193 members meet continuously to negotiate further refinement and development of the agreement. Only one major industrialised nation, the United States, has not ratified the protocol. In 2011, Canada announced its intention to withdraw from the protocol.

box 1.1: **what does the kyoto protocol do?**

The Kyoto Protocol commits 193 countries (signatories) to reduce their greenhouse gas emissions by 5.2% from their 1990 level. The global target period to achieve cuts was 2008-2012. Under the protocol, many countries and regions have adopted regional and national reduction targets. The European Union commitment is for overall reduction of 8%, for example. In order to help reach this target, the EU also created a target to increase its proportion of renewable energy from 6% to 12% by 2010.

In Copenhagen in 2009, the 195 members of the UNFCCC were supposed to deliver a new climate change agreement towards ambitious and fair emission reductions. Unfortunately the ambition to reach such an agreement failed at this conference.

At the 2012 Conference of the Parties in Durban, there was agreement to reach a new agreement by 2015. There is also agreement to adopt a second commitment period at the end of 2012. However, the United Nations Environment Program's examination of the climate action pledges for 2020 shows that there is still a major gap between what the science demands to curb climate change and what the countries plan to do. The proposed mitigation pledges put forward by governments are likely to allow global warming to at least 2.5 to 5 degrees temperature increase above pre-industrial levels.[5]

reference
5 UNEP EMISSIONS GAP REPORT.

This means that the new agreement in 2015, with the Fifth Assessment Report of the IPCC on its heels, should strive for climate action for 2020 that ensures that the world stay as far below an average temperature increase of 2°C as possible. Such an agreement will need to ensure:

- That industrialised countries reduce their emissions on average by at least 40% by 2020 compared to their 1990 level.
- That industrialised countries provide funding of at least $140 billion a year to developing countries under the newly established Green Climate Fund to enable them to adapt to climate change, protect their forests and be part of the energy revolution.
- That developing countries reduce their greenhouse gas emissions by 15 to 30% compared to their projected growth by 2020.

1.2 international energy policy

At present there is a distortion in many energy markets, where renewable energy generators have to compete with old nuclear and fossil fuel power stations but not on a level playing field. This is because consumers and taxpayers have already paid the interest and depreciation on the original investments so the generators are running at a marginal cost. Political action is needed to overcome market distortions so renewable energy technologies can compete on their own merits.

While governments around the world are liberalising their electricity markets, the increasing competitiveness of renewable energy should lead to higher demand. Without political support, however, renewable energy remains at a disadvantage, marginalised because there has been decades of massive financial, political and structural support to conventional technologies. Developing renewables will therefore require strong political and economic efforts for example, through laws that guarantee stable tariffs over a period of up to 20 years. Renewable energy will also contribute to sustainable economic growth, high quality jobs, technology development, global competitiveness and industrial and research leadership.

1.3 renewable energy targets

A growing number of countries have established targets for renewable energy in order to reduce greenhouse emissions and increase energy security. Targets are usually expressed as installed capacity or as a percentage of energy consumption and they are important catalysts for increasing the share of renewable energy worldwide.

However, in the electricity sector the investment horizon can be up to 40 years. Renewable energy targets therefore need to have short, medium and long term steps and must be legally binding in order to be effective. They should also be supported by incentive mechanisms such as feed-in tariffs for renewable electricity generation. To get significant increases in the proportion of renewable energy, targets must be set in accordance with the local potential for each technology (wind, solar, biomass etc) and be complemented by policies that develop the skills and manufacturing bases to deliver the agreed quantity.

image GREENPEACE AND AN INDEPENDENT NASA-FUNDED SCIENTIST COMPLETED MEASUREMENTS OF MELT LAKES ON THE GREENLAND ICE SHEET THAT SHOW ITS VULNERABILITY TO WARMING TEMPERATURES.

Data from the wind and solar power industries show that it is possible to maintain a growth rate of 30 to 35% in the renewable energy sector. In conjunction with the European Photovoltaic Industry Association,[6] the European Solar Thermal Power Industry Association[7] and the Global Wind Energy Council,[8] the European Renewable Energy Council, Greenpeace has documented the development of these clean energy industries in a series of Global Outlook documents from 1990 onwards and predicted growth up to 2020 and 2040.

1.4 policy changes in the energy sector

Greenpeace and the renewable energy industry share a clear agenda for the policy changes which need to be made to encourage a shift to renewable sources.

The main demands are:

1. Phase out all subsidies for fossil fuels and nuclear energy.
2. Internalise external (social and environmental) costs through 'cap and trade' emissions trading.
3. Mandate strict efficiency standards for all energy consuming appliances, buildings and vehicles.
4. Establish legally binding targets for renewable energy and combined heat and power generation.
5. Reform the electricity markets by guaranteeing priority access to the grid for renewable power generators.
6. Provide defined and stable returns for investors, for example through feed-in tariff payments.
7. Implement better labelling and disclosure mechanisms to provide more environmental product information.
8. Increase research and development budgets for renewable energy and energy efficiency.

Conventional energy sources receive an estimated $409 billion[9] in subsidies in 2010, resulting in heavily distorted markets. Subsidies artificially reduce the price of power, keep renewable energy out of the market place and prop up non-competitive technologies and fuels. Eliminating direct and indirect subsidies to fossil fuels and nuclear power would help move us towards a level playing field across the energy sector. Renewable energy would not need special provisions if markets factored in the cost of climate damage from greenhouse gas pollution. Subsidies to polluting technologies are perverse in that they are economically as well as environmentally detrimental. Removing subsidies from conventional electricity supply would not only save taxpayers' money, it would also dramatically reduce the need for renewable energy support.

1.4.1 the most effective way to implement the energy [r]evolution: feed-in laws

To plan and invest in energy infrastructure whether for conventional or renewable energy requires secure policy frameworks over decades.

The key requirements are:

a. Long term security for the investment The investor needs to know if the energy policy will remain stable over the entire investment period (until the generator is paid off). Investors want a "good" return on investment and while there is no universal definition of a good return, it depends to a large extent on the inflation rate of the country. Germany, for example, has an average inflation rate of 2% per year and a minimum return of investment expected by the financial sector is 6% to 7%. Achieving 10 to 15% returns is seen as extremely good and everything above 20% is seen as suspicious.

b. Long-term security for market conditions The investor needs to know, if the electricity or heat from the power plant can be sold to the market for a price which guarantees a "good" return on investment (ROI). If the ROI is high, the financial sector will invest, it is low compared to other investments financial institutions will not invest.

c. Transparent Planning Process A transparent planning process is key for project developers, so they can sell the planned project to investors or utilities. The entire licensing process must be clear and transparent.

d. Access to the grid A fair access to the grid is essential for renewable power plants. If there is no grid connection available or if the costs to access the grid are too high the project will not be built. In order to operate a power plant it is essential for investors to know if the asset can reliably deliver and sell electricity to the grid. If a specific power plant (e.g. a wind farm) does not have priority access to the grid , the operator might have to switch the plant off when there is an over supply from other power plants or due to a bottleneck situation in the grid. This arrangement can add high risk to the project financing and it may not be financed or it will attract a "risk-premium" which will lower the ROI.

references

6 'SOLARGENERATION IV', SEPTEMBER 2009.
7 'GLOBAL CONCENTRATED SOLAR POWER OUTLOOK – WHY RENEWABLES ARE HOT!' MAY, 2009.
8 'GLOBAL WIND ENERGY OUTLOOK 2008', OCTOBER 2008.
9 'IEA WORLD ENERGY OUTLOOK 2011', PARIS NOVEMBER 2011, CHAPTER 14, PAGE 507.

box 1.2: example of a sustainable feed-in tariff

The German Feed-in Law ("Erneuerbare Energien Gesetz" = EEG) is among the most effective pieces of legislation to phase in renewable energy technologies. Greenpeace supports this law and encourages other countries to implement a similar effective renewable energy law.

Structure of the German renewable energy Act:

a. Definitions & Purpose Chapter 1 of the law provides a general overview about the purpose, the scope of the applications, specific definitions for all used terms in the law as well as the statutory obligation.

b. Regulation of all grid related issues Chapter 2 of the law provides the general provisions of grid connection, technical and operational requirements, how to establish and use grid connection and how the renewable electricity purchase, the transmission and distribution of this electricity must be organised.

c. Regulation how for grid expansion and renewable power management in the grid This part of the law regulates the grid capacity expansion and feed-in management, how to organise the compensation for required grid expansion, the feed-in management and a hardship clause.

d. Regulations for all tariff-related subjects This part provides the general provisions regarding tariffs, the payment claims, how to organise direct sale of renewable electricity, how to calculate the tariffs, details about tariffs paid for electricity from several installations, the degression rate for each technology as well as the commencement and duration of tariff payment and setting of payment claims. There are special provisions regarding tariffs for the different fuel sources (hydropower, landfill gas, sewage treatment gas, mine gas, biomass, geothermal energy, wind energy – re-powering, offshore wind energy, solar power, rooftop installations for solar radiation).

e. Equalisation scheme This part defines how to organise the nationwide equalisation scheme for the payment of all feed-in tariffs. The delivery to transmission system operator, tariffs paid by transmission system operator, the equalisation amongst transmission system operators, the delivery to suppliers, subsequent corrections and advance payments

f. Special regulations for energy intensive industries The part defines the special equalisation scheme for electricity-intensive enterprises and rail operators, the basic principle, the list of sectors which are excluded from the payment of feed-in law costs and how to apply for this exclusion.

g. Transparency Regulations This part established a detailed process how to make the entire process transparent and publicly accessible to minimise corruption, false treatments of consumers, or some scale power plant operators. The regulations provides the basic information principles for installation operators, grid system operators, transmission system operators, utility companies, certification, data to be provided to the Federal Network Agency (the governmental control body for all 800 grid operators in Germany), data to be made public, notification regulations, details for billing.

Another subchapter identifies regulations for the guarantee of origin of the renewable electricity feed into the grid and the prohibition of multiple sales.

h. Legal roles and responsibilities This part identifies the legal protection and official procedure for clearing house and consumer protection, temporary legal protection, use of maritime shipping lanes, tasks of the Federal Network Agency Administrative fines provisions and supervision.

i. Governmental procedures to control and review the law on a regular basis Authorisation to issue ordinances, when and how to commission the progress report (published every second year to capture lessons learned and to change regulation which do not work), transitional provisions, authorisation to issue ordinances and transitional provisions.

© GP/JOHN NOVIS

image WANG WAN YI, AGE 76, ADJUSTS THE SUNLIGHT POINT ON A SOLAR DEVICE USED TO BOIL HIS KETTLE. HE LIVES WITH HIS WIFE IN ONE ROOM CARVED OUT OF THE SANDSTONE, A TYPICAL DWELLING FOR LOCAL PEOPLE IN THE REGION. DROUGHT IS ONE OF THE MOST HARMFUL NATURAL HAZARDS IN NORTHWEST CHINA. CLIMATE CHANGE HAS A SIGNIFICANT IMPACT ON CHINA'S ENVIRONMENT AND ECONOMY.

1.4.2 bankable renewable energy support schemes

Since the early development of renewable energies within the power sector, there has been an ongoing debate about the best and most effective type of support scheme. The European Commission published a survey in December 2005 which concluded that feed-in tariffs are by far the most efficient and successful mechanism. A more recent update of this report, presented in March 2010 at the IEA Renewable Energy Workshop by the Fraunhofer Institute[10] underscores the same conclusion. The Stern Review on the Economics of Climate Change also concluded that feed-in tariffs "achieve larger deployment at lower costs". Globally more than 40 countries have adopted some version of the system.

Although the organisational form of these tariffs differs from country to country some criteria have emerged as essential for successful renewable energy policy. At the heart of these is a reliable, bankable support scheme for renewable projects which provides long term stability and certainty.[11] Bankable support schemes result in lower-cost projects because they lower the risk for both investors and equipment suppliers. The cost of wind-powered electricity in Germany is up to 40% cheaper than in the United Kingdom,[12] for example, because the support system is more secure and reliable.

box 1.3: experience of feed-in tariffs

- Feed-in tariffs are seen as the best way forward, especially in developing countries. By 2009 this system has created an incentive for 75% of PV capacity worldwide and 45% of wind capacity.
- Based on experience, feed-in tariffs are the most effective mechanism to create a stable framework to build a domestic market for renewable energy. They have the lowest investment risk, highest technology diversity, lowest windfall profits for mature technologies and attract a broad spectrum of investors.[13]
- The main argument against them is the increase in electricity prices for households and industry, because the extra costs are shared across all customers. This is particularly difficult for developing countries, where many people can't afford to spend more money for electricity services.

For developing countries, feed-in laws would be an ideal mechanism to boost development of new renewable energies. The extra costs to consumers' electricity bills are an obstacle for countries with low average incomes. In order to enable technology transfer from Annex 1 countries under the Kyoto Protocol to developing countries, a mix of a feed-in law, international finance and emissions trading could establish a locally-based renewable energy infrastructure and industry with help from the wealthier countries.

Finance for renewable energy projects is one of the main obstacles in developing countries. While large scale projects have fewer funding problems, there are difficulties for small, community-based projects, even though they have a high degree of public support. The experiences from micro credits for small hydro projects in Bangladesh, for example, or wind farms in Denmark and Germany, show how economic benefits can flow to the local community. With careful project planning based on good local knowledge and understanding, projects can achieve local involvement and acceptance. When the community identifies the project rather than the project identifying the community, the result is generally faster bottom-up growth of the renewable energy sector.

The four main elements for successful renewable energy support schemes are therefore:

- A clear, bankable pricing system.
- Priority access to the grid with clear identification of who is responsible for the connection, and how it is incentivised.
- Clear, simple administrative and planning permission procedures.
- Public acceptance/support.

The first is fundamentally important, but it is no good if you don't have the other three elements as well.

references

10 EFFECTIVE AND EFFICIENT LONG-TERM ORIENTED RENEWABLE ENERGY SUPPORT POLICIES, FRAUNHOFER INSTITUTE, MARIO RAGWITZ, MARCH 2010.
11 'THE SUPPORT OF ELECTRICITY FROM RENEWABLE ENERGY SOURCES', EUROPEAN COMMISSION, 2005.
12 SEE ABOVE REPORT, P. 27, FIGURE 4.
13 EFFECTIVE AND EFFICIENT LONG-TERM ORIENTED RENEWABLE ENERGY SUPPORT POLICIES, FRAUNHOFER INSTITUTE, MARIO RAGWITZ, MARCH 2010.

1.5 ftsm: a special feed-in law proposal for developing countries

This section outlines a Greenpeace proposal for a feed-in tariff system in developing countries whose additional costs would be financed by developed nations. The financial resources for this could come from a combination of innovative sources and could be managed by International Climate Mitigation Funds or other available financial resources.

Energy [R]evolution scenarios show that renewable electricity generation has huge environmental and economic benefits. However its investment and generation costs, especially in developing countries, will remain higher than those of existing coal or gas-fired power stations for the next five to ten years. To bridge this cost gap a specific support mechanism for the power sector is needed. The Feed-in Tariff Support Mechanism (FTSM) is a concept conceived by Greenpeace International.[14] The aim is the rapid expansion of renewable energy in developing countries with financial support from industrialised nations.

Since the FTSM concept was first presented in 2008, the idea has received considerable support from a variety of different stakeholders. The Deutsche Bank Group's Climate Change Advisors, for example, have developed a proposal based on FTSM called "GET FiT". Announced in April 2010, this took on board major aspects of the Greenpeace concept.

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- Clear, simple administrative and planning permission procedures.
- Public acceptance/support.

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1.5.1 the feed-in tariff support mechanism

The basic aim of the FTSM is to facilitate the introduction of feed-in laws in developing countries by providing additional financial resources on a scale appropriate to local circumstances. For those countries with higher potential renewable energy capacity, it could be appropriate to create a new sectoral no-lose mechanism generating emission reduction credits for sale to Annex I countries, with the proceeds being used to offset part of the additional cost of the feed-in tariff system. For others there would need to be a more directly-funded approach to paying for the additional costs to consumers of the tariff. The ultimate objective would be to provide bankable and long term stable support for the development of a local renewable energy market. The tariffs would bridge the gap between conventional power generation costs and those of renewable generation. The FTSM could also be used for rural electrification concepts such as the Greenpeace-energynautics "RE cluster concept" (see Chapter 2).

The key parameters for feed in tariffs under FTSM are:

- Variable tariffs for different renewable energy technologies, depending on their costs and technology maturity, paid for 20 years.
- Payments based on actual generation in order to achieve properly maintained projects with high performance ratios.
- Payment of the 'additional costs' for renewable generation based on the German system, where the fixed tariff is paid minus the wholesale electricity price which all generators receive.
- Payment could include an element for infrastructure costs such as grid connection, grid reinforcement or the development of a smart grid. A specific regulation needs to define when the payments for infrastructure costs are needed in order to achieve a timely market expansion of renewable power generation.

A developing country which wants to take part in the FTSM would need to establish clear regulations for the following:

- Guaranteed access to the electricity grid for renewable electricity projects.
- Establishment of a feed-in law based on successful examples.
- Transparent access to all data needed to establish the feed-in tariff, including full records of generated electricity.
- Clear planning and licensing procedures.

The design of the FTSM would need to ensure that there were stable flows of funds to renewable energy suppliers. There may therefore need to be a buffer between fluctuating CO_2 emission prices and stable long term feed-in tariffs. The FTSM will need to secure payment of the required feed-in tariffs over the whole lifetime (about 20 years) of each project.

reference

14 IMPLEMENTING THE ENERGY [R]EVOLUTION, OCTOBER 2008, SVEN TESKE, GREENPEACE INTERNATIONAL.

image THE WIND TURBINES ARE GOING TO BE USED FOR THE CONSTRUCTION OF AN OFFSHORE WINDFARM AT MIDDELGRUNDEN WHICH IS CLOSE TO COPENHAGEN, DENMARK.

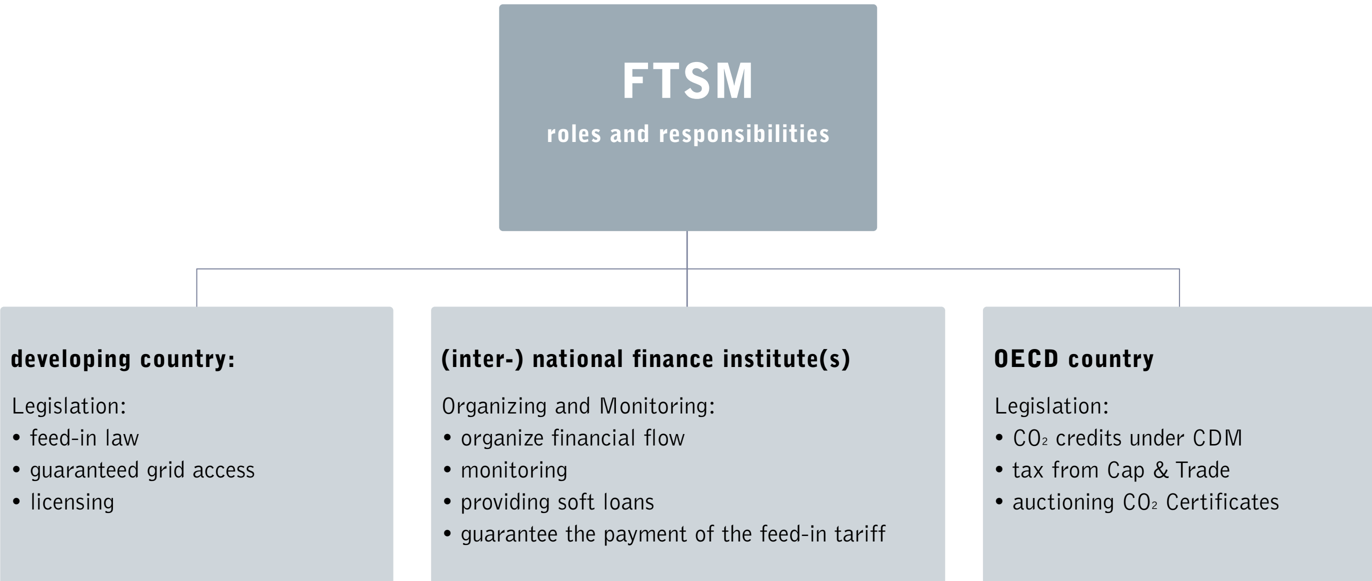
In order to be eligible, all renewable energy projects must have a clear set of environmental criteria which are built into national licensing procedure in the country where the project will generate electricity. The criteria's minimum environmental standards will need to be defined by an independent monitoring group. If there are already acceptable criteria developed these should be adopted rather than reinventing the wheel. The members of the monitoring group would include NGOs, energy and finance experts as well as members of the governments involved. Funding will not be made available for speculative investments, only as soft loans for FTSM projects.

The FTSM would also seek to create the conditions for private sector actors, such as local banks and energy service companies, to gain experience in technology development, project development, project financing and operation and maintenance in order to develop track records which would help reduce barriers to further renewable energy development.

The key parameters for the FTSM fund will be:

- The mechanism will guarantee payment of the feed-in tariffs over a period of 20 years as long as the project is operated properly.
- The mechanism will receive annual income from emissions trading or from direct funding.
- The mechanism will pay feed-in tariffs annually only on the basis of generated electricity.
- Every FTSM project must have a professional maintenance company to ensure high availability.
- The grid operator must do its own monitoring and send generation data to the FTSM fund. Data from the project managers and grid operators will be compared regularly to check consistency.

figure 1.1: ftsm scheme



the energy [r]evolution concept

KEY PRINCIPLES
THE "3 STEP IMPLEMENTATION"
THE NEW ELECTRICITY GRID
CASE STUDY GERMANY
CASE STUDY BIHAR, INDIA

image TIKEHAU ATOLL, FRENCH POLYNESIA. THE ISLANDS AND CORAL ATOLLS OF FRENCH POLYNESIA, LOCATED IN THE SOUTHERN PACIFIC OCEAN, EPITOMIZE THE IDEA OF TROPICAL PARADISE: WHITE SANDY BEACHES, TURQUOISE LAGOONS, AND PALM TREES. EVEN FROM THE DISTANCE OF SPACE, THE VIEW OF THESE ATOLLS IS BEAUTIFUL.

image A WOMAN STUDIES SOLAR POWER SYSTEMS AT THE BAREFOOT COLLEGE. THE COLLEGE SPECIALISES IN SUSTAINABLE DEVELOPMENT AND PROVIDES A SPACE WHERE STUDENTS FROM ALL OVER THE WORLD CAN LEARN TO UTILISE RENEWABLE ENERGY. THE STUDENTS TAKE THEIR NEW SKILLS HOME AND GIVE THEIR VILLAGES CLEAN ENERGY.

The expert consensus is that this fundamental shift in the way we consume and generate energy must begin immediately and be well underway within the next ten years in order to avert the worst impacts of climate change.[15] The scale of the challenge requires a complete transformation of the way we produce, consume and distribute energy, while maintaining economic growth. Nothing short of such a revolution will enable us to limit global warming to a rise in temperature of lower than 2°C, above which the impacts become devastating. This chapter explains the basic principles and strategic approach of the Energy [R]evolution concept, which is basis for the scenario modelling since the very first Energy [R]evolution scenario published in 2005. However, this concept has been constantly improved as technologies develops and new technical and economical possibilities emerge.

Current electricity generation relies mainly on burning fossil fuels in very large power stations which generate carbon dioxide and also waste much of their primary input energy. More energy is lost as the power is moved around the electricity network and is converted from high transmission voltage down to a supply suitable for domestic or commercial consumers. The system is vulnerable to disruption: localised technical, weather-related or even deliberately caused faults can quickly cascade, resulting in widespread blackouts. Whichever technology generates the electricity within this old fashioned configuration, it will inevitably be subject to some, or all, of these problems. At the core of the Energy [R]evolution there therefore there are change boths to the way that energy is produced and distributed.

2.1 key principles

The Energy [R]evolution can be achieved by adhering to five key principles:

1. **Respect natural limits – phase out fossil fuels by the end of this century** We must learn to respect natural limits. There is only so much carbon that the atmosphere can absorb. Each year we emit almost 30 billion tonnes of carbon equivalent; we are literally filling up the sky. Geological resources of coal could provide several hundred years of fuel, but we cannot burn them and keep within safe limits. Oil and coal development must be ended.

   The Energy [R]evolution scenario has a target to reduce energy related CO_2 emissions to a maximum of 3.5 Gigatonnes (Gt) by 2050 and phase out over 80% of fossil fuels by 2050.

2. **Equity and fair access to energy** As long as there are natural limits there needs to be a fair distribution of benefits and costs within societies, between nations and between present and future generations. At one extreme, a third of the world's population has no access to electricity, whilst the most industrialised countries consume much more than their fair share.

   The effects of climate change on the poorest communities are exacerbated by massive global energy inequality. If we are to address climate change, one of the principles must be equity and fairness, so that the benefits of energy services – such as light, heat, power and transport – are available for all: north and south, rich and poor. Only in this way can we create true energy security, as well as the conditions for genuine human wellbeing.

   The Energy [R]evolution scenario has a target to achieve energy equity as soon as technically possible. By 2050 the average per capita emission should be between 0.5 and 1 tonne of CO_2.

3. **Implement clean, renewable solutions and decentralise energy systems** There is no energy shortage. All we need to do is use existing technologies to harness energy effectively and efficiently. Renewable energy and energy efficiency measures are ready, viable and increasingly competitive. Wind, solar and other renewable energy technologies have experienced double digit market growth for the past decade.[16]

   Just as climate change is real, so is the renewable energy sector. Sustainable decentralised energy systems produce less carbon emissions, are cheaper and involve less dependence on imported fuel. They create more jobs and empower local communities. Decentralised systems are more secure and more efficient. This is what the Energy [R]evolution must aim to create.

"THE STONE AGE DID NOT END FOR LACK OF STONE, AND THE OIL AGE WILL END LONG BEFORE THE WORLD RUNS OUT OF OIL."

Sheikh Zaki Yamani, former Saudi Arabian oil minister

   To stop the earth's climate spinning out of control, most of the world's fossil fuel reserves – coal, oil and gas – must remain in the ground. Our goal is for humans to live within the natural limits of our small planet.

4. **Decouple growth from fossil fuel use** Starting in the developed countries, economic growth must be fully decoupled from fossil fuel usage. It is a fallacy to suggest that economic growth must be predicated on their increased combustion.

   We need to use the energy we produce much more efficiently, and we need to make the transition to renewable energy and away from fossil fuels quickly in order to enable clean and sustainable growth.

5. **Phase out dirty, unsustainable energy** We need to phase out coal and nuclear power. We cannot continue to build coal plants at a time when emissions pose a real and present danger to both ecosystems and people. And we cannot continue to fuel the myriad nuclear threats by pretending nuclear power can in any way help to combat climate change. There is no role for nuclear power in the Energy [R]evolution.

references

15 IPCC – SPECIAL REPORT RENEWABLES, CHAPTER 1, MAY 2011.
16 REN 21, RENEWABLE ENERGY STATUS REPORT 2012, JUNE 2012.

2.2 the "3 step implementation"

In 2009, renewable energy sources accounted for 13% of the world's primary energy demand. Biomass, which is mostly used for heating, was the main renewable energy source. The share of renewable energy in electricity generation was 18%. About 81% of primary energy supply today still comes from fossil fuels.[17]

Now is the time to make substantial structural changes in the energy and power sector within the next decade. Many power plants in industrialised countries, such as the USA, Japan and the European Union, are nearing retirement; more than half of all operating power plants are over 20 years old. At the same time developing countries, such as China, India, South Africa and Brazil, are looking to satisfy the growing energy demand created by their expanding economies.

Within this decade, the power sector will decide how new electricity demand will be met, either by fossil and nuclear fuels or by the efficient use of renewable energy. The Energy [R]evolution scenario puts forwards a policy and technical model for renewable energy and cogeneration combined with energy efficiency to meet the world's needs.

Both renewable energy and cogeneration on a large scale and through decentralised, smaller units – have to grow faster than overall global energy demand. Both approaches must replace old generating technologies and deliver the additional energy required in the developing world.

A transition phase is required to build up the necessary infrastructure because it is not possible to switch directly from a large scale fossil and nuclear fuel based energy system to a full renewable energy supply. Whilst remaining firmly committed to the promotion of renewable sources of energy, we appreciate that conventional natural gas, used in appropriately scaled cogeneration plants, is valuable as a transition fuel, and can also drive cost-effective decentralisation of the energy infrastructure. With warmer summers, tri-generation which incorporates heat-fired absorption chillers to deliver cooling capacity in addition to heat and power, will become a valuable means of achieving emissions reductions. The Energy [R]evolution envisages a development pathway which turns the present energy supply structure into a sustainable system. There are three main stages to this.

Step 1: energy efficiency and equity The Energy [R]evolution makes an ambitious exploitation of the potential for energy efficiency. It focuses on current best practice and technologies that will become available in the future, assuming continuous innovation. The energy savings are fairly equally distributed over the three sectors – industry, transport and domestic/business. Intelligent use, not abstinence, is the basic philosophy.

The most important energy saving options are improved heat insulation and building design, super efficient electrical machines and drives, replacement of old style electrical heating systems by renewable heat production (such as solar collectors) and a reduction in energy consumption by vehicles used for goods and passenger traffic. Industrialised countries currently use energy in the most inefficient way and can reduce their consumption drastically without the loss of either housing comfort or information and entertainment electronics. The Energy [R]evolution scenario depends on energy saved in OECD countries to meet the increasing power requirements in developing countries. The ultimate goal is stabilisation of global energy consumption within the next two decades. At the same time the aim is to create 'energy equity' – shifting towards a fairer worldwide distribution of efficiently-used supply.

A dramatic reduction in primary energy demand compared to the Reference scenario – but with the same GDP and population development – is a crucial prerequisite for achieving a significant share of renewable energy sources in the overall energy supply system, compensating for the phasing out of nuclear energy and reducing the consumption of fossil fuels.

figure 2.1: centralised generation systems waste more than two thirds of their original energy input

61.5 units
LOST THROUGH INEFFICIENT GENERATION AND HEAT WASTAGE

3.5 units
LOST THROUGH TRANSMISSION AND DISTRIBUTION

13 units
WASTED THROUGH INEFFICIENT END USE

100 units >>
ENERGY WITHIN FOSSIL FUEL

38.5 units >>
OF ENERGY FED TO NATIONAL GRID

35 units >>
OF ENERGY SUPPLIED

22 units
OF ENERGY ACTUALLY UTILISED

reference
17 IEA WORLD ENERGY OUTLOOK 2011, PARIS NOVEMBER 2011.

image THE MARANCHON WIND TURBINE FARM IN GUADALAJARA, SPAIN IS THE LARGEST IN EUROPE WITH 104 GENERATORS, WHICH COLLECTIVELY PRODUCE 208 MEGAWATTS OF ELECTRICITY, ENOUGH POWER FOR 590,000 PEOPLE, ANUALLY.

Step 2: the renewable energy [r]evolution Decentralised energy and large scale renewables In order to achieve higher fuel efficiencies and reduce distribution losses, the Energy [R]evolution scenario makes extensive use of Decentralised Energy (DE).This terms refers to energy generated at or near the point of use.

Decentralised energy is connected to a local distribution network system, supplying homes and offices, rather than the high voltage transmission system. Because electricity generation is closer to consumers any waste heat from combustion processes can to be piped to nearby buildings, a system known as cogeneration or combined heat and power. This means that for a fuel like gas, all the input energy is used, not just a fraction as with traditional centralised fossil fuel electricity plant.

Decentralised energy also includes stand-alone systems entirely separate from the public networks, for example heat pumps, solar thermal panels or biomass heating. These can all be commercialised for domestic users to provide sustainable, low emission heating. Some consider decentralised energy technologies 'disruptive' because they do not fit the existing electricity market and system. However, with appropriate changes they can grow exponentially with overall benefit and diversification for the energy sector.

A huge proportion of global energy in 2050 will be produced by decentralised energy sources, although large scale renewable energy supply will still be needed for an energy revolution. Large offshore wind farms and concentrating solar power (CSP) plants in the sunbelt regions of the world will therefore have an important role to play.

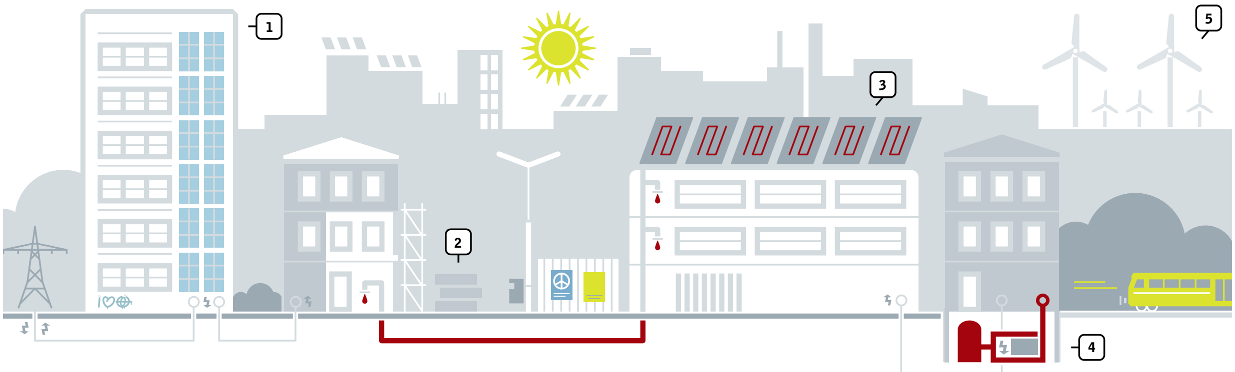
Cogeneration (CHP) The increased use of combined heat and power generation (CHP) will improve the supply system's energy conversion efficiency, whether using natural gas or biomass. In the longer term, a decreasing demand for heat and the large potential for producing heat directly from renewable energy sources will limit the need for further expansion of CHP.

Renewable electricity The electricity sector will be the pioneer of renewable energy utilisation. Many renewable electricity technologies have been experiencing steady growth over the past 20 to 30 years of up to 35% annually and are expected to consolidate at a high level between 2030 and 2050. By 2050, under the Energy [R]evolution scenario, the majority of electricity will be produced from renewable energy sources. The anticipated growth of electricity use in transport will further promote the effective use of renewable power generation technologies.

figure 2.2: a decentralised energy future

EXISTING TECHNOLOGIES, APPLIED IN A DECENTRALISED WAY AND COMBINED WITH EFFICIENCY MEASURES AND ZERO EMISSION DEVELOPMENTS, CAN DELIVER LOW CARBON COMMUNITIES AS ILLUSTRATED HERE. POWER IS GENERATED USING EFFICIENT COGENERATION TECHNOLOGIES PRODUCING BOTH HEAT (AND SOMETIMES COOLING) PLUS ELECTRICITY, DISTRIBUTED VIA LOCAL NETWORKS. THIS SUPPLEMENTS THE ENERGY PRODUCED FROM BUILDING INTEGRATED GENERATION. ENERGY SOLUTIONS COME FROM LOCAL OPPORTUNITIES AT BOTH A SMALL AND COMMUNITY SCALE. THE TOWN SHOWN HERE MAKES USE OF – AMONG OTHERS – WIND, BIOMASS AND HYDRO RESOURCES. NATURAL GAS, WHERE NEEDED, CAN BE DEPLOYED IN A HIGHLY EFFICIENT MANNER.

city



1. **PHOTOVOLTAIC, SOLAR FAÇADES** WILL BE A DECORATIVE ELEMENT ON OFFICE AND APARTMENT BUILDINGS. PHOTOVOLTAIC SYSTEMS WILL BECOME MORE COMPETITIVE AND IMPROVED DESIGN WILL ENABLE ARCHITECTS TO USE THEM MORE WIDELY.
2. **RENOVATION CAN CUT ENERGY CONSUMPTION OF OLD BUILDINGS** BY AS MUCH AS 80% - WITH IMPROVED HEAT INSULATION, INSULATED WINDOWS AND MODERN VENTILATION SYSTEMS.
3. **SOLAR THERMAL COLLECTORS** PRODUCE HOT WATER FOR BOTH THEIR OWN AND NEIGHBOURING BUILDINGS.
4. **EFFICIENT THERMAL POWER (CHP) STATIONS** WILL COME IN A VARIETY OF SIZES - FITTING THE CELLAR OF A DETACHED HOUSE OR SUPPLYING WHOLE BUILDING COMPLEXES OR APARTMENT BLOCKS WITH POWER AND WARMTH WITHOUT LOSSES IN TRANSMISSION.
5. **CLEAN ELECTRICITY** FOR THE CITIES WILL ALSO COME FROM FARTHER AFIELD. OFFSHORE WIND PARKS AND SOLAR POWER STATIONS IN DESERTS HAVE ENORMOUS POTENTIAL.

Renewable heating In the heat supply sector, the contribution of renewable energy will increase significantly. Growth rates are expected to be similar to those of the renewable electricity sector. Fossil fuels will be increasingly replaced by more efficient modern technologies, in particular biomass, solar collectors and geothermal. By 2050, renewable energy technologies will satisfy the major part of heating and cooling demand.

Transport Before new technologies including hybrid and electric cars can seriously enter the transport sector, the other electricity users need to make large efficiency gains. In this study, biomass is primarily committed to stationary applications; the use of biofuels for transport is limited by the availability of sustainably grown biomass and only for heavy duty vehicles, ships and aviation. In contrast to previous versions of Energy [R]evolution scenarios, biofuels are entirely banned now for the use in private cars.[18] Electric vehicles will therefore play an even more important role in improving energy efficiency in transport and substituting for fossil fuels.

Overall, to achieve an economically attractive growth of renewable energy sources, requires a balanced and timely mobilisation of all technologies. Such a mobilisation depends on the resource availability, cost reduction potential and technological maturity. And alongside technology driven solutions, lifestyle changes - like simply driving less and using more public transport – have a huge potential to reduce greenhouse gas emissions.

New business model The Energy [R]evolution scenario will also result in a dramatic change in the business model of energy companies, utilities, fuel suppliers and the manufacturers of energy technologies. Decentralised energy generation and large solar or offshore wind arrays which operate in remote areas, without the need for any fuel, will have a profound impact on the way utilities operate in 2020 and beyond.

Today's power supply value chain is broken down into clearly defined players but a global renewable power supply will inevitably change this division of roles and responsibilities. The following table provides an overview of how the value chain would change in a revolutionised energy mix.

The current model is a relatively small number of large power plants that are owned and operated by utilities or their subsidiaries, generating electricity for the population. Under the Energy [R]evolution scenario, around 60 to 70% of electricity will be made by small but numerous decentralised power plants. Ownership will shift towards more private investors, the manufacturer of renewable energy technologies and EPC

table 2.1: power plant value chain

TASK & MARKET PLAYER	PROJECT DEVELOPMENT	MANUFACTURE OF GEN. EQUIPMENT	INSTALLATION	OWNER OF THE POWER PLANT	OPERATION & MAINTENANCE	FUEL SUPPLY	TRANSMISSION TO THE CUSTOMER
CURRENT SITUATION POWER MARKET	Coal, gas and nuclear power stations are larger than renewables. Average number of power plants needed per 1 GW installed only 1 or 2 projects.			Relatively view power plants owned and sometimes operated by utilities.		A few large multinational oil, gas and coal mining companies dominate: today approx 75-80% of power plants need fuel supply.	Grid operation will move towards state controlled grid companies or communities due to liberalisation.
Market player							
Power plant engineering companies	■	■	■				
Utilities				■	■		
Mining companies						■	
Grid operator							■
2020 AND BEYOND POWER MARKET	Renewable power plants are small in capacity, the amount of projects for project development, manufacturers and installation companies per installed 1 GW is bigger by an order of magnitude. In the case of PV it could be up to 500 projects, for onshore wind still 25 to 50 projects.			Many projects will be owned by private households or investment banks in the case of larger projects.		By 2050 almost all power generation technologies - accept biomass - will operate without the need of fuel supply.	Grid operation will move towards state controlled grid companies or communities due to liberalisation.
Market player							
Renewable power plant engineering companies	■	■	■		■		
Private & public investors				■			
Grid operator							■

reference
18 SEE CHAPTER 11.

image A MAINTENANCE WORKER MARKS A BLADE OF A WINDMILL AT GUAZHOU WIND FARM NEAR YUMEN IN GANSU PROVINCE, CHINA.

companies (engineering, procurement and construction) away from centralised utilities. In turn, the value chain for power companies will shift towards project development, equipment manufacturing and operation and maintenance.

Simply selling electricity to customers will play a smaller role, as the power companies of the future will deliver a total power plant and the required IT services to the customer, not just electricity. They will therefore move towards becoming service suppliers for the customer. The majority of power plants will also not require any fuel supply, so mining and other fuel production companies will lose their strategic importance.

The future pattern under the Energy [R]evolution will see more and more renewable energy companies, such as wind turbine manufacturers becoming involved in project development, installation and operation and maintenance, whilst utilities will lose their status. Those traditional energy supply companies which do not move towards renewable project development will either lose market share or drop out of the market completely.

Access to energy in 2012: The International Year of Sustainable Energy for All In December 2010, the United Nations General Assembly declared 2012 the International Year of Sustainable Energy for All, recognizing that "...access to modern affordable energy services in developing countries is essential for the achievement of the internationally agreed development goals, including the Millennium Development Goals, and sustainable development, which would help to reduce poverty and to improve the conditions and standard of living for the majority of the world's population."

box 2.1: about sustainable energy for all

From the IEA Report "Energy for All – financing access for the poor.[19]

The International Energy Agency's World Energy Outlook (WEO) has focused attention on modern energy access for a decade. In a special early excerpt of World Energy Outlook 2011, the IEA tackled the critical issue of financing the delivery of universal access to modern forms of energy. The report recognised that energy access can create a better life for individuals, alleviating poverty and improving health, literacy and equity.

Globally, over 1.3 billion people, more than a quarter of the world's population are without access to electricity and 2.7 billion people are without clean cooking facilities. More than 95% of these people are either in sub-Saharan Africa or developing Asia and 84% are in rural areas. In 2009, the IEA estimates that $9.1 billion was invested globally in extending access to modern energy services and will average $14 billion per year, projected between 2010 and 2030, mostly devoted to new on-grid electricity connections in urban areas. Even with this there will be one billion people without electricity and 2.7 billion people without clean cooking facilities in 2030. To provide universal modern energy access by 2030 the IEA forecasts that annual average investment needs would need to be $48 billion per year, more than five-times the level of 2009, and most in sub-Saharan Africa.

The IEA puts forwards five actions to achieve universal, modern energy access:

1. Adopt a clear and consistent statement that modern energy access is a political priority and that policies and funding will be reoriented accordingly. National governments need to adopt a specific energy access target, allocate funds and define their delivery strategy.
2. Mobilise additional investment in universal access, above the $14 billion per year assumed in our central scenario, of $34 billion per year - equivalent to around 3% of global investment in energy infrastructure over the period to 2030. All sources and forms of investment have their part to play, reflecting the varying risks and returns of particular solutions.
3. Overcome the significant banners to large growth in private sector investment. National governments need to adopt strong governance and regulatory frameworks and invest in internal capacity building. The public sector, including multilateral and bilateral institutions, needs to use its tools to leverage greater private sector investment where the business case is marginal and encourage the development of repeatable business models. When used, public subsidies must be well targeted to reach the poorest.
4. Concentrate a large part of multilateral and bilateral direct funding on those difficult areas of access which do not initially offer an adequate commercial return. Provision of end-user finance is required to overcome the barrier of the initial capitals. Local banks and microfinance arrangements can support the creation of local networks and the necessary capacity in energy sector activity.
5. Collection of robust, regular and comprehensive data to quantify the outstanding challenge and monitor progress towards its elimination. International concern about the issue of energy access is growing.

Discussions at the Energy for All Conference in Oslo, Norway (October 2011) and the COP17 in Durban, South Africa (December 2011) have established the link between energy access, climate change and development which can now be addressed at the United Nations Conference on Sustainable Development (Rio+20) in Rio de Janeiro, Brazil in June 2012. That conference will be the occasion for commitments to specific action to achieve sustainable development, including universal energy access, since as currently the United Nations Millennium Development Goals do not include specific targets in relation to access to electricity or to clean cooking facilities.

reference
19 SPECIAL EXCERPT OF THE WORLD ENERGY OUTLOOK 2011.

The General Assembly's Resolution 65/151 called on UN Secretary-General Ban Ki-Moon to organize and coordinate activities during the Year in order to "increase awareness of the importance of addressing energy issues", including access to and sustainability of affordable energy and energy efficiency at local, national, regional and international levels.

In response, the new global initiative, Sustainable Energy for All, launched at the General Assembly in September 2011, along with a High Level Group, is designed to mobilise action from governments, the private sector and civil society globally. The initiative has three inter-linked objectives: universal access to modern energy services, improved rates of energy efficiency, and expanded use of renewable energy sources.

The role of sustainable, clean renewable energy To achieve the dramatic emissions cuts needed to avoid climate change, around 80% in OECD countries by 2050, will require a massive uptake of renewable energy. The targets for renewable energy must be greatly expanded in industrialised countries both to substitute for fossil fuel and nuclear generation and to create the necessary economies of scale necessary for global expansion. Within the Energy [R]evolution scenario we assume that modern renewable energy sources, such as solar collectors, solar cookers and modern forms of bio energy, will replace inefficient, traditional biomass use.

Step 3: optimised integration – renewables 24/7 A complete transformation of the energy system will be necessary to accommodate the significantly higher shares of renewable energy expected under the Energy [R]evolution scenario. The grid network of cables and sub-stations that brings electricity to our homes and factories was designed for large, centralised generators running at huge loads, providing 'baseload' power. Until now, renewable energy has been seen as an additional slice of the energy mix and had had adapt to the grid's operating conditions. If the Energy [R]evolution scenario is to be realised, this will have to change.

Because renewable energy relies mostly on natural resources, which are not available at all times, some critics say this makes it unsuitable for large portions of energy demand. Existing practice in a number of countries has already shown that this is false.

Clever technologies can track and manage energy use patterns, provide flexible power that follows demand through the day, use better storage options and group customers together to form 'virtual batteries'. With current and emerging solutions we can secure the renewable energy future needed to avert catastrophic climate change. Renewable energy 24/7 is technically and economically possible, it just needs the right policy and the commercial investment to get things moving and 'keep the lights on'.[20] Further adaptations to how the grid network operates will allow integration of even larger quantities of renewable capacity.

Changes to the grid required to support decentralised energy Most grids around the world have large power plants in the middle connected by high voltage alternating current (AC) power lines and smaller distribution network carries power to final consumers. The centralised grid model was designed and planned up to 60 years ago, and brought great benefit to cities and rural areas. However the system is very wasteful, with much energy lost in transition. A system based on renewable energy, requiring lots of smaller generators, some with variable amounts of power output will need a new architecture.

The overall concept of a smart grid is one that balances fluctuations in energy demand and supply to share out power effectively among users. New measures to manage demand, forecasting the weather for storage needs, plus advanced communication and control technologies will help deliver electricity effectively.

Technological opportunities Changes to the power system by 2050 will create huge business opportunities for the information, communication and technology (ICT) sector. A smart grid has power supplied from a diverse range of sources and places and it relies on the gathering and analysis of a lot of data. Smart grids require software, hardware and data networks capable of delivering data quickly, and of responding to the information that they contain. Several important ICT players are racing to smarten up energy grids across the globe and hundreds of companies could be involved with smart grids.

There are numerous IT companies offering products and services to manage and monitor energy. These include IBM, Fujitsu, Google, Microsoft and Cisco. These and other giants of the telecommunications and technology sector have the power to make the grid smarter, and to move us faster towards a clean energy future. Greenpeace has initiated the 'Cool IT' campaign to put pressure on the IT sector to make such technologies a reality.

2.3 the new electricity grid

All over the developed world, the grids were built with large fossil fuel power plants in the middle and high voltage alternating current (AC) transmission power lines connecting up to the areas where the power is used. A lower voltage distribution network then carries the current to the final consumers.

In the future power generators will be smaller and distributed throughout the grid, which is more efficient and avoids energy losses during long distance transmission. There will also be some concentrated supply from large renewable power plants. Examples of the large generators of the future are massive wind farms already being built in Europe's North Sea and plans for large areas of concentrating solar mirrors to generate energy in Southern Europe or Northern Africa.

The challenge ahead will require an innovative power system architecture involving both new technologies and new ways of managing the network to ensure a balance between fluctuations in energy demand and supply. The key elements of this new power system architecture are micro grids, smart grids and an efficient large scale super grid. The three types of system will support and interconnect with each other (see Figure 2.3).

reference

20 THE ARGUMENTS AND TECHNICAL SOLUTIONS OUTLINED HERE ARE EXPLAINED IN MORE DETAIL IN THE EUROPEAN RENEWABLE ENERGY COUNCIL/GREENPEACE REPORT, "[R]ENEWABLES 24/7: INFRASTRUCTURE NEEDED TO SAVE THE CLIMATE", NOVEMBER 2009.

image AERIAL VIEW OF THE WORLD'S LARGEST OFFSHORE WINDPARK IN THE NORTH SEA HORNS REV IN ESBJERG, DENMARK.

box 2.2: definitions and technical terms

The electricity 'grid' is the collective name for all the cables, transformers and infrastructure that transport electricity from power plants to the end users.

Micro grids supply local power needs. Monitoring and control infrastructure are embedded inside distribution networks and use local energy generation resources. An example microgrid would be a combination of solar panels, micro turbines, fuel cells, energy efficiency and information/communication technology to manage the load, for example on an island or small rural town.

Smart grids balance demand out over a region. A 'smart' electricity grid connects decentralised renewable energy sources and cogeneration and distributes power highly efficiently. Advanced types of control and management technologies for the electricity grid can also make it run more efficiently overall. For example, smart electricity meters show real-time use and costs, allowing big energy users to switch off or down on a signal from the grid operator, and avoid high power prices.

Super grids transport large energy loads between regions. This refers to interconnection - typically based on HVDC technology - between countries or areas with large supply and large demand. An example would be the interconnection of all the large renewable based power plants in the North Sea or a connection between Southern Europe and Africa where renewable energy could be exported to bigger cities and towns, from places with large locally available resources.

Baseload is the concept that there must be a minimum, uninterruptible supply of power to the grid at all times, traditionally provided by coal or nuclear power. The Energy [R]evolution challenges this, and instead relies on a variety of 'flexible' energy sources combined over a large area to meet demand. Currently, 'baseload' is part of the business model for nuclear and coal power plants, where the operator can produce electricity around the clock whether or not it is actually needed.

Constrained power refers to when there is a local oversupply of free wind and solar power which has to be shut down, either because it cannot be transferred to other locations (bottlenecks) or because it is competing with inflexible nuclear or coal power that has been given priority access to the grid. Constrained power is also available for storage once the technology is available.

Variable power is electricity produced by wind or solar power depending on the weather. Some technologies can make variable power dispatchable, eg by adding heat storage to concentrated solar power.

Dispatchable is a type of power that can be stored and 'dispatched' when needed to areas of high demand, e.g. gas-fired power plants or hydro power plants.

Interconnector is a transmission line that connects different parts of the electricity grid.Load curve is the typical pattern of electricity through the day, which has a predictable peak and trough that can be anticipated from outside temperatures and historical data.

Node is a point of connection in the electricity grid between regions or countries, where there can be local supply feeding into the grid as well.

2.3.1 hybrid systems

While grid in the developed world supply power to nearly 100% of the population, many rural areas in the developing world rely on unreliable grids or polluting electricity, for example from stand-alone diesel generators. This is also very expensive for small communities.

The standard approach of extending the grid used in developed countries is often not economic in rural areas of developing countries where potential electricity is low and there are long distances to existing grid.

Electrification based on renewable energy systems with a hybrid mix of sources is often the cheapest as well as the least polluting alternative. Hybrid systems connect renewable energy sources such as wind and solar power to a battery via a charge controller, which stores the generated electricity and acts as the main power supply. Back-up supply typically comes from a fossil fuel, for example in a wind-battery-diesel or PV-battery-diesel system.

Such decentralised hybrid systems are more reliable, consumers can be involved in their operation through innovative technologies and they can make best use of local resources. They are also less dependent on large scale infrastructure and can be constructed and connected faster, especially in rural areas.

Finance can often be an issue for relatively poor rural communities wanting to install such hybrid renewable systems. Greenpeace's funding model, the Feed-in Tariff Support Mechanism (FTSM), discussed in Chapter 1 allows project to be bundled together so the financial package is large enough to be eligible for international investment support. In the Pacific region, for example, power generation projects from a number of islands, an entire island state such as the Maldives or even several island states could be bundled into one project package. This would make it large enough for funding as an international project by OECD countries. In terms of project planning, it is essential that the communities themselves are directly involved in the process.

2.3.2 smart grids

The task of integrating renewable energy technologies into existing power systems is similar in all power systems around the world, whether they are large centralised networks or island systems. The main aim of power system operation is to balance electricity consumption and generation.

Thorough forward planning is needed to ensure that the available production can match demand at all times. In addition to balancing supply and demand, the power system must also be able to:

- Fulfil defined power quality standards – voltage/frequency - which may require additional technical equipment, and
- Survive extreme situations such as sudden interruptions of supply, for example from a fault at a generation unit or a breakdown in the transmission system.

Integrating renewable energy by using a smart grid means moving away from the concept of baseload power towards a mix of flexible and dispatch able renewable power plants. In a smart grid a portfolio of flexible energy providers can follow the load during both day and night (for example, solar plus gas, geothermal, wind and demand management) without blackouts.

What is a smart grid? Until now renewable power technology development has put most effort into adjusting its technical performance to the needs of the existing network, mainly by complying with grid codes, which cover such issues as voltage frequency and reactive power. However, the time has come for the power systems themselves to better adjust to the needs of variable generation. This means that they must become flexible enough to follow the fluctuations of variable renewable power, for example by adjusting demand via demand-side management and/or deploying storage systems.

The future power system will consist of tens of thousands of generation units such as solar panels, wind turbines and other renewable generation, partly distributed in the distribution network, partly concentrated in large power plants such as offshore wind parks. The power system planning will become more complex due to the larger number of generation assets and the significant share of variable power generation causing constantly changing power flows.

Smart grid technology will be needed to support power system planning. This will operate by actively supporting day-ahead forecasts and system balancing, providing real-time information about the status of the network and the generation units, in combination with weather forecasts. It will also play a significant role in making sure systems can meet the peak demand and make better use of distribution and transmission assets, thereby keeping the need for network extensions to the absolute minimum.

To develop a power system based almost entirely on renewable energy sources requires a completely new power system architecture, which will need substantial amounts of further work to fully emerge.[21] Figure 2.3 shows a simplified graphic representation of the key elements in future renewable-based power systems using smart grid technology.

A range of options are available to enable the large-scale integration of variable renewable energy resources into the power supply system. Some features of smart grids could be:

Managing level and timing of demand for electricity. Changes to pricing schemes can give consumers financial incentives to reduce or shut off their supply at periods of peak consumption, as system that is already used for some large industrial customers. A Norwegian power supplier even involves private household customers by sending them a text message with a signal to shut down. Each household can decide in advance whether or not they want to participate. In Germany, experiments are being conducted with time flexible tariffs so that washing machines operate at night and refrigerators turn off temporarily during periods of high demand.

Advances in communications technology. In Italy, for example, 30 million 'smart meters' have been installed to allow remote meter reading and control of consumer and service information. Many household electrical products or systems, such as refrigerators, dishwashers, washing machines, storage heaters, water pumps and air conditioning, can be managed either by temporary shut-off or by rescheduling their time of operation, thus freeing up electricity load for other uses and dovetailing it with variations in renewable supply.

Creating Virtual Power Plants (VPP). Virtual power plants interconnect a range of real power plants (for example solar, wind and hydro) as well as storage options distributed in the power system using information technology. A real life example of a VPP is the Combined Renewable Energy Power Plant developed by three German companies.[22] This system interconnects and controls 11 wind power plants, 20 solar power plants, four CHP plants based on biomass and a pumped storage unit, all geographically spread around Germany. The VPP monitors (and anticipates through weather forecasts) when the wind turbines and solar modules will be generating electricity. Biogas and pumped storage units are used to make up the difference, either delivering electricity as needed in order to balance short term fluctuations or temporarily storing it.[23] Together the combination ensures sufficient electricity supply to cover demand.

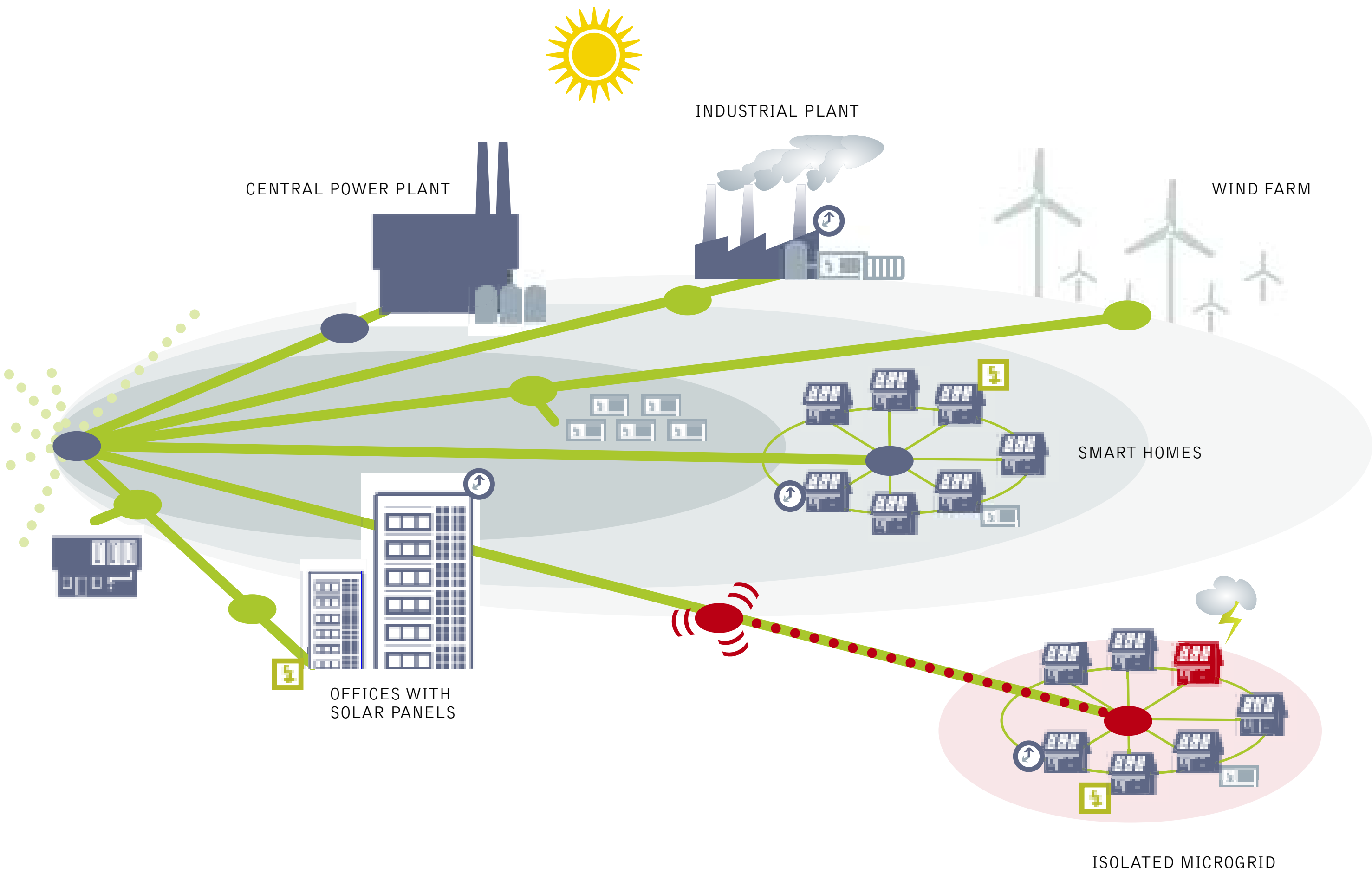
Electricity storage options. Pumped storage is the most established technology for storing energy from a type of hydroelectric power station. Water is pumped from a lower elevation reservoir to a higher elevation during times of low cost, off-peak electricity. During periods of high electrical demand, the stored water is released through turbines. Taking into account evaporation losses from the exposed water surface and conversion losses, roughly 70 to 85% of the electrical energy used to pump the water into the elevated reservoir can be regained when it is released. Pumped storage plants can also respond to changes in the power system load demand within seconds. Pumped storage has been successfully used for many decades all over the world.

references
21 SEE ALSO ECOGRID PHASE 1 SUMMARY REPORT, AVAILABLE AT: HTTP://WWW.ENERGINET.DK/NR/RDONLYRES/8B1A4A06-CBA3-41DA-9402-B56C2C288FB0/0/ECOGRIDDK_PHASE1_SUMMARYREPORT.PDF.
22 SEE ALSO HTTP://WWW.KOMBIKRAFTWERK.DE/INDEX.PHP?ID=27.
23 SEE ALSO HTTP://WWW.SOLARSERVER.DE/SOLARMAGAZIN/ANLAGEJANUAR2008_E.HTML.

image A WORKER ASSEMBLES WIND TURBINE ROTORS AT GANSU JINFENG WIND POWER EQUIPMENT CO. LTD. IN JIUQUAN, GANSU PROVINCE, CHINA.

figure 2.3: the smart-grid vision for the energy [r]evolution

A VISION FOR THE FUTURE – A NETWORK OF INTEGRATED MICROGRIDS THAT CAN MONITOR AND HEAL ITSELF.



PROCESSORS
EXECUTE SPECIAL PROTECTION SCHEMES IN MICROSECONDS

SENSORS (ON ‘STANDBY’)
– DETECT FLUCTUATIONS AND DISTURBANCES, AND CAN SIGNAL FOR AREAS TO BE ISOLATED

SENSORS (‘ACTIVATED’)
– DETECT FLUCTUATIONS AND DISTURBANCES, AND CAN SIGNAL FOR AREAS TO BE ISOLATED

SMART APPLIANCES
CAN SHUT OFF IN RESPONSE TO FREQUENCY FLUCTUATIONS

DEMAND MANAGEMENT
USE CAN BE SHIFTED TO OFF-PEAK TIMES TO SAVE MONEY

GENERATORS
ENERGY FROM SMALL GENERATORS AND SOLAR PANELS CAN REDUCE OVERALL DEMAND ON THE GRID

STORAGE ENERGY GENERATED AT OFF-PEAK TIMES COULD BE STORED IN BATTERIES FOR LATER USE

DISTURBANCE IN THE GRID

In 2007 the European Union had 38 GW of pumped storage capacity, representing 5% of total electrical capacity.

Vehicle-to-Grid. Another way of 'storing' electricity is to use it to directly meet the demand from electric vehicles. The number of electric cars and trucks is expected to increase dramatically under the Energy [R]evolution scenario. The Vehicle-to-Grid (V2G) concept, for example, is based on electric cars equipped with batteries that can be charged during times when there is surplus renewable generation and then discharged to supply peaking capacity or ancillary services to the power system while they are parked. During peak demand times cars are often parked close to main load centres, for instance outside factories, so there would be no network issues. Within the V2G concept a Virtual Power Plant would be built using ICT technology to aggregate the electric cars participating in the relevant electricity markets and to meter the charging/de-charging activities. In 2009 the EDISON demonstration project was launched to develop and test the infrastructure for integrating electric cars into the power system of the Danish island of Bornholm.

2.3.3 the super grid

Greenpeace simulation studies Renewables 24/7 (2010) and Battle of the Grids (2011) have shown that extreme situations with low solar radiation and little wind in many parts of Europe are not frequent, but they can occur. The power system, even with massive amounts of renewable energy, must be adequately designed to cope with such an event. A key element in achieving this is through the construction of new onshore and offshore super grids.

The Energy [R]evolution scenario assumes that about 70% of all generation is distributed and located close to load centres. The remaining 30% will be large scale renewable generation such as large offshore wind farms or large arrays of concentrating solar power plants. A North Sea offshore super grid, for example, would enable the efficient integration of renewable energy into the power system across the whole North Sea region, linking the UK, France, Germany, Belgium, the Netherlands, Denmark and Norway. By aggregating power generation from wind farms spread across the whole area, periods of very low or very high power flows would be reduced to a negligible amount. A dip in wind power generation in one area would be balanced by higher production in another area, even hundreds of kilometres away. Over a year, an installed offshore wind power capacity of 68.4 GW in the North Sea would be able to generate an estimated 247 TWh of electricity.[24]

2.3.4 baseload blocks progress

Generally, coal and nuclear plants run as so-called base load, meaning they work most of the time at maximum capacity regardless of how much electricity consumers need. When demand is low the power is wasted. When demand is high additional gas is needed as a backup.

However, coal and nuclear cannot be turned down on windy days so wind turbines will get switched off to prevent overloading the system.

box 2.3: do we need baseload power plants?[25]

Power from some renewable plants, such as wind and solar, varies during the day and week. Some see this as an insurmountable problem, because up until now we have relied on coal or nuclear to provide a fixed amount of power at all times. In current policy-making there is a struggle to determine which type of infrastructure or management we choose and which energy mix to favour as we move away from a polluting, carbon intensive energy system. Some important facts include:

- electricity demand fluctuates in a predictable way.
- smart management can work with big electricity users, so their peak demand moves to a different part of the day, evening out the load on the overall system.
- electricity from renewable sources can be stored and 'dispatched' to where it is needed in a number of ways, using advanced grid technologies.

Wind-rich countries in Europe are already experiencing conflict between renewable and conventional power. In Spain, where a lot of wind and solar is now connected to the grid, gas power is stepping in to bridge the gap between demand and supply. This is because gas plants can be switched off or run at reduced power, for example when there is low electricity demand or high wind production. As we move to a mostly renewable electricity sector, gas plants will be needed as backup for times of high demand and low renewable production. Effectively, a kWh from a wind turbine displaces a kWh from a gas plant, avoiding carbon dioxide emissions. Renewable electricity sources such as thermal solar plants (CSP), geothermal, hydro, biomass and biogas can gradually phase out the need for natural gas. (See Case Studies for more). The gas plants and pipelines would then progressively be converted for transporting biogas.

The recent global economic crisis triggered drop in energy demand and revealed system conflict between inflexible base load power, especially nuclear, and variable renewable sources, especially wind power, with wind operators told to shut off their generators. In Northern Spain and Germany, this uncomfortable mix is already exposing the limits of the grid capacity. If Europe continues to support nuclear and coal power alongside a growth in renewables, clashes will occur more and more, creating a bloated, inefficient grid.

Despite the disadvantages stacked against renewable energy it has begun to challenge the profitability of older plants. After construction costs, a wind turbine is generating electricity almost for free and without burning any fuel. Meanwhile, coal and nuclear plants use expensive and highly polluting fuels. Even where nuclear plants are kept running and wind turbines are switched off, conventional energy providers are concerned. Like any commodity, oversupply reduces price across the market. In energy markets, this affects nuclear and coal too. We can expect more intense conflicts over access to the grids over the coming years.

references
24 GREENPEACE REPORT, 'NORTH SEA ELECTRICITY GRID [R]EVOLUTION', SEPTEMBER 2008.
25 BATTLE OF THE GRIDS, GREENPEACE INTERNATIONAL, FEBRUARY 2011.

image GREENPEACE OPENS A SOLAR ENERGY WORKSHOP IN BOMA. A MOBILE PHONE GETS CHARGED BY A SOLAR ENERGY POWERED CHARGER.

figure 2.4: a typical load curve throughout europe, shows electricity use peaking and falling on a daily basis

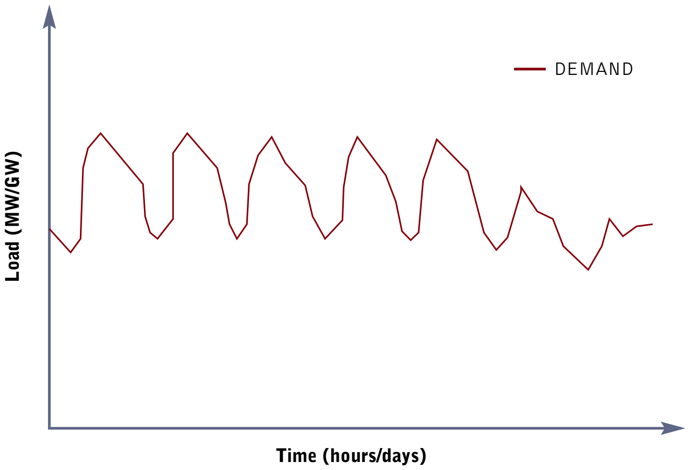
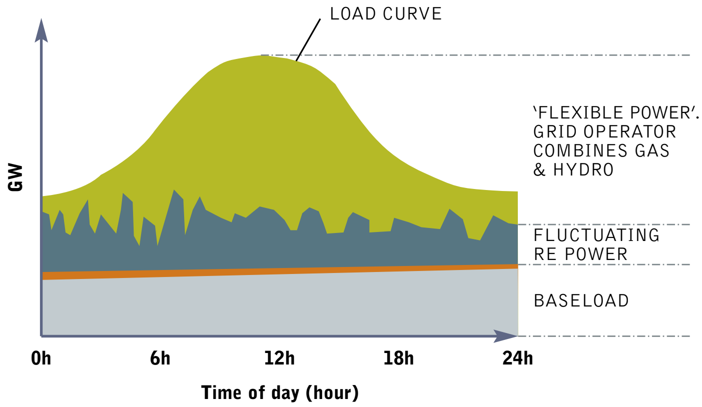


figure 2.5: the evolving approach to grids

Current supply system

- Low shares of fluctuating renewable energy
- The 'base load' power is a solid bar at the bottom of the graph.
- Renewable energy forms a 'variable' layer because sun and wind levels changes throughout the day.
- Gas and hydro power which can be switched on and off in response to demand. This is sustainable using weather forecasting and clever grid management.
- With this arrangement there is room for about 25 percent variable renewable energy.

To combat climate change much more than 25 percent renewable electricity is needed.



Supply system with more than 25 percent fluctuating renewable energy > base load priority

- This approach adds renewable energy but gives priority to base load.
- As renewable energy supplies grow they will exceed the demand at some times of the day, creating surplus power.
- To a point, this can be overcome by storing power, moving power between areas, shifting demand during the day or shutting down the renewable generators at peak times.

Does not work when renewables exceed 50 percent of the mix, and can not provide renewable energy as 90- 100% of the mix.

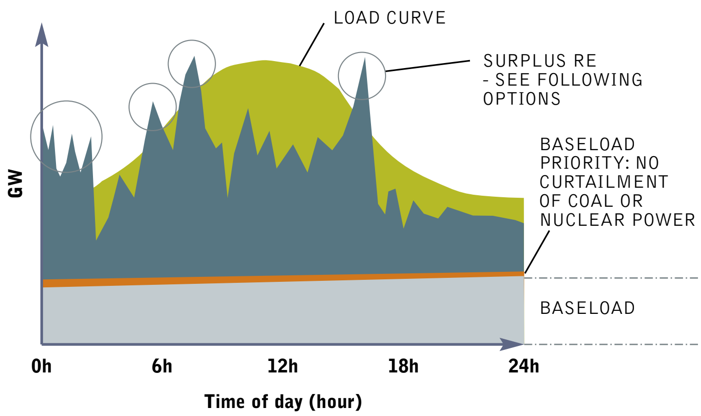
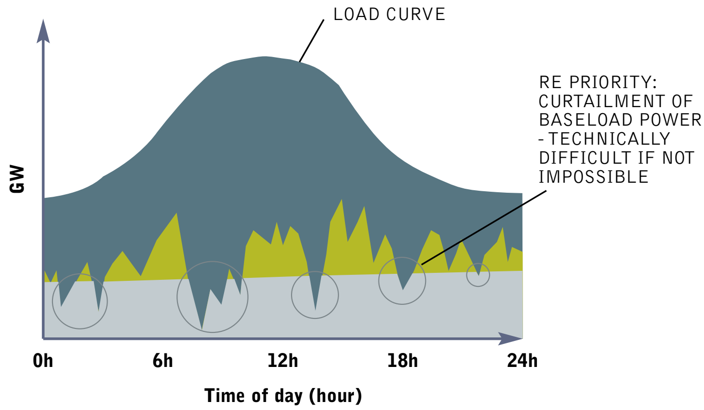


figure 2.5: the evolving approach to grids *continued*

Supply system with more than 25 percent fluctuating renewable energy – renewable energy priority

- This approach adds renewables but gives priority to clean energy.
- If renewable energy is given priority to the grid, it "cuts into" the base load power.
- Theoretically, nuclear and coal need to run at reduced capacity or be entirely turned off in peak supply times (very sunny or windy).
- There are technical and safety limitations to the speed, scale and frequency of changes in power output for nuclear and coal-CCS plants.

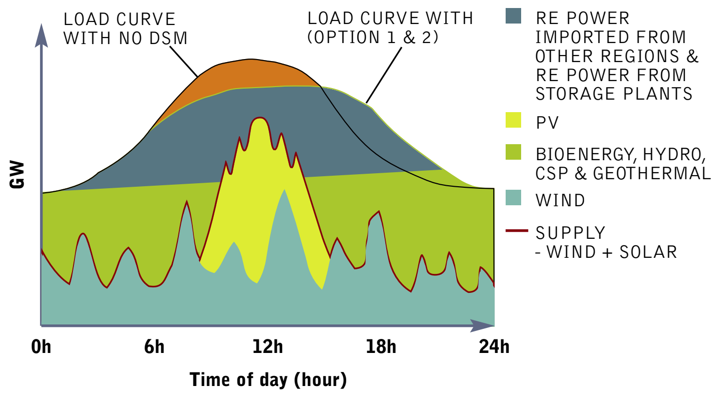
Technically difficult, not a solution.



The solution: an optimised system with over 90% renewable energy supply

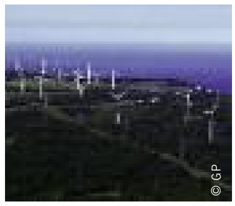
- A fully optimised grid, where 100 percent renewables operate with storage, transmission of electricity to other regions, demand management and curtailment only when required.
- Demand management effectively moves the highest peak and 'flattens out' the curve of electricity use over a day.

Works!



One of the key conclusions from Greenpeace research is that in the coming decades, traditional power plants will have less and less space to run in baseload mode. With increasing penetration of variable generation from wind and photovoltaic in the electricity grid, the remaining part of the system will have to run in more 'load following' mode, filling the immediate gap between demand and production. This means the economics of base load plants like nuclear and coal will change fundamentally as more variable generation is introduced to the electricity grid.

image LE NORDAIS WINDMILL PARK, ONE OF THE MOST IMPORTANT IN AMERICA, LOCATED ON THE GASPÈ PENINSULA IN CAP-CHAT, QUEBEC, CANADA.



2.4 case study: a year after the german nuclear phase out

On 30 May 2011, the German environment minister, Norbert Röttgen, announced the Germany would close its eight oldest nuclear plants and phase out the remaining nine reactors by 2022. The plan is to replace most of the generating capacity of these nine reactors with renewables. The experience so far gives a real example of the steps needed for a global Energy [R]evolution at a national scale.

2.4.1 target and method

The German government expects renewables to generate 35% of German electricity by 2020.[26] The German Federal Environment Agency believes that the phase out would be technically feasible from 2017 , requiring only 5 GWh of additional combined heat-and-power or combined cycle gas plant (other than those already under construction) to meet peak time demand.[27]

2.4.2 carbon dioxide emissions trends

The Germany energy ambassador, Dr. Georg Maue reported to a meeting in the British Parliament in February 2012 that Germany was still on track to meet its CO_2 reduction targets of 40% by 2020 and 80% by 2050 from 1990 levels. Figures for Germany's 2011 greenhouse gas emissions were not available for this report, although the small growth in use of lignite fuels is likely to have increased emissions in the short term.

However, the decision to phase out nuclear energy has renewed the political pressure to deliver a secure climate-friendly energy policy and ensure Germany still meets its greenhouse targets. The Energiewende ('energy transition') measures include €200billion investment in renewable energy over the next decade, a major push on energy efficiency and an accelerated roll out of infrastructure to support the transition.[28] Germany has also become an advocate for renewables at the European level.[29] In the longer-term, by deploying a large amount of renewable capability Germany should be able to continue reducing its emissions at this accelerated rate and its improved industrial production should make it more viable for other countries to deliver greater and faster emissions reductions.

2.4.3 shortfall from first round of closures

The oldest eight nuclear reactors were closed immediately and based on figures available it looks like the 'shortfall' will be covered by a mix of lower demand, increasing renewable energy supply, and a small part by fossil-fuelled power.

In 2011 only 18% of the country's energy generation came from nuclear, as shown in Figure 2.7.[30] In the previous year, nuclear energy's contribution had already fallen from 22% to 18%, a shortfall covered mostly by renewable electricity which increased from 16% to 20% in the same period, while use of lignite (a greenhouse-intensive fossil fuel) increased from 23% to 25% (Figure 2.6).

In the first half of 2011, Germany was a net exporter of electricity, exporting 29 billion kWh and importing 24 kWh.[31] Complete figures for electricity imports and exports in the second half of 2011, once nuclear reactors were decommissioned, however it is known that Germany exported electricity to France during a cold spell in February 2012.[32]

Inside Germany, the demand for energy is falling.[33] Between 2010 and 2011 energy demand dropped by 5%, because the mild weather reduced demand for gas heating. While the British government is planning for electricity demand in the UK to double by 2050, the German government expects a cut of 25% from 2008 levels.[34] Total energy demand is expected to halve over the same time period.

2.4.4 the renewable energy sector in germany

Germany has successfully increased the share of renewable energy constantly over the last twenty years, and the sector was employing over 350,000 employees by the end of 2011. The back bone of this development has been the Renewable Energy Act (Erneuerbare Energien Gesetz – EEG); a feed-in law which guarantees a fixed tariff per kWh for 20 years. The tariffs are different for each technology and between smaller and larger, to reflect their market penetration rates.

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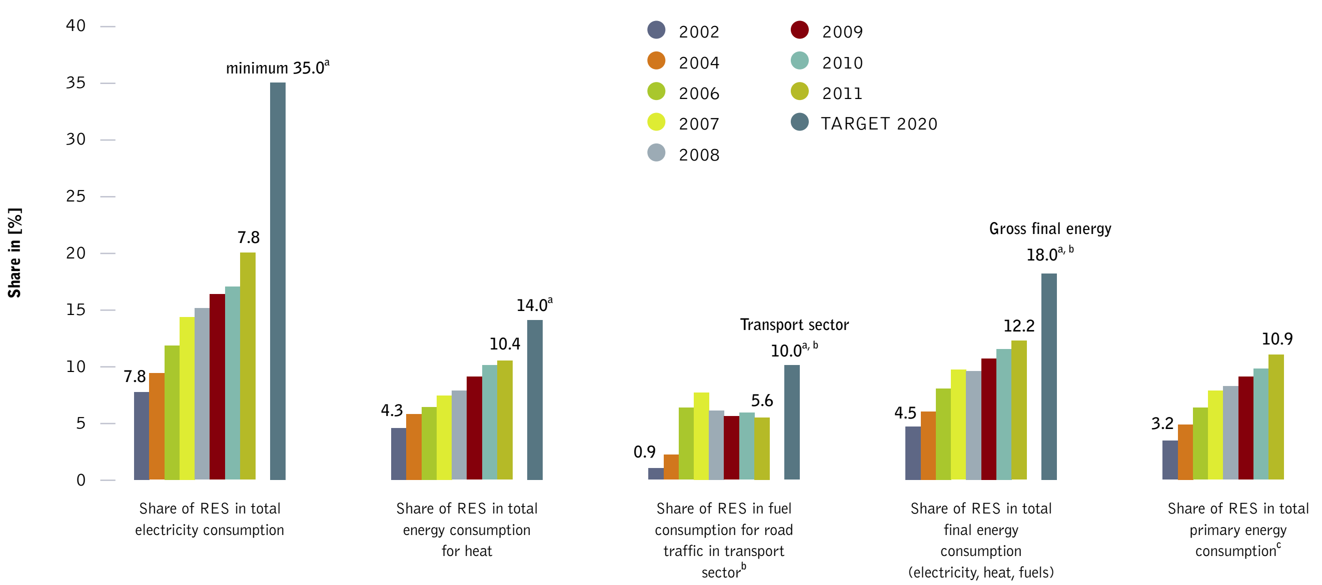
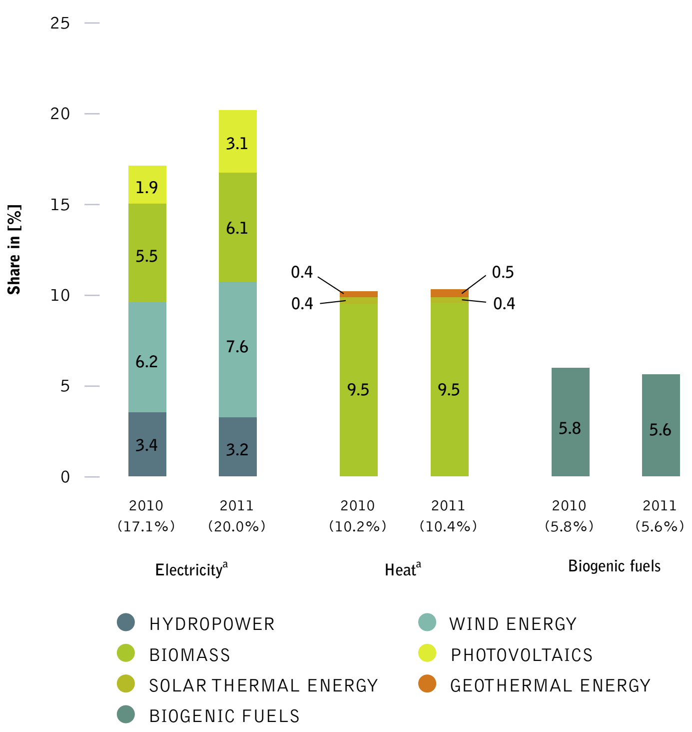
34 HTTP://WWW.BMU.DE/FILES/ENGLISH/PDF/APPLICATION/PDF/ENERGIEKONZEPT_BUNDESREGIERUNG_EN.PDF (PAGE 5)

figure 2.6: renewable energy sources as a share of energy supply in germany



source
a TARGETS OF THE GERMAN GOVERNMENT, RENEWABLE ENERGY SOURCES ACT (EEG). RENEWABLE ENERGY SOURCES HEAT ACT (EEWärmeG). EU-DIRECTIVE 2009/28/EC.
b TOTAL CONSUMPTION OF ENGINE FUELS, EXCLUDING FUEL IN AIR TRAFFIC.
c CALCULATED USING EFFICIENCY METHOD; SOURCE: WORKING GROUP ON ENERGY BALANCES e.V. (AGEB); RES: RENEWABLE ENERGY SOURCES; SOURCE: BMU-KI III 1 ACCORDING TO WORKING GROUP ON RENEWABLE ENERGY-STATISTICS (AGEE-STAT); AS AT: MARCH 2012; ALL FIGURES PROVISIONAL.

figure 2.7: renewable energy sources in total final energy consumption in germany 2011/2010



source
a BIOMASS: SOLID AND LIQUID BIOMASS, BIOGAS, SEWAGE AND LANDFILL GAS, BIOGENIC SHARE OF WASTE; ELECTRICITY FROM GEOTHERMAL ENERGY NOT PRESENTED DUE TO NEGLIBLE QUANTITIES PRODUCED; DEVIATIONS IN THE TOTALS ARE DUE TO ROUNDING; SOURCE: BMU-KI III 1 ACCORDING TO WORKING GROUP ON RENEWABLE ENERGY-STATISTICS (AGEE-STAT); AS AT: MARCH 2012; ALL FIGURES PROVISIONAL.

2.4.5 the renewable energy sector in germany

The German government agreed on short, medium and long term – binding - targets for renewable, energy efficiency and greenhouse gas reduction.

2.4.6 the renewable energy sector in germany

The graph below shows where the nuclear power stations are located and when they will be shut down. The last nuclear reactor will be closed down in 2022.

2.4.7 no 'blackouts'

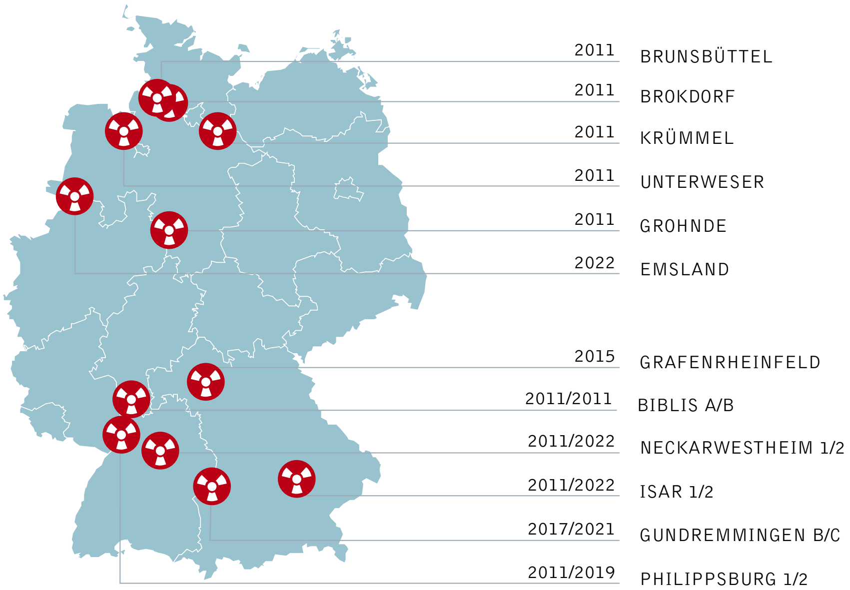
The nuclear industry has implied there would be a "black-out" in winter 2011 - 2012, or that Germany would need to import electricity from neighbouring countries, when the first set of reactors were closed. Neither event happened, and Germany actually remained a net- export of electricity during the first winter. The table below shows the electricity flow over the borders.

image A COW IN FRONT OF A BIOREACTOR IN THE BIOENERGY VILLAGE OF JUEHNDE. IT IS THE FIRST COMMUNITY IN GERMANY THAT PRODUCES ALL OF ITS ENERGY NEEDED FOR HEATING AND ELECTRICITY, WITH CO_2 NEUTRAL BIOMASS.

table 2.2: german government short, medium and long term binding targets

	CLIMATE	EFFICIENCY		RENEWABLE ENERGIES		
	GREENHOUSE GASES (VS 1990)	SHARE OF ELECTRICITY	OVERALL SHARE (Gross final energy consumption)	PRIMARY ENERGY CONSUMPTION	ENERGY PRODUCTIVITY	BUILDING MODERNISATION
2020	- 40%	35%	18%	-20%		
2030	- 55%	50%	30%	↓	Increase to 2.1% annum	Double the rate 1%-2%
2040	- 70%	65%	45%			
2040	- 85-95%	80%	60%	-50%		

figure 2.8: phase out of nuclear energy

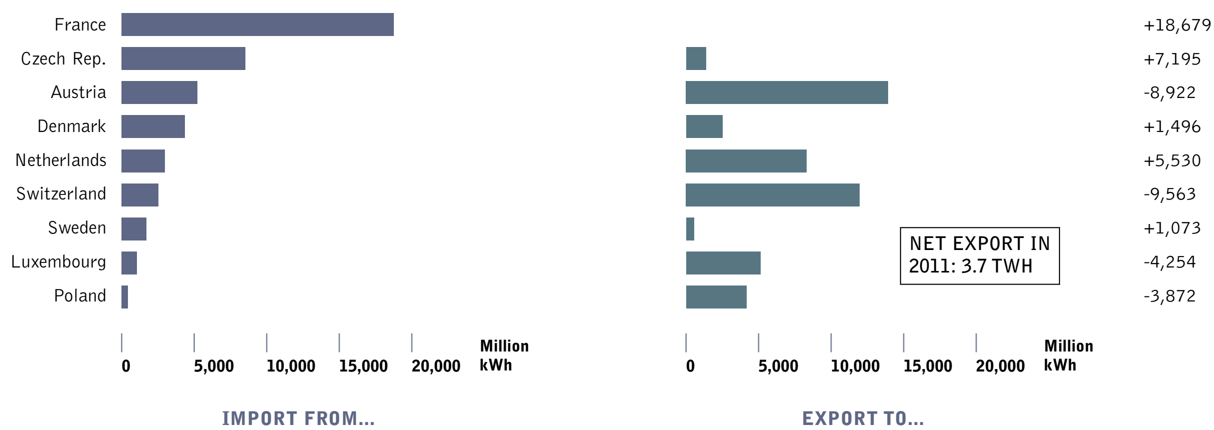


- Seven oldest plants plus Krümmel: immediate decommissioning
- Gradual phasing out of nuclear power by 2022
- Shutdown years: 2015, 2017, 2019, 2021, 2022

source UMWELTBUNDESAMT (UBA) 2012, GERMAN MINSTERY FOR ENVIRONMENT

figure 2.9: electricity imports/exports germany

JANUARY TO NOVEMBER 2011. (VOLUME MEASURE IN



2.5 case study: providing smart energy to Bihar, from the "bottom-up"

Over one billion people do not have any access to energy services – most of them are living in rural areas, far away from electricity grids. Rural electrification is known to bring economic development to communities, and the premise of an Energy [R]evolution is to strive for more equity, not to entrench disadvantage.

Greenpeace worked with a community in northern India in the state of Bihar to see how a real community could create their own, new electricity services in a sustainable way. The core concept was for communities to be able to organise their own electricity supply step by step, building up a local micro-grid that runs on locally available, renewable resources.

For example, households may start with only a few hours of electricity for lighting each day, but they are on a pathway towards continuous supply. As each community builds the infrastructure, they can connect their smart microgrids with each other. The advantages are that it is faster than waiting for a centralised approach, communities take their electricity supply into their own hands, and investment stays in the region and creates local jobs.

Greenpeace International asked the German/Swedish engineering company energynautics to develop a technical concept. Called *Smart Energy Access*, it proposes a proactive, bottom-up approach to building smart microgrids in developing countries.

They are flexible, close to users so reduce transmission losses, help facilitate integration of renewable energy and educe transmission losses by having generation close to demand.

2.5.1 methodology

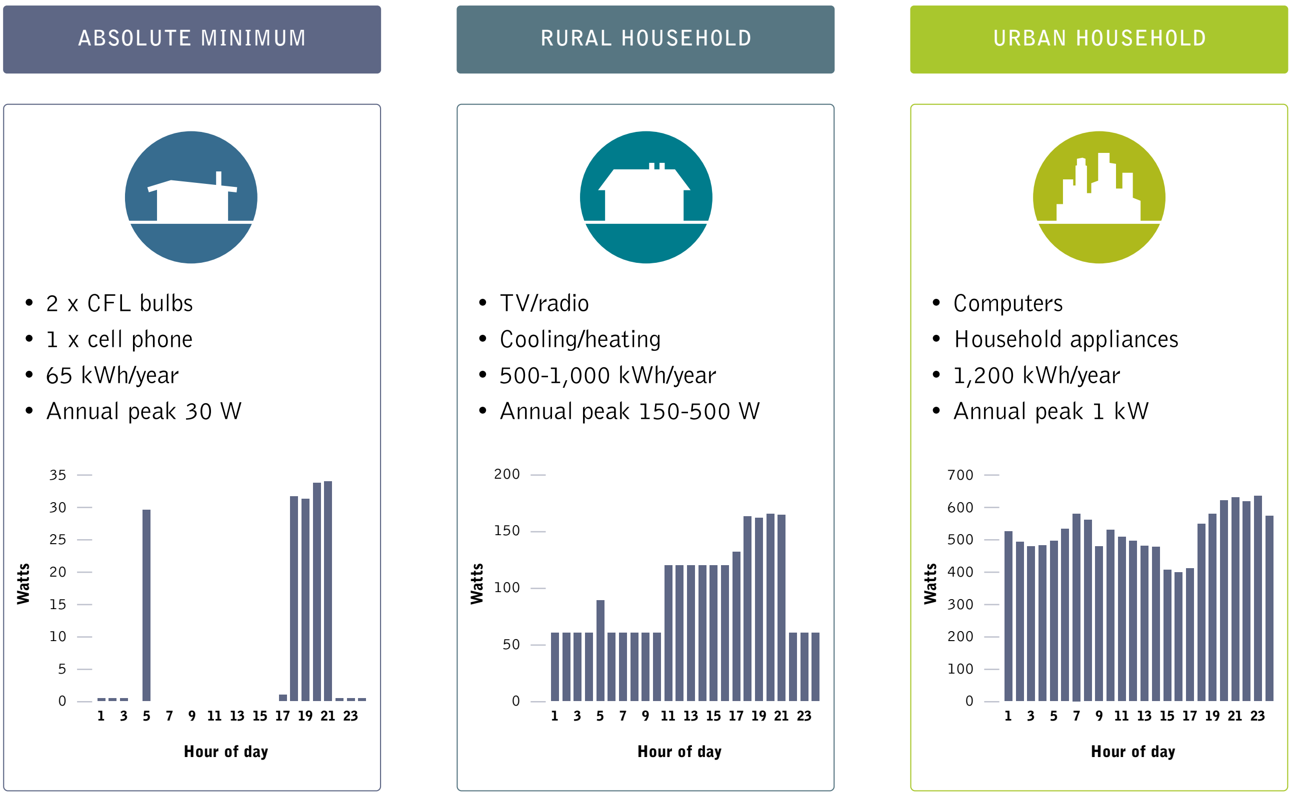
The first step is to **assess the resources** available in the area. In Bihar, these are biomass, hydro and solar PV power.

The second step is to **assess the level of electrical demand** for the area, taking into account that the after initial access, demand will almost always grow, following the economic growth electricity allows. For Bihar, demand levels shown in Figure 2.10 were considered.

The third and final step is to design a system which can serve the demand using the resources available in the most economic manner. Key parameters for developing a system are:

- That system design uses standard components and is kept modular so that it can be replicated easily for expansion across the region.
- An appropriate generation mix which can meet demand 99% of the time at the lowest production cost, e.g. using simulation software such as HOMER.[35] (Figure 2.11)
- That electricity can be distributed through a physical network without breaching safe operating limits, and that the quality of the supply is adequate for its use, e.g. using a software model such as PowerFactory[36] which tests system behaviour under different operating conditions. (Figure 2.12)

figure 2.10: development of household demand



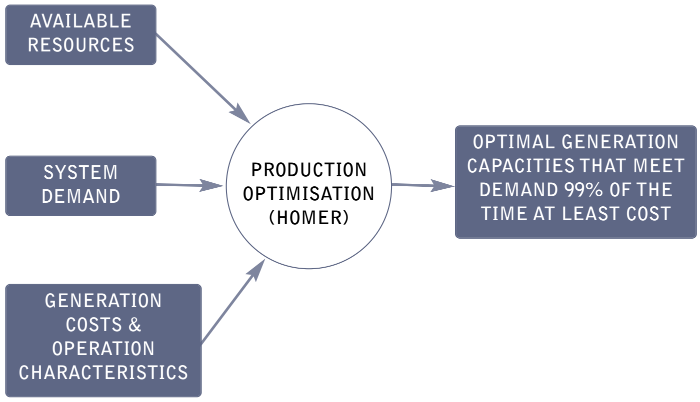
source
"E[R] CLUSTER FOR A SMART ENERGY ACCESS", GREENPEACE MAY 2012.

image CONSTRUCTION OF THE OFFSHORE WINDFARM AT MIDDELGRUNDEN NEAR COPENHAGEN, DENMARK.

- A suitable strategy for switching between "grid-connected" and "island" modes, so that the community can connect to the neighbours. There are many options for systems designers by typically for microgrids in rural parts of developing countries, design simplicity and cost efficiency are more valuable than an expensive but sophisticated control system.

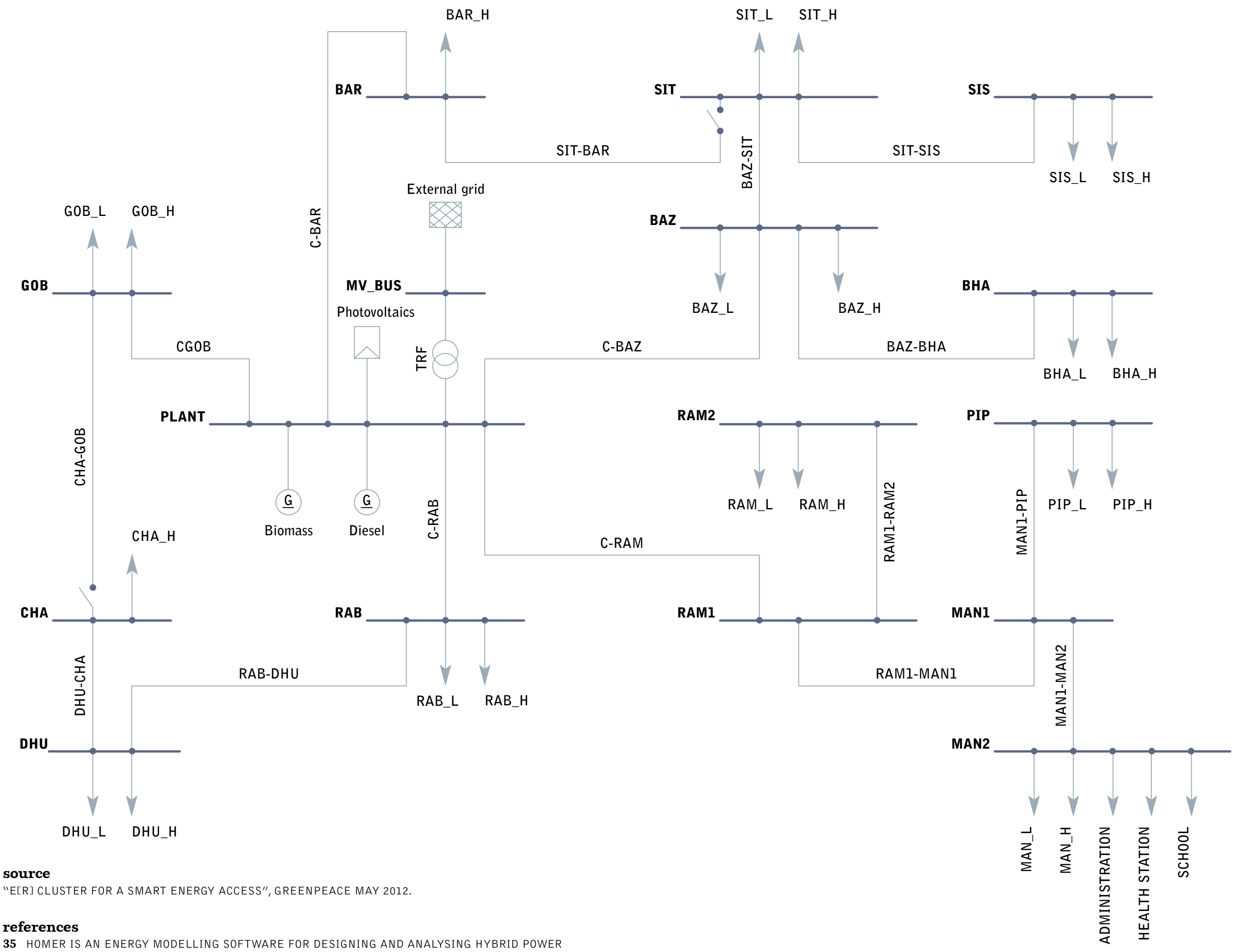
The *Smart Energy Access Concept* method can be used to develop roadmap visions and general strategy directions. It must be noted however, that detailed resource assessments, cost evaluations, demand profile forecasts and power system simulations are always required to ensure that a specific microgrid design is viable in a specific location.

figure 2.11: process overview of supply system design by production optimisation



source ENERGYNAUTICS

figure 2.12: screenshot of the PowerFactory grid model.



source
"E[R] CLUSTER FOR A SMART ENERGY ACCESS", GREENPEACE MAY 2012.

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35 HOMER IS AN ENERGY MODELLING SOFTWARE FOR DESIGNING AND ANALYSING HYBRID POWER SYSTEMS. A TRIAL VERSION OF THE SOFTWARE CAN BE DOWNLOADED FOR FREE AT THE WEBSITE: HTTP://WWW.HOMERENERGY.COM/
36 POWERFACTORY IS A POWER SYSTEM SIMULATION SOFTWARE FOR DESIGNING AND ANALYSING POWER SYSTEMS. IT IS A LICENSED PRODUCT DEVELOPED BY DIGSILENT.

source ENERGYNAUTICS

2.5.2 implementation

Once an electricity service is available, people generally increase their consumption. A typical pattern for system growth in India is:

- 60kWh per household, covering basic lighting, based on two energy-efficient globes per household for a few hours. In Bihar, this can be provided efficiently with a predominantly biomass-powered system, such as the Husk Power Systems[37], which are already in use in a number of villages.
- 500 kWh per household, provided by a predominantly biomass-diesel system or a biomass-hydro system (if water is available nearby). Such systems can be achieved at costs of around 14-15 INR/kWh, or 9-10 INR/kWh respectively and will cover demand from appliances such as fans, television sets and cellular phones
- 1,200 kWh per year per household – an urban level of electricity consumption – can not be provided by the simple systems described above. Without hydro power solar PV would be required, and where hydro power is available, diesel would need to be included to cover seasonal flows. These systems can be achieved also at costs of 14-15 INR/kWh, or 9-10 INR/kWh respectively.

2.5.3 lessons from the study

When considering bottom-up microgrid developments some key points for the system's expansion are:

Unit Sizes. From 32 kW and 52 kW for biomass husks to 100 kW minimum for an economic micro-hydro system (based on the general flows for the state of Bihar) to a tiny 100-1,000 W for rooftop solar PV. Diesel generators which could operate with biofuels come in all sizes as they are a more conventional product. The system owner would have to decide how best to expand the system in a piecewise fashion.

Connection to the grid. When eventually connected to State or National grid, different arrangements mean the community can be connected or autonomous, depending on the situation. However, expensive and experimental control systems that manage complex transitions would be difficult to implement in a rural area in a developing country which has financial barriers, lower operational capacity, less market flexibility and regulatory considerations. A simplified design concept limits transitions from grid-connected mode to "island mode" when there are central grid blackouts, and back again.

Capacity and number systems. To replicate this type of microgrid design across the entire state of Bihar, a rough approximation based on geographical division indicates that 13,960 villages can be supplied by a non-hydro no wind system and 3,140 villages with a hydro system. It is assumed that there is potential for up to 1,900 systems where wind power may be used, and that a total number of 19,000 villages are appropriate to cover all rural areas in the state of Bihar. With such an expansion strategy, at minimum (corresponding to demand scenario 2) approximately 1,700 MW of biomass, 314 MW of hydro and 114 MW of PV power installations would be required. At the stage when microgrids are fully integrated with the central grid (demand scenario 4), it is expected that at least 4,000 MW of biomass, 785 MW of hydro and 10,000 MW of PV power installations would be required.

Distance to the grid. System costs of the optimal microgrid designs were compared with the cost of extending the grid to determine the break-even grid distance. Calculations show the break-even grid distance for a biomass + solar + hydro + diesel system (with or without wind) is approximately 5 kilometres, while for a biomass + solar + diesel system (with or without wind) is approximately 10 kilometres.

Technology type. The system costs did not vary significantly with the addition of wind power in the generation mix, or with a significant reduction in solar PV installation costs because the costs per installed kilowatt of such systems are already higher than for the other generators. However, when diesel prices increase, the overall system costs also rise, as the cost of energy production from the diesel units increase, but the installation costs are still lower than for solar PV and wind power systems.

The case study in Bihar, India, show how microgrids can function as an off-grid system, incorporate multiple generation sources, adapt to demand growth, and be integrated with the central grid while still separate and operate as an island grid if needed.

reference
37 WWW.HUSKPOWERSYSTEMS.COM

image A TRUCK DROPS ANOTHER LOAD OF WOOD CHIPS AT THE BIOMASS POWER PLANT IN LELYSTAD, THE NETHERLANDS.

2.6 greenpeace proposal to support a renewable energy cluster

This energy cluster system builds upon Greenpeace's Energy [R]evolution scenario[38] which sets out a global energy pathway that not only phases out dirty and dangerous fossil fuels over time to help cut CO_2 levels, but also brings energy to the 2 billion people on the planet that currently don't have access to energy. The most effective way to ensure financing for the energy [r]evolution in the power sector is via Feed-in laws.

To plan and invest in an energy infrastructure, whether for conventional or renewable energy, requires secure policy frameworks over decades. The key requirements are:

long term security for the investment The investor needs to know the pattern of evolution of the energy policy over the entire investment period (until the generator is paid off). Investors want a "good" return of investment and while there is no universal definition of a good return, it depends on the long term profitability of the activity as well as on the inflation rate of the country and the short term availability of cash throughout the year to sustain operations.

maximize the leverage of scarce financial resources Access to privileged credit facilities, under State guarantee, are one of the possible instruments that can be deployed by governments to maximise the distribution of scarce public and international financial resources, leverage on private investment and incentivize developers to rely on technologies that guarantee long term financial sustainability.

long-term security for market conditions The investor needs to know if the electricity or heat from the power plant can be sold to the market for a price which guarantees a "good" return of investment (ROI). If the ROI is high, the financial sector will invest; if it is low compared to other investments then financial institutions will not invest. Moreover, the supply chain of producers needs to enjoy the same level of favourable market conditions and stability (e.g. agricultural feedstock).

transparent planning process A transparent planning process is key for project developers, so they can sell the planned project to investors or utilities. The entire licensing process must be clear, transparent and fast.

access to the (micro) grid A fair access to the grid is essential for renewable power plants. If there is no grid connection available or if the costs to access the grid are too high the project will not be built. In order to operate a power plant it is essential for investors to know if the asset can reliably deliver and sell electricity to the grid. If a specific power plant (e.g. a wind farm) does not have priority access to the grid, the operator might have to switch the plant off when there is an oversupply from other power plants or due to a bottleneck situation in the grid. This arrangement can add high risk to the project financing and it may not be financed or it will attract a "risk-premium" which will lower the ROI.

table 2.3: key results for energy [r]evolution village cluster - state of bihar (rural) - employment, environment + fit

	EMPLOYMENT			CO_2 SAVINGS		FIT
SCENARIO	GENERATION Jobs	GRID Jobs	TOTAL Jobs	SPECIFIC t CO_2 /GWh	TOTAL million t CO_2/a	AVERAGE ACCROSS ALL TECHNOLOGIES INR/kWh
Scenario A: Solar + Biomass						
Absolute Minimum (state-wide)	1,778	10	1,788	1,100	0.8	25
Low income demand (state-wide)	5,936	75	6,011		6.7	19
Medium income demand (state-wide)	14,326	153	14,479		13.4	25
Urban households (state-wide)	16,340	447	16,787		32.0	19
Scenario B: Solar + Small Hydro + Biomass						
Absolute Minimum (state-wide)	1,778	10	1,788	1,100	0.8	25
Low income demand (state-wide)	2,782	141	2,922		6.7	11
Medium income demand (state-wide)	11,742	343	12,085		13.4	13
Urban households (state-wide)	15,770	541	16,311		32.0	13
Scenario C: Solar + Wind + Biomass						
Absolute Minimum (state-wide)	1,778	10	1,788	1,100	0.8	25
Low income demand (state-wide)	5,936	75	6,011		6.7	19
Medium income demand (state-wide)	14,326	153	14,479		13.4	25
Urban households (state-wide)	21,470	410	21,880		32.0	21

source
"E[R] CLUSTER FOR A SMART ENERGY ACCESS", GREENPEACE MAY 2012.

reference
38 ENERGY [R]EVOLUTION – A SUSTAINABLE ENERG Y WORLD ENERGY OUTLOOK 2012, GREENPEACE INTERNATIONAL, AMSTERDAM – THE NETHERLANDS, JUNE 2012.

2.6.1 a rural feed-in tariff for bihar

In order to help implement the Energy [R]evolution clusters in Bihar, Greenpeace suggests starting a feed-in regulation for the cluster, which will be partly financed by international funds. The international program should add a CO_2 saving premium of 10 Indian Rupee (INR) per kWh for 10 years. This premium should be used to help finance the required power generation as well as the required infrastructure (grids). In the Table 2.2 the CO_2 savings, rough estimation of employment effects as well as the required total funding for the CO_2 premium for the state of Bihar are shown.

2.7 energy [r]evolution cluster jobs

While the employment effect for the operation and maintenance (O&M) for solar photovoltaics (0.4/MW), wind (0.4/MW), hydro (0.2/MW) and bio energy (3.1/MW) are very well documented,[39] the employment effect of grid operations and maintenance are not. Therefore Greenpeace assumed in this calculation that for each 100 GWh one job will be created. This number is based on grid operators in Europe and might be too conservative. However it is believed that the majority of the jobs will be created by the O&M of power generation; grid operation may be part of this work as well.

Due to the high uncertainty of employment effects from grid operation, these numbers are only indicative.

Microgrids can offer reliable and cost competitive electricity services, providing a viable alternative to the conventional topdown approach of extending grid services. The microgrid approach is "smart" because it can facilitate the integration of renewable energies, thereby contributing to national renewable energy (RE) targets. In addition it can reduce transmission losses by having generation close to demand. Being built from modular distributed generation units, it can adequately adjust to demand growth. It can operate both in island mode and grid-connected mode, making operation flexible and can also offer grid support features. This report demonstrates with a case study how this bottom-up approach with microgrids would work. It focuses on development in the state of Bihar in India.

Step 1: renewable resource assessment The first step to this approach is to make an assessment of the resources available in the area. In the case of Bihar, these are biomass, hydro and solar PV power. While there are no detailed wind measurements available, there are indications that in some areas wind turbines could operate economically as well.

Step 2: demand projections The second step is to assess the level of electrical demand that will need to be serviced. Once there is access to electricity services, demand will almost always grow, accompanying economic growth. For the case of Bihar the following demand levels were considered, which are characterised by total energy consumption, peak demand and daily load profiles as shown in Figure 2.10.

As the proposed bottom-up electrification approach starts on a per village basis, a set of village demand profiles is generated based on these hypothetical household demand profiles. The village demand profiles also contain assumptions about non-household loads such as a school, health stations or public lighting.

The village-based electricity supply system forms the smallest individual unit of a supply system. Therefore the matching set of generation assets is also determined on a per-village basis.

Step 3: define optimal generation mix The third step in this approach is to design a system which can serve the demand using the resources available in the most economic manner. At this point it is of utmost importance that the system design uses standard components and is kept modular so that it can be replicated easily for expansion across the entire state. In designing such a system, an appropriate generation mix needs to be developed, which can meet demand 99% of the time at the lowest production cost. This can be determined using production simulation software such as HOMER[40], which calculates the optimal generation capacities based on a number of inputs about the installation and operation costs of different types of generation technologies in India.

reference

39 INSTITUTE FOR SUSTAINABLE FUTURES (ISF), UNIVERS ITY OF TECHNOLOGY, SYDNEY, AUSTRALIA: JAY RUTOVITZ, ALISON ATHERTON.

40 HOMER IS AN ENERGY MODELLING SOFTWARE FOR DESIGNING AND ANALYSING HYBRID POWER SYSTEMS . A TRIAL VERSION OF THE SOFTWARE CAN BE DOWNLOADED FOR FREE AT THE WEBSITE: HTTP://WWW.HOMERENERG Y.COM/

image CHECKING THE SOLAR PANELS ON TOP OF THE GREENPEACE POSITIVE ENERGY TRUCK IN BRAZIL.

Step 4: network design Once the optimal supply system design is determined, it is also important to make sure that such a supply system can be distributed through a physical network without breaching safe operating limits, and that the quality of the delivered electricity is adequate for its use. This can be done by modelling the physical system using power system simulation software such as PowerFactory.[41] In this way the behaviour of the electrical system under different operating conditions can be tested, for example in steady-state power flow calculations. Figure 2.12 shows a diagram of the village power system model used in this study.

Step 5: control system considerations The final part of the system design involves the development of a suitable strategy for switching between grid-connected and island modes. Depending on the quality of service required by the loads in the microgrid, the regulations stipulated in the grid code for operation practices, and number of grid support features desired, several different designs could be developed. For microgrids as part of rural electrification efforts in developing countries however, design simplicity and cost efficiency weighs more than the benefits of having an expensive but sophisticated control system. Through the use of microgrids, the gap between rural electrification and universal electrification with grid expansion can be met, while at the same time bringing many additional benefits both for the consumers and grid operators. By developing a system which is modular and constructed using standard components, it makes it easier to replicate it across wide areas with varying geographic characteristics. The method demonstrated in this report can be used to develop roadmap visions and general strategy directions. It must be noted however, that detailed resource assessments, cost evaluations, demand profile forecasts and power system simulations are always required to ensure that a specific microgrid design is viable in a specific location.

table 2.4: village cluster demand overview

DEMAND SCENARIOS		SUPPLY NEEDS		
SCENARIO	DEMAND PER DAY kWh/day	TOTAL ANNUAL DEMAND kWh/a	PEAK DEMAND kW peak	TOTAL INSTALLED CAPACITY kW
Absolute Minimum (state-wide)	111	40,514	22	31.5
Low income demand (state-wide)	881	321,563	99.4	106
Medium income demand (state-wide)	1,754	640,117	271	265
Urban households (state-wide)	4,192	1,530,037	554	800

source
"E[R] CLUSTER FOR A SMART ENERGY ACCESS", GREENPEACE MAY 2012.

reference
41 POWER FACTORY IS A POWER SYSTEM SIMULATION SOFTWARE FOR DESIGNING AND ANALYSING POWER SYSTEMS. IT IS A LICENSED PRODUCT DEVELOPED BY DIGSILENT.

implementing the energy [r]evolution

image THE FORESTS OF THE SOUTH-CENTRAL AMAZON BASIN, RONDONIA, BRAZIL, 1975.

image GEOTHERMAL ACTIVITY NEAR HOLSSELSNALAR CLOSE TO REYKJAVIK, ICELAND.

3.1 renewable energy project planning basics

The renewable energy market works significantly different than the coal, gas or nuclear power market. The table below provides an overview of the ten steps from "field to an operating power plant" for renewable energy projects in the current market situation. Those steps are similar same for each renewable energy technology, however step 3 and 4 are especially important for wind and solar projects. In developing countries the government and the mostly state owned utilities might directly or indirectly take responsibilities of the project developers. The project developer might also work as a subdivision of a state owned utility.

table 3.1: how does the current renewable energy market work in practice?

STEP	WHAT WILL BE DONE?	WHO?	NEEDED INFORMATION / POLICY AND/OR INVESTMENT FRAMEWORK
Step 1: Site identification	Identify the best locations for generators e.g. wind turbines and pay special attention to technical and commercial data, conservation issues and any concerns that local communities may have.	P	Resource analysis to identify possible sites Policy stability in order to make sure that the policy is still in place once Step 10 has been reached. Without a certainty that the renewable electricity produced can be fed entirely into the grid to a reliable tariff, the entire process will not start.
Step 2: Securing land under civil law	Secure suitable locations through purchase and lease agreements with land owners.	P	Transparent planning, efficient authorisation and permitting.
Step 3: Determining site specific potential	Site specific resource analysis (e.g. wind measurement on hub height) from independent experts. This will NOT be done by the project developer as (wind) data from independent experts is a requirement for risk assessments by investors.	P + M	See above.
Step 4: Technical planning/ micrositing	Specialists develop the optimum wind farm configuration or solar panel sites etc, taking a wide range of parameters into consideration in order to achieve the best performance.	P	See above.
Step 5: Permit process	Organise all necessary surveys, put together the required documentation and follow the whole permit process.	P	Transparent planning, efficient authorisation and permitting.
Step 6: Grid connection planning	Electrical engineers work with grid operators to develop the optimum grid connection concept.	P + U	Priority access to the grid. Certainty that the entire amount of electricity produced can be feed into the grid.
Step 7: Financing	Once the entire project design is ready and the estimated annual output (in kWh/a) has been calculated, all permits are processed and the total finance concept (incl. total investment and profit estimation) has been developed, the project developer will contact financial institutions to either apply for a loan and/or sell the entire project.	P + I	Long term power purchase contract. Prior and mandatory access to the grid. Site specific analysis (possible annual output).
Step 8: Construction	Civil engineers organise the entire construction phase. This can be done by the project developer or another. EPC (Engineering, procurement & construction) company – with the financial support from the investor.	P + I	Signed contracts with grid operator. Signed contract with investors.
Step 9: Start of operation	Electrical engineers make sure that the power plant will be connected to the power grid.	P + U	Prior access to the grid (to avoid curtailment).
Step 10: Business and operations management	Optimum technical and commercial operation of power plants/farms throughout their entire operating life – for the owner (e.g. a bank).	P + U + I	Good technology & knowledge (A cost-saving approach and "copy + paste engineering" will be more expensive in the long-term).

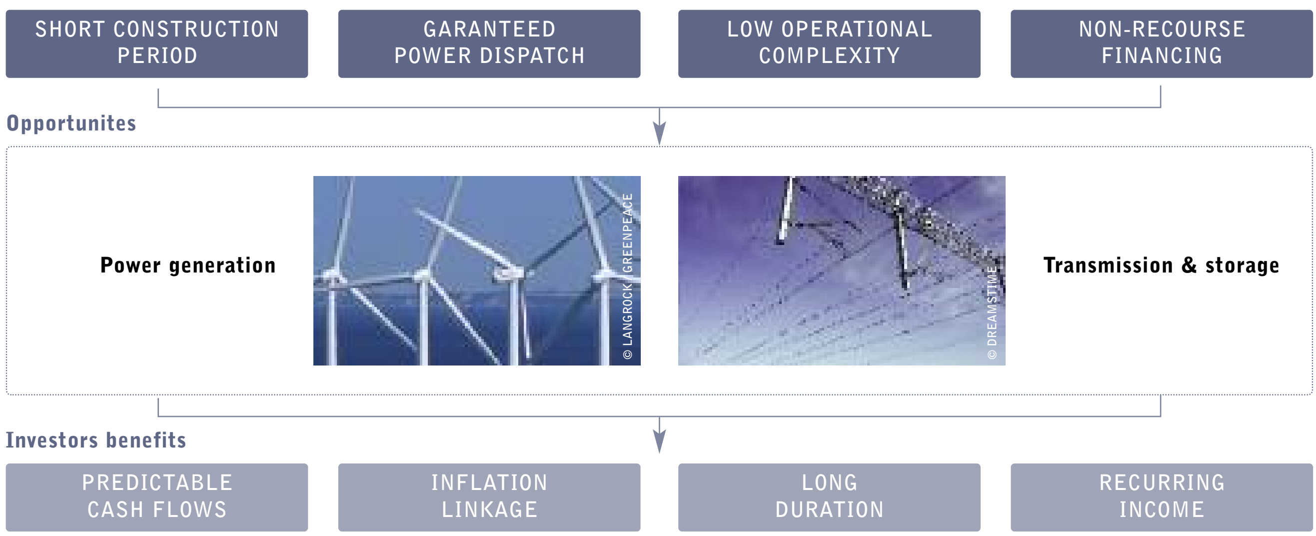
P = Project developer, **M** = Meteorological Experts, **I** = Investor, **U** = utility.

3.2 renewable energy financing basics

The Swiss RE Private Equity Partners have provide an introduction to renewable energy infrastructure investing (September 2011) which describes what makes renewable energy projects different from fossil-fuel based energy assets from a finance perspective:

- Renewable energy projects have short construction period compared to conventional energy generation and other infrastructure assets. Renewable projects have limited ramp-up periods, and construction periods of one to three years, compared to 10 years to build large conventional power plants.
- In several countries, renewable energy producers have been granted priority of dispatch. Where in place, grid operators are usually obliged to connect renewable power plants to their grid and for retailers or other authorised entities to purchase all renewable electricity produced.
- Renewable projects present relatively low operational complexity compared to other energy generation assets or other infrastructure asset classes. Onshore wind and solar PV projects in particular have well established operational track records. This is obviously less the case for biomass or offshore wind plants.
- Renewable projects typically have non-recourse financining, through a mix of debt and equity. In contrast to traditional corporate lending, project finance relies on future cash flows for interest and debt repayment, rather than the asset value or the historical financial performance of a company. Project finance debt typically covers 70–90% of the cost of a project, is non-recourse to the investors, and ideally matches the duration of the underlying contractual agreements.
- Renewable power typically has predictable cash flows and it is not subject to fuel price volatility because the primary energy resource is generally freely available. Contractually guaranteed tariffs, as well as moderate costs of erecting, operating and maintaining renewable generation facilities, allow for high profit margins and predictable cash flows.
- Renewable electricity remuneration mechanisms often include some kind of inflation indexation, although incentive schemes may vary on a case-by-case basis. For example, several tariffs in the EU are indexed to consumer price indices and adjusted on an annual basis (e.g. Spain, Italy). In projects where specific inflation protection is not provided (e.g. Germany), the regulatory framework allows selling power on the spot market, should the power price be higher than the guaranteed tariff.
- Renewable power plants have expected long useful lives (over 20 years). Transmission lines usually have economic lives of over 40 years. Renewable assets are typically underpinned by long-term contracts with utilities and benefit from governmental support and manufacturer warranties.
- Renewable energy projects deliver attractive and stable sources of income, only loosely linked to the economic cycle. Project owners do not have to manage fuel cost volatility and projects generate high operating margins with relatively secure revenues and generally limited market risk.
- The widespread development of renewable power generation will require significant investments in the electricity network. As discussed in Chapter 2 future networks (smart grids) will have to integrate an ever-increasing, decentralised, fluctuating supply of renewable energy. Furthermore, suppliers and/or distribution companies will be expected to deliver a sophisticated range of services by embedding digital grid devices into power networks.

figure 3.1: return characteristics of renewable energies



source
SWISS RE PRIVATE EQUITY PARTNERS.

image A LARGE SOLAR SYSTEM OF 63M² RISES ON THE ROOF OF A HOTEL IN CELERINA, SWITZERLAND. THE COLLECTOR IS EXPECTED TO PRODUCE HOT WATER AND HEATING SUPPORT AND CAN SAVE ABOUT 6,000 LITERS OF OIL PER YEAR. THUS, THE CO_2 EMISSIONS AND COMPANY COSTS CAN BE REDUCED.

Risk assessment and allocation is at the centre of project finance. Accordingly, project structuring and expected return are directly related to the risk profile of the project. The four main risk factors to consider when investing in renewable energy assets are:

- **Regulatory risks** refer to adverse changes in laws and regulations, unfavourable tariff setting and change or breach of contracts. As long as renewable energy relies on government policy dependent tariff schemes, it will remain vulnerable to changes in regulation. However a diversified investment across regulatory jurisdictions, geographies, and technologies can help mitigate those risks.
- **Construction risks** relate to the delayed or costly delivery of an asset, the default of a contracting party, or an engineering/design failure. Construction risks are less prevalent for renewable energy projects because they have relatively simple design, however, construction risks can be mitigated by selecting high-quality and experienced turnkey partners, using proven technologies and established equipment suppliers as well as agreeing on retentions and construction guarantees.
- **Financing risks** refer to the inadequate use of debt in the financial structure of an asset. This comprises the abusive use of leverage, the exposure to interest rate volatility as well as the need to refinance at less favourable terms.
- **Operational risks** include equipment failure, counterparty default and reduced availability of the primary energy source (e.g. wind, heat, radiation). For renewable assets a lower than forecasted resource availability will result in lower revenues and profitability so this risk can damage the business case. For instance, abnormal wind regimes in Northern Europe over the last few years have resulted in some cases in breach of coverage ratios and in the inability of some projects to pay dividends to shareholders.

figure 3.2: overview risk factors for renewable energy projects

REGULATORY RISKS	CONSTRUCTION RISKS
FINANCING RISKS	OPERATIONAL RISKS

source
SWISS RE PRIVATE EQUITY PARTNERS.

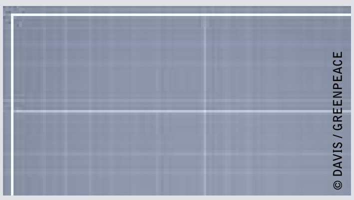
figure 3.3: investment stages of renewable energy projects

RISKS

Higher — Lower

Stage

DEVELOPMENT



- Site identification
- Approval & permitting process
- Land procurement
- Technical planning

CONSTRUCTION

- Financing close
- Equipment procurement
- Engineering
- Construction
- Commissioning

OPERATIONS

- Operations
- Maintenance
- Refinancing
- Refurbishment/Repowering

Strategy

DEVELOPMENT	CONSTRUCTION	OPERATIONS
EARLY-STAGE GREENFIELD	LATE-STAGE GREENFIELD	BROWNFIELD

source
SWISS RE PRIVATE EQUITY PARTNERS.

3.2.1 overcoming barriers to finance and investment for renewable energy

table 3.2: categorisation of barriers to renewable energy investment

CATEGORY	SUB-CATEGORY	EXAMPLE BARRIERS
Barriers to finance	Cost barriers	Costs of renewable energy to generate Market failures (e.g. No carbon price) Energy prices Technical barriers Competing technologies (Gas, nuclear, CCS and coal)
	Insufficient information and experience	Overrated risks Lack of experienced investors Lack of experienced project developers Weak finance sectors in some countries
	Financial structure	Up-front investment cost Costs of debt and equity Leverage Risk levels and finance horizon Equity/credit/bond options Security for investment
	Project and industry scale	Relative small industry scale Smaller project scale
	Investor confidence	Confidence in long term policy Confidence in short term policy Confidence in the renewable energy market
Other investment barriers	Government renewable energy policy and law	Feed-in tariffs Renewable energy targets Framework law stability Local content rules
	System integration and infrastructure	Access to grid Energy infrastructure Overall national infrastructure quality Energy market Contracts between generators and users
	Lock in of existing technologies	Subsidies to other technologies Grid lock-in Skills lock-in Lobbying power
	Permitting and planning regulation	Favourability Transparency Public support
	Government economic position and policy	Monetary policy e.g. interest rates Fiscal policy e.g. stimulus and austerity Currency risks Tariffs in international trade
	Skilled human resources	Lack of training courses
	National governance and legal system	Political stability Corruption Robustness of legal system Litigation risks Intellectual property rights Institutional awareness

Despite the relatively strong growth in renewable energies in some countries, there are still many barriers which hinder the rapid uptake of renewable energy needed to achieve the scale of development required. The key barriers to renewable energy investment identified by Greenpeace through a literature review[42] and interviews with renewable energy sector financiers and developers are shown in Figure 3.4.

There are broad categories of common barriers to renewable energy development that are present in many countries, however the nature of the barriers differs significantly. At the local level, political and policy support, grid infrastructure, electricity markets and planning regulations have to be negotiated for new projects.

image AERIAL PHOTO OF THE ANDASOL 1 SOLAR POWER STATION, EUROPE'S FIRST COMMERCIAL PARABOLIC TROUGH SOLAR POWER PLANT. ANDASOL 1 WILL SUPPLY UP TO 200,000 PEOPLE WITH CLIMATE-FRIENDLY ELECTRICITY AND SAVE ABOUT 149,000 TONNES OF CARBON DIOXIDE PER YEAR COMPARED WITH A MODERN COAL POWER PLANT.

In some regions, it is uncertainty of policy that is holding back investment more than an absence of policy support mechanisms. In the short term, investors aren't confident rules will remain unaltered and aren't confident that renewable energy goals will be met in the longer term, let alone increased.

When investors are cautious about taking on these risks, it drives up investment costs and the difficulty in accessing finance is a barrier to renewable energy project developers. Contributing factors include a lack of information and experience among investors and project developers, involvement of smaller companies and projects and a high proportion of up-front costs.

Grid access and grid infrastructure is also a major barriers to developers, because they are not certain they will be able to sell all the electricity they generate in many countries, during project development.

In many regions, both state owned and private utilities are contributing to blocking renewable energy through their market power and political power, maintaining 'status quo' in the grid, electricity markets for centralised coal and nuclear power and lobbying against pro-renewable and climate protection laws.

The sometimes higher cost of renewable energy relative to competitors is still a barrier, though many are confident that it will be overcome in the coming decades. The Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN) identifies cost as the most significant barrier to investment[43] and while it exists, renewable energy will rely on policy intervention by governments in order to be competitive, which creates additional risks for investors. It is important to note though, that in some regions of the world specific renewable technologies are broadly competitive with current market energy prices (e.g. onshore wind in Europe and solar hot water heaters in China).

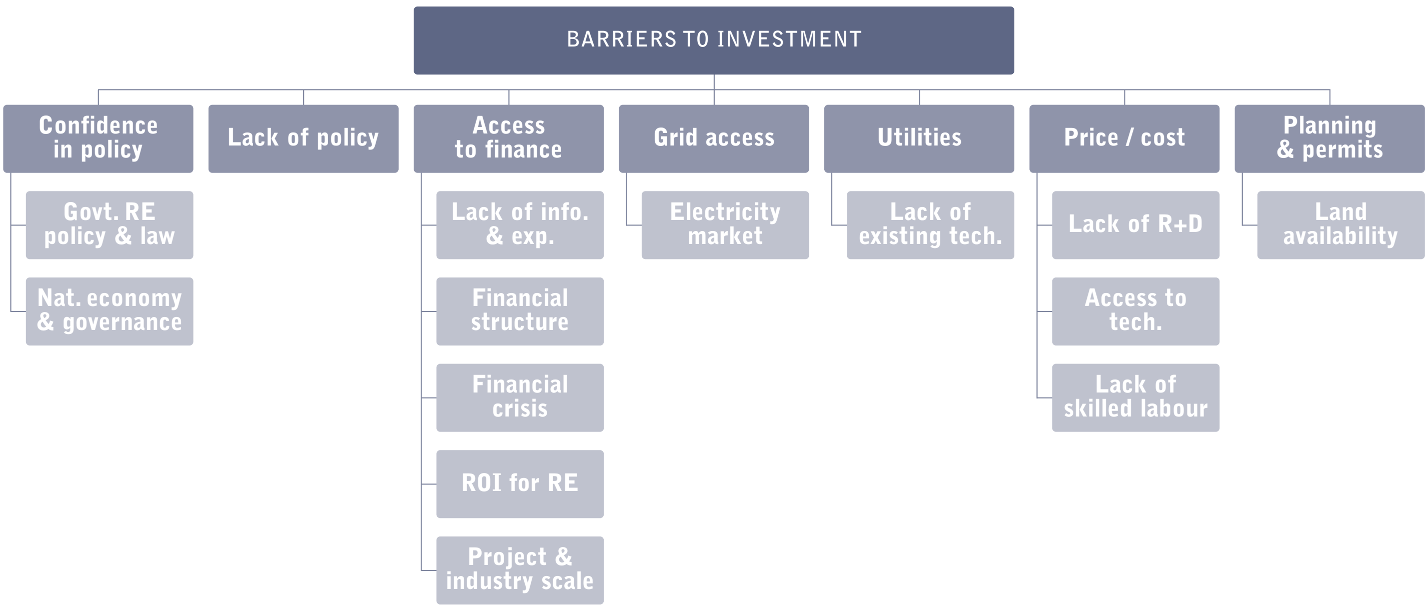
Concerns over planning and permit issues are significant, though vary significantly in their strength and nature depending on the jurisdiction.

3.2.2 how to overcome investment barriers for renewable energy

To see an Energy [R]evolution will require a mix of policy measures, finance, grid, and development. In summary:

- Additional and improved policy support mechanisms for renewable energy are needed in all countries and regions.
- Building confidence in the existing policy mechanisms may be just as important as making them stronger, particularly in the short term.
- Improved policy mechanisms can also lower the cost of finance, particularly by providing longer durations of revenue support and increasing revenue certainty.[44]
- Access to finance can be increased by greater involvement of governments and development banks in programs like loan guarantees and green bonds as well as more active private investors.
- Grid access and infrastructure needs to be improved through investment in smart, decentralised grids.
- Lowering the cost of renewable energy technologies directly will require industry development and boosted research and development.
- A smoother pathway for renewable energy needs to be established through planning and permit issues at the local level.

figure 3.4: key barriers to renewable energy investment



references

42 SOURCES INCLUDE: INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) (2011) SPECIAL REPORT ON RENEWABLE ENERGY SOURCES AND CLIMATE CHANGE MITIGATION (SRREN), 15TH JUNE 2011. UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP), BLOOMBERG NEW ENERGY FINANCE (BNEF) (2011). GLOBAL TRENDS IN RENEWABLE ENERGY INVESTMENT 2011, JULY 2011. RENEWABLE ENERGY POLICY NETWORK FOR THE 21ST CENTURY (REN21) (2011). RENEWABLES 2011, GLOBAL STATUS REPORT, 12 JULY, 2011. ECOFYS, FRAUNHOFER ISI, TU VIENNA EEG, ERNST & YOUNG (2011). FINANCING RENEWABLE ENERGY IN THE EUROPEAN ENERGY MARKET BY ORDER OF EUROPEAN COMMISSION, DG ENERGY, 2ND OF JANUARY, 2011.

43 INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) (2011) SPECIAL REPORT ON RENEWABLE ENERGY SOURCES AND CLIMATE CHANGE MITIGATION (SRREN). 15TH JUNE 2011. CHP. 11, P.24.

44 CLIMATE POLICY INITIATIVE (2011):THE IMPACTS OF POLICY ON THE FINANCING OF RENEWABLE PROJECTS: A CASE STUDY ANALYSIS, 3 OCTOBER 2011.

scenario for a future energy supply

image THE OB' RIVER ON THE WESTERN EDGE OF THE CENTRAL SIBERIAN PLATEAU, JUNE 20, 2002. THE MOUTH OF THE OB' RIVER (LARGE RIVER AT LEFT) WHERE IT EMPTIES INTO KARA SEA. IN THE FALSE-COLOR IMAGE, VEGETATION APPEARS IN BRIGHT GREEN, WATER APPEARS DARK BLUE OR BLACK, AND ICE APPEARS BRIGHT BLUE.

image MAINTENANCE WORKERS FIX THE BLADES OF A WINDMILL AT GUAZHOU WIND FARM NEAR YUMEN IN GANSU PROVINCE, CHINA.

Moving from principles to action for energy supply that mitigates against climate change requires a long-term perspective. Energy infrastructure takes time to build up; new energy technologies take time to develop. Policy shifts often also need many years to take effect. In most world regions the transformation from fossil to renewable energies will require additional investment and higher supply costs over about twenty years. However, there will be tremendous economic benefits in the long term, due to much lower consumption of increasingly expensive, rare or imported fuels. Any analysis that seeks to tackle energy and environmental issues therefore needs to look ahead at least half a century.

Scenarios are necessary to describe possible development paths, to give decision-makers a broad overview and indicate how far they can shape the future energy system. Two scenarios are used here to show the wide range of possible pathways in each world region for a future energy supply system:

- **Reference scenario**, reflecting a continuation of current trends and policies.
- The **Energy [R]evolution scenario**, designed to achieve a set of environmental policy targets.

The Reference scenario is based on the Current Policies scenarios published by the International Energy Agency (IEA) in World Energy Outlook 2011 (WEO 2011).[45] It only takes existing international energy and environmental policies into account. Its assumptions include, for example, continuing progress in electricity and gas market reforms, the liberalisation of cross-border energy trade and recent policies designed to combat environmental pollution. The Reference scenario does not include additional policies to reduce greenhouse gas emissions. As the IEA's projections only extend to 2035, they have been extended by extrapolating their key macroeconomic and energy indicators forward to 2050. This provides a baseline for comparison with the Energy [R]evolution scenarios.

The Energy [R]evolution scenario has a key target to reduce worldwide carbon dioxide emissions from energy use down to a level of below 4 Gigatonnes per year by 2050 in order to hold the increase in global temperature under +2°C. A second objective is the global phasing out of nuclear energy. The Energy [R]evolution scenarios published by Greenpeace in 2007, 2008 and 2010 included 'basic' and 'advanced' scenarios, the less ambitious target was for 10 Gigatonnes CO_2 emissions per year by 2050. However, this 2012 revision only focuses on the more ambitious "advanced" Energy [R]evolution scenario first published in 2010.

To achieve the target, the scenario includes significant efforts to fully exploit the large potential for energy efficiency using currently available best practice technology. At the same time, all cost-effective renewable energy sources are used for heat and electricity generation as well as the production of biofuels. The general framework parameters for population and GDP growth remain unchanged from the Reference scenario.

This new global Energy [R]evolution scenario is aimed at an even stronger decrease in CO_2 emissions, considering that even 10 Gigatonnes – the target of the 2007 and 2008 editions - might be too high to keep global temperature rises at bay. All general framework parameters such as population and economic growth remain similar to previous editions, however the uptake of renewable energies has been accelerated partly based on the latest very positive developments in the wind and solar photovoltaic sectors.

Efficiency in use of electricity and fuels in industry and "other sectors" has been completely re-evaluated using a consistent approach based on technical efficiency potentials and energy intensities. The resulting consumption pathway is close to the projection of the earlier editions. One key difference for the new Energy [R]evolution scenarios is incorporating stronger efforts to develop better technologies to achieve CO_2 reduction. There is lower demand factored into the transport sector (compared to the basic scenario in 2008 and 2010), from a change in driving patterns and a faster uptake of efficient combustion vehicles and a larger share of electric and plug-in hybrid vehicles after 2025. This scenario contains a lower use of biofuels for private vehicles following the latest scientific reports that indicate that biofuels might have a higher greenhouse gas emission footprint than fossil fuels. There are no global sustainability standards for biofuels yet, which would be needed to avoid competition with food growing and to avoid deforestation.

The new Energy [R]evolution scenario also foresees a shift in the use of renewables from power to heat, thanks to the enormous and diverse potential for renewable power. Assumptions for the heating sector include a fast expansion of the use of district heat and more electricity for process heat in the industry sector. More geothermal heat pumps are also included, which leads to a higher overall electricity demand, when combined with a larger share of electric cars for transport. A faster expansion of solar and geothermal heating systems is also assumed. Hydrogen generated by electrolysis and renewable electricity is introduced in this scenario as third renewable fuel in the transport sector after 2025 complementary to biofuels and direct use of renewable electricity. Hydrogen is also applied as a chemical storage medium for electricity from renewables and used in industrial combustion processes and cogeneration for provision of heat and electricity, as well, and for short periods also reconversion into electricity. Hydrogen generation can have high energy losses, however the limited potentials of biofuels and probably also battery electric mobility makes it necessary to have a third renewable option. Alternatively, this renewable hydrogen could be converted into synthetic methane or liquid fuels depending on economic benefits (storage costs vs. additional losses) as well as technology and market development in the transport sector (combustion engines vs. fuel cells).

reference
45 INTERNATIONAL ENERGY AGENCY (IEA), 'WORLD ENERGY OUTLOOK 2011', OECD/IEA 2011.

In all sectors, the latest market development projections of the renewable energy industry[46] have been taken into account (See Table 4.1 "Assumed average growth rates and annual market volumes by renewable technology"). In developing countries in particular, a shorter operational lifetime for coal power plants, of up to 20 instead of 35 years, has been assumed in order to allow a faster uptake of renewable energy. This is particularly the case of China, as around 90% of new global coal power plants built between 2005 and 2011 have been in China (see Chapter 7). The fast introduction of electric vehicles, combined with the implementation of smart grids and faster expansion of transmission grids (accelerated by about 10 years compared to previous scenarios) allows a higher share of fluctuating renewable power generation (photovoltaic and wind) to be employed. In this scenario, renewable energy would pass 30% of the global energy supply just after 2020.

The global quantities of biomass power generators and large hydro power remain limited in the new Energy [R]evolution scenarios, for reasons of ecological sustainability.

These scenarios by no means claim to predict the future; they simply describe and compare two potential consistent development pathways out of the broad range of possible 'futures'. The Energy [R]evolution scenarios are designed to indicate the efforts and actions required to achieve their ambitious objectives and to illustrate the options we have at hand to change our energy supply system into one that is truly sustainable.

table 4.1: assumed average growth rates and annual market volumes by renewable technology

	ENERGY PARAMETER GENERATION (TWh/a)		ANNUAL GROWTH RATE (%/a)		ANNUAL MARKET VOLUME (GW/a)	
RE	REF	E[R]	REF	E[R]	REF	E[R]
2020	28,490	24,028				
2030	35,461	33,041				
2050	48,316	46,573				
Solar						
PV 2020	158	878	22%	48%	8	54
PV 2030	341	2,634	9%	13%	21	162
PV 2050	696	7,290	8%	12%	43	223
CSP 2020	35	466	16%	55%	0	8
CSP 2030	81	2,672	10%	21%	1	44
CSP 2050	269	9,348	14%	15%	4	69
Wind						
On + Offshore 2020	1,127	2,989	13%	26%	31	107
On + Offshore 2030	1,710	6,971	5%	10%	67	274
On + Offshore 2050	2,841	13,767	6%	8%	53	257
Geothermal (for power generation)						
2020	118	400	6%	21%	1	5
2030	172	1,301	4%	14%	2	18
2050	301	3,765	6%	13%	2	26
Bioenergy (for power generation)						
2020	574	932	15%	21%	7	14
2030	937	1,521	6%	6%	16	26
2050	1,629	2,691	6%	7%	11	17
Ocean						
2020	2	139	8%	73%	0	5
2030	13	560	24%	17%	0	16
2050	56	2,053	17%	16%	1	29
Hydro						
2020	4,223	4,192	3%	2%	26	25
2030	4,834	4,542	2%	1%	139	130
2050	5,887	5,009	2%	1%	77	65

reference
46 SEE EREC ('RE-THINKING 2050'), GWEC, EPIA ET AL.

image FIRE BOAT RESPONSE CREWS BATTLE THE BLAZING REMNANTS OF THE OFFSHORE OIL RIG DEEPWATER HORIZON APRIL 21, 2010. MULTIPLE COAST GUARD HELICOPTERS, PLANES AND CUTTERS RESPONDED TO RESCUE THE DEEPWATER HORIZON'S 126 PERSON CREW.

4.1 scenario background

The scenarios in this report were jointly commissioned by Greenpeace and the European Renewable Energy Council from the Systems Analysis group of the Institute of Technical Thermodynamics, part of the German Aerospace Center (DLR). The supply scenarios were calculated using the MESAP/PlaNet simulation model adopted in the previous Energy [R]evolution studies.[47] The new energy demand projections were developed from Utrecht University, Netherlands, based on a new analysis of the future potential for energy efficiency measures in 2012. The biomass potential calculated for previous editions, judged according to Greenpeace sustainability criteria, has been developed by the German Biomass Research Centre in 2009 and has been further reduced for precautionary principles. The future development pathway for car technologies is based on a special report produced in 2012 by the Institute of Vehicle Concepts, DLR for Greenpeace International. These studies are described briefly below.

4.1.1 energy efficiency study for industry, households and services

The demand study by Utrecht University aimed to develop a low energy demand scenario for the period 2009 to 2050 covering the world regions as defined in the IEA's World Energy Outlook report series. Calculations were made for each decade from 2009 onwards. Energy demand was split up into electricity and fuels and their consumption was considered in industry and for 'other' consumers, including households, agriculture and services.

Under the low energy demand scenario, worldwide final energy demand in industry and other sectors is 31% lower in 2050 compared to the Reference scenario, resulting in a final energy demand of 256 EJ (ExaJoules). The energy savings are fairly equally distributed over the two main sectors. The most important energy saving options would be efficient production and combustion processes and improved heat insulation and building design. Chapter 10 provides more details about this study. The demand projections for the Reference scenario have been updated on the basis of the Current Policies scenario from IEA's World Energy Outlook 2011.

4.1.2 the future for transport

The DLR Institute of Vehicle Concepts in Stuttgart, Germany has developed a global scenario for all transport modes covering ten world regions. The aim was to produce a demanding but feasible scenario to lower global CO_2 emissions from transport in keeping with the overall objectives of this report. The approach takes into account a vast range of technical measures to reduce the energy consumption of vehicles, but also considers the dramatic increase in vehicle ownership and annual mileage taking place in developing countries. The major parameters are vehicle technology, alternative fuels, changes in sales of different vehicle sizes of light duty vehicles (called the segment split) and changes in tonne-kilometres and vehicle-kilometres travelled (described as modal split). The Reference scenario for the transport sector is also based on the fuel consumption path of the Current Policies scenario from WEO 2011.

By combining ambitious efforts towards higher efficiency in vehicle technologies, a major switch to grid-connected electric vehicles (especially LDVs) and incentives for vehicle users to save carbon dioxide the study finds that it is possible to reduce CO_2 emissions from 'well-to-wheel' in the transport sector in 2050 by roughly 77%[48] compared to 1990 and 81% compared to 2009. By 2050, in this scenario, 25% of the final energy used in transport will still come from fossil sources, mainly gasoline, kerosene and diesel. Renewable electricity will cover 41%, biofuels 11% and hydrogen 20%. Total energy consumption will be reduced by 26% in 2050 compared to 2009 even though there are enormous increases in fuel use in some regions of the world. The peak in global CO_2 emissions from transport occurs between 2015 and 2020. From 2012 onwards, new legislation in the US and Europe will contribute to breaking the upwards trend. From 2020, the effect of introducing grid-connected electric cars can be clearly seen. Chapter 11 provides more details of this report.

4.1.3 fossil fuel assessment report

As part of the Energy [R]evolution scenario, Greenpeace also commissioned the Ludwig-Bölkow-Systemtechnik Institute in Munich, Germany to research a new fossil fuel resources assessment taking into account planned and ongoing investments in coal, gas and oil on a global and regional basis (see fossil fuel pathway Chapter 7).

4.1.4 status and future projections for renewable heating technologies

EREC and the DLR undertook a detailed research about the current renewable heating technology markets, market forecasts, cost projections and state of the technology development. The cost projection (see section 4.9) as well as the technology option (see Chapter 9) have been used as an input information for this new Energy [R]evolution scenario.

references

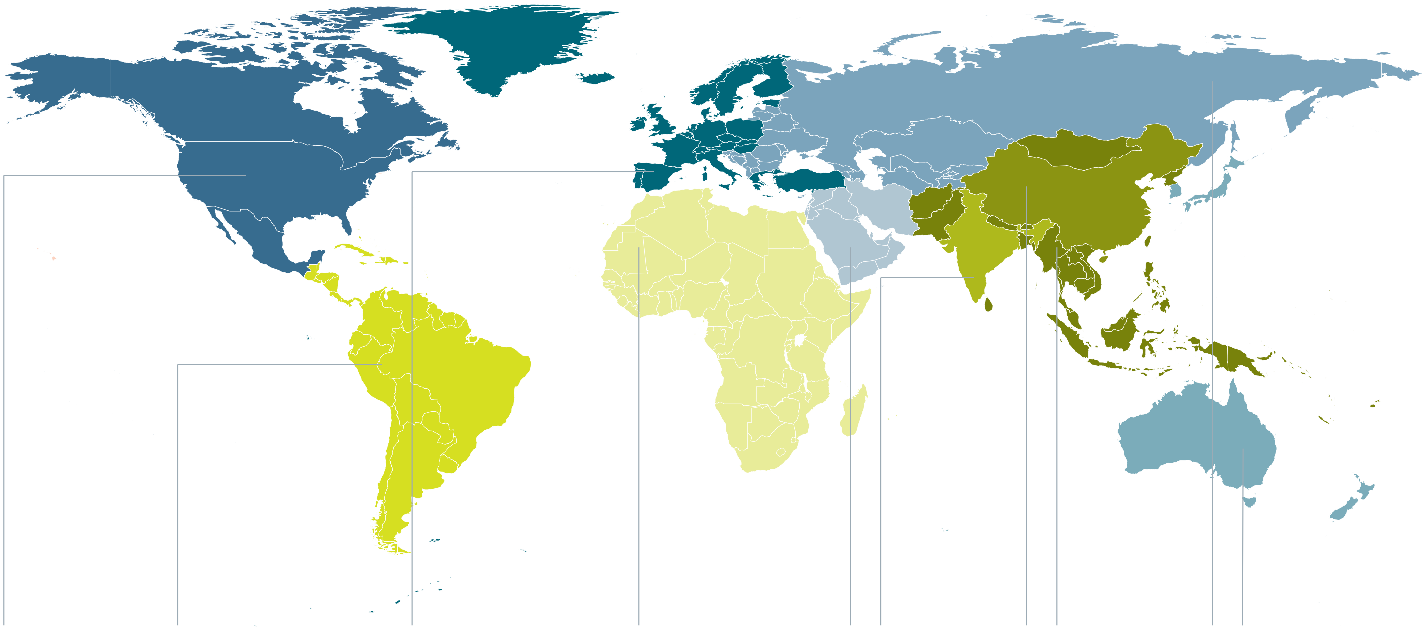
47 ENERGY [R]EVOLUTION: A SUSTAINABLE WORLD ENERGY OUTLOOK', GREENPEACE INTERNATIONAL, 2007, 2008 AND 2010.

48 TRANSPORT EMISSIONS IN 1990 BASED ON WEO 2011.

4.2 main scenario assumptions

To develop a global energy scenario requires a model that reflects the significant structural differences between different countries' energy supply systems. The International Energy Agency breakdown of ten world regions, as used in the ongoing series of World Energy Outlook reports, has been chosen because the IEA also provides the most comprehensive global energy statistics.[49] In line with WEO 2011, this new edition maintains the ten region approach. The countries in each of the world regions are listed in Figure 4.1.

figure 4.1: world regions used in the scenarios



oecd north america[50]

Canada, Mexico, United States of America

latin america

Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St. Kitts-Nevis-Anguila, Saint Lucia, St. Vincent and Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela

oecd europe

Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom

africa

Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo, Cote d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, United Republic of Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe

middle east

Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen

india

India

china

People's Republic of China including Hong Kong

other non oecd asia[52]

Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia, Chinese Taipei, Fiji, French Polynesia, Indonesia, Kiribati, Democratic People's Republic of Korea, Laos, Macao, Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Vietnam, Vanuatu

eastern europe/eurasia

Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Serbia and Montenegro, former Republic of Macedonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Romania, Russia, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Cyprus[51], Malta[51]

oecd asia oceania

Australia, Japan, Korea (South), New Zealand

references

49 INTERNATIONAL ENERGY AGENCY (IEA), PARIS: 'ENERGY BALANCES OF NON-OECD COUNTRIES' AND 'ENERGY BALANCES OF OECD COUNTRIES', 2011 EDITION.

50 WEO 2011 DEFINES THE REGION „OECD AMERICAS" AS USA, CANADA, MEXICO, AND CHILE. CHILE THUS BELONGS TO BOTH, OECD AMERICAS AND LATIN AMERICA IN WEO 2011. TO AVOID DOUBLE COUNTING OF CHILE, THE REGION "OECD NORTH AMERICA" HERE IS DEFINED WITHOUT CHILE, IN CONTRAST TO WEO 2011.

51 CYPRUS AND MALTA ARE ALLOCATED TO THE REGION EASTERN EUROPE/EURASIA FOR STATISTICAL REASONS.

52 WEO 2011 DEFINES THE REGION "NON OECD ASIA" INCLUDING CHINA AND INDIA. AS CHINA AND INDIA ARE ANALYSED INDIVIDUALLY IN THIS STUDY, THE REGION "REMAINING NON OECD ASIA" HERE IS BASED ON WEO'S "NON OECD ASIA", BUT WITHOUT CHINA AND INDIA.

image A WOMAN STUDIES SOLAR POWER SYSTEMS AT THE BAREFOOT COLLEGE. THE COLLEGE SPECIALISES IN SUSTAINABLE DEVELOPMENT AND PROVIDES A SPACE WHERE STUDENTS FROM ALL OVER THE WORLD CAN LEARN TO UTILISE RENEWABLE ENERGY. THE STUDENTS TAKE THEIR NEW SKILLS HOME AND GIVE THEIR VILLAGES CLEAN ENERGY.

4.3 population development

Future population development is an important factor in energy scenario building because population size affects the size and composition of energy demand, directly and through its impact on economic growth and development. The IEA World Energy Outlook 2011 uses the United Nations Development Programme (UNDP) projections for population development. For this study the most recent population projections from UNDP up to 2050 are applied[53], in addition, the current national population projection is used for China (see Table 4.2).

Based on UNDP's 2010 assessment, the world's population is expected to grow by 0.76 % on average over the period 2007 to 2050, from 6.8 billion people in 2009 to nearly 9.3 billion by 2050. The rate of population growth will slow over the projection period, from 1.1% per year during 2009-2020 to 0.5% per year during 2040-2050. The updated projections show an increase in population estimates by 2050 of around 150 million compared to the UNDP 2008 edition. This will slightly increase the demand for energy. From a regional perspective,the population of the developing regions will continue to grow most rapidly. The Eastern Europe/Eurasia will face a continuous decline, followed after a short while by the OECD Asia Oceania. The population in OECD Europe and OECD North America are expected to increase through 2050. The share of the population living in today's non-OECD countries will increase from the current 82% to 85% in 2050. China's contribution to world population will drop from 20% today to 14% in 2050. Africa will remain the region with the highest growth rate, leading to a share of 24% of world population in 2050.

Satisfying the energy needs of a growing population in the developing regions of the world in an environmentally friendly manner is the fundamental challenge to achieve a global sustainable energy supply.

table 4.2: population development projections

(IN MILLIONS)

REGION	2009	2015	2020	2025	2030	2040	**2050**
World	6,818	7,284	7,668	8,036	8,372	8,978	**9,469**
OECD Europe	555	570	579	587	593	599	**600**
OECD North America	458	484	504	524	541	571	**595**
OECD Asia Oceania	201	204	205	205	204	199	**193**
Eastern Europe/ Eurasia	339	340	341	340	337	331	**324**
India	1,208	1,308	1,387	1,459	1,523	1,627	**1,692**
China	1,342	1,377	1,407	1,436	1,452	1,474	**1,468**
Non OECD Asia	1,046	1,128	1,194	1,254	1,307	1,392	**1,445**
Latin America	468	499	522	544	562	589	**603**
Africa	999	1.045	1,278	1,417	1,562	1,870	**2,192**
Middle East	203	229	250	270	289	326	**358**

source UN WORLD POPULATION PROSPECTS - 2010 REVISION, MEDIUM VARIANT, AND NATIONAL POPULATION SCENARIO FOR CHINA.

4.4 economic growth

Economic growth is a key driver for energy demand. Since 1971, each 1% increase in global Gross Domestic Product (GDP) has been accompanied by a 0.6% increase in primary energy consumption. The decoupling of energy demand and GDP growth is therefore a prerequisite for an Energy [R]evolution. Most global energy/economic/environmental models constructed in the past have relied on market exchange rates to place countries in a common currency for estimation and calibration. This approach has been the subject of considerable discussion in recent years, and an alternative has been proposed in the form of purchasing power parity (PPP) exchange rates. Purchasing power parities compare the costs in different currencies of a fixed basket of traded and non-traded goods and services and yield a widely-based measure of the standard of living. This is important in analysing the main drivers of energy demand or for comparing energy intensities among countries.

Although PPP assessments are still relatively imprecise compared to statistics based on national income and product trade and national price indexes, they are considered to provide a better basis for global scenario development.[54] Thus all data on economic development in WEO 2011 refers to purchasing power adjusted GDP. However, as WEO 2011 only covers the time period up to 2035, the projections for 2035-2050 for the Energy [R]evolution scenario are based on our own estimates. Furthermore, estimates of Africa's GDP development have been adjusted upward compared to WEO 2011.

Prospects for GDP growth have decreased considerably since the previous study, due to the financial crisis at the beginning of 2009, although underlying growth trends continue much the same. GDP growth in all regions is expected to slow gradually over the coming decades. World GDP is assumed to grow on average by 3.8% per year over the period 2009-2030, compared to 3.1% from 1971 to 2007, and on average by 3.1% per year over the entire modelling period (2009-2011). China and India are expected to grow faster than other regions, followed by the Middle East, Africa, remaining Non OECD Asia, and Eastern Europe/Eurasia. The Chinese economy will slow as it becomes more mature, but will nonetheless become the largest in the world in PPP terms early in the 2020s. GDP in OECD Europe and OECD Asia Oceania is assumed to grow by around 1.6 and 1.3% per year over the projection period, while economic growth in OECD North America is expected to be slightly higher. The OECD share of global PPP-adjusted GDP will decrease from 56% in 2009 to 33% in 2050.

references

53 'WORLD POPULATION PROSPECTS: THE 2010 REVISION (MEDIUM VARIANT)', UNITED NATIONS, POPULATION DIVISION, DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS (UNDP), 2011.

54 NORDHAUS, W, 'ALTERNATIVE MEASURES OF OUTPUT IN GLOBAL ECONOMIC-ENVIRONMENTAL MODELS: PURCHASING POWER PARITY OR MARKET EXCHANGE RATES?', REPORT PREPARED FOR IPCC EXPERT MEETING ON EMISSION SCENARIOS, US-EPA WASHINGTON DC, JANUARY 12-14, 2005.

table 4.3: gdp development projections

(AVERAGE ANNUAL GROWTH RATES)

REGION	2009-2020	2020-2035	2035-2050	**2009-2050**
World	4.2%	3.2%	2.2%	3.1%
OECD Americas	2.7%	2.3%	1.2%	2.0%
OECD Asia Oceania	2.4%	1.4%	0.5%	1.3%
OECD Europe	2.1%	1.8%	1.0%	1.6%
Eastern Europe/ Eurasia	4.2%	3.2%	1.9%	3.0%
India	7.6%	5.8%	3.1%	5.3%
China	8.2%	4.2%	2.7%	4.7%
Non OECD Asia	5.2%	3.2%	2.6%	3.5%
Latin America	4.0%	2.8%	2.2%	2.9%
Middle East	4.3%	3.7%	2.8%	3.5%
Africa	4.5%	4.4%	4.2%	4.4%

source 2009-2035: IEA WEO 2011 AND 2035-2050: DLR, PERSONAL COMMUNICATION (2012)

4.5 oil and gas price projections

The recent dramatic fluctuations in global oil prices have resulted in slightly higher forward price projections for fossil fuels. Under the 2004 'high oil and gas price' scenario from the European Commission, for example, an oil price of just $ 34 per barrel was assumed in 2030. More recent projections of oil prices by 2035 in the IEA's WEO 2011 range from $$_{2010}$ 97/bbl in the 450 ppm scenario up to $$_{2010}$ 140/bbl in current policies scenario.

Since the first Energy [R]evolution study was published in 2007, however, the actual price of oil has moved over $ 100/bbl for the first time, and in July 2008 reached a record high of more than $ 140/bbl. Although oil prices fell back to $ 100/bbl in September 2008 and around $ 80/bbl in April 2010, prices have increased to more than $ 110/bbl in early 2012. Thus, the projections in the IEA Current Policies scenario might still be considered too conservative. Taking into account the growing global demand for oil we have assumed a price development path for fossil fuels slightly higher than the IEA WEO 2011 "Current Policies" case extrapolated forward to 2050 (see Table 4.4).

As the supply of natural gas is limited by the availability of pipeline infrastructure, there is no world market price for gas. In most regions of the world the gas price is directly tied to the price of oil. Gas prices are therefore assumed to increase to $24-30/GJ by 2050.

table 4.4: development projections for fossil fuel and biomass prices in $ 2010

FOSSIL FUEL	UNIT	2000	2005	2007	2008	2010	2015	2020	2025	2030	2035	2040	2050
Crude oil imports													
Historic prices (from WEO)	barrel	35	51	76	98	78							
WEO "450 ppm scenario"	barrel					78	97	97	97	97	97		
WEO Current policies	barrel					78	106	106	106	135	140		
Energy [R]evolution 2012	barrel					78	112	112	112	152	152	152	152
Natural gas imports													
Historic prices (from WEO)													
United States	GJ	5.07	2.35	3.28		4.64							
Europe	GJ	3.75	4.55	6.37		7.91							
Japan LNG	GJ	6.18	4.58	6.41		11.61							
WEO 2011 "450 ppm scenario"													
United States	GJ					4.64	6.22	6.86	8.44	8.85	8.23		
Europe	GJ					7.91	9.92	10.34	10.34	10.23	9.92		
Japan LNG	GJ					11.61	12.56	12.66	12.66	12.77	12.77		
WEO 2011 Current policies													
United States	GJ					4.64	6.44	7.39	8.12	8.85	9.50		
Europe	GJ					7.91	10.34	11.61	12.56	13.29	13.72		
Japan LNG	GJ					11.61	13.40	14.24	14.98	15.61	16.04		
Energy [R]evolution 2012													
United States	GJ					4.64	8.49	10.84	12.56	14.57	16.45	18.34	24.04
Europe	GJ					7.91	14.22	16.78	18.22	19.54	20.91	22.29	26.37
Japan LNG	GJ					11.61	16.22	19.08	20.63	22.12	23.62	25.12	29.77
OECD steam coal imports													
Historic prices (from WEO)	tonne	42	50	70	122	99							
WEO 2011 "450 ppm scenario"	tonne					99	100	93	83	74	68		
WEO 2011 Current policies	tonne					99	105	109	113	116	118		
Energy [R]evolution 2012	tonne						126.7	139	162.3	171.0	181.3	199.0	206.3
Biomass (solid)													
Energy [R]evolution 2012													
OECD Europe	GJ			7.50		7.80	8.31	9.32	9.72	10.13	10.28	10.43	10.64
OECD Asia Oceania & North America	GJ			3.34		3.44	3.55	3.85	4.10	4.36	4.56	4.76	5.27
Other regions	GJ			2.74		2.84	3.24	3.55	3.80	4.05	4.36	4.66	4.96

source IEA WEO 2009 & 2011 own assumptions.

image SATELLITE IMAGE OF JAPAN'S DAI ICHI POWER PLANT SHOWING DAMAGE AFTER THE EARTHQUAKE AND TSUNAMI OF 2011.

4.6 cost of CO_2 emissions

Assuming that a carbon emissions trading system is established across all world regions in the longer term, the cost of CO_2 allowances needs to be included in the calculation of electricity generation costs. Projections of emissions costs are even more uncertain than energy prices, and a broad range of future estimates has been made in studies. The CO_2 costs assumed in 2050 are often higher than those included in this Energy [R]evolution study (75 $\$_{2010}$/t$CO_2$)[55], reflecting estimates of the total external costs of CO_2 emissions. The CO_2 cost estimates in the 2010 version of Energy [R]evolution were rather conservative (50 $\$_{2008}$/t). CO_2 costs are applied in Kyoto Protocol Non-Annex B countries only from 2030 on.

table 4.5: assumptions on CO_2 emissions cost development for Annex-B and Non-Annex-B countries of the UNFCCC.

($2000/t$CO_2$)

COUNTRIES	2010	2015	2020	2030	2040	2050
Annex-B countries	0	15	25	40	55	75
Non-Annex-B countries	0	0	0	40	55	75

4.7 cost projections for efficient fossil fuel generation and carbon capture and storage (CCS)

Further cost reduction potentials are assumed for fuel power technologies in use today for coal, gas, lignite and oil. Because they are at an advanced stage of market development the potential for cost reductions is limited, and will be achieved mainly through an increase in efficiency.[56]

There is much speculation about the potential for carbon capture and storage (CCS) to mitigate the effect of fossil fuel consumption on climate change, even though the technology is still under development.

CCS means trapping CO_2 from fossil fuels, either before or after they are burned, and 'storing' (effectively disposing of) it in the sea or beneath the surface of the earth. There are currently three different methods of capturing CO_2: 'pre-combustion', 'post-combustion' and 'oxyfuel combustion'. However, development is at a very early stage and CCS will not be implemented - in the best case - before 2020 and will probably not become commercially viable as a possible effective mitigation option until 2030.

Cost estimates for CCS vary considerably, depending on factors such as power station configuration, technology, fuel costs, size of project and location. One thing is certain, however: CCS is expensive. It requires significant funds to construct the power stations and the necessary infrastructure to transport and store carbon. The IPCC special report on CCS assesses costs at $15-75 per ton of captured CO_2[57], while a 2007 US Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs.[58] These costs are estimated to increase the price of electricity in a range from 21-91%.[59]

table 4.6: development of efficiency and investment costs for selected new power plant technologies

POWER PLANT		2009	2015	2020	2030	2040	2050
Coal-fired condensing power plant	Max. efficiency (%)	45	46	48	50	52	53
	Investment costs ($2010/kW)	1,436	1,384	1,363	1,330	1,295	1,262
	CO_2 emissions [a)](g/kWh)	744	728	697	670	644	632
Lignite-fired condensing power plant	Max. efficiency (%)	41	43	44	44,5	45	45
	Investment costs ($2010/kW)	1,693	1,614	1,578	1,545	1,511	1,478
	CO_2 emissions [a)](g/kWh)	975	929	908	898	888	888
Natural gas combined cycle	Max. efficiency (%)	57	59	61	62	63	64
	Investment costs ($2010/kW)	777	754	736	701	666	631
	CO_2 emissions [a)](g/kWh)	354	342	330	325	320	315

source
WEO 2010, DLR 2010 [a)]CO_2 emissions refer to power station outputs only; life-cycle emissions are not considered.

references
55 KREWITT, W., SCHLOMANN, B., EXTERNAL COSTS OF ELECTRICITY GENERATION FROM RENEWABLE ENERGIES COMPARED TO ELECTRICITY GENERATION FROM FOSSIL ENERGY SOURCES, GERMAN FEDERAL MINISTRY FOR THE ENVIRONMENT, NATURE CONSERVATION AND NUCLEAR SAFETY, BERLIN 2006.
56 GREENPEACE INTERNATIONAL BRIEFING: CARBON CAPTURE AND STORAGE', GOERNE, 2007.
57 ABANADES, J C ET AL., 2005, PG 10.
58 NATIONAL ENERGY TECHNOLOGY LABORATORIES, 2007.
59 RUBIN ET AL., 2005A, PG 40.

Pipeline networks will also need to be constructed to move CO_2 to storage sites. This is likely to require a considerable outlay of capital.[60] Costs will vary depending on a number of factors, including pipeline length, diameter and manufacture from corrosion-resistant steel, as well as the volume of CO_2 to be transported. Pipelines built near population centres or on difficult terrain, such as marshy or rocky ground, are more expensive.[61]

The Intergovernmental Panel on Climate Change (IPCC) estimates a cost range for pipelines of $1-8/tonne of CO_2 transported. A United States Congressional Research Services report calculated capital costs for an 11 mile pipeline in the Midwestern region of the US at approximately $6 million. The same report estimates that a dedicated interstate pipeline network in North Carolina would cost upwards of $5 billion due to the limited geological sequestration potential in that part of the country.[62] Storage and subsequent monitoring and verification costs are estimated by the IPCC to range from $0.5-8/t$CO_2$ (for storage) and $0.1-0.3/t$CO_2$ (for monitoring). The overall cost of CCS could therefore be a major barrier to its deployment.[63]

For the above reasons, CCS power plants are not included in our economic analysis.

Table 4.6 summarises our assumptions on the technical and economic parameters of future fossil-fuelled power plant technologies. Based on estimates from WEO 2010, we assume that further technical innovation will not prevent an increase of future investment costs because raw material costs and technical complexity will continue to increase. Also, improvements in power plant efficiency are outweighed by the expected increase in fossil fuel prices, which would increase electricity generation costs significantly.

4.8 cost projections for renewable energy technologies

The different renewable energy technologies available today all have different technical maturity, costs and development potential. Whereas hydro power has been widely used for decades, other technologies, such as the gasification of biomass or ocean energy, have yet to find their way to market maturity. Some renewable sources by their very nature, including wind and solar power, provide a variable supply, requiring a revised coordination with the grid network. But although in many cases renewable energy technologies are 'distributed' - their output being generated and delivered locally to the consumer – in the future we can also have large-scale applications like offshore wind parks, photovoltaic power plants or concentrating solar power stations.

It is possible to develop a wide spectrum of options to market maturity, using the individual advantages of the different technologies, and linking them with each other, and integrating them step by step into the existing supply structures. This approach will provide a complementary portfolio of environmentally friendly technologies for heat and power supply and the provision of transport fuels.

Many of the renewable technologies employed today are at a relatively early stage of market development. As a result, the costs of electricity, heat and fuel production are generally higher than those of competing conventional systems - a reminder that the environmental and social costs of conventional power production are not reflected in market prices. It is expected, however that large cost reductions can come from technical advances, manufacturing improvements and large-scale production, unlike conventional technologies. The dynamic trend of cost developments over time plays a crucial role in identifying economically sensible expansion strategies for scenarios spanning several decades.

To identify long-term cost developments, learning curves have been applied to the model calculations to reflect how cost of a particular technology change in relation to the cumulative production volumes. For many technologies, the learning factor (or progress ratio) is between 0.75 for less mature systems to 0.95 and higher for well-established technologies. A learning factor of 0.9 means that costs are expected to fall by 10% every time the cumulative output from the technology doubles. Empirical data shows, for example, that the learning factor for PV solar modules has been fairly constant at 0.8 over 30 years whilst that for wind energy varies from 0.75 in the UK to 0.94 in the more advanced German market.

Assumptions on future costs for renewable electricity technologies in the Energy [R]evolution scenario are derived from a review of learning curve studies, for example by Lena Neij and others[64], from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS project (New Energy Externalities Developments for Sustainability)[65] or the IEA Energy Technology Perspectives 2008, projections by the European Renewable Energy Council published in April 2010 ("Re-Thinking 2050") and discussions with experts from different sectors of the renewable energy industry.

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62 PARFOMAK, P & FOLGER, P, 2008, PG 5 AND 12.
63 RUBIN ET AL., 2005B, PG 4444.
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65 WWW.NEEDS-PROJECT.ORG.

image AN EXCAVATOR DIGS A HOLE AT GUAZHOU WIND FARM CONSTRUCTION SITE, CHINA, WHERE IT IS PLANNED TO BUILD 134 WINDMILLS.

4.8.1 photovoltaics (PV)

The worldwide photovoltaics (PV) market has been growing at over 40% per annum in recent years and the contribution is starting to make a significant contribution to electricity generation.

Photovoltaics are important because of their decentralised/centralised character, its flexibility for use in an urban environment and huge potential for cost reduction. The PV industry has been increasingly exploiting this potential during the last few years, with installation prices more than halving in the last few years. Current development is focused on improving existing modules and system components by increasing their energy efficiency and reducing material usage. Technologies like PV thin film (using alternative semiconductor materials) or dye sensitive solar cells are developing quickly and present a huge potential for cost reduction. The mature technology crystalline silicon, with a proven lifetime of 30 years, is continually increasing its cell and module efficiency (by 0.5% annually), whereas the cell thickness is rapidly decreasing (from 230 to 180 microns over the last five years). Commercial module efficiency varies from 14 to 21%, depending on silicon quality and fabrication process.

The learning factor for PV modules has been fairly constant over the last 30 years with costs reducing by 20% each time the installed capacity doubles, indicating a high rate of technical learning. Assuming a globally installed capacity of about 1,500 GW between 2030 and 2040 in the Energy [R]evolution scenario with an electricity output of 2,600 TWh/a, generation costs of around $ 5-10 cents/kWh (depending on the region) will be achieved. During the following five to ten years, PV will become competitive with retail electricity prices in many parts of the world, and competitive with fossil fuel costs around 2030. Cost data applied in this study is shown in Table 4.7. In the long term, additional costs for the integration into the power supply system of up to 25% of PV investment have been taken into account (estimation for local batteries and load and generation management measures).

4.8.2 concentrating solar power (CSP)

Solar thermal 'concentrating' power stations (CSP) can only use direct sunlight and are therefore dependent on very sunny locations. North Africa, for example, has a technical potential for this technology which far exceeds regional demand. The various solar thermal technologies (detailed in Chapter 9) have good prospects for further development and cost reductions. Because of their more simple design, 'Fresnel' collectors are considered as an option for additional cost trimming. The efficiency of central receiver systems can be increased by producing compressed air at a temperature of up to 1,000°C, which is then used to run a combined gas and steam turbine.

Thermal storage systems are a way for CSP electricity generators to reduce costs. The Spanish Andasol 1 plant, for example, is equipped with molten salt storage with a capacity of 7.5 hours. A higher level of full load operation can be realised by using a thermal storage system and a large collector field. Although this leads to higher investment costs, it reduces the cost of electricity generation.

Depending on the level of irradiation and mode of operation, it is expected that long term future electricity generation costs of $ 6-10 cents/kWh can be achieved. This presupposes rapid market introduction in the next few years. CSP investment costs assumed for this study and shown in Table 4.8 include costs for an increasing storage capacity up to 12 hours per day and additional solar fields up to solar multiple 3, achieving a maximum of 6,500 full load hours per year.

table 4.7: photovoltaics (PV) cost assumptions

INCLUDING ADDITIONAL COSTS FOR GRID INTEGRATION OF UP TO 25% OF PV INVESTMENT

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Investment costs ($/kWp)	3,000	2,300	1,650	1,280	1,040	1,060
O & M costs $/(kW · a)	43	38	21	15	14	15

O & M = Operation and maintenance.

table 4.8: concentrating solar power (CSP) cost assumptions

INCLUDING COSTS FOR HEAT STORAGE AND ADDITIONAL SOLAR FIELDS

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Investment costs ($/kWp)	9,300	8,100	6,600	5,750	5,300	4,800
O & M costs $/(kW · a)	420	330	265	229	211	193

O & M = Operation and maintenance.

4.8.3 wind power

Within a short period of time, the dynamic development of wind power has resulted in the establishment of a flourishing global market. In Europe, favourable policy incentives were the early drivers for the global wind market. However, since 2009 more than three quarters of the annual capacity installed was outside Europe and this trend is likely to continue. The boom in demand for wind power technology has nonetheless led to supply constraints. As a consequence, the cost of new systems has increased. The industry is continuously expanding production capacity, however, so it is already resolving the bottlenecks in the supply chain. Taking into account market development projections, learning curve analysis and industry expectations, we assume that investment costs for wind turbines will reduce by 25% for onshore and more than 50% for offshore installations up to 2050. Additional costs for grid integration of up to 25% of investment has been taken into account also in the cost data for wind power shown in Table 4.9.

4.8.4 biomass

The crucial factor for the economics of using biomass for energy is the cost of the feedstock, which today ranges from a negative for waste wood (based on credit for waste disposal costs avoided) through inexpensive residual materials to the more expensive energy crops. The resulting spectrum of energy generation costs is correspondingly broad. One of the most economic options is the use of waste wood in steam turbine combined heat and power (CHP) plants. Gasification of solid biomass, on the other hand, which has a wide range of applications, is still relatively expensive. In the long term it is expected that using wood gas both in micro CHP units (engines and fuel cells) and in gas-and-steam power plants will have the most favourable electricity production costs. Converting crops into ethanol and 'bio diesel' made from rapeseed methyl ester (RME) has become increasingly important in recent years, for example in Brazil, the USA and Europe – although its climate benefit is disputed. Processes for obtaining synthetic fuels from biogenic synthesis gases will also play a larger role.

A large potential for exploiting modern technologies exists in Latin and North America, Europe and Eurasia, either in stationary appliances or the transport sector. In the long term, OECD Europe and Eastern Europe/Eurasia could realise 20-50% of the potential for biomass from energy crops, whilst biomass use in all the other regions will have to rely on forest residues, industrial wood waste and straw. In Latin America, North America and Africa in particular, an increasing residue potential will be available.

In other regions, such as the Middle East and all Asian regions, increased use of biomass is restricted, either due to a generally low availability or already high traditional use. For the latter, using modern, more efficient technologies will improve the sustainability of current usage and will have positive side effects, such as reducing indoor pollution and heavy workloads currently associated with traditional biomass use.

table 4.9: wind power cost assumptions

INCLUDING ADDITIONAL COSTS FOR GRID INTEGRATION OF UP TO 25% OF INVESTMENT

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Wind turbine offshore						
Investment costs ($/kWp)	6,000	5,100	3,800	3,000	2,700	2,350
O & M costs $/(kW · a)	230	205	161	131	124	107
Wind turbine onshore						
Investment costs ($/kWp)	1,800	1,500	1,290	1,280	1,300	1,350
O & M costs $/(kW · a)	64	55	55	56	59	61

O & M = Operation and maintenance.

table 4.10: biomass cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Biomass power plant						
Investment costs ($/kWp)	3,350	3,100	3,000	2,800	2,700	2,650
O & M costs $/(kW · a)	201	185	175	169	162	166
Biomass CHP						
Investment costs ($/kWp)	5,700	5,050	4,400	3,850	3,550	3,380
O & M costs $/(kW · a)	397	354	310	270	250	237

O & M = Operation and maintenance.

image ANDASOL 1 SOLAR POWER STATION IS EUROPE'S FIRST COMMERCIAL PARABOLIC TROUGH SOLAR POWER PLANT. IT WILL SUPPLY UP TO 200,000 PEOPLE WITH CLIMATE-FRIENDLY ELECTRICITY AND SAVE ABOUT 149,000 TONNES OF CARBON DIOXIDE PER YEAR COMPARED WITH A MODERN COAL POWER PLANT.

4.8.5 geothermal

Geothermal energy has long been used worldwide for supplying heat, and since the beginning of the last century for electricity generation. Geothermally generated electricity was previously limited to sites with specific geological conditions, but further intensive research and development work widened potential sites. In particular the creation of large underground heat exchange surfaces - Enhanced Geothermal Systems (EGS) - and the improvement of low temperature power conversion, for example with the Organic Rankine Cycle, could make it possible to produce geothermal electricity anywhere. Advanced heat and power cogeneration plants will also improve the economics of geothermal electricity.

A large part of the costs for a geothermal power plant come from deep underground drilling, so further development of innovative drilling technology is expected. Assuming a global average market growth for geothermal power capacity of 15% per year up to 2020, adjusting to 12% up to 2030 and still 7% per year beyond 2030, the result would be a cost reduction potential of more than 60% by 2050:

- for conventional geothermal power (without heat credits), from $ 15 cents/kWh to about $ 9 cents/kWh;
- for EGS, despite the presently high figures (about $ 20-30 cents/kWh), electricity production costs - depending on the credits for heat supply - are expected to come down to around $ 8 cents/kWh in the long term.

Because of its non-fluctuating supply and a grid load operating almost 100% of the time, geothermal energy is considered to be a key element in a future supply structure based on renewable sources. Up to now we have only used a marginal part of the potential. Shallow geothermal drilling, for example, can deliver energy for heating and cooling at any time anywhere, and can be used for thermal energy storage.

4.8.6 ocean energy

Ocean energy, particularly offshore wave energy, is a significant resource and has the potential to satisfy an important percentage of electricity supply worldwide. Globally, the potential of ocean energy has been estimated at around 90,000 TWh/year. The most significant advantages are the vast availability and high predictability of the resource and a technology with very low visual impact and no CO_2 emissions. Many different concepts and devices have been developed, including taking energy from the tides, waves, currents and both thermal and saline gradient resources. Many of these are in an advanced phase of research and development, large scale prototypes have been deployed in real sea conditions and some have reached pre-market deployment. There are a few grid connected, fully operational commercial wave and tidal generating plants.

The cost of energy from initial tidal and wave energy farms has been estimated to be in the range of $ 25-95 cents/kWh[66], and for initial tidal stream farms in the range of $ 14-28 cents/kWh. Generation costs of $ 8-10 cents/kWh are expected by 2030. Key areas for development will include concept design, optimisation of the device configuration, reduction of capital costs by exploring the use of alternative structural materials, economies of scale and learning from operation. According to the latest research findings, the learning factor is estimated to be 10-15% for offshore wave and 5-10% for tidal stream. In the long term, ocean energy has the potential to become one of the most competitive and cost effective forms of generation. In the next few years a dynamic market penetration is expected, following a similar curve to wind energy.

Because of the early development stage any future cost estimates for ocean energy systems are uncertain. Present cost estimates are based on analysis from the European NEEDS project.[67]

table 4.11: geothermal cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Geothermal power plant						
Investment costs ($/kWp)	13,500	11,100	9,300	6,400	5,300	4,550
O & M costs $/(kW · a)	637	538	418	318	297	281

O & M = Operation and maintenance.

table 4.12: ocean energy cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Geothermal power plant	5,900	4,650	3,300	2,300	1,900	1,700
Investment costs ($/kWp)	237	185	132	91	77	68
O & M costs $/(kW · a)						

O & M = Operation and maintenance.

references
66 G.J. DALTON, T. LEWIS (2011): PERFORMANCE AND ECONOMIC FEASIBILITY ANALYSIS OF 5 WAVE ENERGY DEVICES OFF THE WEST COAST OF IRELAND; EWTEC 2011.
67 WWW.NEEDS-PROJECT.ORG.

4.8.7 hydro power

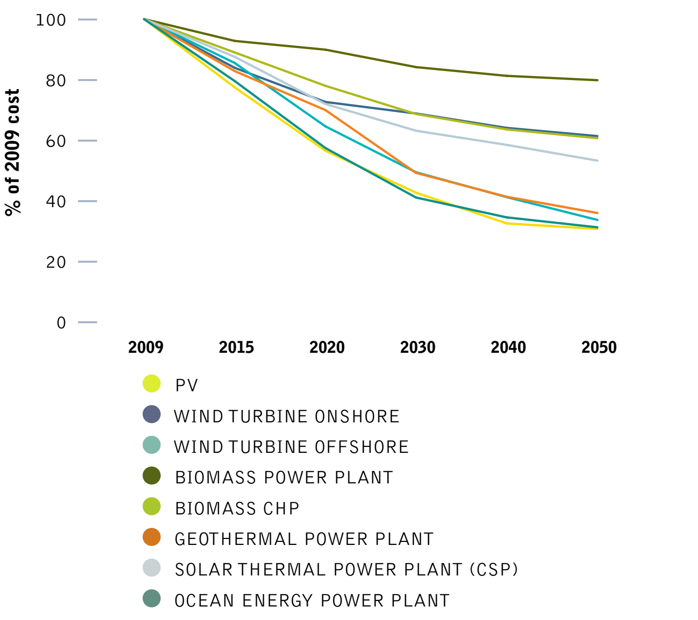
Hydropower is a mature technology with a significant part of its global resource already exploited. There is still, however, some potential left both for new schemes (especially small scale run-of-river projects with little or no reservoir impoundment) and for repowering of existing sites. There is likely to be some more potential for hydropower with the increasing need for flood control and the maintenance of water supply during dry periods. Sustainable hydropower makes an effort to integrate plants with river ecosystems while reconciling ecology with economically attractive power generation.

table 4.13: hydro power cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Investment costs ($/kWp)	3,300	3,400	3,500	3,650	3,500	3,900
O & M costs $/(kW · a)	132	136	141	146	152	156

O & M = Operation and maintenance.

figure 4.2: future development of investment costs for renewable energy technologies (NORMALISED TO 2010 COST LEVELS)



4.8.8 summary of renewable energy cost development

Figure 4.2 summarises the cost trends for renewable power technologies derived from the respective learning curves. It is important to note that the expected cost reduction is not a function of time, but of cumulative capacity (production of units), so dynamic market developments are required. Most of the technologies will be able to reduce their specific investment costs to between 30% and 60% of current levels once they have achieved full maturity (after 2040).

Reduced investment costs for renewable energy technologies lead directly to reduced electricity generation costs, as shown in Figure 4.3. Generation costs in 2009 were around $ 8 to 35 cents/kWh for the most important technologies, with the exception of photovoltaic. In the long term, costs are expected to converge at around $ 6 to 12 cents/kWh (examples for OECD Europe). These estimates depend on site-specific conditions such as the local wind regime or solar irradiation, the availability of biomass at reasonable prices or the credit granted for heat supply in the case of combined heat and power generation.

figure 4.3: expected development of electricity generation costs from fossil fuel and renewable options
EXAMPLE FOR OECD EUROPE

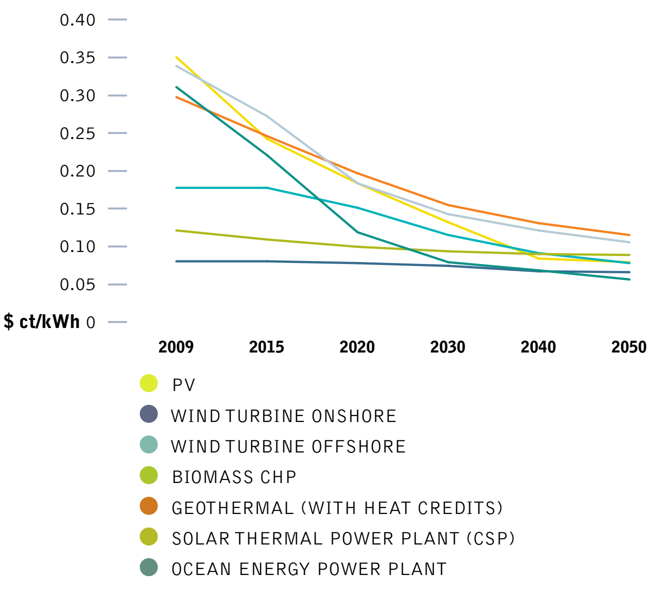


image A SATELLITE IMAGE OF EYJAFJALLAJOKULL VOLCANO ERUPTION, ICELAND, 2010.

4.9 cost projections for renewable heating technologies

Renewable heating has the longest tradition of all renewable technologies. In a joint survey EREC and DLR carried out a survey on renewable heating technologies in Europe (see also technology chapter 9). The report analyses installation costs of renewable heating technologies, ranging from direct solar collector systems to geothermal and ambient heat applications and biomass technologies. Some technologies are already mature and compete on the market – especially simple heating systems in the domestic sector. However, more sophisticated technologies, which can provide higher shares of heat demand from renewable sources, are still under development. Costs of different technologies show quite a large range depending not only on the maturity of the technology but also on the complexity of the system as well as the local conditions. Market barriers slow down the further implementation and cost reduction of renewable heating systems, especially for heating networks. Nevertheless, significant learning rates can be expected if renewable heating is increasingly implemented as projected in the Energy [R]evolution scenario.

4.9.1 solar thermal technologies

Solar collectors depend on direct solar irradiation, so the yield strongly depends on the location. In very sunny regions even very simple collectors can provide hot water to households at very low cost. In Europe, thermosiphon systems can provide total hot water demand in households at around 400 €/m² installation costs. In regions with less sun, where additional space heating is needed, installation cost for pumped systems are twice as high. In these areas, economies of scales can decrease solar heating costs significantly. Large scale solar collector system are known from 250-600 €/m², depending on the share of solar energy in the whole heating system and the level of storage required. While those cost assumptions were transferred to all OECD Regions and the Eastern European Economies, a lower cost level for households was assumed in very sunny or developing regions.

4.9.2 deep geothermal applications

(Deep) geothermal heat from aquifers or reservoirs can be used directly in hydrothermal heating plants to supply heat demand close to the plant or in a district heating network for several different types of heat (see Chapter 8). Due to the high drilling costs deep geothermal energy is mostly feasibly for large applications in combination with heat networks. It is already economic feasible and has been in use for a long time, where aquifers can be found near the surface, e.g. in the Pacific Island or along the Pacific ring of fire. Also in Europe deep geothermal applications are being developed for heating purposes at investment costs from 500€/kWth (shallow) to 3000 €/kWth (deep), with the costs strongly dependent on the drilling depth. As deep geothermal systems require a high technology level, European cost assumptions were transferred to all regions worldwide.

4.9.3 heat pumps

Heat pumps typically provide hot water or space heat for heating systems with relatively low supply temperature or can serve as a supplement to other heating technologies. They have become increasingly popular for underfloor heating in buildings in Europe. Economies of scale are less important than for deep geothermal, so there is focus on small household applications with investment costs in Europe ranging from 500-1,600 €/kW for ground water systems and from 1,200-3,000 €/kW for ground source or aerothermal systems.

4.9.4 biomass applications

There is broad portfolio of modern technologies for heat production from biomass, ranging from small scale single room stoves to heating or CHP-plants in MW scale. Investments costs in Europe show a similar variety: simple log wood stoves can be obtained from 100 €/kW, more sophisticated automated heating systems that cover the whole heat demand of a building are significantly more expensive. Log wood or pellet boilers range from 400-1200 €/kW, with large applications being cheaper than small systems. Considering the possible applications of this wide range of technologies especially in the household sector, higher investment costs were assumed for hightech regions of the OECD, the Eastern European Economies and Middle East. Sunny regions with low space heat demand as well as developing regions are covered with very low investment costs. Economy of scales apply to heating plants above 500kW, with investment cost between 400-700 €/kW. Heating plants can deliver process heat or provide whole neighbourhoods with heat. Even if heat networks demand additional investment, there is great potential to use solid biomass for heat generation in both small and large heating centres linked to local heating networks.

Cost reductions expected vary strongly within each technology sector, depending on the maturity of a specific technology. E.g. Small wood stoves will not see significant cost reductions, while there is still learning potential for automated pellet heating systems. Cost for simple solar collectors for swimming pools might be already optimised, whereas integration in large systems is neither technological nor economical mature. Table 4.14 shows average development pathways for a variety of heat technology options.

table 4.14: overview over expected investment costs pathways for heating technologies IN $/KW

	2015	2020	2030	2040	2050
Geothermal distict heating*	2,650	2,520	2,250	2,000	1,760
Heat pumps	1,990	1,930	1,810	1,710	1,600
Low tech solar collectors	140	140	140	140	140
Small solar collector systems	1,170	1,120	1,010	890	750
Large solar collector systems	950	910	810	720	610
Solar district heating*	1,080	1,030	920	820	690
Low tech biomass stoves	130	130	130	130	130
Biomass heating systems	930	900	850	800	750
Biomass district heating*	660	640	600	570	530

* WITHOUT NETWORK

4.10 assumptions for fossil fuel phase out

More than 80% of the current energy supply is based on fossil fuels. Oil dominates the entire transport sector; oil and gas make up the heating sector and coal is the most-used fuel for power. Each sector has different renewable energy and energy efficiency technologies combinations which depend on the locally available resources, infrastructure and to some extent, lifestyle. The renewable energy technology pathways used in this scenario are based on currently available "off-the-shelf" technologies, market situations and market projections developed from renewable industry associations such as the Global Wind Energy Council, the European Photovoltaic Industry Association and the European Renewable Energy Council, the DLR and Greenpeace International.

In line with this modelling, the Energy [R]evolution aims to map out a clear pathway to phase-out oil and gas in the long term. This pathway has been identified on the basis of a detailed analysis of the global conventional oil resources, current infrastructure of those industries, the estimated production capacities of existing oil wells in the light of projected production decline rates and the investment plans known by end 2011. Those remaining fossil fuel resources between 2012 and 2050 form the oil pathway so no new deep sea and Arctic oil exploration, no oil shale and tar sand mining are required for two reasons:

- First and foremost, to limit carbon emissions to save the climate.
- Second, financial resources must flow from 2012 onwards in the development of new and larger markets for renewable energy technologies and energy efficiency to avoid "locking-in" new fossil fuel infrastructure.

4.10.1 oil – production decline assumptions

Figure 4.4 shows the remaining production capacities with an annual production decline between 2.5% and 5% and the additional production capacities assuming all new projects planned for 2012 to 2020 will go ahead. Even with new projects, the amount of remaining conventional oil is very limited and therefore a transition towards a low oil demand pattern is essential.

4.10.2 coal – production decline assumptions

While there is an urgent need for a transition away from oil and gas to avoid "locking-in" investments in new production wells, the climate is the clearly limiting factor for the coal resource, not its availability. All existing coal mines – even without new expansions of mines – could produce more coal, but its burning puts the world on a catastrophic climate change pathway.

figure 4.4: global oil production 1950 to 2011 and projection till 2050

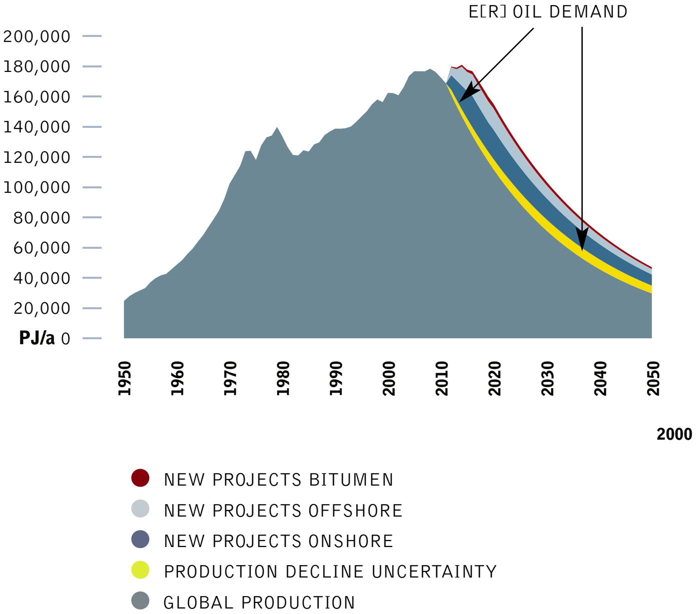


figure 4.5: coal scenario: base decline of 2% per year and new projects

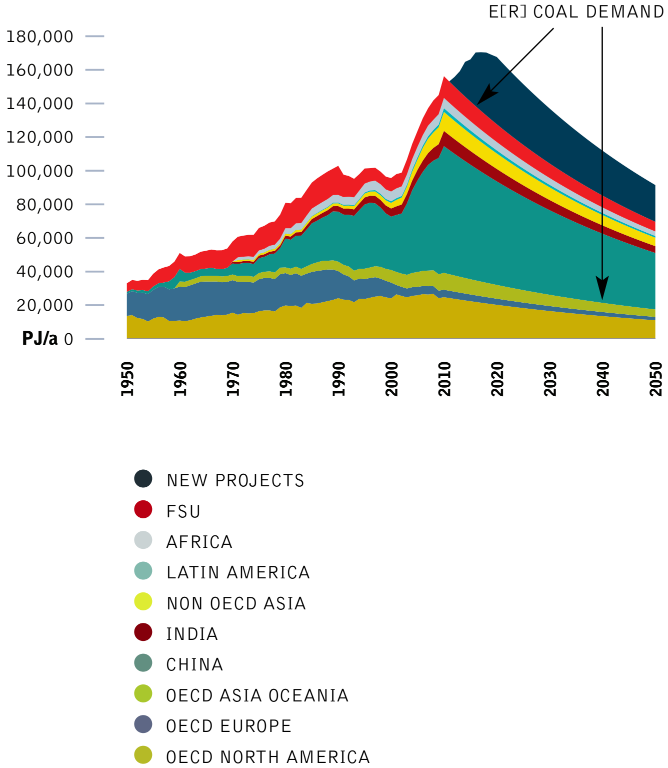


image A PRAWN SEED FARM ON MAINLAND INDIA'S SUNDARBANS COAST LIES FLOODED AFTER CYCLONE AILA. INUNDATING AND DESTROYING NEARBY ROADS AND HOUSES WITH SALT WATER.

4.11 review: greenpeace scenario projections of the past

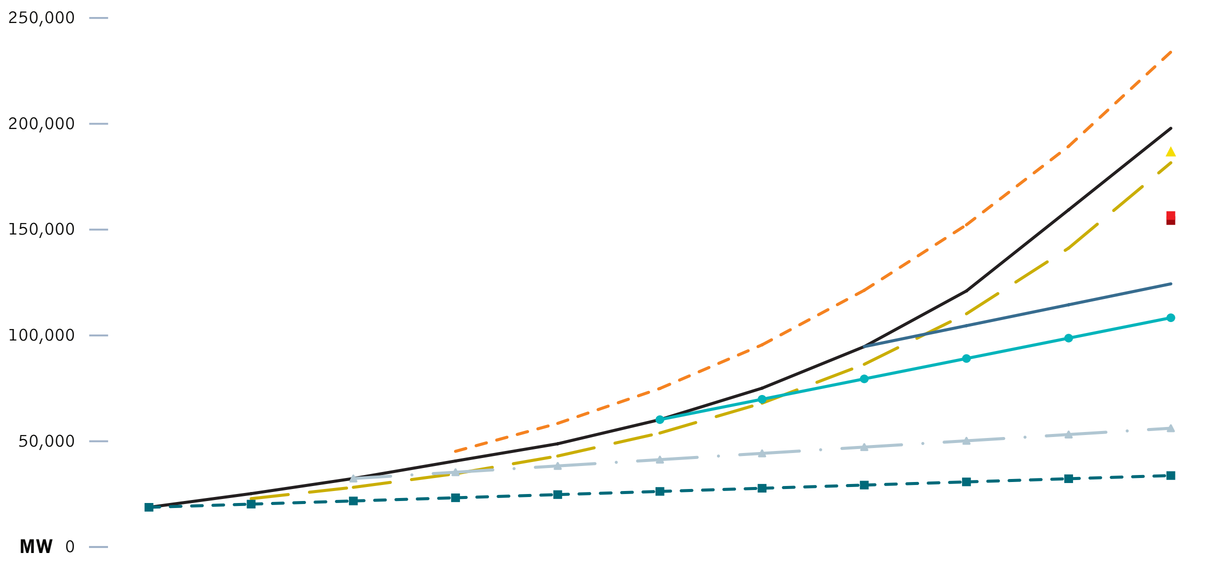
Greenpeace has published numerous projections in cooperation with Renewable Industry Associations and scientific institutions in the past decade. This section provides an overview of the projections between 2000 and 2011 and compares them with real market developments and projections of the IEA World Energy Outlook – our Reference scenario.

4.11.1 the development of the global wind industry

Greenpeace and the European Wind Energy Association published "Windforce 10" for the first time in 1999– a global market projection for wind turbines until 2030. Since then, an updated prognosis has been published every second year. Since 2006 the report has been renamed to "Global Wind Energy Outlook" with a new partner – the Global Wind Energy Council (GWEC) – a new umbrella organisation of all regional wind industry associations. Figure 4.6 shows the projections made each year between 2000 and 2010 compared to the real market data. The graph also includes the first two Energy [R]evolution (ER) editions (published in 2007 and 2008) against the IEA's wind projections published in World Energy Outlook (WEO) 2000, 2002, 2005 and 2007.

The projections from the "Wind force 10" and "Windforce 12" were calculated by BTM consultants, Denmark. "Windforce 10" (2001 - 2011) exact projection for the global wind market published during this time, at 10% below the actual market development. Also all following editions where around 10% above or below the real market. In 2006, the new "Global Wind Energy Outlook" had two different scenarios, a moderate and an advanced wind power market projections calculated by GWEC and Greenpeace International. The figures here show only the advanced projections, as the moderate were too low. However, these very projections were the most criticised at the time, being called "over ambitious" or even "impossible".

figure 4.6: wind power: short term prognosis vs real market development - global cummulative capacity

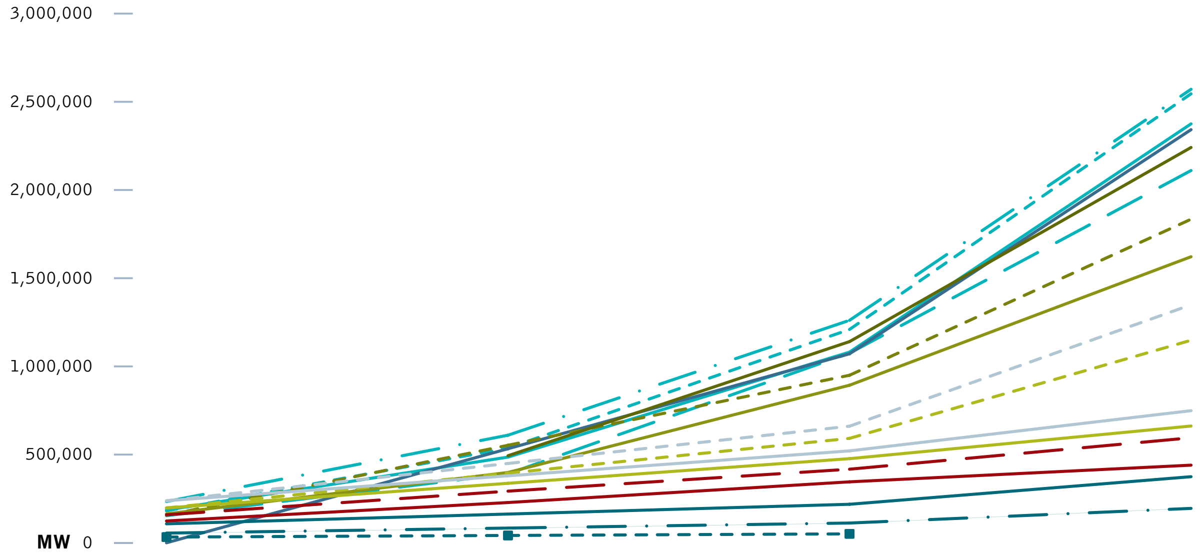


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
REAL	17,400	23,900	31,100	39,431	47,620	59,091	74,052	93,820	120,291	158,864	197,637
WF 10 (1999)		21,510	26,901	33,371	41,781	52,715	66,929	85,407	109,428	140,656	181,252
WF 12 (2002)				44,025	57,306	73,908	94,660	120,600	151,728	189,081	233,905
GWEO 2006 (Advanced)											153,759
GWEO 2008 (Advanced)											186,309
ER 2007											156,149
ER 2008											163,855
ADVANCED ER 2010											
IEA WEO 2000 (REF)	17,400	18,910	20,420	21,930	23,440	24,950	26,460	27,970	29,480	30,990	32,500
IEA WEO 2002 (REF)			31,100	34,088	37,075	40,063	43,050	46,038	49,025	52,013	55,000
IEA WEO 2005 (REF)						59,091	68,781	78,471	88,161	97,851	107,541
IEA WEO 2007 (REF)								93,820	103,767	113,713	123,660

In contrast, the IEA "Current Policy" projections seriously under estimated the wind industry's ability to increase manufacturing capacity and reduce costs. In 2000, the IEA WEO published a projections of global installed capacity for wind turbines of 32,500 MW for 2010. This capacity had been connected to the grid by early 2003, only two-and-a-half years later. By 2010, the global wind capacity was close to 200,000 MW; around six times more than the IEA's assumption a decade earlier.

Only time will tell if the GPI/DLR/GWEC longer-term projections for the global wind industry will remain close to the real market. However the International Energy Agency's World Energy Outlook projections over the past decade have been constantly increased and keep coming close to our progressive growth rates.

figure 4.7: wind power: long term market projects until 2030



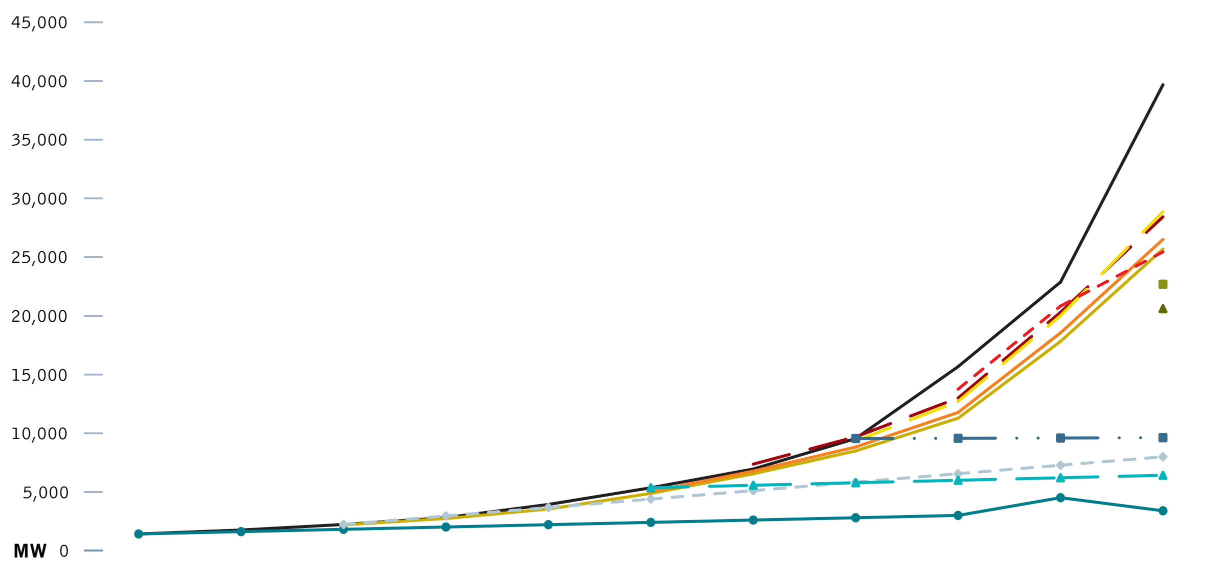
	2010	2015	2020	2030
WF 10 (1999)	181,252	537,059	1,209,466	2,545,232
WF 12 (2002)	233,905	610,000	1,261,157	2,571,000
GWEO 2006 (Advanced)	153,759	391,077	1,074,835	2,110,401
GWEO 2008 (Advanced)	186,309	485,834	1,080,886	2,375,000
GWEO 2008 (Advanced)	0	533,233	1,071,415	2,341,984
E[R] 2007	156,149	552,973	949,796	1,834,286
E[R] 2008	163,855	398,716	893,317	1,621,704
ADVANCED E[R] 2010		493,542	1,140,492	2,241,080
IEA WEO 2000 (REF)	32,500	41,550	50,600	
IEA WEO 2002 (REF)	55,000	83,500	112,000	195,000
IEA WEO 2005 (REF)	107,541	162,954	218,367	374,694
IEA WEO 2007 (REF)	123,660	228,205	345,521	440,117
IEA WEO 2009 (REF)	158,864	292,754	417,198	595,365
IEA WEO 2010 (REF)	197,637	337,319	477,000	662,000
IEA WEO 2010 (450ppm)	197,637	394,819	592,000	1,148,000
IEA WEO 2011 (REF)	238,351	379,676	521,000	749,000
IEA WEO 2011 (450ppm)	238,351	449,676	661,000	1,349,000

4.11.2 the development of the global solar photovoltaic industry

Inspired by the successful work with the European Wind Energy Association (EWEA), Greenpeace began working with the European Photovoltaic Industry Association to publish "Solar Generation 10" – a global market projection for solar photovoltaic technology up to 2020 for the first time in 2001. Since then, six editions have been published and EPIA and Greenpeace have continuously improved the calculation methodology with experts from both organisations.

Figure 4.8 shows the actual projections for each year between 2001 and 2010 compared to the real market data, against the first two Energy [R]evolution editions (published in 2007 and 2008) and the IEA's solar projections published in World Energy Outlook (WEO) 2000, 2002, 2005 and 2007. The IEA did not make specific projections for solar photovoltaic in the first editions analysed in the research, instead the category "Solar/Tidal/Other" are presented in Figure 4.8 and 4.9.

figure 4.8: photovoltaics: short term prognosis vs real market development - global cummulative capacity

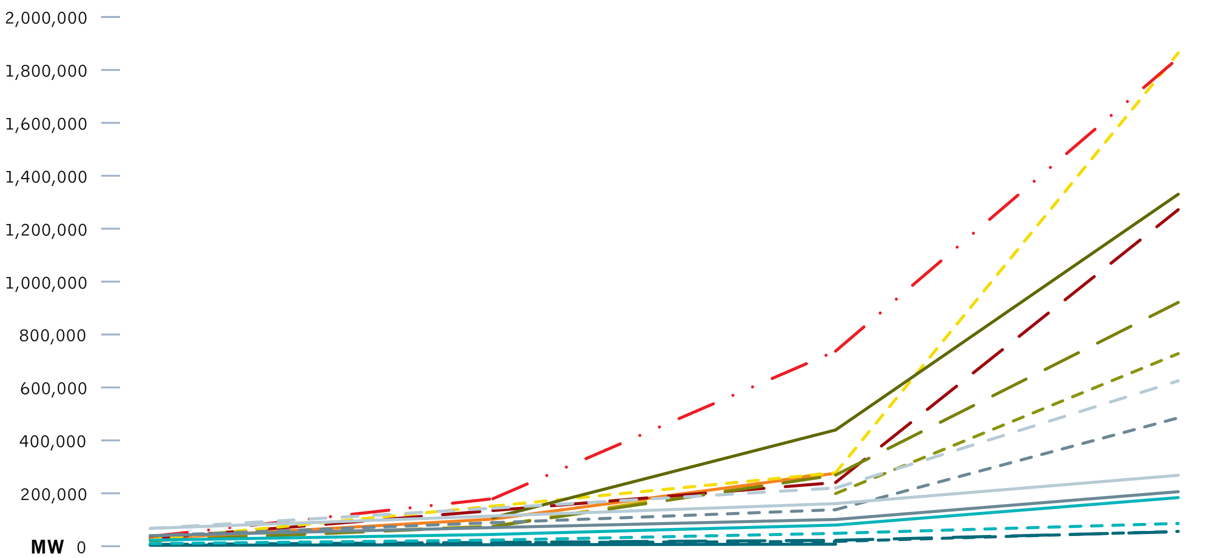


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
REAL	1,428	1,762	2,236	2,818	3,939	5,361	6,956	9,550	15,675	22,878	39,678
SG I 2001			2,205	2,742	3,546	4,879	6,549	8,498	11,285	17,825	25,688
SG II 2004						5,026	6,772	8,833	11,775	18,552	26,512
SG III 2006							7,372	9,698	13,005	20,305	28,428
SG IV 2007 (Advanced)								9,337	12,714	20,014	28,862
SG V 2008 (Advanced)									13,760	20,835	25,447
SG VI 2010 (Advanced)											36,629
ER 2007											22,694
ER 2008											20,606
ADVANCED ER 2010											
IEA WEO 2000 (REF)	1,428	1,625	1,822	2,020	2,217	2,414	2,611	2,808	3,006	4,516	3,400
IEA WEO 2002 (REF)			2,236	2,957	3,677	4,398	5,118	5,839	6,559	7,280	8,000
IEA WEO 2005 (REF)						5,361	5,574	5,787	6,000	6,213	6,425
IEA WEO 2007 (REF)								9550	9,575	9,600	9,625

In contrast to the wind projections, all the SolarGeneration projections have been too conservative. The total installed capacity in 2010 was close to 40,000 MW about 30% higher than projected in SolarGeneration published ten years earlier. Even SolarGeneration 5, published in 2008, under-estimated the possible market growth of photovoltaic in the advanced scenario. In contrast, the IEA WEO 2000 estimations for 2010 were reached in 2004.

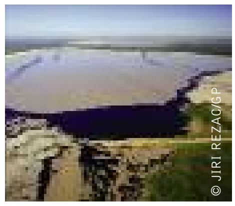
The long-term projections for solar photovoltaic are more difficult than for wind because the costs have dropped significantly faster than projected. For some OECD countries, solar has reached grid parity with fossil fuels in 2012 and other solar technologies, such as concentrated solar power plants (CSP), are also headed in that direction. Therefore, future projections for solar photovoltaic do not just depend on cost improvements, but also on available storage technologies. Grid integration can actually be a bottle-neck to solar that is now expected much earlier than estimated.

figure 4.9: photovoltaic: long term market projects until 2030



	2010	2015	2020	2030
SG I 2001	25,688		207,000	
SG II 2004	26,512	75,600	282,350	
SG III 2006	28,428	102,400	275,700	
SG IV 2007 (Advanced)	28,862	134,752	240,641	1,271,773
SG V 2008 (Advanced)	25,447	151,486	277,524	1,864,219
SG VI 2010 (Advanced)	36,629	179,442	737,173	1,844,937
ER 2007	22,694		198,897	727,816
ER 2008	20,606	74,325	268,789	921,332
ADVANCED ER 2010		107,640	439,269	1,330,243
IEA WEO 2000 (REF)	3,400	5,500	7,600	
IEA WEO 2002 (REF)	8,000	13,000	18,000	56,000
IEA WEO 2005 (REF)	6,425	14,356	22,286	54,625
IEA WEO 2007 (REF)	9,625	22,946	48,547	86,055
IEA WEO 2009 (REF)	22,878	44,452	79,878	183,723
IEA WEO 2010 (REF)	39,678	70,339	101,000	206,000
IEA WEO 2010 (450ppm)	39,678	88,839	138,000	485,000
IEA WEO 2011 (REF)	67,300	114,150	161,000	268,000
IEA WEO 2011 (450ppm)	67,300	143,650	220,000	625,000

image AERIAL VIEW OF SUNCOR MILLENNIUM TAR SANDS MINE, UPGRADER AND TAILINGS POND IN THE BOREAL FOREST NORTH OF FORT MCMURRAY.



4.12 how does the energy [r]evolution scenario compare to other scenarios?

The International Panel on Climate Change (IPCC) published a ground-breaking new "Special Report on Renewables" (SRREN) in May 2011. This report showed the latest and most comprehensive analysis of scientific reports on all renewable energy resources and global scientifically accepted energy scenarios. The Energy [R]evolution was among three scenarios chosen as an indicative scenario for an ambitious renewable energy pathway. The following summarises the IPCC's view.

Four future pathways, from the following models were assessed intensively:

- International Energy Agency World Energy Outlook 2009, (IEA WEO 2009)
- Greenpeace Energy [R]evolution 2010, (ER 2010)
- (ReMIND-RECIPE)
- (MiniCam EMF 22)

The World Energy Outlook of the International Energy Agency was used as an example baseline scenario (least amount of development of renewable energy) and the other three treated as "mitigation scenarios", to address climate change risks. The four scenarios provide substantial additional information on a number of technical details, represent a range of underlying assumptions and follow different methodologies. They provide different renewable energy deployment paths, including Greenpeace's "optimistic application path for renewable energy assuming that . . . the current high dynamic (increase rates) in the sector can be maintained".

The IPCC notes that scenario results are determined partly by assumptions, but also might depend on the underlying modelling architecture and model specific restrictions. The scenarios analysed use different modelling architectures, demand projections and technology portfolios for the supply side. The full results are provided in Table 4.15, but in summary:

- The IEA baseline has a high demand projection with low renewable energy development.
- ReMind-RECIPE, MiniCam EMF 22 scenarios portrays a high demand expectation and significant increase of renewable energy is combined with the possibility to employ CCS and nuclear.
- The ER 2010 relies on and low demand (due to a significant increase of energy efficiency) combined with high renewable energy deployment, no CCS employment and a global nuclear phase-out by 2045.

Both population increase and GDP development are major driving forces on future energy demand and therefore at least indirectly determining the resulting shares of renewable energy. The IPCC analysis shows which models use assumptions based on outside inputs and what results are generated from within the models. All scenarios take a 50% increase of the global population into account on baseline 2009. Regards gross domestic product (GDP), all assume or calculate a significant increase in terms of the GDP. The IEA WEO 2009 and the ER 2010 model uses forecasts of International Monetary Fund (IMF 2009) and the Organisation of Economic Co-Operation and Development (OECD) as inputs to project GSP. The other two scenarios calculate GDP from within their model.

table 4.15: overview of key parameter of the illustrative scenarios based on assumptions that are exogenous to the models respective endogenous model results

CATEGORY		STATUS QUO	BASELINE		CAT III+IV (>450-660PPM)		CAT I+II (<440 PPM)		CAT I+II (<440 PPM)	
SCENARIO NAME			IEA WEO 2009		ReMind		MiniCam		ER 2010	
MODEL					ReMind		EMF 22		MESAP/PlaNet	
	UNIT	2007	2030	2050(1)	2030	2050	2030	2050	2030	2050
Technology pathway										
Renewables			al	all	generec solar	generec solar	generec solar - no ocean energy	>no ocean energy	all	all
CCS			+	+	+	+	+	+	-	-
Nuclear			+	+	+	+	+	+	+	-
Population	billion	6.67	8.31	8.31	8.32	9.19	8.07	8.82	8.31	9.15
GDP/capita	$k\$_{2005}$/capita	10.9	17.4	17.4	12.4	18.2	9.7	13.9	17.4	24.3
Input/Indogenous model results										
Energy demand (direct equivalent)	EJ/yr	469	674	674	590	674	608	690	501	466
Energy intensity	$MJ/\$_{2005}$	6.5	4.5	4.5	5.7	4.0	7.8	5.6	3.3	1.8
Renewable energy	%	13	14	14	32	48	24	31	39	77
Fossil & industrial CO_2 emissions	Gt CO_2/y	27.4	38.5	38.5	26.6	15.8	29.9	12.4	18.4	3.3
Carbon intensity	kg CO_2/GJ	58.4	57.1	57.1	45.0	23.5	49.2	18.0	36.7	7.1

source
DLR/IEA 2010: IEA World Energy Outlook 2009 does not cover the years 2031 till 2050. As the IEA's projection only covers a time horizon up to 2030 for this scenario exercise, an extrapolation of the scenario has been used which was provided by the German Aerospace Agency (DLR) by extrapolating the key macroeconomic and energy indicators of the WEO 2009 forward to 2050 (Publication filed in June 2010 to Energy Policy).

key results of the energy [r]evolution scenario

GLOBAL SCENARIO

image SPRAWLING OVER PARTS OF SAUDI ARABIA, YEMEN, OMAN, AND THE UNITED ARAB EMIRATES, THE EMPTY QUARTER—OR RUB' AL KHALI—IS THE WORLD'S LARGEST SAND SEA. ROUGHLY THE SIZE OF FRANCE, THE EMPTY QUARTER HOLDS ABOUT HALF AS MUCH SAND AS THE ENTIRE SAHARA DESERT. MUCH OF THE LAND IN THIS REGION ACTUALLY LIES AT AN ELEVATION BELOW SEA LEVEL, BUT NEAR THE YEMEN BORDER, DUNES CAN REACH AN ALTITUDE OF 1,200 METERS ABOVE SEA LEVEL.

image FOREST CREEK WIND FARM PRODUCING 2.3 MW WITH WIND TURBINES MADE BY SIEMENS. A WORKER WORKING ON TOP OF THE WIND TURBINE.

The development of future global energy demand is determined by three key factors:

- Population development: the number of people consuming energy or using energy services.
- Economic development, for which Gross Domestic Product (GDP) is the most commonly used indicator: in general an increase in GDP triggers an increase in energy demand.
- Energy intensity: how much energy is required to produce a unit of GDP.

The Reference scenario and the Energy [R]evolution scenario are based on the same projections of population and economic development. The future development of energy intensity, however, differs between the reference and the alternative case, taking into account the measures to increase energy efficiency under the Energy [R]evolution scenario.

global: projection of energy intensity

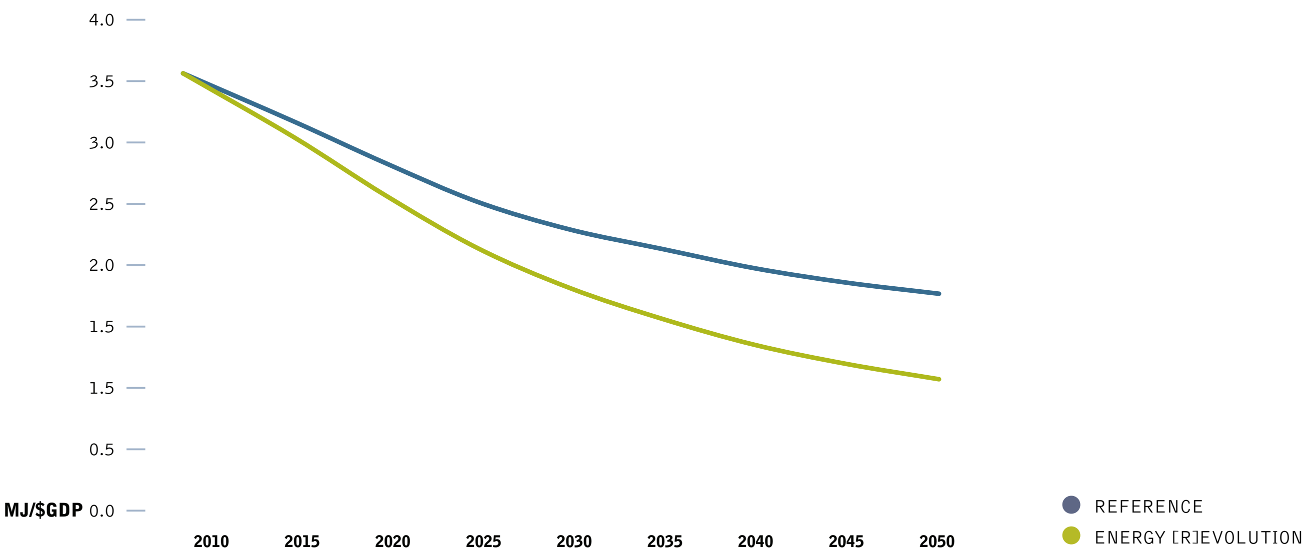
An increase in economic activity and a growing population does not necessarily have to result in an equivalent increase in energy demand. There is still a large potential for exploiting energy efficiency measures. Under the Reference scenario we assume that energy intensity will be reduced by 1.7% on average per year, leading to a reduction in final energy demand per unit of GDP of about 50% between 2009 and 2050. Under the Energy [R]evolution scenario it is assumed that active policy and technical support for energy efficiency measures will lead to an even higher reduction in energy intensity of almost 70% until 2050.

global: development of global energy demand

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for the world's energy demand. These are shown in Figure 5.2 for the Reference and the Energy [R]evolution scenario. Under the Reference scenario, total primary energy demand increases by 61% from 499,024 PJ/a in 2009 to about 805,600 PJ/a in 2050. In the Energy [R]evolution scenario, demand increases by 10% until 2020 and decreases by 4% afterwards and it is expected by 2050 to reach 481,050 PJ/a.

The accelerated increase in energy efficiency, which is a crucial prerequisite for achieving a sufficiently large share of renewable energy sources in our energy supply, is beneficial not only for the environment but also for economics. Taking into account the full lifecycle costs, in most cases the implementation of energy efficiency measures saves money compared to creating an additional energy supply. A dedicated energy efficiency strategy therefore helps to compensate in part for the additional costs required during the market introduction phase of renewable energy technologies.

figure 5.1: global: final energy intensity under the reference scenario and the energy [r]evolution scenario



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OECD ASIA OCEANIA

global: energy demand by sector

Under the Energy [R]evolution scenario, electricity demand is expected to increase disproportionately, with households and services the main source of growing consumption (see Figure 5.3). With the exploitation of efficiency measures, however, an even higher increase can be avoided, leading to electricity demand of around 40,900 TWh/a in 2050. Compared to the Reference scenario, efficiency measures avoid the generation of about 12,800 TWh/a.

This reduction in energy demand can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors. Deployment of solar architecture in both residential and commercial buildings will help to curb the growing demand for active air conditioning.

Efficiency gains in the heat supply sector are even larger than in the electricity sector. Under the Energy [R]evolution scenario, final demand for heat supply can eventually be reduced significantly (see Figure 5.5). Compared to the Reference scenario, consumption equivalent to 46,500 PJ/a is avoided through efficiency measures by 2050. As a result of energy related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards, 'passive houses' or even 'energyplus-houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

figure 5.2: global: total final energy demand by sector under the reference scenario and the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

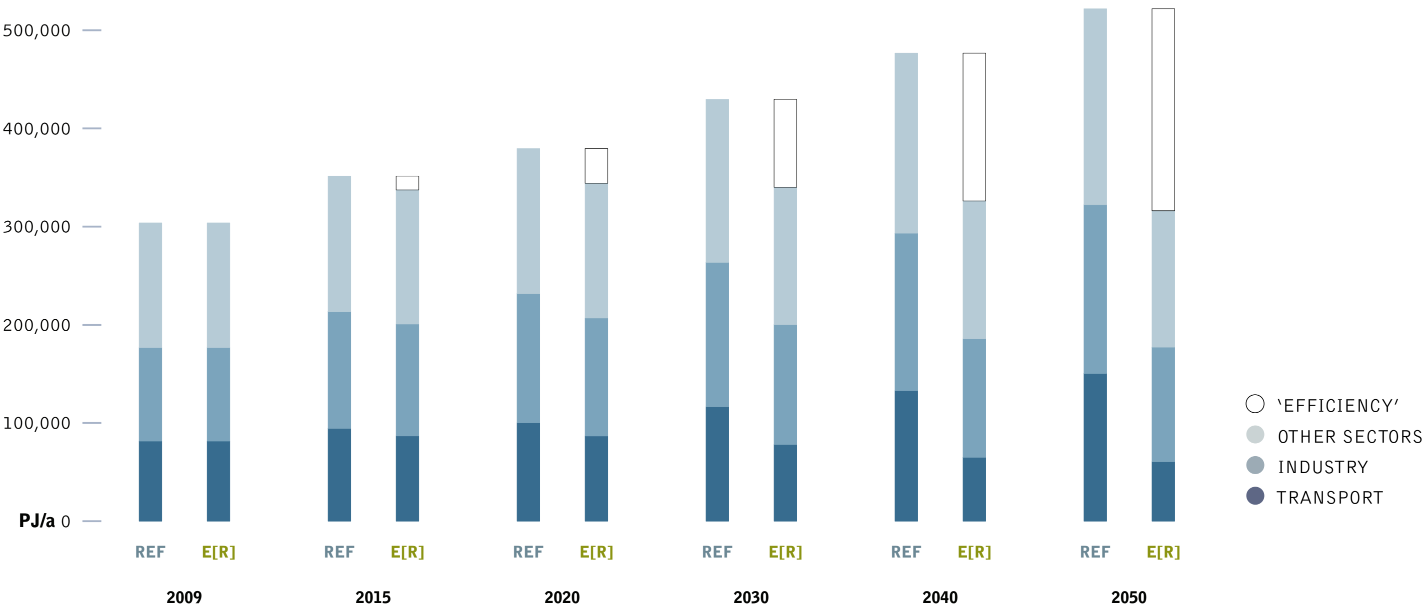


image THE PS20 SOLAR TOWER PLANT SITS AT SANLUCAR LA MAYOR OUTSIDE SEVILLE, SPAIN. THE FIRST COMMERCIAL SOLAR TOWER PLANT IN THE WORLD IS OWNED BY THE SPANISH COMPANY SOLUCAR (ABENGOA) AND CAN PROVIDE ELECTRICITY FOR UP TO 6,000 HOMES. SOLUCAR (ABENGOA) PLANS TO BUILD A TOTAL OF 9 SOLAR TOWERS OVER THE NEXT 7 YEARS TO PROVIDE ELECTRICITY FOR AN ESTIMATED 180,000 HOMES.

image MAINTENANCE WORKERS FIX THE BLADES OF A WINDMILL AT GUAZHOU WIND FARM NEAR YUMEN IN GANSU PROVINCE, CHINA.

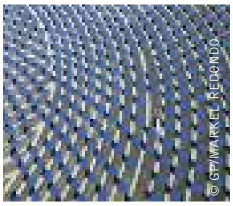


figure 5.3: global: development of electricity demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

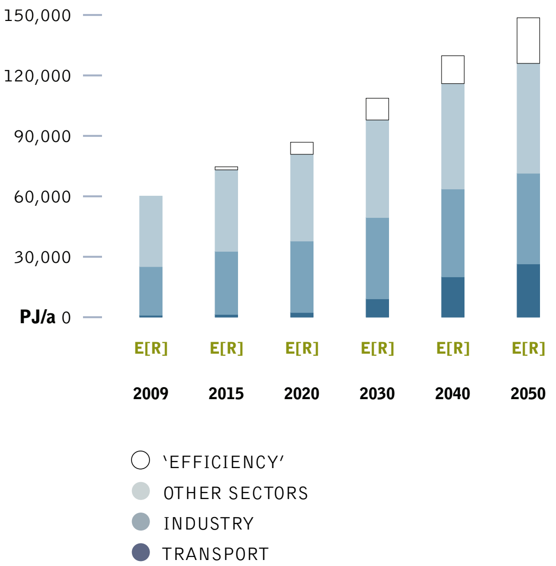


figure 5.5: global: development of heat demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

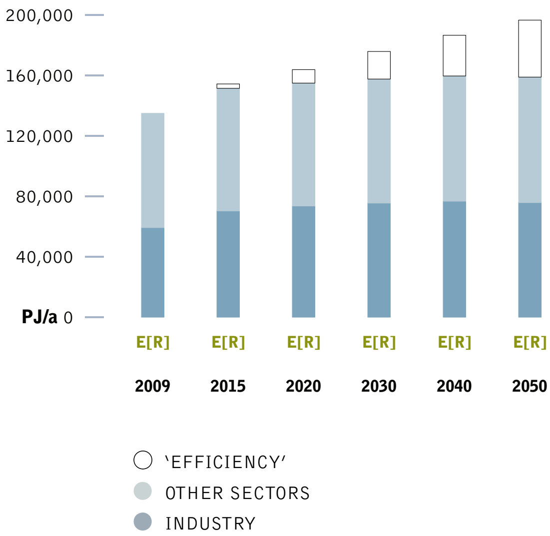
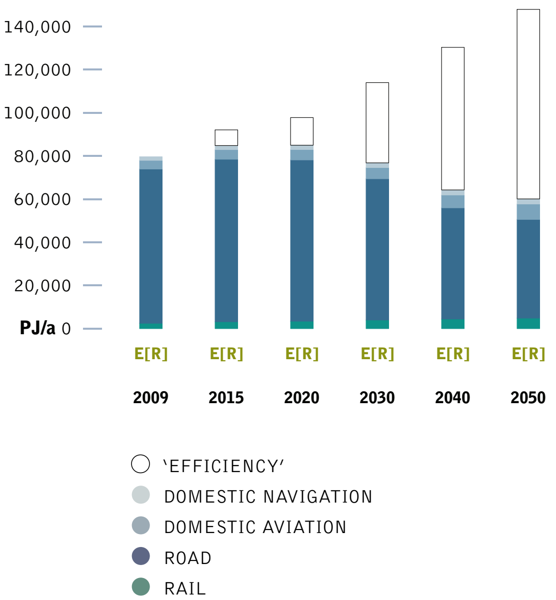


figure 5.4: global: development of the transport demand by sector in the energy [r]evolution scenario



The energy demand in the industry sector will grow in both scenarios. While the economic growth rates in the Reference and the Energy [R]evolution scenario are identical, the growth of the overall energy demand is different due to a faster increase of the energy intensity in the alternative case. Decoupling economic growth with the energy demand is key to reach a sustainable energy supply. By 2050, the Energy [R]evolution scenario requires 40% less than the Reference scenario.

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global: electricity generation

The development of the electricity supply market is charaterised by a dynamically growing renewable energy market. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 94% of the electricity produced worldwide will come from renewable energy sources. 'New' renewables – mainly wind, PV and geothermal energy – will contribute 60% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 37% already by 2020 and 61% by 2030. The installed capacity of renewables will reach 7,400 GW in 2030 and 15,100 GW by 2050.

Table 5.1 shows the global development of the different renewable technologies over time. Up to 2020 hydro and wind will remain the main contributors of the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from photovoltaics solar thermal (CSP), ocean energy and bioenergy. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 31% by 2030, therefore the expansion of smart grids, demand side management (DSM) and storage capacity will be required. The further expansion of conventional power plants - especially coal in China and India needs to slow down immediately and peak no later than 2025 in order to avoid long term lock-in effects in coal the the related long term CO_2 emissions in the power sector.

table 5.1: global: renewable electricity generation capacity under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Hydro	REF	995	1,250	1,425	1,564	1,695
	E[R]	995	1,246	1,347	1,428	1,484
Biomass	REF	51	98	155	215	272
	E[R]	51	162	265	390	490
Wind	REF	147	525	754	959	1,135
	E[R]	147	1,357	2,908	4,287	5,236
Geothermal	REF	11	18	27	37	47
	E[R]	11	65	219	446	666
PV	REF	19	124	234	351	471
	E[R]	19	674	1,764	3,335	4,548
CSP	REF	0	11	24	40	62
	E[R]	0	166	714	1,362	2,054
Ocean energy	REF	0	1	4	13	18
	E[R]	0	54	176	345	610
Total	**REF**	**1,224**	**2,028**	**2,622**	**3,179**	**3,699**
	E[R]	**1,224**	**3,724**	**7,392**	**11,594**	**15,088**

figure 5.6: global: electricity generation structure under the reference scenario and the energy [r]evolution scenario (INCLUDING ELECTRICITY FOR ELECTROMOBILITY, HEAT PUMPS AND HYDROGEN GENERATION)

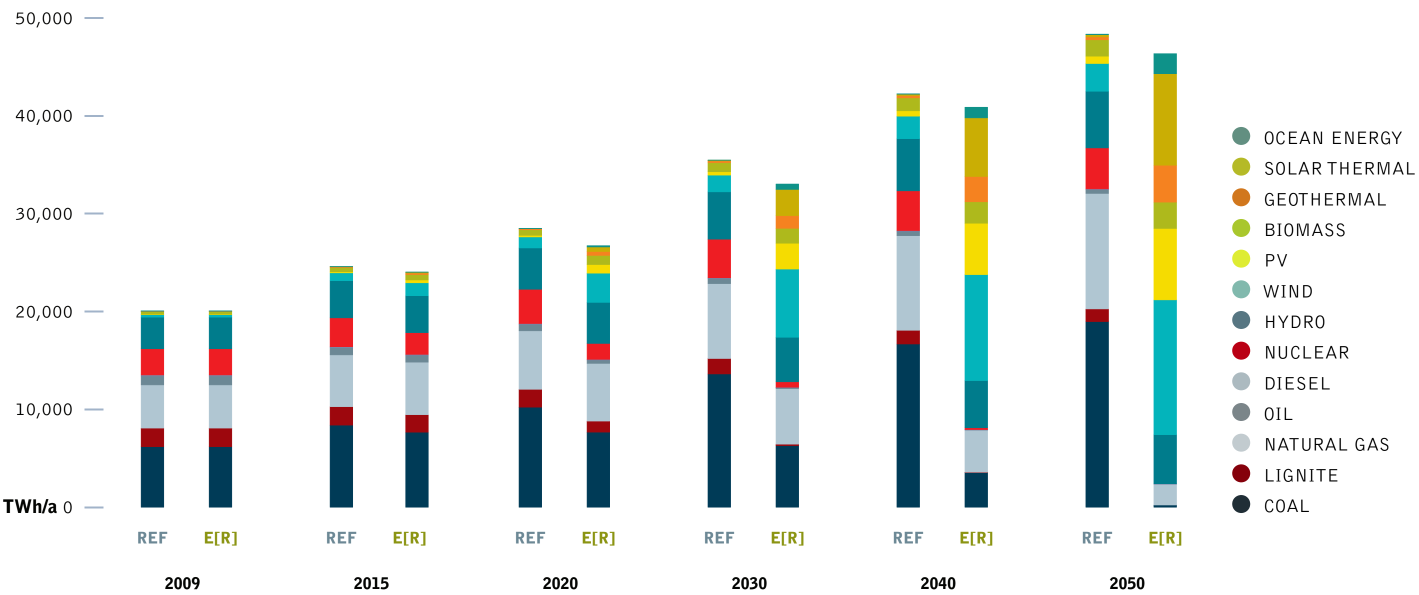


image 23 YEAR OLD PARMARAM WORKS ON THE REVERSE OSMOSIS PLANT, AT THE MANTHAN CAMPUS IN KOTRI RAJASTHAN, INDIA. PARMARAM IS A DALIT AND HE GOT HIS PRIMARY EDUCATION AT THE NIGHT SCHOOL. AFTER SCHOOL, HE UNDERTOOK TRAINING IN CARPENTRY, FOLLOWED BY TRAINING IN WATER TESTING AND AS A BAREFOOT SOLAR ENGINEER. HE ASSEMBLES, INSTALLS AND REPAIRS SOLAR LANTERNS AND FIXED SOLAR UNITS FOR VILLAGERS WHO NEED THEM. HE HAS ALSO BEEN OPERATING THE SOLAR-POWERED REVERE OSMOSIS PLANT AT MANTHAN CAMPUS.

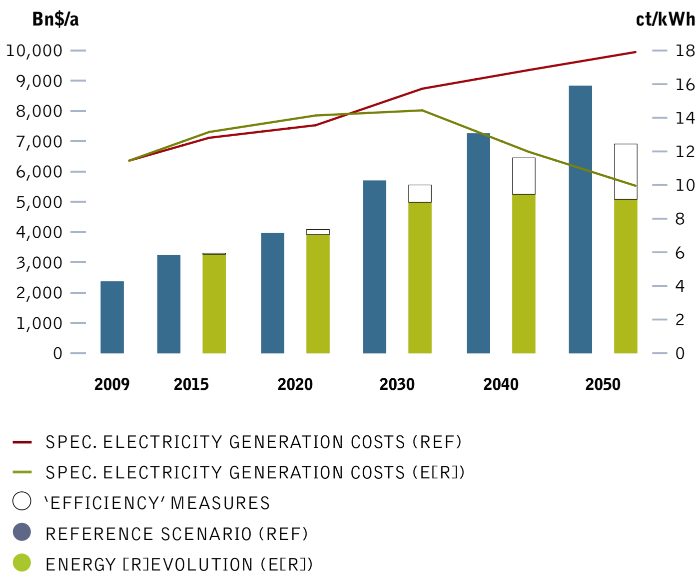
image WORKERS AT DAFENG POWER STATION, CHINA'S LARGEST SOLAR PHOTOVOLTAIC-WIND HYBRID POWER STATION, WITH 220MW OF GRID-CONNECTED CAPACITY, OF WHICH 20 MW IS SOLAR PV. LOCATED IN YANCHENG, JIANGSU PROVINCE, IT CAME INTO OPERATION ON DECEMBER 31, 2010 AND HAS 1,100 ANNUAL UTILIZATION HOURS. EVERY YEAR IT CAN GENERATE 23 MILLION KW-H OF ELECTRICITY, ALLOWING IT TO SAVE 7,000 TONS OF COAL AND 18,600 TONS OF CARBON DIOXIDE EMISSIONS.

global: future costs of electricity generation

Figure 5.7 shows that the introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the costs of electricity generation compared to the Reference scenario. This difference will be less than $ 0.6 cent/kWh up to 2020. Any increase in fossil fuel prices beyond the projection given in table 4.3, however, will reduce the gap. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be $ 7.9 cents/kWh below those in the Reference version.

Under the Reference scenario, the unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $ 2,364 billion per year to about $ 8,830 billion in 2050. Figure 5.7 shows that the Energy [R]evolution scenario not only complies with CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to enewables lead to long term costs for electricity supply that are 22% lower in 2050 than in the Reference scenario (including estimated costs for efficiency measures up to $ 4 ct/kWh).

figure 5.7: global: total electricity supply costs and specific electricity generation costs under two scenarios



global: future investments in the power sector

The overall global level of investment required in new power plants up to 2030 will be in the region of $ 11.5 trillion in the Reference case and $ 20.1 trillion in the Energy [R]evolution. A major driving force for investment in new generation capacity will be the replacement of the ageing fleet of power plants in OECD countries and the build up of new power plants in developing countries. Utilities and new players such as project developers and independent power producers base their technology choices on current and future equipment costs and national energy policies, in particular market liberalisation, renewable energy and CO_2 reduction targets. Within Europe, the EU emissions trading scheme could have a major impact on whether the majority of investment goes into fossil fueled power plants or renewable energy and co-generation. In developing countries, international financial institutions will play a major role in future technology choices, as well as whether the investment costs for renewable energy become competitive with conventional power plants.

In regions with a good wind regime, for example, wind farms can already produce electricity at the same cost levels as coal or gas power plants. While solar photovoltaics already reach 'grid parity' in many industrialized countries. It would require about $ 50,400 billion in investment in the power sector for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately $ 714 billion annual more than in the Reference scenario.

Under the Reference version, the levels of investment in conventional power plants add up to almost 49% while approximately 51% would be invested in renewable energy and cogeneration (CHP) until 2050. Under the Energy [R]evolution scenario the global investment would shift by 95% towards renewables and cogeneration. Until 2030, the fossil fuel share of power sector investment would be focused mainly on CHP plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be $ 1,260 billion.

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INDIA

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OECD ASIA OCEANIA

figure 5.8: global: investment shares - reference scenario versus energy [r]evolution scenario

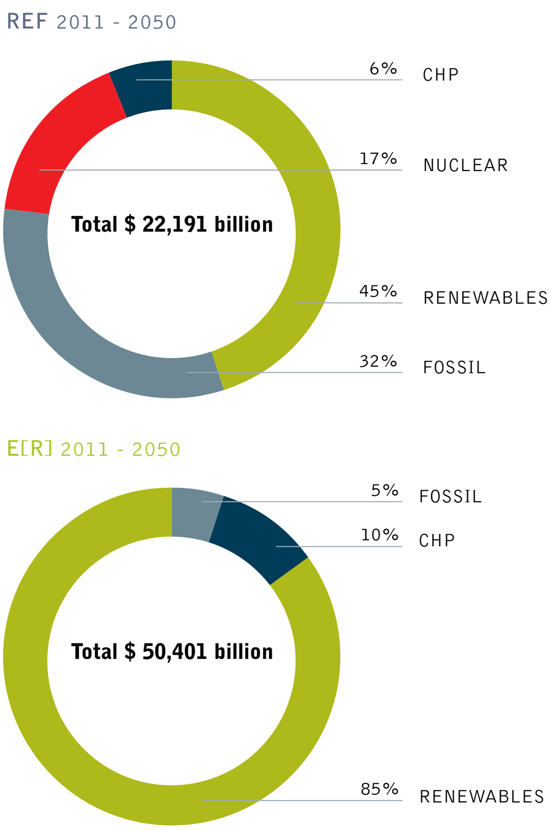
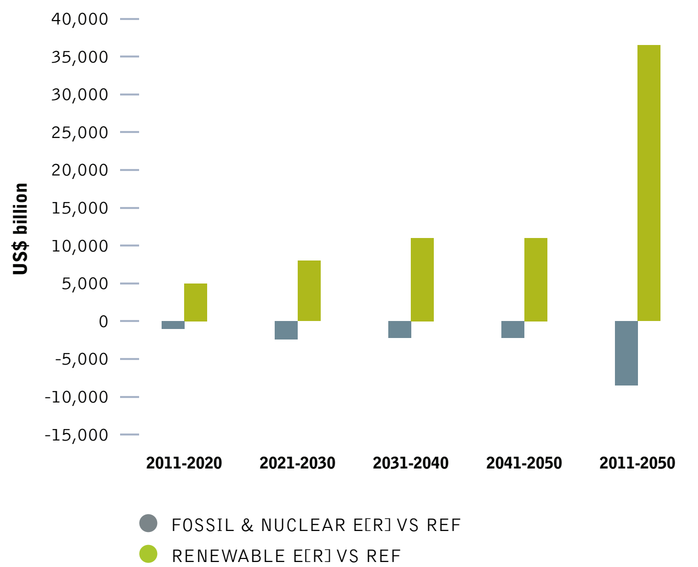


figure 5.9: global: change in cumulative power plant investment



Because renewable energy except biomasss has no fuel costs, however, the fuel cost savings in the Energy [R]evolution scenario reach a total of about $ 52,800 billion up to 2050, or $ 1,320 billion per year. The total fuel cost savings therefore would cover two times the total additional investments compared to the Reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.

table 5.2: global: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

INVESTMENT COSTS	$	2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion $	-1,780	-2,310	-2,108	-2,108	-8,508	-213
Renewables	billion $	4,596	8,087	10,896	10,896	36,720	918
Total	billion $	2,816	5,777	8,788	8,788	28,213	705
CUMULATIVE FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion $/a	304	1,088	1,252	1,107	3,750	94
Gas	billion $/a	-209.1	1,837	7,731	16,886	26,244	656
Hard coal	billion $/a	625	3,152	7,155	11,140	22,072	552
Lignite	billion $/a	42	185	245	259	731	18
Total	billion $/a	762	6,262	16,382	29,390	52,797	1,320

image A RICE FIELD DESTROYED BY SALT WATER FROM HUGE TIDAL SURGES DURING THE CYCLONE ALIA IN BALI ISLAND IN THE SUNDARBANS.

image PORTLAND, IN THE STATE OF VICTORIA, WAS THE FIRST AUSTRALIAN COUNCIL TO RECEIVE A DEVELOPMENT APPLICATION FOR WIND TURBINES AND NOW HAS ENOUGH IN THE SHIRE TO PROVIDE ENERGY FOR SEVERAL LOCAL TOWNS COMBINED.

global: heating supply

Renewables currently provide 25% of the global energy demand for heat supply, the main contribution coming from the use of biomass. In the Energy [R]evolution scenario, renewables provide 51% of global total heat demand in 2030 and 91% in 2050. The lack of district heating networks is a severe structural barrier to the large scale utilisation of geothermal and solar thermal energy as well as the lack of specific renewable heating policy. Past experience shows that it is easier to implement effective support instruments in the grid-connected electricity sector than in the heat market, with its multitude of different actors. Dedicated support instruments are required to ensure a dynamic development.

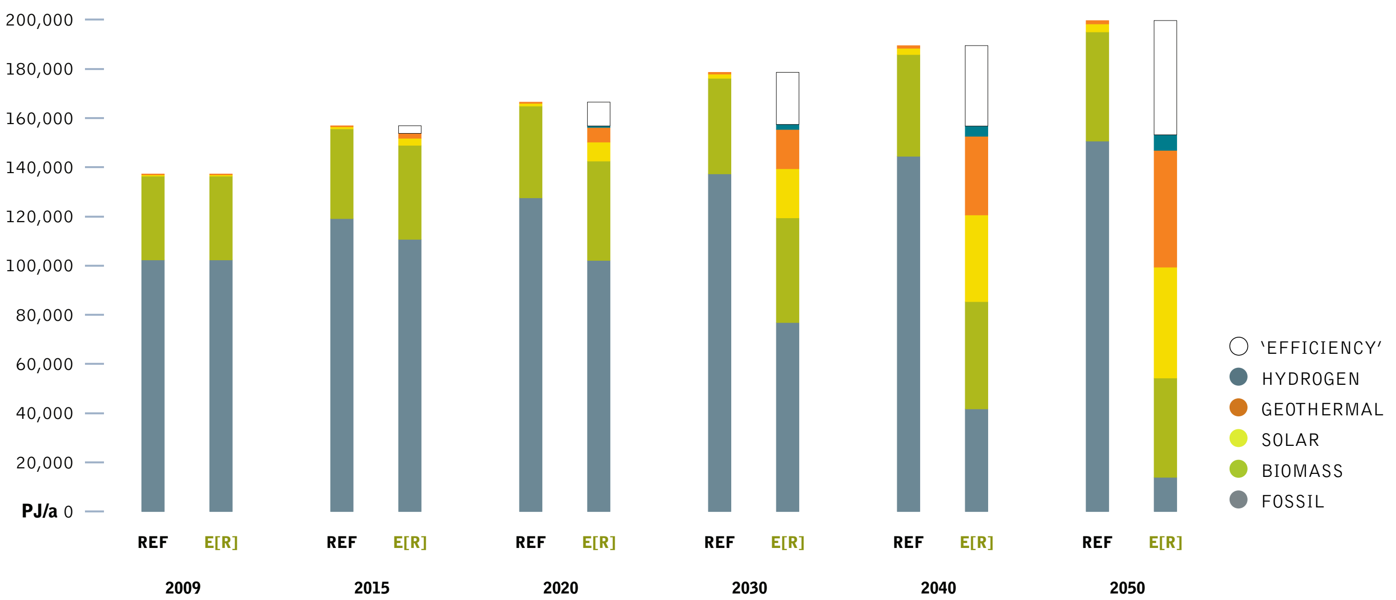
- Energy efficiency measures can decrease the demand for heat supply by 23 % compared to the Reference scenario, in spite of a growing global population, increasing economic activities and improving living standards.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for fossil fuel-fired systems.
- The introduction of strict efficiency measures e.g. via strict building standards and ambitious support programs for renewable heating systems are needed to achieve economies of scale within the next 5 to 10 years.

Table 5.3 shows the worldwide development of the different renewable technologies for heating over time. Up to 2020 biomass will remain the main contributor of the growing market share. After 2020, the continuing growth of solar collectors and a growing share of geothermal energy and heat pumps will reduce the dependence on fossil fuels.

table 5.3: global: renewable heating capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	34,085	37,311	38,856	41,356	44,380
	E[R]	34,085	40,397	42,573	43,605	40,368
Solar collectors	REF	546	1,100	1,743	2,543	3,255
	E[R]	546	7,724	20,004	35,236	45,092
Geothermal	REF	342	525	725	1,110	1,400
	E[R]	342	5,942	15,938	32,023	47,488
Hydrogen	REF	0	0	0	0	0
	E[R]	0	604	2,054	4,145	6,343
Total	**REF**	**34,972**	**38,935**	**41,325**	**45,009**	**49,035**
	E[R]	**34,972**	**54,667**	**80,568**	**115,009**	**139,292**

figure 5.10: global: heat supply structure under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)



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global: future investments in the heat sector

Also in the heat sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially the not yet so common solar and geothermal and heat pump technologies need an enormous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity needs to increase by the factor of 60 for solar thermal and even by the factor of 3,000 for geothermal and heat pumps. Capacity of biomass technologies, which are already rather wide spread still need to remain a main pillar of heat supply, however current combustion systems mostly need to be replaced by new efficient technologies.

Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar themal district heating plants with seasonal storage.Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around $ 27,000 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately $ 670 billion per year.

table 5.4: global: renewable heat generation capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	11,753	12,115	12,242	12,548	13,097
	E[R]	11,753	12,092	11,394	10,387	8,639
Geothermal	REF	1	3	12	39	52
	E[R]	1	448	1,086	2,152	3,099
Solar thermal	REF	175	343	533	766	965
	E[R]	175	2,027	5,148	9,089	11,266
Heat pumps	REF	59	87	116	168	207
	E[R]	59	538	1,392	2,372	3,399
Total	**REF**	**11,988**	**12,548**	**12,902**	**13,521**	**14,321**
	E[R]	**11,988**	**15,105**	**19,019**	**24,000**	**26,402**

figure 5.11: global: investments for renewable heat generation technologies under the reference scenario and the energy [r]evolution scenario

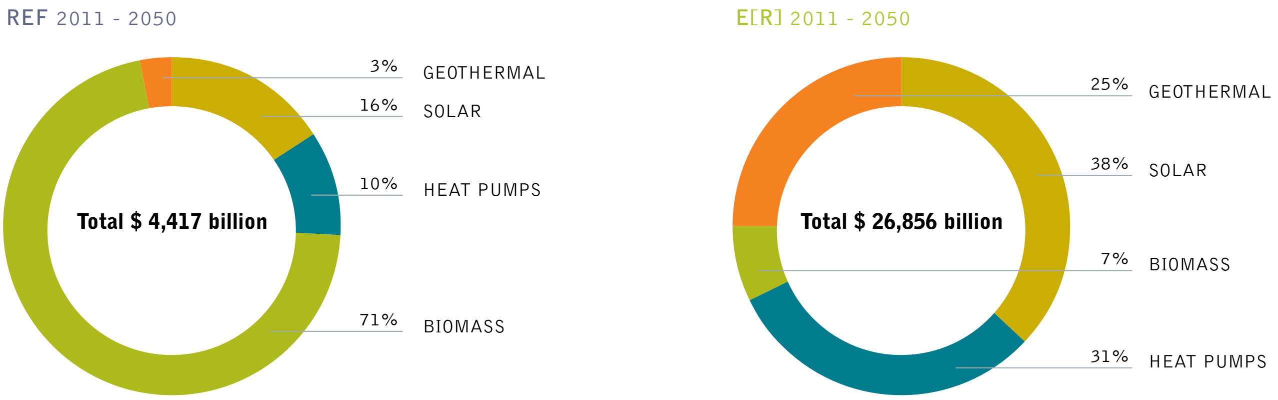
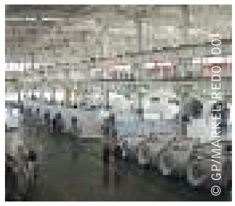


image SOLNOVA 1, 3, AND 4, COMPLETED IN 2010 IN SANLÚCAR LA MAYOR, SPAIN. THE SOLNOVA PARABOLIC TROUGH POWER PLANT STATIONS, OWNED BY ABENGOA SOLAR CAN GENERATE 50 MWS OF POWER EACH.

image WORKERS AT GANSU JINFENG WIND POWER EQUIPMENT CO. LTD. IN JIUQUAN, GANSU PROVINCE, CHINA.



global: future employment in the energy sector

The Energy [R]evolution scenario results in more energy sector jobs globally at every stage of the projection.

- There are 23.3 million energy sector jobs in the Energy [R]evolution scenario in 2015, and 18.7 million in the Reference scenario.
- In 2020, there are 22.6 million jobs in the Energy [R]evolution scenario, and 17.7 million in the Reference scenario.
- In 2030, there are 18.2 million jobs in the Energy [R]evolution scenario and 15.6 million in the Reference scenario.

Figure 5.12a shows the change in job numbers under all scenarios for each technology between 2010 and 2030.

Jobs in the coal sector decline steeply in both the Reference scenario and the Energy [R]evolution scenario, as a result of productivity improvements in the industy, coupled with a move away from coal in the Energy [R]evolution scenario.

The reduction in coal jobs leads to a signficant decline in overall energy jobs in the Reference scenario, with jobs falling by 21% by 2015. Jobs continue to fall in this scenario between 2020 and 2030, mainly driven by losses in the coal sector. At 2030, jobs are 30% (3.1 million) below 2010 levels.

In the Energy [R]evolution scenario, strong growth in the renewable sector leads to an increase of 4% in total energy sector jobs by 2015. Job numbers fall after 2020 because as renewable technologies mature costs fall and they become less labour intensive. Jobs in the Energy [R]evolution are 19% below 2010 levels at 2030. However, this is 2.5 million more jobs than in the Reference scenario.

figure 5.12a: global: employment in the energy scenario under the reference and energy [r]evolution scenarios

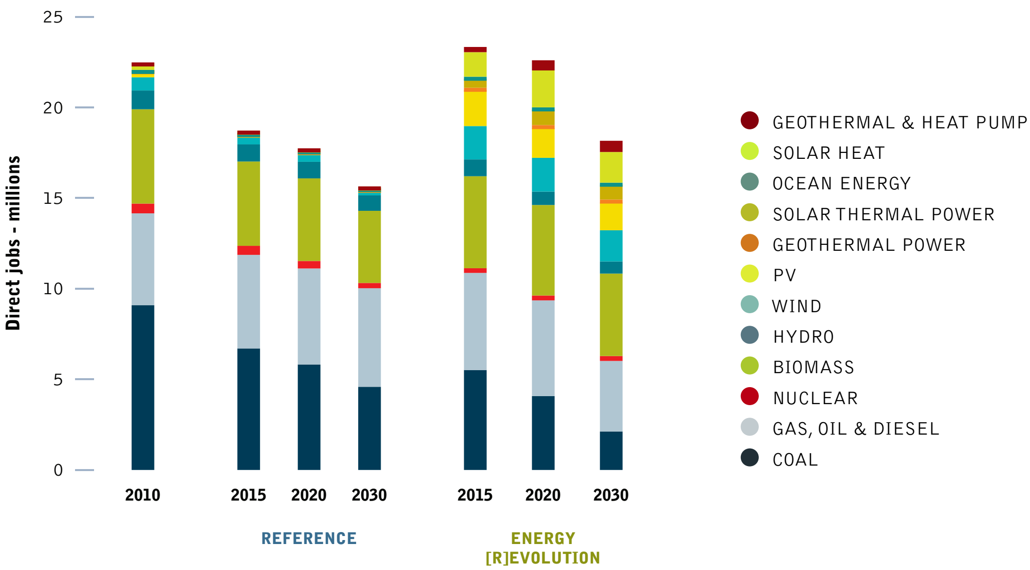


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table 5.5: global: total employment in the energy sector MILLION JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	9.1	6.7	5.8	4.6	5.5	4.1	2.1
Gas, oil & diesel	5.1	5.2	5.3	5.4	5.4	5.3	3.9
Nuclear	0.54	0.50	0.41	0.29	0.26	0.27	0.27
Renewable	7.8	6.4	6.2	5.3	12.2	13.0	11.9
Total Jobs	**22.5**	**18.7**	**17.7**	**15.6**	**23.3**	**22.6**	**18.2**
Construction and installation	3.3	1.9	1.7	1.2	4.5	4.7	4.0
Manufacturing	1.7	0.9	0.8	0.6	2.7	2.7	2.2
Operations and maintenance	1.7	1.8	2.0	1.9	1.9	2.3	2.6
Fuel supply (domestic)	14.7	12.7	11.9	10.7	12.9	11.7	8.8
Coal and gas export	1.1	1.3	1.5	1.2	1.3	1.2	0.6
Total Jobs	**22.5**	**18.7**	**17.7**	**15.6**	**23.3**	**22.6**	**18.2**
Coal	9.1	6.7	5.8	4.6	5.5	4.1	2.1
Gas, oil & diesel	5.1	5.2	5.3	5.4	5.4	5.3	3.9
Nuclear	0.5	0.5	0.4	0.3	0.3	0.3	0.3
Biomass	5.2	4.7	4.6	4.0	5.1	5.0	4.5
Hydro	1.0	0.9	0.9	0.9	0.9	0.7	0.7
Wind	0.7	0.4	0.4	0.2	1.8	1.9	1.7
PV	0.4	0.2	0.2	0.1	2.0	1.6	1.5
Geothermal power	0.02	0.02	0.01	0.01	0.12	0.17	0.16
Solar thermal power	0.01	0.02	0.03	0.03	0.5	0.85	0.83
Ocean	0.001	0.001	0.002	0.01	0.11	0.12	0.10
Solar - heat	0.38	0.12	0.09	0.08	1.4	2.0	1.7
Geothermal & heat pump	0.03	0.01	0.01	0.01	0.29	0.56	0.62
Total Jobs	**22.5**	**18.7**	**17.7**	**15.6**	**23.3**	**22.6**	**18.2**

figure 5.12b: global: proportion of fossil fuel and renewable employment at 2010 and 2030

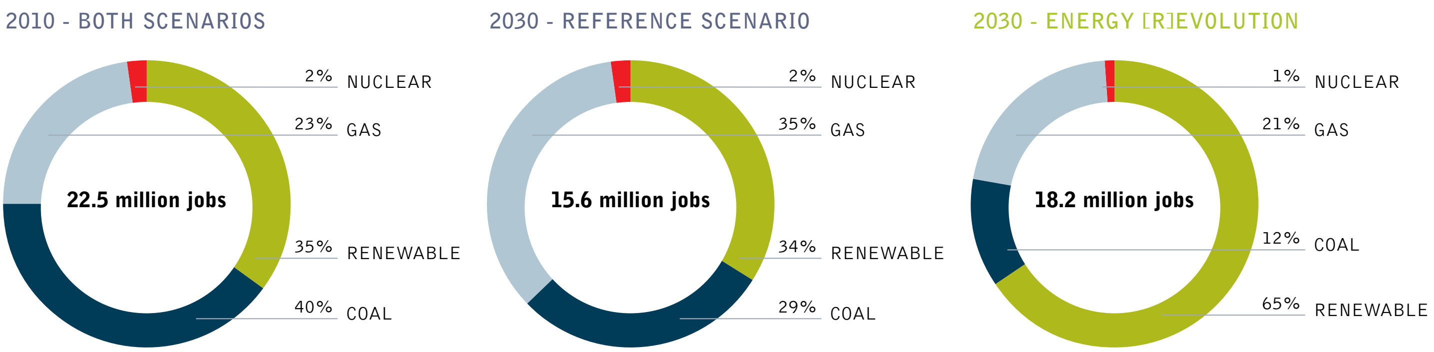
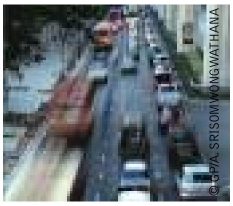


image TRAFFIC JAM IN BANGKOK, THAILAND.

image 100 KW PV GENERATING PLANT NEAR BELLINZONA-LOCARNO RAILWAY LINE. GORDOLA, SWITZERLAND.



global: transport

In the transport sector it is assumed that, due to fast growing demand for services, energy consumption will continue to increase under the Energy [R]evolution scenario up to 2020. After that it will decrease, falling below the level of the current demand by 2050. Compared to the Reference scenario, transport energy demand is reduced overall by 60% or about 90,000 PJ/a by 2050. Energy demand for transport under the Energy [R]evolution scenario will therefore increase between 2009 and 2050 by 26% to about 60,000 PJ/a.

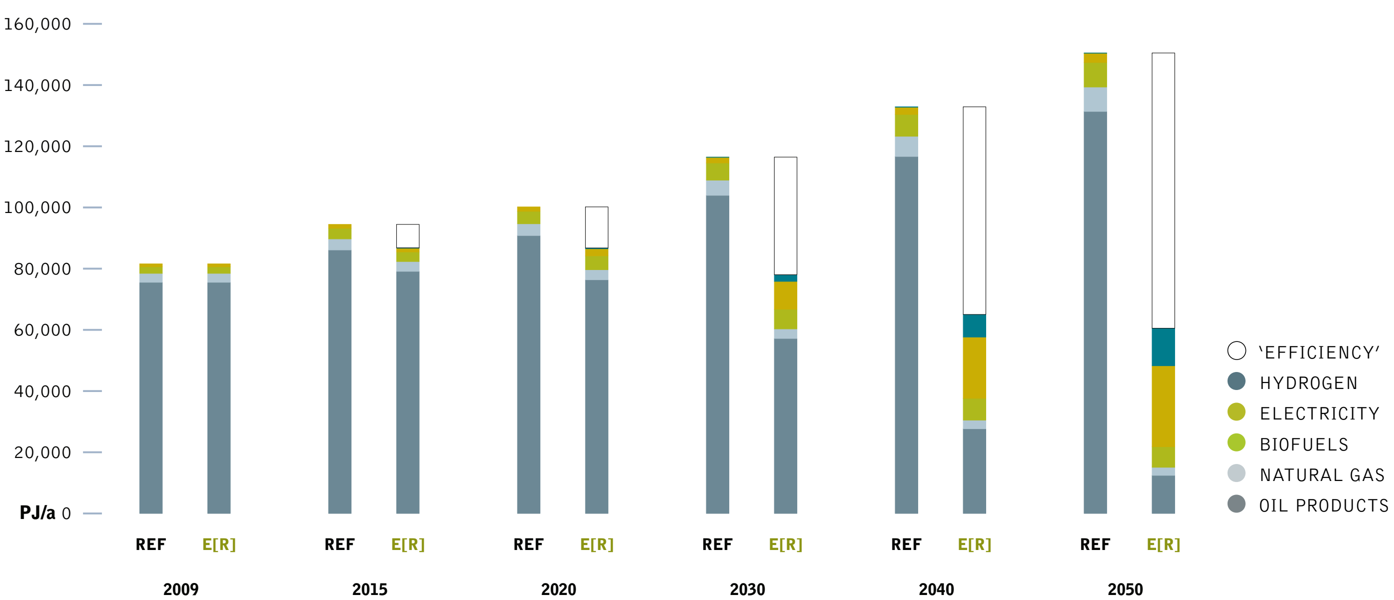
Significant savings are made by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns. Implementing a mix of increased public transport as attractive alternatives to individual cars, the car stock is growing slower and annual person kilometres are lower than in the Reference scenario. A shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains and a reduction of vehicle kilometres travelled per year lead to significant energy savings. In 2030, electricity will provide 12% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 44%.

table 5.6: global: transport energy demand by mode under the reference scenario and the energy [r]evolution scenario

(WITHOUT ENERGY FOR PIPELINE TRANSPORT) IN PJ/A

		2009	2020	2030	2040	2050
Rail	REF	2,483	3,199	3,641	4,181	4,671
	E[R]	2,483	3,435	3,987	4,438	4,849
Road	REF	71,229	86,995	101,380	115,163	129,096
	E[R]	71,229	74,491	65,222	51,348	45,586
Domestic aviation	REF	3,994	5,195	6,142	7,715	10,289
	E[R]	3,994	4,775	5,159	5,941	7,115
Domestic navigation	REF	1,685	2,089	2,454	2,853	3,394
	E[R]	1,685	2,016	2,200	2,337	2,364
Total	**REF**	**79,391**	**97,479**	**113,617**	**129,912**	**147,450**
	E[R]	**79,391**	**84,718**	**76,568**	**64,063**	**59,914**

figure 5.13: global: final energy consumption for transport under the reference scenario and the energy [r]evolution scenario



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global: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 5.14. Compared to the Reference scenario, overall primary energy demand will be reduced by 40% in 2050.

The Energy [R]evolution scenario would even achieve a renewable energy share of 41% by 2030 and 82% by 2050. In this projection almost the entire global electricity supply, including the majority of the energy used in buildings and industry, would come from renewable energy sources. The transport sector, in particular aviation and shipping, would be the last sector to become fossil fuel free.

figure 5.14: global: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

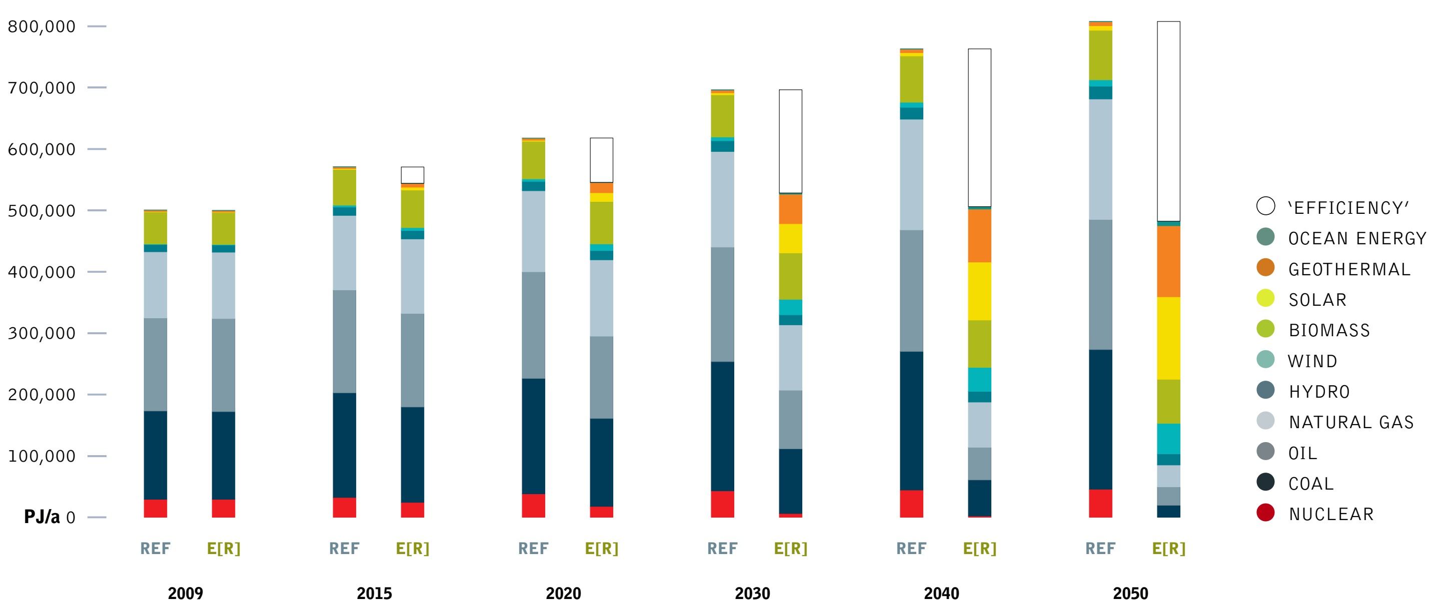


image COWS FROM A FARM WITH A BIOGAS PLANT IN ITTIGEN BERN, SWITZERLAND. THE FARMER PETER WYSS PRODUCES ON HIS FARM WITH A BIOGAS PLANT, GREEN ELECTRICITY WITH DUNG FROM COWS, LIQUID MANURE AND WASTE FROM FOOD PRODUCTION.

image SMOKE BILLOWING FROM THE CHIMNEY AT THE MARSHALL STEAM STATION IN CATAWBA COUNTY, NORTH CAROLINA. THIS COAL-FIRED POWER STATION HAS A 2,090-MEGAWATT GENERATING CAPACITY AND EMITS 14.5 MILLION TONS OF CARBON DIOXIDE ANNUALLY.

global: development of CO_2 emissions

Whilst worldwide CO_2 emissions will increase by 62% in the Reference scenario, under the Energy [R]evolution scenario they will decrease from 27,925 million tonnes in 2009 to 3,076 million tonnes in 2050 (excluding international bunkers). Annual per capita emissions will drop from 4.1 tonnes to 2.4 tonnes in 2030 and 0.3 tonne in 2050. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will even reduce emissions in the transport sector. With a share of 23% of CO_2 emissions in 2050, the power sector will drop below transport as the largest source of emissions. By 2050, global CO_2 emissions are 15% of 1990 levels.

global: energy related CO_2 emissions from bio energy

The Energy [R]evolution scenario is an energy scenario, therefore only direct energy related CO_2 emissions of combustion processes are calculated and presented. Greenpeace estimates that also sustainable bio energy may result in indirect CO_2 emissions in the range of 10% to 40% of the replaced fossil fuels, leading to additional CO_2 emissions between 358 and 1,432 million tonnes by 2050 (see also Bio Energy disclaimer in Chapter 8).

figure 5.16: global: development of CO_2 emissions by sector under the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

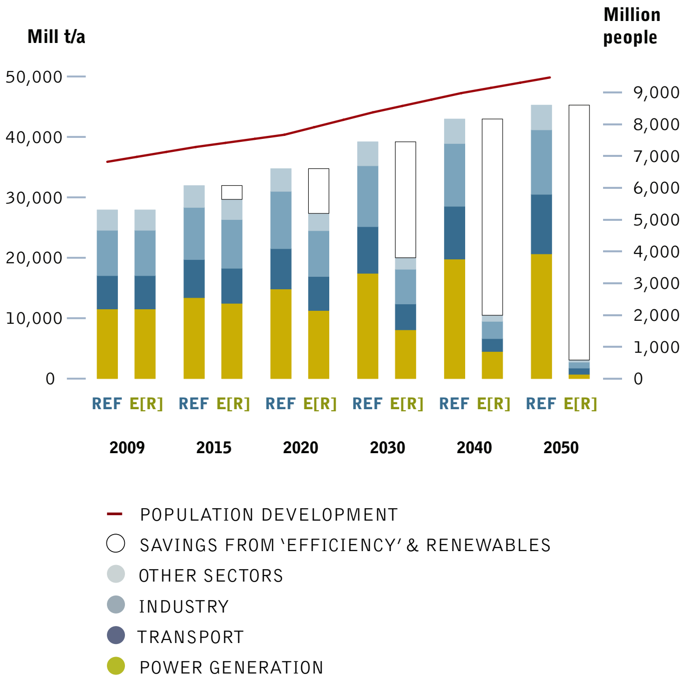


figure 5.15: global: regional breakdown of CO_2 emissions in the energy [r]evolution in 2050

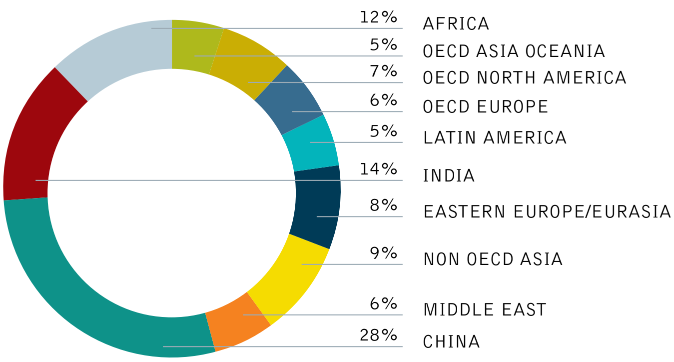
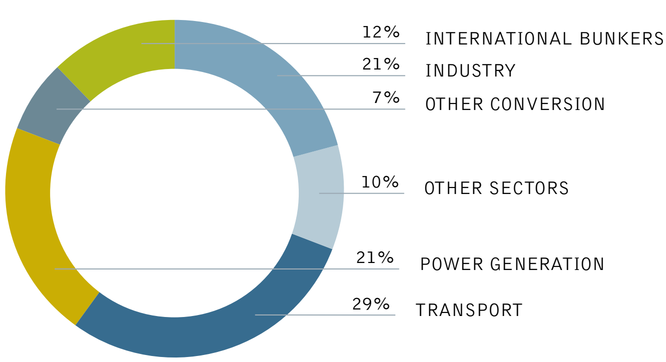


figure 5.17: global: CO_2 emissions by sector in the energy [r]evolution in 2050



oecd north america

GLOBAL SCENARIO	**OECD NORTH AMERICA** LATIN AMERICA OECD EUROPE AFRICA	MIDDLE EAST EASTERN EUROPE/EURASIA INDIA	NON OECD ASIA CHINA OECD ASIA OCEANIA

oecd north america: electricity generation energy demand by sector

The future development pathways for OECD North America's energy demand are shown in Figure 5.18 for the Reference and the Energy [R]evolution scenario. Under the Reference scenario, total primary energy demand in OECD North America increases by 16% from the current 108,501 PJ/a to 108,501 PJ/a in 2050. In the Energy [R]evolution scenario, by contrast, energy demand decreases by 33% compared to current consumption and it is expected by 2050 to reach 73,000 PJ/a.

Under the Energy [R]evolution scenario, electricity demand in the industrial, residential, and service sectors is expected to fall slightly below the current level (see Figure 5.19). In the transport sector - for both freight and persons - a shift towards electric trains and public transport as well as efficient electric vehicle is expected. Fossil fuels for industrial process heat generation are also phased out more quickly and replaced by electric heat pumps, solar energy, electric direct heating and hydrogen. This means that electricity demand (final energy) in the Energy [R]evolution scenario increases in the industry, residential, service, and transport sectors and reaches 4,082 TWh/a in 2050, still 36% below the Reference case.

Efficiency gains in the heat supply sector allow a significant reduction of the heat demand relative to the reference case. Under the Energy [R]evolution scenario, heat demand can even be reduced significantly (see Figure 5.21) compared to the Reference scenario: Heat production equivalent to 2,283 PJ/a is avoided through efficiency measures by 2050.

figure 5.18: oecd north america: total final energy demand by sector under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

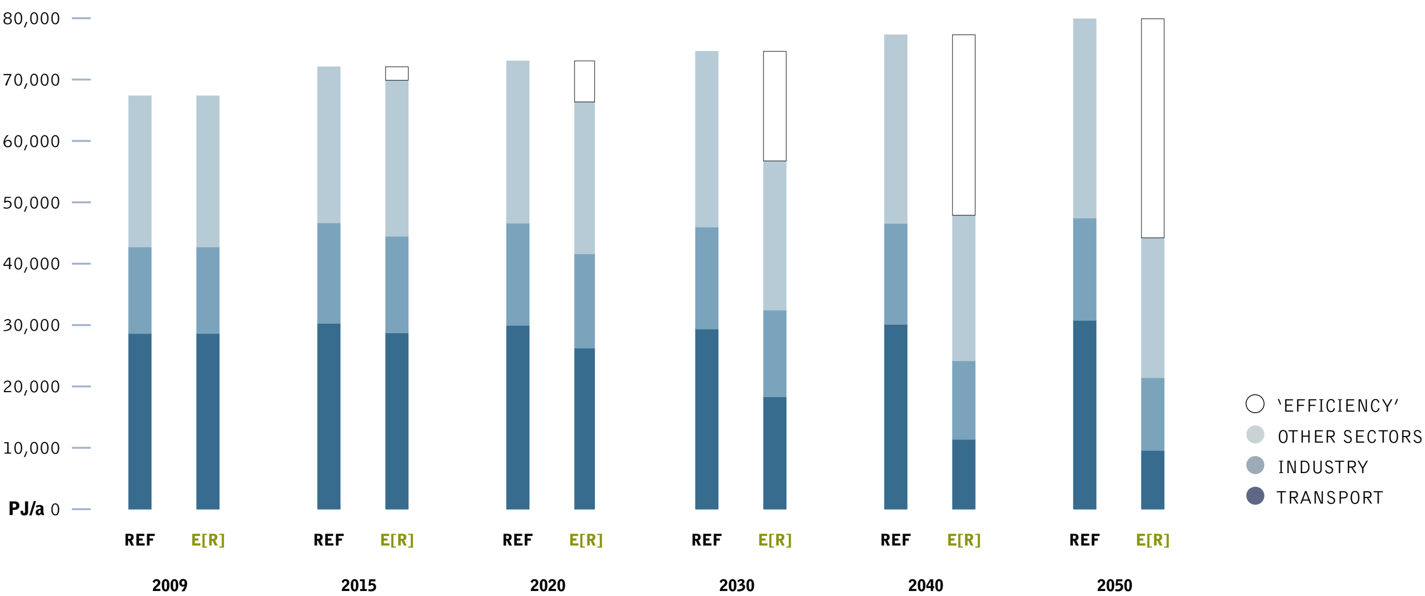


image CONTROL ROOM OF LUZ SOLAR POWER PLANT, CALIFORNIA, USA.

image LUZ INTERNATIONAL SOLAR POWER PLANT, CALIFORNIA, USA.

figure 5.19: oecd north america: development of electricity demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

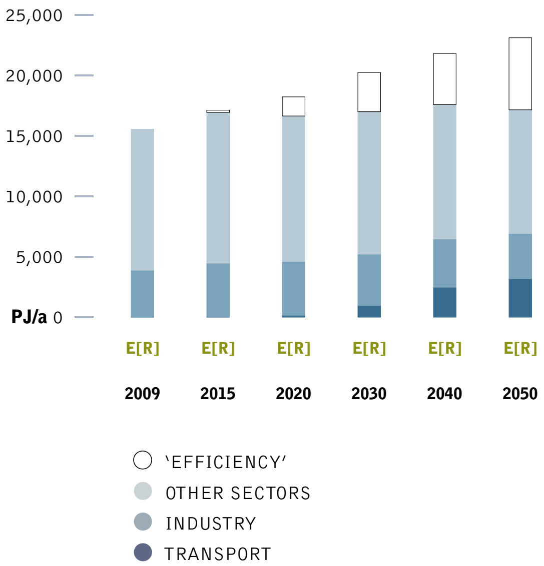


figure 5.21: oecd north america: development of heat demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

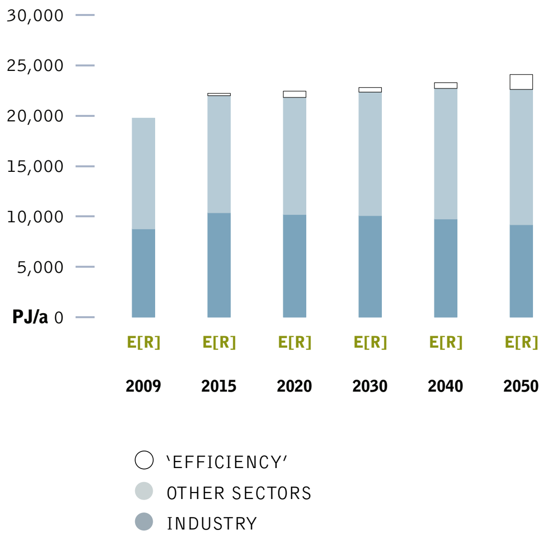
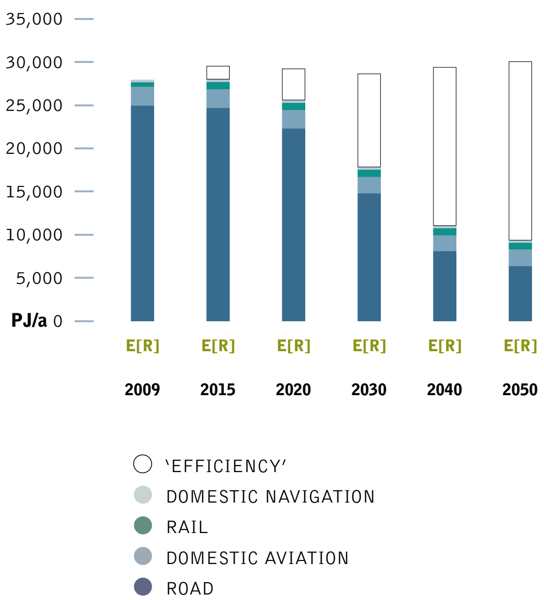


figure 5.20: oecd north america: development of the transport demand by sector in the energy [r]evolution scenario



In the transport sector, it is assumed under the Energy [R]evolution scenario that energy demand will decrease by 67% to 9,554 PJ/a by 2050, saving 69% compared to the Reference scenario. The Energy [R]evolution scenario factors in a faster decrease of the final energy demand for transport. This can be achieved through a mix of increased public transport, reduced annual person kilometres and wider use of more efficient engines and electric drives. Consequently, electricity demand in the transport sector increases, the final energy use of fossil fuels falls to 1,451 PJ/a, compared to 27,203 PJ/a in the Reference case.

oecd north america

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oecd north america: electricity generation

The development of the electricity supply market is charaterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 97% of the electricity produced in OECD North America will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 84% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with higher annual growth rates achieving a renewable electricity share of 42% by 2020 and 75% by 2030. The installed capacity of renewables will reach 1,721 GW in 2030 and 2,780 GW by 2050.

Table 5.7 shows the comparative evolution of the different renewable technologies in OECD North America over time. Up to 2020 hydro and wind will remain the main contributors of the growing market share. After 2020, the continuing growth of wind will be complemented by elelctricty mainly from photovoltaics, solar thermal (CSP), and geothermal energy. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation source (photovoltaic, wind and ocean) of 43% by 2030, therefore the expansion of smart grids, demand side management (DSM) and storage capacity from the increased share of electric vehicles will be used for a better grid integration and power generation management.

table 5.7: oecd north america: renewable electricity generation capacity under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Hydro	REF	187	197	204	208	214
	E[R]	187	217	224	224	224
Biomass	REF	15	23	36	49	59
	E[R]	15	20	26	34	40
Wind	REF	39	109	150	192	241
	E[R]	39	386	759	961	1,011
Geothermal	REF	4	6	9	10	12
	E[R]	4	23	59	93	107
PV	REF	2	22	39	51	55
	E[R]	2	132	384	552	639
CSP	REF	0	3	7	12	22
	E[R]	0	46	218	467	651
Ocean energy	REF	0	0	1	1	2
	E[R]	0	20	51	89	108
Total	**REF**	**247**	**361**	**445**	**523**	**606**
	E[R]	**247**	**843**	**1,721**	**2,420**	**2,780**

figure 5.22: oecd north america: electricity generation structure under the reference scenario and the energy [r]evolution scenario (INCLUDING ELECTRICITY FOR ELECTROMOBILITY, HEAT PUMPS AND HYDROGEN GENERATION)

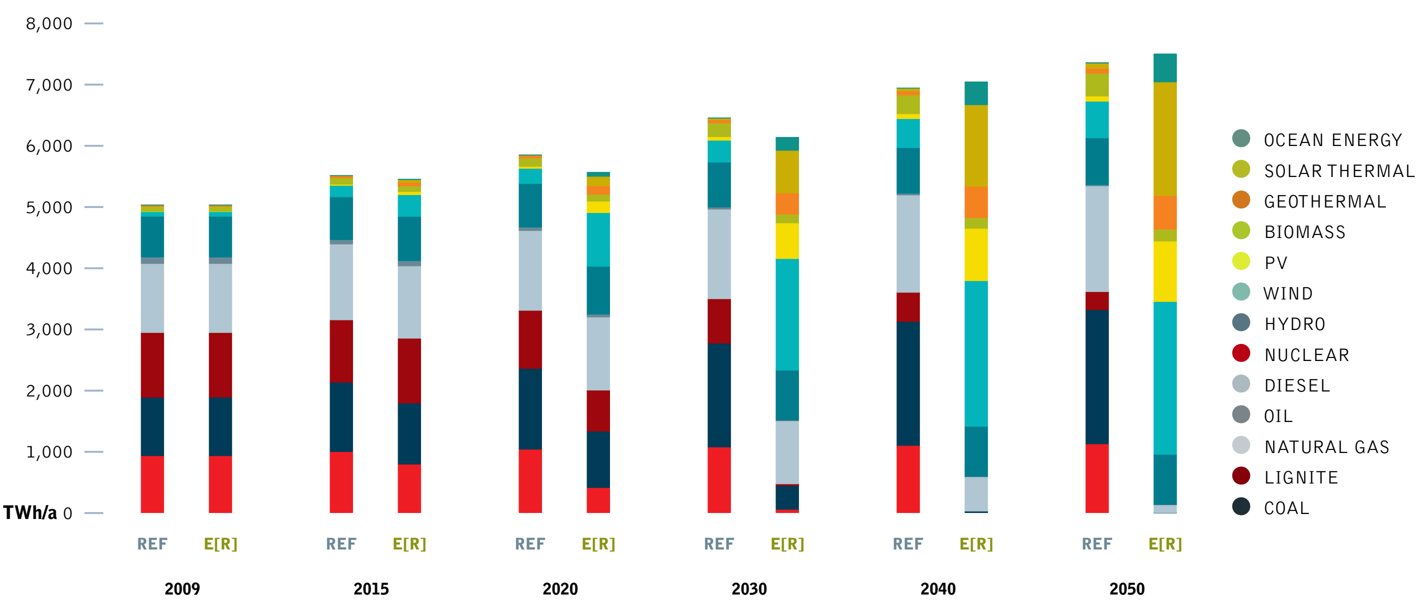


image CONCENTRATING SOLAR POWER (CSP) AT A SOLAR FARM IN DAGGETT, CALIFORNIA, USA.

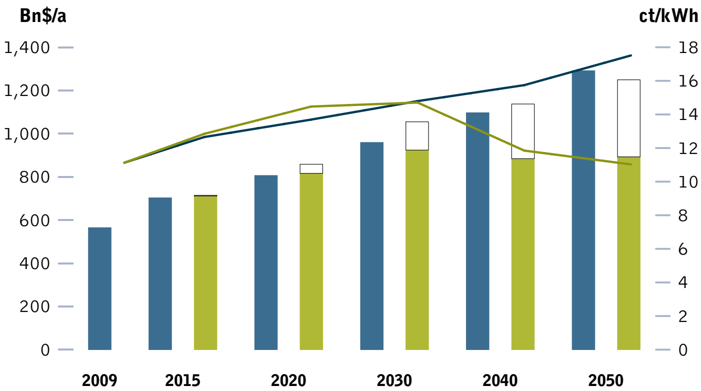
image AN OFFSHORE DRILLING RIG DAMAGED BY HURRICANE KATRINA, GULF OF MEXICO.

oecd north america: future costs of electricity generation

Figure 5.23 shows that the introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the costs of electricity generation in OECD North America compared to the Reference scenario. This difference will be less than $ 1 cent/kWh up to 2030, however. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be $ 6.5 cents/kWh below those in the Reference version.

Under the Reference scenario, the unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $ 565 billion per year to about $ 1,290 billion in 2050. Figure 5.23 shows that the Energy [R]evolution scenario not only complies with OECD North America's CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are more than one third than in the Reference scenario.

figure 5.23: oecd north america: total electricity supply costs and specific electricity generation costs under two scenarios



- SPEC. ELECTRICITY GENERATION COSTS (REF)
- SPEC. ELECTRICITY GENERATION COSTS (E[R])
- 'EFFICIENCY' MEASURES
- REFERENCE SCENARIO (REF)
- ENERGY [R]EVOLUTION (E[R])

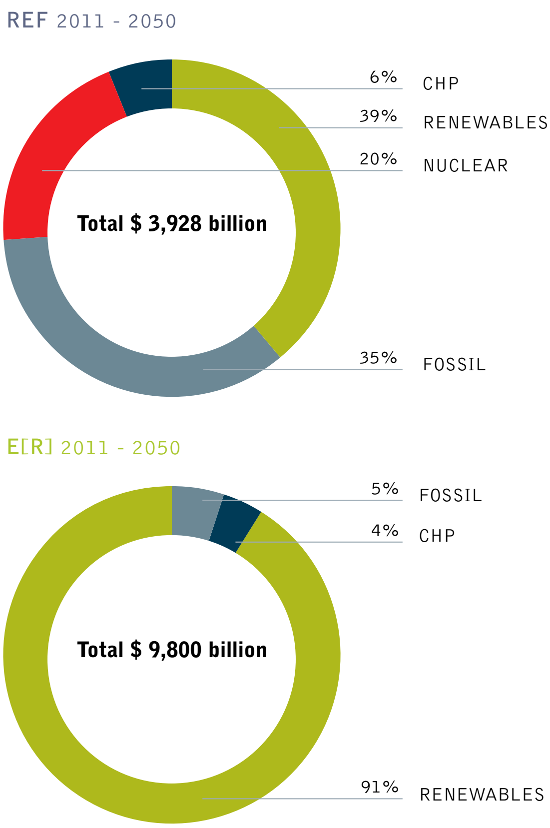
oecd north america: future investments in the power sector

It would require $ 9,800 billion in investment for the Energy [R]evolution scenario to become reality (through 2050, including investments for replacement after the economic lifetime of the plants) - approximately $ 5,872 billion or $ 147 billion per year more than in the Reference scenario ($ 3,928 billion). Under the Reference version, the levels of investment in conventional power plants adds up to almost 55% while approximately 45% would be invested in renewable energy and cogeneration until 2050.

Under the Energy [R]evolution scenario, however, North America would shift almost 95% of the entire investment towards renewables and cogeneration. Until 2030 the fossil fuel share of power sector investment would be focused mainly on combined heat and power plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately $ 245 billion.

Because renewable energy has no fuel costs, however, the fuel cost savings in the Energy [R]evolution scenario reach a total of $ 5,775 billion, or $ 144.4 billion per year. The total fuel cost savings therefore would cover 98% of the total additional investments compared to the reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.

figure 5.24: oecd north america: investment shares - reference scenario versus energy [r]evolution scenario



oecd north america

GLOBAL SCENARIO
OECD NORTH AMERICA
LATIN AMERICA
OECD EUROPE
AFRICA
MIDDLE EAST
EASTERN EUROPE/EURASIA
INDIA
NON OECD ASIA
CHINA
OECD ASIA OCEANIA

oecd north america: heating supply

Renewables currently provide 11% of North America's energy heat demand, the main contribution coming from biomass. Dedicated support instruments are required to ensure a dynamic future development. In the Energy [R]evolution scenario, renewables provide 88% of North America's total heat demand in 2050.

- Energy efficiency measures can decrease the heat demand by 9% in 2050 compared to the Reference scenario, in spite of improving living standards.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for fossil fuel-fired systems.
- A shift from coal and oil to natural gas in the remaining conventional applications will lead to a further reduction of CO_2 emissions.

The Energy [R]evolution case introduces renewable heating systems around 5 years ahead of the Energy [R]evolution scenario. Solar collectors and geothermal heating systems achieve economies of scale via ambitious support programmes 5 to 10 years earlier and reach a share of 52% by 2030 and 96% by 2050.

Table 5.8 shows the development of the different renewable technologies for heating in North America over time. Up to 2020 biomass will remain the main contributors of the growing market share. After 2020, the continuing growth of solar collectors and a growing share of geothermal heat pumps will reduce the dependence on fossil fuels.

table 5.8: oecd north america: renewable heating capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	2,052	2,788	3,093	3,331	3,511
	E[R]	2,052	2,705	2,837	2,764	2,288
Solar collectors	REF	64	154	330	620	796
	E[R]	64	1,272	4,303	6,751	7,874
Geothermal	REF	14	31	60	143	193
	E[R]	14	1,227	3,742	6,527	9,007
Hydrogen	REF	0	0	0	0	0
	E[R]	0	271	873	1,605	1,976
Total	**REF**	**2,130**	**2,973**	**3,483**	**4,094**	**4,500**
	E[R]	**2,130**	**5,475**	**11,755**	**17,647**	**21,146**

figure 5.25: oecd north america: heat supply structure under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

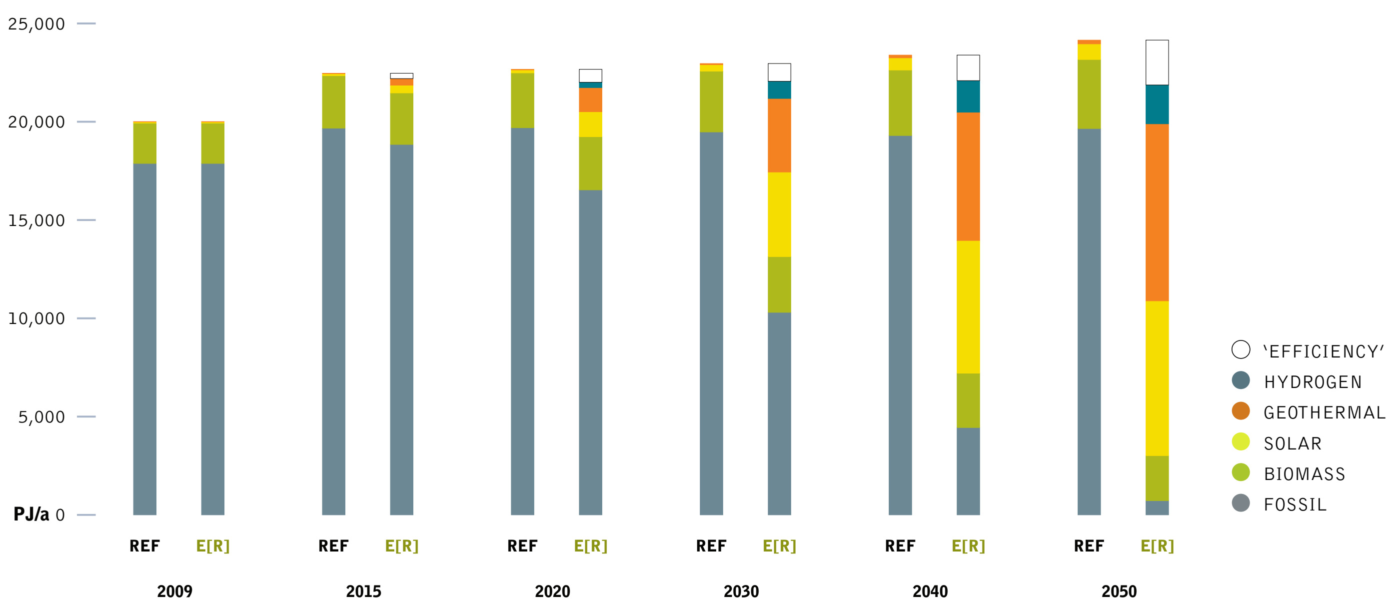


image AN OPEN-PIT MINE IN FRONT OF SYNCRUDES MILDRED LAKE FACILITY AT THE ALBERTA TAR SANDS. CANADA'S TAR SANDS ARE AN OIL RESERVE THE SIZE OF ENGLAND. EXTRACTING THE CRUDE OIL CALLED BITUMEN FROM UNDERNEATH UNSPOILED WILDERNESS REQUIRES A MASSIVE INDUSTRIALIZED EFFORT WITH FAR-REACHING IMPACTS ON THE LAND, AIR, WATER, AND CLIMATE.

image CONCENTRATING SOLAR POWER (CSP) AT A SOLAR FARM IN DAGGETT, CALIFORNIA, USA.

oecd north america: future investments in the heat sector

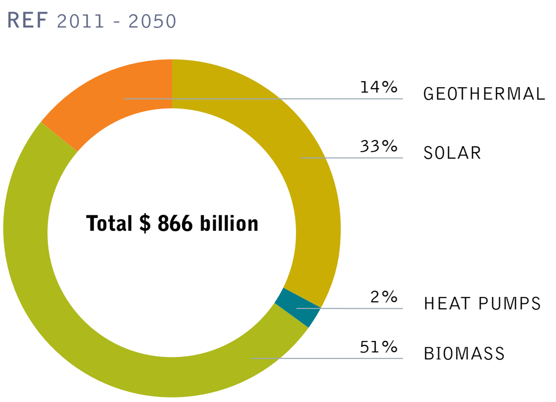
Also in the heat sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially the not yet so common solar and geothermal and heat pump technologies need enourmous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity needs to increase from today 19 GW to more than 2000 GW for solar thermal and from 2 GW to more than 1400 GW for geothermal and heat pumps. Capacity of biomass technologies, which are already rather wide spread will decrease by more than 50% due to the limited availability of sustainable biomass.

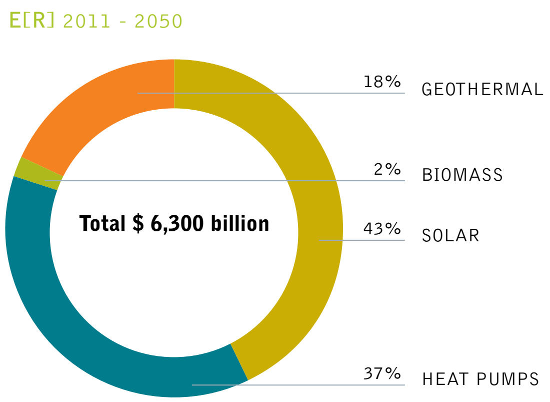
Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar thermal district heating plants with seasonal storage. Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around $ 6,300 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately $ 160 billion per year."

table 5.9: oecd north america: renewable heat generation capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	310	374	422	465	496
	E[R]	310	337	297	250	149
Geothermal	REF	0	1	9	36	49
	E[R]	0	85	271	448	505
Solar thermal	REF	19	45	97	182	232
	E[R]	19	329	1,088	1,709	2,016
Heat pumps	REF	2	3	4	7	9
	E[R]	2	140	407	666	916
Total	**REF**	331	424	533	689	786
	E[R]	331	891	2,063	3,073	3,586

figure 5.26: oecd north america: investments for renewable heat generation technologies under the reference scenario and the energy [r]evolution scenario





oecd north america

oecd north america: future employment in the energy sector

The Energy [R]evolution scenario results in more energy sector jobs in the OECD Americas at every stage of the projection.

- There are 2 million energy sector jobs in the Energy [R]evolution scenario in 2015, and 1.4 million in the Reference scenario.
- In 2020, there are 2.1 million jobs in the Energy [R]evolution scenario, and 1.4 million in the Reference scenario.
- In 2030, there are 1.8 million jobs in the Energy [R]evolution scenario and 1.4 million in the Reference scenario.

Figure 5.27 shows the change in job numbers under both scenarios for each technology between 2010 and 2030. Jobs in the coal sector decline in both scenarios, leading to a small decline in overall energy jobs in the Reference scenario.

Strong growth in the renewable sector leads to an increase of 44% in total energy sector jobs in the [R]evolution scenario by 2015. At 2030, jobs are 29% above 2010 levels. Renewable energy accounts for 67% of energy jobs by 2030, with the majority spread evenly over wind, solar PV, solar heating, and biomass.

figure 5.27: oecd north america: employment in the energy scenario under the reference and energy [r]evolution scenarios

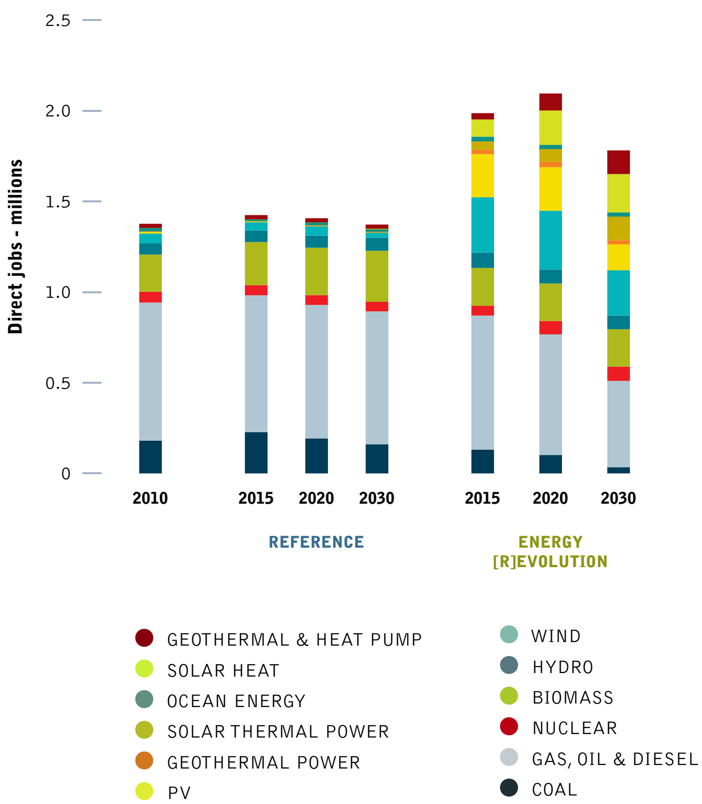


table 5.11: oecd north america: total employment in the energy sector THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	181	228	193	171	131	102	34
Gas, oil & diesel	761	755	736	733	740	665	477
Nuclear	60	56	54	53	54	74	79
Renewable	375	386	424	426	1,062	1,255	1,193
Total Jobs	**1,377**	**1,425**	**1,408**	**1,383**	**1,987**	**2,095**	**1,782**
Construction and installation	130	124	101	73	464	545	503
Manufacturing	64	65	60	40	332	407	299
Operations and maintenance	226	243	259	277	254	292	355
Fuel supply (domestic)	953	986	978	982	933.6	851	626
Coal and gas export	4	7	10	10	4	1	-
Total Jobs	**1,377**	**1,425**	**1,408**	**1,383**	**1,987**	**2,095**	**1,782**

image GAS PIPELINE CONSTRUCTION IN THE BRADFORD COUNTY COUNTRYSIDE. IN DECEMBER 2011, THE PITTSBURGH TRIBUNE-REVIEW REPORTED THAT THE 8,500 MILES (29,773 KMS) OF GAS PIPELINE IN PENNSYLVANIA COULD QUADRUPLE OVER THE NEXT 20 YEARS. THE ARTICLE POINTS OUT THAT COMPANIES HAVE ALREADY DOUBLED ANNUAL SPENDING ON PIPELINE PROJECTS IN PENNSYLVANIA TO $800 MILLION.

image WIND TURBINES ON THE STORY COUNTY 1 ENERGY CENTER, JUST NORTH OF COLO. EACH TURBINE HAS A 1.5-MEGAWATT CAPACITY AND CONTRIBUTES TO GENERATING ELECTRICITY FOR UP TO 75,000 HOMES. THE NEXTERA ENERGY-OWNED WIND FARM HAS BEEN IN OPERATION SINCE 2008.

oecd north america: transport

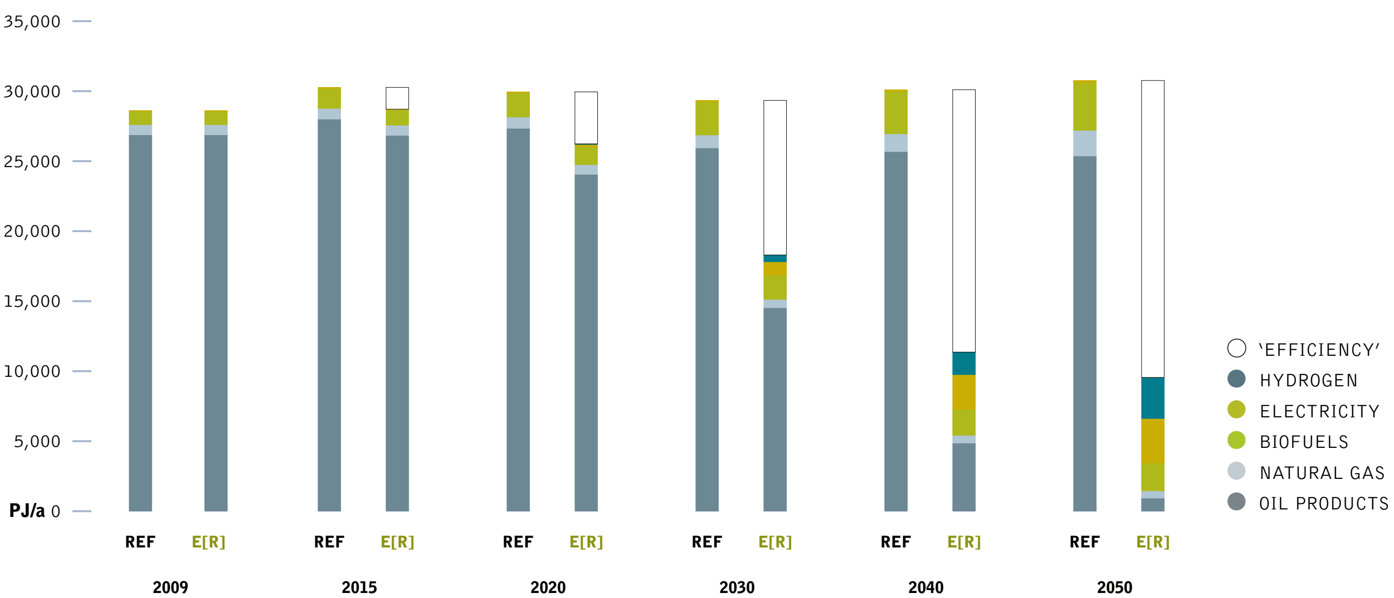
In the transport sector, it is assumed under the Energy [R]evolution scenario that an energy demand reduction of 21,207 PJ/a can be achieved by 2050 compared to the Reference scenario, saving 69%. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns. Implementing attractive alternatives to individual cars, the car stock is growing slower than in the Reference scenario.

A shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains and a reduction of vehicle kilometres travelled by 0.25% per year leads to significant final energy savings. In 2030, electricity will provide 5% of the transport sector's total energy demand in the Energy [R]evolution, 33% by 2050.

table 5.10: oecd north america: transport energy demand by mode under the reference scenario and the energy [r]evolution scenario (WITHOUT ENERGY FOR PIPELINE TRANSPORT) IN PJ/A

		2009	2020	2030	2040	2050
Rail	REF	522	699	692	719	746
	E[R]	522	832	839	826	764
Road	REF	24,975	25,902	25,378	25,917	26,224
	E[R]	24,975	22,319	14,810	8,120	6,382
Domestic aviation	REF	2,186	2,321	2,272	2,446	2,753
	E[R]	2,186	2,151	1,906	1,827	1,947
Domestic navigation	REF	237	286	286	299	312
	E[R]	237	294	285	271	263
Total	**REF**	**27,920**	**29,208**	**28,628**	**29,382**	**30,036**
	E[R]	**27,920**	**25,596**	**17,839**	**11,044**	**9,356**

figure 5.28: oecd north america: final energy consumption for transport under the reference scenario and the energy [r]evolution scenario



oecd north america

GLOBAL SCENARIO

OECD NORTH AMERICA
LATIN AMERICA
OECD EUROPE
AFRICA

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oecd north america: development of CO_2 emissions

Whilst the OECD North America's emissions of CO_2 will decrease by 2% under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 6,119 million tonnes in 2009 to 204 million tonnes in 2050. Annual per capita emissions will fall from 13.4 tonne (2009) to 0.3 tonne (2050). In the long run efficiency gains and the increased use of renewable electricity in vehicles will even reduce emissions in the transport sector. With a share of 42% of total CO_2 in 2050, the transport sector will remain the largest sources of emissions. By 2050, OECD North America's CO_2 emissions are 4% of 1990 levels.

oecd north america: primary energy consumption

Taking into account the above assumptions, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 5.30. Compared to the Reference scenario, overall energy demand will be reduced by 42% in 2050. Around 87% of the remaining demand will be covered by renewable energy sources.

The Energy [R]evolution version phases out coal and oil about 10 to 15 years faster than the previous Energy [R]evolution scenario published in 2010. This is made possible mainly by replacement of coal power plants with renewables after 20 rather than 40 years lifetime and a faster introduction of electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 45% in 2030 and 87% in 2050. Nuclear energy is phased out in just after 2035.

figure 5.29: oecd north america: development of CO_2 emissions by sector under the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

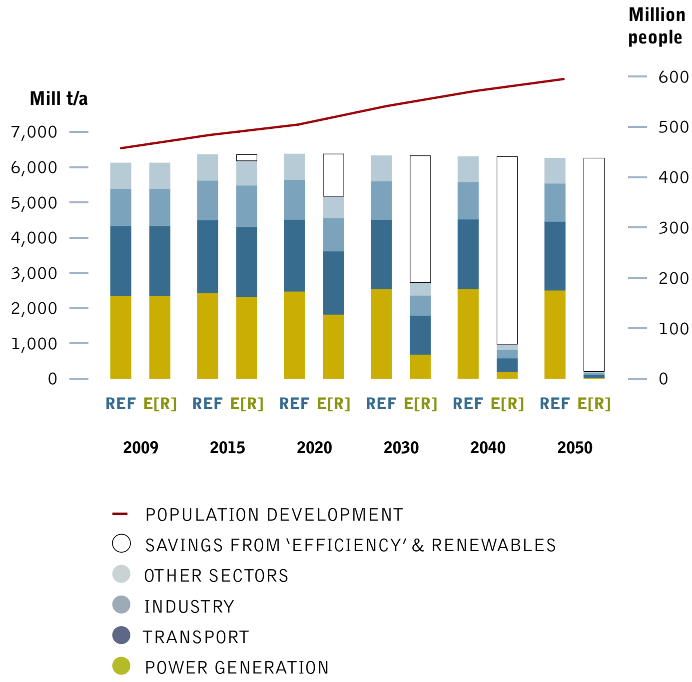


figure 5.30: oecd north america: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

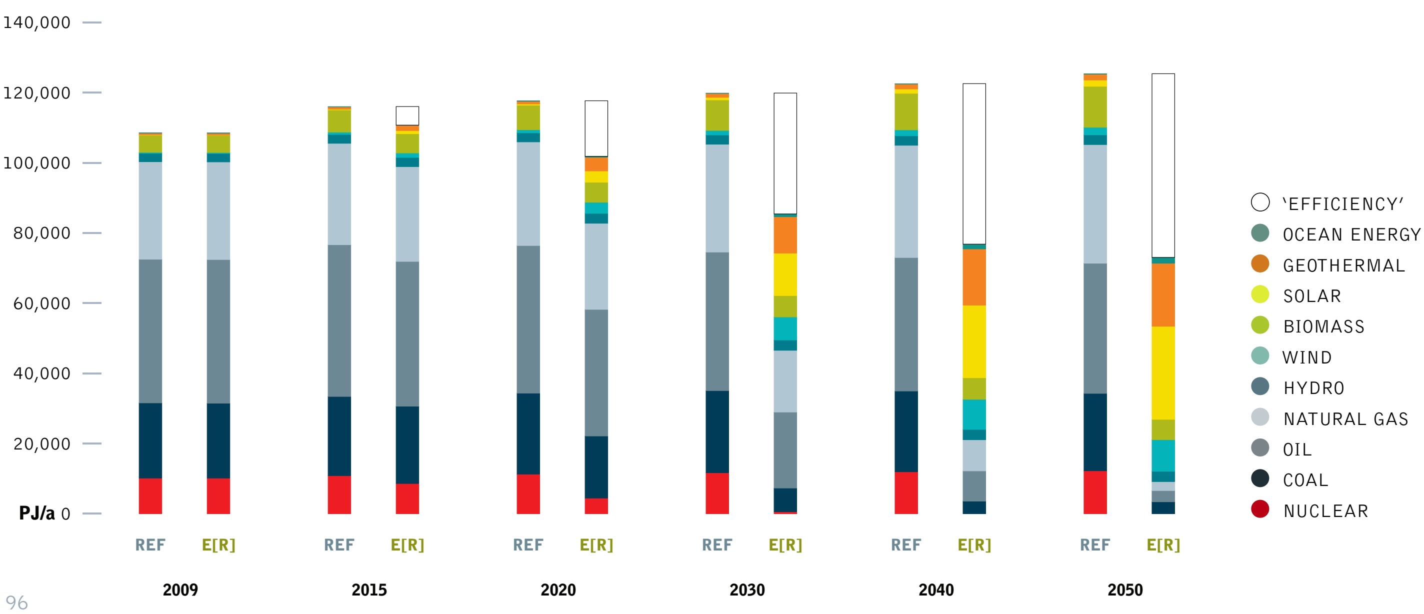


image THE ALLEN STEAM STATION, A FIVE-UNIT COAL-FIRED GENERATING STATION IN GASTON COUNTY, NORTH CAROLINA. IT HAS BEEN OPERATING SINCE 1957 AND HAS A 1,140-MEGAWATT CAPACITY AND EMITS 6.9 MILLION TONS OF CARBON DIOXIDE EACH YEAR.

image AERIAL PHOTOGRAPH OF THE MARSHALL STEAM STATION, A COAL-FIRED POWER STATION SITUATED ON LAKE NORMAN. OPERATING SINCE 1965, THIS COAL-FIRED POWER STATION HAS A 2,090-MEGAWATT GENERATING CAPACITY AND EMITTED 11.5 MILLION TONS OF CARBON DIOXIDE IN 2011.

table 5.12: oecd north america: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

INVESTMENT COSTS	$	2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion $	-416.9	-496.7	-380.7	-352.5	-1,646.9	-41.2
Renewables	billion $	1,125.0	1,853.2	2,353.2	2,187.5	7,518.9	188.0
Total	billion $	**708.1**	**1,356.5**	**1,972.5**	**1,835.0**	**5,872.0**	**146.8**

CUMULATIVE FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion $/a	-12.6	22.9	36.1	24.9	71.3	1.8
Gas	billion $/a	77.4	422.3	1,329.8	2,711.7	4,541.1	113.5
Hard coal	billion $/a	82.4	474.6	987.2	1,256.1	2,800.2	70.0
Lignite	billion $/a	9.0	75.4	88.5	61.4	234.1	5.9
Total	billion $/a	**156.2**	**995.1**	**2,441.5**	**4,054.0**	**7,646.8**	**191.2**

latin america

latin america: energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for Latin America's energy demand. These are shown in Figure 5.31 for both the Reference and the Energy [R]evolution scenario. Under the Reference scenario, total primary energy demand almost doubles from the current 22,050 PJ/a to 40,740 PJ/a in 2050. In the Energy [R]evolution scenario a smaller increase of 34% compared to current consumption is expected, reaching 29,500 PJ/a by 2050.

Under the Energy [R]evolution scenario, electricity demand is expected to increase disproportionately, with households and services the main sources for growing consumption. This is due to wider access to energy services especially in the developing regions within Latin America (see Figure 5.32). With the exploitation of efficiency measures, however an even higher increase can be avoided, leading to an electricity demand of around 2030 TWh/a in 2050.

Compared to the Reference scenario, efficiency measures in the industry, residential and service sectors avoid the generation of about 605 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic devices. Employment of solar architecture in both residential and commercial buildings will help to curb the growing demand for air-conditioning.

Efficiency gains in the heat supply sector are even larger. Under the Energy [R]evolution scenario, final energy demand for heat supply eventually even stagnates (see Figure 5.34). Compared to the Reference scenario, consumption equivalent to 2,370 PJ/a is avoided through efficiency gains by 2050. In the transport sector, it is assumed under the Energy [R]evolution scenario that energy demand will peak around 2020 and will drop back to 5,400 PJ/a by 2050, saving 51% compared to the Reference scenario.

figure 5.31: latin america: total final energy demand by sector under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

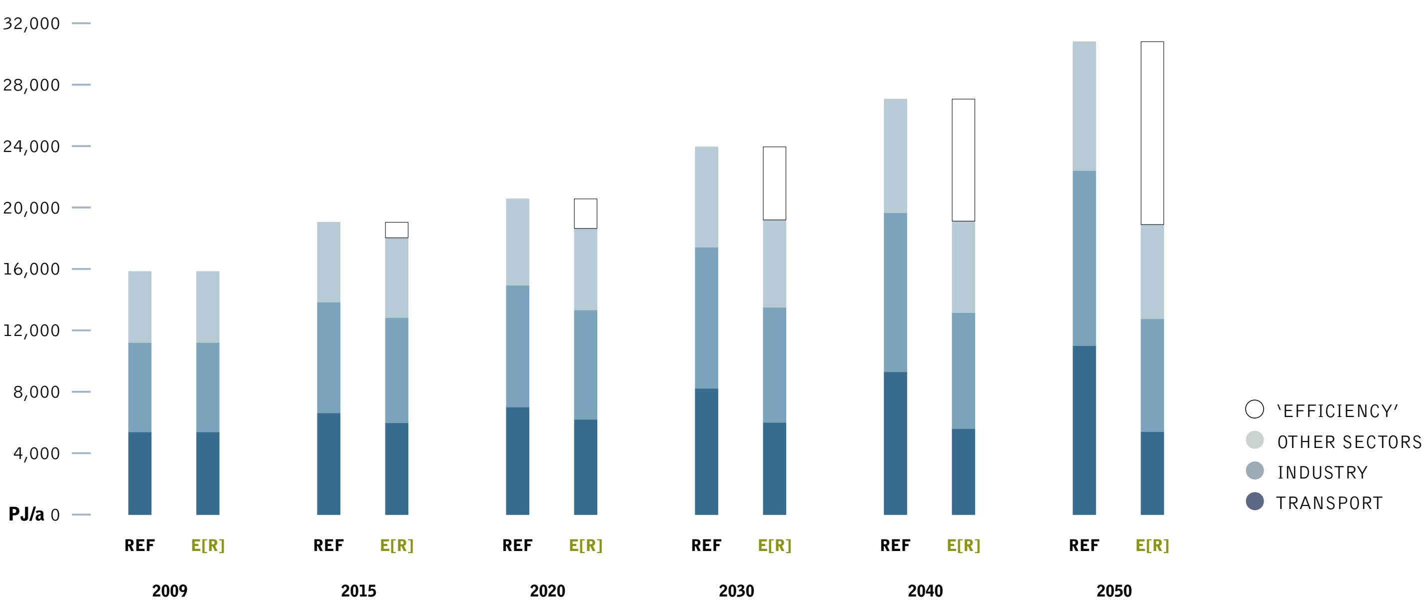


image VOLUNTEERS CHECK THE SOLAR PANELS ON TOP OF GREENPEACE POSITIVE ENERGY TRUCK, BRAZIL.

image WIND TURBINES IN FORTALEZ, CEARÀ, BRAZIL.

figure 5.32: latin america: development of electricity demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

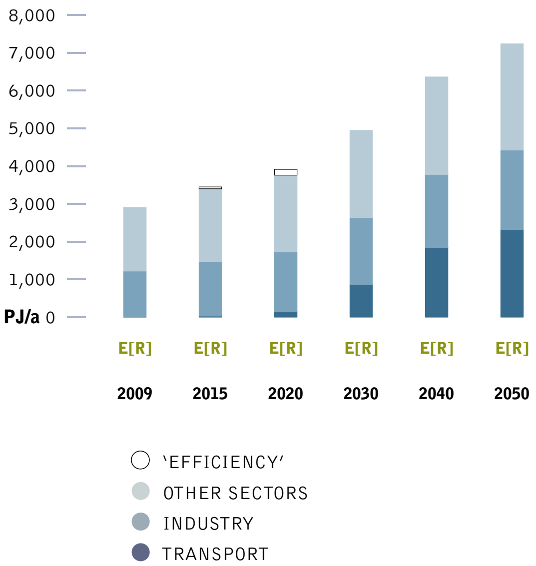


figure 5.34: latin america: development of heat demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

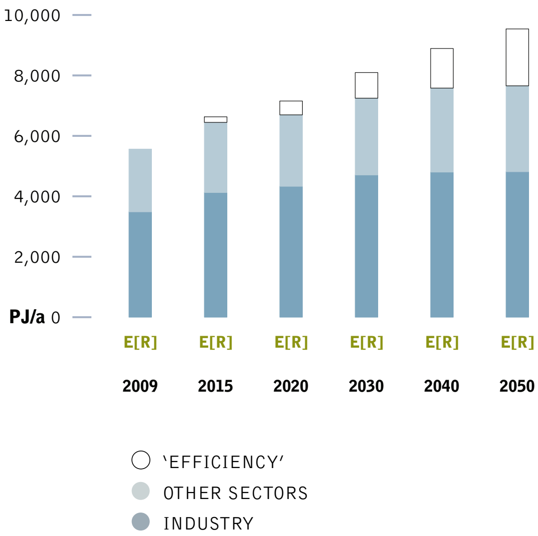
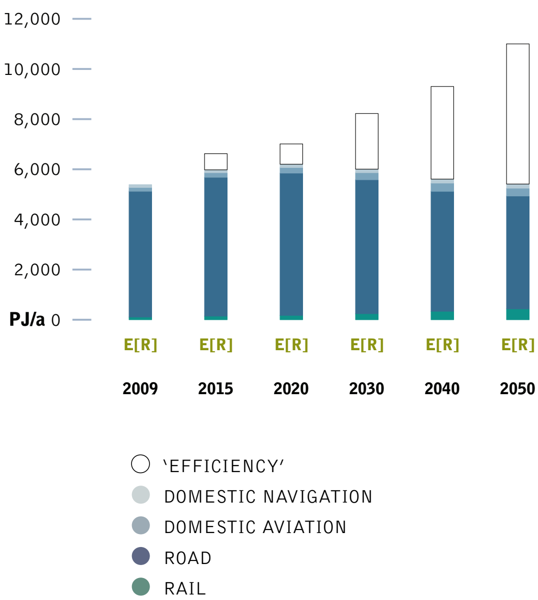


figure 5.33: latin america: development of the transport demand by sector in the energy [r]evolution scenario



latin america

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latin america: electricity generation

The development of the electricity supply market in the Energy [R]evolution scenario is charaterised by an increasing share of renewable energy sources. By 2050, 95% of the electricity produced in Latin America will come from renewable energy sources. 'New' renewables – mainly wind, PV and biomass – will contribute 54% of electricity generation. The installed capacity of renewable energy technologies will grow from the current 148 GW to 436 GW in 2030 and 863 GW in 2050, increasing renewable capacity by a factor of six within the next 40 years.

Table 5.13 shows the comparative evolution of the different renewable technologies in Latin America over time. Up to 2030 hydro will remain the main contributor, while wind and photovoltaics (PV) gain a growing market share. After 2020, the continuing growth of wind and PV will be complemented by electricity from biomass and solar thermal (CSP) energy. The Energy [R]evolution scenario will lead to a high share of renewables achieving an electricity share of 80% already by 2020 and 86% by 2030.

table 5.13: latin america: renewable electricity generation capacity under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Hydro	REF	142	170	198	218	228
	E[R]	142	159	167	169	170
Biomass	REF	5	7	9	10	12
	E[R]	5	15	33	50	66
Wind	REF	1	6	11	17	27
	E[R]	1	49	130	202	258
Geothermal	REF	1	1	2	2	3
	E[R]	1	2	4	12	19
PV	REF	0	4	11	17	25
	E[R]	0	33	74	152	243
CSP	REF	0	0	1	2	3
	E[R]	0	8	21	44	69
Ocean energy	REF	0	0	0	0	0
	E[R]	0	1	7	25	37
Total	**REF**	**148**	188	**231**	**266**	**298**
	E[R]	**148**	266	**436**	**654**	**863**

figure 5.35: latin america: electricity generation structure under the reference scenario and the energy [r]evolution scenario (INCLUDING ELECTRICITY FOR ELECTROMOBILITY, HEAT PUMPS AND HYDROGEN GENERATION)

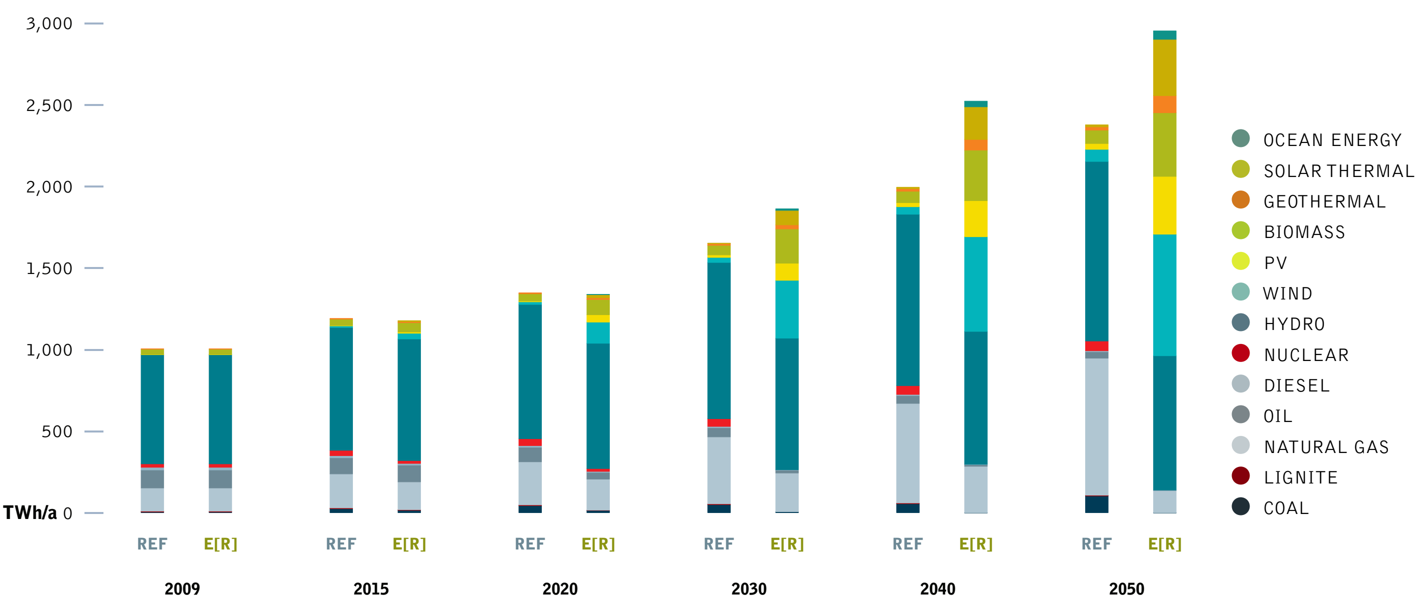


image GROUP OF YOUNG PEOPLE FEEL THE HEAT GENERATED BY A SOLAR COOKING STOVE IN BRAZIL.

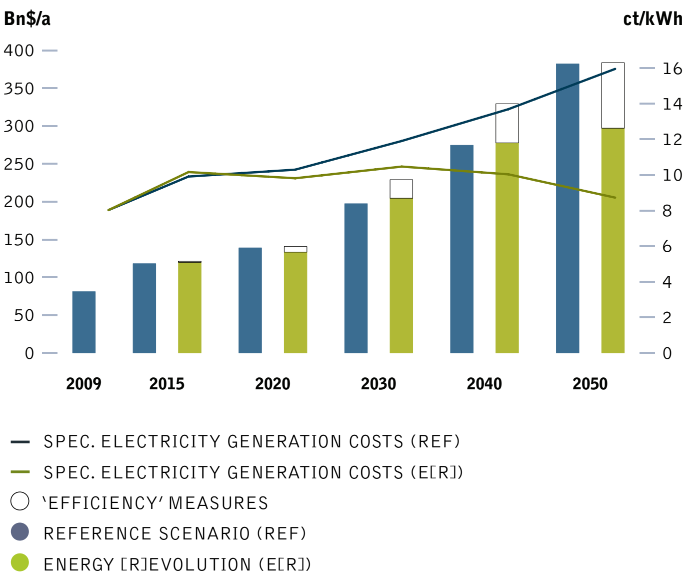
image IN 2005 THE WORST DROUGHT IN MORE THAN 40 YEARS DAMAGED THE WORLD'S LARGEST RAIN FOREST IN THE BRAZILIAN AMAZON, WITH WILDFIRES BREAKING OUT, POLLUTED DRINKING WATER AND THE DEATH OF MILLIONS FISH AS STREAMS DRY UP.

latin america: future costs of electricity generation

Figure 5.36 shows that the introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the costs of electricity generation in Latin America compared to the Reference scenario. This difference will be less than $ 0.3 cent/kWh up to 2030, however. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be $ 7.2 cents/kWh below those in the Reference version.

Under the Reference scenario, the unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $ 81 billion per year to more than $ 382 billion in 2050. Figure 5.36 shows that the Energy [R]evolution scenario complies with Latin America's CO_2 reduction targets without increasing energy costs. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are in the same range as in the Reference scenario in 2050.

figure 5.36: latin america: total electricity supply costs and specific electricity generation costs under two scenarios



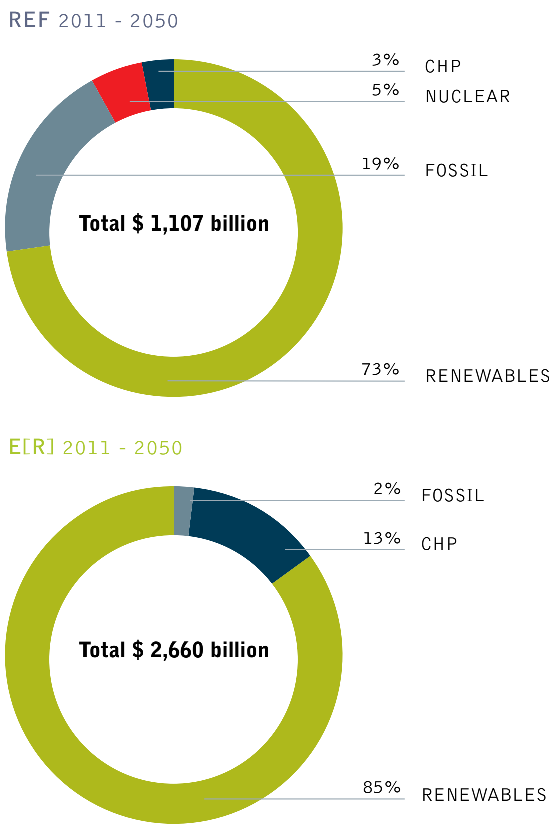
latin america: future investments in the power sector

It would require $ 2,660 billion in investment in the power sector for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately $ 1,553 billion or $ 39 billion annually more than in the Reference scenario ($ 1,107 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 24% while approximately 76% would be invested in renewable energy and cogeneration (CHP) until 2050.

Under the Energy [R]evolution scenario, however, Latin America would shift almost 98% of the entire investment towards renewables and cogeneration. Until 2030, the fossil fuel share of power sector investment would be focused mainly on CHP plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately $ 67 billion.

Because renewable energy except biomasss has no fuel costs, however, the fuel cost savings in the Energy [R]evolution scenario reach a total of $ 1,400 billion up to 2050, or $ 35 billion per year. The total fuel cost savings therefore would cover 90% of the total additional investments compared to the Reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.

figure 5.37: latin america: investment shares - reference scenario versus energy [r]evolution scenario



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latin america: heating supply

Renewables currently provide 38% of Latin America's energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large scale utilisation of geothermal and solar thermal energy. In the Energy [R]evolution scenario, renewables provide 67% of Latin America's total heat demand in 2030 and 97% in 2050.

- Energy efficiency measures can restrict the future primary energy demand for heat supply to a 29% increase, in spite of improving living standards.
- In the industry sector solar collectors, biomass/biogas as well as geothermal energy are increasingly replacing conventional fossil fuelled heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

In the Energy [R]evolution scenario about 2,370 PJ/a are saved by 2050, or 25% compared to the Reference scenario.

Table 5.14 shows the development of the different renewable technologies for heating in Latin America over time. Biomass will remain the main contributor for renewable heat. After 2020, the continuing growth of solar collectors and a growing share of geothermal heat (including heat pumps) will reduce the dependence on fossil fuels.

table 5.14: latin america: renewable heating capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	2,089	2,452	2,626	2,801	2,902
	E[R]	2,089	2,679	3,117	3,529	3,451
Solar collectors	REF	17	42	72	126	209
	E[R]	17	461	840	1,262	1,465
Geothermal	REF	0	3	7	15	25
	E[R]	0	257	563	1,213	1,757
Hydrogen	REF	0	0	0	0	0
	E[R]	0	71	261	322	303
Total	**REF**	2,106	2,497	2,705	2,941	3,136
	E[R]	2,106	3,467	4,781	6,327	6,976

figure 5.38: latin america: heat supply structure under the reference scenario and the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

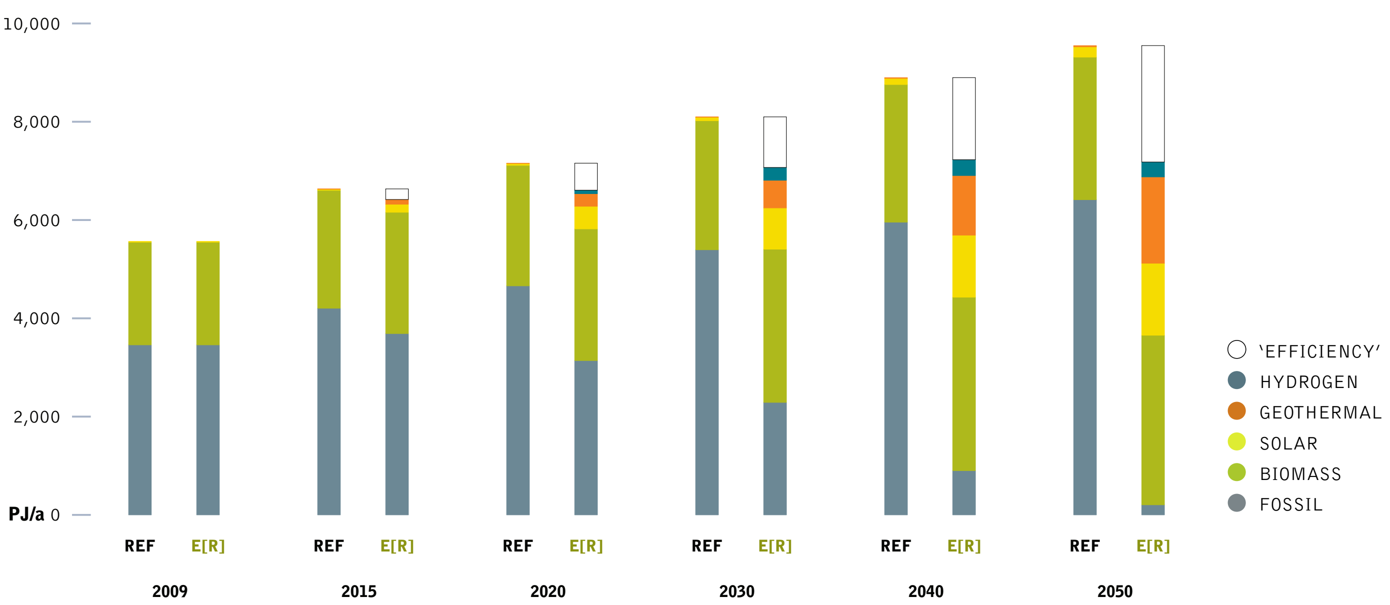


image CHILDREN IN THE FLOODED CACAO PEREIRA VILLAGE IN THE AMAZON, BRAZIL. THE NEGRO RIVER ROSE TO 29.77 METERS, SURPASSING THE MARK OF 29.69 METERS REGISTERED IN 1953, THE LAST RECORDED FLOOD.

image MAN MADE FIRES NEAR ARAGUAYA RIVER OUTSIDE THE ARAGUAYA NATIONAL PARK. FIRES ARE STARTED TO CLEAR THE LAND FOR FUTURE CATTLE USE.

latin america: future investments in the heat sector

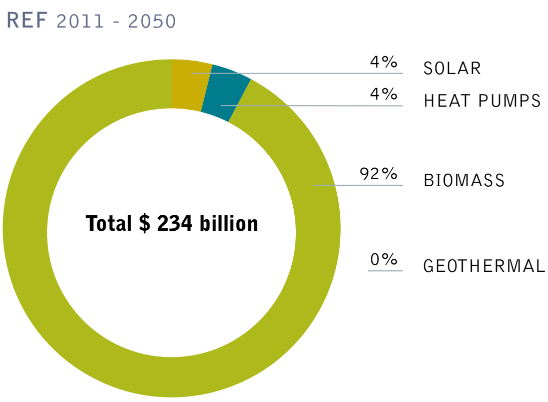
Also in the heat sector the Energy [R]evolution scenario would require a major revision of current investment strategies in direct heating technologies. Especially the not yet so common solar and up to now nonexistent geothermal and heat pump technologies need an enormous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity need to increase by the factor of 90 for solar thermal. Geothermal heat and heat pumps even first need to be introduced. Capacity of traditional biomass technologies, which are already rather wide spread need to be replaced by modern, efficient technologies in order to remain a main pillar of direct heat supply.

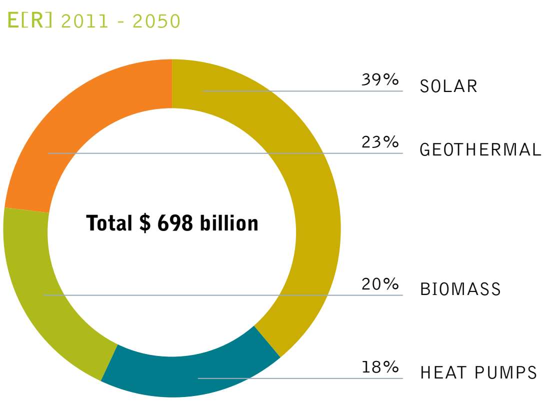
Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar themal district heating plants with seasonal storage.Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around $ 698 billion to be invested in direct renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately $ 17 billion per year.

table 5.15: latin america: renewable heat generation capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	558	607	625	644	667
	E[R]	558	665	652	647	591
Geothermal	REF	0	0	0	0	0
	E[R]	0	52	99	144	146
Solar thermal	REF	4	10	18	31	52
	E[R]	4	114	208	313	363
Heat pumps	REF	0	1	1	3	5
	E[R]	0	7	16	33	59
Total	**REF**	562	618	644	678	723
	E[R]	562	839	975	1,135	1,159

figure 5.39: latin america: investments for renewable heat generation technologies under the reference scenario and the energy [r]evolution scenario





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latin america: future employment in the energy sector

The Energy [R]evolution scenario results in more energy sector jobs in Latin America at every stage of the projection.

- There are 1.6 million energy sector jobs in the Energy [R]evolution scenario in 2015, and 1.2 million in the Reference scenario.
- In 2020, there are 1.7 million jobs in the Energy [R]evolution scenario, and 1.3 million in the Reference scenario.
- In 2030, there are 1.6 million jobs in the Energy [R]evolution scenario and 1.3 million in the Reference scenario.

Figure 5.40 shows the change in job numbers under both scenarios for each technology between 2010 and 2030. Jobs in the Reference scenario increase by 10% by 2030. Gas has the largest share, followed by biomass.

Exceptionally strong growth in renewable energy leads to an increase of 33% in energy sector jobs in the Energy [R]evolution scenario by 2015, and further growth to 41% above 2010 levels by 2030. Renewable energy accounts for 78% of energy sector jobs in 2030, with biomass having the largest share (41%), followed by solar PV, wind, and solar heating.

figure 5.40: latin america: employment in the energy scenario under the reference and energy [r]evolution scenarios

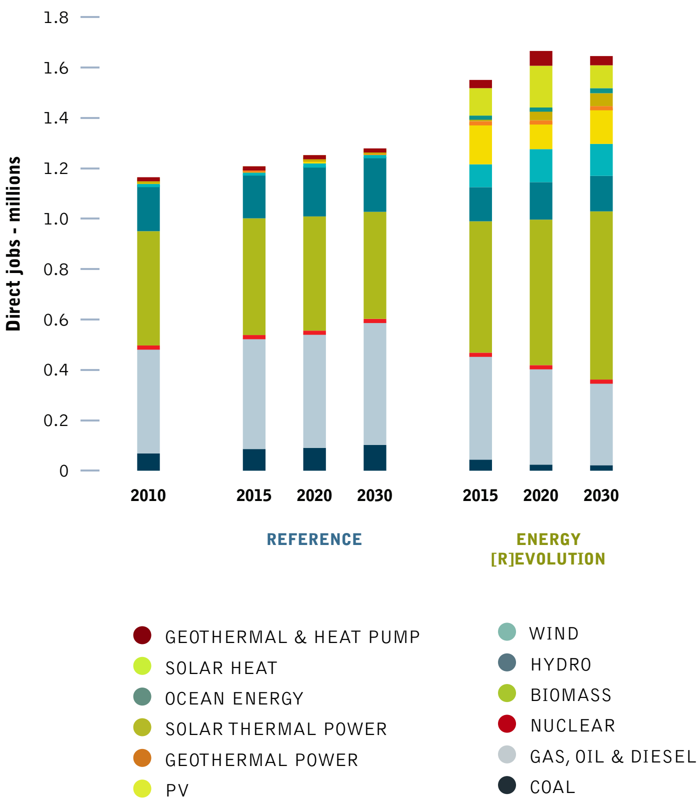


table 5.16: latin america: total employment in the energy sector THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	69	86	91	102	44	24	22
Gas, oil & diesel	414	441	457	491	422	392	336
Nuclear	14	11	8	9	3	3	4
Renewable	668	670	697	677	1,082	1,247	1,284
Total Jobs	**1,165**	**1,208**	**1,252**	**1,279**	**1,551**	**1,666**	**1,646**
Construction and installation	112	96	98	87	331	380	303
Manufacturing	35	32	37	34	142	185	175
Operations and maintenance	166	178	196	224	198	247	338
Fuel supply (domestic)	767	811	816	830	807.0	801	809
Coal and gas export	85	91	106	103	73	53	21
Total Jobs	**1,165**	**1,208**	**1,252**	**1,279**	**1,551**	**1,666**	**1,646**

image THE INTAKE/OUTLET PIPE FROM THE ANGRA NUCLEAR REACTOR FROM WHICH SEAWATER USED TO COOL THE POWER PLANT IS POURED BACK INTO THE SEA. A POPULAR SWIMMING SPOT BECAUSE OF THE WARMED WATER, THERE IS NO WARNING SIGN. BRAZIL.

image ANGRA 1 AND 2 NUCLEAR POWER STATION. IF BNP PARIBAS FINANCING GOES AHEAD, A THIRD REACTOR ANGRA 3 WILL BE BUILT USING DANGEROUSLY OBSOLETE TECHNOLOGY BURDENING BRAZIL WITH A REACTOR THAT WOULD NOT BE PERMITTED IN THE COUNTRIES THAT ARE FINANCING IT.

latin america: transport

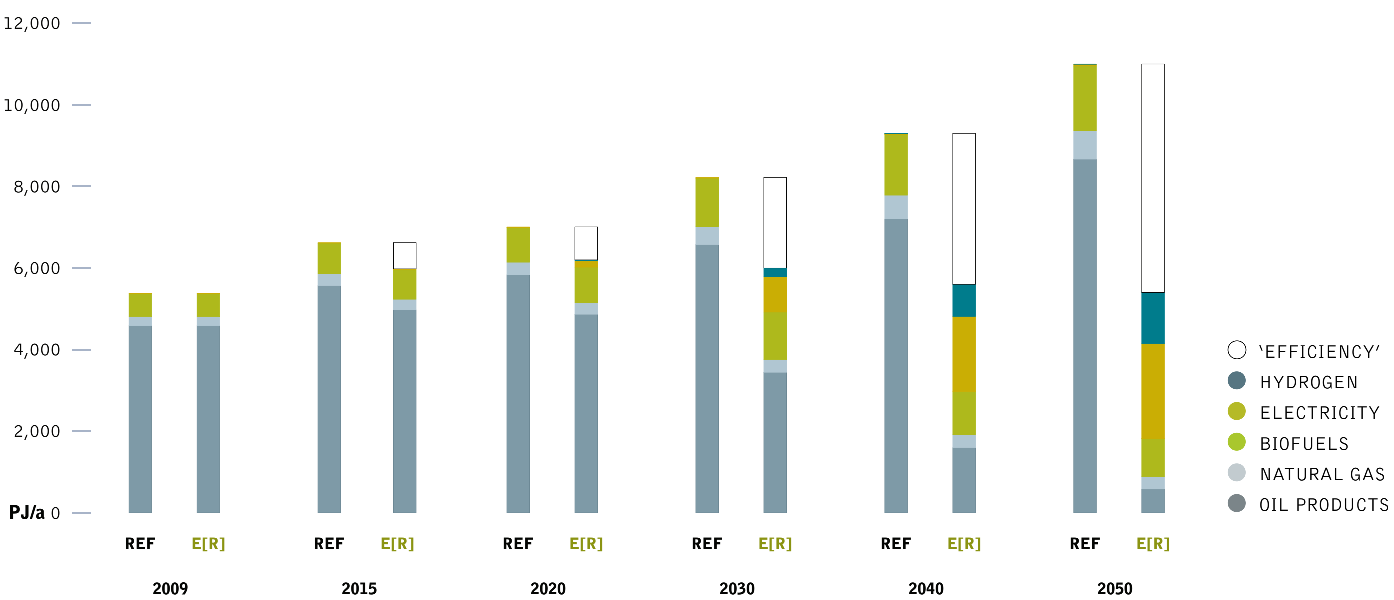
Despite a huge growth in transport services, the energy consumption in the transport sector by 2050 can be limited to the current level in the Energy [R]evolution scenario. Dependency on fossil fuels, which now account for 89% of this supply, is gradually transformed by using 15% renewable energy by 2030 and 35% by 2030. The electricity share in the transport sector further increases up to 21% by 2050.

A shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains and a reduction of vehicle kilometres travelled per year leads to significant energy savings. In 2030, electricity will provide 14% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 43%.

table 5.17: latin america: transport energy demand by mode under the reference scenario and the energy [r]evolution scenario (WITHOUT ENERGY FOR PIPELINE TRANSPORT) IN PJ/A

		2009	2020	2030	2040	2050
Rail	REF	106	140	164	186	220
	E[R]	106	174	240	336	432
Road	REF	4,995	6,458	7,526	8,447	9,844
	E[R]	4,995	5,649	5,319	4,763	4,482
Domestic aviation	REF	152	238	329	437	561
	E[R]	152	222	280	328	309
Domestic navigation	REF	111	145	170	192	330
	E[R]	111	132	143	159	166
Total	**REF**	5,364	6,982	8,189	9,263	10,955
	E[R]	5,364	6,177	5,982	5,586	5,389

figure 5.41: latin america: final energy consumption for transport under the reference scenario and the energy [r]evolution scenario



latin america

latin america: development of CO_2 emissions

While Latin America's emissions of CO_2 will almost double under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 972 million tonnes in 2009 to 155 million tonnes in 2050. Annual per capita emissions will drop from 2.1 tonnes to 1.2 tonnes in 2030 and 0.3 tonne in 2050. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will even reduce emissions in the transport sector. With a share of 38% of CO_2 emissions in 2050, the transport sector will remain the largest source of emissions. By 2050, Latin America's CO_2 emissions are 27% of 1990 levels.

latin america: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 5.43. Compared to the Reference scenario, overall primary energy demand will be reduced by 28% in 2050. Latin America's primary energy demand will increase from 22,045 PJ/a to about 29,500 PJ/a.

The Energy [R]evolution version phases out coal and oil about 5 to 10 years faster than the previous Energy [R]evolution scenario published in 2010. This is made possible mainly by replacement of fossil-fueled power plants with renewables and a faster introduction of very efficient electric vehicles in the transport sector to replace conventional combustion engines. This leads to an overall renewable primary energy share of 57% in 2030 and 85% in 2050. Nuclear energy is phased out before 2030.

figure 5.42: latin america: development of CO_2 emissions by sector under the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

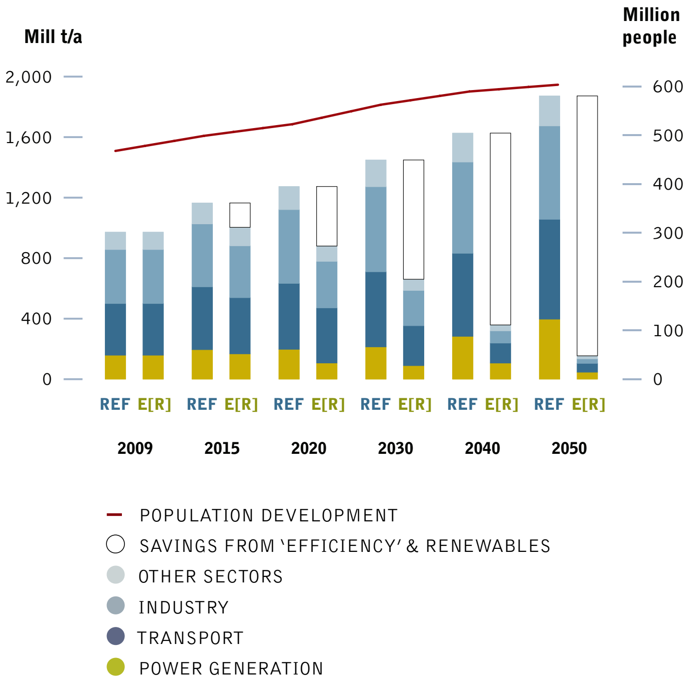


figure 5.43: latin america: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

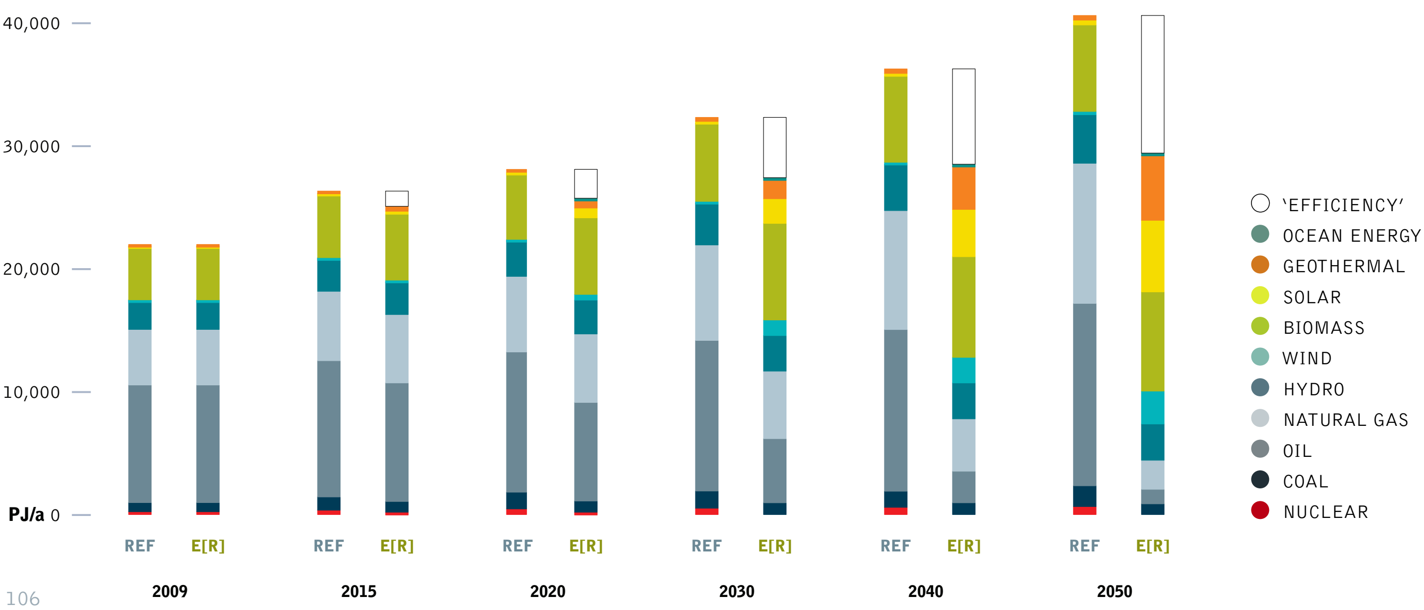


image CONSTRUCTION OF THE BELO MONTE DAM PROJECT, NEAR ALTAMIRA. THE BELO MONTE DAM WILL BE THE THIRD LARGEST IN THE WORLD, SUBMERGING 400,000 HECTARES AND DISPLACING 20,000 PEOPLE. THE CONTROVERSIAL HYDROPOWER PLANT IS BEING BUILT IN THE XINGU RIVER. FOR 20 YEARS INDIGENOUS GROUPS, RURAL COMMUNITIES AND ENVIRONMENTALISTS HAVE FOUGHT AGAINST THE CONSTRUCTION. THE AERIAL IMAGES EXPOSE THE MASSIVE CONSTRUCTION AND CONSIDERABLE ENVIRONMENTAL DESTRUCTION THAT HAS NOT YET BEEN DOCUMENTED VISUALLY; THIS IS ONE OF THE FIRST COMPELLING IMAGES TO BE CIRCULATED OF THE IMPACTS OF THE CONSTRUCTION.

image A 5-YEAR-OLD BOY IN TAMAQUITO, NEAR THE OPEN CAST CERREJON ZONA NORTE COAL MINE, ONE OF THE LARGEST IN THE WORLD. LIKE MANY HE SUFFERS SKIN RASHES FROM THE EFFECTS OF THE MINE DUST.

table 5.18a: latin america: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

INVESTMENT COSTS	$	2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion $	-47.4	-28.7	-45.2	-45.2	-207.5	-5.2
Renewables	billion $	197.2	318.2	560.5	560.5	1,760.7	44.0
Total	billion $	**149.8**	**289.5**	**515.2**	**515.2**	**1,553.2**	**38.8**
CUMULATIVE FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion $/a	23.7	87.0	80.3	85.2	276.1	6.9
Gas	billion $/a	30.6	105.6	340.2	983.2	1,459.6	36.5
Hard coal	billion $/a	6.7	21.4	31.6	53.9	113.5	2.8
Lignite	billion $/a	0.2	0.7	0.8	0.9	2.7	0.1
Total	billion $/a	**46.2**	**162.1**	**342.0**	**848.2**	**1,398.6**	**35.0**

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oecd europe: energy demand by sector

The future development pathways for Europe's energy demand are shown in Figure 5.44 for the Reference and the Energy [R]evolution scenario. Under the Reference scenario, total primary energy demand in OECD Europe increases by 9% from the current 75,200 PJ/a to 82,080 PJ/a in 2050. The energy demand in 2050 in the Energy [R]evolution scenario decreases by 36% compared to current consumption and it is expected by 2050 to reach 47,800 PJ/a.

Under the Energy [R]evolution scenario, electricity demand in the industry as well as in the residential and service sectors is expected to decrease after 2015 (see Figure 5.45). Because of the growing shares of electric vehicles, heat pumps and hydrogen generation however, electricity demand increases to 3,470 TWh/a in 2050, still 21% below the Reference case.

Efficiency gains in the heat supply sector are larger than in the electricity sector. Under the Energy [R]evolution scenario, final demand for heat supply can even be reduced significantly (see Figure 5.47). Compared to the Reference scenario, consumption equivalent to 8,921 PJ/a is avoided through efficiency measures by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

figure 5.44: oecd europe: total final energy demand by sector under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

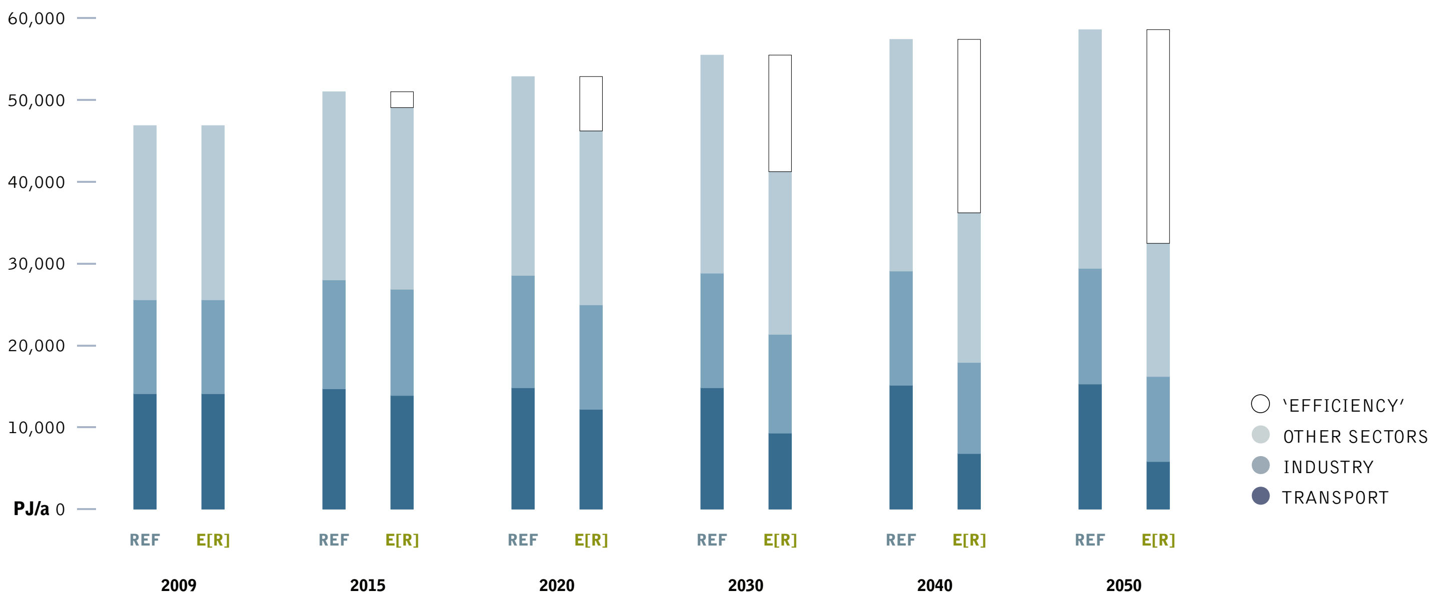


image PLANT NEAR REYKJAVIK WHERE ENERGY IS PRODUCED FROM THE GEOTHERMAL ACTIVITY.

image WORKERS EXAMINE PARABOLIC TROUGH COLLECTORS IN THE PS10 SOLAR TOWER PLANT AT SAN LUCAR LA MAYOR OUTSIDE SEVILLE, SPAIN, 2008.

figure 5.45: oecd europe: development of electricity demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

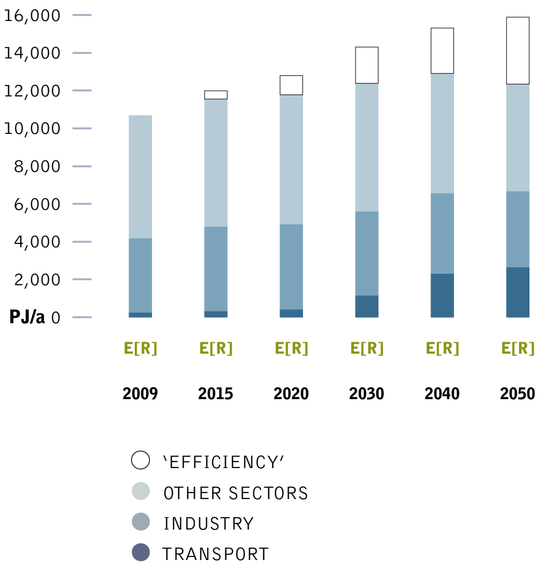


figure 5.47: oecd europe: development of heat demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

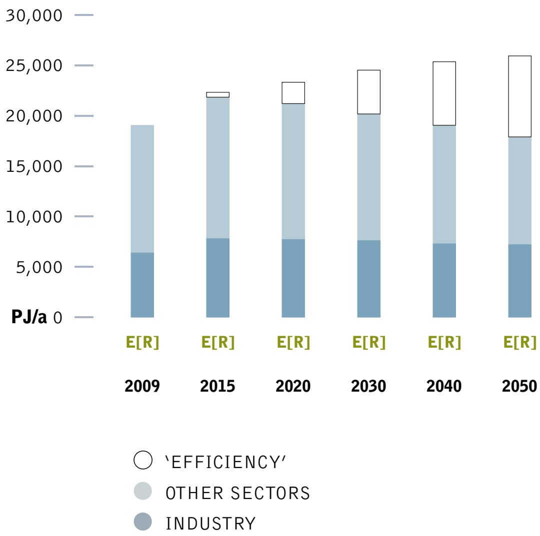
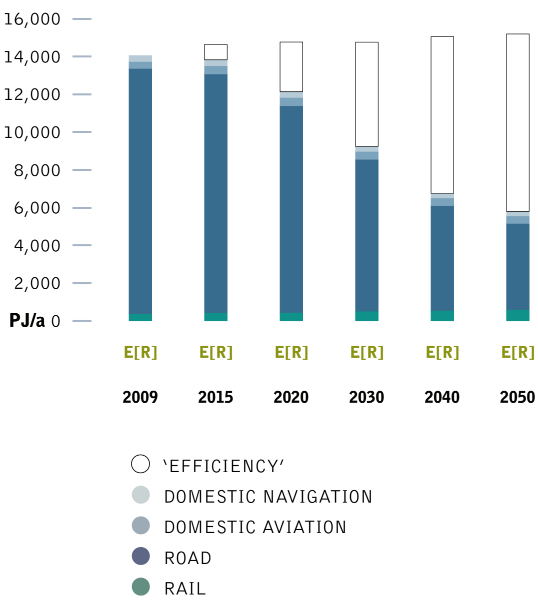


figure 5.46: oecd europe: development of the transport demand by sector in the energy [r]evolution scenario



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oecd europe: electricity generation

The development of the electricity supply market is charaterised by a dynamically growing renewable energy market. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 96% of the electricity produced in OECD Europe will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 71% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 49% already by 2020 and 71% by 2030. The installed capacity of renewables will reach 1038 GW in 2030 and 1,498 GW by 2050.

Table 5.19 shows the comparative evolution of the different renewable technologies in OECD Europe over time. Up to 2020 hydro and wind will remain the main contributors of the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaics and solar thermal (CSP) energy. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 37% by 2030, therefore the expansion of smart grids, demand side management (DSM) and storage capacity e.g. from the increased share of electric vehicles will be used for a better grid integration and power generation management.

table 5.19: oecd europe: renewable electricity generation capacity under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Hydro	REF	193	210	220	227	234
	E[R]	193	207	215	218	219
Biomass	REF	21	30	37	43	49
	E[R]	21	48	60	72	70
Wind	REF	76	195	256	295	313
	E[R]	76	276	414	496	516
Geothermal	REF	2	3	3	4	5
	E[R]	2	8	30	45	53
PV	REF	14	45	79	115	152
	E[R]	14	197	270	489	518
CSP	REF	0	2	4	5	6
	E[R]	0	12	32	55	82
Ocean energy	REF	0	0	2	9	11
	E[R]	0	3	18	31	40
Total	**REF**	**306**	**486**	**602**	**699**	**770**
	E[R]	**306**	**750**	**1,038**	**1,407**	**1,498**

figure 5.48: oecd europe: electricity generation structure under the reference scenario and the energy [r]evolution scenario (INCLUDING ELECTRICITY FOR ELECTROMOBILITY, HEAT PUMPS AND HYDROGEN GENERATION)

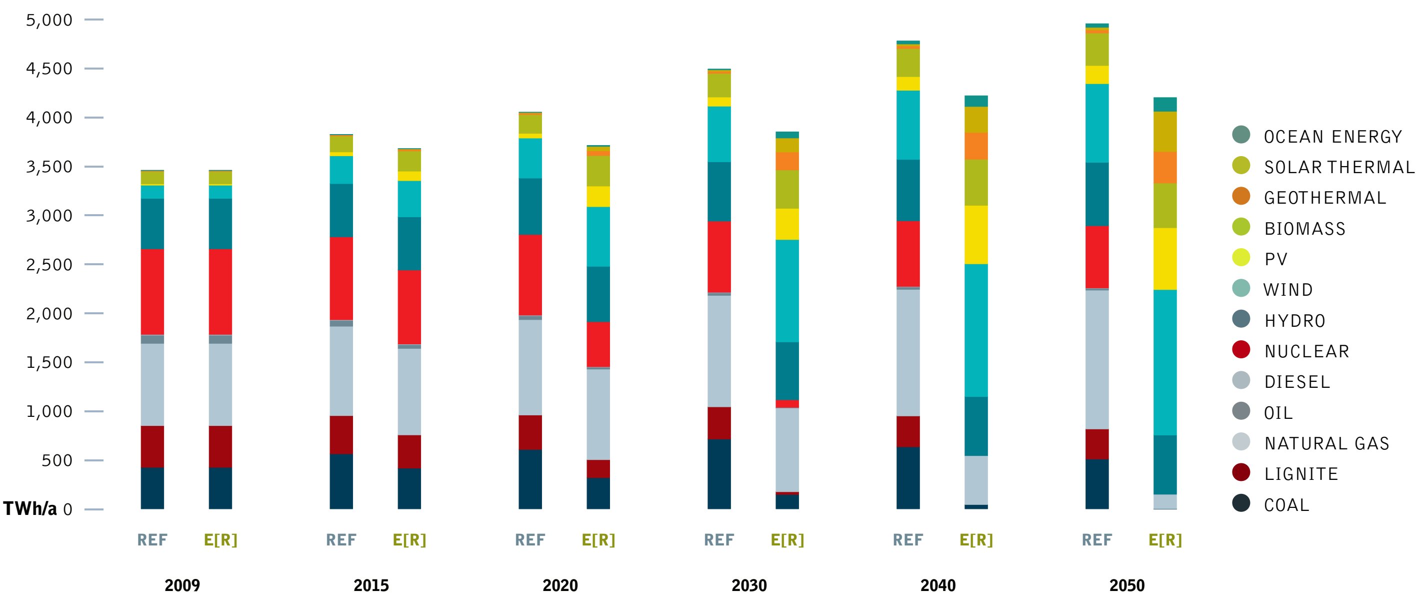


image OFFSHORE WINDFARM, MIDDELGRUNDEN, COPENHAGEN, DENMARK.

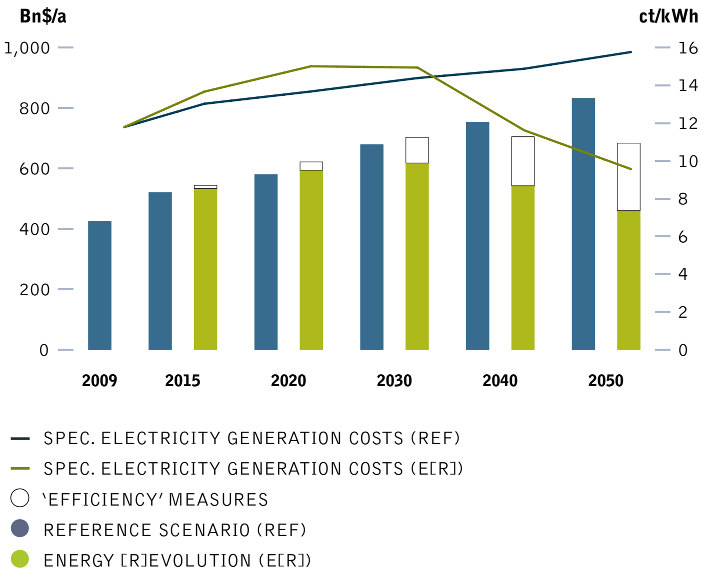
image MAN USING METAL GRINDER ON PART OF A WIND TURBINE MAST IN THE VESTAS FACTORY, CAMBELTOWN, SCOTLAND, GREAT BRITAIN.

oecd europe: future costs of electricity generation

Figure 5.49 shows that the introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the costs of electricity generation in OECD Europe compared to the Reference scenario. This difference will be less than $ 1.3 cent/kWh up to 2020, however. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be $ 6.2 cents/kWh below those in the Reference version.

Under the Reference scenario, the unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $ 426 billion per year to more than $ 832 billion in 2050. Figure 5.49 shows that the Energy [R]evolution scenario not only complies with OECD Europe's CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are 18% lower than in the Reference scenario, although costs for efficiency measures of up to $ 4 cents/kWh are taken into account.

figure 5.49: oecd europe: total electricity supply costs and specific electricity generation costs under two scenarios



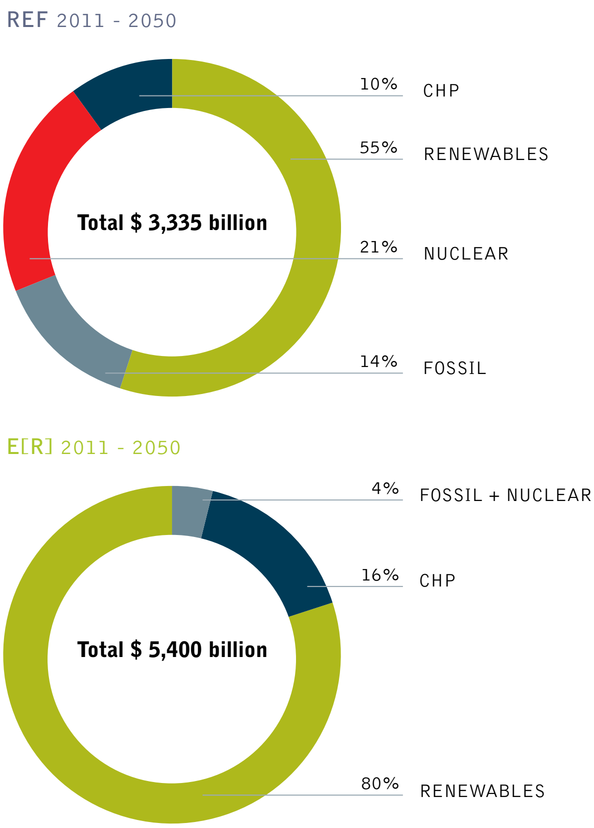
oecd europe: future investments in the power sector

It would require about $ 5,400 billion in investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately $ 2,065 billion or $ 52 billion annually more than in the Reference scenario ($ 3,335 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 35% while approximately 65% would be invested in renewable energy and cogeneration (CHP) until 2050.

Under the Energy [R]evolution scenario, however, OECD Europe would shift almost 96% of the entire investment towards renewables and cogeneration. Until 2030, the fossil fuel share of power sector investment would be focused mainly on CHP plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately $ 135 billion.

Because renewable energy has no fuel costs, however, the fuel cost savings in the Energy [R]evolution scenario reach a total of $ 4,760 billion up to 2050, or $ 119 billion per year. The total fuel cost savings based on the assumed energy price path therefore would cover 230% of the total additional investments compared to the Reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.

figure 5.50: oecd europe: investment shares - reference scenario versus energy [r]evolution scenario



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oecd europe: heating supply

Renewables currently provide 14% of OECD Europe's energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large scale utilisation of geothermal and solar thermal energy. In the Energy [R]evolution scenario, renewables provide 48% of OECD Europe's total heat demand in 2030 and 92% in 2050.

- Energy efficiency measures can decrease the current total demand for heat supply by at least 10%, in spite of growing population and economic activities and improving living standards.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for fossil fuel-fired systems.
- The introduction of strict efficiency measures e.g. via strict building standards and ambitious support programs for renewable heating systems are needed to achieve economies of scale within the next 5 to 10 years.

Table 5.20 shows the development of the different renewable technologies for heating in OECD Europe over time. Up to 2020 biomass will remain the main contributors of the growing market share. After 2020, the continuing growth of solar collectors and a growing share of geothermal heat pumps will reduce the dependence on fossil fuels.

table 5.20: oecd europe: renewable heating capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	2,413	3,291	3,865	4,456	4,907
	E[R]	2,413	4,170	4,265	4,061	3,580
Solar collectors	REF	64	204	332	459	586
	E[R]	64	954	2,697	4,441	5,675
Geothermal	REF	186	261	336	475	568
	E[R]	186	1,345	2,781	5,012	6,741
Hydrogen	REF	0	0	0	0	0
	E[R]	0	0	1	37	204
Total	**REF**	**2,662**	**3,756**	**4,533**	**5,390**	**6,061**
	E[R]	**2,662**	**6,469**	**9,744**	**13,551**	**16,199**

figure 5.51: oecd europe: heat supply structure under the reference scenario and the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

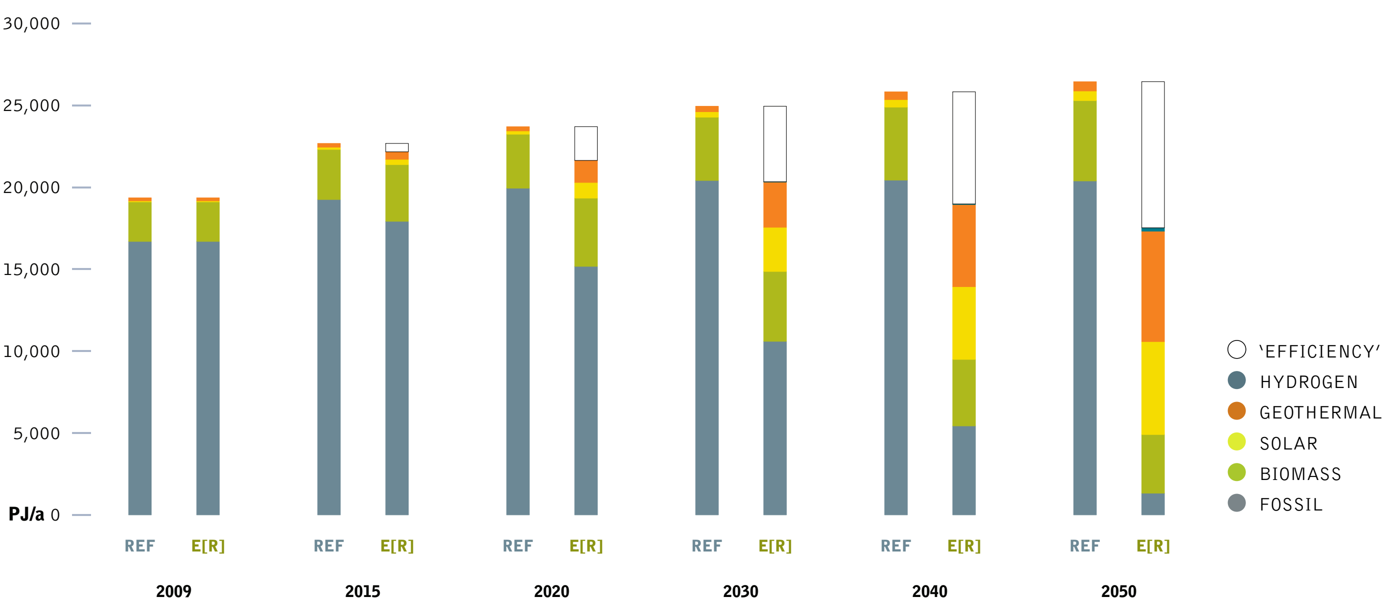


image INSTALLATION AND TESTING OF A WINDPOWER STATION IN RYSUMER NACKEN NEAR EMDEN WHICH IS MADE FOR OFFSHORE USAGE ONSHORE. A WORKER CONTROLS THE SECURITY LIGHTS AT DARK.

image THE MARANCHON WIND FARM IS THE LARGEST IN EUROPE WITH 104 GENERATORS, AND IS OPERATED BY IBERDROLA, THE LARGEST WIND ENERGY COMPANY IN THE WORLD.

oecd europe: future investments in the heat sector

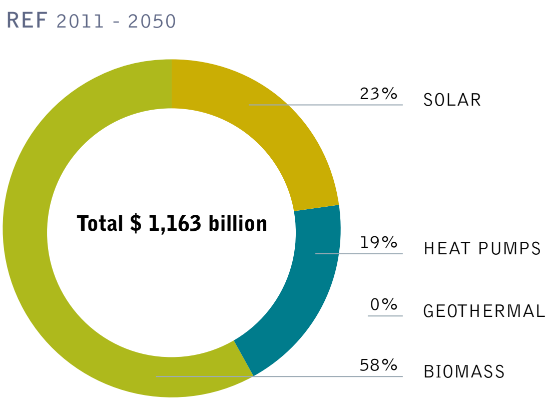
Also in the heat sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially the not yet so common solar, geothermal and heat pump technologies need enormous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity needs to be increased by a factor of 70 for solar thermal and even by the factor of 510 for geothermal and heat pumps. Capacity of biomass technologies, which are already rather wide spread still need to remain a pillar of heat supply.

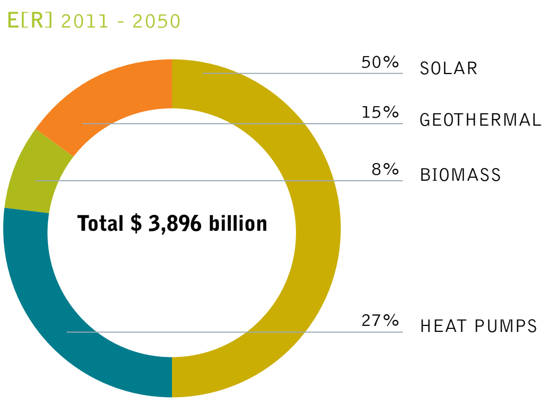
Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar thermal district heating plants with seasonal storage.Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around $ 3,896 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately $ 97 billion per year. Due to a lack of (regional) information on costs for conventional heating systems and fuel prices, total investments and fuel cost savings for the heat supply in the scenarios have not been estimated.

table 5.21: oecd europe: renewable heat generation capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	390	481	569	653	709
	E[R]	390	523	506	435	354
Geothermal	REF	1	1	1	1	1
	E[R]	1	93	214	396	495
Solar thermal	REF	21	67	108	150	191
	E[R]	21	279	781	1,209	1,513
Heat pumps	REF	32	45	58	84	101
	E[R]	32	114	204	296	420
Total	**REF**	443	593	737	888	1,002
	E[R]	443	1,009	1,705	2,336	2,782

figure 5.52: oecd europe: investments for renewable heat generation technologies under the reference scenario and the energy [r]evolution scenario





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oecd europe: future employment in the energy sector

The Energy [R]evolution scenario results in more energy sector jobs in OECD Europe at every stage of the projection.

- There are 1.8 million energy sector jobs in the Energy [R]evolution scenario in 2015, and 1.2 million in the Reference scenario.
- In 2020, there are 1.6 million jobs in the Energy [R]evolution scenario, and 1.1 million in the Reference scenario.
- In 2030, there are 1.4 million jobs in the Energy [R]evolution scenario and 1 million in the Reference scenario.

Figure 5.53 shows the change in job numbers under both scenarios for each technology between 2010 and 2030. Jobs in the coal sector decline in both scenarios, leading to an overall decline of 19% in energy sector jobs in the Reference scenario.

Exceptionally strong growth in renewable energy leads to an increase of 43% in total energy sector jobs in the Energy [R]evolution scenario by 2015. Renewable energy accounts for 72% of energy jobs by 2030, with biomass having the greatest share (22%), followed by solar PV, wind and solar heating.

figure 5.53: oecd europe: employment in the energy scenario under the reference and energy [r]evolution scenarios

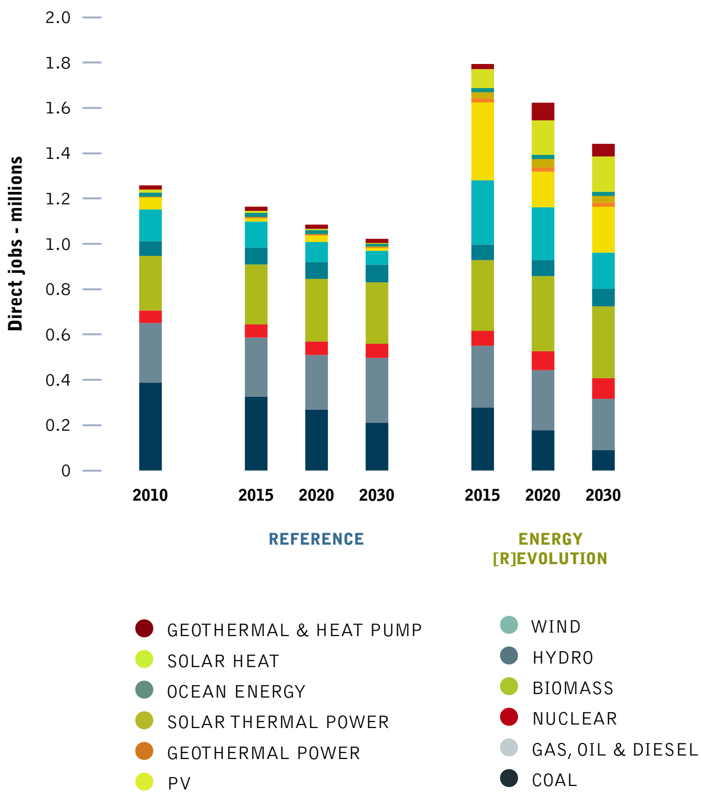

table 5.22: oecd europe: total employment in the energy sector THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	387	326	269	211	278	177	91
Gas, oil & diesel	264	261	241	286	272	265	226
Nuclear	55	58	60	62	66	84	91
Renewable	552	519	516	463	1,177	1,097	1,034
Total Jobs	**1,258**	**1,164**	**1,085**	**1,022**	**1,794**	**1,623**	**1,442**
Construction and installation	161	114	97	83	415	370	391
Manufacturing	158	103	72	44	421	330	263
Operations and maintenance	222	239	254	253	262	293	289
Fuel supply (domestic)	717	708	662	642	696	629	498
Coal and gas export	-	-	-	-	-	-	-
Total Jobs	**1,258**	**1,164**	**1,085**	**1,022**	**1,794**	**1,623**	**1,442**

image THE PIONEERING REYKJANES GEOTHERMAL POWER PLANT USES STEAM AND BRINE FROM A RESERVOIR AT 290 TO 320°C, WHICH IS EXTRACTED FROM 12 WELLS THAT ARE 2,700 METERS DEEP. THIS IS THE FIRST TIME THAT GEOTHERMAL STEAM OF SUCH HIGH TEMPERATURE HAS BEEN USED FOR ELECTRICAL GENERATION. THE REYKJANES GEOTHERMAL POWER PLANT GENERATES 100 MWE FROM TWO 50 MWE TURBINES, WITH AN EXPANSION PLAN TO INCREASE THIS BY AN ADDITIONAL 50 MWE BY THE END OF 2010.

image RENEWABLE ENERGY FACILITIES ON A FORMER US-BASE IN MORBACH, GERMANY. MIXTURE OF WIND, BIOMASS AND SOLAR POWER RUN BY THE JUWI GROUP.


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oecd europe: transport

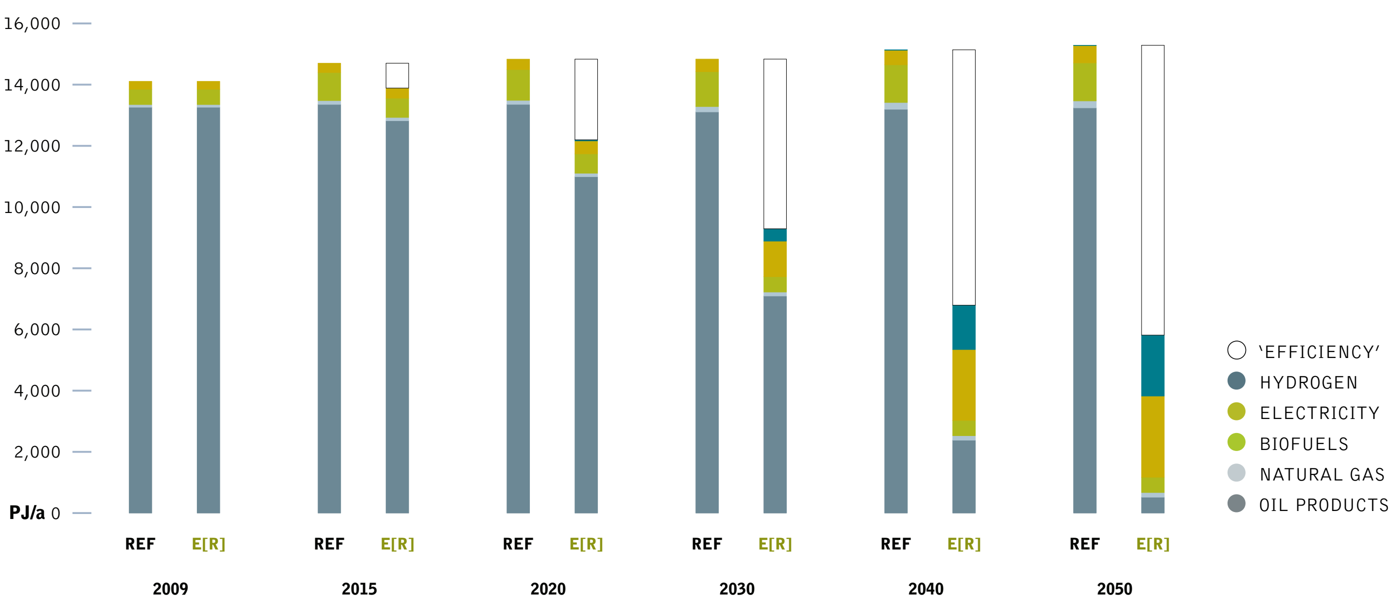
In the transport sector, it is assumed under the Energy [R]evolution scenario that an energy demand reduction of about 9,500 PJ/a can be achieved by 2050, saving 62% compared to the Reference scenario. Energy demand will therefore decrease between 2009 and 2050 by 59% to 5,800 PJ/a. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility related behaviour patterns. Implementing a mix of increased public transport as attractive alternatives to individual cars, the car stock is growing slower and annual person kilometres are lower than in the Reference scenario.

A shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains and the reduction of vehicle kilometres travelled lead to significant energy savings. In 2030, electricity will provide 13% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 46%.

table 5.23: oecd europe: transport energy demand by mode under the reference scenario and the energy [r]evolution scenario (WITHOUT ENERGY FOR PIPELINE TRANSPORT) IN PJ/A

		2009	2020	2030	2040	2050
Rail	REF	389	430	482	537	581
	E[R]	389	457	520	562	596
Road	REF	12,984	13,535	13,460	13,675	13,757
	E[R]	12,984	10,939	8,040	5,543	4,572
Domestic aviation	REF	368	475	491	507	518
	E[R]	368	442	420	410	392
Domestic navigation	REF	315	331	331	338	341
	E[R]	315	303	265	247	240
Total	**REF**	**14,055**	**14,771**	**14,764**	**15,057**	**15,198**
	E[R]	**14,055**	**12,141**	**9,244**	**6,762**	**5,800**

figure 5.54: oecd europe: final energy consumption for transport under the reference scenario and the energy [r]evolution scenario



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oecd europe: development of CO_2 emissions

While CO_2 emissions in OECD Europe will decrease by 4% in the Reference scenario, under the Energy [R]evolution scenario they will decrease from around 3,800 million tonnes in 2009 to 192 million tonnes in 2050. Annual per capita emissions will drop from 6.8 tonnes to 2.9 tonnes in 2030 and 0.3 tonne in 2050. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will reduce emissions in the transport sector. With a share of 28% of CO_2 emissions in 2050, the power sector will drop below transport and other sectors as the largest sources of emissions. By 2050, OECD Europe's CO_2 emissions are 5% of 1990 levels.

oecd europe: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 5.56. Compared to the Reference scenario, overall primary energy demand will be reduced by 43% in 2050. Around 85% of the remaining demand will be covered by renewable energy sources.

The Energy [R]evolution version phases out coal and oil about 10 to 15 years faster than the previous Energy [R]evolution scenario published in 2010. This is made possible mainly by the replacement of coal power plants with renewables and a faster introduction of very efficient electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 46% in 2030 and 85% in 2050. Nuclear energy is phased out just after 2030.

figure 5.55: oecd europe: development of CO_2 emissions by sector under the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

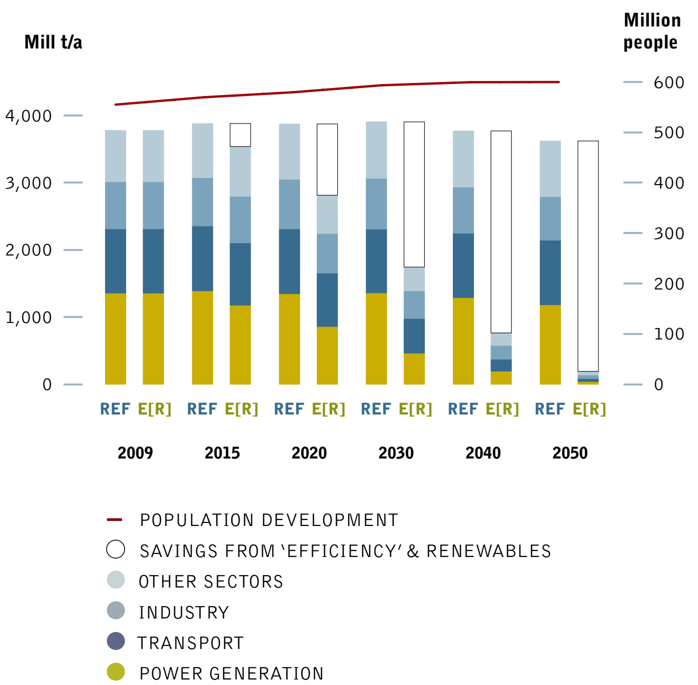

figure 5.56: oecd europe: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

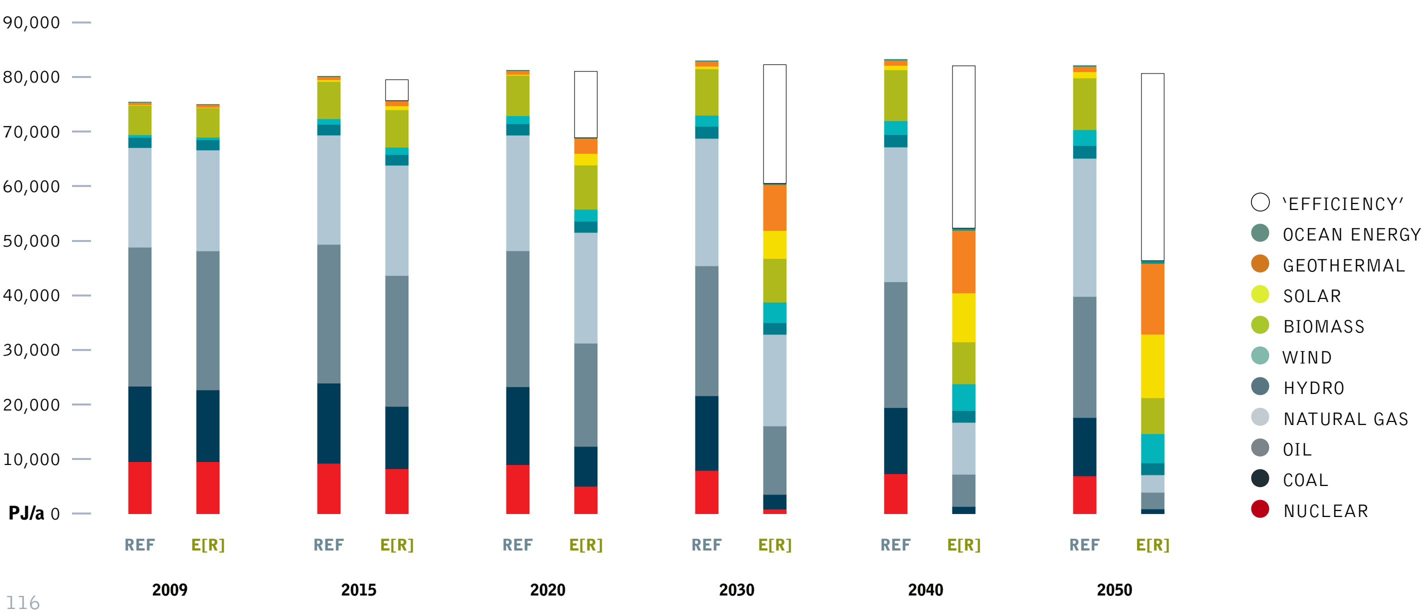

image TESTING THE SCOTRENEWABLES TIDAL TURBINE OFF KIRWALL IN THE ORKNEY ISLANDS.

image GEMASOLAR IS A 15 MWE SOLAR-ONLY POWER TOWER PLANT, EMPLOYING MOLTEN SALT TECHNOLOGIES FOR RECEIVING AND STORING ENERGY. IT'S 16 HOUR MOLTEN SALT STORAGE SYSTEM CAN DELIVER POWER AROUND THE CLOCK. IT RUNS AN EQUIVALENT OF 6,570 FULL HOURS OUT OF 8,769 TOTAL. GEMASOLAR IS OWNED BY TORRESOL ENERGY AND WAS COMPLETED IN MAY 2011. FUENTES DE ANDALUCÍA SEVILLE, SPAIN.


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table 5.24: oecd europe: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

INVESTMENT COSTS	$	2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion $	-309.0	-269.0	-221.5	-221.5	-1,005.2	-25.1
Renewables	billion $	785.5	677.3	996.3	996.3	3,071.1	76.8
Total	billion $	**476.5**	**408.3**	**774.8**	**774.8**	**2,065.9**	**51.6**

CUMULATIVE FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion $/a	39.9	62.1	68.3	59.3	229.5	5.7
Gas	billion $/a	-102.7	123.5	936.6	2,329.6	3,287.0	82.2
Hard coal	billion $/a	81.2	265.4	375.4	361.8	1,083.8	27.1
Lignite	billion $/a	11.8	43.1	50.7	53.9	159.5	4.0
Total	billion $/a	**30.2**	**494.0**	**1,430.9**	**2,804.6**	**4,759.8**	**119.0**

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africa: energy demand by sector

The future development pathways for Africa's energy demand are shown in Figure 5.57 for the Reference and the Energy [R]evolution scenario. Under the Reference scenario, total primary energy demand in Africa increases by 104% from the current 27,681 PJ/a to 56,500 PJ/a in 2050. In the Energy [R]evolution scenario, by contrast, energy demand increases by 53% compared to current consumption and it is expected by 2050 to reach 42,300 PJ/a.

Under the Energy [R]evolution scenario, electricity demand in the industrial, residential, and service sectors is expected to increase disproportionately (see Figure 5.58). With the exploitation of efficiency measures, however, an even higher increase can be avoided, leading to 2040 TWh/a in 2050. Compared to the Reference case, efficiency measures in industry and other sectors avoid the generation of about 500 TWh/a or 22%. In contrast, electricity consumption in the transport sector will grow significantly, as the Energy [R]evolution scenario introduces electric trains and public transport as well as efficient electric vehicles faster than the Reference case. Fossil fuels for industrial process heat generation are also phased out more quickly and replaced by electric heat pumps and hydrogen.

Efficiency gains in the heat supply sector are larger than in the electricity sector. Under the Energy [R]evolution scenario, final demand for heat supply can even be reduced significantly (see Figure 5.60). Compared to the Reference scenario, consumption equivalent to 4,820 PJ/a is avoided through efficiency measures by 2050.

In the transport sector it is assumed under the Energy [R]evolution scenario that energy demand will increase from 3,301 PJ/a in 2009 to 4,440 PJ/a by 2050. However this still saves 37% compared to the Reference scenario. By 2030 electricity will provide 4% of the transport sector's total energy demand in the Energy [R]evolution scenario increasing to 20% by 2050.

figure 5.57: africa: total final energy demand by sector under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

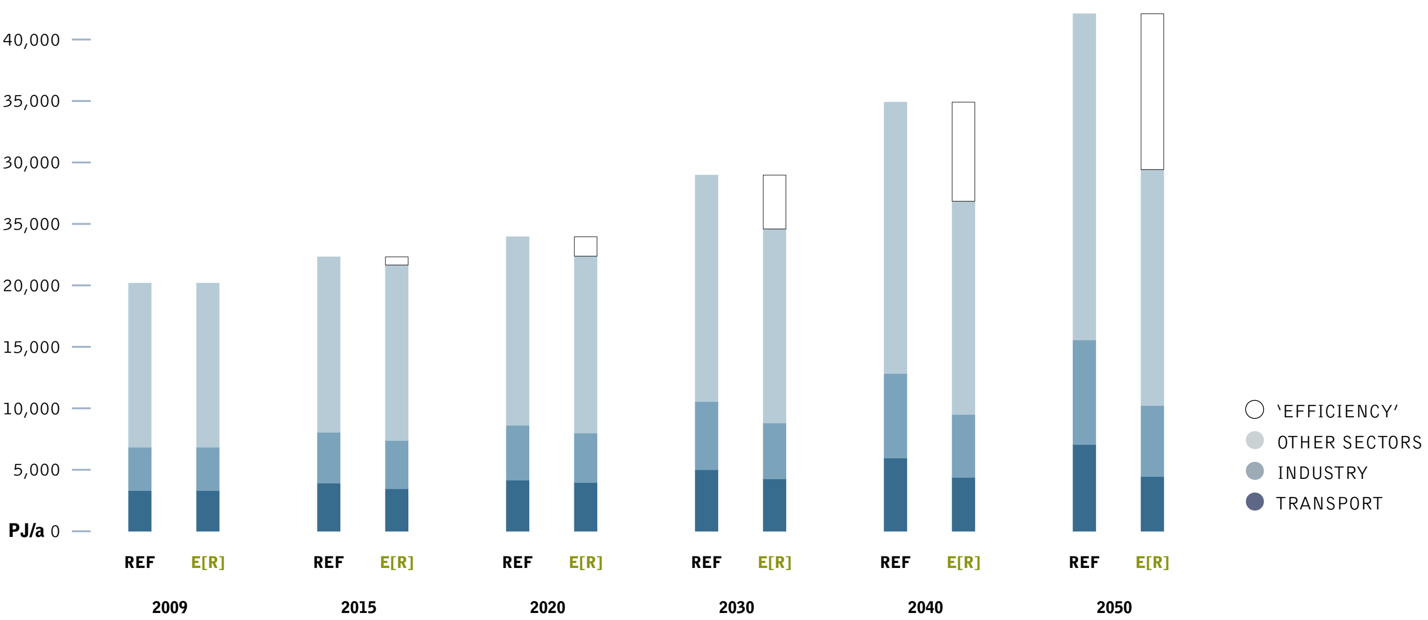

image GARIEP DAM, FREE STATE, SOUTH AFRICA.

image WOMEN FARMERS FROM LILONGWE, MALAWI STAND IN THEIR DRY, BARREN FIELDS CARRYING ON THEIR HEADS AID ORGANISATION HANDOUTS. THIS AREA, THOUGH EXTREMELY POOR HAS BEEN SELF-SUFFICIENT WITH FOOD. NOW THESE WOMEN'S CHILDREN ARE SUFFERING FROM MALNUTRITION.

figure 5.58: africa: development of electricity demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

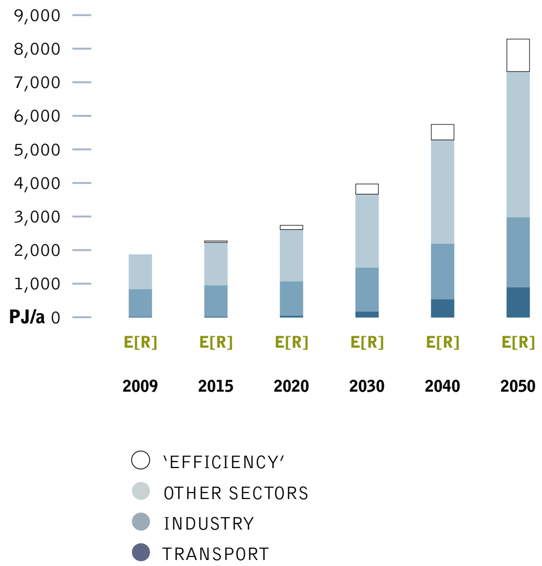

figure 5.60: africa: development of heat demand by sector in the energy [r]evolution scenario

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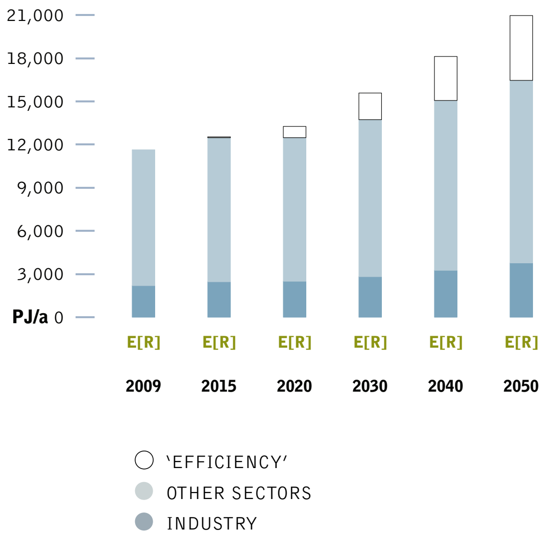
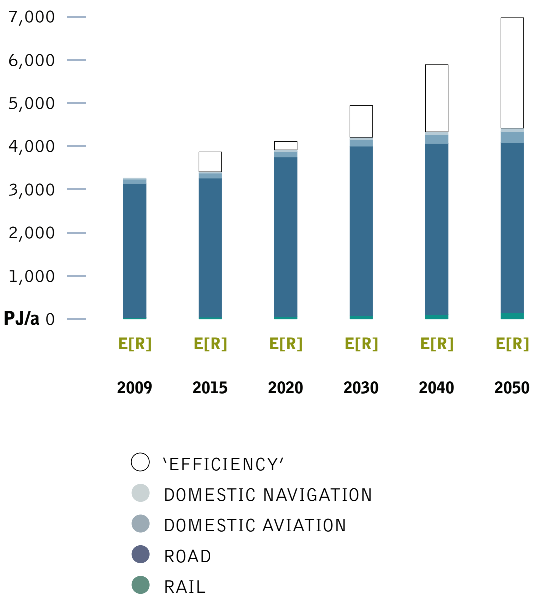


figure 5.59: africa: development of the transport demand by sector in the energy [r]evolution scenario



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africa: electricity generation

The development of the electricity supply market is characterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 92% of the electricity produced in Africa will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal power and PV – will contribute 71% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 34% already by 2020 and 62% by 2030. The installed capacity of renewables will reach 250 GW in 2030 and 639 GW by 2050, an enormous increase.

Table 5.25 shows the comparative evolution of the different renewable technologies in Africa over time. Up to 2020 hydro and wind will remain the main contributors of the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaics and solar thermal (CSP) energy. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 28% by 2030 and 40% by 2050, therefore the expansion of smart grids, demand side management (DSM) and increased storage capacity e.g. from the share of electric vehicles will be used for a better grid integration and power generation management.

table 5.25: africa: renewable electricity generation capacity under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Hydro	REF	25	37	53	73	93
	E[R]	25	39	45	49	50
Biomass	REF	0	2	5	10	15
	E[R]	0	4	8	9	10
Wind	REF	1	5	9	15	21
	E[R]	1	25	89	125	200
Geothermal	REF	0	1	1	3	4
	E[R]	0	3	12	23	38
PV	REF	0	4	11	22	33
	E[R]	0	12	49	90	155
CSP	REF	0	1	4	8	14
	E[R]	0	13	42	101	161
Ocean energy	REF	0	0	0	0	0
	E[R]	0	2	6	13	26
Total	**REF**	**26**	**49**	**84**	**131**	**179**
	E[R]	**26**	**97**	**250**	**410**	**639**

figure 5.61: africa: electricity generation structure under the reference scenario and the energy [r]evolution scenario (INCLUDING ELECTRICITY FOR ELECTROMOBILITY, HEAT PUMPS AND HYDROGEN GENERATION)

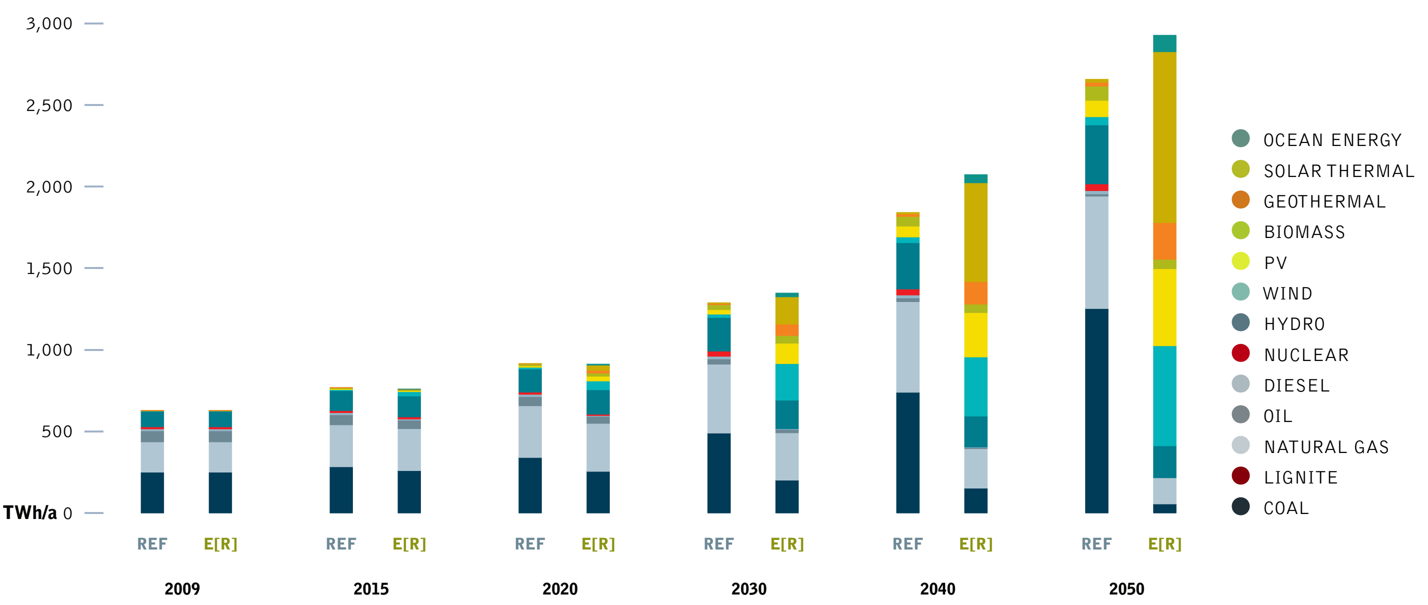


image FLOWING WATERS OF THE TUGELA RIVER IN NORTHERN DRAKENSBERG IN SOUTH AFRICA.

image A SMALL HYDRO ELECTRIC ALTERNATOR MAKES ELECTRICITY FOR A SMALL AFRICAN TOWN.

africa: future costs of electricity generation

Figure 5.62 shows that the introduction of renewable technologies under the Energy [R]evolution scenario does not increase the costs of electricity generation in Africa compared to the Reference scenario - assuming fossil fuel prices and investment costs according to the pathways defined in Chapter 4. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be $ 9.7 cents/kWh below those in the Reference version.

Under the Reference scenario, by contrast, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $ 85 billion per year to more than $ 493 billion in 2050. Figure 5.62 shows that the Energy [R]evolution scenario not only complies with Africa's CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are 31% lower than in the Reference scenario, including estimated costs for efficiency measures.

Under the Reference version, the levels of investment in conventional power plants add up to almost 40% while approximately 60% would be invested in renewable energy and cogeneration (CHP) until 2050. Under the Energy [R]evolution scenario, however, Africa would shift almost 97% of the entire investment towards renewables and cogeneration. Until 2030, the fossil fuel share of power sector investment would be focused mainly on CHP plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately $ 62 billion.

Because renewable energy has no fuel costs, however, the fuel cost savings in the Energy [R]evolution scenario reach a total of $ 2,596 billion up to 2050, or $ 65 billion per year. The total fuel cost savings therefore would cover almost 2 times the total additional investments compared to the Reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.

figure 5.62: africa: total electricity supply costs and specific electricity generation costs under two scenarios

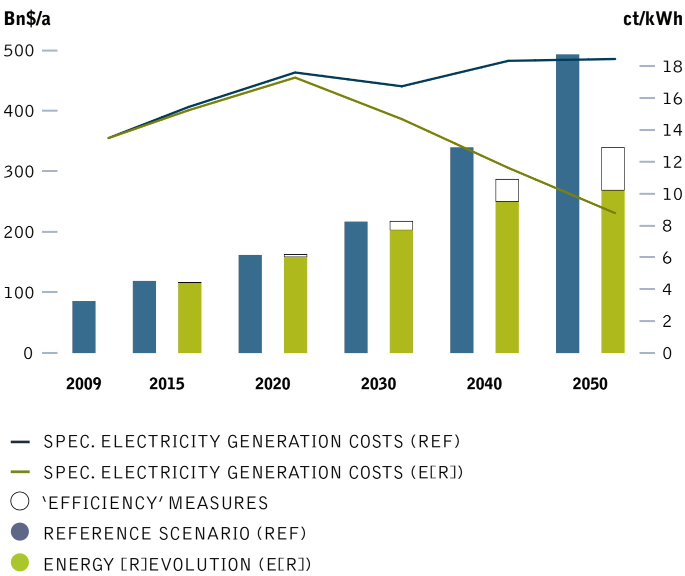
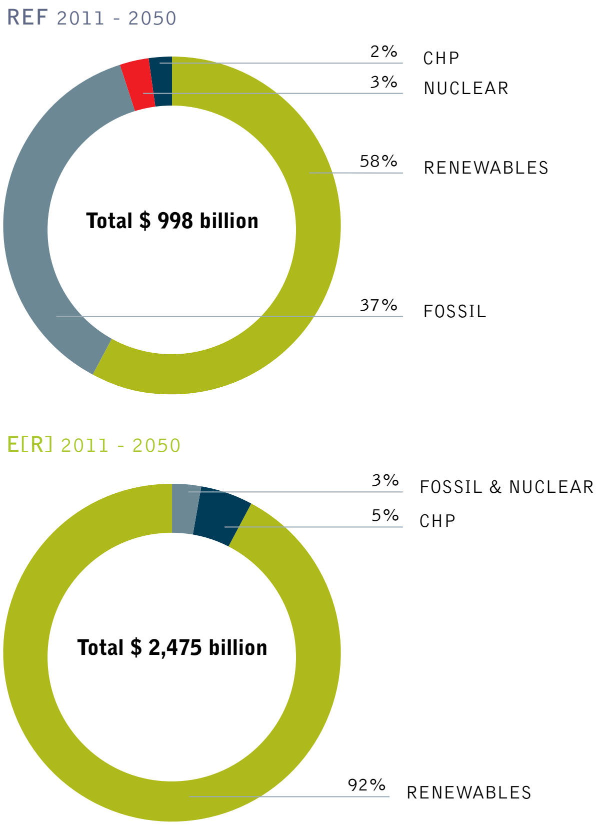


figure 5.63: africa: investment shares - reference scenario versus energy [r]evolution scenario



africa: future investments in the power sector

It would require $ 2,475 billion in investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately $ 62 billion annually or $ 37 billion more than in the Reference scenario ($ 998 billion).

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africa: heating supply

Today, renewables provide 79% of Africa's energy demand for heat supply, the main contribution coming from the traditional use of biomass. Dedicated support instruments are required to ensure a dynamic future development. In the Energy [R]evolution scenario, renewables provide 84% of Africa's total heat demand in 2030 and 93% in 2050.

- Energy efficiency measures will restrict the future energy demand for heat supply in 2020 to an increase of 18% compared to 34% in the Reference scenario, in spite of improving living standards.
- In the industry sector solar collectors, biomass/biogas as well as geothermal energy are increasingly substituted for conventional fossil-fired heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

Table 5.26 shows the development of the different renewable technologies for heating in Africa over time. Biomass will remain the main contributor of the growing market share. After 2020, the continuing growth of solar collectors and a growing share of geothermal energy and heat pumps will reduce the dependence on fossil fuels.

table 5.26: africa: renewable heating capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	9,148	10,169	11,517	13,196	14,900
	E[R]	9,148	8,999	8,918	8,698	7,893
Solar collectors	REF	3	8	57	111	166
	E[R]	3	791	2,143	3,306	5,004
Geothermal	REF	0	0	4	9	12
	E[R]	0	37	517	1,274	1,972
Hydrogen	REF	0	0	0	0	0
	E[R]	0	0	0	18	208
Total	**REF**	**9,150**	**10,178**	**11,578**	**13,315**	**15,077**
	E[R]	**9,150**	**9,827**	**11,577**	**13,296**	**15,077**

figure 5.64: africa: heat supply structure under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

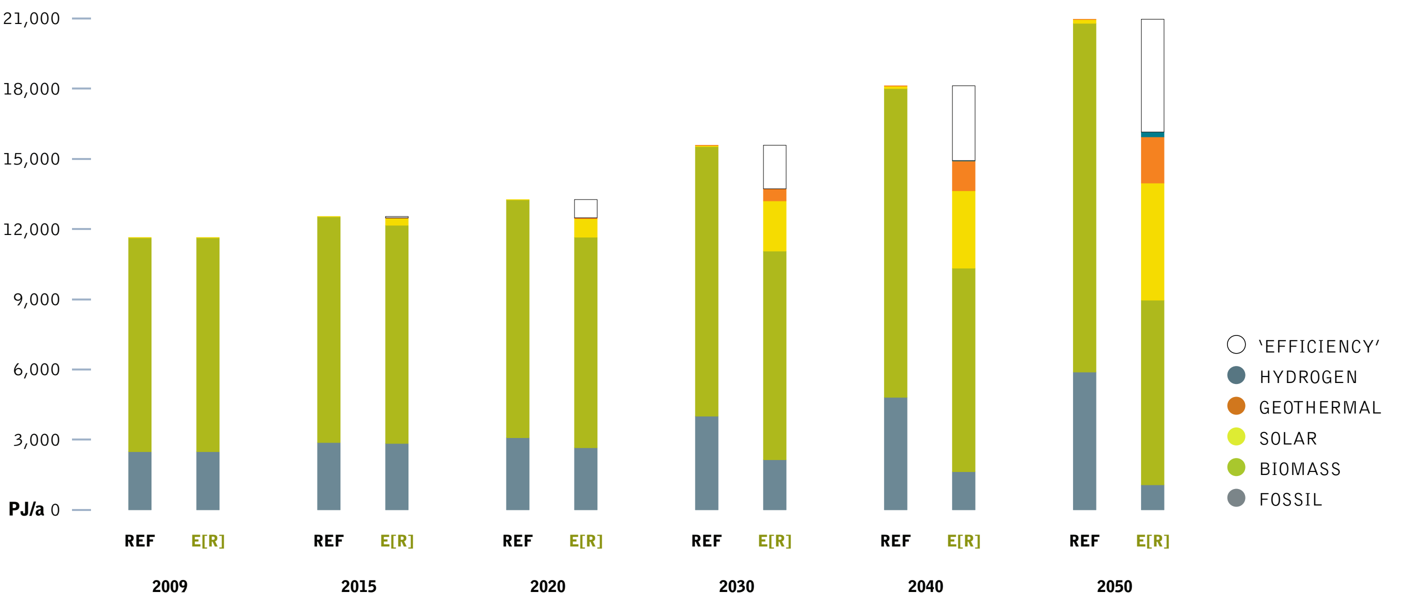


image MAMA SARA OBAMA, THE US PRESIDENT'S GRANDMOTHER, FLICKS ON THE LIGHTS AFTER A GREENPEACE TEAM INSTALLED A SOLAR POWER SYSTEM AT HER HOME IN KOGELO VILLAGE.

image STORM OVER SODWANA BAY, SOUTH AFRICA.

africa: future investments in the heat sector

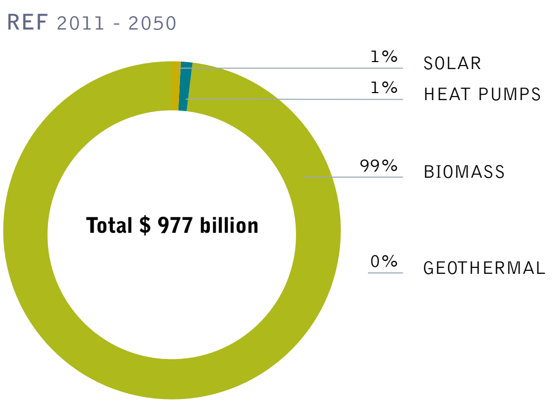
In the heat sector, the Energy [R]evolution scenario would require also a major revision of current investment strategies. Especially solar, geothermal and heat pump technologies need an enormous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity for direct heating (excluding district heating and CHP) need to be increased up to around 1,000 GW for solar thermal and up to 300 GW for geothermal and heat pumps. Capacity of biomass use for heat supply needs to remain a pillar of heat supply, however current traditional combustion systems need to be replaced by new efficient technologies.

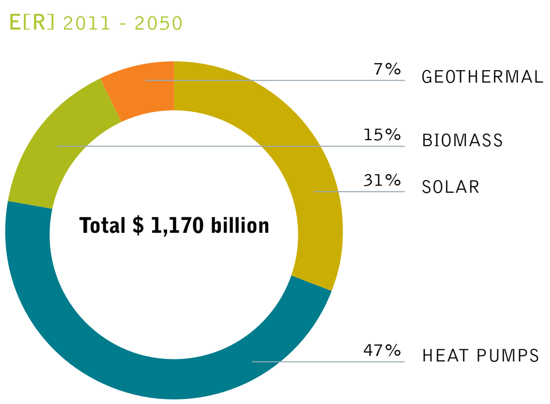
Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar thermal district heating plants with seasonal storage.Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around $ 1,170 billion to be invested in renewable direct heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately $ 29 billion per year.

table 5.27: africa: renewable heat generation capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	3,643	3,983	4,497	5,128	5,760
	E[R]	3,643	3,513	3,431	3,360	3,049
Geothermal	REF	0	0	0	0	0
	E[R]	0	2	8	13	29
Solar thermal	REF	1	2	12	23	34
	E[R]	1	163	441	680	1,030
Heat pumps	REF	0	0	1	2	2
	E[R]	0	1	67	173	251
Total	**REF**	**3,644**	**3,985**	**4,509**	**5,153**	**5,796**
	E[R]	**3,644**	**3,679**	**3,948**	**4,226**	**4,358**

figure 5.65: africa: investments for renewable heat generation technologies under the reference scenario and the energy [r]evolution scenario





africa

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africa: future employment in the energy sector

The Energy [R]evolution scenario results in more energy sector jobs in Africa at every stage of the projection.

- There are 3.5 million energy sector jobs in the Energy [R]evolution scenario in 2015, and 2.8 million in the Reference scenario.
- In 2020, there are 3.7 million jobs in the Energy [R]evolution scenario, and 3 million in the Reference scenario.
- In 2030, there are 3.5 million jobs in the Energy [R]evolution scenario and 3.2 million in the Reference scenario.

Figure 5.66 shows the change in job numbers under both scenarios for each technology between 2010 and 2030. Jobs in the Reference scenario increase by 16% by 2030. Bionergy accounts for the largest share of jobs in both scenarios.

Strong growth in renewable energy leads to an increase of 28% in energy sector jobs in the Energy [R]evolution scenario by 2015. Energy jobs increase to 36% above 2010 levels by 2020, and are still 28% above 2010 levels in 2030. Renewable energy accounts for 73% of energy sector jobs by 2030, with biomass having the largest share (46%), followed by solar heating.

figure 5.66: africa: employment in the energy scenario under the reference and energy [r]evolution scenarios

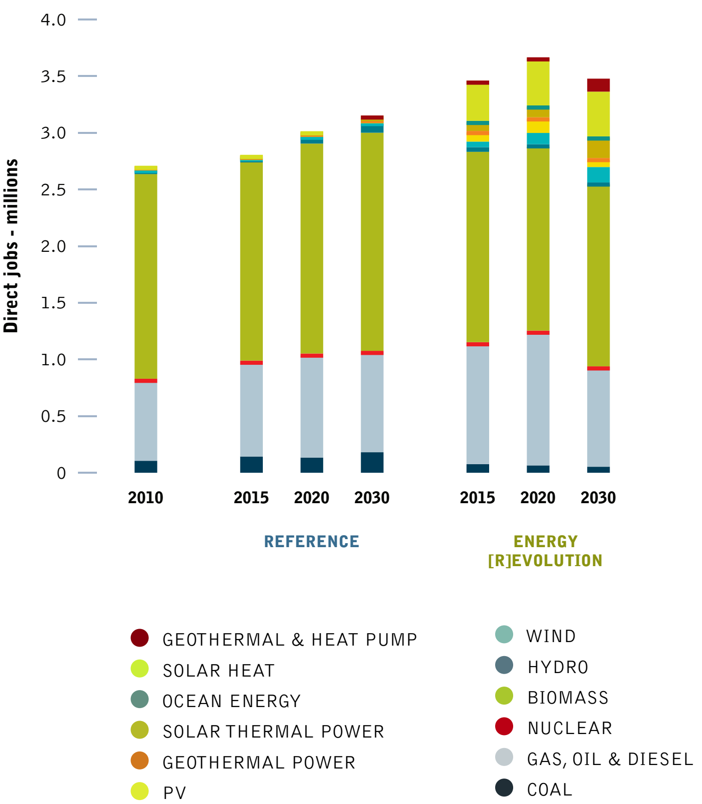


table 5.28: africa: total employment in the energy sector THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	106	143	134	181	76	65	53
Gas, oil & diesel	723	837	901	888	1,076	1,187	881
Nuclear	1	9	17	7	1	3	5
Renewable	1,880	1,816	1,962	2,077	2,309	2,412	2,539
Total Jobs	**2,709**	**2,806**	**3,014**	**3,153**	**3,461**	**3,667**	**3,478**
Construction and installation	100	110	142	164	514	614	595
Manufacturing	46	59	51	78	149	186	241
Operations and maintenance	42	56	73	108	63	114	219
Fuel supply (domestic)	2,123	2,096	2,217	2,336	2,091.0	2,048	2,049
Coal and gas export	398	485	531	466	645	705	374
Total Jobs	**2,709**	**2,806**	**3,014**	**3,153**	**3,461**	3,667	**3,478**

image A SOLAR COOKER BEING USED TO PREPARE POP CORN AT THE JERICHO COMMUNITY CENTER. A SOLAR POWERED PUBLIC VIEWING AREA WAS CREATED FOR THE WORLD CUP.

image ESKOM'S KUSILE POWER PLANT IN THE DELMAS MUNICIPAL AREA OF THE MPUMALANGA PROVINCE IS SET TO BECOME WORLDS FOURTH MOST POLLUTING POWER PLANT IN TERMS OF GREENHOUSE GAS EMISSIONS.

africa: transport

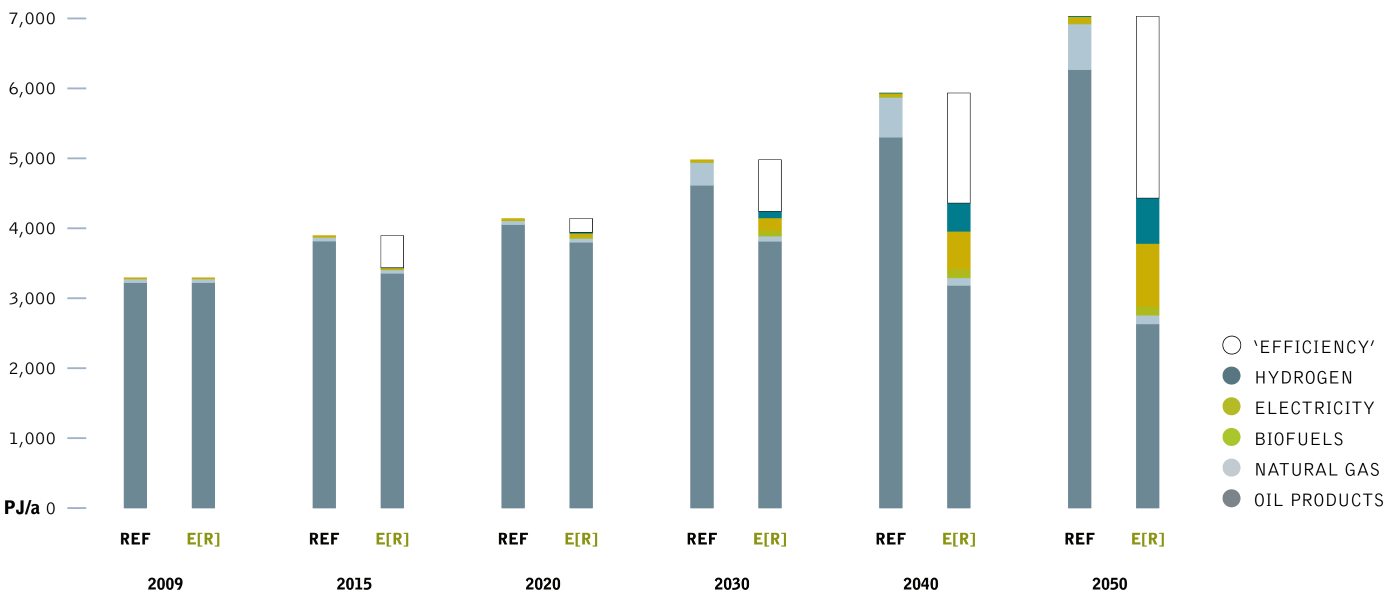
In 2050, the car fleet in Africa will be significantly larger than today. Today, a large share of old cars are driven in Africa. With growing individual mobility, an increasing share of small efficient cars is projected, with vehicle kilometres driven resembling industrialised countries averages. More efficient propulsion technologies, including hybrid-electric power trains, will help to limit the growth in total transport energy demand to a factor of 1.3, reaching 4,400 PJ/a in 2050. In Africa, the fleet of electric vehicles will grow to the point where almost 20% of total transport energy is covered by electricity.

By 2030 electricity will provide 4% of the transport sector's total energy demand under the Energy [R]evolution scenario. Under both scenario road transport volumes increases significantly. However, under the Energy [R]evolution scenario, the total energy demand for road transport increases from 3,100 PJ/a in 2009 to 3,940 PJ/a in 2050, compared to 6,390 PJ/a in the Reference case.

table 5.29: africa: transport energy demand by mode under the reference scenario and the energy [r]evolution scenario (WITHOUT ENERGY FOR PIPELINE TRANSPORT) IN PJ/A

		2009	2020	2030	2040	2050
Rail	REF	36	45	52	61	73
	E[R]	36	52	74	103	143
Road	REF	3,096	3,897	4,655	5,493	6,393
	E[R]	3,096	3,697	3,926	3,961	3,943
Domestic aviation	REF	105	130	177	257	410
	E[R]	105	127	155	200	254
Domestic navigation	REF	28	38	56	76	98
	E[R]	28	38	52	68	79
Total	**REF**	**3,264**	**4,110**	**4,941**	**5,887**	**6,974**
	E[R]	**3,264**	**3,914**	**4,207**	**4,332**	**4,420**

figure 5.67: africa: final energy consumption for transport under the reference scenario and the energy [r]evolution scenario



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africa: development of CO_2 emissions

Whilst Africa's emissions of CO_2 will increase by 157% under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 928 million tonnes in 2009 to 381 million tonnes in 2050. Annual per capita emissions will increase from 0.9 tonne to 0.8 tonne in 2030 and decrease afterward to 0.2 tonne in 2050. In the long run efficiency gains and the increased use of renewable electricity in vehicles will also significantly reduce emissions in the transport sector. With a share of 51% of CO_2 emissions in 2050, the transport sector will be the largest energy related source of emissions. By 2050, Africa's CO_2 emissions are 70% of 1990 levels.

africa: primary energy consumption

Taking into account the above assumptions, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 5.69. Compared to the Reference scenario, overall primary energy demand will be reduced by 23% in 2050. Around 84% of the remaining demand will be covered by renewable energy sources.

The coal demand in the Energy [R]evolution scenario will peak by 2020 with 3,700 PJ/a compared to 4,560 PJ/a in 2009 and decrease afterwards to 869 PJ/a by 2050. This is made possible mainly by replacement of coal power plants with renewables after 20 rather than 40 years lifetime. This leads to an overall renewable primary energy share of 63% in 2030 and 84% in 2050. Nuclear energy is phased out before 2030.

figure 5.68: africa: development of CO_2 emissions by sector under the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

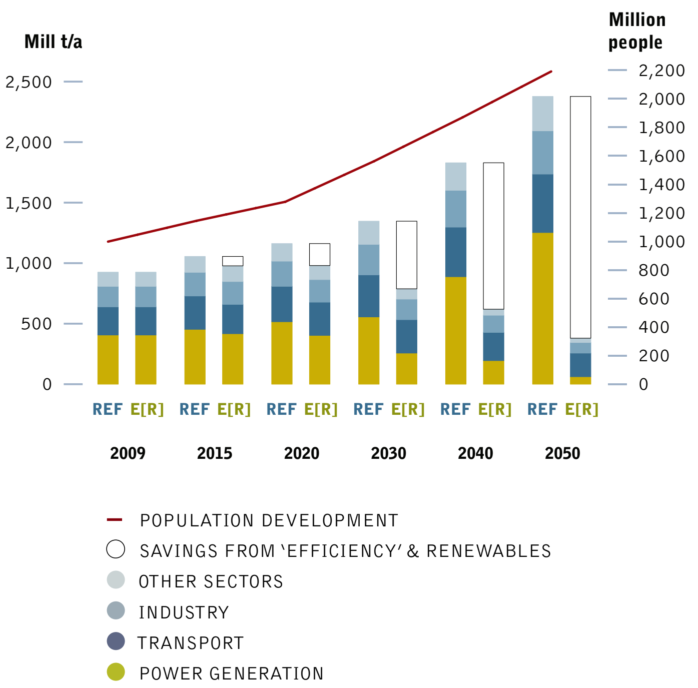

figure 5.69: africa: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

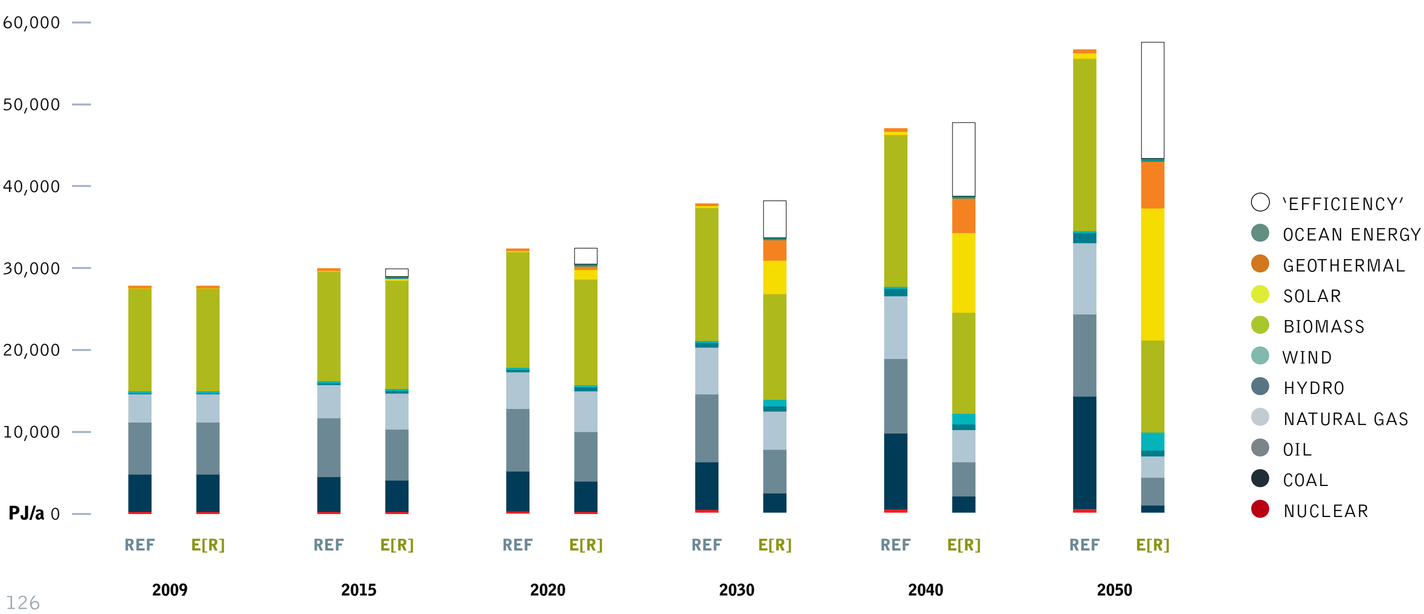

image PANORAMIC VIEW OF THE SOMAIR URANIUM MINE IN ARLIT, OPERATED BY FRENCH COMPANY AREVA.

image CRACKED SOIL IN AKOKAN.

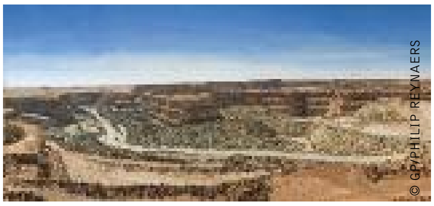

table 5.30: africa: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

INVESTMENT COSTS	$	2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion $	-27.0	-64.1	-69.9	-69.9	-301.1	-7.5
Renewables	billion $	182.9	375.9	463.2	463.2	1,778.7	44.5
Total	billion $	**155.9**	**311.7**	**393.3**	**393.3**	**1,477.5**	**36.9**

CUMULATIVE FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion $/a	18.7	30.6	37.8	40.4	127.5	3.2
Gas	billion $/a	7.6	98.5	392.4	967.2	1,465.7	36.6
Hard coal	billion $/a	19.9	100.5	256.6	626.1	1,003.0	25.1
Lignite	billion $/a	0.0	0.0	0.0	0.0	0.0	0.0
Total	billion $/a	**46.2**	**229.6**	**686.9**	**1,633.7**	**2,596.3**	**64.9**

middle east

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middle east: energy demand by sector

The future development pathways for Middle East's energy demand are shown in Figure 5.70 for the Reference and the Energy [R]evolution scenario. Under the Reference scenario, total primary energy demand in Middle East increases by 104% from the current 24,750 PJ/a to about 50,600 PJ/a in 2050. The energy demand in 2050 in the Energy [R]evolution scenario increases by 9% compared to current consumption and it is expected by 2050 to reach 27,100 PJ/a.

Under the Energy [R]evolution scenario, electricity demand in the industry as well as in the residential, and service sectors is expected to stagnate after 2020 (see Figure 5.71). Because of the growing use of electric vehicles however, electricity consumption increases strongly to 1,958 TWh/a by 2050 just 10% below the electricity demand of the Reference case.

Efficiency gains in the heat supply sector are larger than in the electricity sector. Under the Energy [R]evolution scenario, final demand for heat supply can eventually even be reduced significantly (see Figure 5.73). Compared to the Reference scenario, consumption equivalent to 1,939 PJ/a is avoided through efficiency measures by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

figure 5.70: middle east: total final energy demand by sector under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

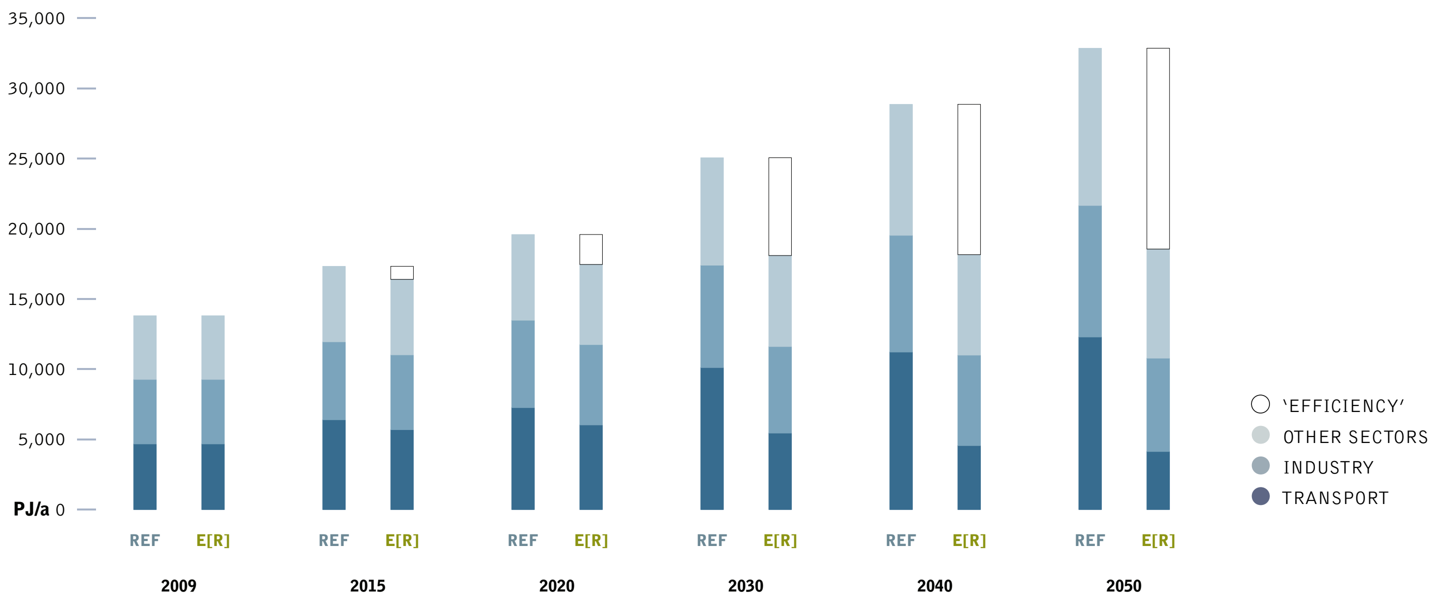


image A LARGE POWER PLANT ALONG THE ROCKY COASTLINE IN CAESAREA, ISRAEL.

image WIND TURBINES IN THE GOLAN HEIGHTS IN ISRAEL.

figure 5.71: middle east: development of electricity demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

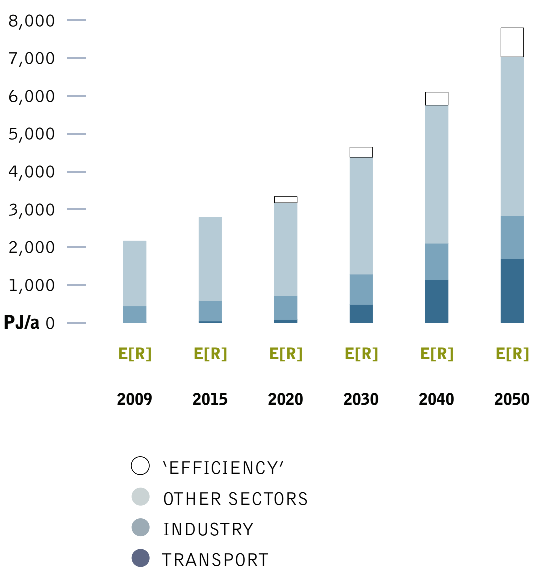


figure 5.73: middle east: development of heat demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

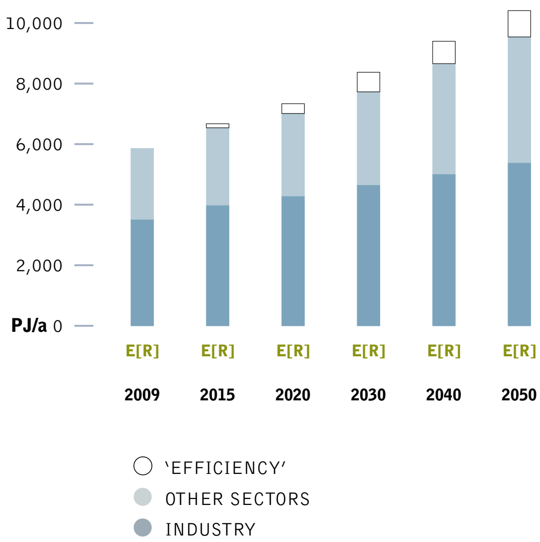
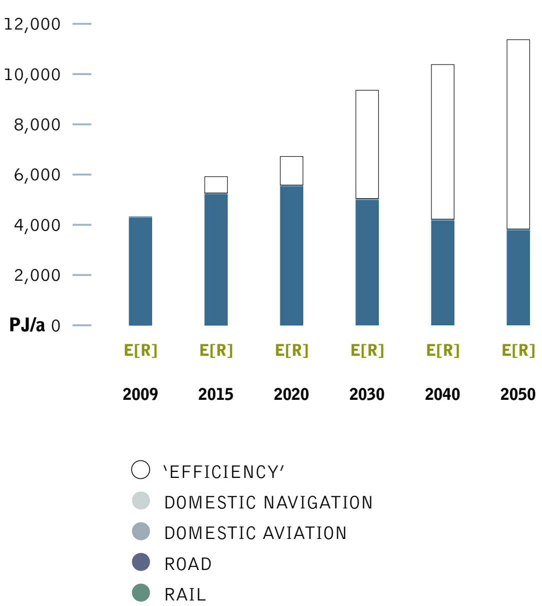


figure 5.72: middle east: development of the transport demand by sector in the energy [r]evolution scenario



middle east

middle east: electricity generation

The development of the electricity supply market is charaterised by a dynamically growing renewable energy market. This will compensate for the phasing out of nuclear energy, reduce the number of fossil fuel-fired power plants required for grid stabilisation and will cover the demand for additionally necessary storable fuels such as hydrogen (increasing to more than 900 TWh in 2050). By 2050, 98% of the electricity produced in Middle East will come from renewable energy sources. 'New' renewables – mainly wind, PV and solar thermal energy – will contribute 94% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 27% already by 2020 and 62% by 2030. The installed capacity of renewables will reach 412 GW in 2030 and 1089 GW by 2050.

Table 5.31 shows the comparative evolution of the different renewable technologies in Middle East over time. Up to 2020 wind, photovoltaics and solar thermal power will overtake hydro as the main contributor of the growing market share. After 2020, the continuing growth of wind, PV and CSP will be complemented by electricity from geothermal and ocean energy. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 32% by 2030, therefore the expansion of smart grids, demand side management (DSM) and new storage capacities e.g. from the increased share of electric vehicles will be used for a better grid integration and power generation management.

table 5.31: middle east: renewable electricity generation capacity under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Hydro	REF	6	18	24	25	28
	E[R]	6	18	24	25	28
Biomass	REF	0	1	1	2	3
	E[R]	0	2	4	6	8
Wind	REF	0	2	5	10	14
	E[R]	0	31	106	181	283
Geothermal	REF	0	0	0	0	0
	E[R]	0	2	4	16	20
PV	REF	0	2	8	11	16
	E[R]	0	47	162	340	474
CSP	REF	0	1	3	4	6
	E[R]	0	25	102	146	235
Ocean energy	REF	0	0	0	0	0
	E[R]	0	4	9	29	41
Total	**REF**	6	25	42	52	67
	E[R]	6	130	412	742	1,089

figure 5.74: middle east: electricity generation structure under the reference scenario and the energy [r]evolution scenario (INCLUDING ELECTRICITY FOR ELECTROMOBILITY, HEAT PUMPS AND HYDROGEN GENERATION)

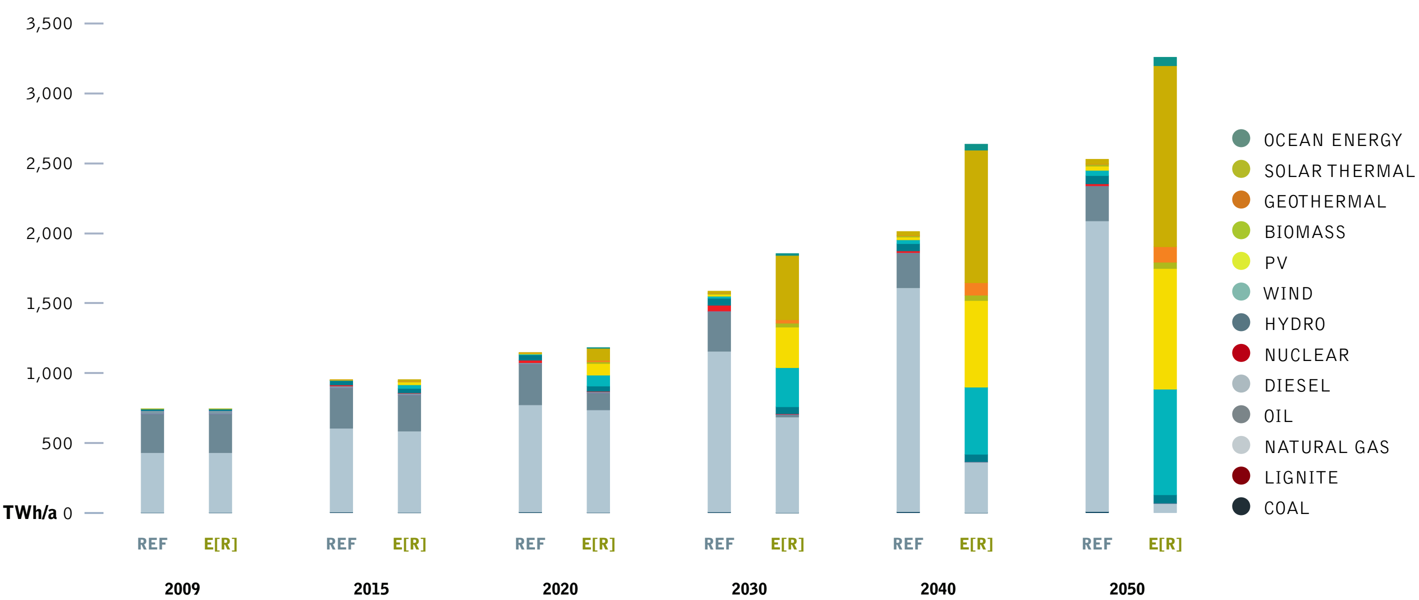
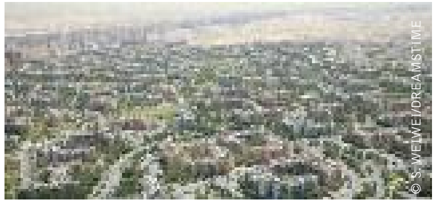


image THE BAHRAIN WORLD TRADE CENTER IN MANAMA GENERATES PART OF ITS OWN ENERGY USING WIND TURBINES.

image SUBURBS OF DUBAI, UNITED ARAB EMIRATES.



middle east: future costs of electricity generation

Figure 5.75 shows that the introduction of renewable technologies under the Energy [R]evolution scenario does not increase the costs of electricity generation in Middle East compared to the Reference scenario - if fossil fuel prices and investment costs are assumed according to the pathways defined in Chapter 4. Because of the lower CO_2 intensity of electricity generation and the high share of gas power plants in the Reference scenario, electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be about 20 cents/kWh below those in the Reference version.

Under the Reference scenario, the unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $ 146 billion per year to more than $ 751 billion in 2050. Figure 5.75 shows that the Energy [R]evolution scenario not only complies with Middle East's CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are 44% lower in 2050 than in the Reference scenario.

Under the Reference version, the levels of investment in conventional power plants add up to almost 66% while approximately 34% would be invested in renewable energy and cogeneration (CHP) until 2050. Under the Energy [R]evolution scenario, however, Middle East would shift almost 96% of the entire investment towards renewables and cogeneration.

Until 2030, the fossil fuel share of power sector investment would be focused mainly on CHP plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately $ 96 billion.

Because renewable energy except biomass has no fuel costs, however, the fuel cost savings in the Energy [R]evolution scenario reach a total of $ 8,281 billion up to 2050, or $ 207 billion per year. The total fuel cost savings therefore would cover 270% of the total additional investments compared to the Reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for fossil fuels will continue to be a burden on national economies.

figure 5.75: middle east: total electricity supply costs and specific electricity generation costs under two scenarios

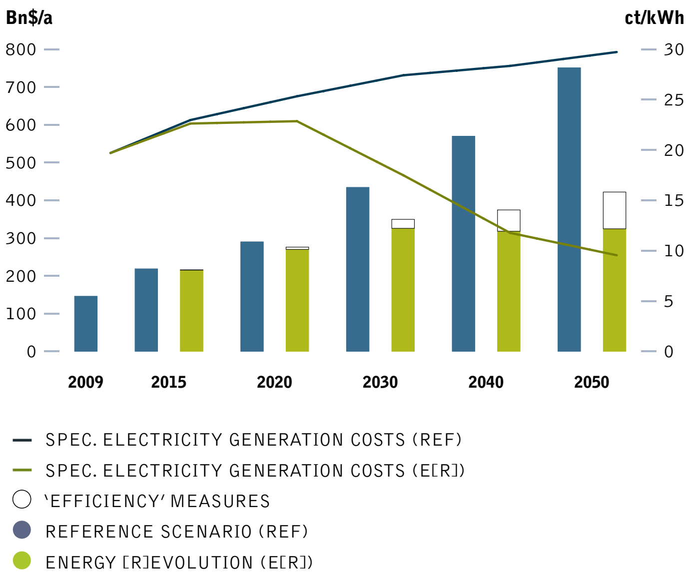
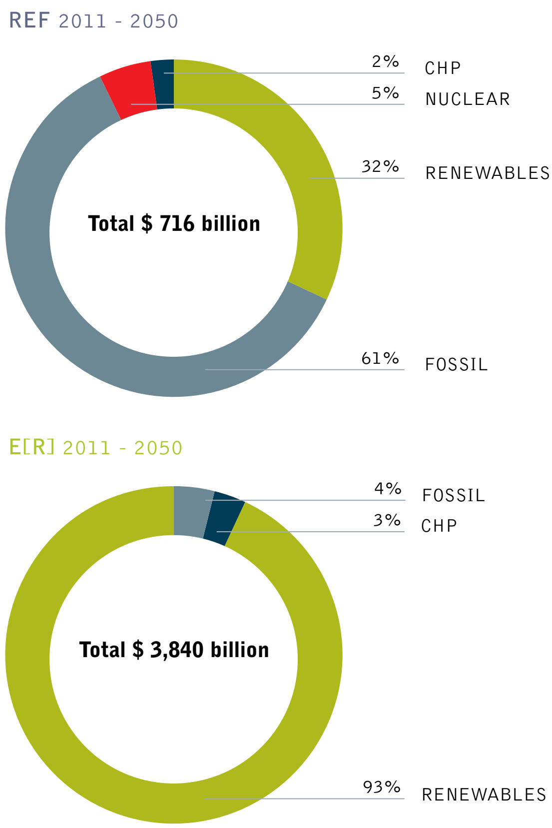


figure 5.76: middle east: investment shares - reference scenario versus energy [r]evolution scenario



middle east: future investments in the power sector

It would require $ 3,840 billion in investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately $ 3,124 billion or $ 78 billion annually more than in the Reference scenario ($ 716 billion).

middle east

middle east: heating supply

Renewables currently provide 0.5% of Middle East's energy demand for heat supply, the main contribution coming from the use of biomass. In the Energy [R]evolution scenario, renewables provide 34% of Middle East's total heat demand in 2030 and 89% in 2050.

- Energy efficiency measures can lower specific process heat consumption and can therefore limit demand increase in a region with a fast growing population and increasing industrial activities.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for fossil fuel-fired systems.
- The introduction of strict efficiency measures e.g. via ambitious support programs for renewable heating systems are needed to achieve economies of scale within the next 5 to 10 years.

Table 5.32 shows the development of the different renewable technologies for heating in Middle East over time. Up to 2020 solar energy becomes the main contributor of the growing market share. After 2020, the continuing growth of solar collectors and a growing share of geothermal energy and heat pumps can significantly reduce the dependence on fossil fuels.

table 5.32: middle east: renewable heating capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	20	32	48	69	77
	E[R]	20	100	203	394	508
Solar collectors	REF	5	62	90	113	151
	E[R]	5	571	1,449	2,954	4,426
Geothermal	REF	1	3	7	14	39
	E[R]	1	216	538	1,026	1,708
Hydrogen	REF	0	0	0	0	0
	E[R]	0	145	504	754	890
Total	**REF**	**27**	**97**	**146**	**196**	**267**
	E[R]	**27**	**1,032**	**2,694**	**5,127**	**7,531**

figure 5.77: middle east: heat supply structure under the reference scenario and the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

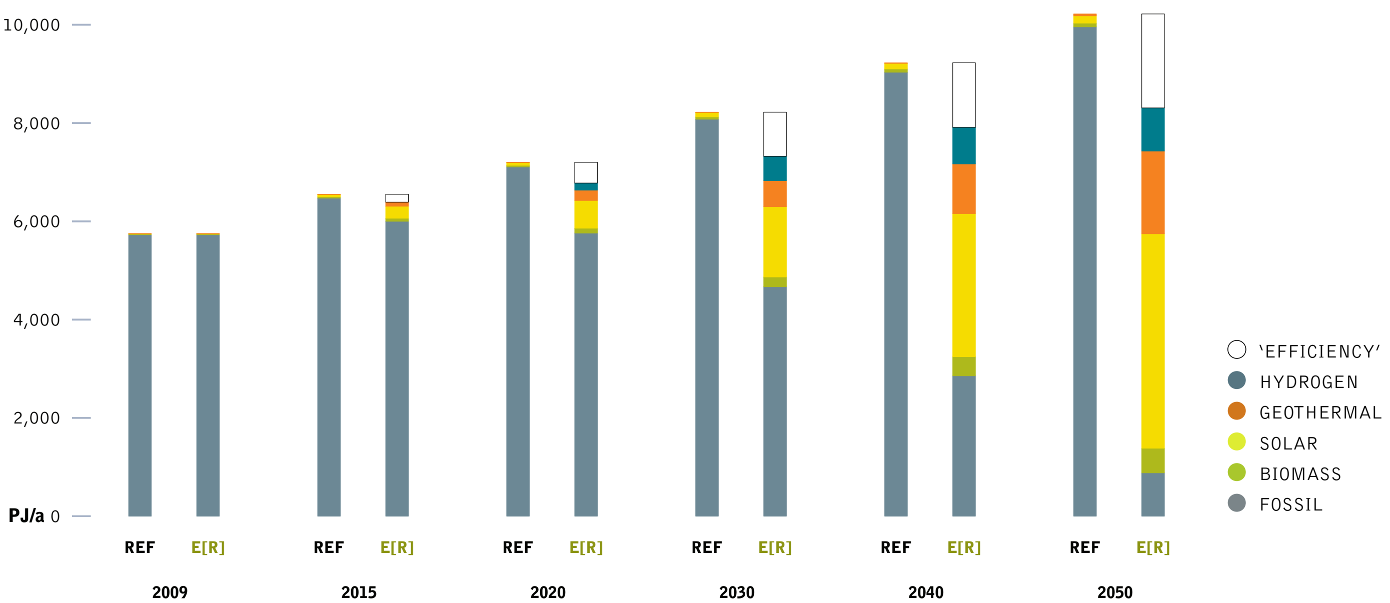


image A RIVER IN AFGHANISTAN.

image GREENPEACE SURVEY OF GULF WAR OIL POLLUTION IN KUWAIT. AERIAL VIEW OF OIL IN THE SEA.

middle east: future investments in the heat sector

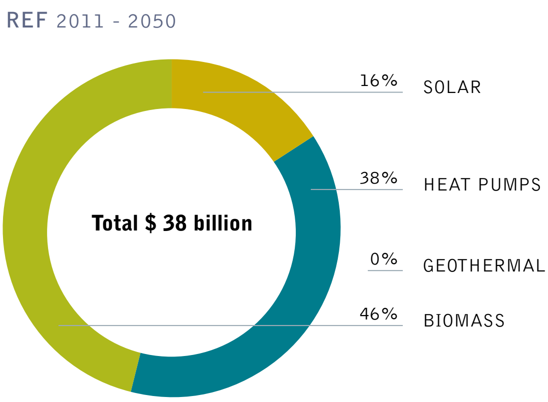
Also in the heat sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially the not yet so common spread solar, geothermal and heat pump technologies need enormous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity needs to increase by a factor of 680 for solar thermal and by a factor of 560 for geothermal and heat pumps. Capacity of biomass technologies, which are already rather wide spread increase by the factor of 13.

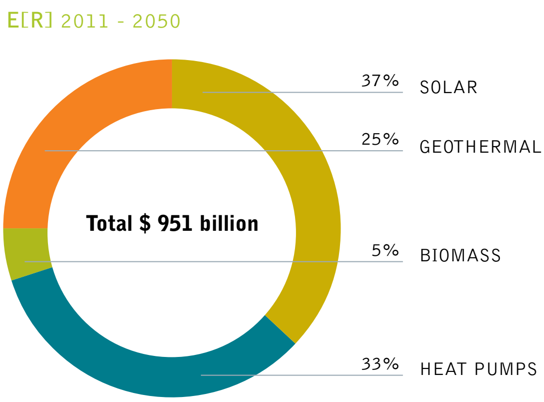
Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar thermal district heating plants with seasonal storage.Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around $ 951 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately $ 24 billion per year.

table 5.33: middle east: renewable heat generation capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	3	6	9	14	15
	E[R]	3	16	23	32	43
Geothermal	REF	0	0	0	0	0
	E[R]	0	20	34	44	76
Solar thermal	REF	1	12	17	22	29
	E[R]	1	110	236	458	663
Heat pumps	REF	0	1	1	3	7
	E[R]	0	17	51	91	131
Total	**REF**	**4**	**18**	**28**	**38**	**52**
	E[R]	**4**	**163**	**344**	**625**	**914**

figure 5.78: middle east: investments for renewable heat generation technologies under the reference scenario and the energy [r]evolution scenario





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OECD NORTH AMERICA
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OECD EUROPE
AFRICA

MIDDLE EAST
EASTERN EUROPE/EURASIA
INDIA

NON OECD ASIA
CHINA
OECD ASIA OCEANIA

middle east: future employment in the energy sector

The Energy [R]evolution scenario results in more energy sector jobs in Middle East at every stage of the projection.

- There are 1.8 million energy sector jobs in the Energy [R]evolution scenario in 2015, and 1.3 million in the Reference scenario.
- In 2020, there are 2 million jobs in the Energy [R]evolution scenario, and 1.4 million in the Reference scenario.
- In 2030, there are 1.6 million jobs in the Energy [R]evolution scenario and 1.5 million in the Reference scenario.

Figure 5.79 shows the change in job numbers under both scenarios for each technology between 2010 and 2030. Jobs in the Reference scenario increase gradually to 12% above 2010 levels by 2030. The gas sector accounts for 95% of energy sector jobs in this scenario.

Growth in renewable energy leads to an increase of 37% in total energy sector jobs in the Energy [R]evolution scenario by 2015, and compensates for a decline in gas sector jobs. There is a reduction between 2020 and 2030, but Energy [R]evolution jobs remain 23% above 2010 levels in 2030.

figure 5.79: middle east: employment in the energy scenario under the reference and energy [r]evolution scenarios

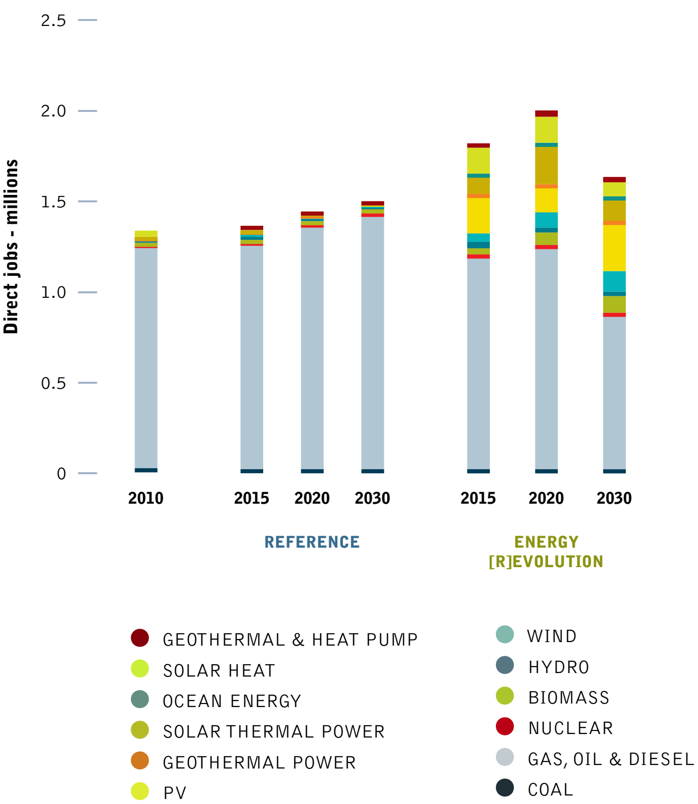


table 5.34: middle east: total employment in the energy sector THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	7	2	1	1	1	1	1
Gas, oil & diesel	1,228	1,241	1,340	1,409	1,184	1,237	863
Nuclear	9	14	15	5	0	0	0
Renewable	73	87	66	64	613	742	749
Total Jobs	**1,317**	**1,344**	**1,422**	**1,479**	**1,798**	**1,980**	**1,613**
Construction and installation	123	90	63	45	452	485	400
Manufacturing	50	27	21	21	119	126	109
Operations and maintenance	51	70	79	89	86	127	196
Fuel supply (domestic)	900	960	1,057	1,182	935.2	1,029	821
Coal and gas export	193	196	203	143	207	213	87
Total Jobs	**1,317**	**1,344**	**1,422**	**1,479**	**1,798**	**1,980**	**1,613**

image LAKE OF OIL, AL BURGAN OILFIELD, KUWAIT.

image ASHDOD COAL POWER PLANT IN ISRAEL.

middle east: transport

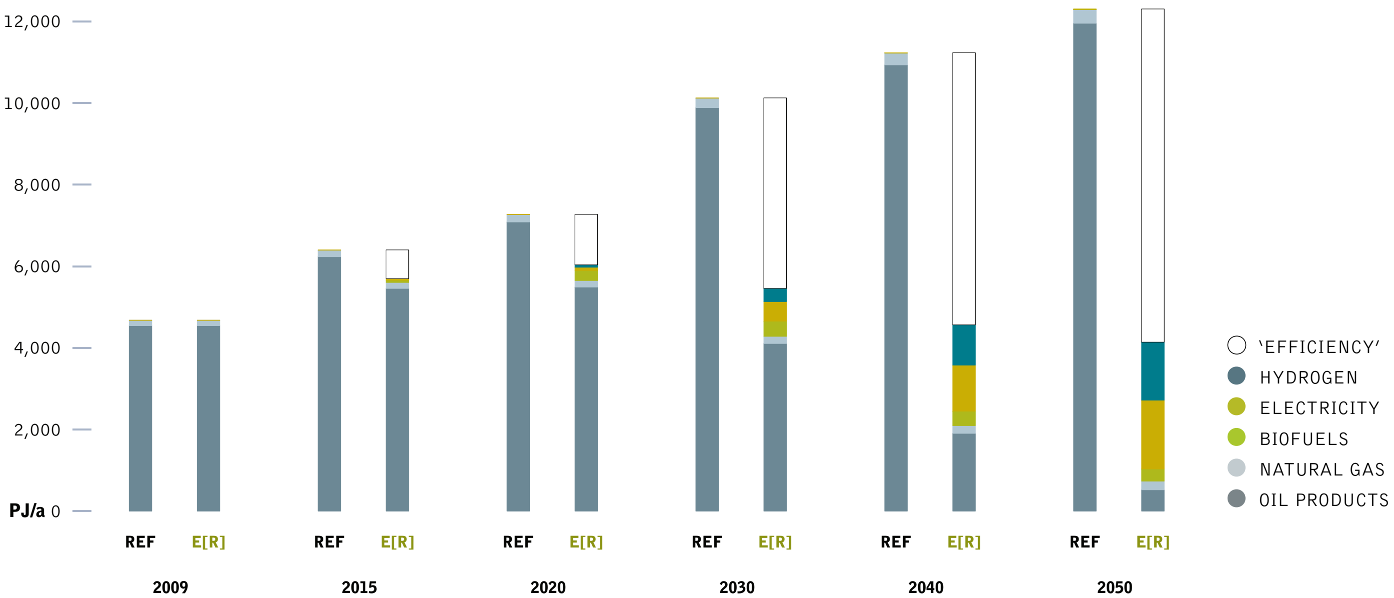
In the transport sector, it is assumed under the Energy [R]evolution scenario compared to the Refence scenario an energy demand reduction of 8,160 PJ/a or 66% can be achieved by 2050. Energy demand will therefore decrease between 2009 and 2050 by 11% to 4,140 PJ/a (including energy for pipeline transport). This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns. Implementing a mix of increased public transport as attractive alternatives to individual cars, the car stock is growing slower and annual person kilometres are lower than in the Reference scenario.

A shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains and a reduction of vehicle kilometres travelled per year leads to significant energy savings. In 2030, electricity will provide 9% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 41%.

table 5.35: middle east: transport energy demand by mode under the reference scenario and the energy [r]evolution scenario (WITHOUT ENERGY FOR PIPELINE TRANSPORT) IN PJ/A

		2009	2020	2030	2040	2050
Rail	REF	1	2	2	2	2
	E[R]	1	4	8	12	19
Road	REF	4,623	7,190	10,024	11,129	12,202
	E[R]	4,623	5,961	5,373	4,481	4,058
Domestic aviation	REF	38	51	61	58	53
	E[R]	38	48	58	55	50
Domestic navigation	REF	0	0	0	0	0
	E[R]	0	0	0	0	0
Total	**REF**	4,662	7,243	10,086	11,189	12,256
	E[R]	4,662	6,013	5,438	4,549	4,127

figure 5.80: middle east: final energy consumption for transport under the reference scenario and the energy [r]evolution scenario



middle east

middle east: development of CO_2 emissions

While CO_2 emissions in Middle East will increase by 104% in the Reference scenario, under the Energy [R]evolution scenario they will decrease from 1,510 million tonnes in 2009 to 173 million tonnes in 2050. Annual per capita emissions will drop from 7.4 tonnes to 4 tonnes in 2030 and 0.5 tonne in 2050. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will even reduce emissions in the transport sector. With a share of 13% of CO_2 emissions in 2050, the power sector will drop below transport as the largest sources of emissions. By 2050, Middle East's CO_2 emissions are 31% of 1990 levels.

middle east: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 5.81. Compared to the Reference scenario, overall primary energy demand will be reduced by 45% in 2050.

The Energy [R]evolution version phases out fossil fuels about 10 to 15 years faster than the previous Energy [R]evolution scenario published in 2010 This is made possible mainly by replacement of coal power plants with renewables and a faster introduction of very efficient electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 26% in 2030 and 75% in 2050. Nuclear energy is phased out just after 2030.

figure 5.81: middle east: development of CO_2 emissions by sector under the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

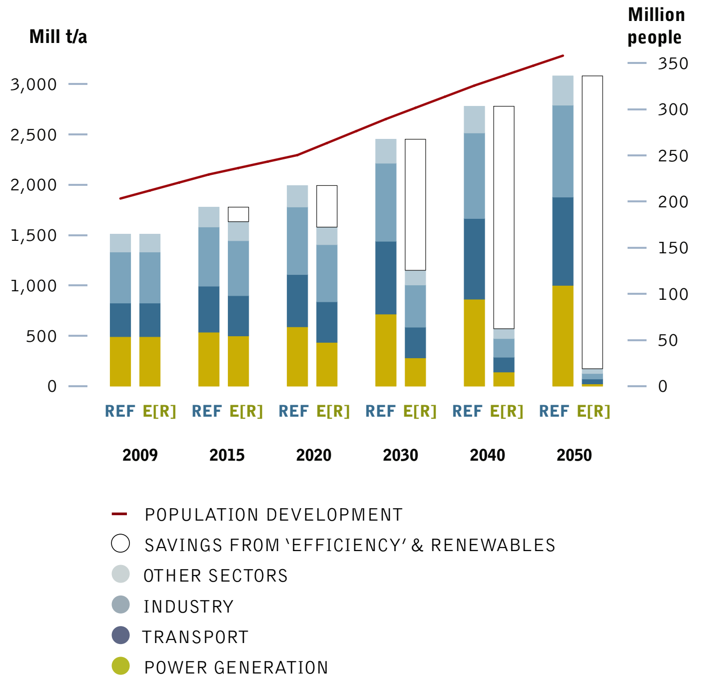


figure 5.82: middle east: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

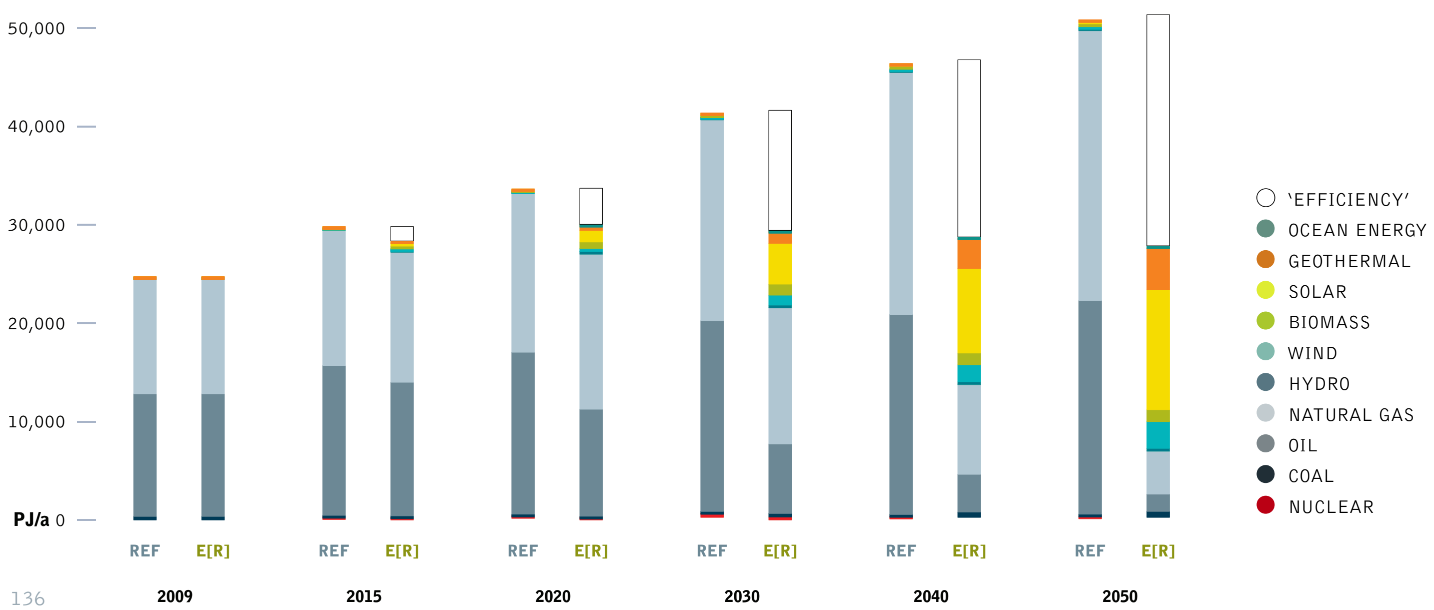


image ALMOST A MONTH AFTER THE ISRAELI AIR FORCE BOMBED IT, SMOKE STILL RISES FROM THE JIYEH POWER PLANT, 20 MILES SOUTH OF BEIRUT. THE ATTACK CAUSED A MASSIVE OIL SPILL THAT HAS BROUGHT AN ENVIRONMENTAL DISASTER UPON THE SHORES OF LEBANON.

image AN AEROPLANE FLIES OVER BEIRUT CITY.

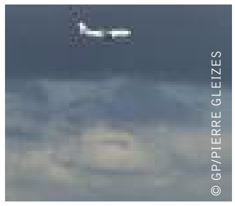


table 5.36: middle east: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

INVESTMENT COSTS	$	2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion $	-50.8	-85.1	-85.5	-85.5	-329.4	-8.2
Renewables	billion $	367.7	801.0	811.0	811.0	3,453.5	86.3
Total	billion $	**316.8**	**715.9**	**725.5**	**725.5**	**3,124.1**	**78.1**

CUMULATIVE FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion $/a	156.4	616.8	712.4	622.0	2,107.6	52.7
Gas	billion $/a	25.6	501.5	1,897.5	3,735.5	6,160.1	154.0
Hard coal	billion $/a	1.4	2.7	3.7	5.2	13.1	0.3
Lignite	billion $/a	0.0	0.0	0.0	0.0	0.0	0.0
Total	billion $/a	**183.4**	**1,121.0**	**2,613.7**	**4,362.7**	**8,280.8**	207.0

eastern europe/eurasia

eastern europe/eurasia: energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for Eastern Europe/Eurasia's final energy demand. These are shown in Figure 5.83 for the Reference and the Energy [R]evolution scenario. Under the Reference scenario, total primary energy demand increases by 46% from the current 47,166 PJ/a to 69,013 PJ/a in 2050. In the Energy [R]evolution scenario, primary energy demand decreases by 21% compared to current consumption and it is expected to reach 37,240 PJ/a by 2050.

Under the Energy [R]evolution scenario, electricity demand is increase to decrease in both the industry sector, the residential and service sectors, as well in the transport sector (see Figure 5.84). Total electricity demand (final energy) will rise from 1,154 TWh/a to 2,122 TWh/a by the year 2050. Compared to the Reference scenario, efficiency measures in the industry, residential and service sectors avoid the generation of about 743 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors.

Efficiency gains in the heat supply sector are even larger. Under the Energy [R]evolution scenario, heat demand is expected to decrease almost constantly (see Figure 5.86). Compared to the Reference scenario, consumption equivalent to 10,028 PJ/a is avoided through efficiency gains by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

figure 5.83: eastern europe/eurasia: total final energy demand by sector under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

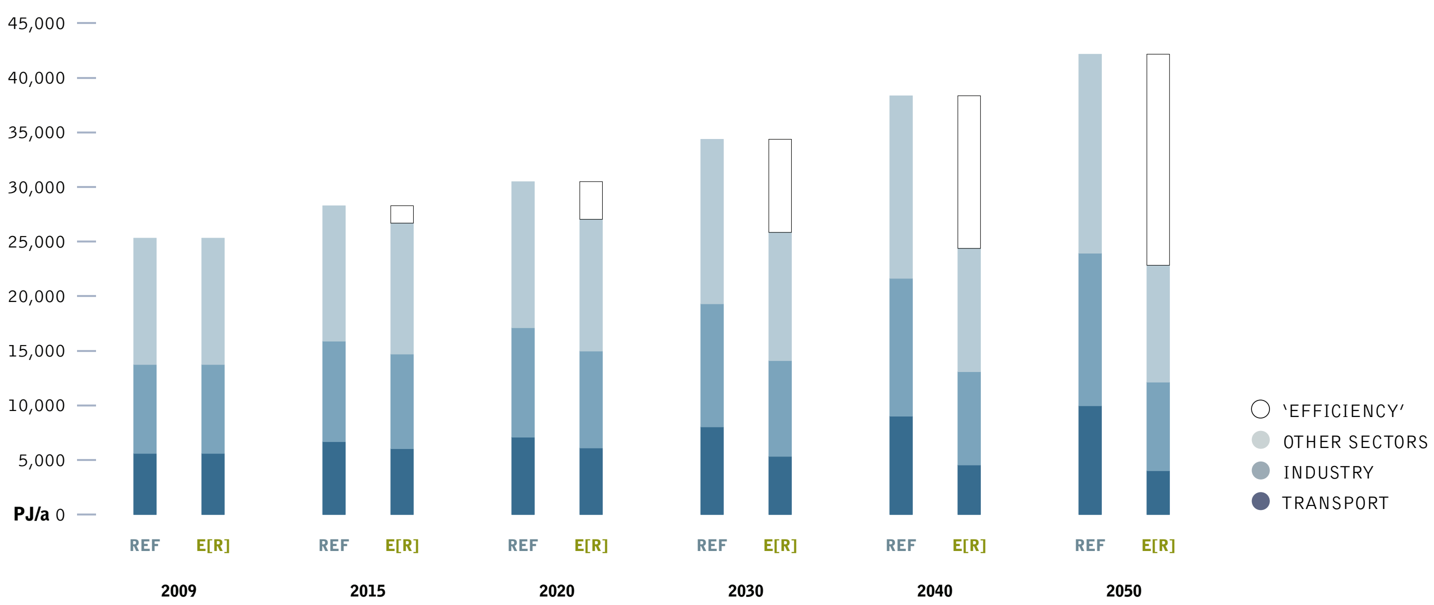


image AN INDIGENOUS NENET WOMAN WITH HER REINDEER. THE NENETS PEOPLE MOVE EVERY 3 OR 4 DAYS SO THAT THEIR HERDS DO NOT OVER GRAZE THE GROUND. THE ENTIRE REGION AND ITS INHABITANTS ARE UNDER HEAVY THREAT FROM GLOBAL WARMING AS TEMPERATURES INCREASE AND RUSSIA'S ANCIENT PERMAFROST MELTS.

image A SITE OF A DISAPPEARED LAKE AFTER PERMAFROST SUBSIDENCE IN RUSSIA.

figure 5.84: eastern europe/eurasia: development of electricity demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

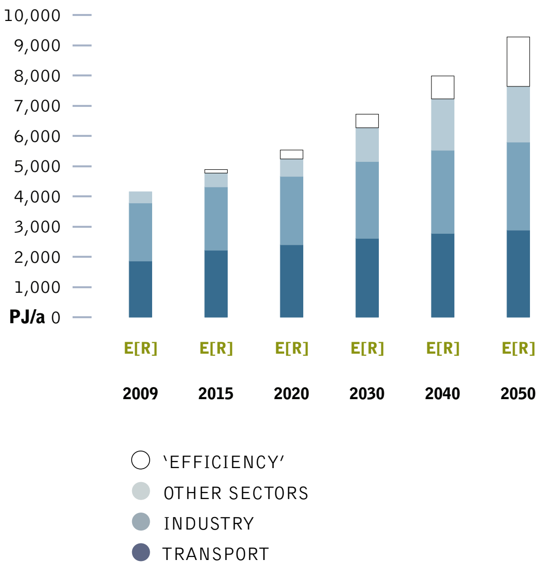


figure 5.85: eastern europe/eurasia: development of the transport demand by sector in the energy [r]evolution scenario

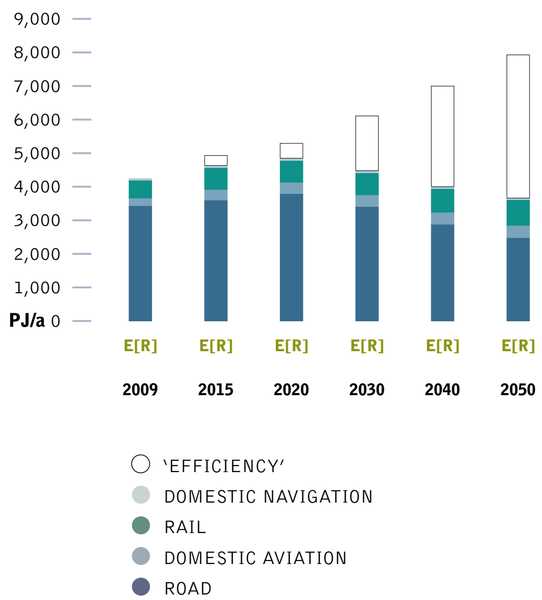
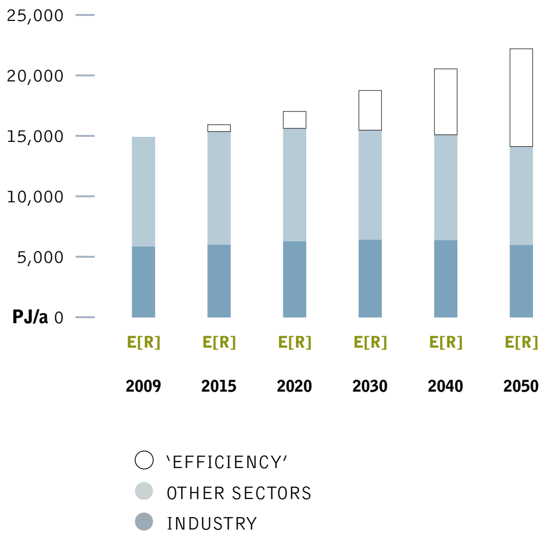


figure 5.86: eastern europe/eurasia: development of heat demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)



eastern europe/eurasia

GLOBAL SCENARIO
OECD NORTH AMERICA
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eastern europe/eurasia: electricity generation

The development of the electricity supply sector is charaterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 94% of the electricity produced in Eastern Europe/Eurasia will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 73% of electricity generation. Already by 2020 the share of renewable electricity production will be 32% and 57% by 2030. The installed capacity of renewables will reach 560 GW in 2030 and 1,312 GW by 2050.

Table 5.37 shows the comparative evolution of the different renewable technologies in Eastern Europe/Eurasia over time. Up to 2020 hydro and wind will remain the main contributors of the growing market share. After 2020, the continuing growth of wind will mainly be complemented by electricity from biomass and photovoltaics. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 32% by 2030, therefore the expansion of smart grids, demand side management (DSM) and storage capacity from the increased share of electric vehicles will be used for a better grid integration and power generation management.

table 5.37: eastern europe/eurasia: renewable electricity generation capacity under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Hydro	REF	90	97	107	119	130
	E[R]	90	108	109	113	114
Biomass	REF	1	2	5	8	10
	E[R]	1	16	36	57	66
Wind	REF	0	8	14	34	47
	E[R]	0	98	328	619	776
Geothermal	REF	0	1	2	3	3
	E[R]	0	4	13	32	56
PV	REF	0	1	3	7	10
	E[R]	0	7	60	163	270
CSP	REF	0	0	0	0	0
	E[R]	0	0	2	8	12
Ocean energy	REF	0	0	0	0	0
	E[R]	0	6	12	16	17
Total	**REF**	**91**	**109**	**130**	**170**	**200**
	E[R]	**91**	**238**	**560**	**1,009**	**1,311**

figure 5.87: eastern europe/eurasia: electricity generation structure under the reference scenario and the energy [r]evolution scenario (INCLUDING ELECTRICITY FOR ELECTROMOBILITY, HEAT PUMPS AND HYDROGEN GENERATION)

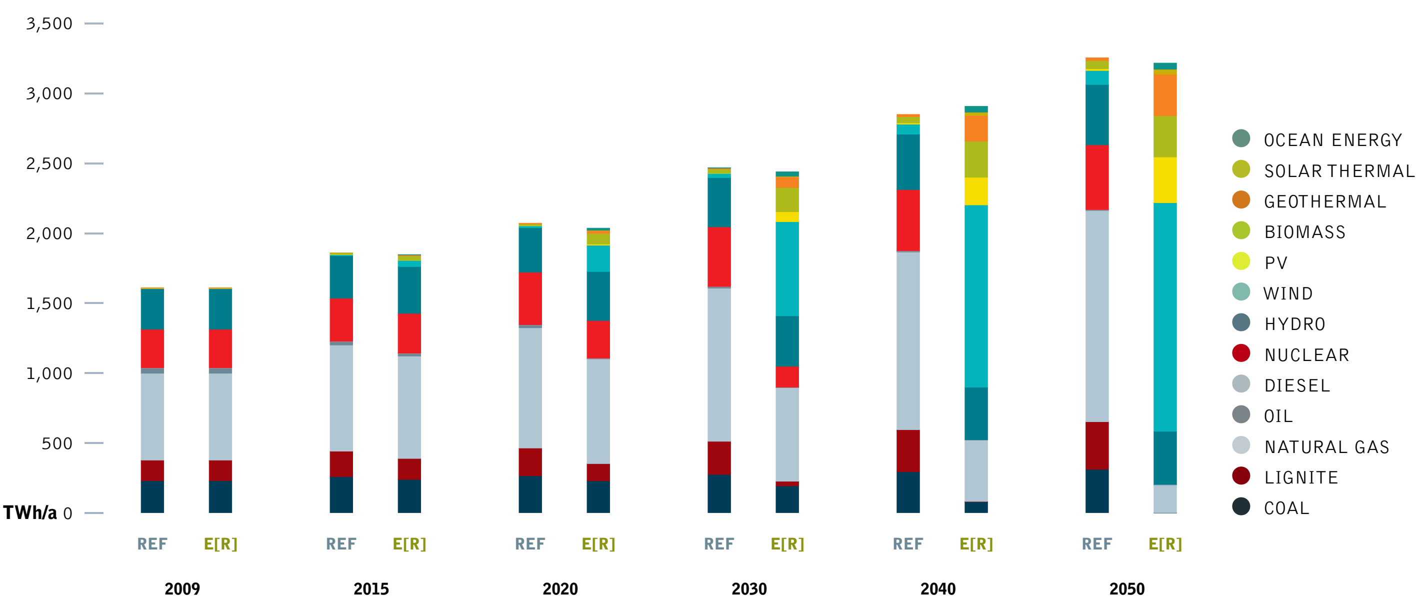


image CHERNOBYL NUCLEAR POWER STATION, UKRAINE.

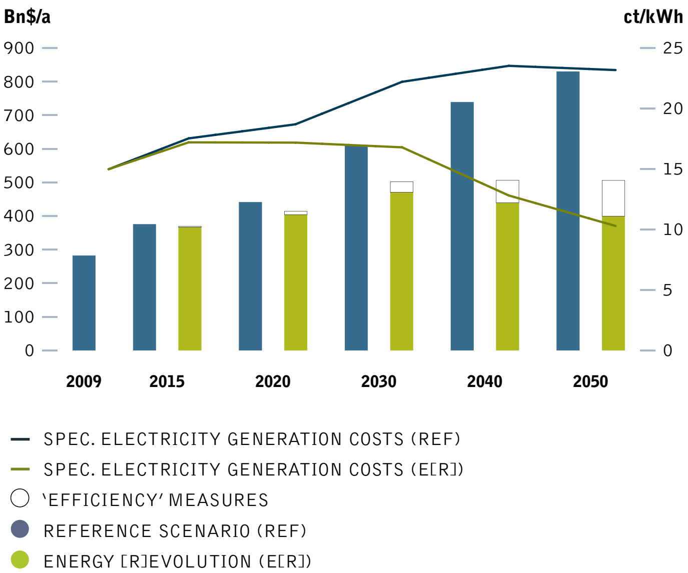
image THE SUN OVER LAKE BAIKAL, RUSSIA.

eastern europe/eurasia: future costs of electricity generation

Figure 5.88 shows that the introduction of renewable technologies under the Energy [R]evolution scenario significantly decreases the future costs of electricity generation compared to the Reference scenario. This difference will be less than $ 1.5 cent/kWh up to 2020, however. Because of high prices for conventional fuels and the lower CO_2 intensity of electricity generation, electricity generation costs will become even more economically favourable under the Energy [R]evolution scenario and by 2050 costs will be $ 12.9 cents/kWh below those in the Reference version.

Under the Reference scenario, on the other hand, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $ 282 billion per year to more than $ 830 billion in 2050. Figure 5.88 shows that the Energy [R]evolution scenario not only complies with Eastern Europe/Eurasia's CO_2 reduction targets, but also helps to stabilise energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are more than 55% lower than in the Reference scenario.

figure 5.88: eastern europe/eurasia: total electricity supply costs and specific electricity generation costs under two scenarios



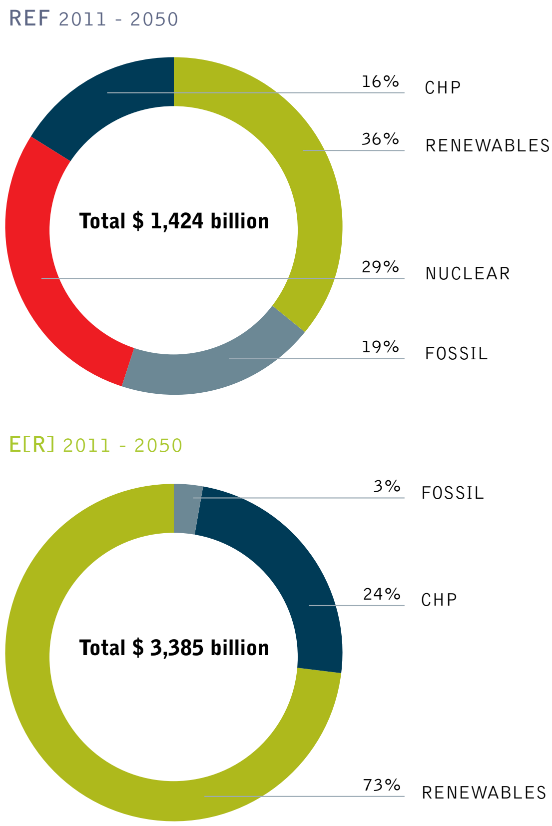
eastern europe/eurasia: future investments in the power sector

It would require $ 3,385 billion in investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately $ 1,961 billion (or annually $ 49 billion) more than in the Reference scenario ($ 1,424 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 48% while approximately 52% would be invested in renewable energy and cogeneration (CHP) until 2050.

Under the Energy [R]evolution scenario, however, Eastern Europe/Eurasia would shift almost 97% of the entire investment towards renewables and cogeneration. Until 2030, the fossil fuel share of power sector investment would be focused mainly on CHP plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately $ 85 billion.

Because renewable energy has no fuel costs, however, the fuel cost savings in the Energy [R]evolution scenario reach a total of $ 7,705 billion up to 2050, or $ 193 billion per year. The total fuel cost savings therefore would cover 390% of the total additional investments compared to the Reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.

figure 5.89: eastern europe/eurasia: investment shares - reference scenario versus energy [r]evolution scenario



eastern europe/eurasia

eastern europe/eurasia: heating supply

Today, renewables meet 3% of Eastern Europe/Eurasia's heat demand, the main contribution coming from the use of biomass. The construction and expansion of district heating networks is a crucial prerequisite for the large scale utilisation of geothermal and solar thermal energy. Dedicated support instruments are required to ensure a dynamic development. In the Energy [R]evolution scenario, renewables provide 45% of Eastern Europe/Eurasia's total heat demand in 2030 and 91% in 2050.

- Energy efficiency measures help to reduce the currently growing energy demand for heating by 42 % in 2050 (relative to the reference scenario), in spite of improving living standards.
- In the industry sector solar collectors, geothermal energy (incl. heat pumps), and electricity and hydrogen from renewable sources are increasingly substituting for fossil fuel-fired systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

Table 5.38 shows the development of the different renewable technologies for heat Eastern Europe/Eurasia over time. Up to 2020 biomass will remain the main contributors of the growing market share. After 2020, the continuing growth of solar collectors and a growing share of geothermal heat pumps will reduce the dependence on fossil fuels.

table 5.38: eastern europe/eurasia: renewable heating capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	523	635	756	886	1,025
	E[R]	523	1,799	3,098	3,659	3,643
Solar collectors	REF	3	6	10	14	18
	E[R]	3	678	1,450	1,961	2,237
Geothermal	REF	7	7	10	58	77
	E[R]	7	1,038	2,460	4,811	6,162
Hydrogen	REF	0	0	0	0	0
	E[R]	0	113	316	620	857
Total	**REF**	**533**	**647**	**777**	**957**	**1,120**
	E[R]	**533**	**3,628**	**7,324**	**11,051**	**12,900**

figure 5.90: eastern europe/eurasia: heat supply structure under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

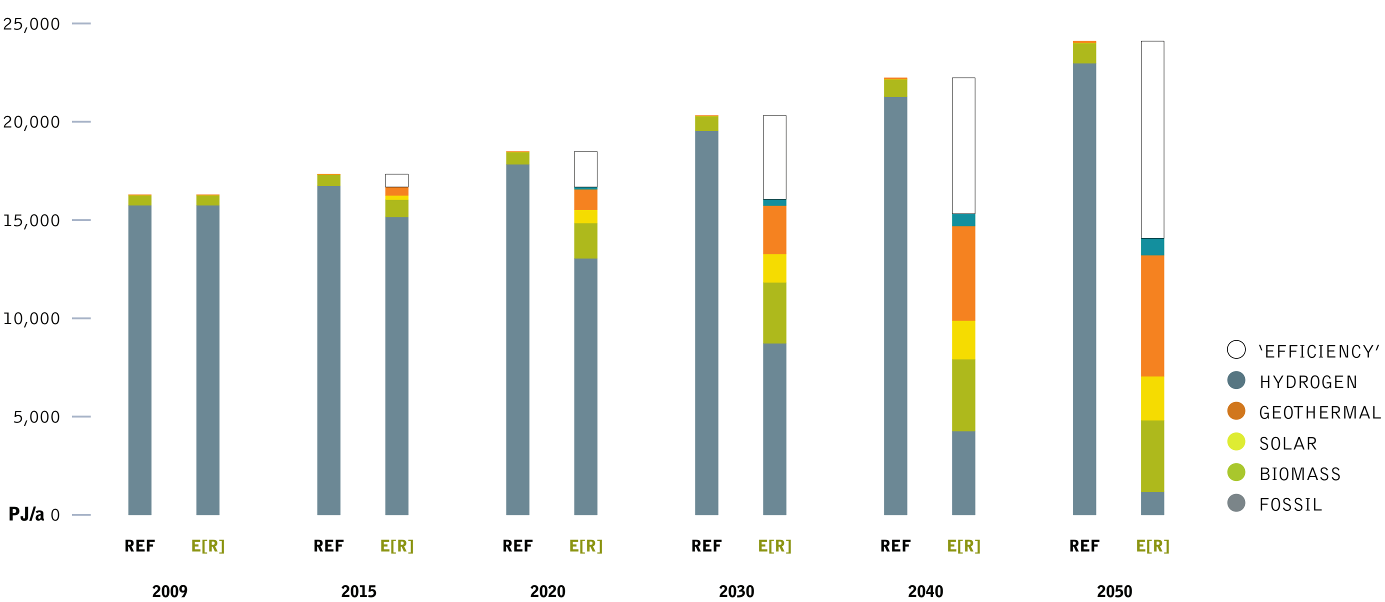


image LAKE BAIKAL, RUSSIA.

image SOLAR PANELS IN A NATURE RESERVE IN CAUCASUSU, RUSSIA.

eastern europe/eurasia: future investments in the heat sector

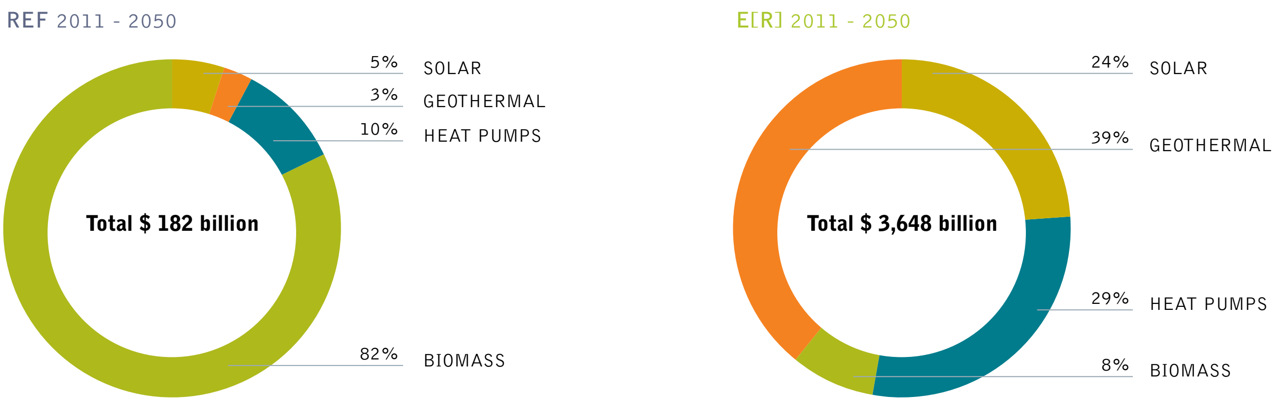
Also in the heat sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially the not yet so common solar and geothermal and heat pump technologies need enourmous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity needs to increase by a factor of 700 for solar thermal and even by a factor of 800 for geothermal and heat pumps. Capacity of biomass technologies, which are already rather wide spread still need to increase by a factor of 3 and will remain a main pillar of heat supply

Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar themal district heating plants with seasonal storage.Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around $ 3,648 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately $ 91 billion per year.

table 5.39: eastern europe/eurasia: renewable heat generation capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	97	110	126	145	165
	E[R]	97	239	357	366	315
Geothermal	REF	0	1	1	2	2
	E[R]	0	125	225	411	492
Solar thermal	REF	1	2	3	4	5
	E[R]	1	185	395	529	577
Heat pumps	REF	1	0	1	8	9
	E[R]	1	54	172	323	423
Total	**REF**	**100**	**113**	**131**	**158**	**181**
	E[R]	**100**	**603**	**1,150**	**1,630**	**1,807**

figure 5.91: eastern europe/eurasia: investments for renewable heat generation technologies under the reference scenario and the energy [r]evolution scenario



eastern europe/eurasia

eastern europe/eurasia: future employment in the energy sector

The Energy [R]evolution scenario results in more energy sector jobs in Eastern Europe/Eurasia at every stage of the projection.

- There are 2 million energy sector jobs in the Energy [R]evolution scenario in 2015, and 1.6 million in the Reference scenario.
- In 2020, there are 2 million jobs in the Energy [R]evolution scenario, and 1.5 million in the Reference scenario.
- In 2030, there are 1.6 million jobs in the Energy [R]evolution scenario and 1.4 million in the Reference scenario.

Figure 5.92 shows the change in job numbers under both scenarios for each technology between 2010 and 2030. Jobs in the Reference scenario reduce gradually over the period, leading to an overall decline of 17% by 2030.

Exceptionally strong growth in renewable energy leads to an increase of 16% in total energy sector jobs in the Energy [R]evolution scenario by 2015. Jobs continue to grow until 2020. By 2030, jobs fall below 2010 levels, but are 0.2 million more than in the Reference scenario. Renewable energy accounts for 64% of energy jobs by 2030, with biomass having the greatest share (24%).

figure 5.92: eastern europe/eurasia: employment in the energy scenario under the reference and energy [r]evolution scenarios

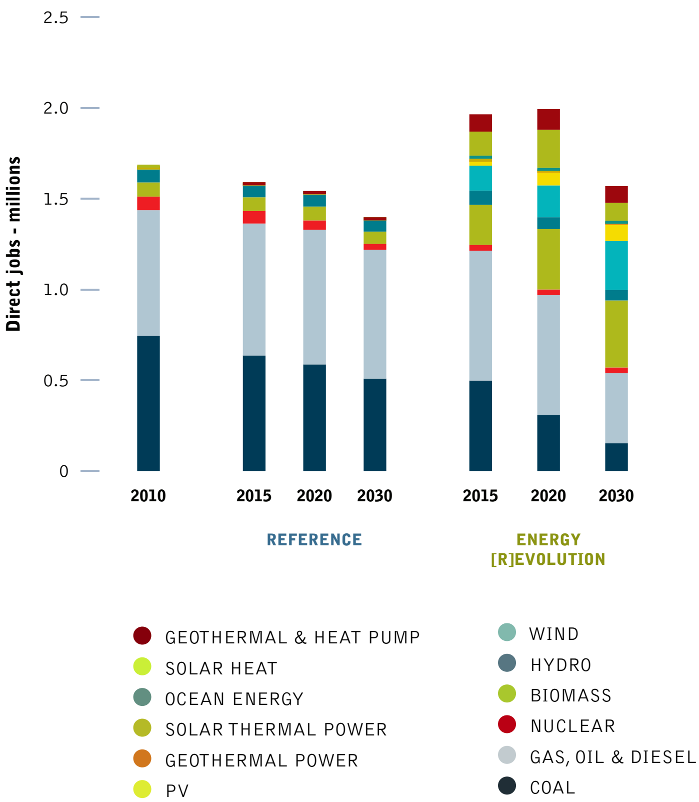


table 5.40: eastern europe/eurasia: total employment in the energy sector THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	745	637	587	509	498	309	153
Gas, oil & diesel	692	727	742	709	715	660	386
Nuclear	75	69	52	33	32	32	32
Renewable	176	158	162	146	719	994	999
Total Jobs	**1,688**	**1,591**	**1,542**	**1,398**	**1,965**	**1,994**	**1,570**
Construction and installation	125	75	57	42	330	413	325
Manufacturing	37	20	19	17	161	214	226
Operations and maintenance	187	177	171	146	203	232	262
Fuel supply (domestic)	975	911	849	819	920.2	866	653
Coal and gas export	363	408	447	373	351	269	104
Total Jobs	**1,688**	**1,591**	**1,542**	**1,398**	**1,965**	**1,994**	**1,570**

image DOCUMENTATION OF OIL POLLUTION AT OIL FIELDS IN THE KOMI-REGION, RUSSIA.THE EXPLOITATION OF OIL CAUSES A STEADY POLLUTION DUE TO OLD AND BROKEN PIPELINES. RIVER KOLVA.

image GAS FLARING IN RUSSIA.

eastern europe/eurasia: transport

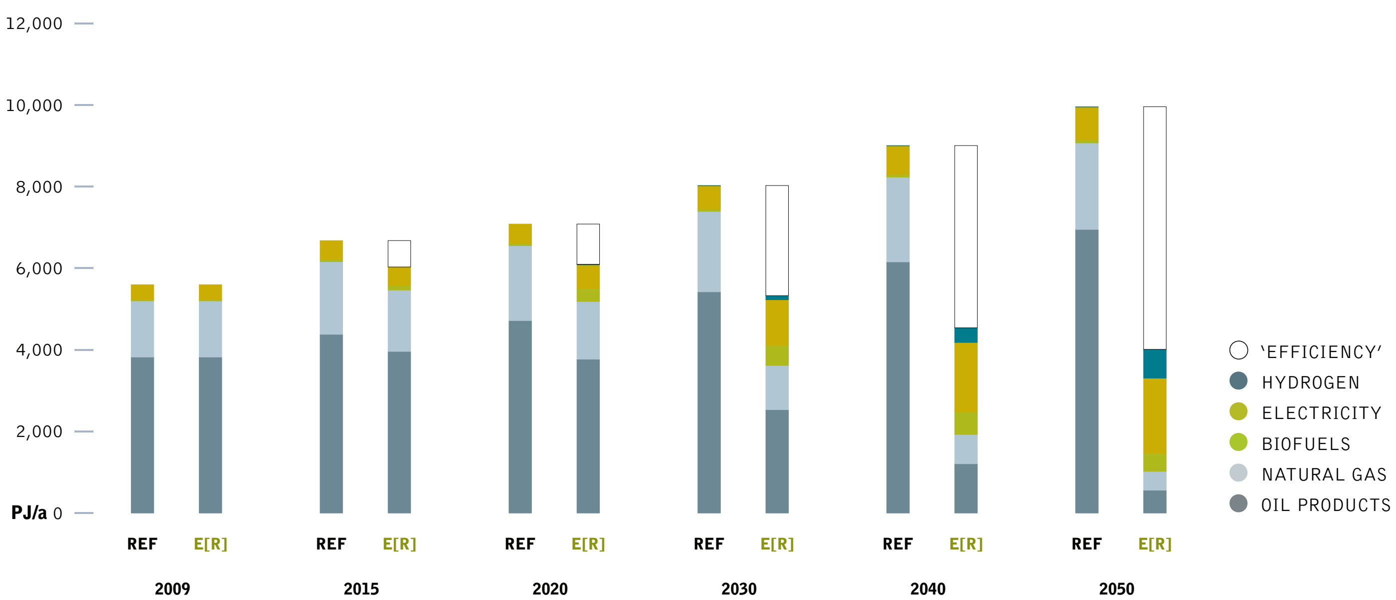
A key target in Eastern Europe/Eurasia is to introduce incentives for people to drive smaller cars, something almost completely absent today. In addition, it is vital to shift transport use to efficient modes like rail, light rail and buses, especially in the expanding large metropolitan areas. Together with rising prices for fossil fuels, these changes reduce the huge growth in car sales projected under the Reference scenario. Compared to the Reference scenario, energy demand from the transport sector is reduced by 5,948 PJ/a 2050, saving 60% compared to the Reference scenario. Energy demand in the transport sector will therefore decrease between 2009 and 2050 by 28% to 4,012 PJ/a (including energy for pipeline transport).

Highly efficient propulsion technology with hybrid, plug-in hybrid and batteryelectric power trains will bring large efficiency gains. By 2030, electricity will provide 21% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 46%.

table 5.41: eastern europe/eurasia: transport energy demand by mode under the reference scenario and the energy [r]evolution scenario (WITHOUT ENERGY FOR PIPELINE TRANSPORT) IN PJ/A

		2009	2020	2030	2040	2050
Rail	REF	531	777	936	1,156	1,331
	E[R]	531	650	655	705	766
Road	REF	3,435	4,111	4,720	5,341	6,048
	E[R]	3,435	3,794	3,411	2,882	2,483
Domestic aviation	REF	228	337	382	429	474
	E[R]	228	337	347	357	365
Domestic navigation	REF	53	66	71	72	75
	E[R]	53	66	64	56	49
Total	**REF**	**4,247**	**5,292**	**6,109**	**6,998**	**7,928**
	E[R]	**4,247**	**4,848**	**4,478**	**4,000**	**3,662**

figure 5.93: eastern europe/eurasia: final energy consumption for transport under the reference scenario and the energy [r]evolution scenario



eastern europe/eurasia

eastern europe/eurasia: development of CO_2 emissions

Whilst Eastern Europe/Eurasia`s emissions of CO_2 will increase by 43% between 2009 and 2050 under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 2,483 million tonnes in 2009 to 243 million tonnes in 2050. Annual per capita emissions will drop from 7.3 tonnes to 0.7 tonne. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable energy in vehicles will reduce emissions in the transport sector. With a share of 43% of CO_2, the power sector will be the largest sources of emissions in 2050. By 2050, Eastern Europe/Eurasia's CO_2 emissions are 94% below 1990 levels.

eastern europe/eurasia: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 5.95. Compared to the Reference scenario, overall primary energy demand will be lower by 46% in 2050. Around 78% of the remaining demand will be covered by renewable energy sources.

The Energy [R]evolution version aims to phases out coal and oil as fast as technically and economically possible. This is made possible mainly by replacement of coal power plants with renewables and a fast introduction of very efficient electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 36% in 2030 and 78% in 2050. Nuclear energy is phased out just after 2035.

figure 5.94: eastern europe/eurasia: development of CO_2 emissions by sector under the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

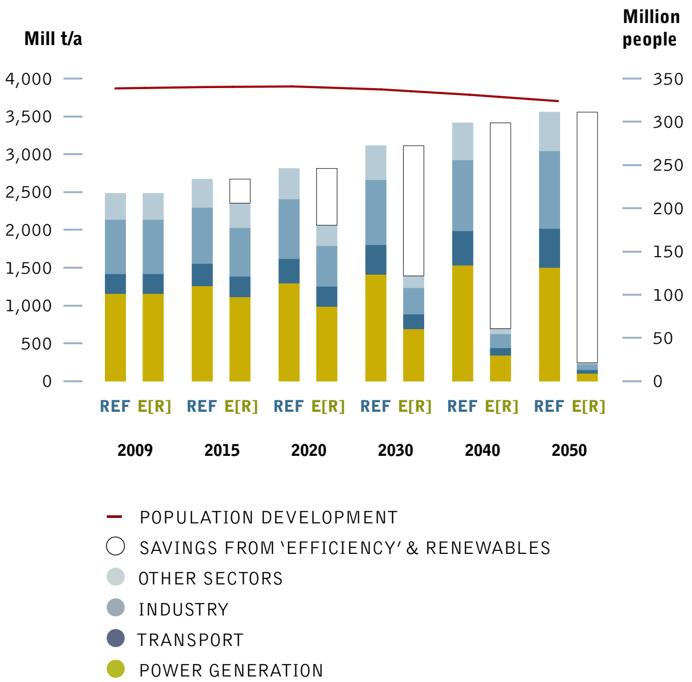


figure 5.95: eastern europe/eurasia: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

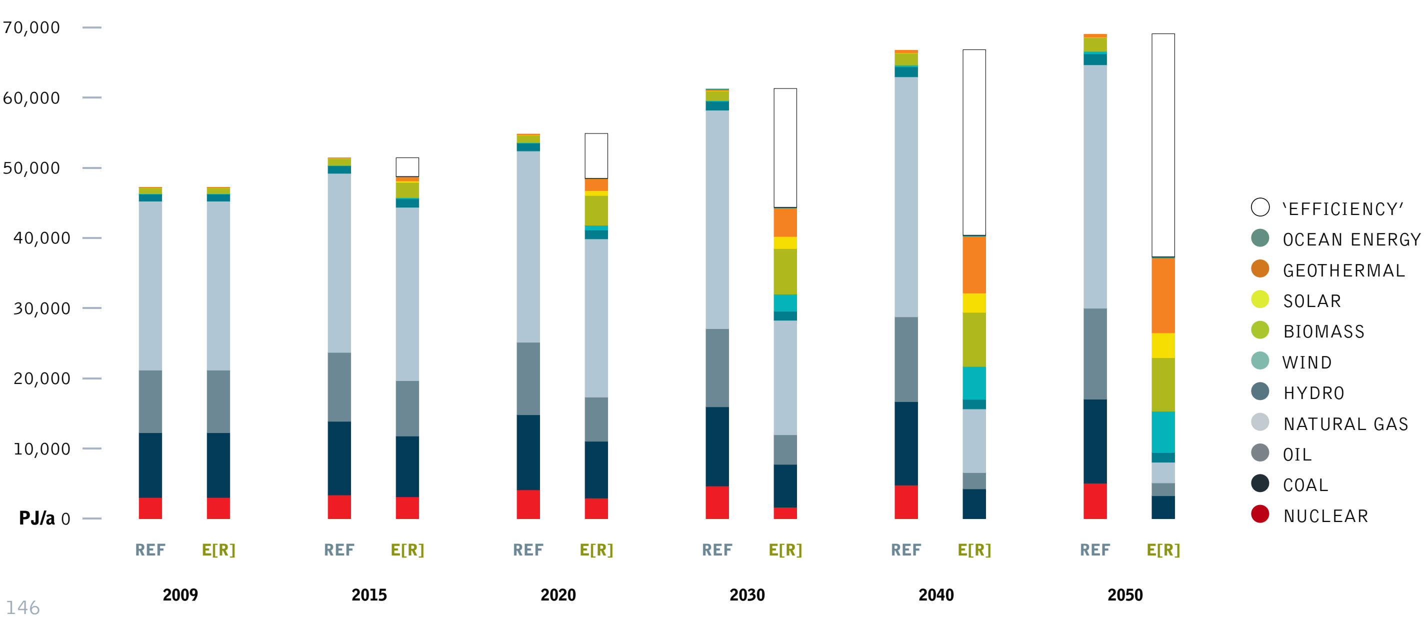


image AN AERIAL VIEW OF PERMAFROST TUNDRA IN THE YAMAL PENINSULA. THE ENTIRE REGION IS UNDER HEAVY THREAT FROM GLOBAL WARMING AS TEMPERATURES INCREASE AND RUSSIAS ANCIENT PERMAFROST MELTS.

image A VIEW OF THE NEW MUSLYUMOVO VILLAGE, JUST 1,6 KMS OUTSIDE THE OLD MUSLYUMOVO, ONE OF THE COUNTRY'S MOST LETHAL NUCLEAR DUMPING GROUNDS.

table 5.42: eastern europe/eurasia: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

INVESTMENT COSTS	$	2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion $	-161.4	-158.4	-139.1	-171.0	-629.9	-15.7
Renewables	billion $	291.8	504.8	868.9	925.1	2,590.7	64.8
Total	billion $	**130.5**	**346.4**	**729.8**	**754.1**	**1,960.8**	**49.0**
CUMULATIVE FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion $/a	51.5	114.7	101.3	79.4	346.8	8.7
Gas	billion $/a	144.1	910.1	2,250.8	3,376.7	6,681.7	167.0
Hard coal	billion $/a	29.9	72.1	149.7	235.0	486.7	12.2
Lignite	billion $/a	8.4	33.2	62.5	85.5	189.6	4.7
Total	billion $/a	**234.0**	**1,130.1**	**2,564.3**	**3,776.5**	**7,704.8**	**192.6**

india

GLOBAL SCENARIO

OECD NORTH AMERICA
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AFRICA

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EASTERN EUROPE/EURASIA
INDIA

NON OECD ASIA
CHINA
OECD ASIA OCEANIA

india: energy demand by sector

The future development pathways for India's energy demand are shown in Figure 5.96 for the Reference scenario and the Energy [R]evolution scenario. Under the Reference scenario, total primary energy demand in India increases by 206% from the current 29,149 PJ/a to about 89,100 PJ/a in 2050. In the Energy [R]evolution scenario, by contrast, energy demand increases by 70% compared to current consumption and it is expected by 2050 to reach 49,600 PJ/a.

Under the Energy [R]evolution scenario, electricity demand in the industrial, residential, and service sectors is expected to fall slightly below the current level (see Figure 5.97). In the transport sector – for both freight and persons – a shift towards electric trains and public transport as well as efficient electric vehicles is expected. Fossil fuels for industrial process heat generation are also phased out and replaced by electric geothermal heat pumps and hydrogen. This means that electricity demand in the Energy [R]evolution increases in those sectors. Total electricity demand reaches 4,050 TWh/a in 2050, 4% above the Reference case.

Efficiency gains in the heat supply sector are larger than in the electricity sector. Under the Energy [R]evolution scenario, final demand for heat supply can even be reduced significantly (see Figure 5.99). Compared to the Reference scenario, consumption equivalent to 3560 PJ/a is avoided through efficiency measures by 2050.

figure 5.96: india: total final energy demand by sector under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

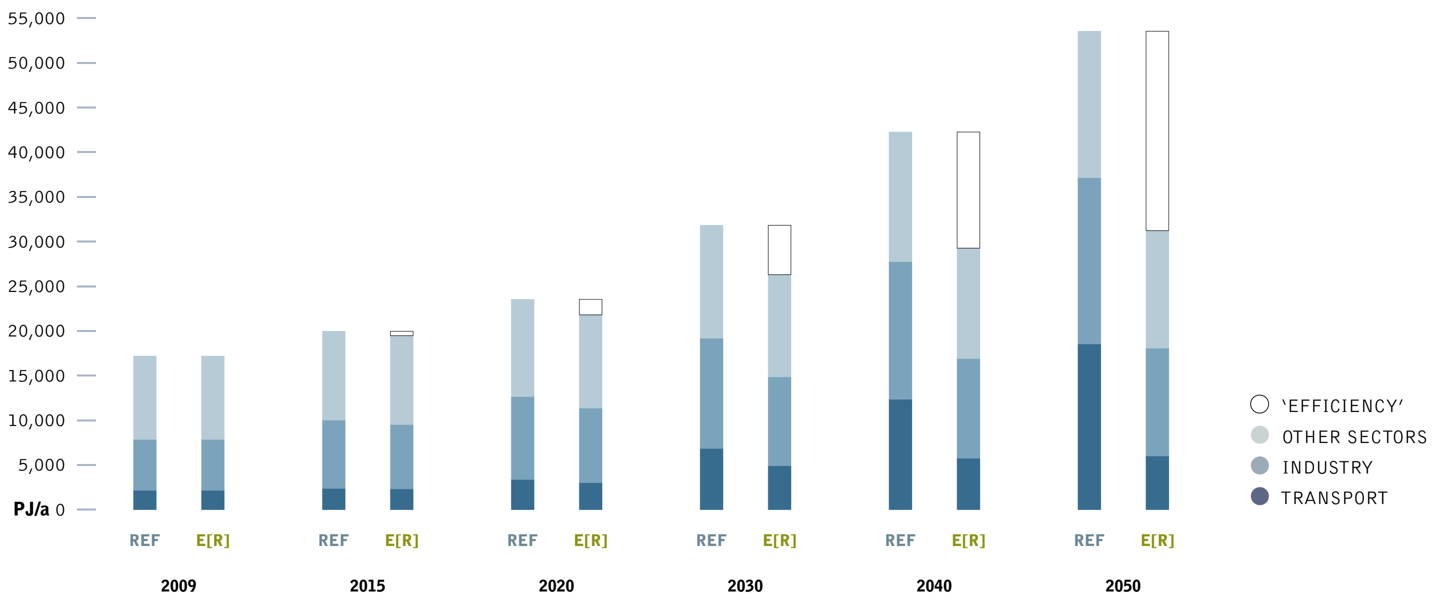


image AJIT DAS LIVES IN GHORAMARA ISLAND AND IS ONE OF THE MANY PEOPLE AFFECTED BY SEA LEVEL RISE: "WE CANNOT STAY HERE BECAUSE OF THE GANGA'S FLOODING. WE HAVE MANY PROBLEMS. WE DON'T KNOW WHERE WE WILL GO OR WHAT WE WILL DO. WE CANNOT BRING OUR GRANDCHILDREN UP HERE. WHATEVER THE GOVERNMENT DECIDES FOR US, WE SHALL FOLLOW THEIR GUIDANCE. EVERYTHING IS GOING UNDER THE WATER. WHILE THE EDGE OF THE LAND IS BREAKING IN GHORAMARA, THE MIDDLE OF THE RIVER IS BECOMING SHALLOWER. WE DON'T KNOW WHERE WE WILL GO OR WHAT WE WILL DO".

image VILLAGERS ORDER THEMSELVES INTO QUEUE TO RECEIVE SOME EMERGENCY RELIEF SUPPLY PROVIDED BY A LOCAL NGO. SCIENTISTS ESTIMATE THAT OVER 70,000 PEOPLE, LIVING EFFECTIVELY ON THE FRONT LINE OF CLIMATE CHANGE, WILL BE DISPLACED FROM THE SUNDARBANS DUE TO SEA LEVEL RISE BY THE YEAR 2030.

figure 5.97: india: development of electricity demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

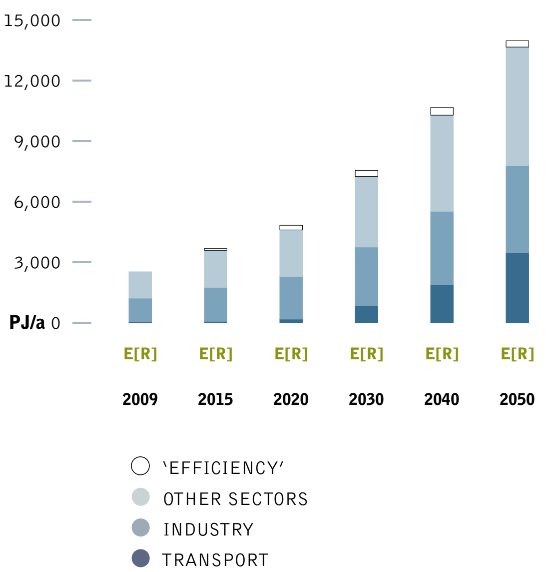


figure 5.99: india: development of heat demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

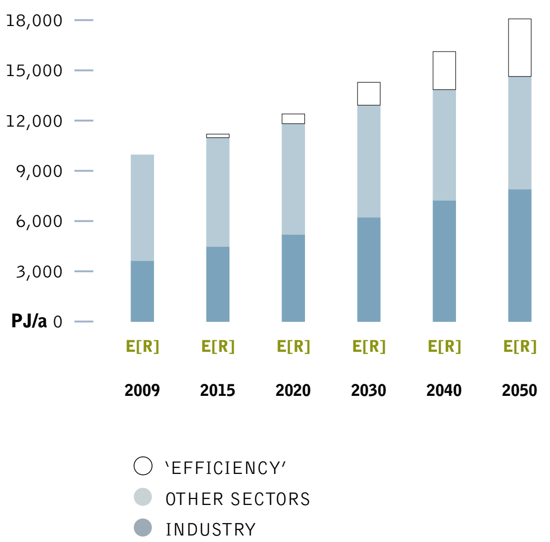
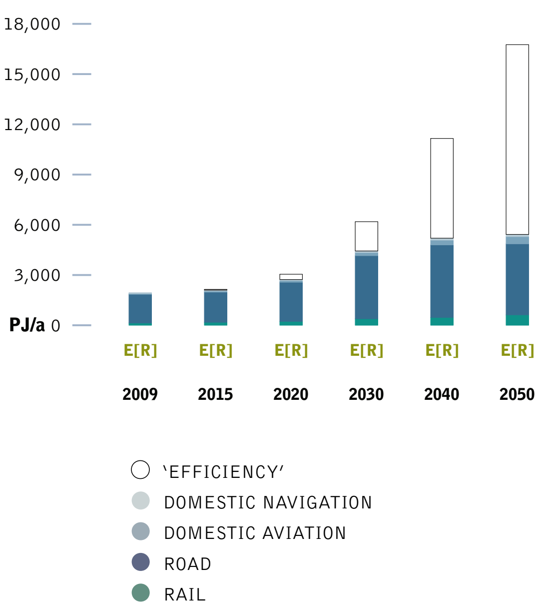


figure 5.98: india: development of the transport demand by sector in the energy [r]evolution scenario



india

GLOBAL SCENARIO

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india: electricity generation

The development of the electricity supply market is charaterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 92% of the electricity produced in India will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 74% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 32% already by 2020 and 62% by 2030. The installed capacity of renewables will reach 548 GW in 2030 and 1,356 GW by 2050.

Table 5.43 shows the comparative evolution of the different renewable technologies in India over time. Up to 2020 hydro and wind will remain the main contributors of the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaics and solar thermal (CSP) energy. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 31% by 2030 and 40% by 2050, therefore the expansion of smart grids, demand side management (DSM) and storage capacity e.g. from the increased share of electric vehicles will be used for a better grid integration and power generation management.

table 5.43: india: renewable electricity generation capacity under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Hydro	REF	39	55	77	98	119
	E[R]	39	62	64	66	67
Biomass	REF	2	4	10	18	27
	E[R]	2	13	19	38	62
Wind	REF	11	30	42	51	60
	E[R]	11	96	185	265	335
Geothermal	REF	0	0	0	0	0
	E[R]	0	1	24	60	103
PV	REF	0	10	26	44	68
	E[R]	0	30	161	338	519
CSP	REF	0	0	0	0	1
	E[R]	0	4	79	142	223
Ocean energy	REF	0	0	0	0	0
	E[R]	0	1	17	29	47
Total	**REF**	**52**	**99**	**155**	**213**	**276**
	E[R]	**52**	**207**	**548**	**937**	**1,356**

figure 5.100: india: electricity generation structure under the reference scenario and the energy [r]evolution scenario (INCLUDING ELECTRICITY FOR ELECTROMOBILITY, HEAT PUMPS AND HYDROGEN GENERATION)

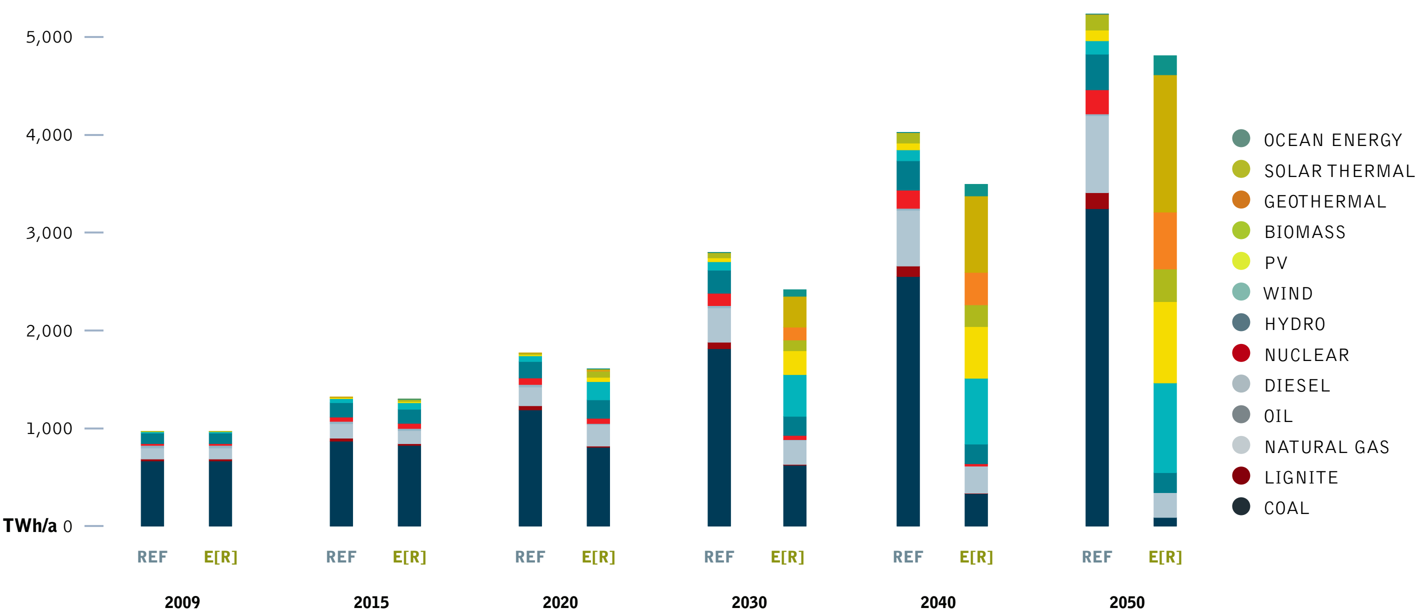


image A LOCAL BENGALI WOMAN PLANTS A MANGROVE (SUNDARI) SAPLING ON SAGAR ISLAND IN THE ECOLOGICALLY SENSITIVE SUNDERBANS RIVER DELTA REGION, IN WEST BENGAL. THOUSANDS OF LOCAL PEOPLE WILL JOIN THE MANGROVE PLANTING INITIATIVE LED BY PROFESSOR SUGATA HAZRA FROM JADAVPUR UNIVERSITY, WHICH WILL HELP TO PROTECT THE COAST FROM EROSION AND WILL ALSO PROVIDE NUTRIENTS FOR FISH AND CAPTURE CARBON IN THEIR EXTENSIVE ROOT SYSTEMS.

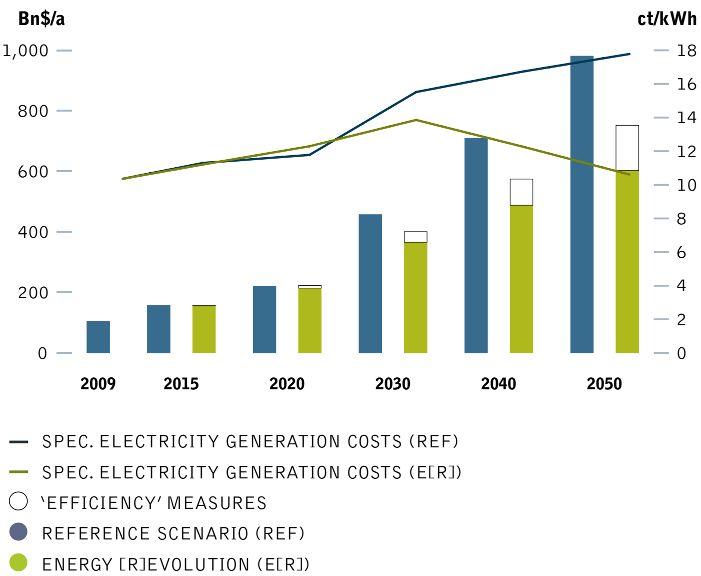
image FEMALE WORKER CLEANING A SOLAR OVEN AT A COLLEGE IN TILONIA, RAJASTHAN, INDIA.

india: future costs of electricity generation

Figure 5.101 shows that the introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the costs of electricity generation in India compared to the Reference scenario. This difference will be less than $ 1 cent/kWh up to 2020, however. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be $ 7.2 cents/kWh below those in the Reference version.

Under the Reference scenario, by contrast, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $ 100 billion per year to more than $ 932 billion in 2050. Figure 5.101 shows that the Energy [R]evolution scenario not only complies with India's CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are 23% lower than in the Reference scenario.

figure 5.101: india: total electricity supply costs and specific electricity generation costs under two scenarios

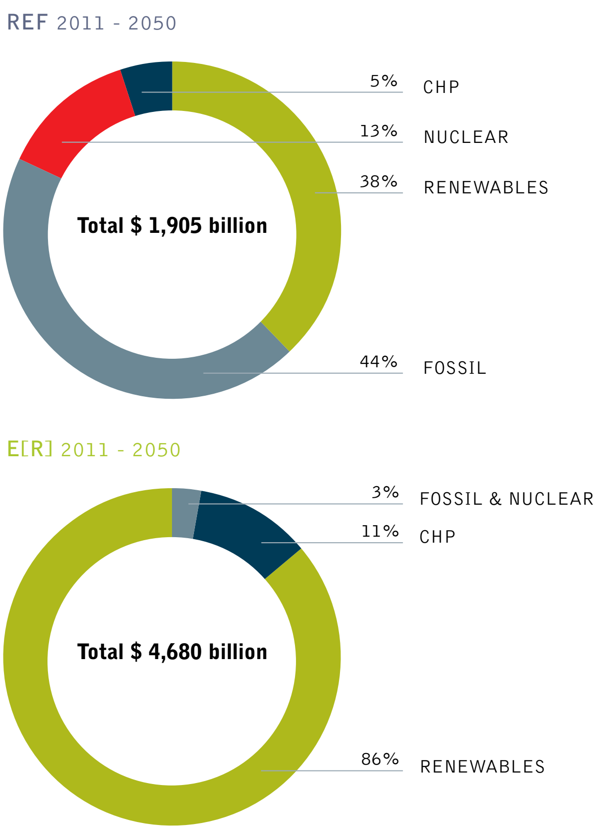


india: future investments in the power sector

It would require about $ 4,680 billion in additional investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately $ 117 billion annually or $ 69 billion more than in the Reference scenario ($ 1,905 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 56% while approximately 44% would be invested in renewable energy and cogeneration (CHP) until 2050. Under the Energy [R]evolution scenario, however, India would shift almost 97% of the entire investment towards renewables and cogeneration. Until 2030, the fossil fuel share of power sector investment would be focused mainly on CHP plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately $ 117 billion.

Because renewable energy has no fuel costs, however, the fuel cost savings in the Energy [R]evolution scenario reach a total of $ 5,500 billion up to 2050, or $ 138 billion per year. The total fuel cost savings herefore would cover 200% of the total additional investments compared to the Reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.

figure 5.102: india: investment shares - reference scenario versus energy [r]evolution scenario



india

GLOBAL SCENARIO	OECD NORTH AMERICA	MIDDLE EAST	NON OECD ASIA
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	AFRICA		

india: heating supply

Renewables currently provide 55% of India's energy demand for heat supply, the main contribution coming from biomass. Dedicated support instruments are required to ensure a dynamic future development. In the Energy [R]evolution scenario, renewables provide 68% of India's total heat demand in 2030 and 91% in 2050.

- Energy efficiency measures can decrease the specific demand in spite of improving living standards.
- For direct heating, solar collectors, new biomass/biogas heating systems as well as geothermal energy are increasingly substituting for fossil fuel-fired systems and traditional biomass use.
- A shift from coal and oil to natural gas in the remaining conventional applications will lead to a further reduction of CO_2 emissions.

Table 5.44 shows the development of the different renewable technologies for heating in India over time. After 2020, the continuing growth of solar collectors and a growing share of geothermal heat pumps will reduce the dependence on fossil fuels and biomass.

table 5.44: india: renewable heating capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	5,497	5,813	5,833	5,868	5,994
	E[R]	5,497	6,117	5,951	5,852	5,242
Solar collectors	REF	11	28	47	90	159
	E[R]	11	742	1,981	2,989	4,215
Geothermal	REF	0	5	22	49	73
	E[R]	0	205	814	1,908	3,116
Hydrogen	REF	0	0	0	0	0
	E[R]	0	0	65	341	741
Total	**REF**	**5,508**	**5,845**	**5,902**	**6,008**	**6,226**
	E[R]	**5,508**	**7,064**	**8,811**	**11,090**	**13,313**

figure 5.103: india: heat supply structure under the reference scenario and the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

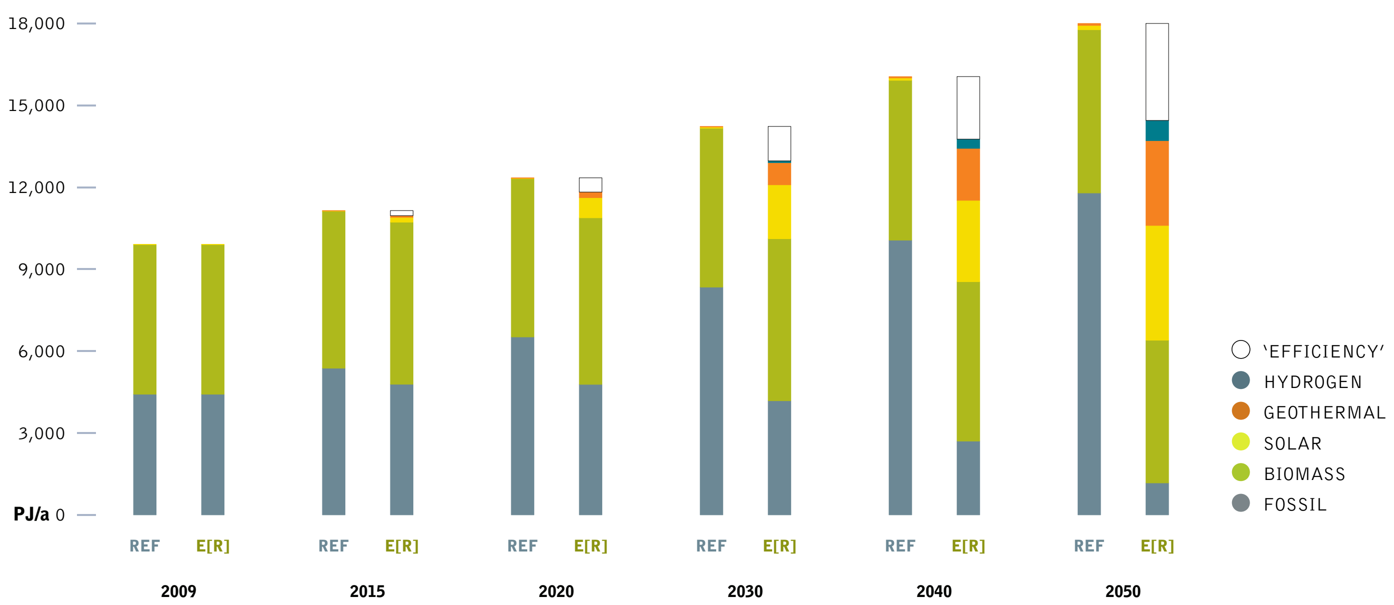
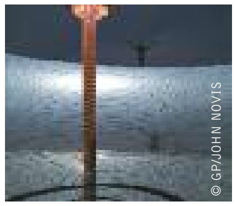


image NANLINIKANT BISWAS, FARMER AGE 43. FIFTEEN YEARS AGO NANLINIKANT'S FAMILY ONCE LIVED WHERE THE SEA IS NOW. THEY WERE AFFLUENT AND OWNED FOUR ACRES OF LAND. BUT RISING SEAWATER INCREASED THE SALINITY OF THE SOIL UNTIL THEY COULD NO LONGER CULTIVATE IT, KANHAPUR, ORISSA, INDIA.

image A SOLAR DISH WHICH IS ON TOP OF THE SOLAR KITCHEN AT AUROVILLE,TAMIL NADU, INDIA.



india: future investments in the heat sector

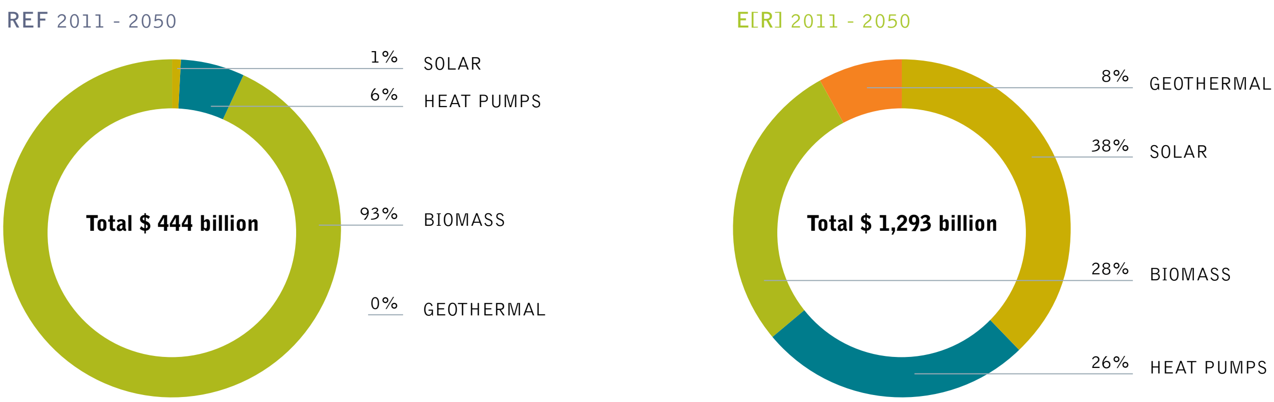
Also in the heat sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially the not yet so common solar and geothermal and heat pump technologies need enormous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity need to increase by the factor of 360 for solar thermal compared to 2009 and - if compared to the Reference scenario - by the factor of 130 for geothermal and heat pumps. Capacity of biomass technologies will remain a main pillar of heat supply.

Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar thermal district heating plants with seasonal storage.Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around $ 1,293 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately $ 32 billion per year.

table 5.45: india: renewable heat generation capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	2,082	2,197	2,176	2,127	2,082
	E[R]	2,082	2,173	1,954	1,699	1,333
Geothermal	REF	0	0	0	0	0
	E[R]	0	11	23	65	120
Solar thermal	REF	3	6	11	21	37
	E[R]	3	170	452	669	927
Heat pumps	REF	0	1	4	9	14
	E[R]	0	17	62	100	141
Total	**REF**	**2,084**	**2,205**	**2,191**	**2,157**	**2,132**
	E[R]	**2,084**	**2,370**	**2,491**	**2,533**	**2,521**

figure 5.104: india: investments for renewable heat generation technologies under the reference scenario and the energy [r]evolution scenario



india

GLOBAL SCENARIO
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india: future employment in the energy sector

The Energy [R]evolution scenario results in more energy sector jobs in India at 2015 and 2020. In 2030, job numbers are the same in both scenarios.

- There are 2.3 million energy sector jobs in the Energy [R]evolution scenario in 2015, and 1.7 million in the Reference scenario.
- In 2020, there are 2.4 million jobs in the Energy [R]evolution scenario, and 1.8 million in the Reference scenario.
- In 2030, there are 1.5 million jobs in the Energy [R]evolution scenario and the Reference scenario.

Figure 5.105 shows the change in job numbers under both scenarios for each technology between 2010 and 2030. Jobs in the Reference scenario reduce sharply, by 29% by 2015, and 39% by 2030.

Exceptionally strong growth in renewable energy compensates for some of the losses in the fossil fuel sector, particularly in earlier years. Energy [R]evolution jobs fall by 4% by 2015, increase somewhat by 2020, and then reduce to 38% below 2010 levels by 2030. Renewable energy accounts for 78% of energy jobs by 2030, with biomass having the greatest share (27%), followed by solar heating, solar PV, and wind.

figure 5.105: india: employment in the energy scenario under the reference and energy [r]evolution scenarios

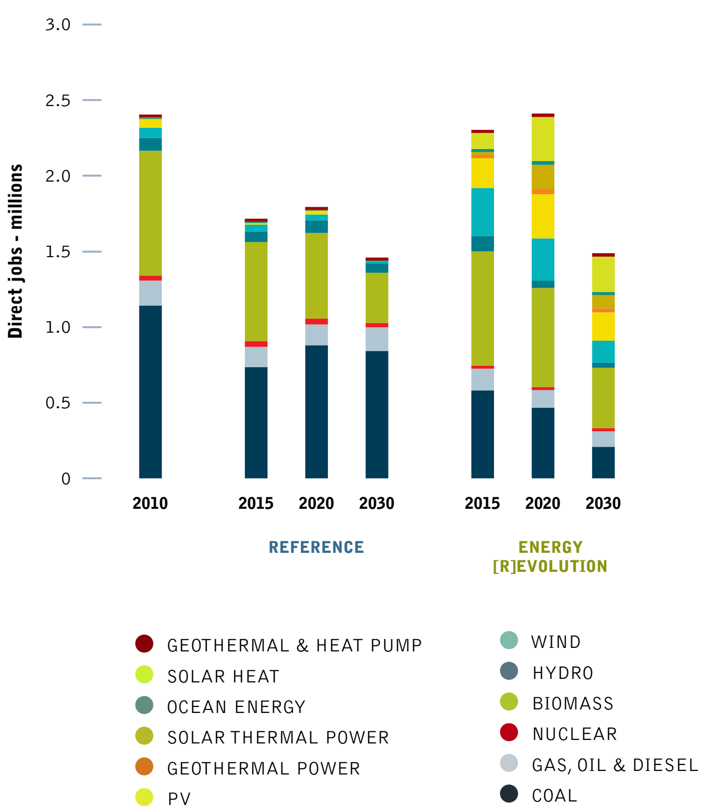


table 5.46: india: total employment in the energy sector THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	1,142	735	880	842	582	467	208
Gas, oil & diesel	165	134	138	156	156	131	120
Nuclear	33	39	39	29	8	7	3
Renewable	1,064	809	738	432	1,558	1,808	1,157
Total Jobs	**2,405**	**1,716**	**1,794**	**1,460**	**2,304**	**2,412**	**1,488**
Construction and installation	494	221	327	227	404	591	393
Manufacturing	246	111	155	99	428	496	274
Operations and maintenance	135	152	154	147	161	200	190
Fuel supply (domestic)	1,530	1,233	1,159	987	1,310.2	1,125	632
Coal and gas export	-	-	-	-	-	-	-
Total Jobs	**2,405**	**1,716**	**1,794**	**1,460**	**2,304**	**2,412**	**1,488**

image CHILDREN STUDY UNDER THE SOLAR POWERED STREETLIGHTS IN ODANTHURAI PANCHAYAT, TAMIL NADU. WHILE MOST OF THE PANCHAYAT HAS NOW BEEN RENOVATED AS NEW HOUSING BLOCKS WITH ELECTRICITY CONNECTIONS, THERE REMAIN A FEW WHERE THE ONLY ELECTRICAL LIGHT IS IN THE STREET.

image A NURSE CLEANS SWETA KUMARIS'S STITCHES WITH INSTRUMENTS STERILIZED BY SOLAR POWERED STEAM IN TRIPOLIO HOSPITAL, PATNA.

india: transport

In the transport sector, it is assumed under the Energy [R]evolution scenario that energy demand increase can be effectively limited, saving 12,541 PJ/a by 2050 or 68% compared to the Reference scenario. Energy demand will therefore increase between 2009 and 2050 by only 178% to 6,000 PJ/a. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility related behaviour patterns. Implementing a mix of increased public transport as attractive alternatives to individual cars, the car stock is growing slower and annual person kilometres are lower than in the Reference scenario.

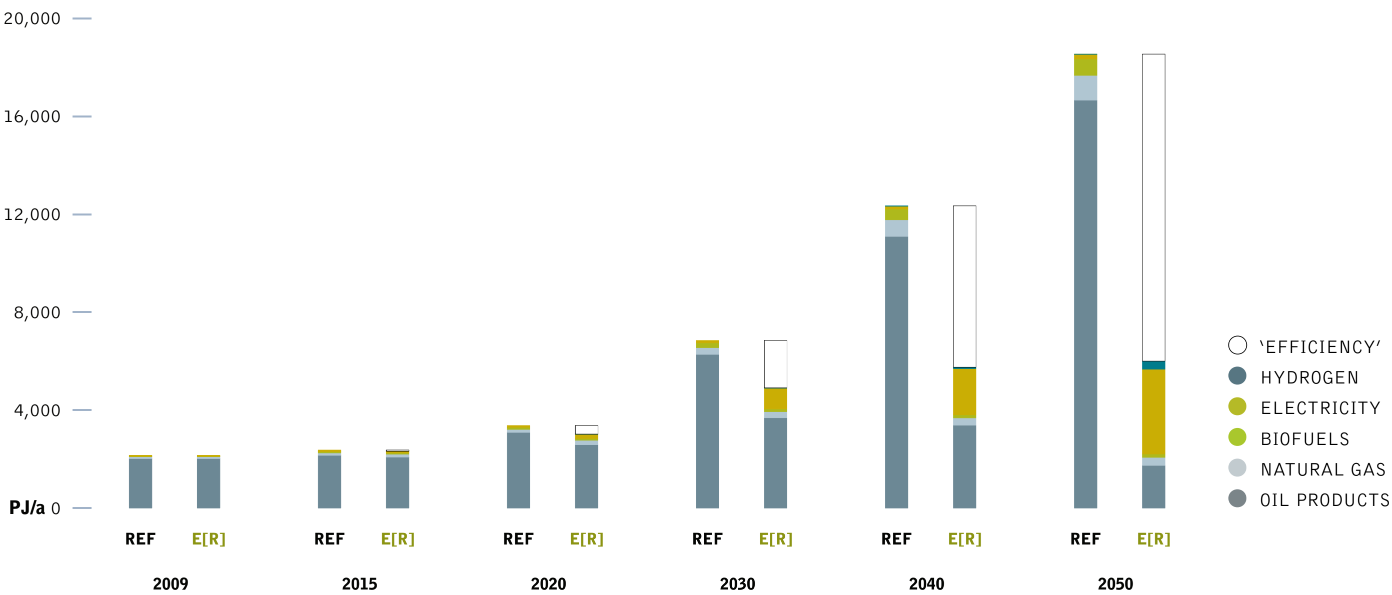
A shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains and a reduction of vehicle kilometres travelled by 0.25% per year leads to significant energy savings. In 2030, electricity will provide 17% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 58%.

table 5.47: india: transport energy demand by mode under the reference scenario and the energy [r]evolution scenario

(WITHOUT ENERGY FOR PIPELINE TRANSPORT) IN PJ/A

		2009	2020	2030	2040	2050
Rail	REF	149	202	274	346	427
	E[R]	149	257	430	518	690
Road	REF	1,892	2,985	6,210	11,334	17,081
	E[R]	1,892	2,587	4,169	4,791	4,693
Domestic aviation	REF	62	115	246	457	723
	E[R]	62	115	209	317	478
Domestic navigation	REF	53	70	116	208	313
	E[R]	53	63	101	128	142
Total	**REF**	**2,156**	**3,372**	**6,846**	**12,345**	**18,544**
	E[R]	**2,156**	**3,022**	**4,910**	**5,754**	**6,002**

figure 5.106: india: final energy consumption for transport under the reference scenario and the energy [r]evolution scenario



india

india: development of CO_2 emissions

Whilst India's emissions of CO_2 will increase by 251% under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 1,704 million tonnes in 2009 to 426 million tonnes in 2050. Annual per capita emissions will fall from 1.4 tonnes to 1 tonne in 2030 and 0.3 tonne in 2050. In the long run, efficiency gains and the increased use of renewable electricity in vehicles will also significantly reduce emissions in the transport sector. With a share of 34% of CO_2 emissions in 2050, the power generation sector will remain the largest energy related source of emissions. By 2050, India's CO_2 emissions are 72% of 1990 levels.

india: primary energy consumption

Taking into account the above assumptions, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 5.108. Compared to the Reference scenario, overall primary energy demand will be reduced by 45% in 2050. Around 81% of the remaining demand (including non energy consumption) will be covered by renewable energy sources.

The Energy [R]evolution version phases out coal and oil about 10 to 15 years faster than the previous Energy [R]evolution scenario published in 2010. This is made possible mainly by replacement of coal power plants with renewables after 20 rather than 40 years lifetime and a faster introduction of electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 48% in 2030 and 81% in 2050. Nuclear energy is phased out just after 2045.

figure 5.107: india: development of CO_2 emissions by sector under the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

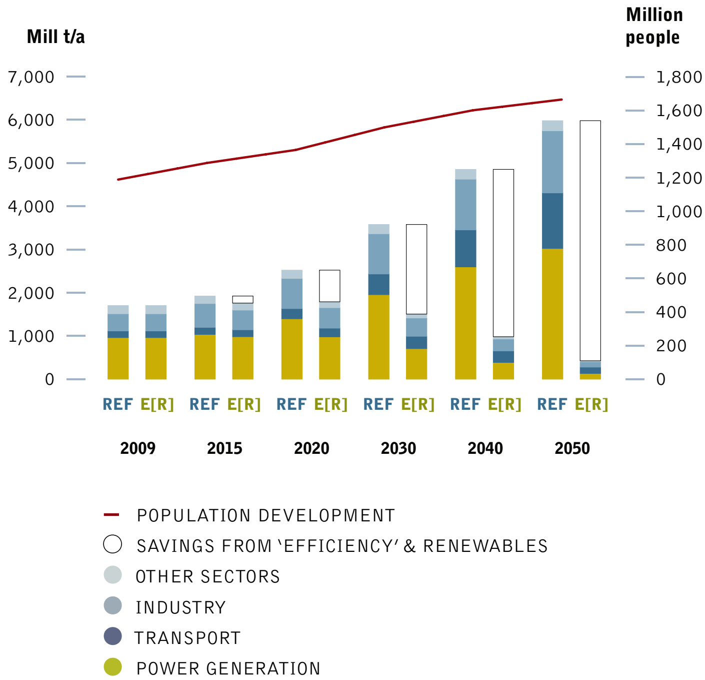


figure 5.108: india: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

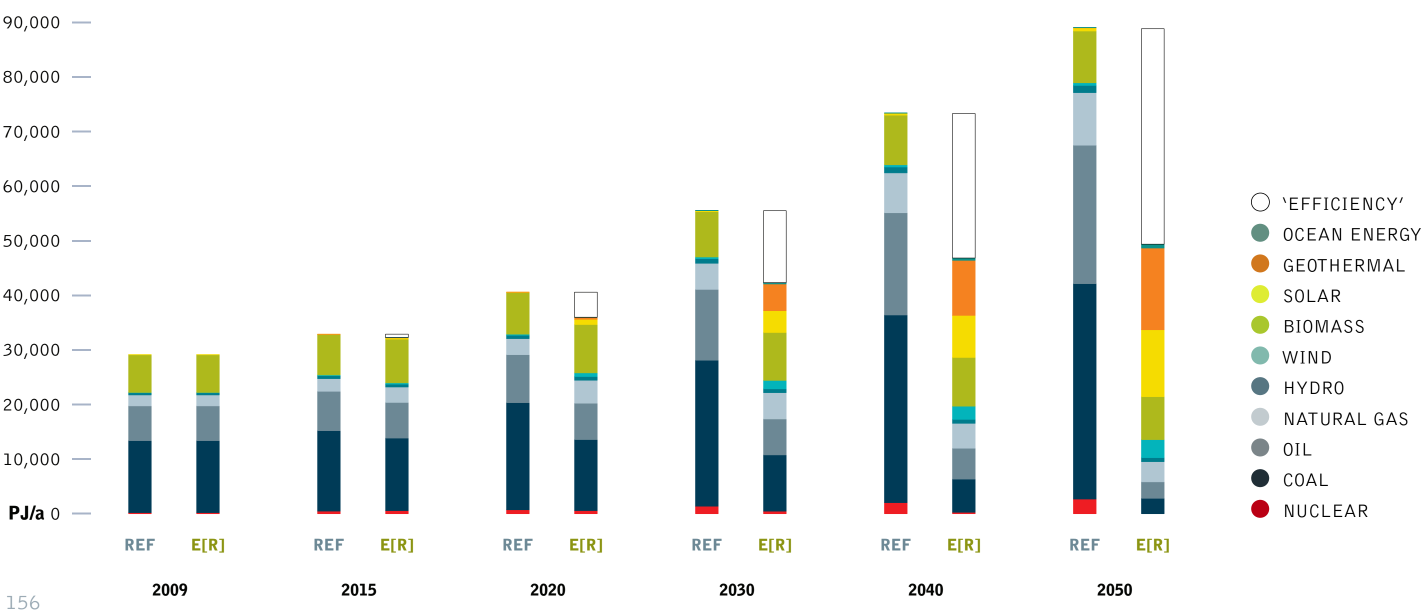


image ANANTHAMMA, A LOCAL WOMAN, RUNS A SMALL SHOP FROM HER HOME IN VADIGERE VILLAGE, AN ACTIVITY ENABLED DUE TO THE TIME SAVED BY RUNNING HER KITCHEN ON BIOGAS. THE COMMUNITY IN BAGEPALLI HAS PIONEERED THE USE OF RENEWABLE ENERGY IN ITS DAILY LIFE THANKS TO THE BIOGAS CLEAN DEVELOPMENT MECHANISM (CDM) PROJECT STARTED IN 2006.

image THE 100 KWP STAND-ALONE SOLAR PHOTOVOLTAIC POWER PLANT AT TANGTSE, DURBUK BLOCK, LADAKH. LOCATED 14,500 FEET AMSL IN THE HIMALAYA, THE PLANT SUPPLIES ELECTRICITY TO A CLINIC, SCHOOL AND 347 HOUSES IN THIS REMOTE LOCATION, FOR AROUND FIVE HOURS EACH DAY.

table 5.48: india: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

INVESTMENT COSTS	$	2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion $	-87.0	-247.1	-310.5	-310.5	-1,002.0	-25.0
Renewables	billion $	243.0	950.2	1,055.0	1,055.0	3,772.9	94.3
Total	billion $	**156.0**	**703.2**	**744.5**	**744.5**	**2,770.9**	**69.3**

CUMULATIVE FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion $/a	21.5	79.1	86.4	67.5	254.5	6.4
Gas	billion $/a	-37.7	-18.2	315.5	860.0	1,119.7	28.0
Hard coal	billion $/a	84.7	589.3	1,323.3	2,076.8	4,074.1	101.9
Lignite	billion $/a	2.9	9.0	16.6	27.4	55.9	1.4
Total	billion $/a	**71.5**	**659.2**	**1,741.8**	**3,031.6**	**5,504.1**	**137.6**

non oecd asia

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AFRICA

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EASTERN EUROPE/EURASIA
INDIA

NON OECD ASIA
CHINA
OECD ASIA OCEANIA

non oecd asia: energy demand by sector

The future development pathways for Non OECD Asia's final energy demand are shown in Figure 5.109 for the Reference and the Energy [R]evolution scenario. Under the Reference scenario, total primary energy demand in Remaining Asia more than doubles form the current 32,536 PJ/a to 73,869 PJ/a in 2050. In the Energy [R]evolution scenario, a much smaller 45% increase is expected, reaching 47,026 PJ/a.

Under the Energy [R]evolution scenario, electricity demand is expected to increase disproportionately in Non OECD Asia (see Figure 5.110). With the introduction of serious efficiency measures in the industry, residential and service sectors, however, an even higher increase can be avoided, leading to electricity demand (final energy) of around 3,205 TWh/a in 2050. Compared to the Reference case, efficiency measures avoid the generation of 1,117 TWh/a or 30% in the industry, residential and service sectors.

Efficiency gains in the heating sector are also significant (see Figure 5.112). Compared to the Reference scenario, consumption equivalent to 3,495 PJ/a is avoided through efficiency measures by 2050. In the transport sector it is assumed under the Energy [R]evolution scenario that energy demand will rise from 4,887 PJ/a in 2009 to 5,707 PJ/a by 2050.

However this still saves 55% compared to the Reference scenario. By 2030 electricity will provide 15% of the transport sector's total energy demand in the Energy [R]evolution scenario increasing to 37% by 2050.

figure 5.109: non oecd asia: total final energy demand by sector under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

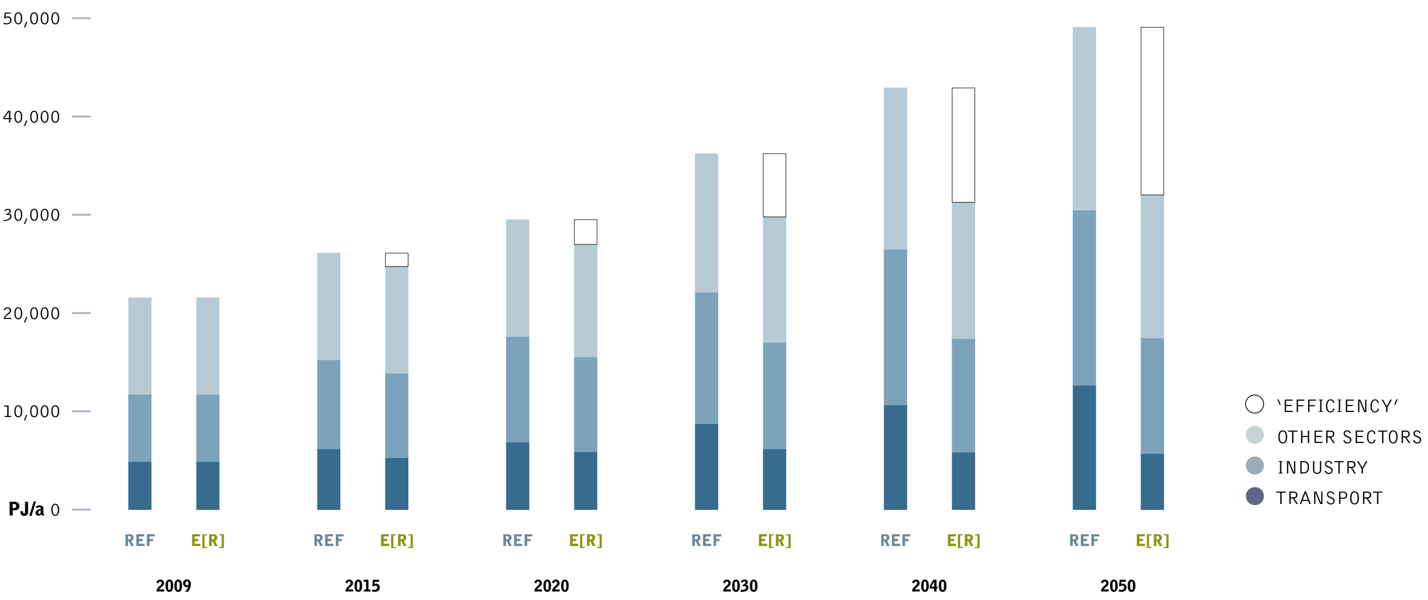


image A WOMAN PREPARING FOOD IN THE PHILIPPINES.

image AMIDST SCORCHING HEAT, AN ELDERLY FISHERWOMAN GATHERS SHELLS IN LAM TAKONG DAM, WHERE WATERS HAVE DRIED UP DUE TO PROLONGED DROUGHT. GREENPEACE LINKS RISING GLOBAL TEMPERATURES AND CLIMATE CHANGE TO THE ONSET OF ONE OF THE WORST DROUGHTS TO HAVE STRUCK THAILAND, CAMBODIA,VIETNAM AND INDONESIA IN RECENT MEMORY. SEVERE WATER SHORTAGE AND DAMAGE TO AGRICULTURE HAS AFFECTED MILLIONS.

figure 5.110: non oecd asia: development of electricity demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

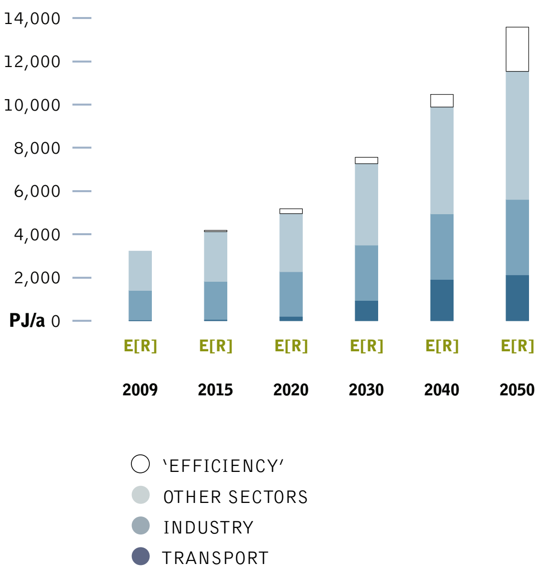


figure 5.112: non oecd asia: development of heat demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

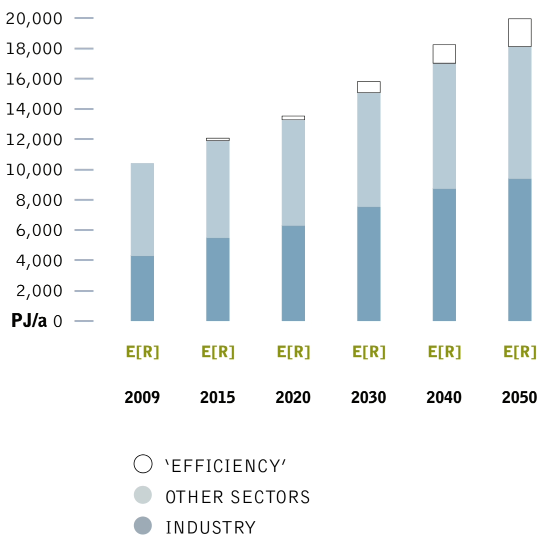
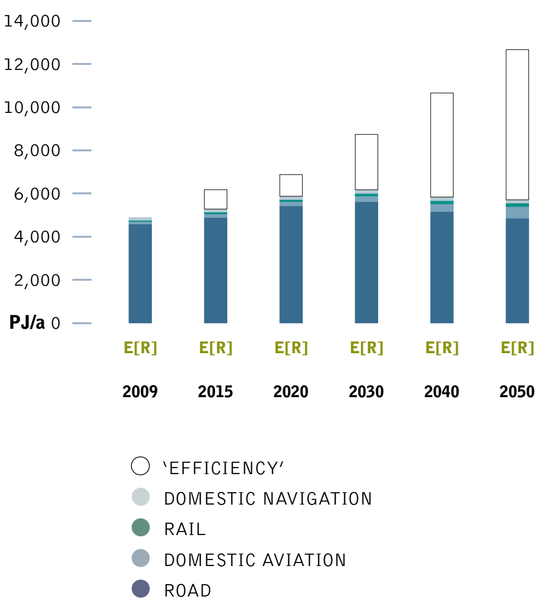
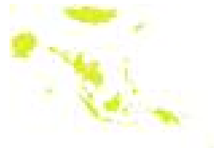


figure 5.111: non oecd asia: development of the transport demand by sector in the energy [r]evolution scenario





non oecd asia

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non oecd asia: electricity generation

The development of the electricity supply market is characterised by an increasing share of renewable electricity. By 2050, 96% of the electricity produced in Non OECD Asia will come from renewable energy sources. 'New' renewables – mainly wind, PV and solar thermal power – will contribute 88% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 36% already by 2020 and 64% by 2030. The installed capacity of renewables will reach 605 GW in 2030 and 1,619 GW by 2050, an enormous increase.

Table 5.49 shows the comparative evolution of the different renewable technologies in Non OECD Asia over time. Up to 2020 hydro and wind will remain the main contributors of the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from photovoltaics, solar thermal (CSP), and ocean energy. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 34% by 2030 and 54% by 2050, therefore the expansion of smart grids, demand side management (DSM) and storage capacity from the increased share of electric vehicles will be used for a better grid integration and power generation management.

table 5.49: non oecd asia: renewable electricity generation capacity under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Hydro	REF	48	75	100	123	146
	E[R]	48	69	80	88	96
Biomass	REF	3	6	11	17	23
	E[R]	3	4	7	11	13
Wind	REF	1	6	21	45	71
	E[R]	1	90	210	372	478
Geothermal	REF	3	5	7	10	13
	E[R]	3	12	34	72	107
PV	REF	0	4	11	17	24
	E[R]	0	59	199	391	577
CSP	REF	0	0	0	0	0
	E[R]	0	4	64	171	295
Ocean energy	REF	0	0	0	0	0
	E[R]	0	2	12	27	53
Total	**REF**	**55**	**96**	**150**	**211**	**275**
	E[R]	**55**	**240**	**605**	**1,130**	**1,619**

figure 5.113: non oecd asia: electricity generation structure under the reference scenario and the energy [r]evolution scenario (INCLUDING ELECTRICITY FOR ELECTROMOBILITY, HEAT PUMPS AND HYDROGEN GENERATION)

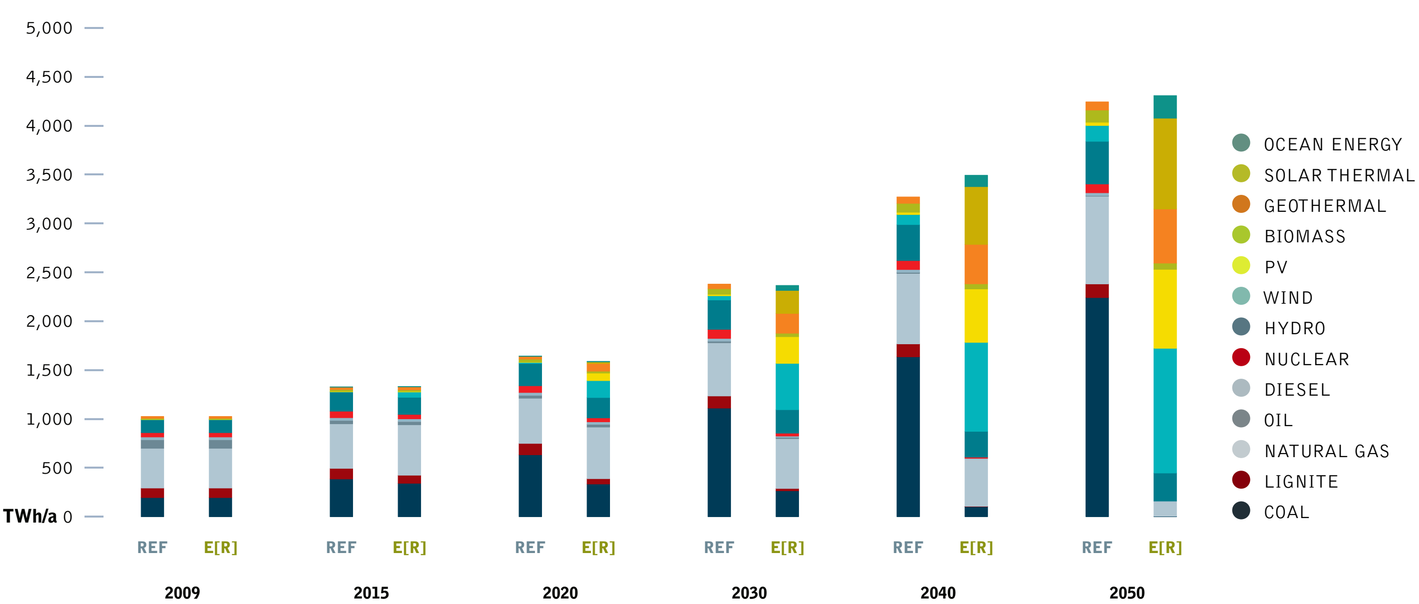


image GREENPEACE DONATES A SOLAR POWER SYSTEM TO A COASTAL VILLAGE IN ACEH, INDONESIA, ONE OF THE WORST HIT AREAS BY THE TSUNAMI IN DECEMBER 2004. IN COOPERATION WITH UPLINK, A LOCAL DEVELOPMENT NGO, GREENPEACE OFFERED ITS EXPERTISE ON ENERGY EFFICIENCY AND RENEWABLE ENERGY AND INSTALLED RENEWABLE ENERGY GENERATORS FOR ONE OF THE BADLY HIT VILLAGES BY THE TSUNAMI.

image A WOMAN GATHERS FIREWOOD ON THE SHORES CLOSE TO THE WIND FARM OF ILOCOS NORTE, AROUND 500 KILOMETERS NORTH OF MANILA.

non oecd asia: future costs of electricity generation

Figure 5.114 shows that the introduction of renewable technologies under the Energy [R]evolution scenario significantly decreases future costs of electricity generation in Non OECD Asia compared to the Reference scenario. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be $ 7.2 cents/kWh below those in the Reference version.

Under the Reference scenario, on the other hand, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $ 145 billion per year to more than $ 777 billion in 2050. Figure 5.114 shows that the Energy [R]evolution scenario helps Non OECD Asia to stabilise energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are 14% lower than in the Reference scenario, including estimated costs for efficiency measures.

non oecd asia: future investments in the power sector

It would require $ 5,150 billion in investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately $ 129 billion annually or $ 88 billion more than in the Reference scenario ($ 1,645 billion).

Under the Reference version, the levels of investment in conventional power plants add up to almost 47% while approximately 53% would be invested in renewable energy and cogeneration (CHP) until 2050. Under the Energy [R]evolution scenario, however, Non OECD Asia would shift almost 97% of the entire investment towards renewables and cogeneration. Until 2030, the fossil fuel share of power sector investment would be focused mainly on CHP plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately $ 129 billion.

figure 5.114: non oecd asia: total electricity supply costs and specific electricity generation costs under two scenarios

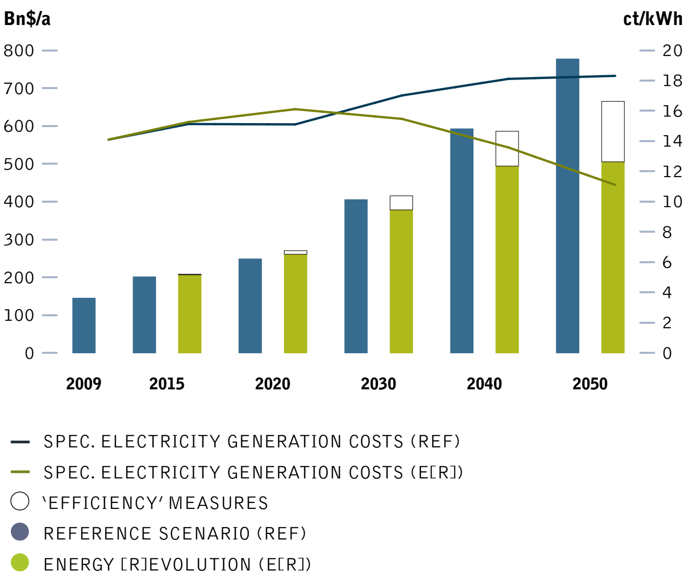
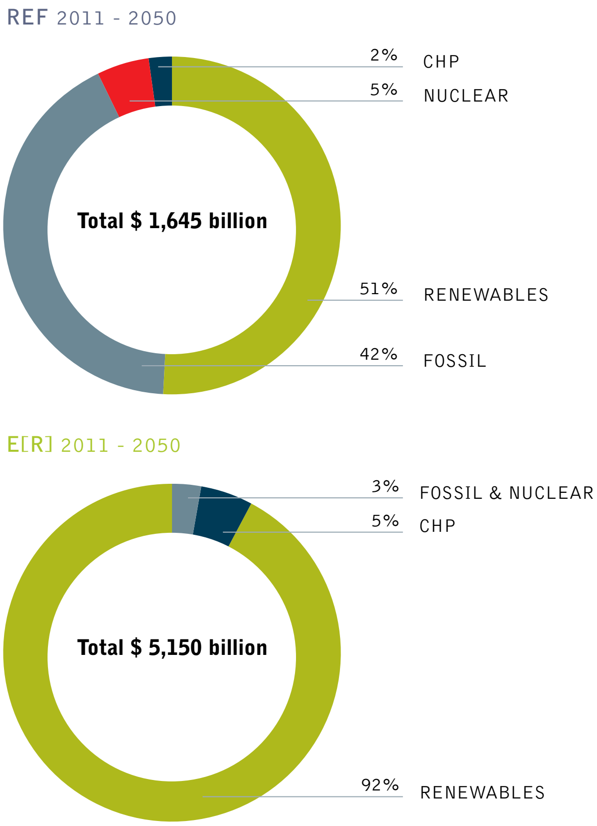


figure 5.115: non oecd asia: investment shares - reference scenario versus energy [r]evolution scenario



non oecd asia

non oecd asia: heating supply

Today, renewables provide 50% of Non OECD Asia's heat demand, the main contribution coming from biomass. Dedicated support instruments are required to ensure a dynamic future development. In the Energy [R]evolution scenario, renewables provide 55% of Non OECD Asia's total heat demand in 2030 and 86% in 2050.

- Energy efficiency measures will restrict the future heat demand in 2030 to an increase of 40% compared to 52% in the Reference scenario, in spite of improving living standards.
- In the industry sector solar collectors, biomass/biogas as well as geothermal energy and hydrogen from renewable sources are increasingly substituted for conventional fossil-fired heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

Table 5.50 shows the development of the different renewable technologies for heating in Non OECD Asia over time. Up to 2020 biomass will remain the main contributors of the growing market share. After 2020, the continuing growth of solar collectors and a growing share of geothermal heat pumps will reduce the dependence on fossil fuels.

table 5.50: non oecd asia: renewable heating capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	5,173	5,489	5,691	6,295	6,876
	E[R]	5,173	4,930	4,748	4,267	4,008
Solar collectors	REF	4	37	77	134	190
	E[R]	4	734	1,978	3,739	5,038
Geothermal	REF	0	0	0	5	9
	E[R]	0	526	1,314	2,729	4,784
Hydrogen	REF	0	0	0	0	0
	E[R]	0	0	0	237	323
Total	**REF**	**5,177**	**5,526**	**5,769**	**6,434**	**7,076**
	E[R]	**5,177**	**6,191**	**8,040**	**10,973**	**14,154**

figure 5.116: non oecd asia: heat supply structure under the reference scenario and the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

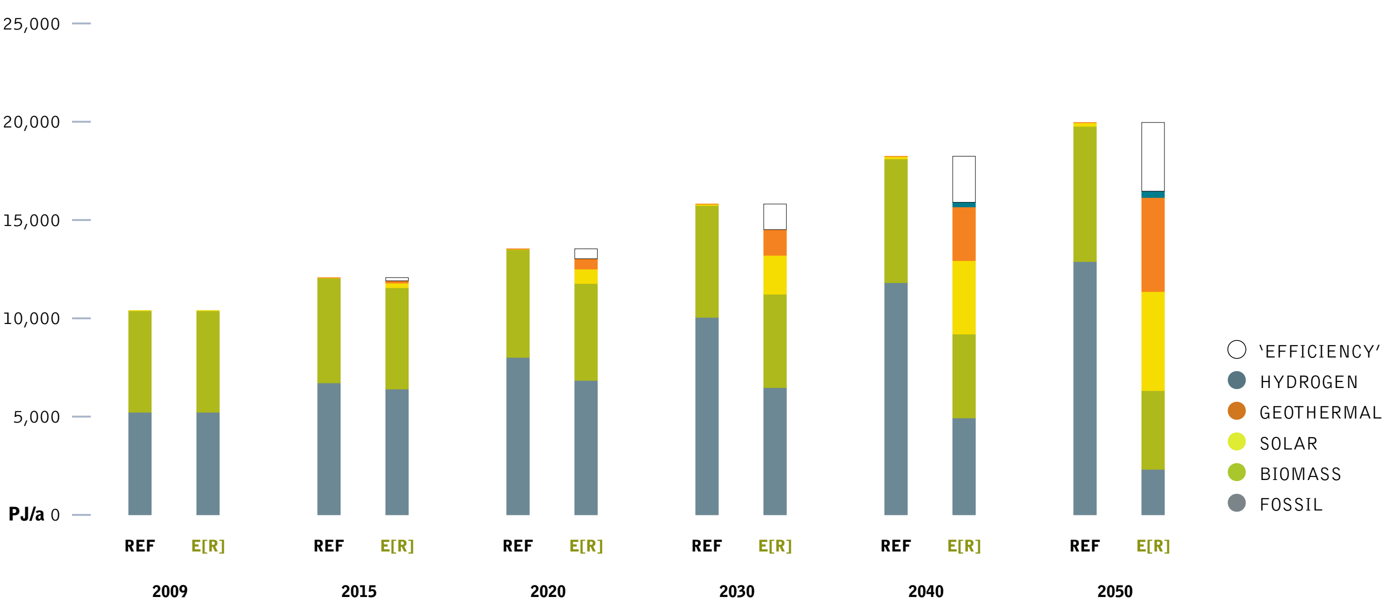


image MAJESTIC VIEW OF THE WIND FARM IN ILOCOS NORTE, AROUND 500 KILOMETRES NORTH OF MANILA. THE 25 MEGAWATT WIND FARM, OWNED AND OPERATED BY DANISH FIRM NORTHWIND, IS THE FIRST OF ITS KIND IN SOUTHEAST ASIA.

image A MAN WORKING IN A RICE FIELD IN THE PHILIPPINES.

non oecd asia: future investments in the heat sector

In the heat sector, the Energy [R]evolution scenario would require also a major revision of current investment strategies. Especially solar, geothermal and heat pump technologies need an enormous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity for direct heating and heating plants (excluding district heat from CHP) need to be increased up to around 1500 GW for solar thermal and up to 700 GW for geothermal and heat pumps. Capacity of biomass use for heat supply needs to remain a pillar of heat supply, however current plants need to be replaced by new efficient technologies.

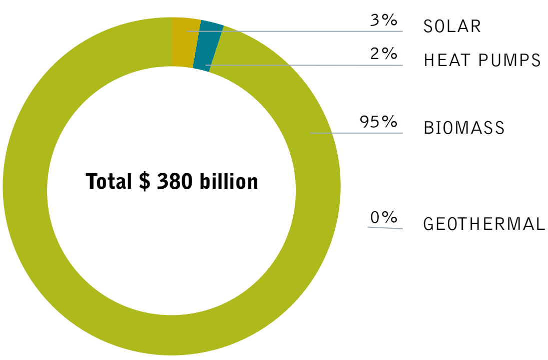
Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar thermal district heating plants with seasonal storage. Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around $ 2,459 billion to be invested in renewable direct heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately $ 61 billion per year.

table 5.51: non oecd asia: renewable heat generation capacities under the reference scenario and the energy [r]evolution scenario IN GW

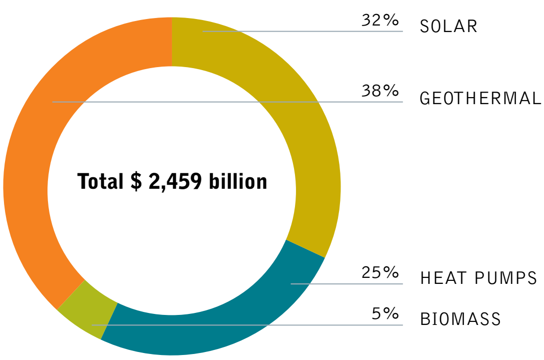
		2009	2020	2030	2040	2050
Biomass	REF	1,697	1,829	1,869	1,851	1,834
	E[R]	1,697	1,626	1,482	1,122	867
Geothermal	REF	0	0	0	0	0
	E[R]	0	41	90	220	376
Solar thermal	REF	1	11	23	40	56
	E[R]	1	214	581	1,100	1,461
Heat pumps	REF	0	0	0	1	2
	E[R]	0	32	76	135	275
Total	**REF**	**1,699**	**1,840**	**1,892**	**1,892**	**1,892**
	E[R]	**1,699**	**1,913**	**2,228**	**2,577**	**2,979**

figure 5.117: non oecd asia: investments for renewable heat generation technologies under the reference scenario and the energy [r]evolution scenario

REF 2011 - 2050



E[R] 2011 - 2050



non oecd asia

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non oecd asia: future employment in the energy sector

The Energy [R]evolution scenario results in more energy sector jobs in non OECD Asia at 2015 and 2020, and slightly fewer jobs at 2030.

- There are 2 million energy sector jobs in the Energy [R]evolution scenario in 2015, and 1.7 million in the Reference scenario.
- In 2020, there are 1.9 million jobs in the Energy [R]evolution scenario, and 1.7 million in the Reference scenario.
- In 2030, there are 1.4 million jobs in the Energy [R]evolution scenario and 1.5 million in the Reference scenario.

Figure 5.118 shows the change in job numbers under both scenarios for each technology between 2010 and 2030. Jobs in the Reference scenario drop by 8% by 2015, and then remain the same until 2020. Jobs drop again to 22% below 2010 levels by 2030.

Strong growth in renewable energy leads to a small increase of 7% in total energy sector jobs in the Energy [R]evolution scenario by 2015. Renewable energy jobs remain high until 2020, and then drop to 23% of energy jobs by 2030, with biomass having the greatest share (22%), followed by solar heating, wind, solar PV, hydro.

figure 5.118: non oecd asia: employment in the energy scenario under the reference and energy [r]evolution scenarios

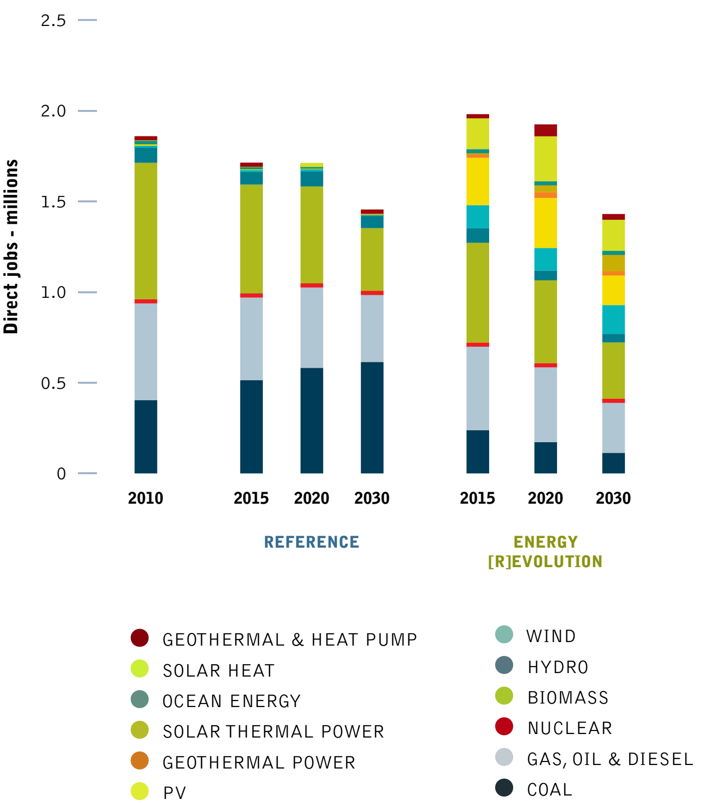


table 5.52: non oecd asia: total employment in the energy sector THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	404	514	582	615	238	173	113
Gas, oil & diesel	537	466	451	386	479	431	295
Nuclear	19	13	15	6	4.8	4.2	3.4
Renewable	900	721	664	448	1,260	1,317	1,019
Total Jobs	**1,860**	**1,714**	**1,713**	**1,455**	**1,982**	**1,925**	**1,431**
Construction and installation	230	206	196	141	492	555	385
Manufacturing	82	83	80	65	184	227	203
Operations and maintenance	125	125	132	129	125	156	173
Fuel supply (domestic)	1,339	1,184	1,156	1,006	1,116.8	978	668
Coal and gas export	84	116	150	115	64	9	**2**
Total Jobs	**1,860**	**1,714**	**1,713**	**1,455**	**1,982**	**1,925**	**1,431**

image THE BATAAN NUCLEAR POWER PLANT MAY FINALLY OPEN BUT THANKFULLY ONLY AS A TOURIST ATTRACTION. ON JUNE 11, 2011.

image WATER IS PUMPED FROM THE FLOODED INDUSTRIAL PARK IN BANGPA-IN AYUTTHAYA, THAILAND. OVER SEVEN MAJOR INDUSTRIAL PARKS IN THAILAND AND THOUSANDS OF FACTORIES HAVE BEEN CLOSED IN THE CENTRAL THAI PROVINCE OF AYUTTHAYA AND NONTHABURI WITH MILLIONS OF TONS OF RICE DAMAGED. THAILAND IS EXPERIENCING THE WORST FLOODING IN OVER 50 YEARS WHICH HAS AFFECTED MORE THAN NINE MILLION PEOPLE.

non oecd asia: transport

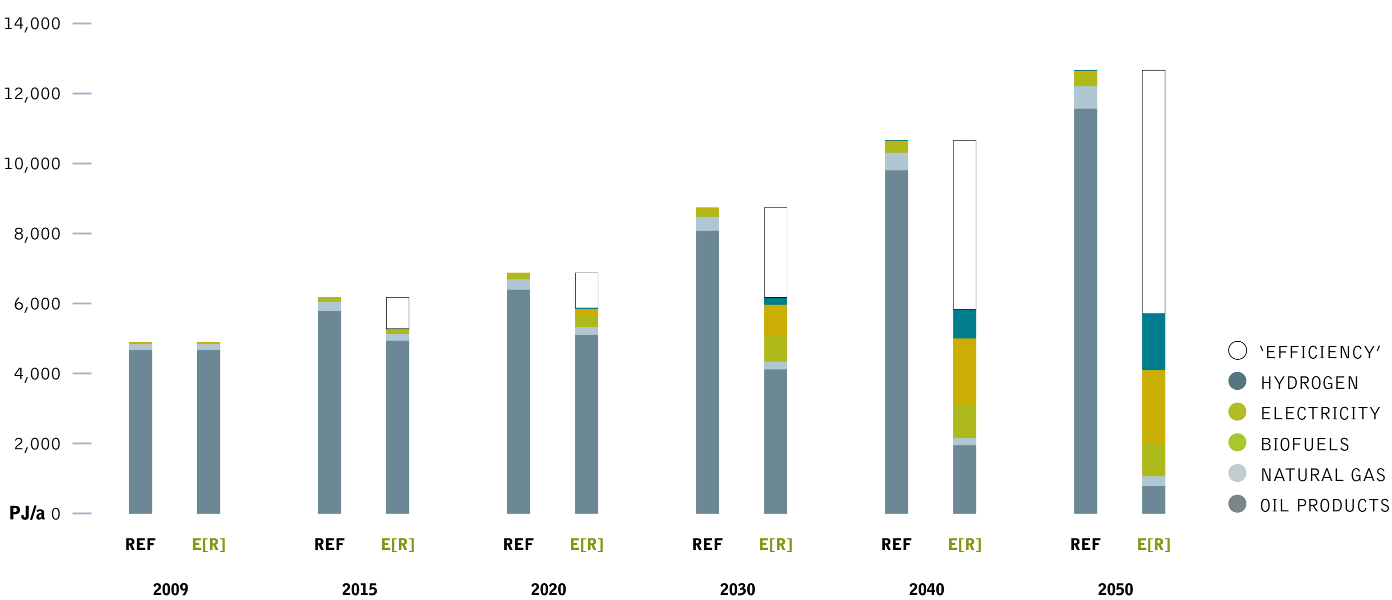
In 2050, the car fleet in Non OECD Asia will be significantly larger than today. Today, more medium to large-sized cars are driven in Non OECD Asia with an unusually high annual mileage. With growing individual mobility, an increasing share of small efficient cars is projected, with vehicle kilometres driven resembling industrialised countries averages. More efficient propulsion technologies, including hybrid-electric power trains, and lightweight construction, will help to limit the growth in total transport energy demand to a factor of 1.17, reaching 5,700 PJ/a in 2050. As Non OECD Asia already has a large fleet of electric vehicles, this will grow to the point where almost 37% of total transport energy is covered by electricity.

By 2030 electricity will provide 15% of the transport sector's total energy demand under the Energy [R]evolution scenario. Under both scenarios road transport volumes increases significantly. However, under the Energy [R]evolution scenario, the total energy demand for road transport increases from 4,588 PJ/a in 2009 to 4,856 PJ/a in 2050, compared to 11,514 PJ/a in the Reference case.

table 5.53: non oecd asia: transport energy demand by mode under the reference scenario and the energy [r]evolution scenario (WITHOUT ENERGY FOR PIPELINE TRANSPORT) IN PJ/A

		2009	2020	2030	2040	2050
Rail	REF	58	82	98	107	118
	E[R]	58	98	123	151	167
Road	REF	4,588	6,439	8,142	9,852	11,514
	E[R]	4,588	5,430	5,623	5,164	4,856
Domestic aviation	REF	114	192	280	425	709
	E[R]	114	193	258	356	536
Domestic navigation	REF	127	160	218	272	322
	E[R]	127	154	168	164	148
Total	**REF**	**4,887**	**6,874**	**8,738**	**10,655**	**12,664**
	E[R]	**4,887**	**5,873**	**6,173**	**5,835**	**5,707**

figure 5.119: non oecd asia: final energy consumption for transport under the reference scenario and the energy [r]evolution scenario



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non oecd asia: development of CO_2 emissions

Whilst the Non OECD Asia's emissions of CO_2 will increase by 178% under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 1,514 million tonnes in 2009 to 278 million tonnes in 2050. Annual per capita emissions will remain at around 1.4 tonnes through 2020 and decrease afterward to 0.2 tonnes in 2050. In the long run efficiency gains and the increased use of renewable electricity in vehicles will also significantly reduce emissions in the transport sector. With a share of 26% of CO_2 emissions in 2050, the transport sector will be the largest energy related sources of emissions. By 2050, Non OECD Asia's CO_2 emissions are 12% of 1990 levels.

non oecd asia: primary energy consumption

Taking into account the above assumptions, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 5.121. Compared to the Reference scenario, overall primary energy demand will be reduced by 36% in 2050. Around 81% of the remaining demand (including non energy consumption) will be covered by renewable energy sources.

The coal demand in the Energy [R]evolution scenario will peak by 2015 with 6,730 PJ/a compared to 5,684 PJ/a in 2009 and decrease afterwards to 1,753 PJ/a by 2050. This is made possible mainly by replacement of coal power plants with renewables after 20 rather than 40 years lifetime. This leads to an overall renewable primary energy share of 46% in 2030 and 81% in 2050. Nuclear energy remains on a very low level and is phased out just after 2045.

figure 5.120: non oecd asia: development of CO_2 emissions by sector under the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

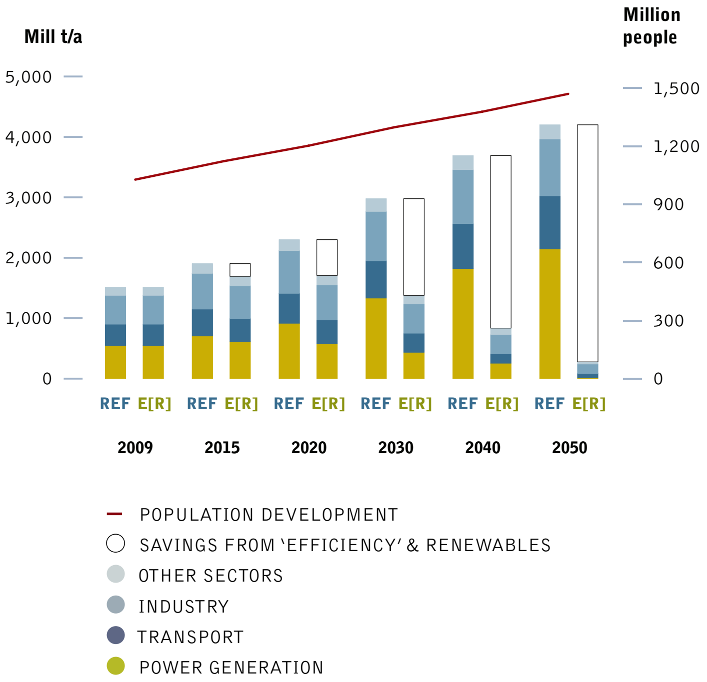

figure 5.121: non oecd asia: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

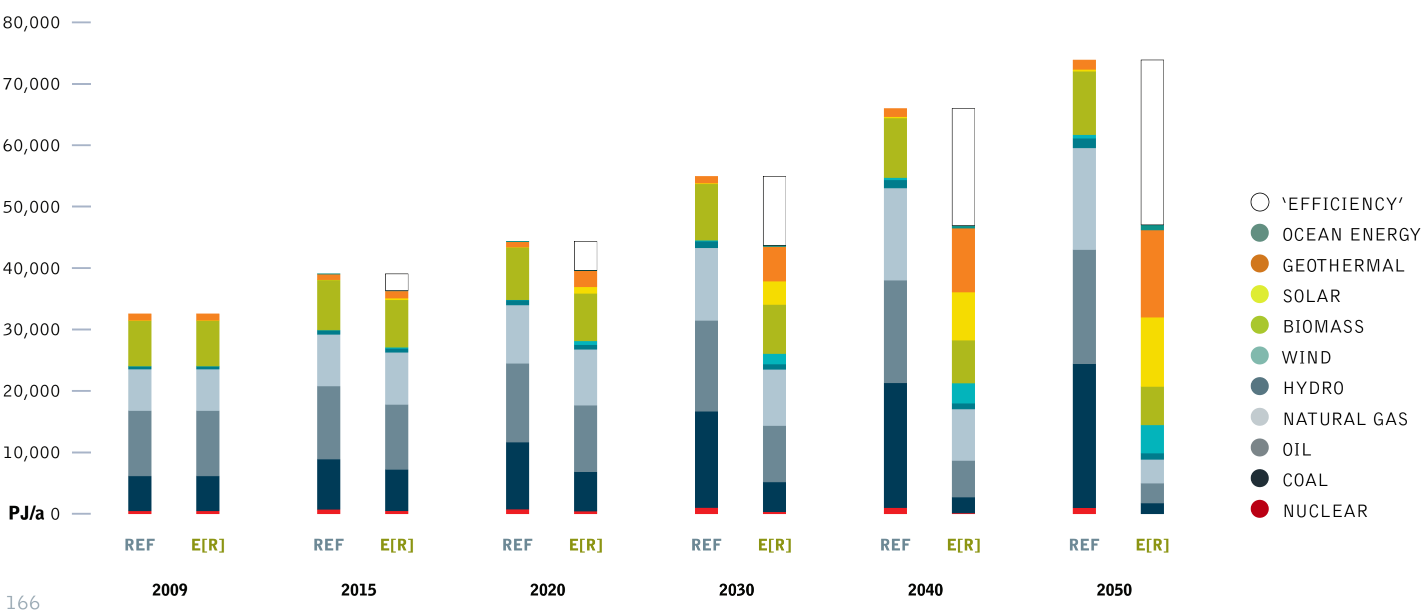

image A STORM OVER THE PACIFIC OCEAN.

image A BOY WASHES NEAR HITEC INDUSTRIAL PARK IN AYUTTHAYA, THAILAND DURING THE WORST FLOODING IN OVER 50 YEARS.

table 5.54: non oecd asia: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

INVESTMENT COSTS	$	2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion $	-89.1	-158.5	-146.6	-196.7	-590.9	-14.8
Renewables	billion $	327.8	838.5	1,353.9	1,576.0	4,096.1	102.4
Total	billion $	**238.7**	**680.0**	**1,207.3**	**1,379.2**	**3,505.2**	**87.6**

CUMULATIVE FUEL COST SAVINGS

SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion $/a	2.9	6.5	16.1	23.6	49.2	1.2
Gas	billion $/a	-75.7	-10.7	324.7	1,139.1	1,377.6	34.4
Hard coal	billion $/a	77.3	372.3	829.7	1,272.6	2,551.9	63.8
Lignite	billion $/a	5.1	14.1	20.4	26.2	65.8	1.6
Total	billion $/a	**9.6**	**382.3**	**1,190.9**	**2,461.6**	**4,044.5**	**101.1**

china

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OECD ASIA OCEANIA

china: energy demand by sector

The future development pathways for China's energy demand are shown in Figure 5.122 for the Reference and the Energy [R]evolution scenario. Under the Reference scenario, total primary energy demand in China increases by 89% from the current 96,000 PJ/a to around 181,300 PJ/a in 2050. In the Energy [R]evolution scenario, by contrast, energy demand increases by 9% compared to current consumption and it is expected by 2050 to reach 104,500 PJ/a.

Under the Energy [R]evolution scenario, electricity demand in the industrial, residential, and service sectors is expected to increase disproportionately (see Figure 5.123). With the exploitation of efficiency measures, however, an even higher increase can be avoided, leading to 10,040 TWh/a in 2050. Compared to the Reference case, efficiency measures in industry and other sectors avoid the generation of about 3,320 TWh/a or 29%. In contrast, electricity consumption in the transport sector will grow significantly, as the Energy [R]evolution scenario introduces electric trains and public transport as well as efficient electric vehicles faster than the Reference case. Fossil fuels for industrial process heat generation are also phased out more quickly and replaced by electric geothermal heat pumps and hydrogen.

Efficiency gains in the heat supply sector are larger than in the electricity sector. Under the Energy [R]evolution scenario, final demand for heat supply can even be reduced significantly (see Figure 5.125). Compared to the Reference scenario, consumption equivalent to 7200 PJ/a is avoided through efficiency measures by 2050.

In the transport sector it is assumed under the Energy [R]evolution scenario that energy demand will increase considerably, from 6,816 PJ/a in 2009 to 12,600 PJ/a by 2050. However this still saves 56% compared to the Reference scenario. By 2030 electricity will provide 13% of the transport sector's total energy demand in the Energy [R]evolution scenario increasing to 55% by 2050.

figure 5.122: china: total final energy demand by sector under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

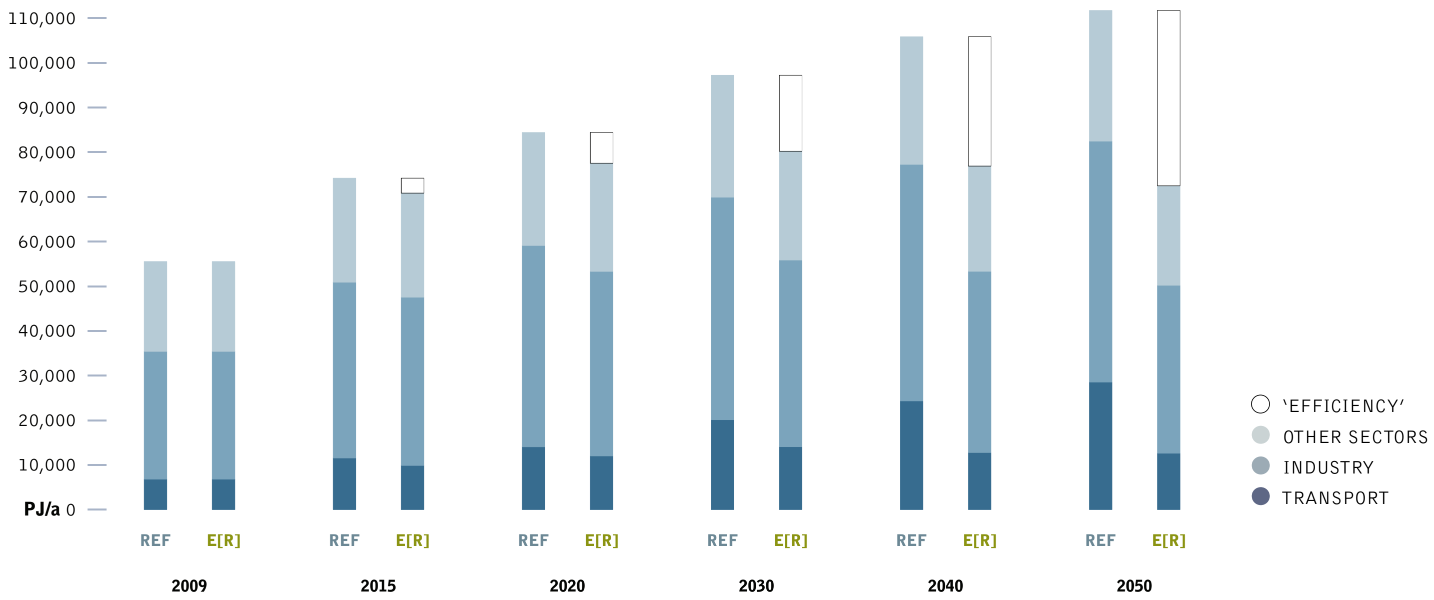


image WANG WAN YI, AGE 76, AND LINANG JUN QIN, AGE 72, EAT NOODLES IN THEIR ONE ROOM HOME CARVED OUT OF THE SANDSTONE, A TYPICAL DWELLING FOR LOCAL PEOPLE IN THE REGION. DROUGHT IS ONE OF THE MOST HARMFUL NATURAL HAZARDS IN NORTHWEST CHINA. CLIMATE CHANGE HAS A SIGNIFICANT IMPACT ON CHINA'S ENVIRONMENT AND ECONOMY.

image image THE BLADES OF A WINDMILL SIT ON THE GROUND WAITING FOR INSTALLATION AT GUAZHOU WIND FARM NEAR YUMEN IN GANSU PROVINCE.

figure 5.123: china: development of electricity demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

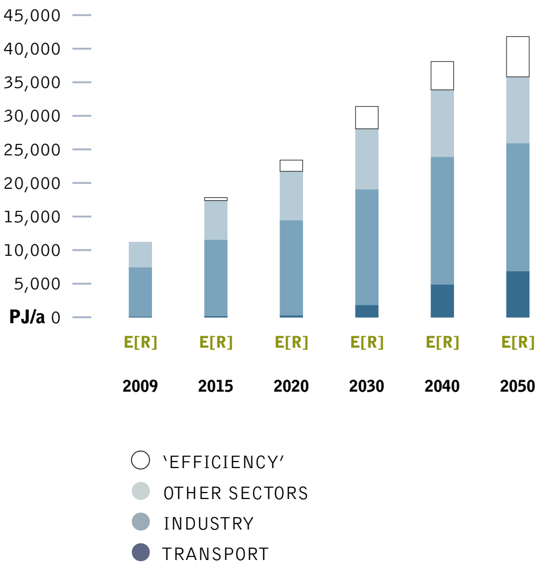


figure 5.125: china: development of heat demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

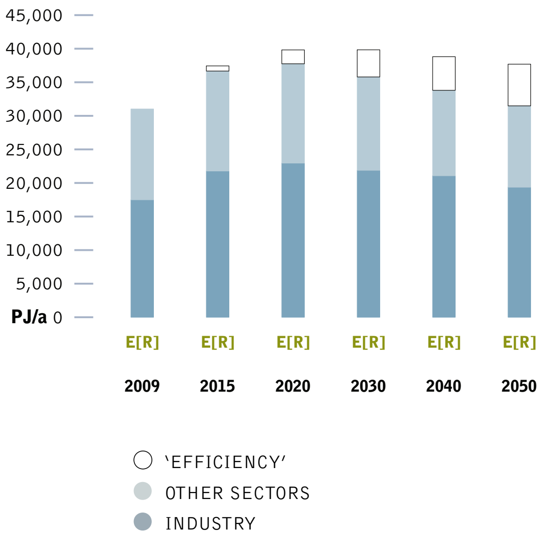
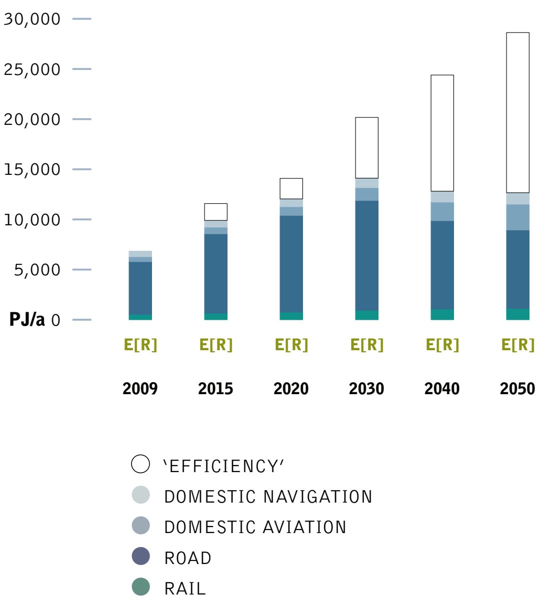


figure 5.124: china: development of the transport demand by sector in the energy [r]evolution scenario



china

china: electricity generation

The development of the electricity supply market is characterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 92% of the electricity produced in China will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal power and PV – will contribute 60% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 27% already by 2020 and 43% by 2030. The installed capacity of renewables will reach 1,298 GW in 2030 and 3,076 GW by 2050, an enormous increase.

Table 5.55 shows the comparative evolution of the different renewable technologies in China over time. Up to 2020 hydro and wind will remain the main contributors of the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaics and solar thermal (CSP) energy. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 19% by 2030 and 48% by 2050, therefore the expansion of smart grids, demand side management (DSM) and storage capacity e.g. from the increasing share of electric vehicles will be used for a better grid integration and power generation management.

table 5.55: china: renewable electricity generation capacity under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Hydro	REF	197	320	370	402	433
	E[R]	197	294	341	397	433
Biomass	REF	1	18	32	48	63
	E[R]	1	31	51	81	112
Wind	REF	13	150	222	266	305
	E[R]	13	234	517	845	1,139
Geothermal	REF	0	0	1	1	2
	E[R]	0	2	22	69	133
PV	REF	0	22	30	45	62
	E[R]	0	83	221	542	803
CSP	REF	0	1	2	2	3
	E[R]	0	42	138	203	295
Ocean energy	REF	0	0	0	0	0
	E[R]	0	1	9	28	161
Total	**REF**	**212**	**511**	**657**	**764**	**868**
	E[R]	**212**	**685**	**1,298**	**2,166**	**3,076**

figure 5.126: china: electricity generation structure under the reference scenario and the energy [r]evolution scenario (INCLUDING ELECTRICITY FOR ELECTROMOBILITY, HEAT PUMPS AND HYDROGEN GENERATION)

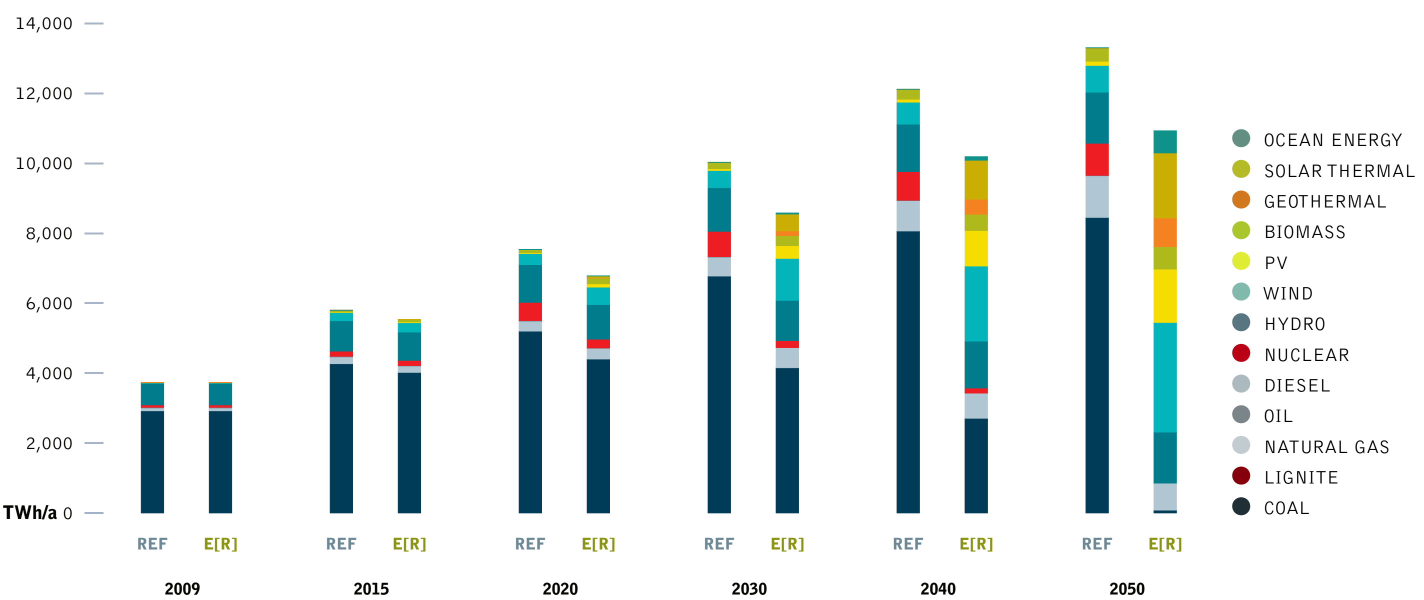


image A WORKER ENTERS A TURBINE TOWER FOR MAINTENANCE AT DABANCHENG WIND FARM. CHINA'S BEST WIND RESOURCES ARE MADE POSSIBLE BY THE NATURAL BREACH IN TIANSHAN (TIAN MOUNTAIN).

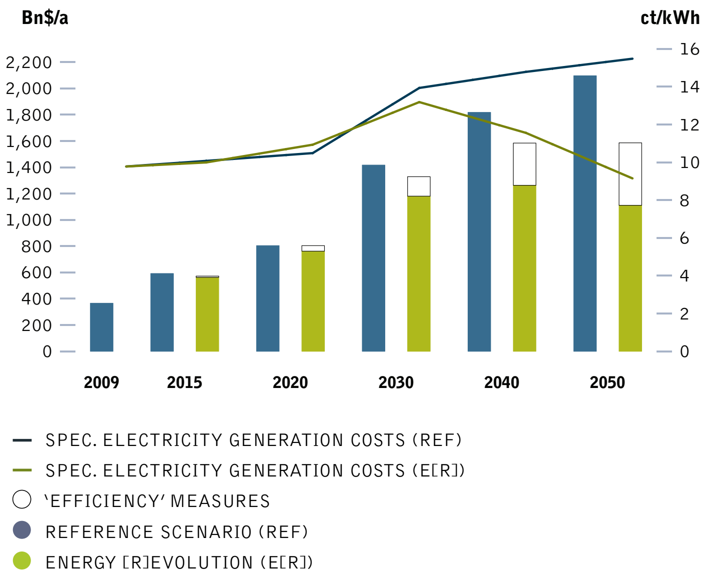
image WOMEN WEAR MASKS AS THEY RIDE BIKES TO WORK IN THE POLLUTED TOWN OF LINFEN. LINFEN, A CITY OF ABOUT 4.3 MILLION, IS ONE OF THE MOST POLLUTED CITIES IN THE WORLD. CHINA'S INCREASINGLY POLLUTED ENVIRONMENT IS LARGELY A RESULT OF THE COUNTRY'S RAPID DEVELOPMENT AND CONSEQUENTLY A LARGE INCREASE IN PRIMARY ENERGY CONSUMPTION, WHICH IS ALMOST ENTIRELY PRODUCED BY BURNING COAL.

china: future costs of electricity generation

Figure 5.127 shows that the introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the costs of electricity generation in China compared to the Reference scenario. However, this difference will be less than 0.4 cent/kWh up to 2020, if the price pathway for fossil fuels defined in Chapter 4 is applied. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be $ 6.3 cents/kWh below those in the Reference version.

Under the Reference scenario, by contrast, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $ 366 billion per year to more than $ 2,096 billion in 2050. Figure 5.127 shows that the Energy [R]evolution scenario not only complies with China's CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are 24% lower than in the Reference scenario, including estimated costs for efficiency measures.

figure 5.127: china: total electricity supply costs and specific electricity generation costs under two scenarios



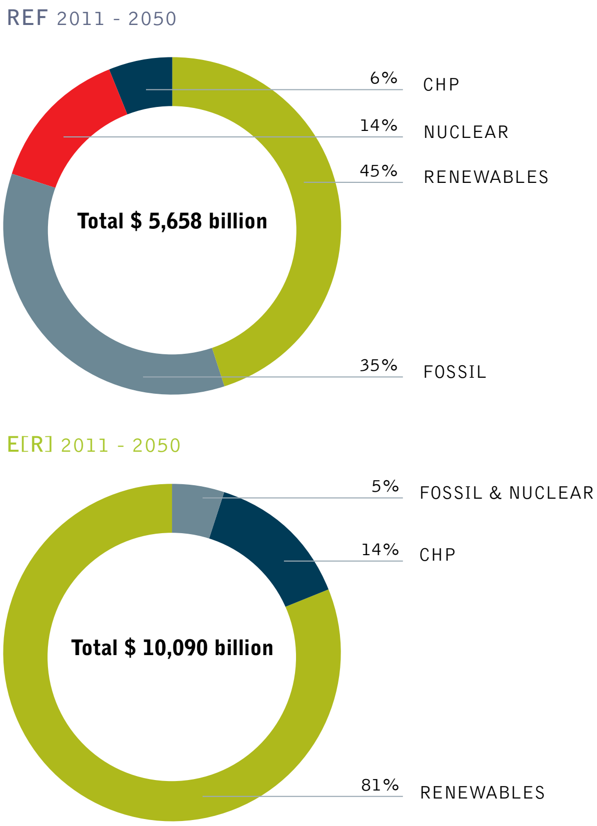
china: future investments in the power sector

It would require $ 10,090 billion in investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately $ 252 billion annually or $ 111 billion more than in the Reference scenario ($ 5,658 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 49% while approximately 51% would be invested in renewable energy and cogeneration (CHP) until 2050.

Under the Energy [R]evolution scenario, however, China would shift almost 95% of the entire investment towards renewables and cogeneration. Until 2030, the fossil fuel share of power sector investment would be focused mainly on CHP plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately $ 252 billion.

Because renewable energy has no fuel costs, savings in the Energy [R]evolution scenario reach a total of $ 9,870 billion up to 2050, or $ 247 billion per year. The total fuel cost savings therefore would cover almost 2 times the total additional investments compared to the Reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.

figure 5.128: china: investment shares - reference scenario versus energy [r]evolution scenario



china

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CHINA
OECD ASIA OCEANIA

china: heating supply

Today, renewables provide 23% of China's energy demand for heat supply, the main contribution coming from biomass. Dedicated support instruments are required to ensure a dynamic future development. In the Energy [R]evolution scenario, renewables provide 35% of China's total heat demand in 2030 and 86% in 2050.

- Energy efficiency measures will restrict the future energy demand for heat supply in 2030 to an increase of 15% compared to 29% in the Reference scenario, in spite of improving living standards.
- In the industry sector solar collectors, biomass/biogas as well as geothermal energy are increasingly substituted for conventional fossil-fired heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

Table 5.56 shows the development of the different renewable technologies for heating in China over time. Up to 2020, biomass will remain the main contributor of the growing market share. After 2020, the continuing growth of solar collectors and a growing share of geothermal heat pumps will reduce the dependence on fossil fuels.

table 5.56: china: renewable heating capacities under the reference scenario and the energy [r]evolution scenario

IN GW

		2009	2020	2030	2040	2050
Biomass	REF	6,833	6,246	4,953	3,916	3,597
	E[R]	6,833	8,054	7,984	8,637	7,949
Solar collectors	REF	301	504	631	755	842
	E[R]	301	1,199	2,287	6,560	7,676
Geothermal	REF	104	181	237	288	336
	E[R]	104	737	2,259	6,125	10,424
Hydrogen	REF	0	0	0	0	0
	E[R]	0	0	0	102	543
Total	**REF**	**7,238**	**6,931**	**5,821**	**4,959**	**4,775**
	E[R]	**7,238**	**9,991**	**12,530**	**21,424**	**26,592**

figure 5.129: china: heat supply structure under the reference scenario and the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

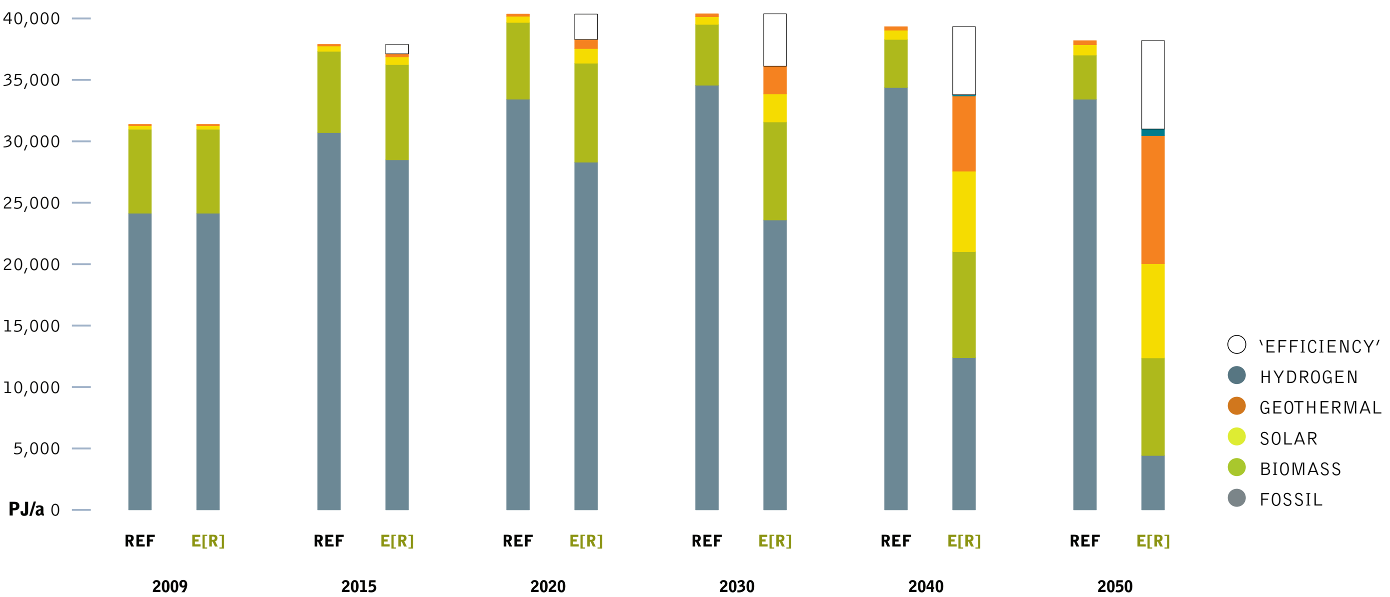


image A MAINTENANCE ENGINEER INSPECTS A WIND TURBINE AT THE NAN WIND FARM IN NAN'AO. GUANGDONG PROVINCE HAS ONE OF THE BEST WIND RESOURCES IN CHINA AND IS ALREADY HOME TO SEVERAL INDUSTRIAL SCALE WIND FARMS. MASSIVE INVESTMENT IN WIND POWER WILL HELP CHINA OVERCOME ITS RELIANCE ON CLIMATE DESTROYING FOSSIL FUEL POWER AND SOLVE ITS ENERGY SUPPLY PROBLEM.

image image A LOCAL TIBETAN WOMAN WHO HAS FIVE CHILDREN AND RUNS A BUSY GUEST HOUSE IN THE VILLAGE OF ZHANG ZONG USES SOLAR PANELS TO SUPPLY ENERGY FOR HER BUSINESS.

china: future investments in the heat sector

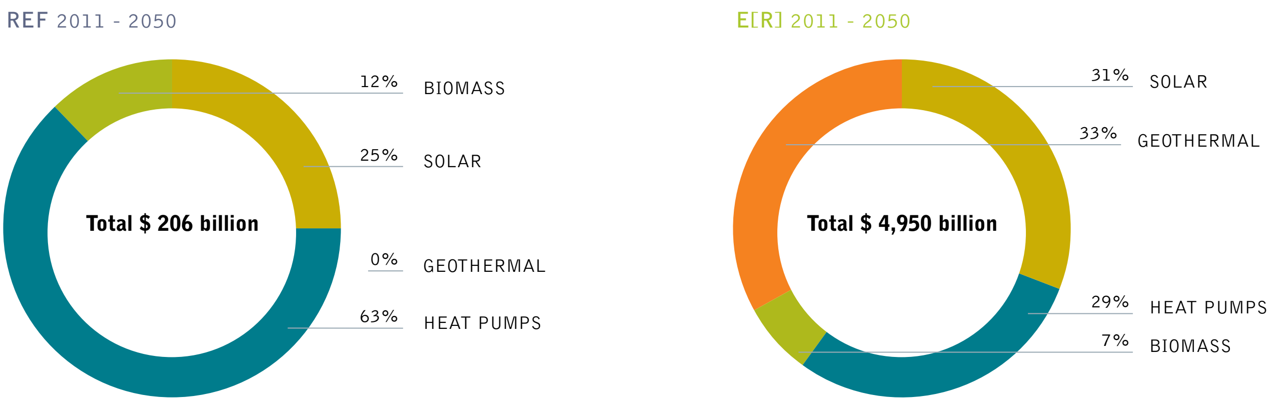
In the heat sector, the Energy [R]evolution scenario would require also a major revision of current investment strategies. Especially solar, geothermal and heat pump technologies need an enormous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity for direct heating (excluding district heating and CHP) need to be increased up to around 2,300 GW for solar thermal and up to 1,400 GW for geothermal and heat pumps. Capacity of biomass use for heat supply needs to remain a pillar of heat supply, however current plants need to be replaced by new efficient technologies.

Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar thermal district heating plants with seasonal storage.Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around $ 4,950 billion to be invested in renewable direct heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately $ 124 billion per year.

table 5.57: china: renewable heat generation capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	2,926	2,476	1,887	1,451	1,295
	E[R]	2,926	2,881	2,499	2,258	1,729
Geothermal	REF	0	0	0	0	0
	E[R]	0	12	78	348	775
Solar thermal	REF	102	171	214	256	285
	E[R]	102	363	710	2,064	2,296
Heat pumps	REF	19	32	41	49	54
	E[R]	19	110	232	410	622
Total	**REF**	**3,047**	**2,679**	**2,142**	**1,755**	**1,634**
	E[R]	**3,047**	**3,366**	**3,519**	**5,079**	**5,422**

figure 5.130: china: investments for renewable heat generation technologies under the reference scenario and the energy [r]evolution scenario



china

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china: future employment in the energy sector

The Energy [R]evolution scenario results in more energy sector jobs in China at every stage of the projection, despite signficant reductions in fossil fuel jobs in both scenarios.

- There are 6 million energy sector jobs in the Energy [R]evolution scenario in 2015, and 5.5 million in the Reference scenario.
- In 2020, there are 4.7 million jobs in the Energy [R]evolution scenario, and 4.2 million in the Reference scenario.
- In 2030, there are 3.2 million jobs in the Energy [R]evolution scenario and 2.8 million in the Reference scenario.

Figure 5.131 shows the change in job numbers under both scenarios for each technology between 2010 and 2030. Jobs in the coal sector decline sharply in both scenarios, reflecting significant increases in productivity in China's coal industry.

Strong growth in the renewable sector compensates for some of the losses in the coal industry, so jobs in the Energy [R]evolution scenario are generally 0.5 million higher than jobs in the Reference scenario. Renewable energy accounts for 47% of energy jobs by 2030.

figure 5.131: china: employment in the energy scenario under the reference and energy [r]evolution scenarios

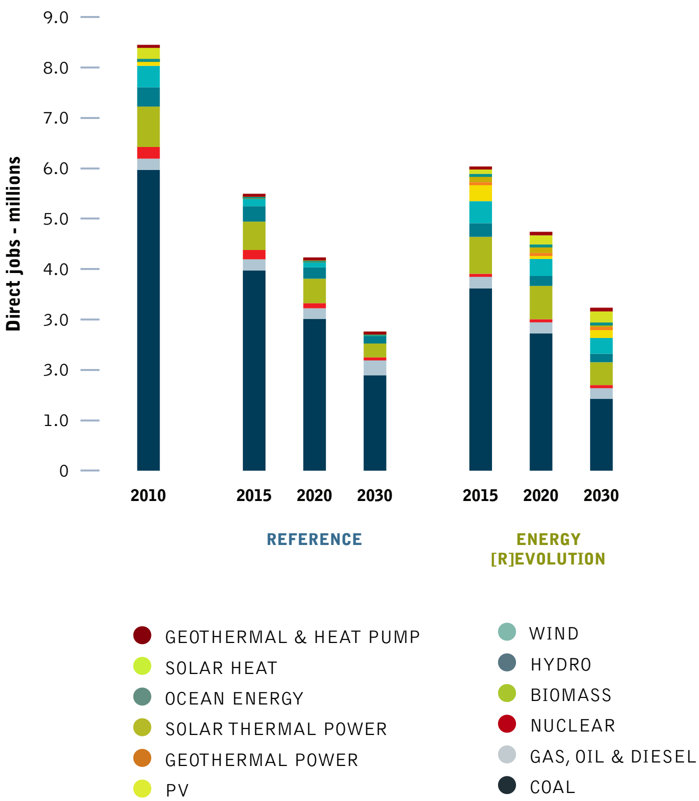


table 5.58: china: total employment in the energy sector THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	5,969	3,972	3,010	1,894	3,618	2,725	1,428
Gas, oil & diesel	223	223	213	302	250	263	262
Nuclear	231	185	101	53	40	18	9
Renewable	2,028	1,116	908	512	2,130	1,735	1,536
Total Jobs	**8,451**	**5,496**	**4,233**	**2,762**	**6,038**	**4,741**	**3,235**
Construction and installation	1,725	868	571	339	883	514	499
Manufacturing	930	394	280	159	702	444	390
Operations and maintenance	478	504	539	429	495	554	459
Fuel supply (domestic)	5,318	3,730	2,842	1,836	3,957.1	3,229	1,888
Coal and gas export	-	-	-	-	-	-	-
Total Jobs	**8,451**	**5,496**	**4,233**	**2,762**	**6,038**	**4,741**	**3,235**

image A WOMAN WASHES UP DISHES USING HOT WATER PROVIDED BY A SOLAR THERMAL WATER HEATER ON THE ROOF OF HER APARTMENT BLOCK. THE CITY OF DEZHOU IS LEADING THE WAY IN ADOPTING SOLAR ENERGY AND HAS BECOME KNOWN AS THE SOLAR VALLEY OF CHINA.

image ZHAO PICHENGS HOME IN SHUIMOTOU VILLAGE HAS BEEN RUINED BY THE SHENTOU NUMBER 2 POWER PLANT IN SHUOZHOU, SHANXI PROVINCE. CONTINUED LEAKAGE FROM THE PLANTS COAL ASH POND HAS RAISED GROUNDWATER LEVELS, FLOODING CELLARS IN THE VILLAGE. EXCESS WATER HAS ALSO DAMAGED HOUSING FOUNDATIONS, CAUSING THE BUILDINGS TO DEVELOP CRACKS OR EVEN COLLAPSE. AFTER A LARGE PART OF HIS ROOF FELL OFF, ZHAO PICHENG AND HIS FAMILY HAD NO CHOICE BUT TO MOVE.

china: transport

In 2050, the car fleet in China will be 10 times larger than today. Today, more medium to large-sized cars are driven in China with an unusually high annual mileage. With growing individual mobility, an increasing share of small efficient cars is projected, with vehicle kilometres driven resembling industrialised countries averages. More efficient propulsion technologies, including hybrid-electric power trains, and lightweight construction, will help to limit the growth in total transport energy demand to a factor of 2, reaching 12,600 PJ/a in 2050. As China already has a large fleet of electric vehicles, this will grow to the point where almost 55% of total transport energy is covered by electricity.

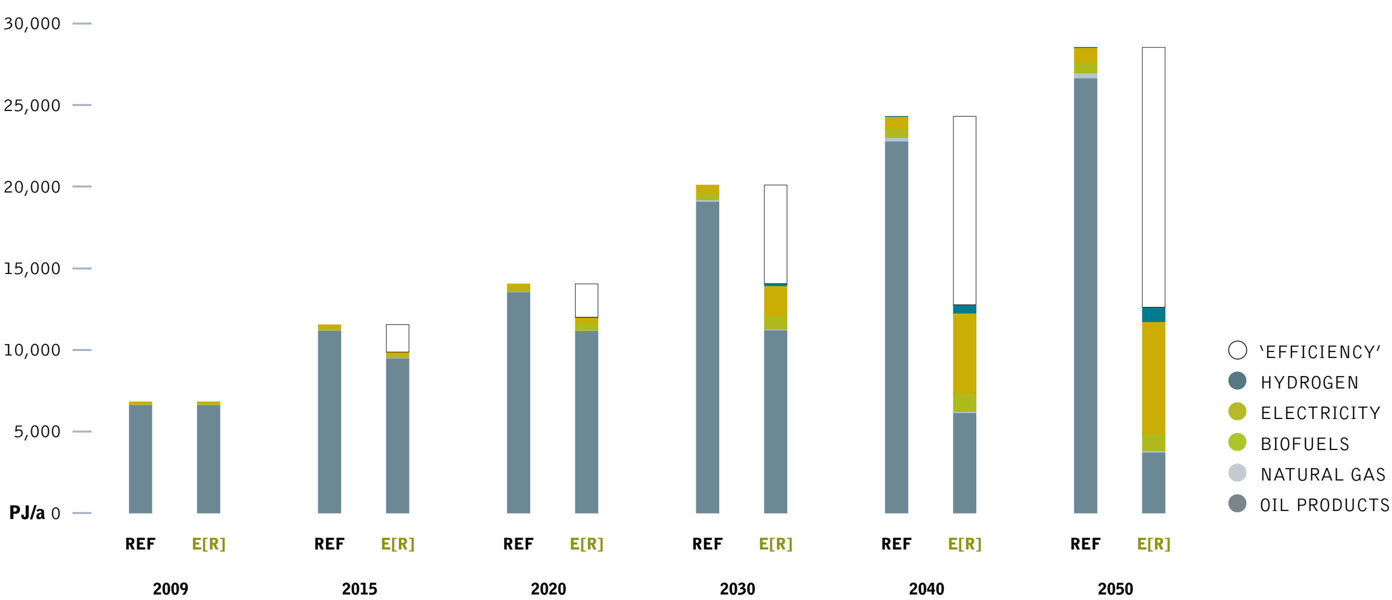
By 2030 electricity will provide 13% of the transport sector's total energy demand under the Energy [R]evolution scenario. Under both scenarios road transport volumes increases significantly. However, under the Energy [R]evolution scenario, the toal energy demand for road transport increases from 5,224 PJ/a in 2009 to 7,794 PJ/a in 2050, compared to about 22,400 PJ/a in the Reference case.

table 5.59: china: transport energy demand by mode under the reference scenario and the energy [r]evolution scenario

(WITHOUT ENERGY FOR PIPELINE TRANSPORT) IN PJ/A

		2009	2020	2030	2040	2050
Rail	REF	541	681	804	936	1,056
	E[R]	541	752	932	1,062	1,118
Road	REF	5,224	11,550	16,750	19,883	22,378
	E[R]	5,224	9,607	10,908	8,768	7,794
Domestic aviation	REF	488	1,022	1,548	2,310	3,709
	E[R]	488	862	1,268	1,846	2,560
Domestic navigation	REF	558	779	985	1,167	1,370
	E[R]	558	775	949	1,085	1,137
Total	**REF**	**6,811**	**14,032**	**20,087**	**24,296**	**28,512**
	E[R]	**6,811**	**11,996**	**14,058**	**12,760**	**12,609**

figure 5.132: china: final energy consumption for transport under the reference scenario and the energy [r]evolution scenario



china

china: development of CO_2 emissions

Whilst China's emissions of CO_2 will increase by 82% under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 6,880 million tonnes in 2009 to 860 million tonnes in 2050. Annual per capita emissions will increase from 5.1 tonnes to 6.1 tonnes in 2030 and decrease afterward to 0.6 tonnes in 2050. In the long run efficiency gains and the increased use of renewable electricity in vehicles will also significantly reduce emissions in the transport sector. With a share of 32% of CO_2 emissions in 2050, the transport sector will be the largest energy related source of emissions. By 2050, China's CO_2 emissions are 38% of 1990 levels.

china: primary energy consumption

Taking into account the above assumptions, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 5.134. Compared to the Reference scenario, overall primary energy demand will be reduced by 42% in 2050. Around 82% of the remaining demand (including non energy consumption) will be covered by renewable energy sources.

The coal demand in the Energy [R]evolution scenario will peak by 2020 with 77,700 PJ/a compared to 65,400 PJ/a in 2009 and decrease afterwards to 4,400 PJ/a by 2050. This is made possible mainly by replacement of coal power plants with renewables after 20 rather than 40 years lifetime. This leads to an overall renewable primary energy share of 27% in 2030 and 82% in 2050. Nuclear energy is phased out just after 2045.

figure 5.133: china: development of CO_2 emissions by sector under the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

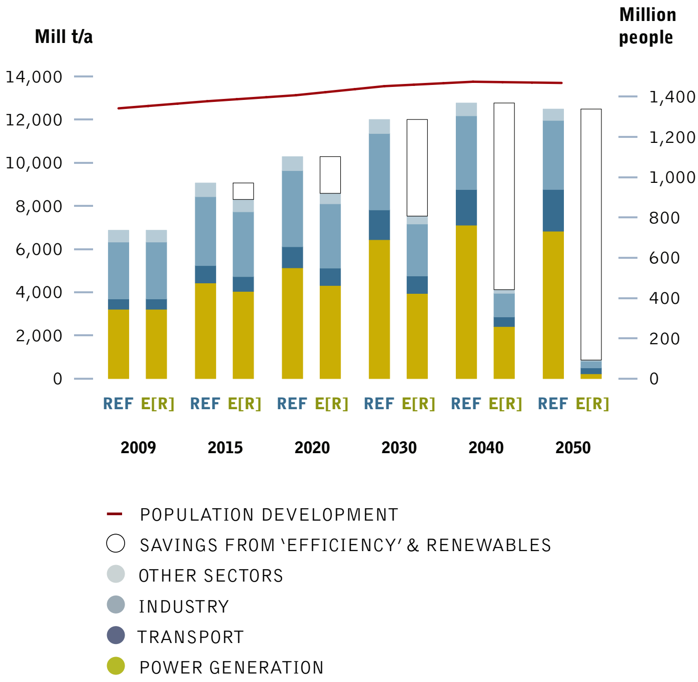


figure 5.134: china: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

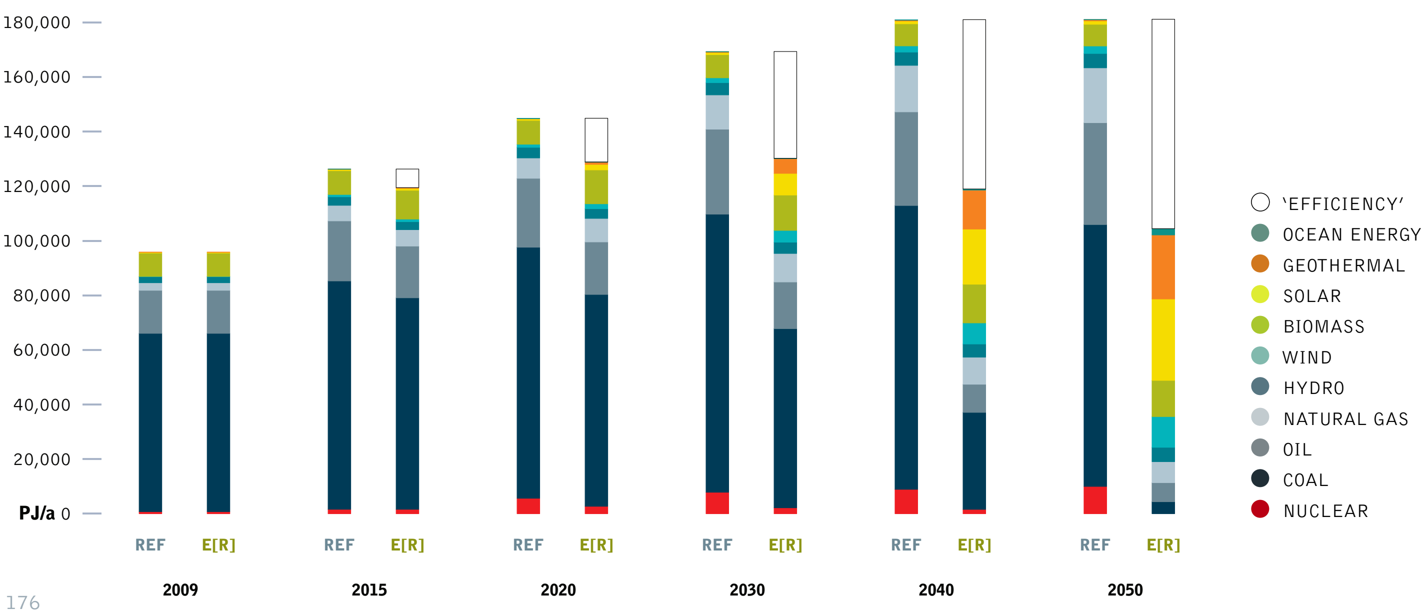


image SOLAR POWERED PHOTO-VOLTAIC (PV) CELLS ARE ASSEMBLED BY WORKERS AT A FACTORY OWNED BY THE HIMIN GROUP, THE WORLDS LARGEST MANUFACTURER OF SOLAR THERMAL WATER HEATERS. THE CITY OF DEZHOU IS LEADING THE WAY IN ADOPTING SOLAR ENERGY AND HAS BECOME KNOWN AS THE SOLAR VALLEY OF CHINA.

image DAFENG POWER STATION IS CHINA'S LARGEST SOLAR PHOTOVOLTAIC-WIND HYBRID POWER STATION, WITH 220MW OF GRID-CONNECTED CAPACITY, OF WHICH 20MW IS SOLAR PV. LOCATED IN YANCHENG, JIANGSU PROVINCE, IT BEGAN OPERATION ON DECEMBER 31, 2010 AND HAS 1,100 ANNUAL UTILIZATION HOURS. EVERY YEAR IT CAN GENERATE 23 MILLION KW-H OF ELECTRICITY, ALLOWING IT TO SAVE 7,000 TONS OF COAL AND 18,600 TONS OF CARBON DIOXIDE EMISSIONS.

table 5.60: china: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

INVESTMENT COSTS	$	2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion $	-421	-534	-555	-555	-2,091	-52
Renewables	billion $	574	1,298	1,869	1,869	6,523	163
Total	billion $	**153**	**763**	**1,313**	**1,313**	**4,432**	**111**

CUMULATIVE FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion $/a	25	56	55	38	174	4.4
Gas	billion $/a	-38	-71	74	619	583	15
Hard coal	billion $/a	234	1,089	2,921	4,868	9,112	228
Lignite	billion $/a	0	0	0	0	0	0
Total	billion $/a	**221**	**1,074**	**3,049**	**5,525**	**9,869**	**247**

oecd asia oceania

GLOBAL SCENARIO
OECD NORTH AMERICA
LATIN AMERICA
OECD EUROPE
AFRICA
MIDDLE EAST
EASTERN EUROPE/EURASIA
INDIA
NON OECD ASIA
CHINA
OECD ASIA OCEANIA

oecd asia oceania: energy demand by sector

The future development pathways for OECD Asia Oceania's energy demand are shown in Figure 5.135 for the Reference and the Energy [R]evolution scenario. Under the Reference scenario, total primary energy demand in OECD Asia Oceania increases by 4% from the current 36,040 PJ/a to 37,400 PJ/a in 2050. The energy demand in 2050 in the Energy [R]evolution scenario decreases by 37% compared to current consumption and it is expected by 2050 to reach 22,860 PJ/a.

Under the Energy [R]evolution scenario, electricity demand in the industry as well as in the residential, and service sectors is expected to decrease after 2020 (see Figure 5.136). Because of the growing use of electric vehicles however, electricity demand remains stable at 1,750 TWh/a in 2050, still 19% below the Reference case.

Efficiency gains in the heat supply sector are larger than in the electricity sector. Under the Energy [R]evolution scenario, final demand for heat supply can eventually even be reduced significantly (see Figure 5.138). Compared to the Reference scenario, consumption equivalent to 1,860 PJ/a is avoided through efficiency measures by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

figure 5.135: oecd asia oceania: total final energy demand by sector under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

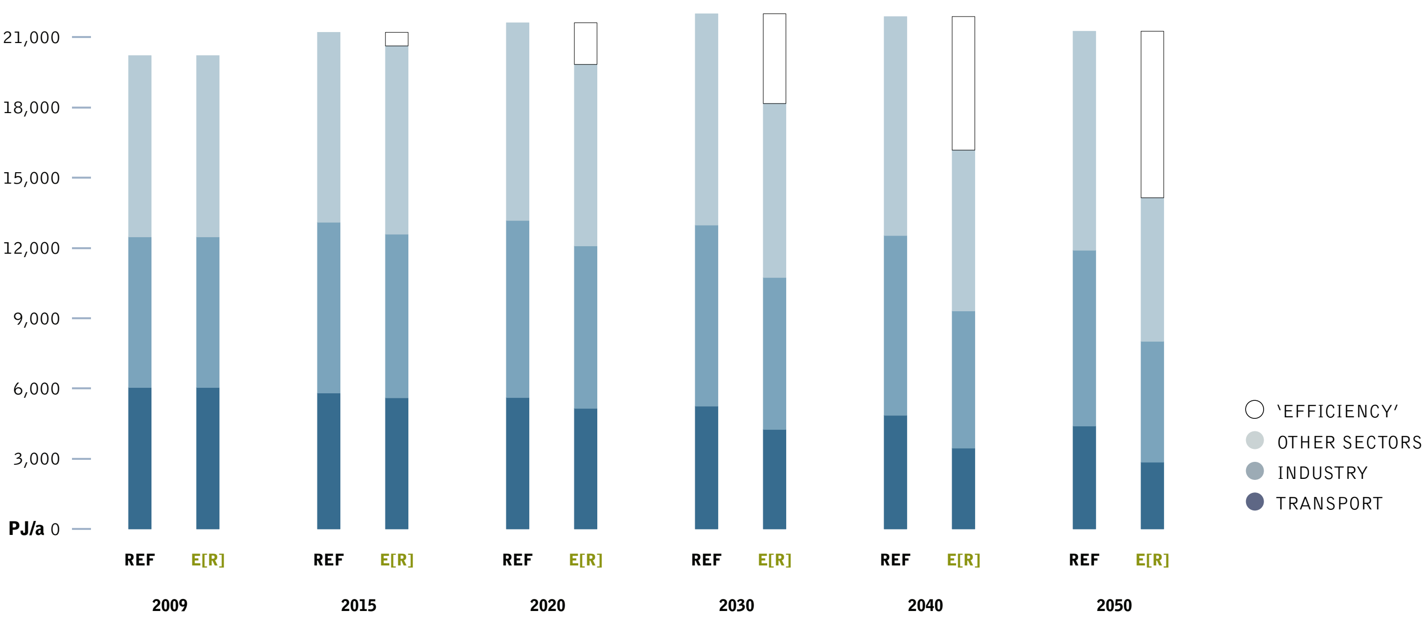


image PORTLAND, IN THE STATE OF VICTORIA, WAS THE FIRST AUSTRALIAN COUNCIL TO RECEIVE A DEVELOPMENT APPLICATION FOR WIND TURBINES AND NOW HAS ENOUGH IN THE SHIRE TO PROVIDE ENERGY FOR SEVERAL LOCAL TOWNS COMBINED.

image THE FORTUNES OF THE TOWN OF INNAMINCKA ARE ABOUT TO CHANGE, BECAUSE THEY ARE SITTING ON THE EDGE OF THE COOPER BASIN. IT MAY BE SIZZLING ABOVE GROUND, BUT THE ROCKS FIVE KILOMETRES BELOW INNAMINCKA ARE SUPER-HEATED, PROVIDING A NEW AND CLEAN SOURCE OF ENERGY. RESIDENT LEON, THE PUBLICAN SAYS, EVERYONE IN TOWN IS EXCITED, EVERYONE HAS TO LIVE NEXT TO A NOISY GENERATOR. AND ANYTHING YOU DO OUT HERE IS EXPENSIVE, IT ALL HAS TO BE FREIGHTED IN. ANYWHERE YOU CAN SAVE SOME MONEY IS GREAT. UP UNTIL NOW, THE PUB HAS BEEN USING BETWEEN AROUND 3,000 LITRES OF DIESEL FUEL EVERY WEEK. WHEN THE NEW GENERATOR IS SWITCHED ON THAT SHOULD DROP TO ZERO.

figure 5.136: oecd asia oceania: development of electricity demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

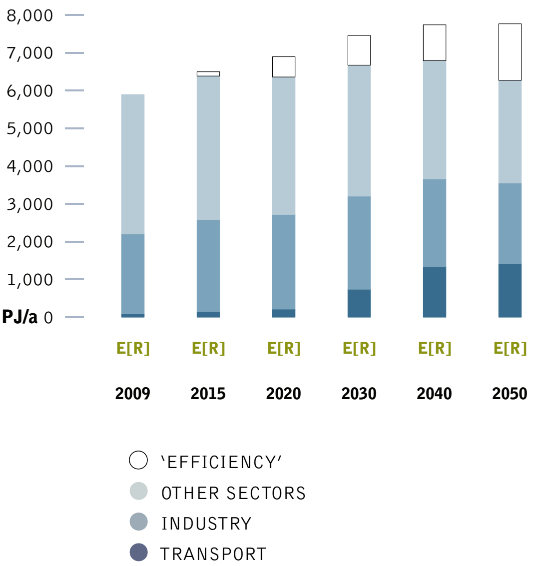


figure 5.138: oecd asia oceania: development of heat demand by sector in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

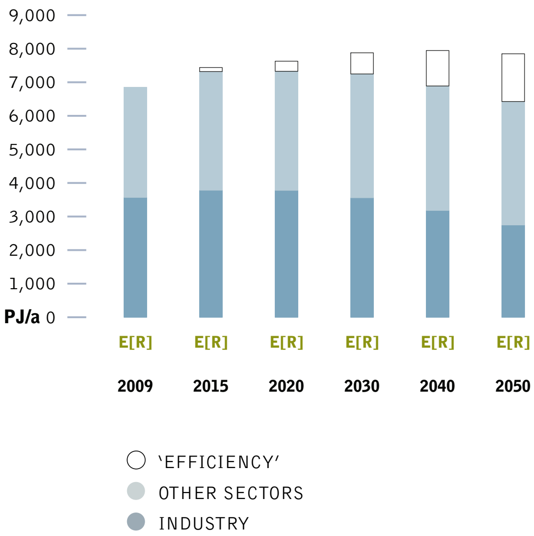
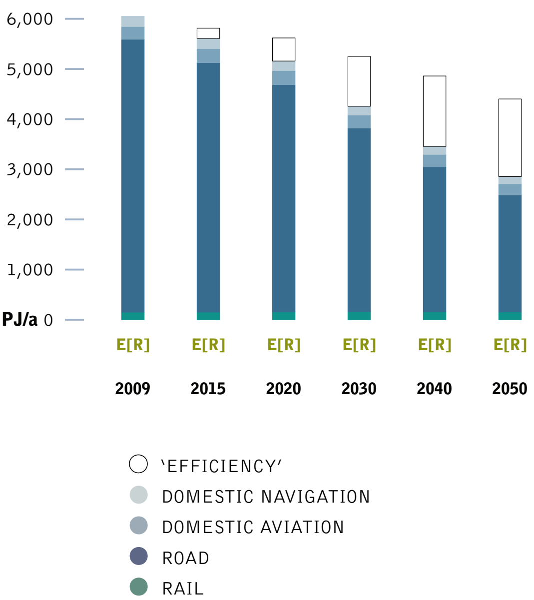


figure 5.137: oecd asia oceania: development of the transport demand by sector in the energy [r]evolution scenario



oecd asia oceania

oecd asia oceania: electricity generation

The development of the electricity supply market is charaterised by a dynamically growing renewable energy market. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 93% of the electricity produced in OECD Asia Oceania will come from renewable energy sources. 'New' renewables – mainly wind, PV and geothermal energy – will contribute 76% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 31% already by 2020 and 56% by 2030. The installed capacity of renewables will reach 524 GW in 2030 and 856 GW by 2050.

Table 5.61 shows the comparative evolution of the different renewable technologies in OECD Asia Oceania over time. Up to 2020 hydro and wind will remain the main contributors of the growing market share. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaics solar thermal (CSP) and ocean energy. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 36% by 2030, therefore the expansion of smart grids, demand side management (DSM) and storage capacity from the increased share of electric vehicles will be used for a better grid integration and power generation management.

table 5.61: oecd asia oceania: renewable electricity generation capacity under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Hydro	REF	67	70	72	72	70
	E[R]	67	75	79	79	82
Biomass	REF	5	6	9	10	12
	E[R]	5	11	20	32	44
Wind	REF	4	14	24	33	37
	E[R]	4	75	171	221	239
Geothermal	REF	1	2	2	4	5
	E[R]	1	9	17	24	31
PV	REF	3	9	16	21	25
	E[R]	3	71	186	279	350
CSP	REF	0	3	3	5	6
	E[R]	0	11	18	25	31
Ocean energy	REF	0	0	1	2	3
	E[R]	0	16	34	59	79
Total	**REF**	**80**	**103**	**127**	**148**	**158**
	E[R]	**80**	**268**	**524**	**718**	**856**

figure 5.139: oecd asia oceania: electricity generation structure under the reference scenario and the energy [r]evolution scenario (INCLUDING ELECTRICITY FOR ELECTROMOBILITY, HEAT PUMPS AND HYDROGEN GENERATION)

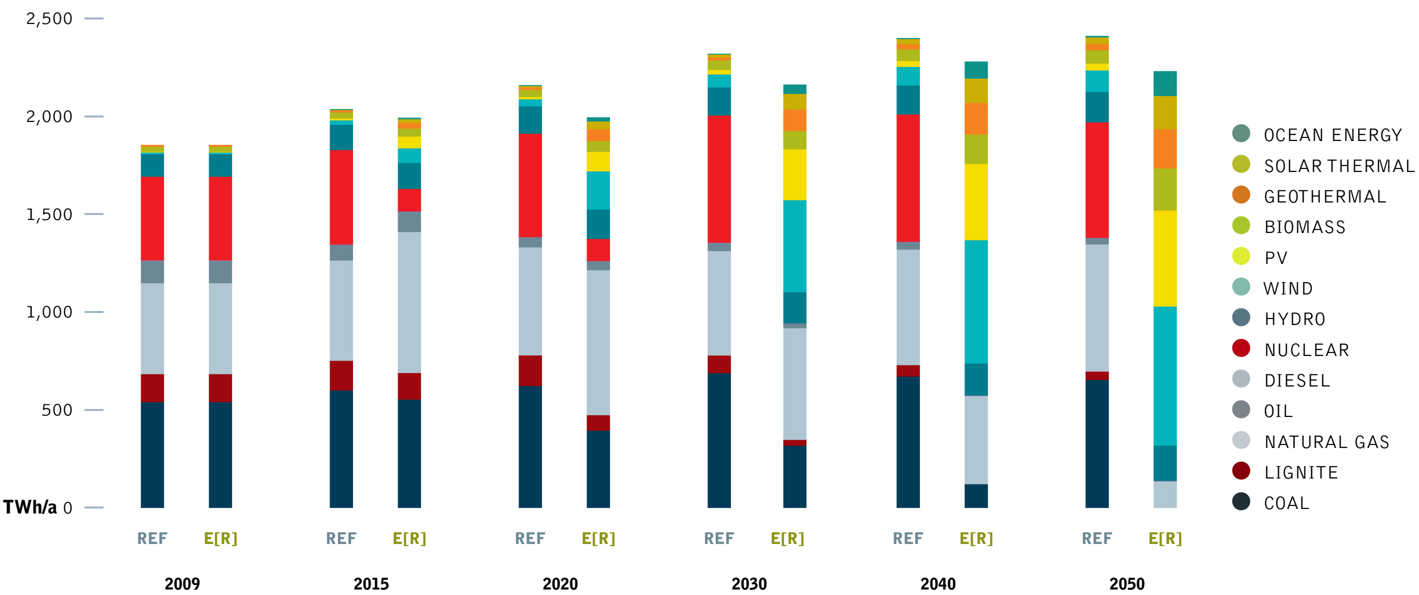


image SOLAR PANELS ON CONISTON STATION, NORTH WEST OF ALICE SPRINGS, NORTHERN TERRITORY.

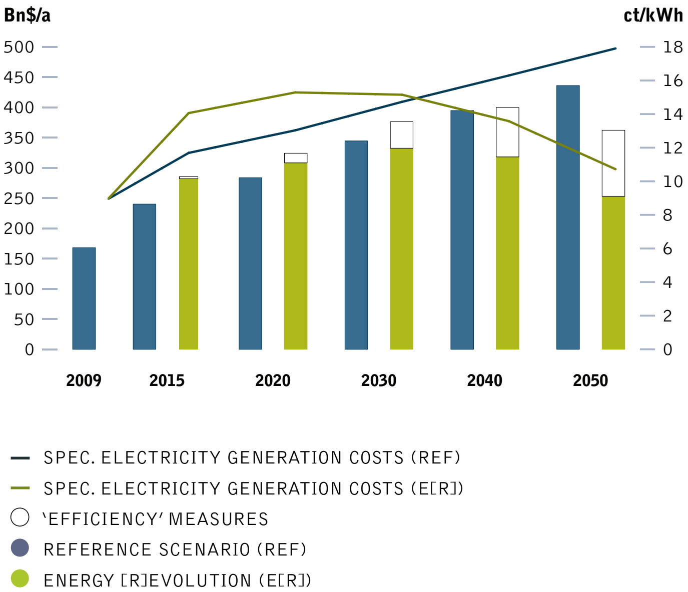
image THE "CITIZENS' WINDMILL" IN AOMORI, NORTHERN JAPAN. PUBLIC GROUPS, SUCH AS CO-OPERATIVES, ARE BUILDING AND RUNNING LARGE-SCALE WIND TURBINES IN SEVERAL CITIES AND TOWNS ACROSS JAPAN.

oecd asia oceania: future costs of electricity generation

Figure 5.140 shows that the introduction of renewable technologies under the Energy [R]evolution scenario slightly increases the costs of electricity generation in OECD Asia Oceania compared to the Reference scenario. This difference will be less than $ 2.3 cent/kWh up to 2030, however. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be $ 7.2 cents/kWh below those in the Reference version.

Under the Reference scenario, the unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $ 168 billion per year to more than $ 436 billion in 2050. Figure 5.140 shows that the Energy [R]evolution scenario not only complies with OECD Asia Oceania's CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are 17% lower in 2050 than in the Reference scenario.

figure 5.140: oecd asia oceania: total electricity supply costs and specific electricity generation costs under two scenarios



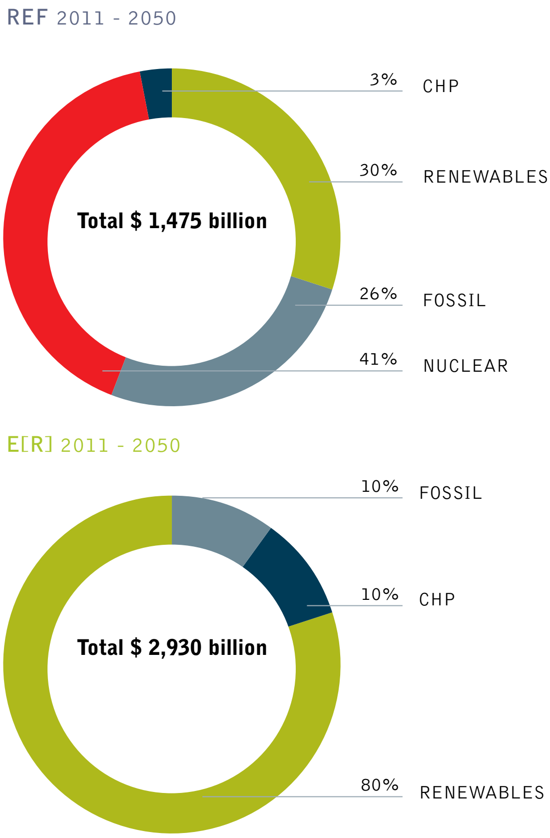
oecd asia oceania: future investments in the power sector

It would require $ 2,930 billion in investment in the power sector for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately $ 1,450 billion or $ 36 billion annually more than in the Reference scenario ($ 1,475 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 67% while approximately 33% would be invested in renewable energy and cogeneration (CHP) until 2050.

Under the Energy [R]evolution scenario, however, OECD Asia Oceania would shift almost 90% of the entire investment towards renewables and cogeneration. Until 2030, the fossil fuel share of power sector investment would be focused mainly on CHP plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately $ 73 billion.

Because renewable energy except biomasss has no fuel costs, the fuel cost savings in the Energy [R]evolution scenario reached a total of $ 1,320 billion up to 2050, or $ 33 billion per year. The total fuel cost savings therefore would cover 90% of the total additional investments compared to the Reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.

figure 5.141: oecd asia oceania: investment shares - reference scenario versus energy [r]evolution scenario



oecd asia oceania

oecd asia oceania: heating supply

Renewables currently provide 6% of OECD Asia Oceania's energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large scale utilisation of geothermal and solar thermal energy. In the Energy [R]evolution scenario, renewables provide 47% of OECD Asia Oceania's total heat demand in 2030 and 90% in 2050.

- Energy efficiency measures can decrease the current demand for heat supply by 13%, in spite of improving living standards.
- For direct heating, solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for fossil fuel-fired systems.
- The introduction of strict efficiency measures e.g. via strict building standards and ambitious support programms for renewable heating systems are needed to achieve economies of scale within the next 5 to 10 years.

Table 5.62 shows the development of the different renewable technologies for heating in OECD Asia Oceania over time. Up to 2020 biomass will remain the main contributors of the growing market share. After 2020, the continuing growth of solar collectors and a growing share of geothermal heat pumps will reduce the dependence on fossil fuels.

table 5.62: oecd asia oceania: renewable heating capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	338	396	473	539	592
	E[R]	338	845	1,469	1,745	1,808
Solar collectors	REF	74	57	96	121	138
	E[R]	74	323	880	1,272	1,482
Geothermal	REF	29	34	42	54	69
	E[R]	29	354	953	1,398	1,806
Hydrogen	REF	0	0	0	0	0
	E[R]	0	4	34	108	297
Total	**REF**	**440**	**486**	**611**	**714**	**798**
	E[R]	**440**	**1,526**	**3,336**	**4,523**	**5,393**

figure 5.142: oecd asia oceania: heat supply structure under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

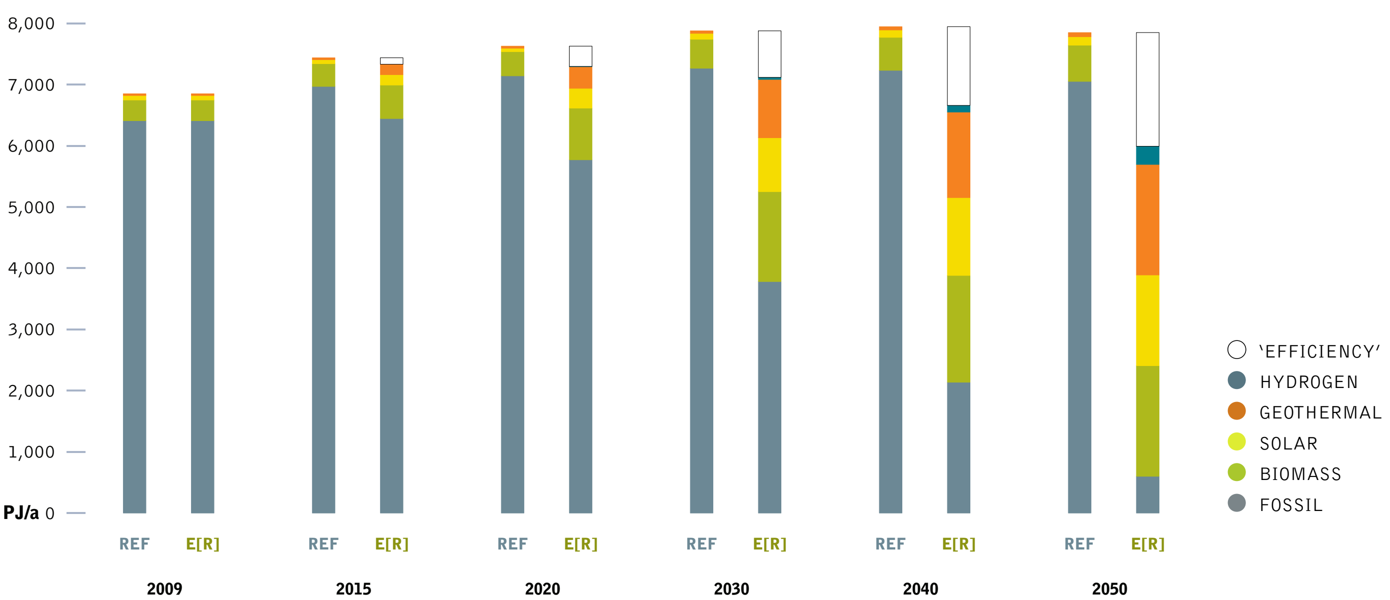


image GEOTHERMAL POWER STATION, NORTH ISLAND, NEW ZEALAND.

image WIND FARM LOOKING OVER THE OCEAN AT CAPE JERVIS, SOUTH AUSTRALIA.

oecd asia oceania: future investments in the heat sector

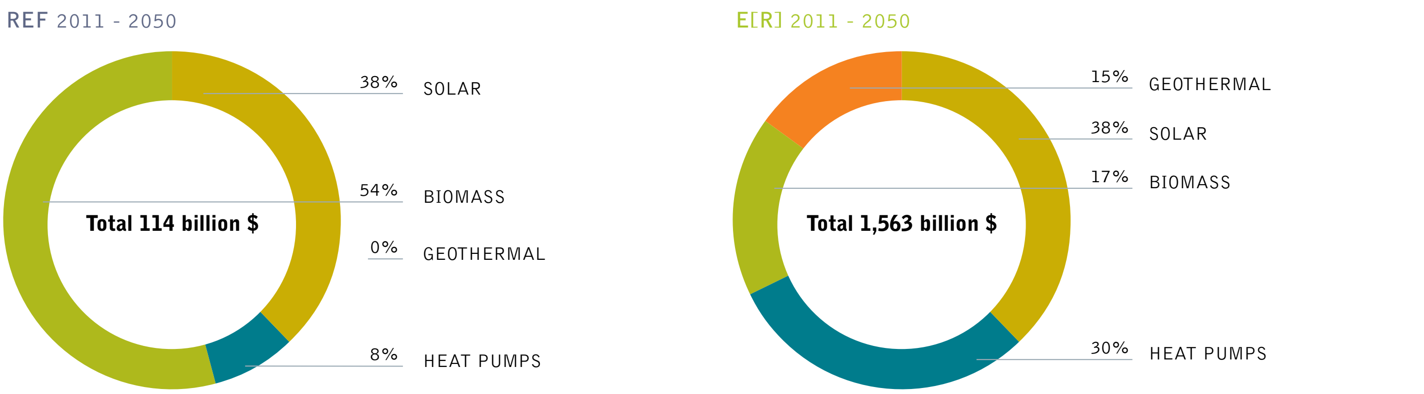
Also in the heat sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially the not yet so common solar and geothermal and heat pump technologies need enourmous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity for need to increase by the factor of 20 for solar thermal and even by the factor of 120 for geothermal and heat pumps. Capacity of biomass technologies, which are already rather wide spread still need to increase by the factor of 5 and will remain a main pillar of heat supply.

Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar thermal district heating plants with seasonal storage.Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around $ 1,563 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately $ 39 billion per year.

table 5.63: oecd asia oceania: renewable heat generation capacities under the reference scenario and the energy [r]evolution scenario IN GW

		2009	2020	2030	2040	2050
Biomass	REF	46	53	62	70	75
	E[R]	46	121	201	218	209
Geothermal	REF	0	0	0	0	0
	E[R]	0	7	44	65	82
Solar thermal	REF	23	18	30	38	43
	E[R]	23	100	257	358	421
Heat pumps	REF	4	4	4	5	5
	E[R]	4	45	105	145	163
Total	**REF**	**74**	**75**	**96**	**112**	**123**
	E[R]	**74**	**274**	**606**	**786**	**875**

figure 5.143: asia oceania: development of investments for renewable heat generation technologies under two scenarios



oecd asia oceania

oecd asia oceania: future employment in the energy sector

The Energy [R]evolution scenario results in more energy sector jobs in OECD Asia-Oceania at every stage of the projection.

- There are 0.5 million energy sector jobs in the Energy [R]evolution scenario in 2015, and 0.3 million in the Reference scenario.
- In 2020, there are 0.5 million jobs in the Energy [R]evolution scenario, and 0.3 million in the Reference scenario.
- In 2030, there are 0.5 million jobs in the Energy [R]evolution scenario and 0.3 million in the Reference scenario.

Figure 5.144 shows the change in job numbers under both scenarios for each technology between 2010 and 2030. Jobs in the Reference scenario remain quite stable, increasing by 11% by 2020, and then declining to just above 2010 levels by 2030.

Exceptionally strong growth in renewable energy leads to an increase of 80% in total energy sector jobs in the Energy [R]evolution scenario by 2015. Renewable energy jobs remain high, and account for 77% of energy jobs by 2030, with biomass having the greatest share (27%), followed by solar PV, wind, hydro, and solar heating.

figure 5.144: oecd asia oceania: employment in the energy scenario under the reference and energy [r]evolution scenarios

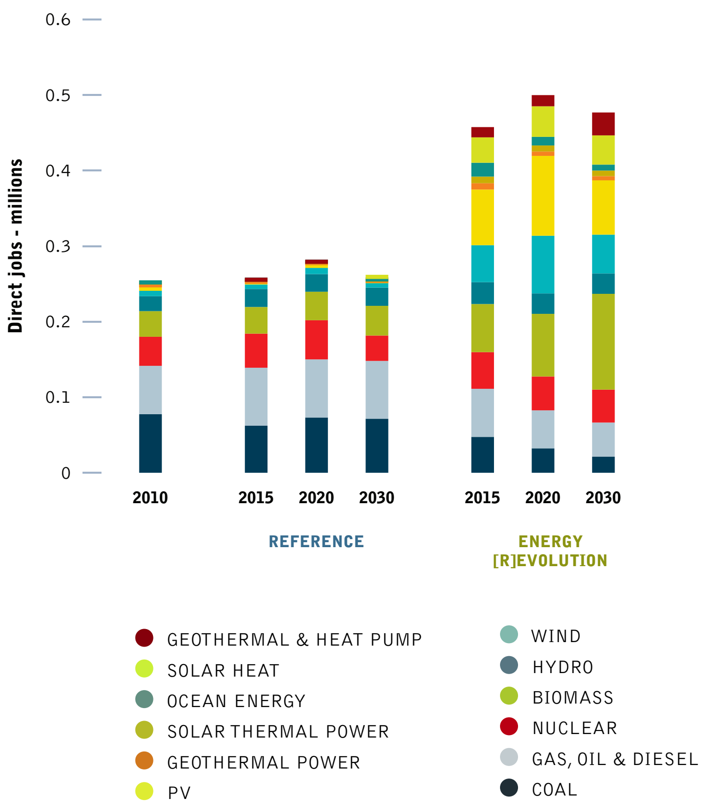
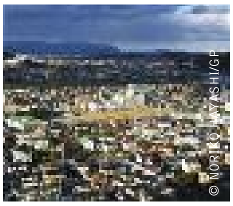


table 5.64: oecd asia oceania: total employment in the energy sector THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	77	62	73	71	47	32	21
Gas, oil & diesel	64	77	77	77	64	50	45
Nuclear	38	45	52	34	49	45	44
Renewable	75	74	80	80	298	372	367
Total Jobs	**255**	**258**	**282**	**262**	**458**	**500**	**477**
Construction and installation	56	43	47	16	185	201	159
Manufacturing	21	13	14	8	64	85	63
Operations and maintenance	81	89	94	103	89	101	124
Fuel supply (domestic)	94	109	121	119	118.0	112	129
Coal and gas export	2	4	6	16	2	0.3	0.3
Total Jobs	**255**	**258**	**282**	**262**	**458**	**500**	**477**

image A GENERAL VIEW OF WATARI. A GREENPEACE RADIATION MONITORING TEAM HAS BEEN CHECKING RADIATION LEVELS AT MANY POINTS IN THE WATARI AREA, APPROXIMATELY 60KM FROM THE FUKUSHIMA DAIICHI NUCLEAR PLANT. GREENPEACE IS CHECKING RADIATION LEVELS AROUND FUKUSHIMA CITY NINE MONTHS AFTER THE TRIPLE NUCLEAR MELTDOWN TO DOCUMENT THE HEALTH RISKS LOCAL COMMUNITIES ARE FACING.

image WIND TURBINES IN JEJU ISLAND.



oecd asia oceania: transport

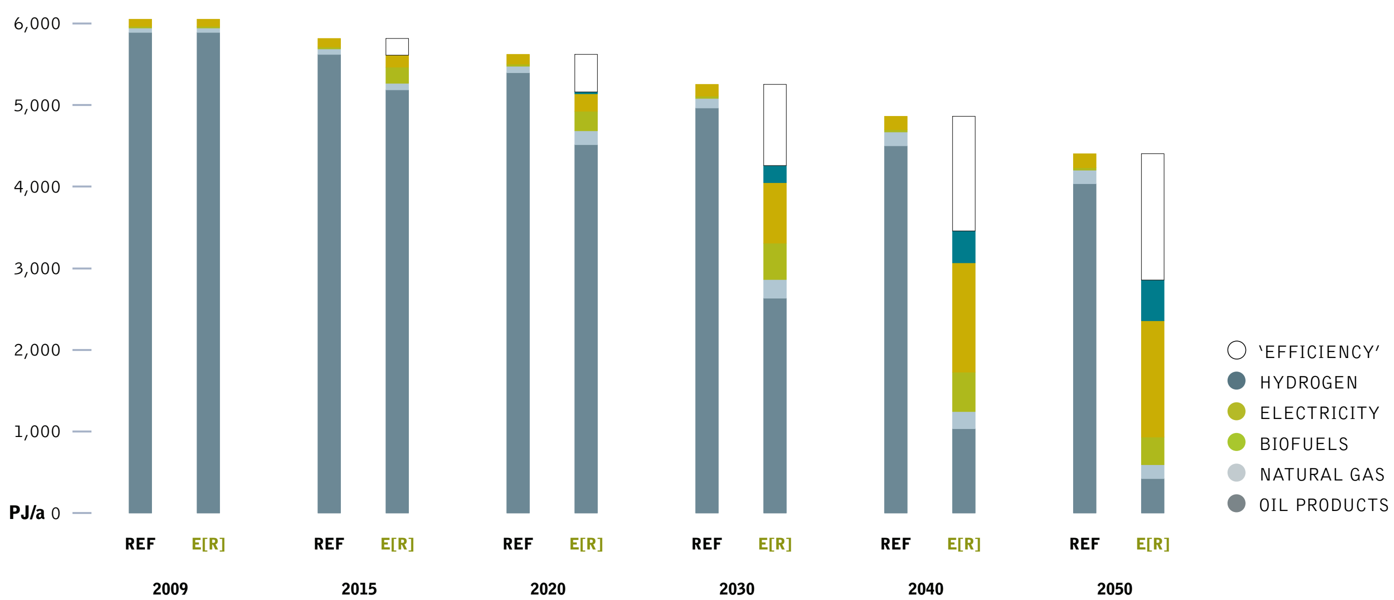
In the transport sector, it is assumed under the Energy [R]evolution scenario that an energy demand reduction of 1,540 PJ/a can be achieved by 2050, saving 35% compared to the Reference scenario. Energy demand will therefore decrease between 2009 and 2050 by 53% to 2,850 PJ/a (including energy for pipeline transport). This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns. Implementing a mix of increased public transport as attractive alternatives to individual cars, the car stock is growing slower and annual person kilometres are lower than in the Reference scenario.

A shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains and a reduction of vehicle kilometres travelled by 0.25% per year leads to significant energy savings. In 2030, electricity will provide 17% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 50%.

table 5.65: oecd asia oceania: transport energy demand by mode under the reference scenario and the energy [r]evolution scenario (WITHOUT ENERGY FOR PIPELINE TRANSPORT) IN PJ/A

		2009	2020	2030	2040	2050
Rail	REF	150	140	136	131	119
	E[R]	150	160	166	162	154
Road	REF	5,418	4,928	4,517	4,093	3,654
	E[R]	5,418	4,509	3,642	2,877	2,323
Domestic aviation	REF	254	314	357	388	378
	E[R]	254	278	258	244	225
Domestic navigation	REF	203	213	220	228	233
	E[R]	203	191	174	159	141
Total	**REF**	**6,025**	**5,596**	**5,230**	**4,840**	**4,384**
	E[R]	**6,025**	**5,137**	**4,239**	**3,441**	**2,843**

figure 5.145: oecd asia oceania: final energy consumption for transport under the reference scenario and the energy [r]evolution scenario



oecd asia oceania

GLOBAL SCENARIO

OECD NORTH AMERICA
LATIN AMERICA
OECD EUROPE
AFRICA

MIDDLE EAST
EASTERN EUROPE/EURASIA
INDIA

NON OECD ASIA
CHINA
OECD ASIA OCEANIA

oecd asia oceania: development of CO_2 emissions

While CO_2 emissions in OECD Asia Oceania will decrease by 11% in the Reference scenario, under the Energy [R]evolution scenario they will decrease from 2,042 million tonnes in 2009 to 164 million tonnes in 2050. Annual per capita emissions will drop from 10.2 tonnes to 5.8 tonnes in 2030 and 0.9 tonne in 2050. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will even reduce emissions in the transport sector. With a share of 31% of CO_2 emissions in 2050, the power sector will drop below transport as the largest sources of emissions. By 2050, OECD Asia Oceania's CO_2 emissions are 10% of 1990 levels.

oecd asia oceania: primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 5.147. Compared to the Reference scenario, overall primary energy demand will be reduced by 39% in 2050.

The Energy [R]evolution version phases out coal and oil about 10 to 15 years faster than the previous Energy [R]evolution scenario published in 2010. This is made possible mainly by replacement of coal power plants with renewables and a faster introduction of very efficient electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 39% in 2030 and 79% in 2050. Nuclear energy is phased out just after 2030.

figure 5.146: oecd asia oceania: development of CO_2 emissions by sector under the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

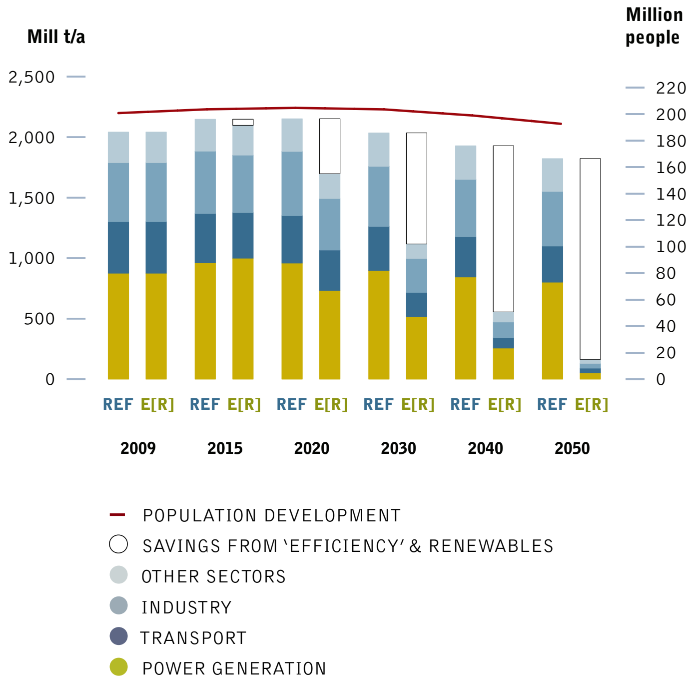


figure 5.147: oecd asia oceania: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

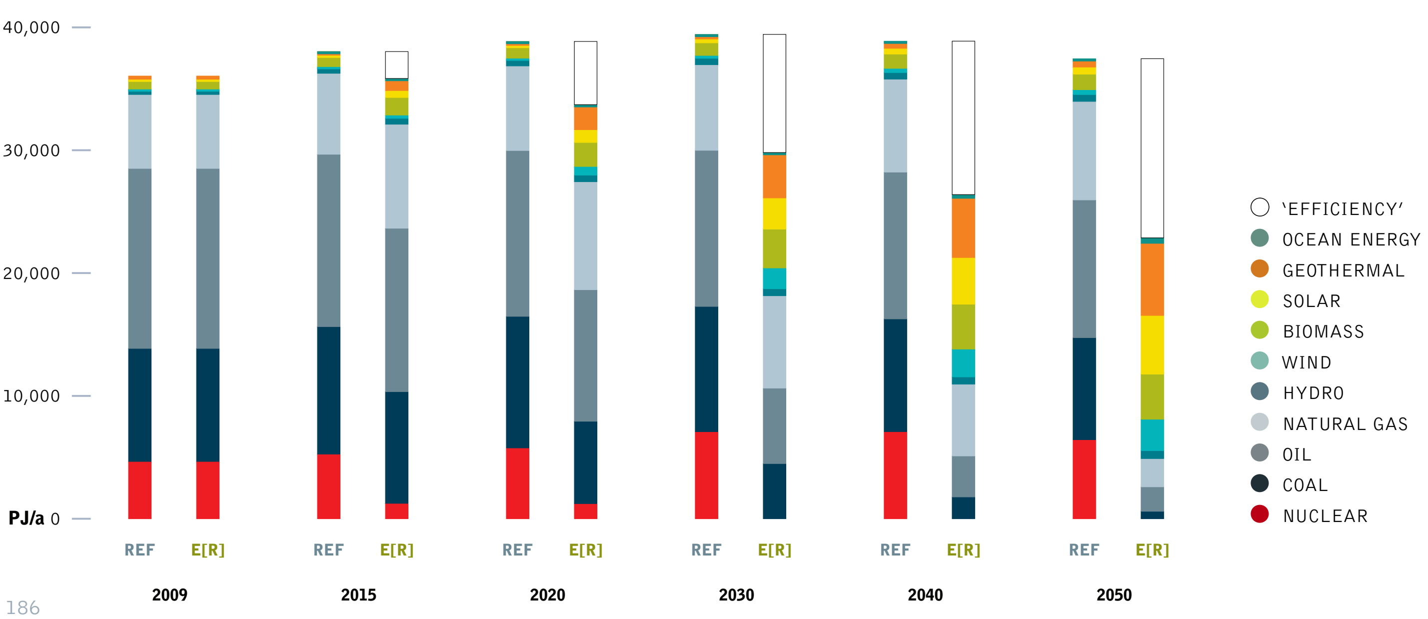


image A YOUNG GIRL RECEIVES FOOD AT YONEZAWA GYMNASIUM WHICH IS NOW PROVIDING A SHELTER FOR 504 PEOPLE WHO EITHER LOST THEIR HOMES BY THE TSUNAMI OR LIVE NEAR FUKUSHIMA NUCLEAR POWER STATION. FOR THOSE WHO LOST THEIR HOMES, OR HAVE BEEN EVACUATED DUE TO RADIATION FEARS, THE FUTURE IS UNCERTAIN.

image TATSUKO OGAWARA HAS BEEN AN ORGANIC FARMER NEAR TAMURA CITY, 40KM FROM THE FUKUSHIMA DAIICHI NUCLEAR PLANT, FOR 30 YEARS. SHE SAYS THAT SHE IS AFRAID FOR HER CHILDREN'S FUTURE, AND FEELS ASHAMED THAT SHE DIDNT TAKE ACTION AGAINST THE NUCLEAR POWER STATION BEFORE IT WAS TOO LATE. SHE NO LONGER KNOWS IF SHE CAN CONTINUE AS A FARMER, AS THE SOIL IN THE AREA MAY BE CONTAMINATED.

table 5.66: oecd asia oceania: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

INVESTMENT COSTS	$	2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion $	-170.4	-268.2	-153.7	-153.7	-703.5	-17.6
Renewables	billion $	501.5	470.7	565.1	565.1	2,154.4	53.9
Total	billion $	**331.1**	**202.5**	**411.4**	**411.4**	**1,450.8**	**36.3**

CUMULATIVE FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion $/a	-18.0	22.0	66.9	72.9	143.8	3.6
Gas	billion $/a	-210.3	-111.6	80.7	459.6	218.3	5.5
Hard coal	billion $/a	45.8	177.5	288.7	404.4	916.4	22.9
Lignite	billion $/a	5.3	12.4	11.2	10.7	39.6	1.0
Total	billion $/a	**-177.3**	**100.3**	**447.5**	**947.6**	**1,318.1**	**33.0**

employment projections

METHODOLOGY AND ASSUMPTIONS

EMPLOYMENT FACTORS

REGIONAL ADJUSTMENTS

FOSSIL FUELS AND NUCLEAR ENERGY

EMPLOYMENT IN RENEWABLE ENERGY TECHNOLOGIES

image SAND DUNES NEAR THE TOWN OF SAHMAH, OMAN.

image THE DABANCHENG WIND POWER ALONG THE URUMQI-TURPAN HIGHWAY, XINJIANG PROVINCE, CHINA. HOME TO ONE OF ASIA'S BIGGEST WIND FARMS AND A PIONEER IN THE INDUSTRY XINJIANG'S DABANCHENG IS CURRENTLY ONE OF THE LARGEST WIND FARMS IN CHINA, WITH 100 MEGAWATTS OF INSTALLED POWER GENERATING CAPACITY.

6.1 methodology and assumptions

The Institute for Sustainable Futures at the University of Technology, Sydney modelled the effects of the Reference scenario and Energy [R]evolution Scenario on jobs in the energy sector. This section provides a simplified overview of how the calculations were performed. A detailed methodology is also available.[68] Chapters 2 and 3 contain all the data on how the scenarios were developed. The calculations were made using conservative assumptions wherever possible. The main inputs to the calculations are:

For each scenario, namely the Reference (business as usual) and Energy [R]evolution scenario:

- The amount of electrical and heating capacity that will be installed each year for each technology,
- The primary energy demand for coal, gas, and biomass fuels in the electricity and heating sectors.
- The amount of electricity generated per year from nuclear, oil, and diesel.

For each technology:

- 'Employment factors', or the number of jobs per unit of capacity, separated into manufacturing, construction, operation and maintenance, and per unit of primary energy for fuel supply.
- For the 2020 and 2030 calculations, a 'decline factor' for each technology which reduces the employment factors by a certain percentage per year. This reflects the fact that employment per unit falls as technology prices fall.

For each region:

- The percentage of local manufacturing and domestic fuel production in each region, in order to calculate the proportion of manufacturing and fuel production jobs which occur in the region.
- The percentage of world trade which originates in each region for coal and gas fuels, and renewable energy traded components.
- A "regional job multiplier", which indicates how labour-intensive economic activity is in that region compared to the OECD. This is used to adjust OECD employment factors where local data is not available.

The electrical capacity increase and energy use figures from each scenario are multiplied by the employment factors for each of the technologies, and then adjusted for regional labour intensity and the proportion of fuel or manufacturing which occurs locally. The calculation is summarised in the Table 6.1.

A range of data sources are used for the model inputs, including the International Energy Agency, US Energy Information Administration, US National Renewable Energy Laboratory, International Labour Organisation, industry associations for wind, geothermal, solar, nuclear and gas, census data from Australia, Canada, and India, academic literature, and the ISF's own research.

These calculations only take into account direct employment, for example the construction team needed to build a new wind farm. They do not cover indirect employment, for example the extra services provided in a town to accommodate construction teams. The calculations do not include jobs in energy efficiency, although these are likely to be substantial, as the Energy [R]evolution leads to a 40% drop in primary energy demand overall.

table 6.1: methodology overview

MANUFACTURING (FOR LOCAL USE)	=	MW INSTALLED PER YEAR IN REGION	×	MANUFACTURING EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER	×	% OF LOCAL MANUFACTURING
MANUFACTURING (FOR EXPORT)	=	MW EXPORTED PER YEAR	×	MANUFACTURING EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER		
CONSTRUCTION	=	MW INSTALLED PER YEAR	×	CONSTRUCTION EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER		
OPERATION & MAINTENANCE	=	CUMULATIVE CAPACITY	×	O&M EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER		
FUEL SUPPLY (NUCLEAR)	=	ELECTRICITY GENERATION	×	FUEL EMPLOYMENT FACTOR	×	REGIONAL JOB MULTIPLIER		
FUEL SUPPLY (COAL, GAS & BIOMASS)	=	PRIMARY ENERGY DEMAND + EXPORTS	×	FUEL EMPLOYMENT FACTOR (ALWAYS REGIONAL FOR COAL)	×	REGIONAL JOB MULTIPLIER	×	% OF LOCAL PRODUCTION
HEAT SUPPLY	=	MW INSTALLED PER YEAR	×	EMPLOYMENT FACTOR FOR HEAT	×	REGIONAL JOB MULTIPLIER		

JOBS IN REGION	=	**MANUFACTURING**	+	**CONSTRUCTION**	+	**OPERATION & MAINTENANCE (O&M)**	+	**FUEL SUPPLY**
EMPLOYMENT FACTOR AT 2020 OR 2030	=	**EMPLOYMENT FACTOR** × TECHNOLOGY DECLINE FACTOR$^{\text{(NUMBER OF YEARS AFTER 2010)}}$						

reference
68 JAY RUTOVITZ AND STEPHEN HARRIS. 2012.CALCULATING GLOBAL ENERGY SECTOR JOBS: 2012 METHODOLOGY.

Several additional aspects of energy employment have been included which were not calculated in previous Energy [R]evolution reports. Employment in nuclear decommissioning has been calculated, and a partial estimate of employment in the heat sector is included.

The large number of assumptions required to make calculations mean that employment numbers are indicative only, especially for regions where little data exists. However, within the limits of data availability, the figures presented are representative of employment levels under the two scenarios.

6.2 employment factors

"Employment factors" are used to calculate how many jobs are required per unit of electrical or heating capacity, or per unit of fuel. They take into account jobs in manufacturing, construction, operation and maintenance and fuel. Table 6.2 lists the employment factors used in the calculations. These factors are usually from OECD countries, as this is where there is most data, although local factors are used wherever possible. For job calculations in non OECD regions, a regional adjustment is used where a local factor is not available.

Employment factors were derived with regional detail for coal mining, because coal is currently so dominant in the global energy supply, and because employment per ton varies enormously by region. In Australia, for example, coal is extracted at an average of 13,800 tons per person per year using highly mechanised processes while in Europe the average coal miner is responsible for only 2,000 tonnes per year. India, China, and Russia have relatively low productivity at present (700, 900, and 2000 tons per worker per year respectively).

The calculation of employment per PJ in coal mining draws on data from national statistics, combined with production figures from the IEA[69] or other sources. Data was collected for as many major coal producing countries as possible, with data obtained for more than 80% of world coal production.

In China, India, and Russia, the changes in productivity over the last 7 to 15 years were used to derive an annual improvement trend, which has been used to project a reduction in the employment factors for coal mining over the study period. In China and Eastern Europe/Eurasia a lower employment factor is also used for increases in coal consumption, as it is assumed that expansion will occur in the more efficient mining areas.

China is a special case. While average productivity of coal per worker is currently low (700 tons per employee per year) this is changing. Some new highly mechanised mines opening in China have productivity of 30,000 tons per person per year.[70] It is assumed that any increase in coal production locally will come from the new type of mine, so the lower employment factor is used for additional consumption which is produced domestically.

Russia accounts for more than half of the total coal production in Eastern Europe/ Eurasia. Productivity is much higher there than some other regions, and is improving year by year. It is assumed that expansion of coal production in the region will be at the current level of productivity in Russia, and that overall productivity will continue the upward trend of the last 20 years.

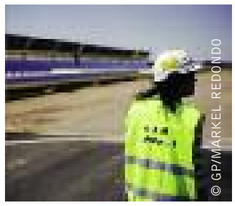
table 6.2: summary of employment factors used in global analysis 2012

FUEL	CONSTRUCTION & INSTALLATION *Job years/MW*	MANUFACTURING *Jobs/MW*	OPERATION & MAINTENANCE *Jobs/MW*	FUEL – PRIMARY ENERGY DEMAND *Jobs/PJ*
Coal	7.7	3.5	0.1	regional
Gas	1.7	1.0	0.08	22
Nuclear	14	1.3	0.3	0.001 jobs per GWh (final energy demand)
Biomass	14	2.9	1.5	32
Hydro-large	6.0	1.5	0.3	
Hydro-small	15	5.5	2.4	
Wind onshore	2.5	6.1	0.2	
Wind offshore	7.1	11	0.2	
PV	11	6.9	0.3	
Geothermal	6.8	3.9	0.4	
Solar thermal	8.9	4.0	0.5	
Ocean	9.0	1.0	0.32	
Geothermal - heat	3.0 jobs/ MW (construction and manufacturing			
Solar - heat	7.4 jobs/ MW (construction and manufacturing			
Nuclear decommissioning	0.95 jobs per MW decommissioned			
Combined heat and power	CHP technologies use the factor for the technology, i.e. coal, gas, biomass, geothermal, etc, increased by a factor of 1.5 for O&M only.			

note For details of sources and derivation of factors please see Rutovitz and Harris, 2012.

references
69 INTERNATIONAL ENERGY AGENCY STATISTICS, AVAILABLE FROM HTTP://WWW.IEA.ORG/STATS/INDEX.ASP
70 INTERNATIONAL ENERGY AGENCY. 2007. WORLD ENERGY OUTLOOK, PAGE 337.

image A WORKER SURVEYS THE EQUIPMENT AT ANDASOL 1 SOLAR POWER STATION, WHICH IS EUROPE'S FIRST COMMERCIAL PARABOLIC TROUGH SOLAR POWER PLANT. ANDASOL 1 WILL SUPPLY UP TO 200,000 PEOPLE WITH CLIMATE-FRIENDLY ELECTRICITY AND SAVE ABOUT 149,000 TONNES OF CARBON DIOXIDE PER YEAR COMPARED WITH A MODERN COAL POWER PLANT.



6.3 regional adjustments

More details of all the regional adjustments, including their derivation, can be found in the detailed methodology document.[71]

6.3.1 regional job multipliers

The employment factors used in this model for all processes apart from coal mining reflect the situation in the OECD regions, which are typically wealthier. The regional multiplier is applied to make the jobs per MW more realistic for other parts of the world. In developing countries it typically means more jobs per unit of electricity because of more labour intensive practices. The multipliers change over the study period in line with the projections for GDP per worker. This reflects the fact that as prosperity increases, labour intensity tends to fall. The multipliers are shown in Table 6.4.

6.3.2 local employment factors

Local employment factors are used where possible. Region specific factors are:

- **Africa:** solar heating (factor for total employment), nuclear, and hydro – factor for operations and maintenance, and coal – all factors.
- **China:** solar heating, coal fuel supply.
- **Eastern Europe/Eurasia:** factor for gas and coal fuel supply.
- **OECD Americas:** factor for gas and coal fuel jobs, and for solar thermal power.
- **OECD Europe:** factor for solar thermal power and for coal fuel supply.
- **India:** factor for solar heating and for coal fuel supply.

6.3.3 local manufacturing and fuel production

Some regions do not manufacture the equipment needed for installation of renewable technologies, for example wind turbines or solar PV panels. The model takes into account a projection of the percentage of renewable technology which is made locally. The jobs in manufacturing components for export are counted in the region where they originate. The same applies to coal and gas fuels, because they are traded internationally, so the model shows the region where the jobs are likely to be located.

6.3.4 learning adjustments or 'decline factors'

This accounts for the projected reduction in the cost of renewable over time, as technologies and companies become more efficient and production processes are scaled up. Generally, jobs per MW would fall in parallel with this trend.

table 6.4: regional multipliers

	2010	2015	2020	2035
World average	1.8	1.7	1.6	1.4
OECD	1.0	1.0	1.0	1.0
Africa	4.3	4.2	4.2	4.6
China	2.6	1.9	1.5	1.0
Eastern Europe/Eurasia	3.0	2.3	1.9	1.4
India	3.6	2.8	2.4	1.5
Latin America	2.9	2.7	2.6	2.4
Middle east	2.9	2.8	2.8	2.5
Non OECD Asia	2.4	2.1	1.9	1.5

note Derived from ILO (2010) Key Indicators of the Labour Market, seventh Edition software, with growth in GDP per capita derived from IEA World Energy Outlook 2011.

table 6.3: employment factors used for coal fuel supply (MINING AND ASSOCIATED JOBS)

	EMPLOYMENT FACTOR (EXISTING GENERATION) *Jobs per PJ*	EMPLOYMENT FACTOR (NEW GENERATION) *Jobs per PJ*	AVERAGE ANNUAL PRODUCTIVITY INCREASE 2010 - 2030 *Jobs per PJ*
World average	23		
OECD North America	3.9	3.9	
OECD Europe	40	40	
OECD Asia Oceania	3.4	3.4	
India	55	55	5%
China	68	1.4	5.5%
Africa	12	12	
Eastern Europe/Eurasia	56	26	4%
Non OECD Asia	Use world average as no employment data available		
Latin America	Use world average as no employment data available		
Middle east	Use world average as no employment data available		

references
71 JAY RUTOVITZ AND STEPHEN HARRIS. 2012. CALCULATING GLOBAL ENERGY SECTOR JOBS: 2012 METHODOLOGY.

table 6.5: total global employment MILLION JOBS

	REFERENCE				ENERGY [R]EVOLUTION		
By sector	2010	2015	2020	2030	2015	2020	2030
Construction and installation	3.3	1.9	1.7	1.2	4.5	4.7	4.0
Manufacturing	1.7	0.9	0.8	0.5	2.7	2.7	2.2
Operations and maintenance	1.7	1.8	2.0	1.9	1.9	2.3	2.6
Fuel supply (domestic)	14.7	12.7	11.9	10.7	12.9	11.7	8.8
Coal and gas export	1.1	1.3	1.5	1.2	1.3	1.2	0.6
Total jobs	**22.5**	**18.7**	**17.7**	**15.6**	**23.3**	**22.6**	**18.1**
By fuel							
Coal	9.1	6.7	5.8	4.6	5.5	4.1	2.1
Gas, oil & diesel	5.1	5.2	5.3	5.4	5.4	5.3	3.9
Nuclear	0.54	0.50	0.41	0.29	0.26	0.27	0.27
Renewable	7.8	6.4	6.2	5.3	12.2	13.0	11.9
Total jobs	**22.5**	**18.7**	**17.7**	**15.6**	**23.3**	**22.6**	**18.2**
By technology							
Coal	9.1	6.7	5.8	4.6	5.5	4.1	2.1
Gas, oil & diesel	5.1	5.2	5.3	5.4	5.4	5.3	3.9
Nuclear	0.5	0.5	0.4	0.3	0.3	0.3	0.3
Biomass	5.2	4.7	4.6	4.0	5.1	5.0	4.5
Hydro	1.0	0.9	0.9	0.9	0.9	0.7	0.7
Wind	0.7	0.4	0.4	0.2	1.8	1.9	1.7
PV	0.4	0.2	0.2	0.1	2.0	1.6	1.5
Geothermal power	0.02	0.02	0.01	0.01	0.12	0.17	0.16
Solar thermal power	0.01	0.02	0.03	0.03	0.5	0.85	0.83
Ocean	0.001	0.001	0.002	0.01	0.11	0.12	0.10
Solar - heat	0.38	0.12	0.09	0.08	1.4	2.0	1.7
Geothermal & heat pump	0.03	0.01	0.01	0.01	0.29	0.56	0.62
Total jobs	**22.5**	**18.7**	**17.7**	**15.6**	**23.3**	**22.6**	**18.2**

figure 6.1: proportion of fossil fuel and renewable employment at 2010 and 2030

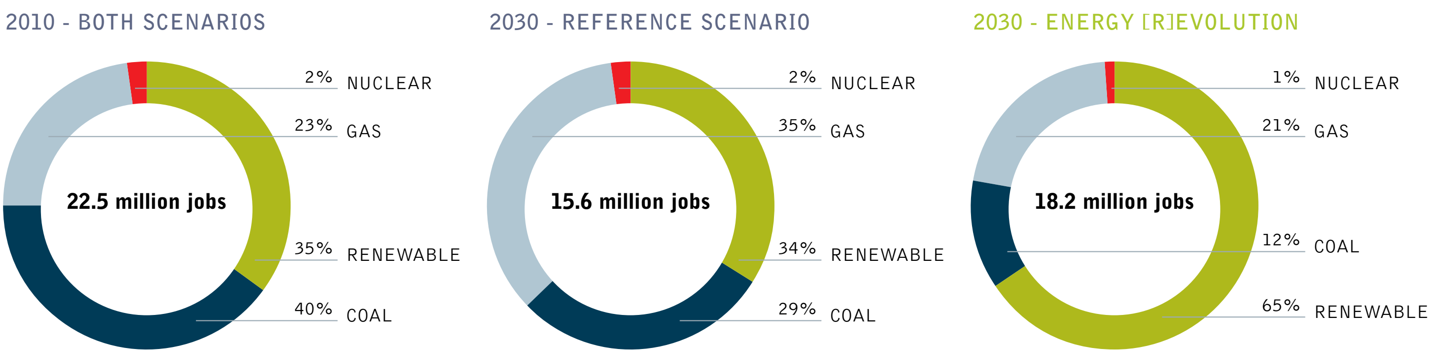


image A WORKER STANDS BETWEEN WIND TURBINE ROTORS AT GANSU JINFENG WIND POWER EQUIPMENT CO. LTD. IN JIUQUAN, GANSU PROVINCE, CHINA.

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6.4 fossil fuels and nuclear energy - employment, investment, and capacities

6.4.1 employment in coal

Jobs in the coal sector drop signficantly in both the Reference scenario and the Energy [R]evolution scenario. In the Reference scenario coal employment drops by 2.1 million jobs between 2015 and 2030, despite generation from coal nearly doubling. Coal employment in 2010 was close to 9 million, so this is in addition to a loss of 2 million jobs from 2010 to 2015.

This is because employment per ton in coal mining is falling dramtatically as efficiencies increase around the world. For example, one worker in the new Chinese 'super mines' is expected to produce 30,000 tons of coal per year, compared to current average productivity across all mines in China close to 700 tons per year, and average productivity per worker in North America close to 12,000 tons.

Unsurprisingly, employment in the coal sector in the Energy [R]evolution scenario falls even more, reflecting a reduction in coal generation from 41% to 19% of all generation, on top of the increase in efficiency.

Coal jobs in both scenarios include coal used for heat supply.

6.4.2 employment in gas, oil and diesel

Employment in the gas sector stays relatatively stable in the Reference scenario, while gas generation increases by 35%. In the Energy [R]evolution scenario generation is reduced by 5% between 2015 and 2030. Employment in the sector also falls, reflecting both increasing efficiencies and the reduced generation. Gas sector jobs in both scenarios include heat supply jobs from gas.

6.4.3 employment in nuclear energy

Employment in nuclear energy falls by 42% in the Reference scenario between 2015 and 2030, while generation increases by 34%. In the Energy [R]evolution generation is reduced by 75% between 2015 and 2030, representing a virtual phase out of nuclear power. Employment in Energy [R]evolution increases slightly, and in 2020 and 2030 is very simliar in both scenarios. This is because jobs in nuclear decomissioning replace jobs in generation. It is expected these jobs will persist for 20 - 30 years.

table 6.6: fossil fuels and nuclear energy: capacity, investment and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Employment	UNIT	2015	2020	2030	2015	2020	2030
Coal	thousands	6,705	5,820	4,598	5,513	4,074	2,123
Gas, oil & diesel	thousands	5,162	5,296	5,440	5,358	5,281	3,891
Nuclear energy	thousands	500	413	290	258	269	270
COAL							
Energy							
Installed capacity	GW	1,985	2,262	2,751	1,732	1,629	1,206
Total generation	TWh	10,092	11,868	15,027	9,333	8,713	6,422
Share of total supply	%	41%	42%	42%	39%	33%	19%
Market and investment							
Annual increase in capacity	GW	71.7	55.5	49	23	-21	-51
Annual investment	$	140,007	136,848	147,086	32,018	32,097	32,256
GAS, OIL & DIESEL							
Energy							
Installed capacity	GW	1,881	2,016	2,283	1,858	1,828	1,722
Total generation	TWh	6,120	6,721	8,248	6,149	6,299	5,811
Share of total supply	%	25%	24%	23%	26%	24%	18%
Market and investment							
Annual increase in capacity	GW	42	26	25	28	-6	-13
Annual investment	%	92,067	79,250	78,650	82,522	49,891	28,590
NUCLEAR							
Energy							
Installed capacity	GW	420	485	539	314	225	75
Total generation	TWh	2,949	3,495	3,938	2,226	1,623	557
Share of total supply	%	12%	12%	11%	9%	6%	2%
Market and investment							
Annual increase in capacity	GW	4.5	12.9	5.4	-17	-18	-15
Annual investment	$	98,602	153,657	105,303	28,201	33,593	152

6.5 employment in renewable energy technologies

This report estimates direct jobs in renewable energy, including construction, manufacturing, operations and maintentance, and fuel supply wherever possible. It includes only direct jobs (such as the job installing a wind turbine), and does not include indirect jobs (for example providing accomodation for construction workers).

The report does not include any estimate of jobs in energy efficiency, although this sector may create significant employment. The Energy [R]evolution scenario includes considerable increase in efficiencies in every sector compared to the Reference scenario, with a 21% decrease in primary energy use overall.

6.5.1 employment in wind energy

In the Energy [R]evolution scenario, wind energy would provide 21% of total electricity generation by 2030, and would employ 1.7 million people. Growth is much more modest in the Reference scenario, with wind energy providing 5% of generation, and employing only 0.2 million people.

6.5.2 employment in biomass

In the Energy [R]evolution scenario, biomass would provide 4.6% of total electricity generation by 2030, and would employ 4.5 million people. Growth is slightly lower in the Reference scenario, with biomass providing 2.6% of generation, and employing 4 million people. Jobs in heating from biomass fuels are included in this total.

table 6.7: wind energy: capacity, investment and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	397	525	754	638	1,357	2,908
Total generation	TWh	806	1,127	1,710	1,320	2,989	6,971
Share of total supply	%	3%	4%	5%	5%	11%	21%
Market and investment							
Annual increase in capacity	GW	41	26	22	89	14	165
Annual investment	$	69,713	44,758	98,105	154,645	221,470	340,428
Employment in the energy sector							
Direct jobs in construction, manufacturing, operation and maintenance	thousands	408	382	235	1,842	1,865	1,723

table 6.8: biomass: capacity, investment and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	79	98	155	101	162	265
Total generation	TWh	433	574	937	548	932	1,521
Share of total supply	%	1.8%	2.0%	2.6%	2.3%	3.5%	4.6%
Market and investment							
Annual increase in capacity	GW	4.4	3.8	5.5	9.3	12.2	12.2
Annual investment	$	18,599	16,324	30,325	31,237	27,467	39,776
Employment in the energy sector							
Direct jobs in construction, manufacturing, operation and maintenance	thousands	4,652	4,557	3,980	5,077	4,995	4,549

image A LOCAL WOMAN WORKS WITH TRADITIONAL AGRICULTURE PRACTICES JUST BELOW 21ST CENTURY ENERGY TECHNOLOGY. THE JILIN TONGYU TONGFA WIND POWER PROJECT, WITH A TOTAL OF 118 WIND TURBINES, IS A GRID CONNECTED RENEWABLE ENERGY PROJECT.

6.5.3 employment in geothermal power

In the Energy [R]evolution scenario, geothermal power would provide 3% of total electricity generation by 2030, and would employ 165 thousand people. Growth is much more modest in the Reference scenario, with geothermal power providing less than 1% of generation, and employing only 11 thousand people.

6.5.4 employment in wave and tidal power

In the Energy [R]evolution scenario, wave and tidal power would provide 2% of total electricity generation by 2030, and would employ 105 thousand people. Growth is much more modest in the Reference scenario, with wave and tidal power providing less than 1% of generation, and employing only 5 thousand people.

table 6.9: geothermal power: capacity, investment and direct jobs

			REFERENCE			ENERGY [R]EVOLUTION	
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	15	18	27	26	65	219
Total generation	TWh	94	118	172	159	400	1,301
Share of total supply	%	0.4%	0.4%	0.463%	0.6%	1.3%	3.3%
Market and investment							
Annual increase in capacity	GW	0.6	0.7	0.8	3	8	18
Annual investment	$	8,771	6,130	5,564	21,445	43,042	71,025
Employment in the energy sector							
Direct jobs in construction, manufacturing, operation and maintenance	thousands	15.6	12.8	10.6	122	173	165

table 6.10: wave and tidal power: capacity, investment and direct jobs

			REFERENCE			ENERGY [R]EVOLUTION	
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	0.5	0.8	4.3	8.6	54	176
Total generation	TWh	1.4	2.0	13	19	139	560
Share of total supply	%	0.0%	0.0%	0.0%	0.1%	0.5%	1.7%
Market and investment							
Annual increase in capacity	GW	0.1	0.1	0.3	1.7	9.0	12.8
Annual investment	$	308	200	803	7,821	29,720	29,280
Employment in the energy sector							
Direct jobs in construction, manufacturing, operation and maintenance	thousands	0.5	2.0	5.2	107	121	105

6.5.5 employment in solar photovoltacis

In the Energy [R]evolution scenario, solar photovoltaics would provide 8% of total electricity generation by 2030, and would employ 1.5 million people. Growth is much more modest in the Reference scenario, with solar photovoltaics providing less than 1% of generation, and employing only 0.1 million people.

6.5.6 employment in solar thermal power

In the Energy [R]evolution scenario, solar thermal power would provide 8.1% of total electricity generation by 2030, and would employ 0.8 million people. Growth is much lower in the Reference scenario, with solar thermal power providing only 0.2% of generation, and employing only 30 thousand people.

table 6.11: solar photovoltaics: capacity, investment and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	88	124	234	234	674	1,764
Total generation	TWh	108	158	341	289	878	2,634
Share of total supply	%	0.4%	0.6%	1.0%	1.2%	3.3%	8.0%
Market and investment							
Annual increase in capacity	GW	10.5	7.1	10.9	40	88	127
Annual investment	$	23,920	11,617	35,104	88,875	141,969	179,922
Employment in the energy sector							
Direct jobs in construction, manufacturing, operation and maintenance	thousands	182	210	124	1,991	1,635	1,528

table 6.12: solar thermal power: capacity, investment and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	5	11	24	34	166	714
Total generation	TWh	0	35	81	92	466	2,672
Share of total supply	%	0.0%	0.1%	0.2%	0.4%	1.7%	8.1%
Market and investment							
Annual increase in capacity	GW	0.8	1.2	1.0	6.5	26	55
Employment in the energy sector							
Direct jobs in construction, manufacturing, operation and maintenance	thousands	23	35	30	504	855	826

image WORKERS BUILD A WIND TURBINE IN A FACTORY IN PATHUM THANI, THAILAND. THE IMPACTS OF SEA-LEVEL RISE DUE TO CLIMATE CHANGE ARE PREDICTED TO HIT HARD ON COASTAL COUNTRIES IN ASIA, AND CLEAN RENEWABLE ENERGY IS A SOLUTION.

6.6 employment in the renewable heating sector

Employment in the renewable heat sector includes jobs in installation, manufacturing, and fuel supply. This analysis includes only jobs associated with fuel supply in the biomass sector, and jobs in installation and manufacturing for direct heat from solar, geothermal and heat pumps. It is therefore only a partial estimate of jobs in this sector.

6.6.1 employment in solar heating

In the Energy [R]evolution scenario, solar heating would provide 13% of total heat supply by 2030, and would employ 1.7 million people. Growth is much more modest in the Reference scenario, with solar heating providing less than 1% of heat supply, and employing only 75 thousand people.

6.6.2 employment in geothermal and heat pump heating

In the Energy [R]evolution scenario, geothermal and heat pump heating would provide 10% of total heat supply by 2030, and would employ 582 thousand people. Growth is much more modest in the Reference scenario, with geothermal and heat pump heating providing less than 1% of heat supply, and employing only 11 thousand people.

6.6.3 employment in biomass heat

In the Energy [R]evolution scenario, biomass heat would provide 27% of total heat supply by 2030, and would employ 2.6 million people in the supply of biomass feedstock. Growth is slightly less in the Reference scenario, with biomass heat providing 22% of heat supply, and employing 2.3 million people.

table 6.13: solar heating: capacity, investment and direct jobs

			REFERENCE			ENERGY [R]EVOLUTION	
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	277	344	540	829	2,132	5,434
Total generation	TWh	884	1,100	1,743	2,866	7,724	20,010
Share of total supply	%	0.6%	0.7%	1.0%	1.9%	5%	13%
Market and investment							
Annual increase in capacity	GW	13.3	13.3	19.1	124	261	326
Employment in the energy sector							
Direct jobs in installation & manufacturing	thousands	121	92	75	1,352	2,036	1,692

table 6.14: geothermal and heat pump heating: capacity, investment and direct jobs

			REFERENCE			ENERGY [R]EVOLUTION	
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	MW	75	90	128	340	986	2,479
Total generation	PJ	438	525	725	2,001	5,959	15,964
Share of total supply	%	0.3%	0.3%	0.4%	1.3%	4%	10%
Market and investment							
Annual increase in capacity	MW	2.4	3.0	4.0	55.3	129	170
Employment in the energy sector							
Direct jobs in installation & manufacturing	thousands	10	12	11	253	502	582

table 6.15: biomass heat: direct jobs in fuel supply

			REFERENCE			ENERGY [R]EVOLUTION	
Biomass heat	UNIT	2015	2020	2030	2015	2020	2030
Heat supplied	PJ	36,464	37,311	38,856	38,233	40,403	42,600
Share of total supply	%	23%	22%	22%	25%	26%	27%
Employment in the energy sector							
Direct jobs in jobs in fuel supply	thousands	2,920	2,784	2,260	3,179	2,932	2,571

the silent revolution
– past and current market developments

POWER PLANT MARKETS

GLOBAL MARKET SHARES
IN THE POWER PLANT MARKET

7

"the bright future for renewable energy is already underway."

© NASA/JESSE ALLEN

technology SOLAR PARKS PS10 AND PS20, SEVILLE, SPAIN. THESE ARE PART OF A LARGER PROJECT INTENDED TO MEET THE ENERGY NEEDS OF SOME 180,000 HOMES — ROUGHLY THE ENERGY NEEDS OF SEVILLE BY 2013, WITHOUT GREENHOUSE GAS EMISSIONS.

image THE SAN GORGONIO PASS WIND FARM IS LOCATED IN THE COACHELLA VALLEY NEAR PALM SPRINGS, ON THE EASTERN SLOPE OF THE PASS IN RIVERSIDE COUNTY, JUST EAST OF WHITE WATER. DEVELOPMENT BEGUN IN THE 1980S, THE SAN GORGONIO PASS IS ONE OF THE WINDIEST PLACES IN SOUTHERN CALIFORNIA. THE PROJECT HAS MORE THAN 4,000 INDIVIDUAL TURBINES AND POWERS PALM SPRINGS AND THE REST OF THE DESERT VALLEY.

A new analysis of the global power plant market shows that since the late 1990s, wind and solar installations grew faster than any other power plant technology across the world - about 430,000 MW total installed capacities between 2000 and 2010. However, it is too early to claim the end of the fossil fuel based power generation, because more than 475,000 MW of new coal power plants were built with embedded cumulative emissions of over 55 billion tonnes CO_2 over their technical lifetime.

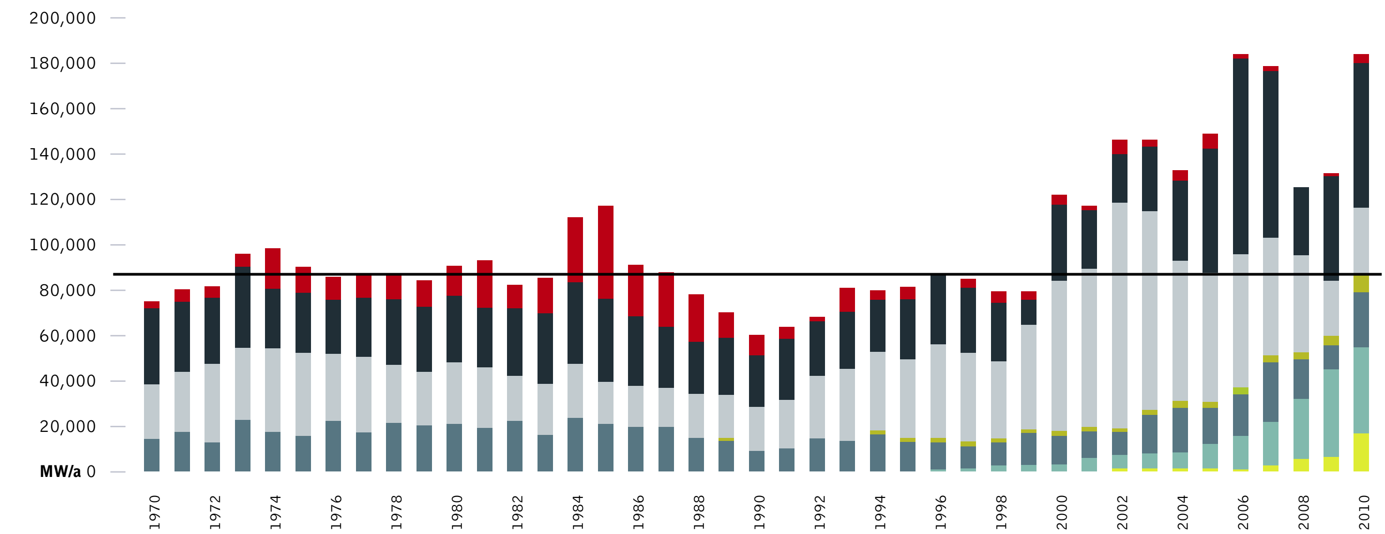
The global market volume of renewable energies in 2010 was on average, equal the total global energy market volume each year between 1970 and 2000. There is a window of opportunity for new renewable energy installations to replace old plants in OECD countries and for electrification in developing countries. However, the window will close within the next years without good renewable energy policies and legally binding CO_2 reduction targets.

Between 1970 and 1990, the OECD[72] global power plant market was dominated by countries that electrified their economies mainly with coal, gas and hydro power plants. The power sector was in the hands of state-owned utilities with regional or nationwide supply monopolies. The nuclear industry had a relatively short period of steady growth between 1970 and the mid 1980s - with a peak in 1985, one year before the Chernobyl accident - and went into decline in following years, with no recent signs of growth.

Between 1990 and 2000, the global power plant industry went through a series of changes. While OECD countries began to liberalise their electricity markets, electricity demand did not match previous growth, so fewer new power plants were built. Capital-intensive projects with long payback times, such as coal and nuclear power plants, were unable to get sufficient financial support. The decade of gas power plants started.

The economies of developing countries, especially in Asia, started growing during the 1990s, triggering a new wave of power plant projects. Similarly to the US and Europe, most of the new markets in the 'tiger states' of Southeast Asia partly deregulated their power sectors. A large number of new power plants in this region were built from Independent Power Producer (IPPs), who sell the electricity mainly to state-owned utilities. The majority of new power plant technology in liberalised power markets is fuelled by gas, except for in China which focused on building new coal power plants. Excluding China, the rest of the global power plant market has seen a phase-out of coal since the late 1990s with growing gas and renewable generation, particularly wind.

figure 7.1: global power plant market 1970-2010

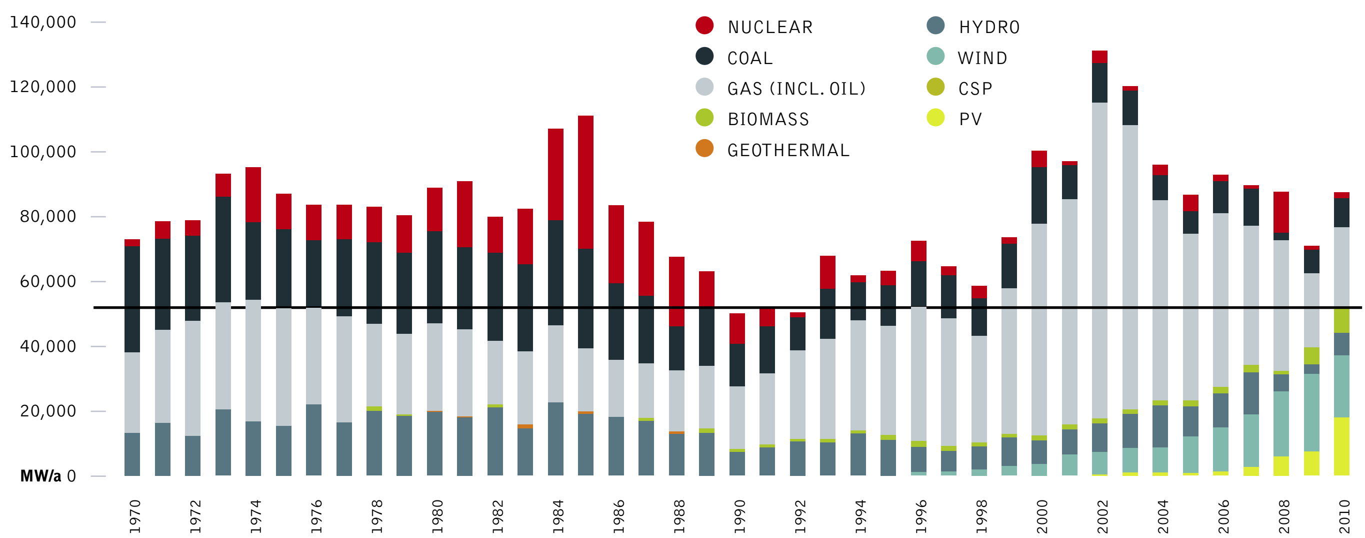


NUCLEAR
COAL
GAS (INCL. OIL)
BIOMASS
GEOTHERMAL
HYDRO
WIND
CSP
PV

source
Platts, IEA, Breyer, Teske.

reference
72 ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT.

figure 7.2: global power plant market 1970-2010, excluding china



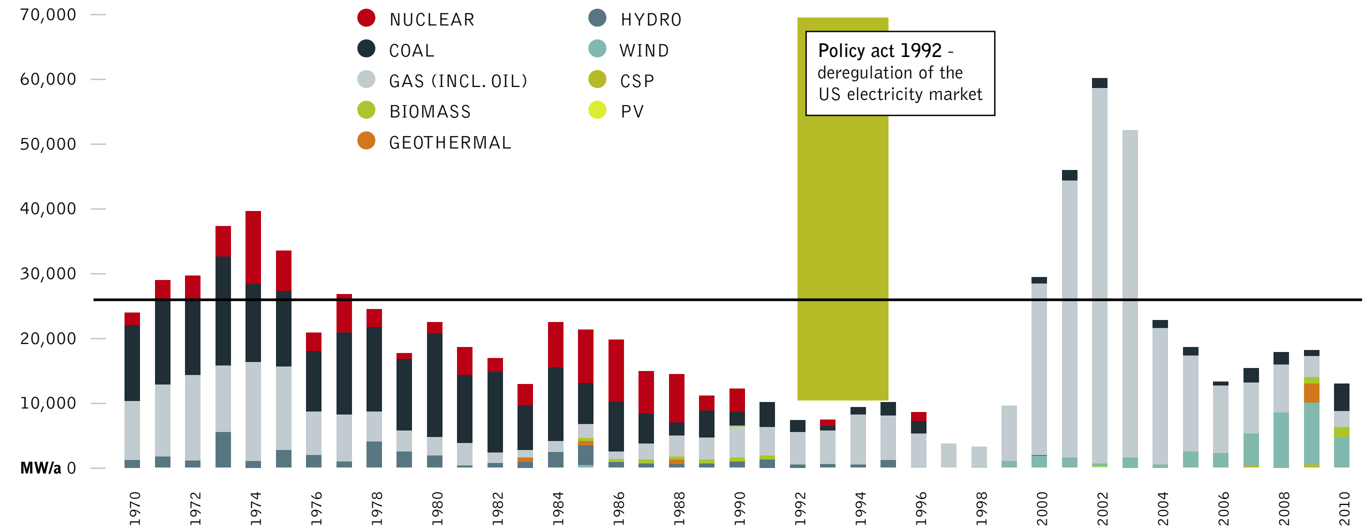
source
Platts, IEA, Breyer, Teske.

7.1 power plant markets in the us, europe and china

The graphs show how much electricity market liberalisation influences the choice of power plant technology. While the US and European power sectors moved towards deregulated markets, which favour mainly gas power plants, China added a large amount of coal until 2009, with the first signs for a change in favour of renewable energy in 2009 and 2010.

USA: Liberalisation of the US power sector started with the Energy Policy Act 1992, and became a game changer for the whole sector. While the US in 2010 is still far away from a fully liberalised electricity market, the effect has been a shift from coal and nuclear towards gas and wind. Since 2005 wind power plants have made up an increasing share of the new installed capacities as a result of mainly state-based renewable eneggy support programmes. Over the past year, solar photovoltaic plays a growing role with a project pipeline of 22,000 MW (Photon 4-2011, page 12).

figure 7.3: usa: power plant market 1970-2010



source
Platts, IEA, Breyer, Teske.

image NESJAVELLIR GEOTHERMAL PLANT GENERATES ELECTRICITY AND HOT WATER BY UTILIZING GEOTHERMAL WATER AND STEAM. IT IS THE SECOND LARGEST GEOTHERMAL POWER STATION IN ICELAND. THE STATION PRODUCES APPROXIMATELY 120MW OF ELECTRICAL POWER, AND DELIVERS AROUND 1,800 LITRES (480 US GAL) OF HOT WATER PER SECOND, SERVICING THE HOT WATER NEEDS OF THE GREATER REYKJAVIK AREA. THE FACILITY IS LOCATED 177 M (581 FT) ABOVE SEA LEVEL IN THE SOUTHWESTERN PART OF THE COUNTRY, NEAR THE HENGILL VOLCANO.

Europe: About five years after the US began deregulating the power sector, the European Community started a similar process with similar effect on the power plant market. Investors backed fewer new power plants and extended the lifetime of the existing ones. New coal and nuclear power plants have seen a market share of well below 10% since then. The growing share of renewables, especially wind and solar photovoltaic, are due to a legally-binding target and the associated feed-in laws which have been in force in several member states of the EU 27 since the late 1990s. Overall, new installed power plant capacity jumped to a record high be the aged power plant fleet in Europe needed re-powering.

figure 7.4: europe (eu 27): power plant market 1970-2010

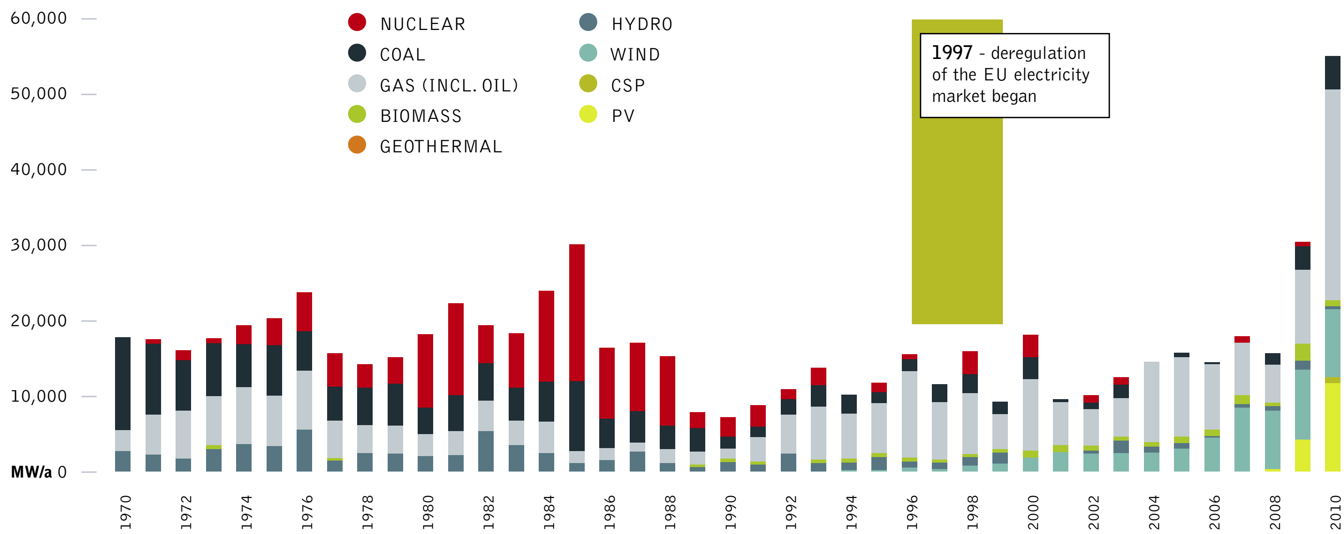
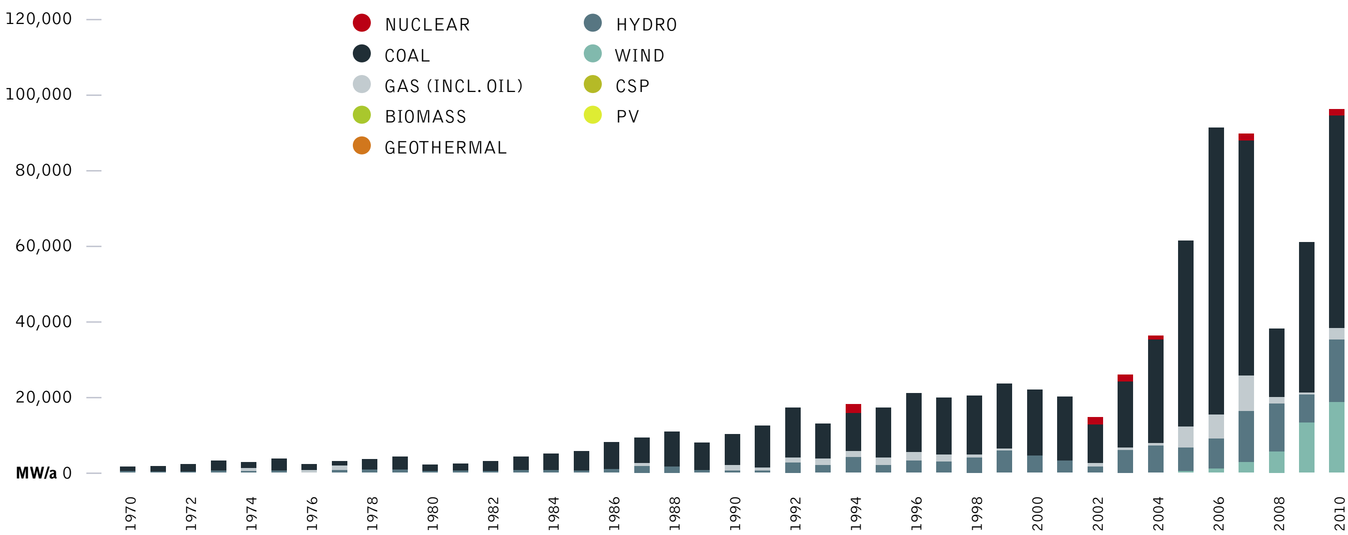


figure 7.5: china: power plant market 1970-2010



source
Platts, IEA, Breyer, Teske.

China: The steady economic growth in China since the late 1990s, and the growing power demand, led to an explosion of the coal power plant market, especially after 2002. In 2006 the market hit the peak year for new coal power plants: 88% of the newly installed coal power plants worldwide were built in China. At the same time, China is trying to take its dirtiest plants offline, between 2006 and 2010, a total of 76,825MW of small coal power plants were phased out under the "11th Five Year" programme. While coal still dominates the new added capacity, wind power is rapidly growing as well. Since 2003 the wind market doubled each year and was over 18,000 MW[73] by 2010, 49% of the global wind market. However, coal still dominates the power plant market with over 55 GW of new installed capacities in 2010 alone. The Chinese government aims to increase investments into renewable energy capacity, and during 2009, about $ 25.1 billion (RMB162.7 billion) went to wind and hydro power plants which represents 44% of the overall investment in new power plants, for the first time larger than that of coal (RMB 149.2billion), and in 2010 the figure was US$26 billion (RMB168 billion) – 4.8% more in the total investment mix compared with the previous year 2009.

7.2 the global market shares in the power plant market: renewables gaining ground

Since the year 2000, the wind power market gained a growing market share within the global power plant market. Initially only a handful of countries, namely Germany, Denmark and Spain, dominated the wind market, but the wind industry now has projects in over 70 countries around the world. Following the example of the wind industry, the solar photovoltaic industry experienced an equal growth since 2005. Between 2000 and 2010, 26% of all new power plants worldwide were renewable-powered – mainly wind – and 42% run on gas. So, two-thirds of all new power plants installed globally are gas power plants and renewable, with close to one-third as coal. Nuclear remains irrelevant on a global scale with just 2% of the global market share. About 430,000 MW of new renewable energy capacity has been installed over the last decade, while 475,000 MW of new coal, with embedded cumulative emissions of more than 55 bn tonnes CO_2 over their technical lifetime, came online – 78% or 375,000 MW in China.

The energy revolution towards renewables and gas, away from coal and nuclear, has already started on a global level. This picture is even clearer when we look into the global market shares excluding China, the only country with a massive expansion of coal. About 28% of all new power plants have been renewables and 60% have been gas power plants (88% in total). Coal gained a market share of only 10% globally, excluding China. Between 2000 and 2010, China has added over 350,000 MW of new coal capacity: twice as much as the entire coal capacity of the EU. However China has recently kick-started its wind market, and solar photovoltaics is expected to follow in the years to come.

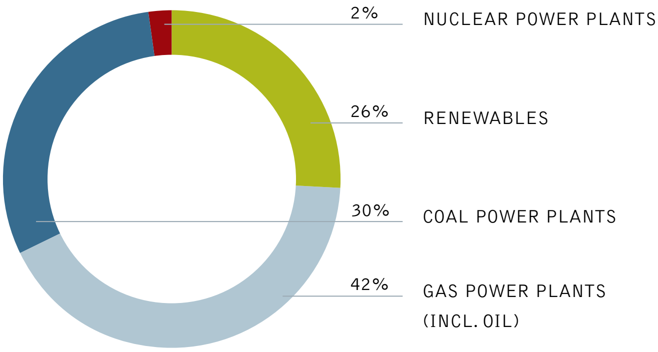
reference

73 WHILE THE OFFICIAL STATISTIC OF THE GLOBAL AND CHINESE WIND INDUSTRY ASSOCIATIONS (GWEC/CREIA) ADDS UP TO 18,900 MW FOR 2010, THE NATIONAL ENERGY BUREAU SPEAKS ABOUT 13,999 MW. DIFFERENCES BETWEEN SOURCES AS DUE TO THE TIME OF GRID CONNECTION, AS SOME TURBINES HAVE BEEN INSTALLED IN THE LAST MONTHS OF 2010, BUT HAVE BEEN CONNECTED TO THE GRID IN 2011.

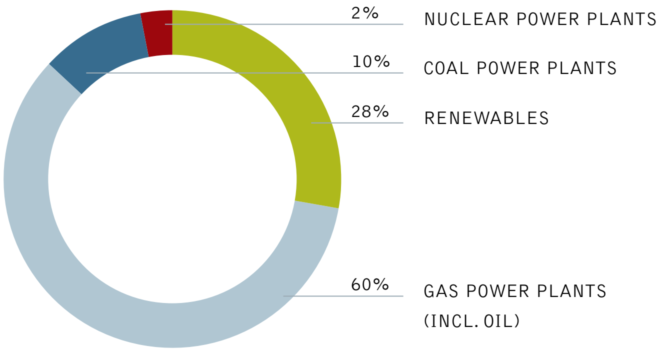
image WITNESSES FROM FUKUSHIMA, JAPAN, KANAKO NISHIKATA, HER TWO CHILDREN KAITO AND FUU AND TATSUKO OGAWARA VISIT A WIND FARM IN KLENNOW IN WENDLAND.

figure 7.6: power plant market shares

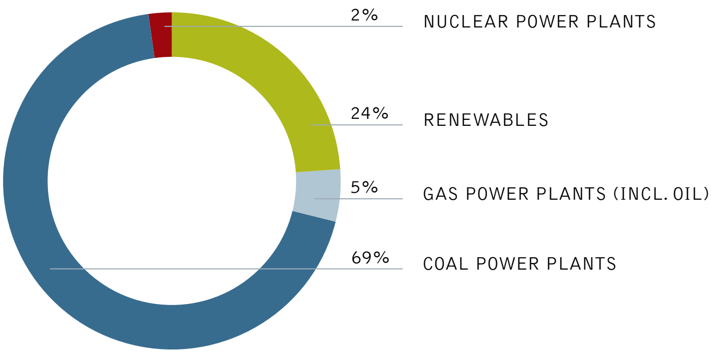
global power plant market shares 2000-2010



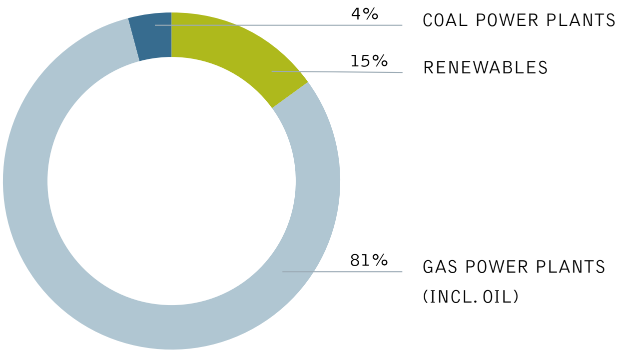
global power plant market shares 2000-2010 - excluding china



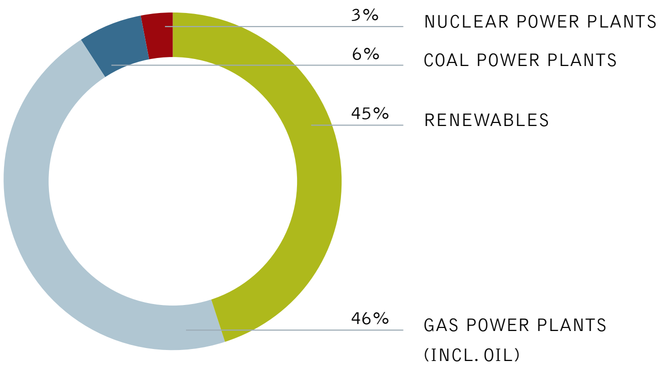
china: power plant market shares 2000-2010



usa: power plant market shares 2000-2010



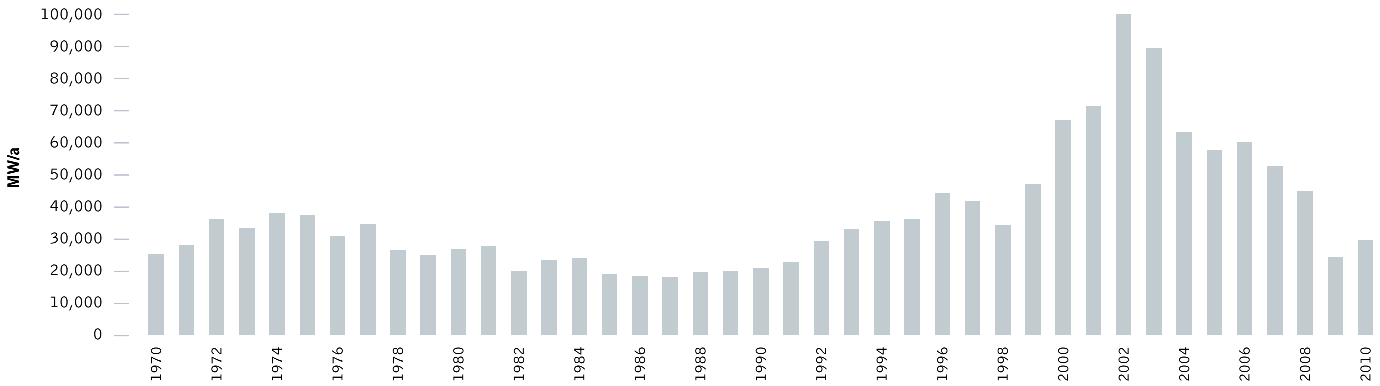
EU27: power plant market shares 2000-2010 - excluding china



source PLATTS, IEA, BREYER, TESKE, GWAC, EPIA.

figure 7.7: historic developments of the global power plant market, by technology

GLOBAL ANNUAL GAS POWER PLANT MARKET (INCL. OIL) 1970-2010



GLOBAL ANNUAL COAL POWER PLANT MARKET 1970-2010

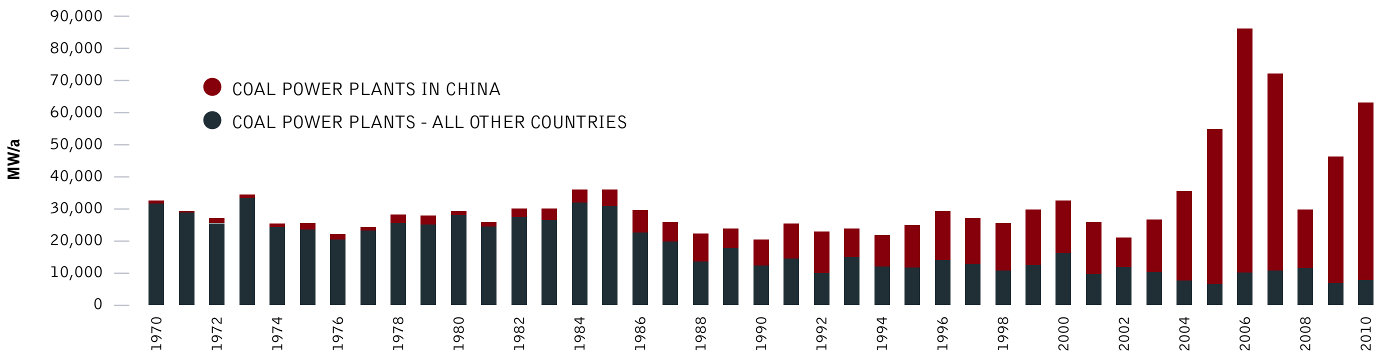
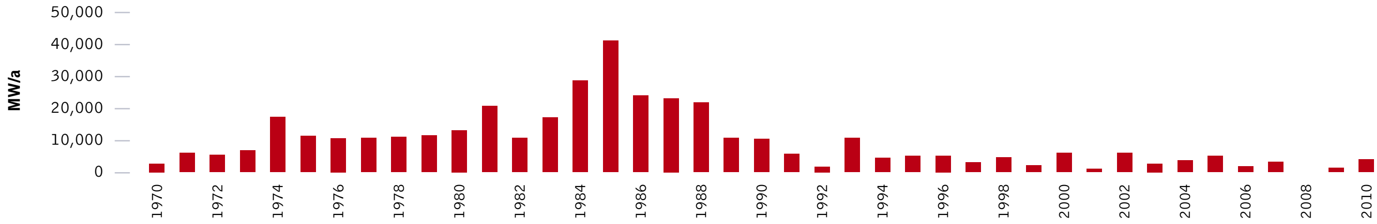


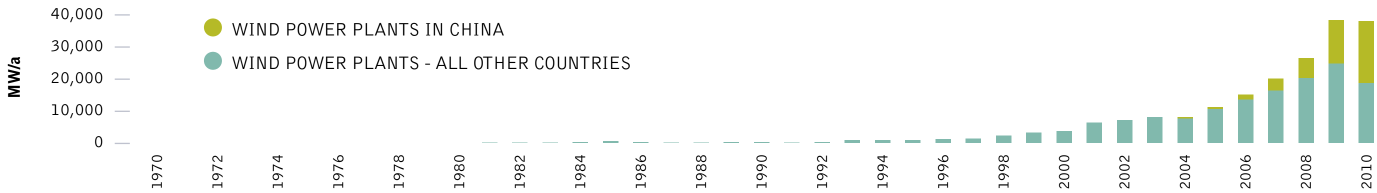
image WIND ENERGY PARK NEAR DAHME. WIND TURBINE IN THE SNOW OPERATED BY VESTAS.

figure 7.7: historic developments of the global power plant market, by technology *continued*

GLOBAL ANNUAL NUCLEAR POWER PLANT MARKET 1970-2010



GLOBAL ANNUAL WIND POWER MARKET 1970-2010



GLOBAL ANNUAL SOLAR PHOTOVOLTAIC MARKET 1970-2010

7.3 the global renewable energy market

The renewable energy sector has been growing substantially over the last 10 years. In 2011, the increases in the installation rates of both wind and solar power were particularly impressive. The total amount of renewable energy installed worldwide is reliably tracked by the Renewable Energy Policy Network for the 21st Century (REN21). Its latest global status report (2012) shows how the technologies have grown. The following text has been taken from the Renewables 2012 – Global Status Report– published in June 2012 with the permit of REN 21 and is a shortened version of the executive summary:

Renewable Energy Growth in All End-Use Sectors

Renewable energy sources have grown to supply an estimated 16.7% of global final energy consumption in 2010. Of this total, modern renewable energy accounted for an estimated 8.2%, a share that has increased in recent years, while the share from traditional biomass has declined slightly to an estimated 8.5%. During 2011, modern renewables continued to grow strongly in all end-use sectors: power, heating and cooling, and transport.

In the power sector, renewables accounted for almost half of the estimated 208 gigawatts (GW) of electric capacity added globally during 2011. Wind and solar photovoltaics (PV) accounted for almost 40% and 30% of new renewable capacity, respectively, followed by hydropower (nearly 25%). By the end of 2011, total renewable power capacity worldwide exceeded 1,360 GW, up 8% over 2010; renewables comprised more than 25% of total global power-generating capacity (estimated at 5,360 GW in 2011) and supplied an estimated 20.3% of global electricity. Non-hydropower renewables exceeded 390 GW, a 24% capacity increase over 2010.

The heating and cooling sector offers an immense yet mostly untapped potential for renewable energy deployment. Heat from biomass, solar, and geothermal sources already represents a significant portion of the energy derived from renewables, and the sector is slowly evolving as countries (particularly in the European Union) are starting to enact supporting policies and to track the share of heat derived from renewable sources. Trends in the heating (and cooling) sector include an increase in system size, expanding use of combined heat and power (CHP), the feeding of renewable heating and cooling into district networks, and the use of renewable heat for industrial purposes.

Renewable energy is used in the transport sector in the form of gaseous and liquid biofuels; liquid biofuels provided about 3% of global road transport fuels in 2011, more than any other renewable energy source in the transport sector. Electricity powers trains, subways, and a small but growing number of passenger cars and motorised cycles, and there are limited but increasing initiatives to link electric transport with renewable energy.

Solar PV grew the fastest of all renewable technologies during the period from end-2006 through 2011, with operating capacity increasing by an average of 58% annually, followed by concentrating solar thermal power (CSP), which increased almost 37% annually over this period from a small base, and wind power (26%). Demand is also growing rapidly for solar thermal heat systems, geothermal ground-source heat pumps, and some solid biomass fuels, such as wood pellets. The development of liquid biofuels has been mixed in recent years, with biodiesel production expanding in 2011 and ethanol production stable or down slightly compared with 2010. Hydropower and geothermal power are growing globally at rates averaging 2–3% per year. In several countries, however, the growth in these and other renewable technologies far exceeds the global average.

A Dynamic Policy Landscape

At least 118 countries, more than half of which are developing countries, had renewable energy targets in place by early 2012, up from 109 as of early 2010. Renewable energy targets and support policies continued to be a driving force behind increasing markets for renewable energy, despite some setbacks resulting from a lack of long-term policy certainty and stability in many countries.

The number of official renewable energy targets and policies in place to support investments in renewable energy continued to increase in 2011 and early 2012, but at a slower adoption rate relative to previous years. Several countries undertook significant policy overhauls that have resulted in reduced support; some changes were intended to improve existing instruments and achieve more targeted results as renewable energy technologies mature, while others were part of the trend towards austerity measures.

Renewable power generation policies remain the most common type of support policy; at least 109 countries had some type of renewable power policy by early 2012, up from the 96 countries reported in the GSR 2011. Feed-in-tariffs (FITs) and renewable portfolio standards (RPS) are the most commonly used policies in this sector. FIT policies were in place in at least 65 countries and 27 states by early 2012. While a number of new FITs were enacted, most related policy activities involved revisions to existing laws, at times under controversy and involving legal disputes. Quotas or Renewable Portfolio Standards (RPS) were in use in 18 countries and at least 53 other jurisdictions, with two new countries having enacted such policies in 2011 and early 2012.

Policies to promote renewable heating and cooling continue to be enacted less aggressively than those in other sectors, but their use has expanded in recent years. By early 2012, at least 19 countries had specific renewable heating/cooling targets in place and at least 17 countries and states had obligations/mandates to promote renewable heat. Numerous local governments also support renewable heating systems through building codes and other measures. The focus of this sector is still primarily in Europe, but interest is expanding to other regions.

image SOLON AG PHOTOVOLTAICS FACILITY IN ARNSTEIN OPERATING 1,500 HORIZONTAL AND VERTICAL SOLAR "MOVERS". LARGEST TRACKING SOLAR FACILITY IN THE WORLD. EACH "MOVER" CAN BE BOUGHT AS A PRIVATE INVESTMENT FROM THE S.A.G. SOLARSTROM AG, BAYERN, GERMANY.

Investment Trends

Global new investment in renewables rose 17% to a record $ 257 billion in 2011. This was more than six times the figure for 2004 and almost twice the total investment in 2007, the last year before the acute phase of the recent global financial crisis. This increase took place at a time when the cost of renewable power equipment was falling rapidly and when there was uncertainty over economic growth and policy priorities in developed countries. Including large hydropower, net investment in renewable power capacity was some $ 40 billion higher than net investment in fossil fuel capacity.

7.3 the global power plant market

The global power plant market continues to grow and reached a record high in 2011 with approximately 292 GW of new capacity added or under construction by beginning of 2012. While renewable energy power plant dominate close to 40% of the overall market, followed by gas power plants with 26%, coal power plants still represent a share of 34% or just over 100 GW or roughly 100 new coal power plants. These power plants will emit CO_2 over the coming decades and lock-in the world's power sector towards a dangerous climate change pathway.

table 7.1: overview global renewable energy market 2011

		2009	2010	2011
Investment in new renewable capacity (annual)	billion USD	161	220	257
Renewable power capacity (total, not including hydro)	GW	250	315	390
Renewable power capacity (total, including hydro)	GW	1,170	1,260	1,360
Hydropower capacity (total)	GW	915	945	970
Solar PV capacity (total)	GW	23	40	70
Concentrating solar thermal power (total)	GW	0.7	1.3	1.8
Wind power capacity (total)	GW	159	198	238
Solar hot water/heat capacity (total)	GW	153	182	232
Ethanol production (annual)	billion litres	73.1	86.5	86.1
Biodiesel production (annual)	billion litres	17.8	18.5	21.4
Countries with policy targets	#	89	109	118
States/provinces/countries with feed in policies	#	82	86	92
States/provinces/countries with RPS/quota policies	#	66	69	71
States/provinces/countries with biofuel mandates	#	57	71	72

figure 7.8: global power plant market 2011

NEW POWER PLANTS BY TECHNOLOGY INSTALLED & UNDER CONSTRUCTION IN 2011

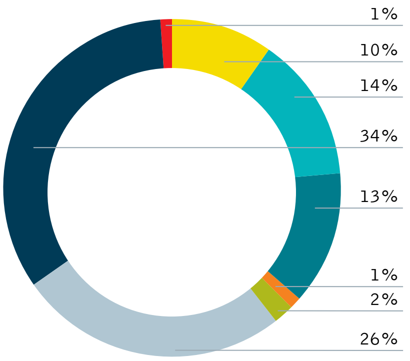
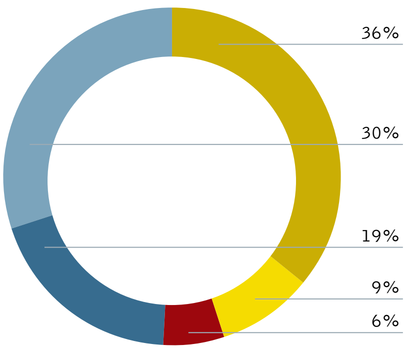


figure 7.9: global power plant by region

NEW INSTALLATIONS IN 2011



energy resources and security of supply

GLOBAL | OIL | GAS | COAL | NUCLEAR | RENEWABLE ENERGY

8

> “the issue of security of supply is now at the top of the energy policy agenda.”

© NASA/JESSE ALLEN, ROBERT SIMMON

image THE HOTTEST SPOT ON EARTH IN THE LUT DESERT. THE SINGLE HIGHEST LST RECORDED IN ANY YEAR, IN ANY REGION, OCCURRED THERE IN 2005, WHEN MODIS RECORDED A TEMPERATURE OF 70.7°C (159.3°F)—MORE THAN 12°C (22°F) WARMER THAN THE OFFICIAL AIR TEMPERATURE RECORD FROM LIBYA.

image TEST WINDMILL N90 2500, BUILT BY THE GERMAN COMPANY NORDEX, IN THE HARBOUR OF ROSTOCK. THIS WINDMILL PRODUCES 2.5 MEGA WATT AND IS TESTED UNDER OFFSHORE CONDITIONS. TWO TECHNICIANS WORKING INSIDE THE TURBINE.

The issue of security of supply is at the top of the energy policy agenda. Concern is focused both on price security and the security of physical supply for countries with none if their own resources. At present around 80% of global energy demand is met by fossil fuels. The world is currently experiencing an unrelenting increase in energy demand in the face of the finite nature of these resources. At the same time, the global distribution of oil and gas resources does not match the distribution of demand. Some countries have to rely almost entirely on fossil fuel imports.

Table 8.1 shows estimated deposits and current use of fossil energy sources. There is no shortage of fossil fuels; there might a shortage of conventional oil and gas. Reducing global fossil fuel consumption for reasons of resource scarcity alone is not mandatory, even though there may be substantial price fluctuations and regional or structural shortages as we have seen in the past.

The presently known coal resources and reserves alone probably amount to around 3,000 times the amount currently mined in a year. Thus, in terms of resource potential, current-level demand could be met for many hundreds of years to come. Coal is also relatively evenly spread across the globe; each continent holds considerable deposits. However, the supply horizon is clearly much lower for conventional mineral oil and gas reserves at 40–50 years. If some resources or deposits currently still classified as 'unconventional' are included, the resource potentials exceed the current consumption rate by far more than one hundred years. However, serious ecological damage is frequently associated with fossil energy mining, particularly of unconventional deposits in oil sands and oil shale.

Over the past few years, new commercial processes have been developed in the natural gas extraction sector, allowing more affordable access to gas deposits previously considered 'unconventional', many of which are more frequently found and evenly distributed globally than traditional gas fields. However, tight gas and shale gas extraction can potentially be accompanied by seismic activities and the pollution of groundwater basins and inshore waters. It therefore needs special regulations. It is expected that an effective gas market will develop using the existing global distribution network for liquid gas via tankers and loading terminals. With greater competitiveness regards price fixing, it is expected that the oil and gas prices will no longer be linked. Having more liquid gas in the energy mix (currently around 10 % of overall gas consumption) significantly increases supply security, e.g. reducing the risks of supply interruptions associated with international pipeline networks.

Gas hydrates are another type of gas deposit found in the form of methane aggregates both in the deep sea and underground in permafrost. They are solid under high pressure and low temperatures. While there is the possibility of continued greenhouse gas emissions from such deposits as a consequence of arctic permafrost soil thaw or a thawing of the relatively flat Siberian continental shelf, there is also potential for extraction of this energy source. Many states, including the USA, Japan, India, China and South Korea have launched relevant research programmes. Estimates of global deposits vary greatly; however, all are in the zettajoule range, for example 70,000–700,000 EJ (Krey et al., 2009). The Global Energy Assessment report estimates the theoretical potential to be 2,650–2,450,000 EJ (GEA, 2011), i.e. possibly more than a thousand times greater than the current annual total energy consumption. Approximately a tenth (1,200–245,600 EJ) is rated as potentially extractable. The WBGU advised against applied research for methane hydrate extraction, as mining bears considerable risks and methane hydrates do not represent a sustainable energy source ('The Future Oceans', WBGU, 2006).

table 8.1: global occurances of fossil and nuclear sources

THERE ARE HIGH UNCERTAINTIES ASSOCIATED WITH THE ASSESSMENT OF RESERVES AND RESOURCES.

FUEL	HISTORICAL PRODUCTION UP TO 2008 (EJ)	PRODUCTION IN 2008 (EJ)	RESERVES (EJ)	RESOURCES (EJ)	FURTHER DEPOSITS (EJ)
Conventional oil	6,500	170	6,350	4,967	-
Unconventional oil	500	23	3,800	34,000	47,000
Conventional gas	3,400	118	6,000	8,041	-
Unconventional gas	160	12	42,500	56,500	490,000
Coal	7,100	150	21,000	440,000	-
Total fossil sources	**17,660**	**473**	**79,650**	**543,507**	**537,000**
Conventional uranium	1,300	26	2,400	7,400	-
Unconventional uranium	-	-	-	4,100	2,600,000

source
The representative figures shown here are WBGU estimates on the basis of the GEA, 2011.

table 8.2: overview of the resulting emissions if all fossil resources were burned

POTENTIAL EMISSIONS AS A CONSEQUENCE OF THE USE OF FOSSIL RESERVES AND RESOURCES. ALSO ILLUSTRATED IS THEIR POTENTIAL FOR ENDANGERING THE 2°C GUARD RAIL. THIS RISK IS EXPRESSED AS THE FACTOR BY WHICH, ASSUMING COMPLETE EXHAUSTION OF THE RESPECTIVE RESERVES AND RESOURCES, THE RESULTANT CO_2 EMISSIONS WOULD EXCEED THE 750 GT C02 BUDGET PERMISSIBLE FROM FOSSIL SOURCES UNTIL 2050.

FOSSIL FUEL	HISTORICAL PRODUCTION UP TO 2008 (GT CO_2)	PRODUCTION IN 2008 (GT CO_2)	RESERVES (GT CO_2)	RESOURCES (GT CO_2)	FURTHER DEPOSITS (GT CO_2)	TOTAL RESERVES, RESOURCES AND FURTHER OCCURENCES (GT CO_2)	FACTOR BY WHICH THESE EMISSIONS ALONE EXCEED THE 2°C EMISSIONS BUDGET
Conventional oil	505	13	493	386	-	879	1
Unconventional oil	39	2	295	2,640	3,649	6,584	9
Conventional gas	192	7	339	455	-	794	1
Unconventional gas	9	1	2,405	3,197	27,724	33,325	44
Coal	666	14	1,970	41,277	-	43,247	58
Total fossil fuels	**1,411**	**36**	**5,502**	**47,954**	**31,373**	**84,829**	**113**

source
GEA, 2011.

box 8.1: the energy [r]evolution fossil fuel pathway

The Energy [R]evolution scenario will phase-out fossil fuel not simply as they are depleted, but to achieve a greenhouse gas reduction pathway required to avoid dangerous climate change. Decisions new need to avoid a "lock-in" situation meaning that investments in new oil production will make it more difficult to change to a renewable energy pathway in the future. Scenario development shows that the Energy [R]evolution can be made without any new oil exploration and production investments in the arctic or deep sea wells. Unconventional oil such as Canada's tars and or Australia's shale oil is not needed to guarantee the supply oil until it is phased out under the Energy [R]evolution scenario (see chapter 3).

8.1 oil

Oil is the lifeblood of the modern global economy, as the effects of the supply disruptions of the 1970s made clear. It is the number one source of energy, providing about one third of the world's needs and the fuel employed almost exclusively for essential uses such as transportation. However, a passionate debate has developed over the ability of supply to meet increasing consumption, a debate obscured by poor information and stirred by recent soaring prices.

8.1.1 the reserves chaos

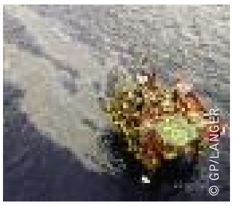
Public information about oil and gas reserves is strikingly inconsistent, and potentially unreliable for legal, commercial, historical and sometimes political reasons. The most widely available and quoted figures, those from the industry journals Oil and Gas Journal and World Oil, have limited value as they report the reserve figures provided by companies and governments without analysis or verification. Moreover, as there is no agreed definition of reserves or standard reporting practice, these figures usually represent different physical and conceptual magnitudes. Confusing terminology - 'proved', 'probable', 'possible', 'recoverable', 'reasonable certainty' - only adds to the problem.

Historically, private oil companies have consistently underestimated their reserves to comply with conservative stock exchange rules and through natural commercial caution. Whenever a discovery was made, only a portion of the geologist's estimate of recoverable resources was reported; subsequent revisions would then increase the reserves from that same oil field over time. National oil companies, mostly represented by OPEC (Organisation of Petroleum Exporting Countries), have taken a very different approach. They are not subject to any sort of accountability and their reporting practices are even less clear. In the late 1980s, the OPEC countries blatantly overstated their reserves while competing for production quotas, which were allocated as a proportion of the reserves. Although some revision was needed after the companies were nationalised, between 1985 and 1990, OPEC countries increased their apparent joint reserves by 82%. Not only were these dubious revisions never corrected, but many of these countries have reported untouched reserves for years, even if no sizeable discoveries were made and production continued at the same pace. Additionally, the Former Soviet Union's oil and gas reserves have been overestimated by about 30% because the original assessments were later misinterpreted.

Whilst private companies are now becoming more realistic about the extent of their resources, the OPEC countries hold by far the majority of the reported reserves, and their information is as unsatisfactory as ever. Their conclusions should therefore be treated with considerable caution. To fairly estimate the world's oil resources would require a regional assessment of the mean backdated (i.e. 'technical') discoveries.

image PLATFORM/OIL RIG DUNLIN IN THE NORTH SEA SHOWING OIL POLLUTION.

image ON A LINFEN STREET, TWO MEN LOAD UP A CART WITH COAL THAT WILL BE USED FOR COOKING. LINFEN, A CITY OF ABOUT 4.3 MILLION, IS ONE OF THE MOST POLLUTED CITIES IN THE WORLD. CHINA'S INCREASINGLY POLLUTED ENVIRONMENT IS LARGELY A RESULT OF THE COUNTRY'S RAPID DEVELOPMENT AND CONSEQUENTLY A LARGE INCREASE IN PRIMARY ENERGY CONSUMPTION, WHICH IS ALMOST ENTIRELY PRODUCED BY BURNING COAL.



8.1.2 non-conventional oil reserves

A large share of the world's remaining oil resources is classified as 'non-conventional'. Potential fuel sources such as oil sands, extra heavy oil and oil shale are generally more costly to exploit and their recovery involves enormous environmental damage. The reserves of oil sands and extra heavy oil in existence worldwide are estimated to amount to around 6 trillion barrels, of which between 1 and 2 trillion barrels are believed to be recoverable if the oil price is high enough and the environmental standards low enough.

One of the worst examples of environmental degradation resulting from the exploitation of unconventional oil reserves is the oil sands that lie beneath the Canadian province of Alberta and form the world's second-largest proven oil reserves after Saudi Arabia.

The 'tar sands' are a heavy mixture of bitumen, water, sand and clay found beneath more than 54,000 square miles[74] of prime forest in northern Alberta, an area the size of England and Wales. Producing crude oil from this resource generates up to four times more carbon dioxide, the principal global warming gas, than conventional drilling. The booming oil sands industry will produce 100 million tonnes of CO_2 a year (equivalent to a fifth of the UK's entire annual emissions) by 2012, ensuring that Canada will miss its emission targets under the Kyoto treaty. The oil rush is also scarring a wilderness landscape: millions of tonnes of plant life and top soil are scooped away in vast opencast mines and millions of litres of water diverted from rivers. Up to five barrels of water are needed to produce a single barrel of crude and the process requires huge amounts of natural gas. It takes two tonnes of the raw sands to produce a single barrel of oil.

8.2 gas

Natural gas has been the fastest growing fossil energy source over the last two decades, boosted by its increasing share in the electricity generation mix. Gas is generally regarded as an abundant resource and there is lower public concern about depletion than for oil, even though few in-depth studies address the subject. Gas resources are more concentrated and a few massive fields make up most of the reserves. The largest gas field in the world holds 15% of the Ultimate Recoverable Resources (URR), compared to 6% for oil. Unfortunately, information about gas resources suffers from the same bad practices as oil data because gas mostly comes from the same geological formations, and the same stakeholders are involved.

Most reserves are initially understated and then gradually revised upwards, giving an optimistic impression of growth. By contrast, Russia's reserves, the largest in the world, are considered to have been overestimated by about 30%. Owing to geological similarities, gas follows the same depletion dynamic as oil, and thus the same discovery and production cycles. In fact, existing data for gas is of worse quality than for oil, with ambiguities arising over the amount produced, partly because flared and vented gas is not always accounted for. As opposed to published reserves, the technical ones have been almost constant since 1980 because discoveries have roughly matched production.

8.2.1 shale gas[75]

Natural gas production, especially in the United States, has recently involved a growing contribution from non-conventional gas supplies such as shale gas. Conventional natural gas deposits have a well-defined geographical area, the reservoirs are porous and permeable, the gas is produced easily through a wellbore and does not generally require artificial stimulation.

Natural gas obtained from unconventional reserves (known as "shale gas" or "tight gas") requires the reservoir rock to be fractured using a process known as hydraulic fracturing or "fracking". Fracking is associated with a range of environmental impacts some of which are not fully documented or understood. In addition, it appears that the greenhouse gas "footprint" of shale gas production may be significantly greater than for conventional gas and is claimed to be even worse than for coal.

Research and investment in non-conventional gas resources has increased significantly in recent years due to the rising price of conventional natural gas. In some areas the technologies for economic production have already been developed, in others it is still at the research stage. Extracting shale gas, however, usually goes hand in hand with environmentally hazardous processes. Even so, it is expected to increase.

Greenpeace is opposed to the exploitation of unconventional gas reserves and these resources are not needed to guarantee the needed gas supply under the Energy [R]evolution scenario.

8.3 coal

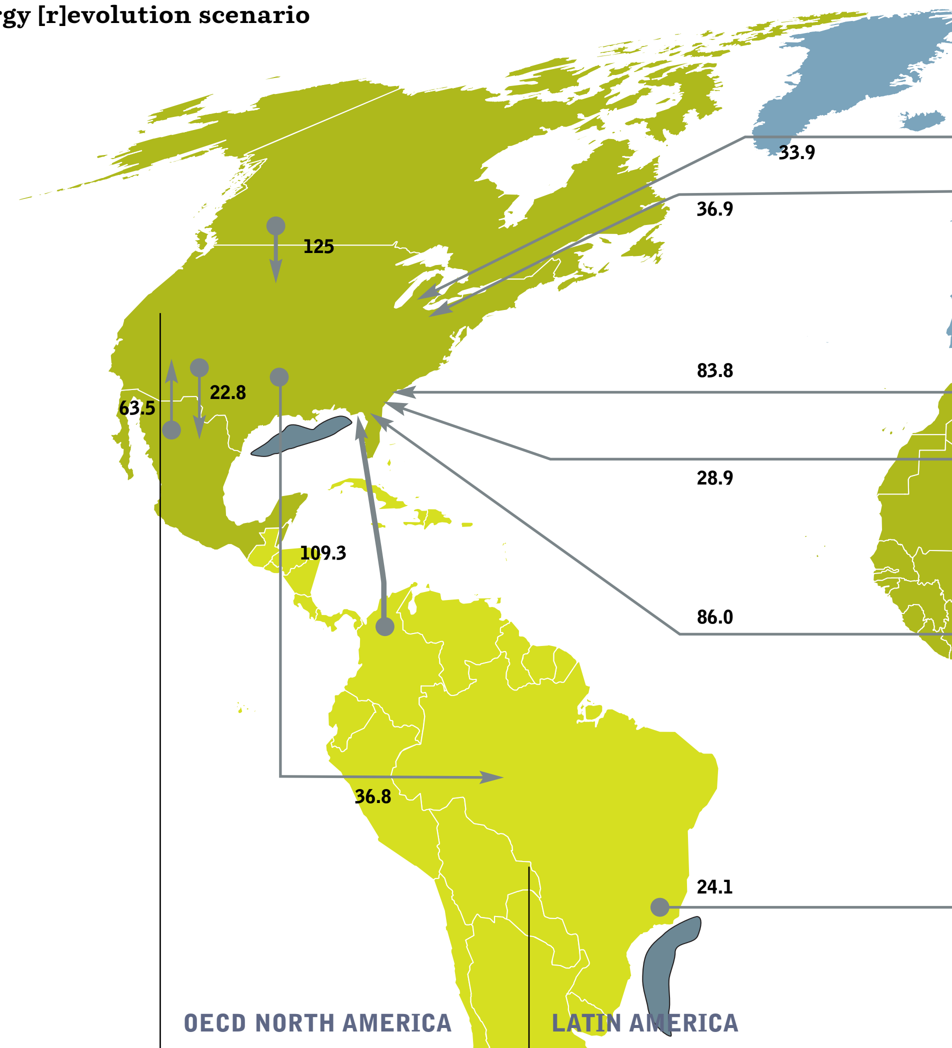
Coal was the world's largest source of primary energy until it was overtaken by oil in the 1960s. Today, coal supplies almost one quarter of the world's energy. Despite being the most abundant of fossil fuels, coal's development is currently threatened by environmental concerns; hence its future will unfold in the context of both energy security and global warming.

Coal is abundant and more equally distributed throughout the world than oil and gas. Global recoverable reserves are the largest of all fossil fuels, and most countries have at least some. Moreover, existing and prospective big energy consumers like the US, China and India are self-sufficient in coal and will be for the foreseeable future. Coal has been exploited on a large scale for two centuries, so both the product and the available resources are well known; no substantial new deposits are expected to be discovered. Extrapolating the demand forecast forward, the world will consume 20% of its current reserves by 2030 and 40% by 2050. Hence, if current trends are maintained, coal would still last several hundred years.

references
74 THE INDEPENDENT, 10 DECEMBER 2007.
75 INTERSTATE NATURAL GAS ASSOCIATION OF AMERICA (INGAA), "AVAILABILITY, ECONOMICS AND PRODUCTION POTENTIAL OF NORTH AMERICAN UNCONVENTIONAL NATURAL GAS SUPPLIES", NOVEMBER 2008.

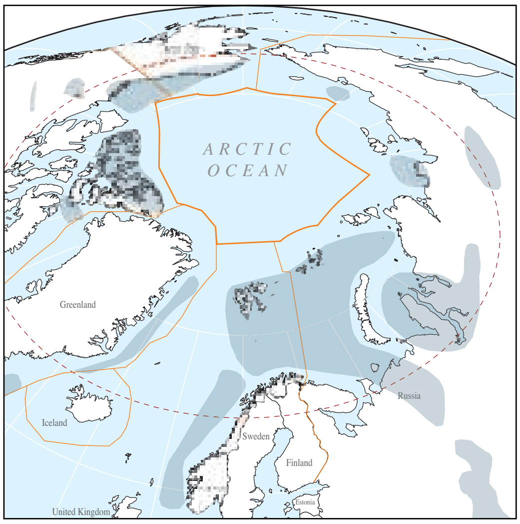
map 8.1: oil reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



NON RENEWABLE RESOURCE

OIL



LEGEND - ARTIC REGION

POSSIBLE OIL & GAS EXPLORATION FIELDS

200 SEA MILE NATIONAL BOUNDARY

OECD NORTH AMERICA

	REF		E[R]	
	TMB	%	TMB	%
2010	74.3	5.5%	74.3	5.5%
	MB	PJ	MB	PJ
2009	6,687H	40,923H	6,687H	40,923H
2050	6,059H	37,080	552	3,193
	L		L	
2009	2,436H		2,436H	
2050	1,668H		144	

LATIN AMERICA

	REF		E[R]	
	TMB	%	TMB	%
2010	239.4	17.8%	239.4	17.8%
	MB	PJ	MB	PJ
2009	1,569	9,600	1,569	9,600
2050	2,433	14,890	194	1,186
	L		L	
2009	555		555	
2050	612		49	

LEGEND - WORLD MAP

>60 | 50-60 | 40-50 | 30-40 | 20-30 | 10-20 | 5-10 | 0-5 — % RESOURCES GLOBALLY

REF REFERENCE SCENARIO

E[R] ENERGY [R]EVOLUTION SCENARIO

POSSIBLE MAIN DEEP SEA OIL EXPLORATION FIELDS

TRADE FLOWS (MLLION TONNES)

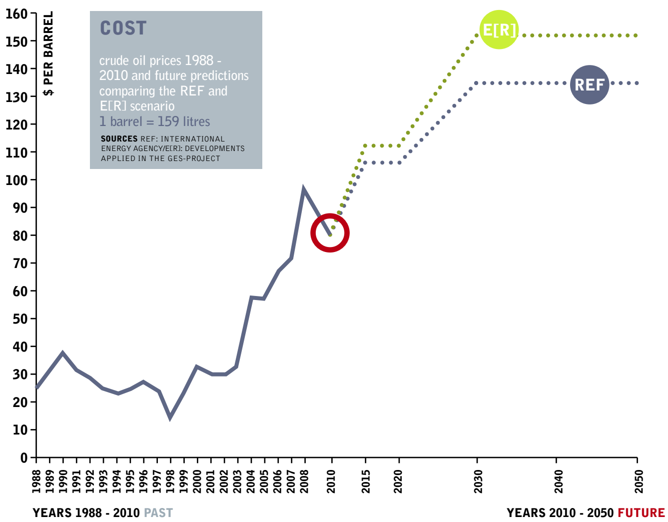
RESERVES TOTAL THOUSAND MILLION BARRELS [TMB] | SHARE IN % OF GLOBAL TOTAL [END OF 2011]

CONSUMPTION PER REGION MILLION BARRELS [MB] | PETA JOULE [PJ]

CONSUMPTION PER PERSON LITERS [L]

H HIGHEST | **M** MIDDLE | **L** LOWEST

0 1000 KM



COST

crude oil prices 1988 - 2010 and future predictions comparing the REF and E[R] scenario
1 barrel = 159 litres

SOURCES REF: INTERNATIONAL ENERGY AGENCY/E[R]: DEVELOPMENTS APPLIED IN THE GES-PROJECT

OECD EUROPE

	REF		E[R]	
	TMB	%	TMB	%
2010	14.8	1.1%M	14.8	1.1%M
	MB	PJ	MB	PJ
2009	4,160	25,462	4,160	25,462
2050	3,621	22,163	497M	3,042M
	L		L	
2009	1,233		1,233	
2050	1,022M		140	

MIDDLE EAST

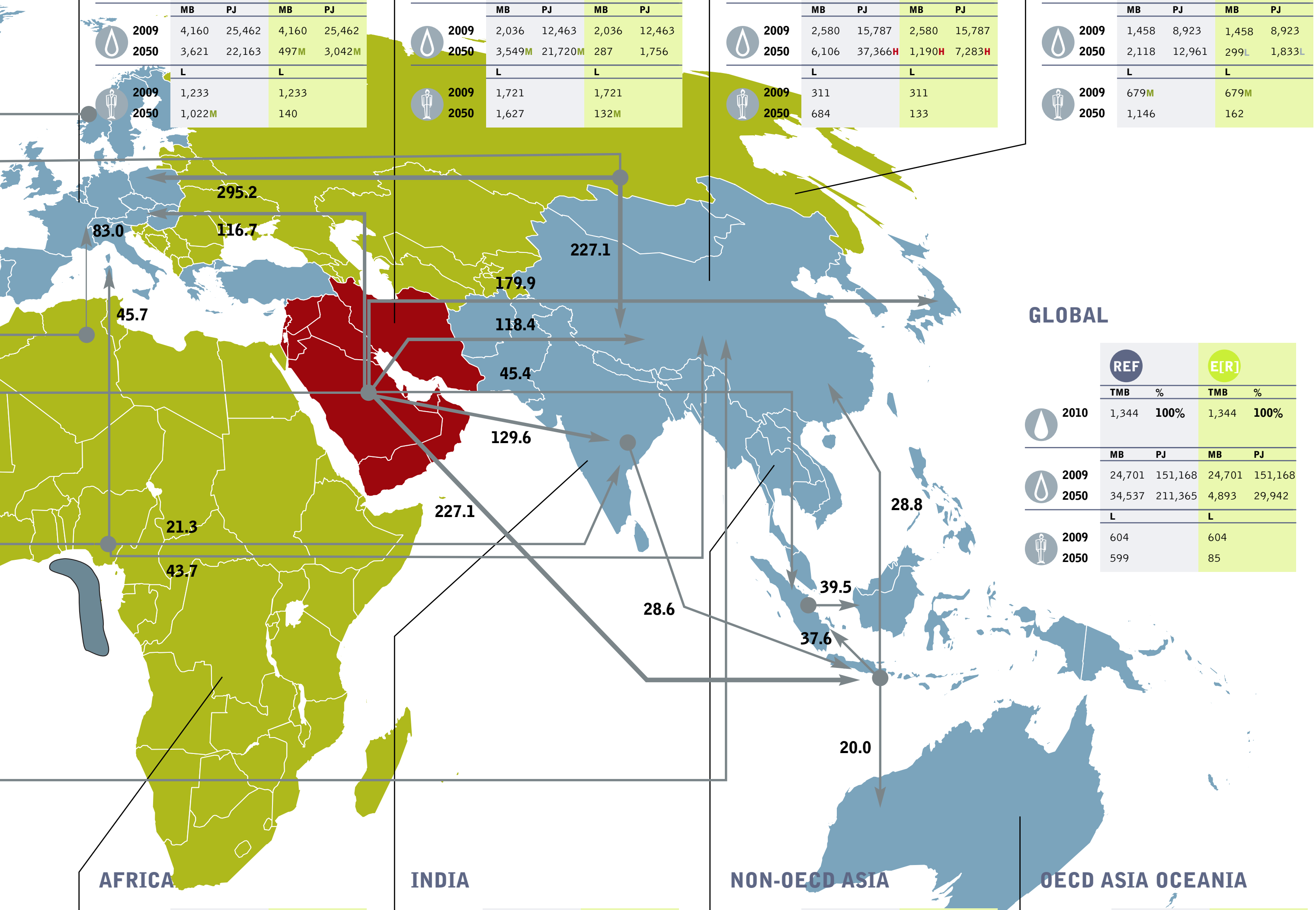
	REF		E[R]	
	TMB	%	TMB	%
2010	752.5H	56.0%H	752.5H	56.0%H
	MB	PJ	MB	PJ
2009	2,036	12,463	2,036	12,463
2050	3,549M	21,720M	287	1,756
	L		L	
2009	1,721		1,721	
2050	1,627		132M	

CHINA

	REF		E[R]	
	TMB	%	TMB	%
2010	14.8	1.1%	14.8	1.1%
	MB	PJ	MB	PJ
2009	2,580	15,787	2,580	15,787
2050	6,106	37,366H	1,190H	7,283H
	L		L	
2009	311		311	
2050	684		133	

EAST EUROPE/EURASIA

	REF		E[R]	
	TMB	%	TMB	%
2010	85.6	6.4%	85.6	6.4%
	MB	PJ	MB	PJ
2009	1,458	8,923	1,458	8,923
2050	2,118	12,961	299L	1,833L
	L		L	
2009	679M		679M	
2050	1,146		162	



GLOBAL

	REF		E[R]	
	TMB	%	TMB	%
2010	1,344	100%	1,344	100%
	MB	PJ	MB	PJ
2009	24,701	151,168	24,701	151,168
2050	34,537	211,365	4,893	29,942
	L		L	
2009	604		604	
2050	599		85	

AFRICA

	REF		E[R]	
	TMB	%	TMB	%
2010	132.1M	9.8%M	132.1M	9.8%M
	MB	PJ	MB	PJ
2009	1,039	6,359L	1,039	6,359
2050	1,640L	10,037L	555	3,398
	L		L	
2009	179		179	
2050	131L		44L	

INDIA

	REF		E[R]	
	TMB	%	TMB	%
2010	9.0	0.7%	9.0	0.7%
	MB	PJ	MB	PJ
2009	1,040L	6,366	1,040L	6,366L
2050	4,143	25,354	494	3,024
	L		L	
2009	146L		146L	
2050	397		47	

NON-OECD ASIA

	REF		E[R]	
	TMB	%	TMB	%
2010	16.0	1.2%	16.0	1.2%
	MB	PJ	MB	PJ
2009	1,738	10,634	1,738	10,634
2050	3,037	18,585	529	3,239
	L		L	
2009	283		283	
2050	321		56	

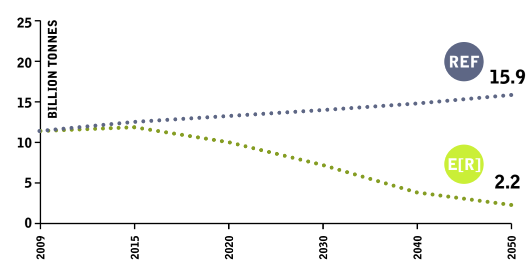
OECD ASIA OCEANIA

	REF		E[R]	
	TMB	%	TMB	%
2010	5.4L	0.4%L	5.4L	0.4%L
	MB	PJ	MB	PJ
2009	2,394M	14,651M	2,394	14,651
2050	1,832	11,209	325	1,990
	L		L	
2009	1,902		1,902	
2050	1,635		290H	

CO_2 EMISSIONS FROM OIL

comparison between the REF and E[R] scenario 2009 - 2050 billion tonnes

SOURCE GPI/EREC



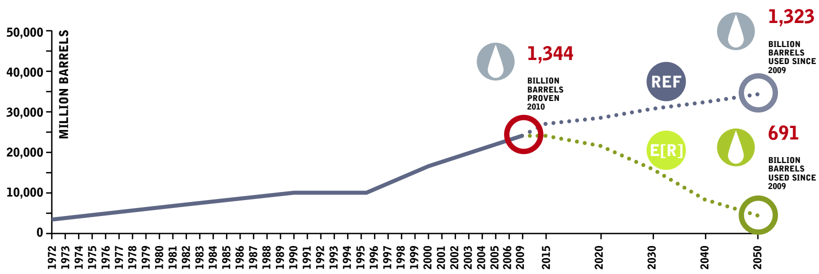
RESERVES AND CONSUMPTION

oil reserves versus global demand, production and consumption. global consumption comparison between the REF and E[R] scenario.

million barrels. 1 barrel = 159 litres

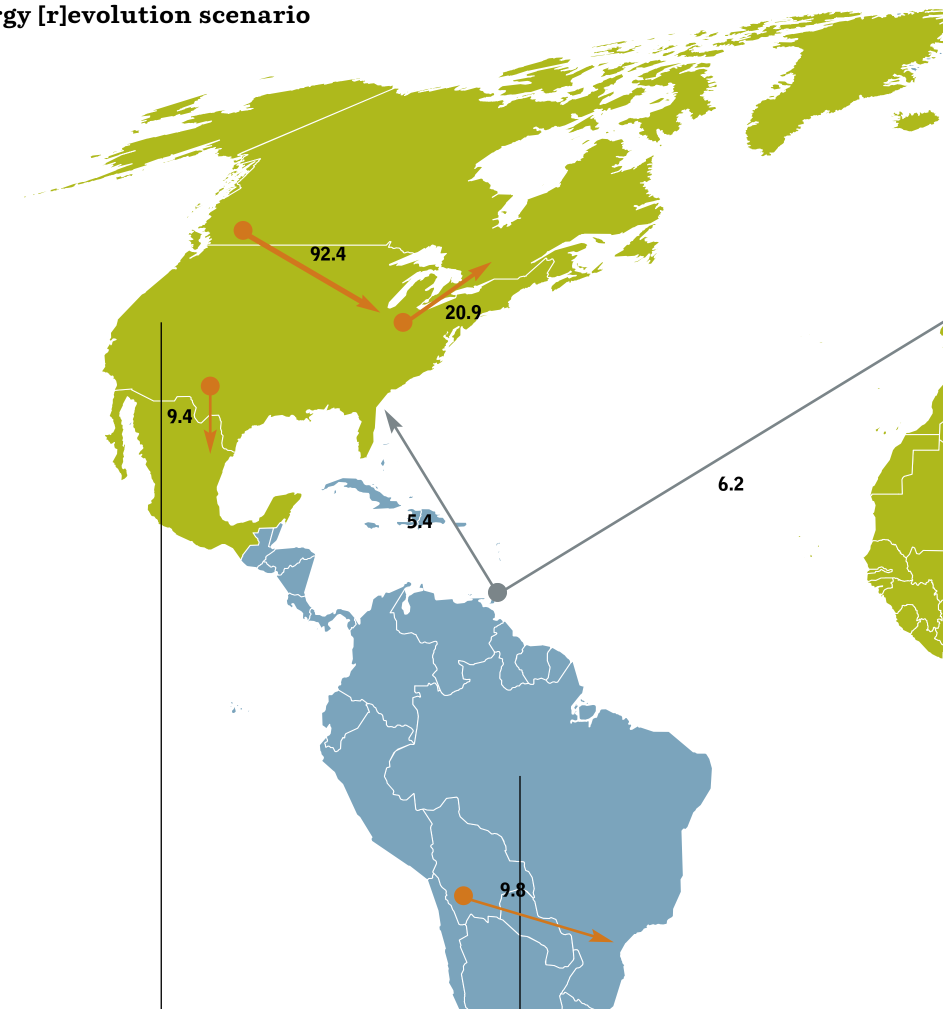
SOURCE BP 2011

REF global consumption
E[R] global consumption



map 8.2: gas reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



OECD NORTH AMERICA

		REF		E[R]	
		tn m³	%	tn m³	%
Reserves	2010	9.9	5.2%	9.9	5.2%
		bn m³	PJ	bn m³	PJ
Consumption per region	2009	731H	27,790H	731H	27,790H
	2050	890H	33,814H	67	2,559
		m³		m³	
Consumption per person	2009	1,598		1,598	
	2050	1,496		113	

LATIN AMERICA

		REF		E[R]	
		tn m³	%	tn m³	%
Reserves	2010	7.4	3.9%	7.4	3.9%
		bn m³	PJ	bn m³	PJ
Consumption per region	2009	119	4,539	119	4,539
	2050	301	11,441	62	2,373
		m³		m³	
Consumption per person	2009	255		255	
	2050	499		104	

NON RENEWABLE RESOURCE

GAS

LEGEND

>50 | 40-50 | 30-40 | 20-30 | 10-20 | 5-10 | 0-5 — % RESOURCES GLOBALLY

REF — REFERENCE SCENARIO

E[R] — ENERGY [R]EVOLUTION SCENARIO

PIPELINE GAS TRADE FLOWS (BILLION CUBIC METRES)

LNG TRADE FLOWS (BILLION CUBIC METRES)

RESERVES TOTAL TRILLION CUBIC METRES [tn m³] | SHARE IN % OF GLOBAL TOTAL [END OF 2011]

CONSUMPTION PER REGION BILLION CUBIC METRES [bn m³] | PETA JOULE [PJ]

CONSUMPTION PER PERSON CUBIC METRES [m³]

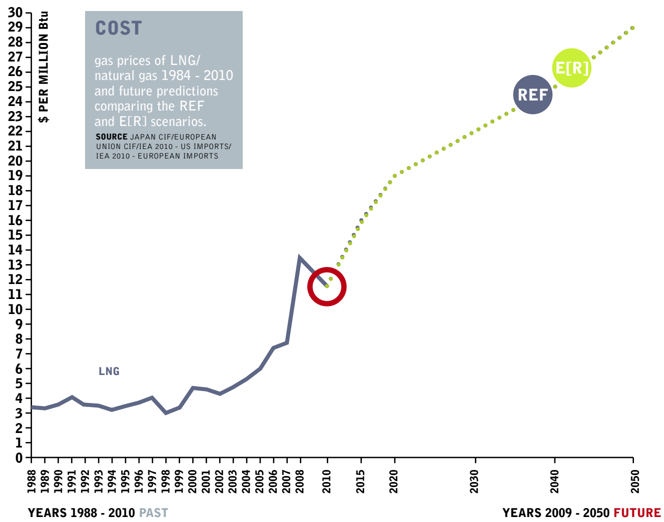
H HIGHEST | **M** MIDDLE | **L** LOWEST

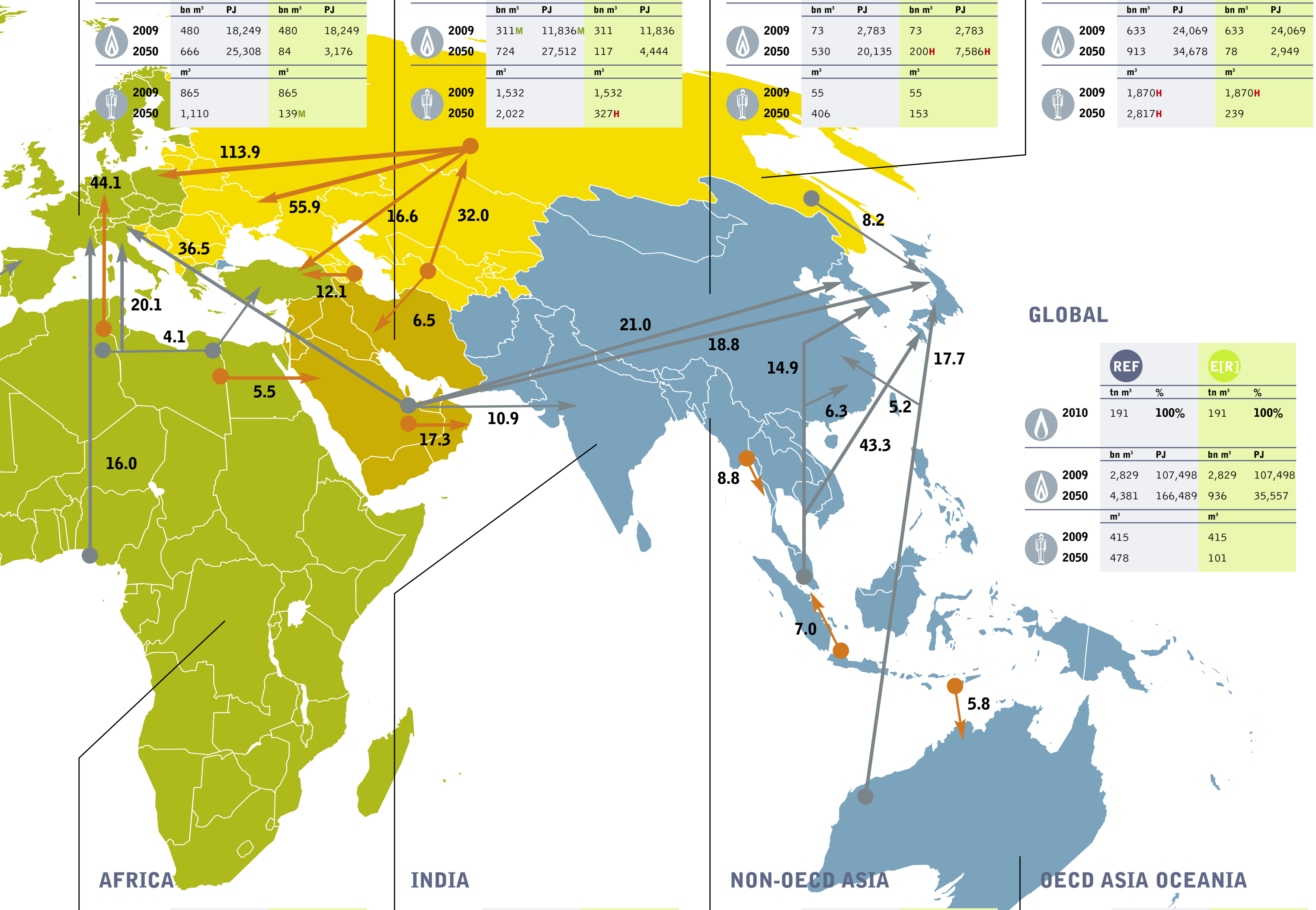
0 1000 KM

COST

gas prices of LNG/ natural gas 1984 - 2010 and future predictions comparing the REF and E[R] scenarios.

SOURCE JAPAN CIF/EUROPEAN UNION CIF/IEA 2010 - US IMPORTS/ IEA 2010 - EUROPEAN IMPORTS





OECD EUROPE

		REF		E[R]	
		tn m³	%	tn m³	%
Reserves	2010	13.6	7.1%	13.6	7.1%
		bn m³	PJ	bn m³	PJ
Production	2009	480	18,249	480	18,249
	2050	666	25,308	84	3,176
		m³		m³	
Per capita	2009	865		865	
	2050	1,110		139M	

MIDDLE EAST

		REF		E[R]	
		tn m³	%	tn m³	%
Reserves	2010	75.8H	39.7%H	75.8H	39.7%H
		bn m³	PJ	bn m³	PJ
Production	2009	311M	11,836M	311	11,836
	2050	724	27,512	117	4,444
		m³		m³	
Per capita	2009	1,532		1,532	
	2050	2,022		327H	

CHINA

		REF		E[R]	
		tn m³	%	tn m³	%
Reserves	2010	2.8	1.5%	2.8	1.5%
		bn m³	PJ	bn m³	PJ
Production	2009	73	2,783	73	2,783
	2050	530	20,135	200H	7,586H
		m³		m³	
Per capita	2009	55		55	
	2050	406		153	

EAST EUROPE/EURASIA

		REF		E[R]	
		tn m³	%	tn m³	%
Reserves	2010	53.3	27.9%	53.3	27.9%
		bn m³	PJ	bn m³	PJ
Production	2009	633	24,069	633	24,069
	2050	913	34,678	78	2,949
		m³		m³	
Per capita	2009	1,870H		1,870H	
	2050	2,817H		239	

GLOBAL

		REF		E[R]	
		tn m³	%	tn m³	%
Reserves	2010	191	100%	191	100%
		bn m³	PJ	bn m³	PJ
Production	2009	2,829	107,498	2,829	107,498
	2050	4,381	166,489	936	35,557
		m³		m³	
Per capita	2009	415		415	
	2050	478		101	

AFRICA

		REF		E[R]	
		tn m³	%	tn m³	%
Reserves	2010	14.7M	7.7%M	14.7M	7.7%M
		bn m³	PJ	bn m³	PJ
Production	2009	91	3,452	91	3,452
	2050	229	8,697	69	2,604
		m³		m³	
Per capita	2009	91		91	
	2050	104L		31L	

INDIA

		REF		E[R]	
		tn m³	%	tn m³	%
Reserves	2010	1.5L	0.8%L	1.5L	0.8%L
		bn m³	PJ	bn m³	PJ
Production	2009	53L	2,005L	53L	2,005L
	2050	254	9,637	97M	3,700M
		m³		m³	
Per capita	2009	44L		44L	
	2050	150		58	

NON-OECD ASIA

		REF		E[R]	
		tn m³	%	tn m³	%
Reserves	2010	8.7	4.5%	8.7	4.5%
		bn m³	PJ	bn m³	PJ
Production	2009	178	6,757	178	6,757
	2050	436M	16,561M	102	3,864
		m³		m³	
Per capita	2009	170		170	
	2050	302		70	

OECD ASIA OCEANIA

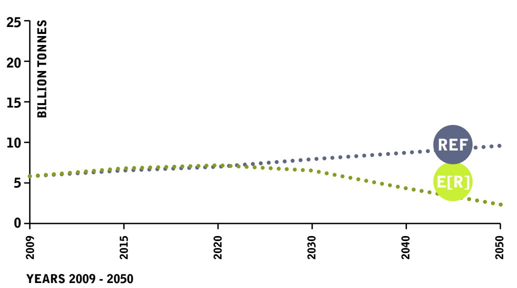
		REF		E[R]	
		tn m³	%	tn m³	%
Reserves	2010	3.3	1.7%	3.3	1.7%
		bn m³	PJ	bn m³	PJ
Production	2009	158	6,019	158	6,019
	2050	211L	8,020L	61L	2,302L
		m³		m³	
Per capita	2009	789M		789M	
	2050	1,095M		314	

CO_2 EMISSIONS FROM GAS

comparison between the REF and E[R] scenario 2009 - 2050

billion tonnes

SOURCE GPI/EREC

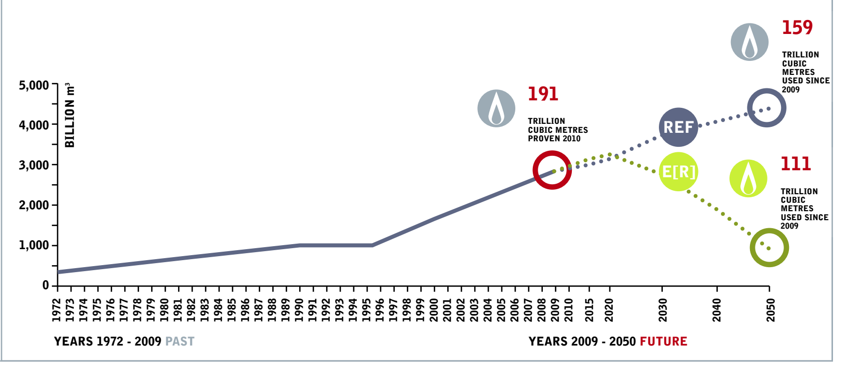


RESERVES AND CONSUMPTION

gas reserves versus global demand, production and consumption. global consumption comparison between the REF and E[R] scenario.

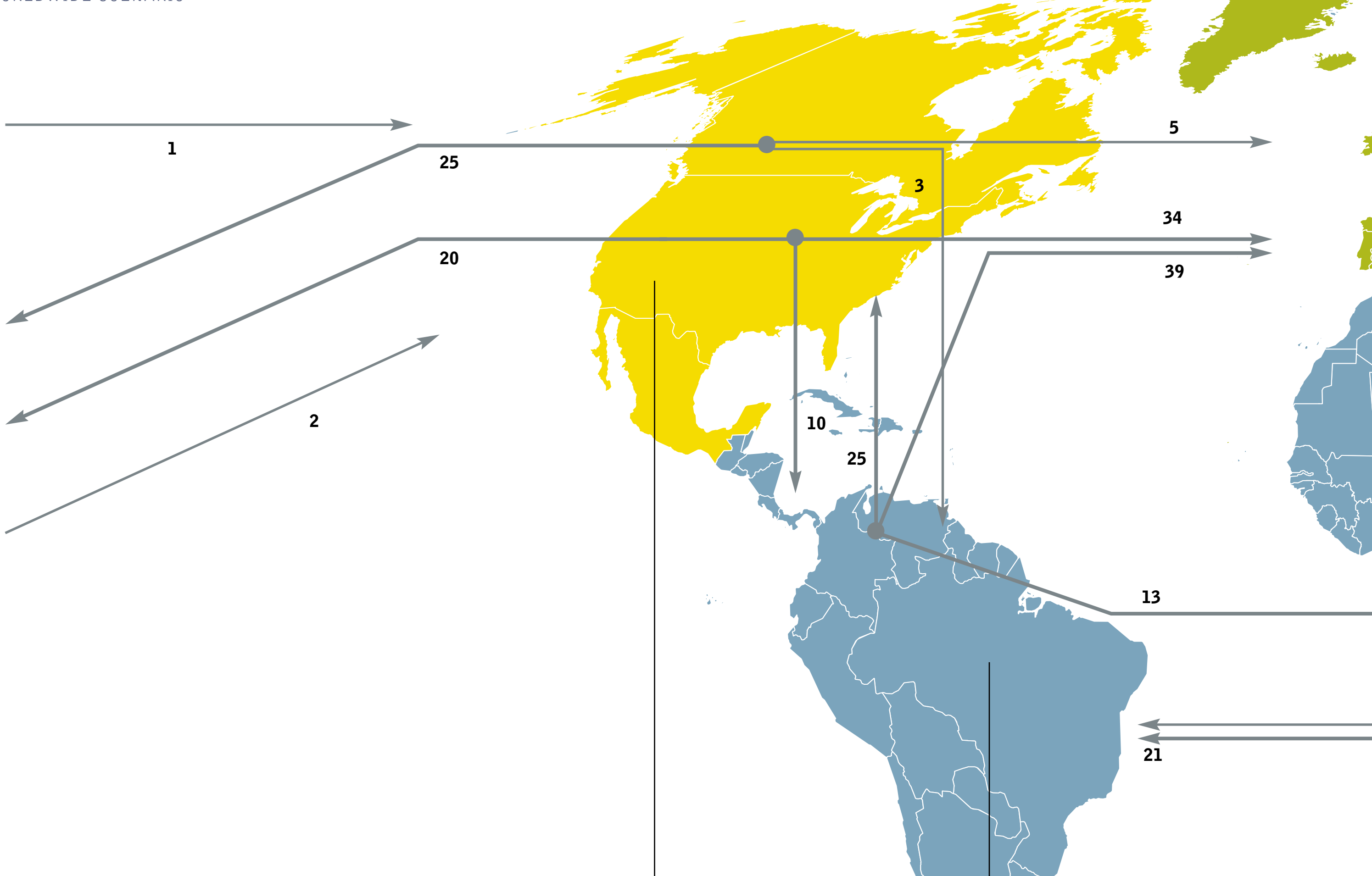
billion cubic metres

SOURCE 1970-2011 BP, 2009-2050 GPI/EREC



map 8.3: coal reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



OECD NORTH AMERICA

		REF mn t	REF %	E[R] mn t	E[R] %
Reserves	2009	245,088 H	28.6% H	245,088 H	28.6% H
		mn t	**PJ**	**mn t**	**PJ**
Consumption	2009	1,701	21,335	1,701	21,335
	2050	1,145 M	21,963	148	3,405
		t		**t**	
Per person	2009	2.0		2.0	
	2050	1.6		0.2	

LATIN AMERICA

		REF mn t	REF %	E[R] mn t	E[R] %
Reserves	2009	12,508	1.5%	12,508	1.5%
		mn t	**PJ**	**mn t**	**PJ**
Consumption	2009	37	737	37	737
	2050	80	1,741	38	873
		t		**t**	
Per person	2009	0.1		0.1	
	2050	0.1		0.1 M	

NON RENEWABLE RESOURCE

COAL

LEGEND

>60 | 50-60 | 40-50 | 30-40 | 20-30 | 10-20 | 5-10 | 0-5 % RESOURCES GLOBALLY

REF REFERENCE SCENARIO

E[R] ENERGY [R]EVOLUTION SCENARIO

0 1000 KM

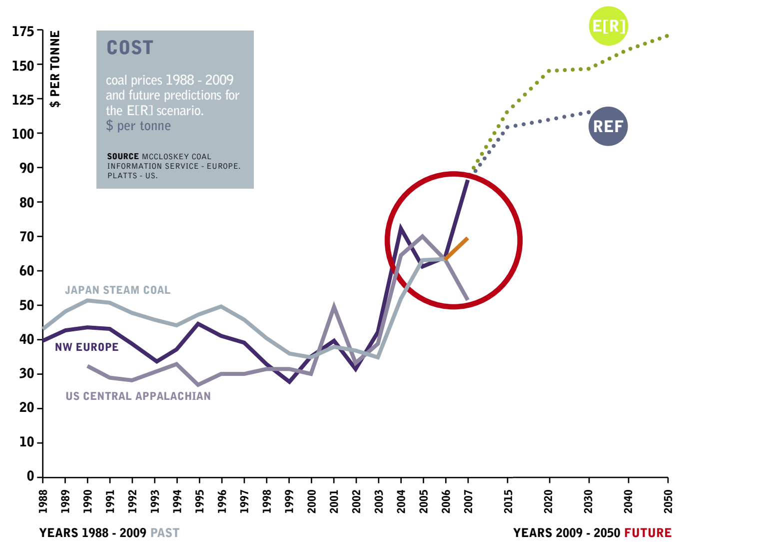
TRADE FLOWS (MILLION TONNES)

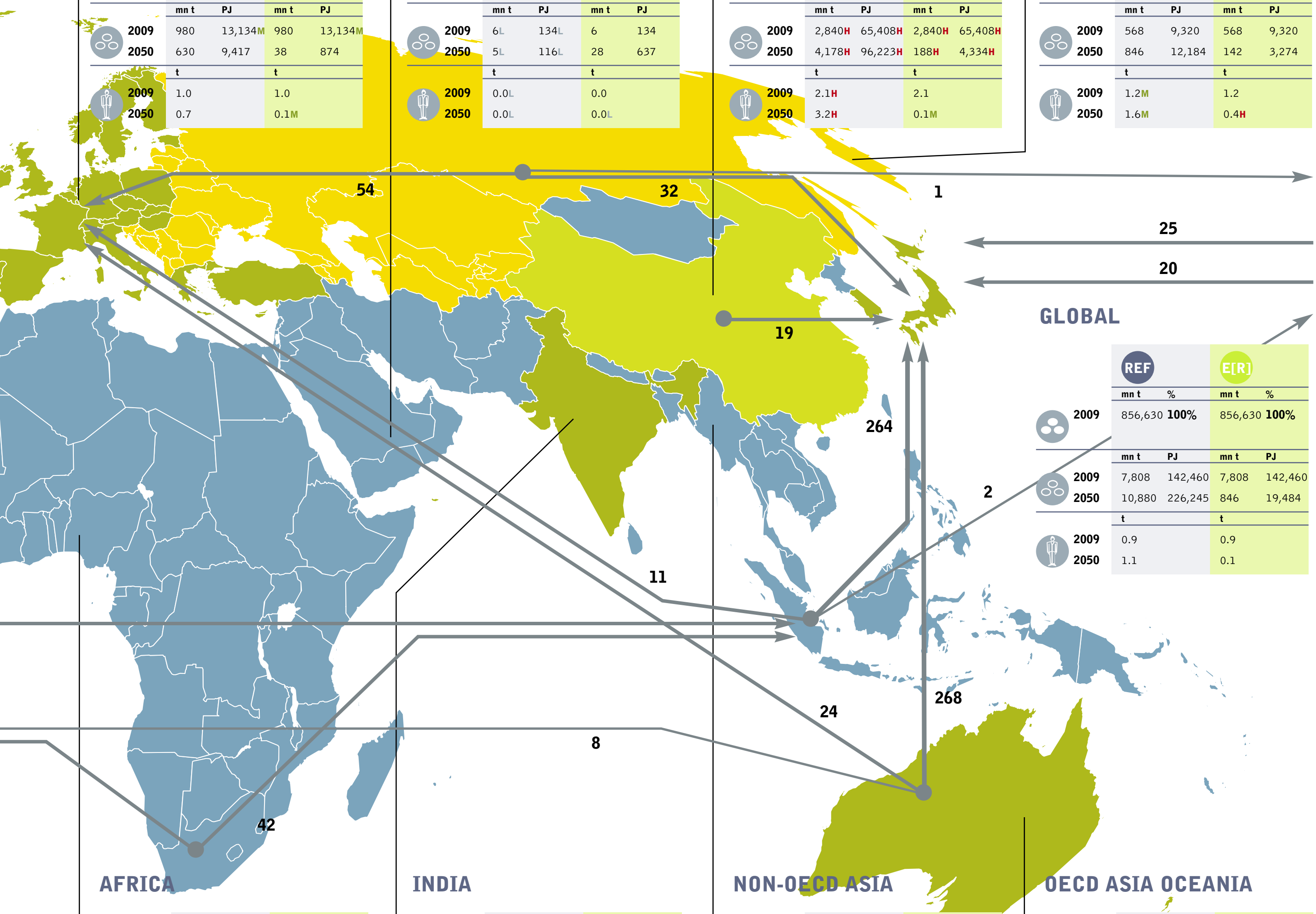
RESERVES TOTAL MILLION TONNES [mn t] | SHARE IN % OF GLOBAL TOTAL [END OF 2011]

CONSUMPTION PER REGION MILLION TONNES [mn t] | PETA JOULE [PJ]

CONSUMPTION PER PERSON TONNES [t]

H HIGHEST | M MIDDLE | L LOWEST





OECD EUROPE

	REF		E[R]	
	mn t	%	mn t	%
2011	80,121 M	9.4%M	80,121	9.4%M
	mn t	PJ	mn t	PJ
2009	980	13,134M	980	13,134M
2050	630	9,417	38	874
	t		t	
2009	1.0		1.0	
2050	0.7		0.1M	

MIDDLE EAST

	REF		E[R]	
	mn t	%	mn t	%
2009	1,203L	0.1%L	1,203L	0.1%L
	mn t	PJ	mn t	PJ
2009	6L	134L	6	134
2050	5L	116L	28	637
	t		t	
2009	0.0L		0.0	
2050	0.0L		0.0L	

CHINA

	REF		E[R]	
	mn t	%	mn t	%
2009	114,500	13.4%	114,500	13.4%
	mn t	PJ	mn t	PJ
2009	2,840H	65,408H	2,840H	65,408H
2050	4,178H	96,223H	188H	4,334H
	t		t	
2009	2.1H		2.1	
2050	3.2H		0.1M	

EAST EUROPE/EURASIA

	REF		E[R]	
	mn t	%	mn t	%
2009	224,483	26.2%	224,483	26.2%
	mn t	PJ	mn t	PJ
2009	568	9,320	568	9,320
2050	846	12,184	142	3,274
	t		t	
2009	1.2M		1.2	
2050	1.6M		0.4H	

GLOBAL

	REF		E[R]	
	mn t	%	mn t	%
2009	856,630	100%	856,630	100%
	mn t	PJ	mn t	PJ
2009	7,808	142,460	7,808	142,460
2050	10,880	226,245	846	19,484
	t		t	
2009	0.9		0.9	
2050	1.1		0.1	

AFRICA

	REF		E[R]	
	mn t	%	mn t	%
2009	31,692	3.7%	31,692	3.7%
	mn t	PJ	mn t	PJ
2009	192	4,414	192	4,414
2050	586	13,493	40	921
	t		t	
2009	0.2		0.2	
2050	0.3		0.0L	

INDIA

	REF		E[R]	
	mn t	%	mn t	%
2009	60,600	7.1%M	60,600	7.1%M
	mn t	PJ	mn t	PJ
2009	593M	13,084	593M	13,084
2050	1,819	39,343	122M	2,803
	t		t	
2009	0.5		0.5	
2050	1.0M		0.1M	

NON-OECD ASIA

	REF		E[R]	
	mn t	%	mn t	%
2009	8,988	1.0%	8,988	1.0%
	mn t	PJ	mn t	PJ
2009	374	5,658	374	5,658
2050	1,199	23,445M	76	1,754M
	t		t	
2009	0.2		0.2	
2050	0.7		0.1M	

OECD ASIA OCEANIA

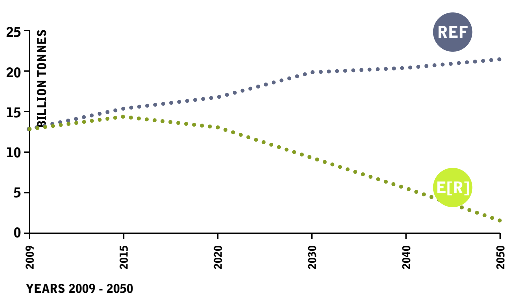
	REF		E[R]	
	mn t	%	mn t	%
2009	77,447	9%	77,447	9%
	mn t	PJ	mn t	PJ
2009	517	9,236	517	9,236
2050	392	8,319	26L	607L
	t		t	
2009	2.0		2.0	
2050	1.9		0.1M	

CO_2 EMISSIONS FROM COAL

comparison between the REF and E[R] scenarios 2009 - 2050

billion tonnes

SOURCE GPI/EREC

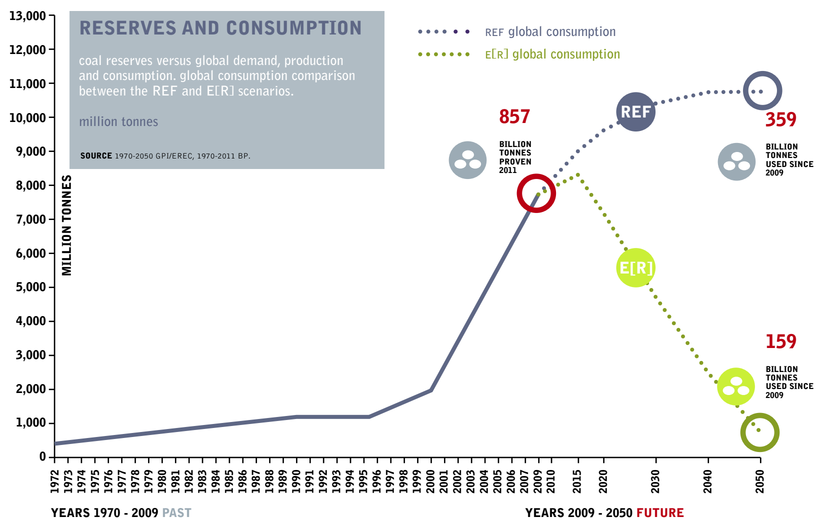


RESERVES AND CONSUMPTION

coal reserves versus global demand, production and consumption. global consumption comparison between the REF and E[R] scenarios.

million tonnes

SOURCE 1970-2050 GPI/EREC, 1970-2011 BP.

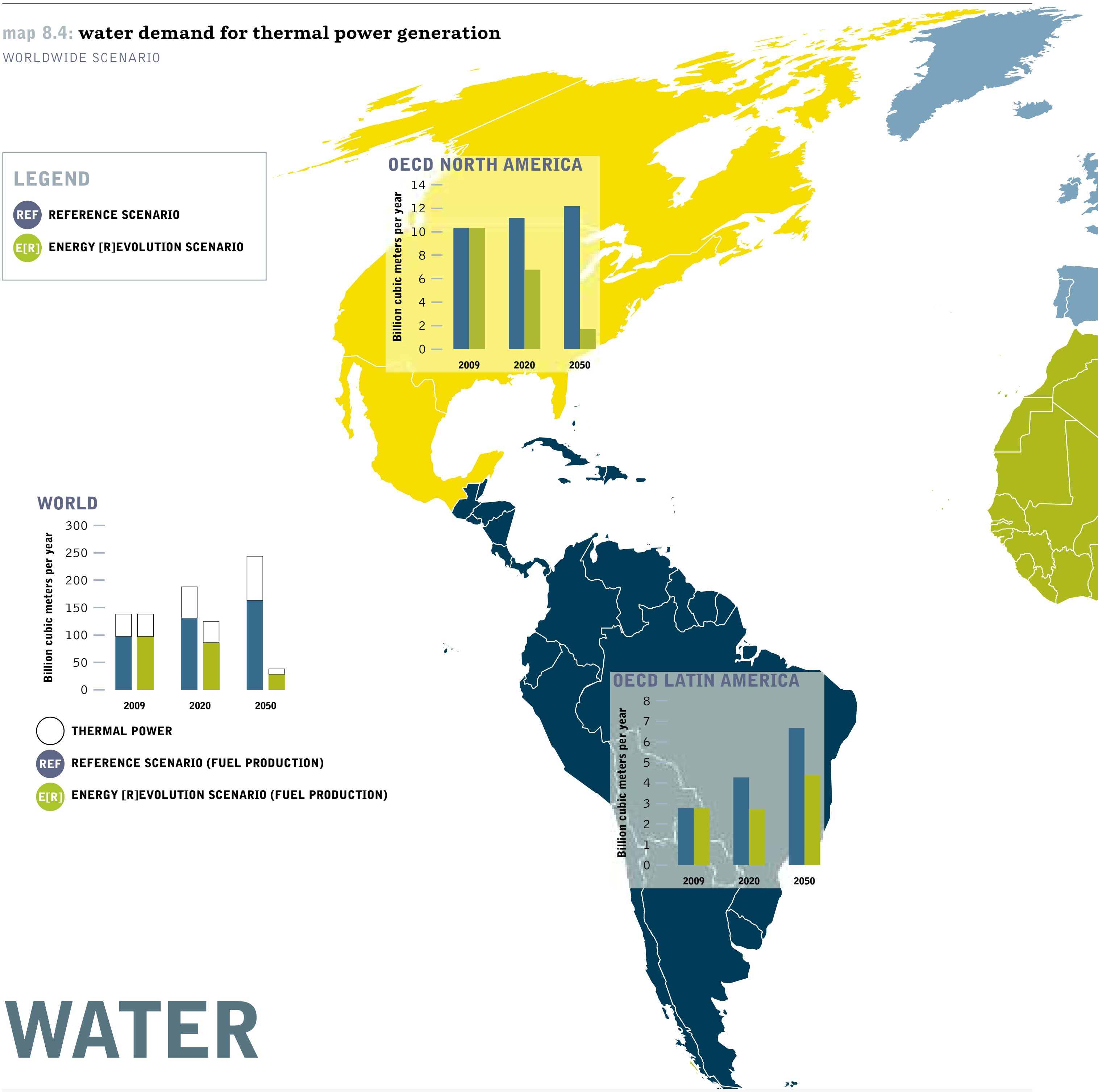


GREENPEACE

DESIGN WWW.ONEHEMISPHERE.SE **CONCEPT** SVEN TESKE/GREENPEACE INTERNATIONAL.

map 8.4: water demand for thermal power generation

WORLDWIDE SCENARIO

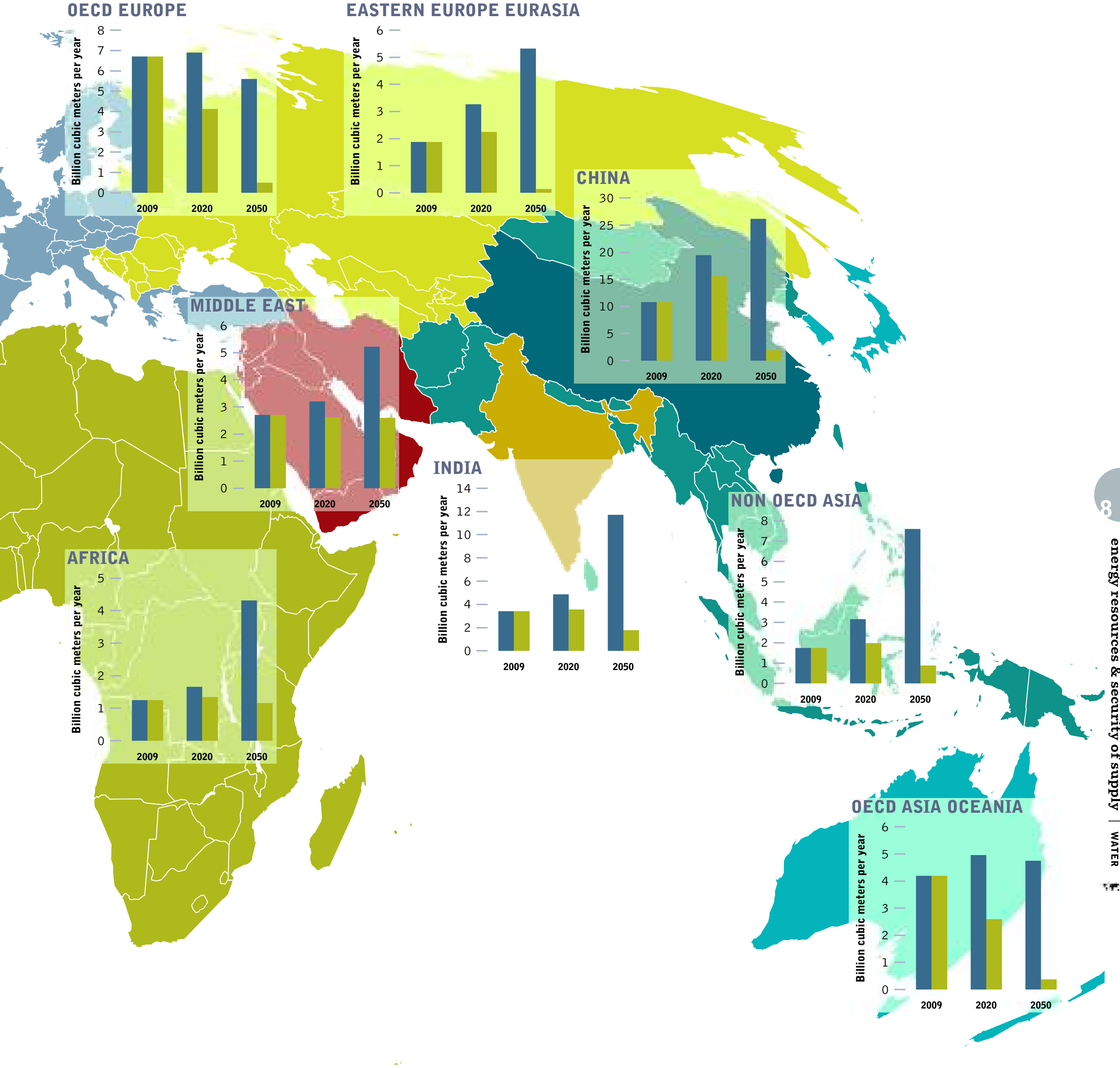


WATER

The Energy [R]evolution is the first global energy scenario to quantify the water needs of different energy pathways. The water footprint of thermal power generation and fuel production is estimated by taking the production levels in each scenario and multiplying by technology-specific water consumption factors. Water consumption factors for power generation technologies are taken from U.S. Department of Energy and University of Texas and adjusted for projected region-specific thermal efficiencies of different operating power plant types.[i] Water footprints of coal, oil and gas extraction are based on data from Wuppertal Institute, complemented by estimates of water footprint of unconventional fossil fuels as well as first and second generation transport biofuels.[ii] As a detailed regional breakdown of fuel production by region is not available for the reference scenario, the water footprint of fuel production is only estimated on the global level.

Benefits of the Energy [R]evolution for water:

- Electric technologies with low to no water requirements – energy efficiency, wind and solar PV – substituted for thermal power generation with high water impacts.
- Reduced water use and contamination from fossil fuel production: no need for unconventional fossil fuels; lowered consumption of conventional coal and oil.
- Bioenergy is based on waste-derived biomass and cellulosic biomass requiring no irrigation (no food for fuel). As a result, water intensity of biomass use is a fraction of that in IEA scenarios.
- Energy efficiency programmes reduce water consumption in buildings and industry.



- Rapid CO_2 emission reductions protect water resources from catastrophic climate change.

Global water consumption for power generation and fuel production has almost doubled in the past two decades, and the trend is projected to continue. The OECD predicts that in a business-as-usual scenario, the power sector would consume 25% of the world's water in 2050 and be responsible for more than half of additional demand.[iii] The Energy [R]evolution pathway would halt the rise in water demand for energy, mitigating the pressures and conflicts on the world's already stressed water resources. Approximately 90 billion cubic meters of water would be saved in fuel production and thermal power generation by 2030, enough to satisfy the water needs of 1.3 billion urban dwellers, or to irrigate enough fields to produce 50 million tonnes of grain, equal to the average direct consumption of 300-500 million people.[iv]

references

i NATIONAL ENERGY TECHNOLOGY LABORATORY 2009: WATER REQUIREMENTS FOR EXISTING AND EMERGING THERMOELECTRIC PLANT TECHNOLOGIES. US DEPARTMENT OF ENERGY. AUGUST 2008 (APRIL 2009 REVISION); U.S. DEPARTMENT OF ENERGY 2006: ENERGY DEMANDS ON WATER RESOURCES. REPORT TO CONGRESS ON THE INTERDEPENDENCY OF ENERGY AND WATER. UNIVERSITY OF TEXAS & ENVIRONMENTAL DEFENSE FUND 2009: ENERGY-WATER NEXUS IN TEXAS.

ii WUPPERTAL INSTITUT: MATERIAL INTENSITY OF MATERIALS, FUELS, TRANSPORT SERVICES, FOOD. HTTP://WWW.WUPPERINST.ORG/UPLOADS/TX_WIBEITRAG/MIT_2011.PDF; WORLD ECONOMIC FORUM 2009: ENERGY VISION UPDATE 2009. THIRSTY ENERGY; HARTO ET AL: LIFE CYCLE WATER CONSUMPTION OF ALTERNATIVE, LOW-CARBON TRANSPORTATION ENERGY SOURCES. FUNDED BY ARIZONA WATER INSTITUTE.

iii OECD ENVIRONMENTAL OUTLOOK TO 2050: THE CONSEQUENCES OF INACTION. HTTP://WWW.OECD.ORG/DOCUMENT/11/0,3746,EN_2649_37465_49036555_1_1_1_37465,00.HTML

iv USING TYPICAL URBAN RESIDENTIAL WATER CONSUMPTION OF 200 LITERS/PERSON/DAY. AVERAGE GRAIN CONSUMPTION RANGES FROM 8 KG/PERSON/MONTH (US) TO 14 (INDIA).

GREENPEACE **DESIGN** WWW.ONEHEMISPHERE.SE **CONCEPT** SVEN TESKE/GREENPEACE INTERNATIONAL.

table 8.3: **assumptions on fossil fuel use in the energy [r]evolution scenario**

FOSSIL FUEL	2009	2015	2020	2030	2040	2050
Oil						
Reference (PJ/a)	151,168	167,159	173,236	185,993	197,522	211,365
Reference (million barrels/a)	24,701	27,314	28,306	30,391	32,275	34,537
E[R] (PJ/a)	151,168	151,996	133,712	95,169	53,030	29,942
E[R] (million barrels/a)	24,701	24,836	21,848	15,550	8,665	4,893
Gas						
Reference (PJ/a)	107,498	121,067	131,682	155,412	179,878	195,804
Reference (billion cubic metres = 10E9m/a)	2,829	3,186	3,465	4,090	4,734	5,153
E[R] (PJ/a)	107,498	120,861	124,069	106,228	73,452	35,557
E[R] (billion cubic metres = 10E9m/a)	2,829	3,181	3,265	2,795	1,933	936
Coal						
Reference (PJ/a)	142,460	169,330	186,742	209,195	224,487	226,245
Reference (million tonnes)	7,808	8,957	9,633	10,349	10,879	10,880
E[R] (PJ/a)	142,460	154,932	142,833	105,219	58,732	19,484
E[R] (million tonnes)	7,808	8,197	7,119	4,707	2,556	846

8.4 nuclear

Uranium, the fuel used in nuclear power plants, is a finite resource whose economically available reserves are limited. Its distribution is almost as concentrated as oil and does not match global consumption. Five countries - Canada, Australia, Kazakhstan, Russia and Niger - control three quarters of the world's supply. As a significant user of uranium, however, Russia's reserves will be exhausted within ten years.

Secondary sources, such as old deposits, currently make up nearly half of worldwide uranium reserves. However, these will soon be used up. Mining capacities will have to be nearly doubled in the next few years to meet current needs.

A joint report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency[76] estimates that all existing nuclear power plants will have used up their nuclear fuel, employing current technology, within less than 70 years. Given the range of scenarios for the worldwide development of nuclear power, it is likely that uranium supplies will be exhausted sometime between 2026 and 2070. This forecast includes the use of mixed oxide fuel (MOX), a mixture of uranium and plutonium.

reference
76 'URANIUM 2003: RESOURCES, PRODUCTION AND DEMAND'.

image THE BIOENERGY VILLAGE OF JUEHNDE, WHICH IS THE FIRST COMMUNITY IN GERMANY THAT PRODUCES ALL ITS ENERGY NEEDED FOR HEATING AND ELECTRICITY WITH CO_2 NEUTRAL BIOMASS.

8.5 renewable energy

Nature offers a variety of freely available options for producing energy. Their exploitation is mainly a question of how to convert sunlight, wind, biomass or water into electricity, heat or power as efficiently, sustainably and cost-effectively as possible.

box 8.1: definition of types of energy resource potential[77]

Theoretical potential The physical upper limit of the energy available from a certain source. For solar energy, for example, this would be the total solar radiation falling on a particular surface.

Conversion potential This is derived from the annual efficiency of the respective conversion technology. It is therefore not a strictly defined value, since the efficiency of a particular technology depends on technological progress.

Technical potential This takes into account additional restrictions regarding the area that is realistically available for energy generation. Technological, structural and ecological restrictions, as well as legislative requirements, are accounted for.

Economic potential The proportion of the technical potential that can be utilised economically. For biomass, for example, those quantities are included that can be exploited economically in competition with other products and land uses.

Sustainable potential This limits the potential of an energy source based on evaluation of ecological and socio-economic factors.

On average, the energy in the sunshine that reaches the earth is about one kilowatt per square metre worldwide. According to the IPCC Special Report Renewables (SRREN)[78] solar power is a renewable energy source gushing out at 7,900 times more than the energy currently needed in the world. In one day, the sunlight which reaches the earth produces enough energy to satisfy the world's current energy requirements for twenty years, even before other renewable energy sources such as wind and ocean energy are taken into account. Even though only a percentage of that potential is technically accessible, this is still enough to provide up to ten times more energy than the world currently requires.

Before looking at the part renewable energies can play in the range of scenarios in this report, it is worth understanding the upper limits of their regional potential and by when this potential can be exploited.

The overall technical potential of renewable energy is huge and several times higher than current total energy demand. Technical potential is defined as the amount of renewable energy output obtainable by full implementation of demonstrated technologies or practices that are likely to develop. It takes into account the primary resources, the socio-geographical constraints and the technical losses in the conversion process. Calculating renewable energy potentials is highly complex because these technologies are comparatively young and their exploitation involves changes to the way in which energy is both generated and distributed. The technical potential is dependent on a number of uncertainties, e.g. a technology breakthrough, for example, could have a dramatic impact, changing the technical potential assessment within a very short time frame. Further, because of the speed of technology change, many existing studies are based on out of date information. More recent data, e.g. significantly increased average wind turbine capacity and output, would increase the technical potentials still further.

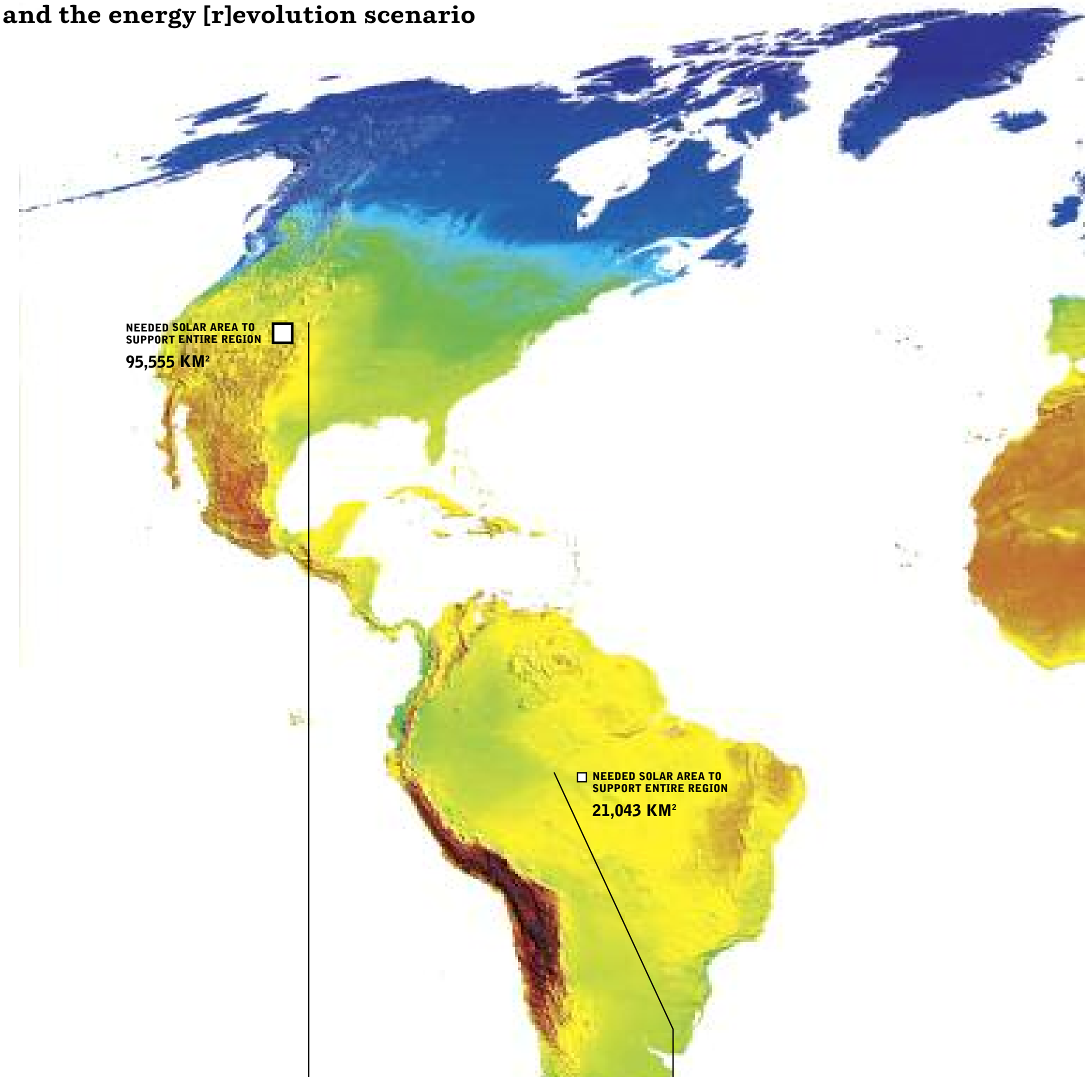
table 8.4: renewable energy theoretical potential

RE	ANNUAL FLUX (EJ/a)	RATIO (ANNUAL ENERGY FLUX/ 2008 PRIMARY ENERGY SUPPLY)	TOTAL RESERVE
Bio energy	1,548	3.1	-
Solar energy	3,900,000	7,900	-
Geothermal energy	1,400	2.8	-
Hydro power	147	0.3	-
Ocean energy	7,400	15	-
Wind energy	6,000	12	-

references
77 WBGU (GERMAN ADVISORY COUNCIL ON GLOBAL CHANGE).
78 IPCC, 2011: IPCC SPECIAL REPORT ON RENEWABLE ENERGY SOURCES AND CLIMATE CHANGE MITIGATION. PREPARED BY WORKING GROUP III OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE [O. EDENHOFER, R. PICHS-MADRUGA, Y. SOKONA, K. SEYBOTH, P. MATSCHOSS, S. KADNER, T. ZWICKEL, P. EICKEMEIER, G. HANSEN, S. SCHLÖMER, C. VON STECHOW (EDS)]. CAMBRIDGE UNIVERSITY PRESS, CAMBRIDGE, UNITED KINGDOM AND NEW YORK, NY, USA, 1075 PP.

map 8.5: solar reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



RENEWABLE RESOURCE

SOLAR

OECD NORTH AMERICA

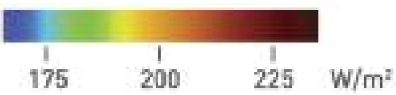
		REF %	REF PJ	E[R] %	E[R] PJ
Production per region	2009	0.07	78M		
	2050	1.49	1,862H	36	26,543
			kWh		kWh
Production per person	2009		48		
	2050		896H		12,395H

LATIN AMERICA

		REF %	REF PJ	E[R] %	E[R] PJ
Production per region	2009	0.08M	17		
	2050	1.12M	456	20	5,845
			kWh		kWh
Production per person	2009		10		
	2050		211		2,691

LEGEND

Global Horizontal Irradiance



REF REFERENCE SCENARIO

E[R] ENERGY [R]EVOLUTION SCENARIO

PRODUCTION PER REGION % OF GLOBAL SHARE | PETA JOULE [PJ]

PRODUCTION PER PERSON KILOWATT HOUR [kWh]

H HIGHEST | M MIDDLE | L LOWEST

0 1000 KM

OECD EUROPE

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.15M	115		
2050	1.84H	1,495	25	11,649

	REF kWh	E[R] kWh
2009	59M	
2050	722	5,395M

MIDDLE EAST

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.02	5		
2050	0.75	378	44H	12,190

	REF kWh	E[R] kWh
2009	7	
2050	297M	9,458

CHINA

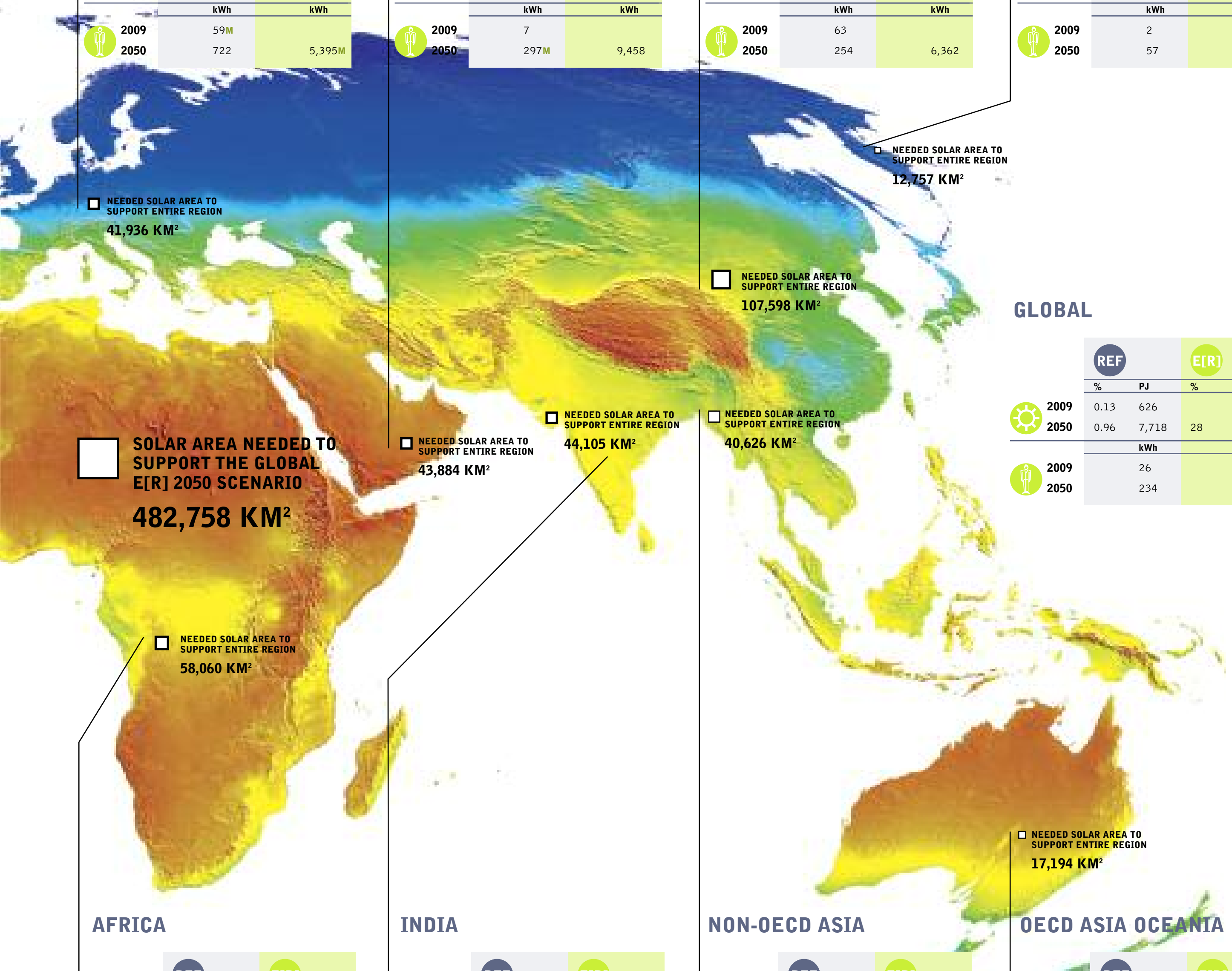
	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.31H	302H		
2050	0.72	1,305	29M	29,888H

	REF kWh	E[R] kWh
2009	63	
2050	254	6,362

EAST EUROPE/EURASIA

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.01L	3L		
2050	0.09L	64L	9L	3,544L

	REF kWh	E[R] kWh
2009	2	
2050	57	3,038



GLOBAL

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.13	626		
2050	0.96	7,718	28	134,099

	REF kWh	E[R] kWh
2009	26	
2050	234	4,062

AFRICA

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.01L	3L		
2050	1.26	707M	37	16,128

	REF kWh	E[R] kWh
2009	1L	
2050	98	2,044

INDIA

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.02	6		
2050	0.23	182	25	12,252M

	REF kWh	E[R] kWh
2009	1L	
2050	31L	2,011L

NON-OECD ASIA

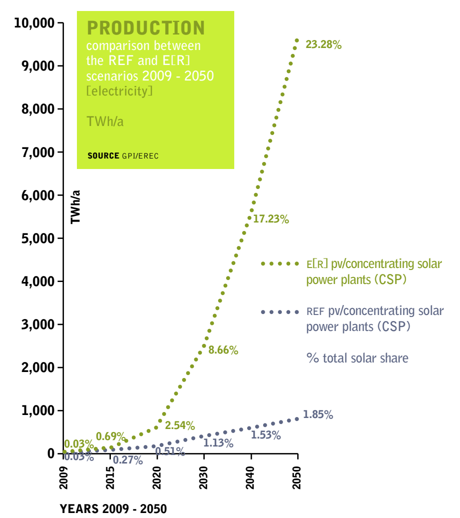
	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.02	5		
2050	0.42	309	24	11,285

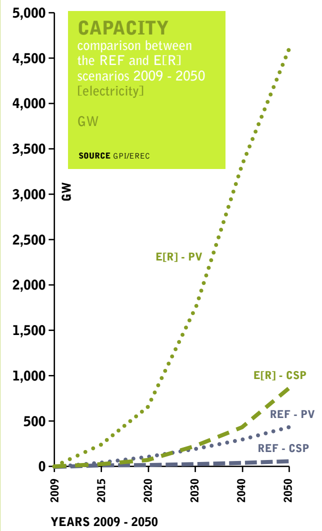
	REF kWh	E[R] kWh
2009	1L	
2050	57	2,169

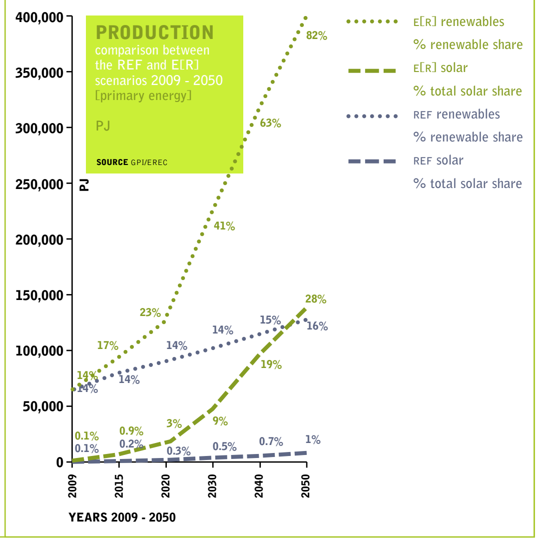
OECD ASIA OCEANIA

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.24	87		
2050	1.54	579	21	4,776

	REF kWh	E[R] kWh
2009	120H	
2050	894	6,885

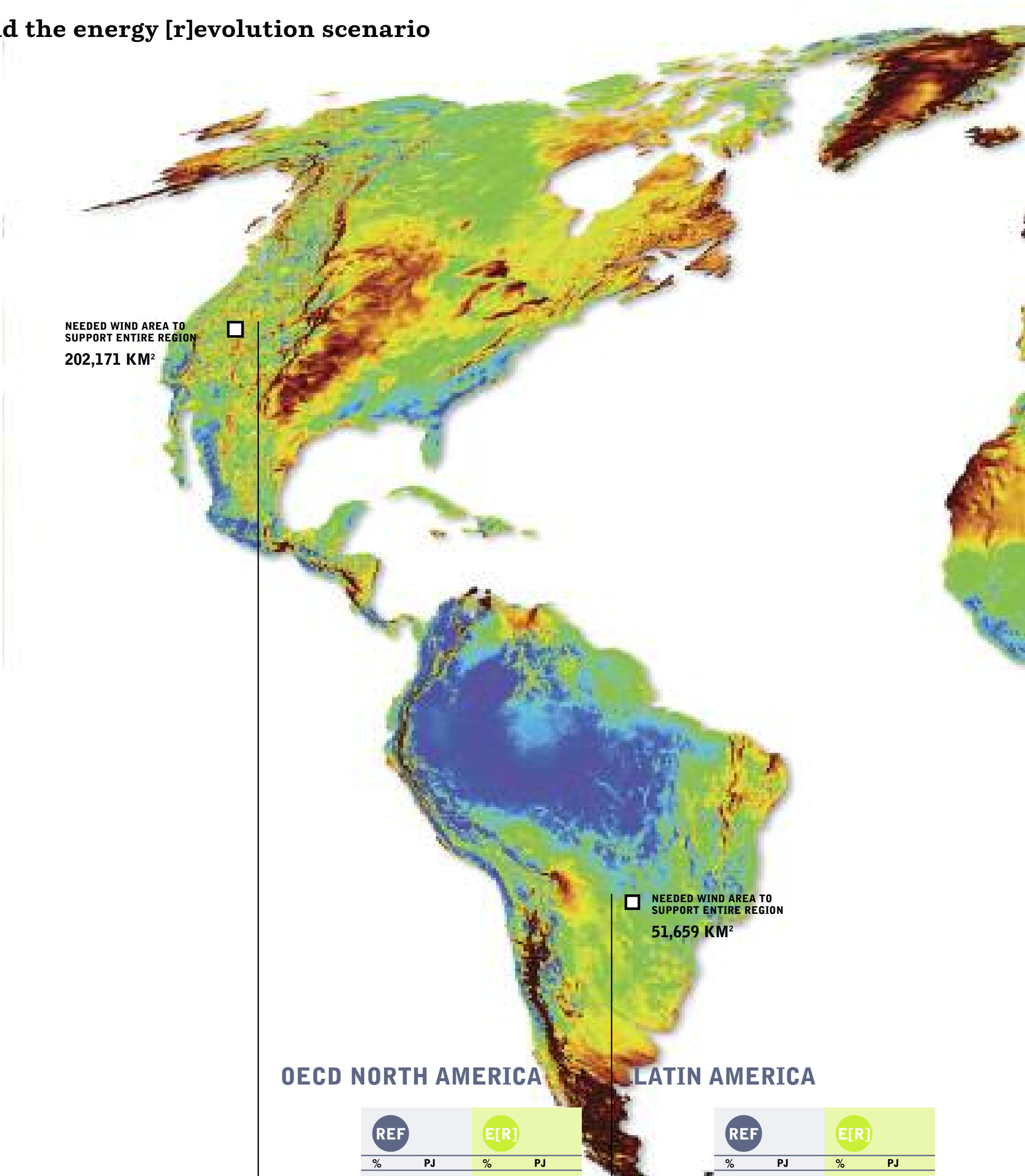






map 8.6: wind reference scenario and the energy [r]evolution scenario

WORLDWIDE SCENARIO



OECD NORTH AMERICA

		REF %	REF PJ	E[R] %	E[R] PJ
Production per region	2009	0.26	286		
	2050	1.72	2,157	12	9,001
			kWh		kWh
Production per person	2009		177		
	2050		1,038		4,203

LATIN AMERICA

		REF %	REF PJ	E[R] %	E[R] PJ
Production per region	2009	0.03	7		
	2050	0.65	266	9	2,683
			kWh		kWh
Production per person	2009		4		
	2050		123		1,235

RENEWABLE RESOURCE

WIND

LEGEND

5km wind map - Mean wind speed at 80m

7 13 20 mph
3 6 9 m/s

REF **REFERENCE SCENARIO**

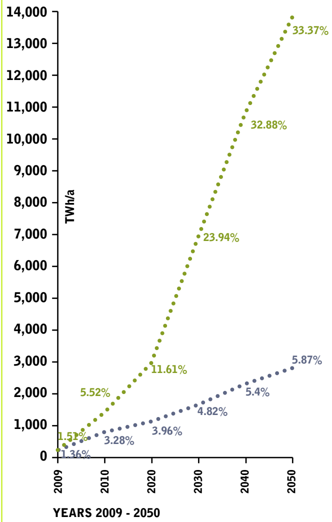
E[R] **ENERGY [R]EVOLUTION SCENARIO**

PRODUCTION PER REGION % OF GLOBAL SHARE | PETA JOULE [PJ]

PRODUCTION PER PERSON KILOWATT HOUR [kWh]

H HIGHEST | M MIDDLE | L LOWEST

0 1000 KM



PRODUCTION
comparison between the REF and E[R] scenarios 2009 - 2050 [electricity]

TWh

SOURCE GWEC

E[R] wind
REF wind
% REF total wind share

OECD EUROPE

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.65H	485H		
2050	3.57H	2,894H	12	5,347
		kWh		kWh
2009		250H		
2050		1,399H		2,476

MIDDLE EAST

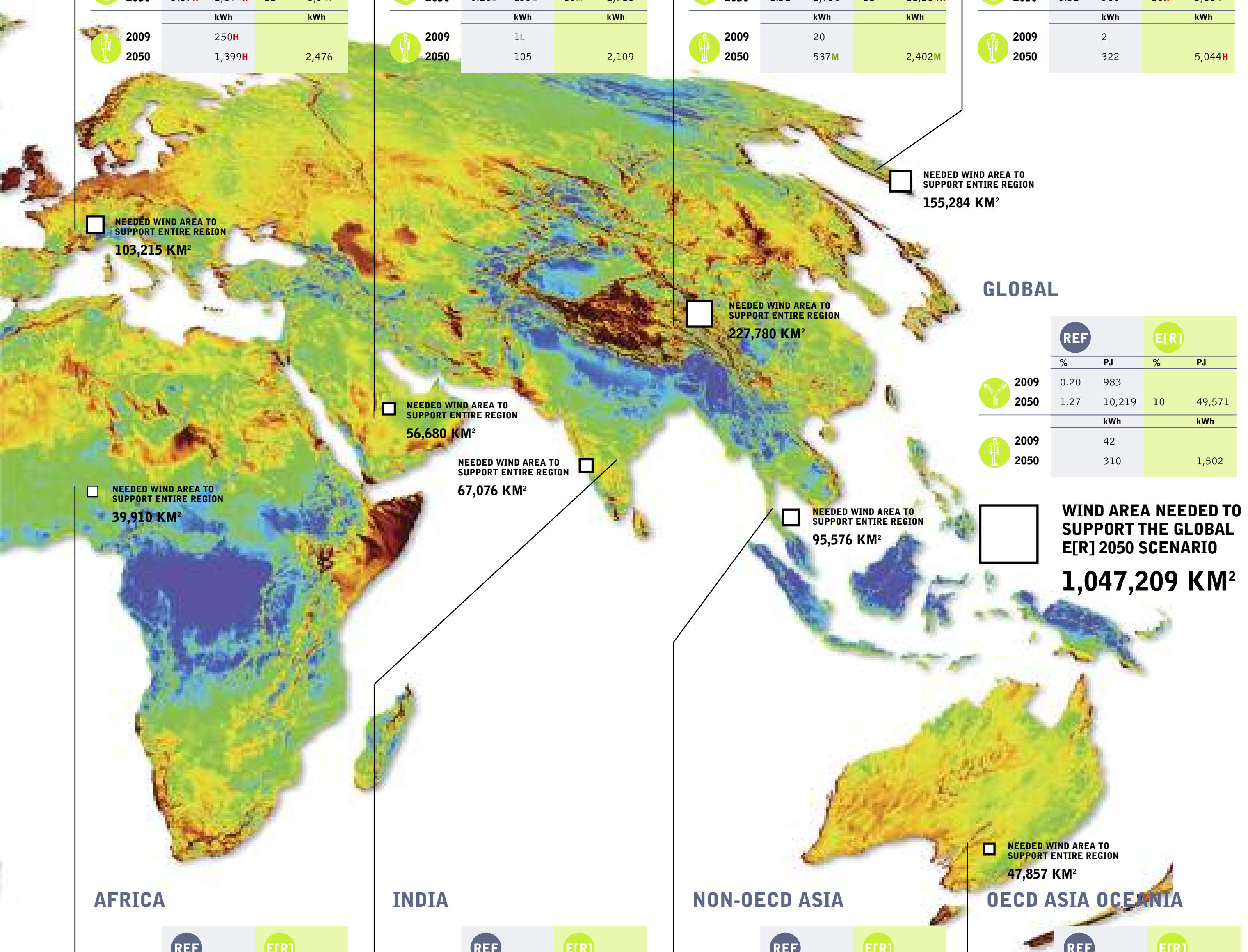
	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.00L	1L		
2050	0.26L	133L	10M	2,718
		kWh		kWh
2009		1L		
2050		105		2,109

CHINA

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.10M	97M		
2050	1.52	2,756	11	11,284H
		kWh		kWh
2009		20		
2050		537M		2,402M

EAST EUROPE/EURASIA

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.00	2		
2050	0.52	360	16H	5,884
		kWh		kWh
2009		2		
2050		322		5,044H



GLOBAL

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.20	983		
2050	1.27	10,219	10	49,571
		kWh		kWh
2009		42		
2050		310		1,502

WIND AREA NEEDED TO SUPPORT THE GLOBAL E[R] 2050 SCENARIO

1,047,209 KM²

AFRICA

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.02	6		
2050	0.32	181	5L	2,207L
		kWh		kWh
2009		2		
2050		25L		280L

INDIA

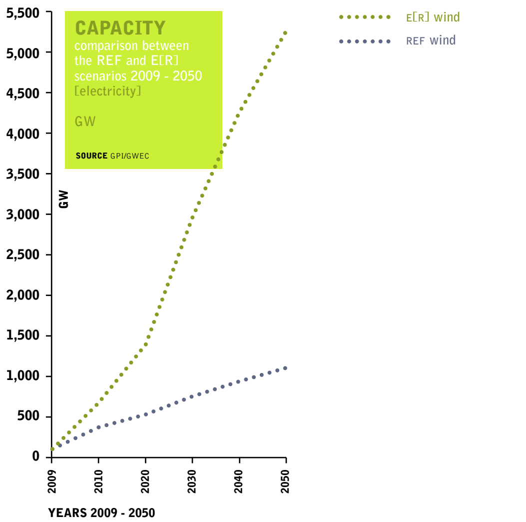
	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.22	65		
2050	0.55	493	7	3,300
		kWh		kWh
2009		15		
2050		85		542

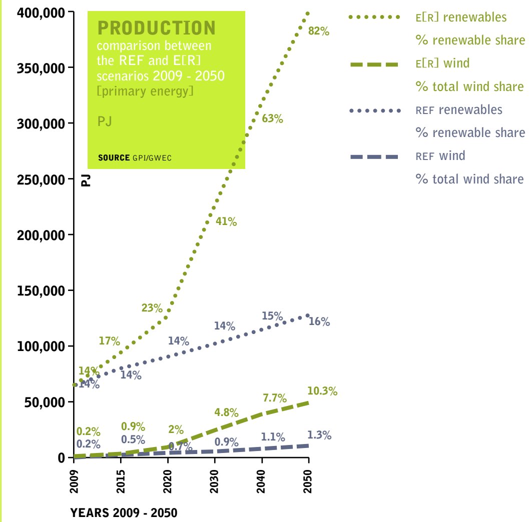
NON-OECD ASIA

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.01	3		
2050	0.79	583M	10M	4,590M
		kWh		kWh
2009		1L		
2050		107		882

OECD ASIA OCEANIA

	REF %	REF PJ	E[R] %	E[R] PJ
2009	0.09	32		
2050	1.06M	396	11	2,556
		kWh		kWh
2009		45M		
2050		612		3,686





GREENPEACE DESIGN WWW.ONEHEMISPHERE.SE CONCEPT SVEN TESKE/GREENPEACE INTERNATIONAL.
MAP DEVELOPED BY 3TIER. WWW.3TIER.COM. © 2011 3TIER INC. 3TIER

A wide range of estimates is provided in the literature but studies have consistently found that the total global technical potential for renewable energy is substantially higher than both current and projected future global energy demand. Solar has the highest technical potential amongst the renewable sources, but substantial technical potential exists for all forms. (SRREN, May 2011)

Taking into account the uncertainty of technical potential estimates, Figure 8.1 provides an overview of the technical potential of various renewable energy resources in the context of current global electricity and heat demand as well as global primary energy supply. Issues related to technology evolution, sustainability, resource availability, land use and other factors that relate to this technical potential are explored in the relevant chapters. The regional distribution of technical potential is addressed in map 8.7.

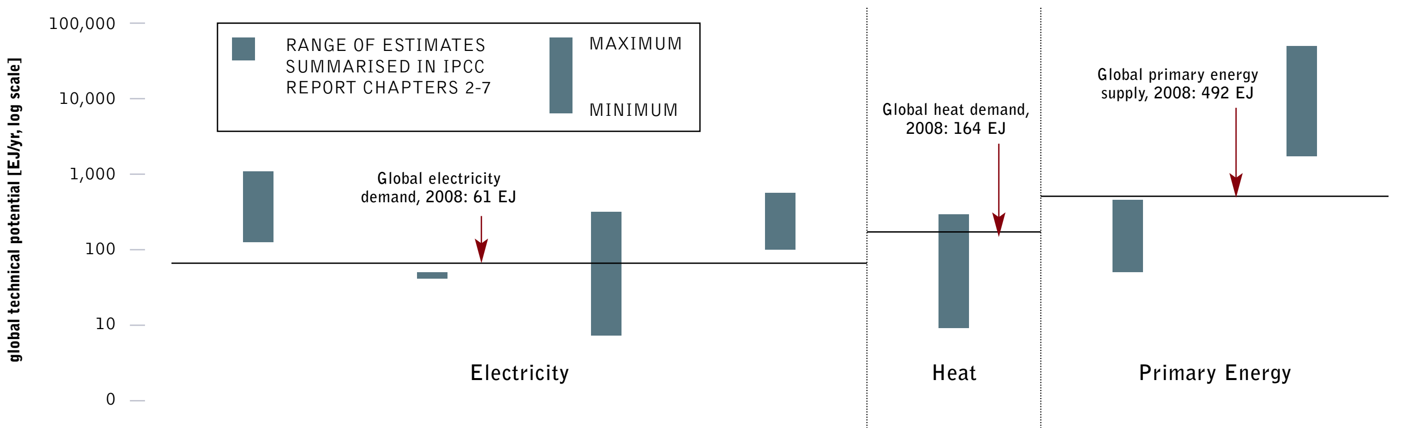
The various types of energy cannot necessarily be added together to estimate a total, because each type was estimated independently of the others (for example, the assessment did not take into account land use allocation; e.g. PV and concentrating solar power cannot occupy the same space even though a particular site is suitable for either of them).

Given the large unexploited resources which exist, even without having reached the full development limits of the various technologies, the technical potential is not a limiting factor to expansion of renewable energy generation. It will not be necessary nor desirable to exploit the entire technical potential.

Implementation of renewable energies must respect sustainability criteria in order to achieve a sound future energy supply. Public acceptance is crucial, especially bearing in mind that renewable energy technologies will be closer to consumers than today's more centralised power plants. Without public acceptance, market expansion will be difficult or even impossible.

In addition to the theoretical and technical potential discussions, this report also considers the economic potential of renewable energy sources that takes into account all social costs and assumes perfect information and the market potential of renewable energy sources. Market potential is often used in different ways. The general understanding is that market potential means the total amount of renewable energy that can be implemented in the market taking into account existing and expected real-world market conditions shaped by policies, availability of capital and other factors. The market potential may therefore in theory be larger than the economic potential. To be realistic, however, market potential analyses have to take into account the behaviour of private economic agents under specific prevailing conditions, which are of course partly shaped by public authorities. The energy policy framework in a particular country or region will have a profound impact on the expansion of renewable energies.

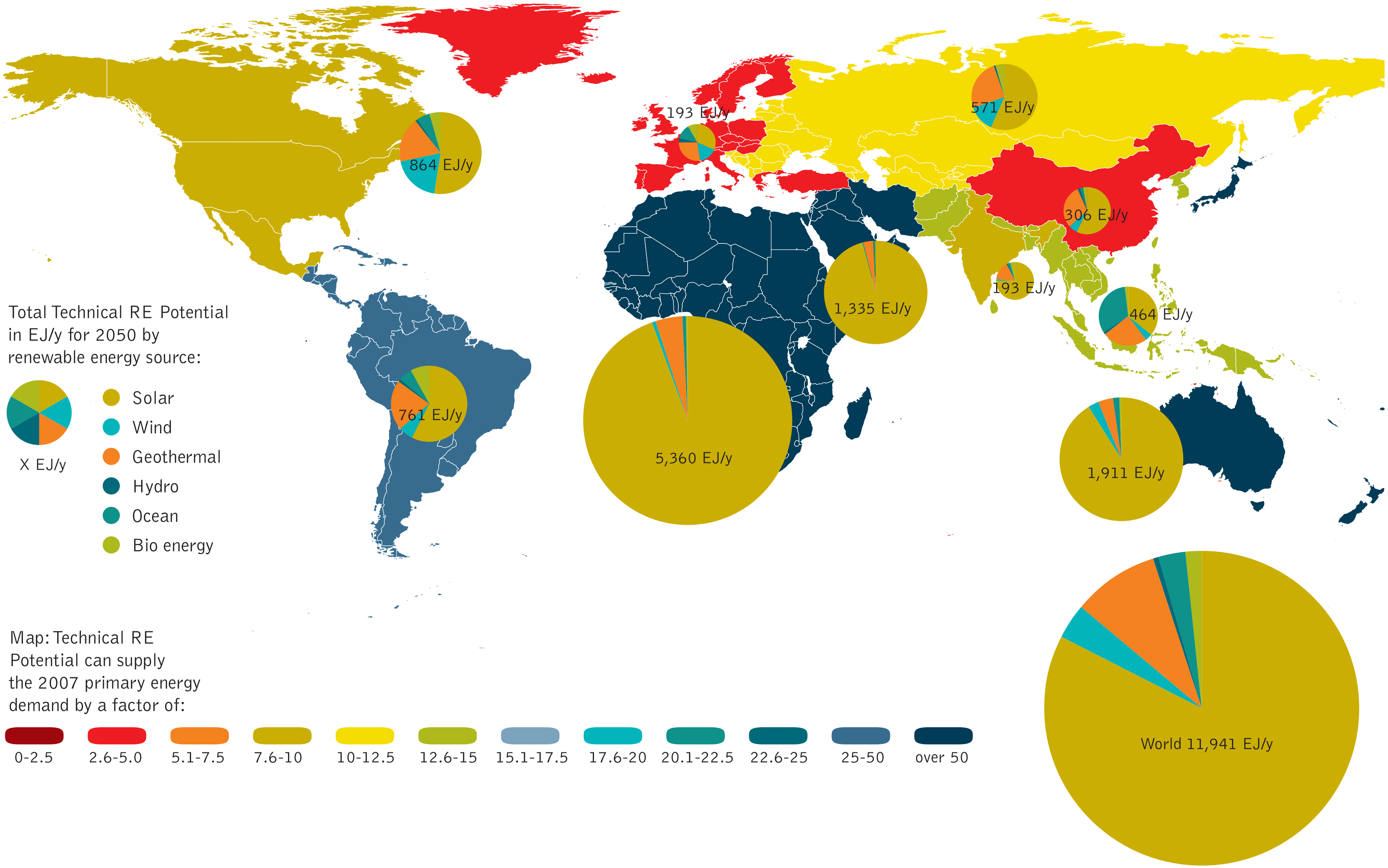
figure 8.1: ranges of global technical potentials of renewable energy sources



	GEOTHERMAL ENERGY	HYDROPOWER	OCEAN ENERGY	WIND ENERGY	GEOTHERMAL ENERGY	BIOMASS	DIRECT SOLAR ENERGY
Max (in EJ/yr)	1,109	52	331	580	312	500	49,837
Min (in EJ/yr)	118	50	7	85	10	50	1,575

source
IPCC/SRREN.
note
RANGES OF GLOBAL TECHNICAL POTENTIALS OF RE SOURCES DERIVED FROM STUDIES PRESENTED IN CHAPTERS 2 THROUGH 7 IN THE IPCC REPORT. BIOMASS AND SOLAR ARE SHOWN AS PRIMARY ENERGY DUE TO THEIR MULTIPLE USES. NOTE THAT THE FIGURE IS PRESENTED IN LOGARITHMIC SCALE DUE TO THE WIDE RANGE OF ASSESSED DATA.

map 8.7: regional renewable energy potential



source

IPCC/SRREN. RE POTENTIAL ANALYSIS: TECHNICAL RE POTENTIALS REPORTED HERE REPRESENT TOTAL WORLDWIDE AND REGIONAL POTENTIALS BASED ON A REVIEW OF STUDIES PUBLISHED BEFORE 2009 BY KREWITT ET AL. (2009). THEY DO NOT DEDUCT ANY POTENTIAL THAT IS ALREADY BEING UTILIZED FOR ENERGY PRODUCTION. DUE TO METHODOLOGICAL DIFFERENCES AND ACCOUNTING METHODS AMONG STUDIES, STRICT COMPARABILITY OF THESE ESTIMATES ACROSS TECHNOLOGIES AND REGIONS, AS WELL AS TO PRIMARY ENERGY DEMAND, IS NOT POSSIBLE. TECHNICAL RE POTENTIAL ANALYSES PUBLISHED AFTER 2009 SHOW HIGHER RESULTS IN SOME CASES BUT ARE NOT INCLUDED IN THIS FIGURE. HOWEVER, SOME RE TECHNOLOGIES MAY COMPETE FOR LAND WHICH COULD LOWER THE OVERALL RE POTENTIAL. SCENARIO DATA: IEA WEO 2009 REFERENCE SCENARIO (INTERNATIONAL ENERGY AGENCY (IEA), 2009; TESKE ET AL., 2010), REMIND-RECIPE 450PPM STABILIZATION SCENARIO (LUDERER ET AL., 2009), MINICAM EMF22 1ST-BEST 2.6 W/2 OVERSHOOT SCENARIO (CALVIN ET AL., 2009), ADVANCED ENERGY [R]EVOLUTION 2010 (TESKE ET AL., 2010.

8.6 biomass in the 2012 energy [r]evolution (4th edition)

The 2012 Energy [R]evolution (4th edn.) is an energy scenario which shows a possible pathway for the global energy system to move from fossil fuels dominated supply towards energy efficiency and sustainable renewable energy use. The aim is to only use sustainable bio energy and reduce the use of unsustainable bio energy in developing countries which is currently in the range of 30 to 40 EJ/a. The fourth edition of the Energy [R]evolution again decreases the amount of bio energy used significantly due to sustainability reasons, and the lack of global environmental and social standards. The amount of bio energy used in this report is based on bio energy potential surveys which are drawn from existing studies, but not necessarily reflecting all the ecological assumptions that Greenpeace would use. It is intended as a coarse-scale, "order-of-magnitude" example of what the energy mix would look like in the future (2050) with largely phased-out fossil fuels. The rationale underpinning the use of biomass in the 2012 Energy [R]evolution is explained here but note the amount of bio energy used in the Energy [R]evolution does not mean that Greenpeace per se agrees to the amount without strict criteria.

The Energy [R]evolution takes a precautionary approach to the future use of bioenergy. This reflects growing concerns about the greenhouse gas balance of many biofuel sources, and also the risks posed by expanded bio fuels crop production to biodiversity (forests, wetlands and grasslands) and food security. It should be stressed, however, that this conservative approach is based on an assessment of today's technologies and their associated risks. The development of advanced forms of bio energies which do not involve significant land take, are demonstrably sustainable in terms of their impacts on the wider environment, and have clear greenhouse gas benefits, should be an objective of public policy, and would provide additional flexibility in the renewable energy mix.

All energy production has some impact on the environment. What is important is to minimize the impact on the environment, through reduction in energy usage, increased efficiency and careful choice of renewable energy sources. Different sources of energy have different impacts and these impacts can vary enormously with scale. Hence, a range of energy sources are needed, each with its own limits of what is sustainable.

Biomass is part of the mix of a wide variety of sustainable energies that, together, provide a practical and possible means to eliminate our dependency on fossil fuels. Thereby we can minimize greenhouse gas emissions, especially from fossil carbon, from energy production. Concerns have also been raised about how countries account for the emissions associated with biofuels production and combustion. The lifecycle emissions of different biofuels can vary enormously. To ensure that biofuels are produced and used in ways which maximize its greenhouse gas saving potential, these accounting problems will need to be resolved in future. The Energy [R]evolution prioritises non-combustion resources (wind, solar etc.). Greenpeace does not consider biomass as carbon, or greenhouse gas, neutral because of the time biomass takes to regrow and because of emissions arising from direct and indirect land use changes. The Energy [R]evolution scenario is an energy scenario, therefore only energy related CO_2 emissions are calculated and no other GHG emissions can be covered, e.g. from agricultural practices. However, the Energy [R]evolution summarizes the entire amount of bio energy used in the energy model and indicates possible additional emissions connected to the use of biofuels. As there are many scientific publications about the GHG emission effects of bio energy which vary between carbon neutral to higher CO_2 emissions than fossil fuels a range is given in the Energy [R]evolution.

Bioenergy in the Energy [R]evolution scenario is largely limited to that which can be gained from wood processing and agricultural (crop harvest and processing) residues as well as from discarded wood products. The amounts are based on existing studies, some of which apply sustainability criteria but do not necessarily reflect all Greenpeace's sustainability criteria. Large-scale biomass from forests would not be sustainable.[79] The Energy [R]evolution recognises that there are competing uses for biomass, e.g. maintaining soil fertility, use of straw as animal feed and bedding, use of woodchip in furniture and does not use the full potential. Importantly, the use of biomass in the 2012 Energy [R]evolution has been developed within the context of Greenpeace's broader Bioenergy Position to minimize and avoid the growth of bio energy and in order to prevent use of unsustainable bio energy. The Energy [R]evolution uses the latest available bio energy technologies for power and heat generation, as well as transport systems. These technologies can use different types of fuel and bio gas is preferred due to higher conversion efficiencies. Therefore the primary source for bio mass is not fixed and can be changed over time. Of course, any individual bioenergy project developed in reality needs to be thoroughly researched to ensure our sustainability criteria are met.

Greenpeace supports the most efficient use of biomass in stationary applications. For example, the use of agricultural and wood processing residues in, preferably regional and efficient cogeneration power plants, such as CHP (combined heat and power plants).

reference
79 SCHULZE, E-D., KÖRNER, C., LAW, B.E .HABERL, H. & LUYSSAERT, S. 2012. LARGE-SCALE BIOENERGY FROM ADDITIONAL HARVEST OF FOREST BIOMASS IS NEITHER SUSTAINABLE NOR GREENHOUSE GAS NEUTRAL. GLOBAL CHANGE BIOLOGY BIOENERGY DOI: 10.1111/J.1757-1707.2012.01169.X.

image THE BIOENERGY VILLAGE OF JUEHNDE WHICH WAS THE FIRST COMMUNITY IN GERMANY TO PRODUCE ALL ITS ENERGY NEEDED FOR HEATING AND ELECTRICITY, WITH CO_2 NEUTRAL BIOMASS.

image A NEWLY DEFORESTED AREA WHICH HAS BEEN CLEARED FOR AGRICULTURAL EXPANSION IN THE AMAZON, BRAZIL.

8.6.1 how much biomass

Roughly 55 EJ/a of bio energy was used globally in 2011[80] (approximately 10% of the world's energy[81]). The Energy [R]evolution assumes an increase to 80 EJ/a. in 2050. Currently, much biomass is used in low-efficiency traditional uses and charcoal.[82] The Energy [R]evolution assumes an increase in the efficiency of biomass usage for energy globally by 2050. In addition to efficiencies in burning, there are potentially better uses of local biogas plants from manure (in developing countries at least), better recovery of residues not suitable as feed and an increase in food production using ecological agriculture. The Energy [R]evolution assumes biofuels will only be used for heavy trucks, marine transport and – after 2035 – to a limited extent for aviation. In those sectors, there are currently no other technologies available – apart from some niche technologies which are not proven yet and therefore the only option to replace oil. No import/export of biomass between regions (e.g. Canada and Europe) is required for the Energy [R]evolution.

In the 2012 Energy [R]evolution, the bioenergy potential has not been broken down into various sources, because different forms of bioenergy (e.g. solid, gas, fluid) and technical development continues so the relative contribution of sources is variable. Dedicated biomass crops are not excluded, but are limited to current amounts of usage. Similarly, 10 % of current tree plantations are already used for bioenergy[83], and the Energy [R]evolution assumes the same usage.

There have been several studies on the availability of biomass for energy production and the consequences for sustainability. Below are brief details of examples of such studies on available biomass. These are not Greenpeace studies, but serve to illustrate the range of estimates available and their principal considerations.

The Energy [R]evolution estimate of 80 EJ/yr is at the low end of the spectrum of estimates of available biomass. The Energy [R]evolution doesn't differentiate between forest and agricultural residues as there is too much uncertainty regarding the amounts available regionally now and in the future.

box 8.2: what is an exajoule?

- One exajoule is a billion billion joules
- One exajoule is about equal to the energy content of 30 million tons of coal. It takes 60 million tons of dry biomass to generate one exajoule.
- Global energy use in 2009 was approximately 500 EJ

references

80 INTERNATIONAL ENERGY AGENCY 2011. WORLD ENERGY OUTLOOK 2011 HTTP://WWW.WORLDENERGYOUTLOOK.ORG/PUBLICATIONS/WEO-2011/

81 IPCC, 2011: IPCC SPECIAL REPORT ON RENEWABLE ENERGY SOURCES AND CLIMATE CHANGE MITIGATION. PREPARED BY WORKING GROUP III OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE [O. EDENHOFER, R. PICHS-MADRUGA, Y. SOKONA, K. SEYBOTH, P. MATSCHOSS, S. KADNER, T. ZWICKEL, P. EICKEMEIER, G. HANSEN, S. SCHLÖMER, C. VON STECHOW (EDS)]. CAMBRIDGE UNIVERSITY PRESS, CAMBRIDGE, UNITED KINGDOM AND NEW YORK, NY, USA.

82 IPCC, 2011: IPCC SPECIAL REPORT ON RENEWABLE ENERGY SOURCES AND CLIMATE CHANGE MITIGATION. PREPARED BY WORKING GROUP III OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE [O. EDENHOFER, R. PICHS-MADRUGA, Y. SOKONA, K. SEYBOTH, P. MATSCHOSS, S. KADNER, T. ZWICKEL, P. EICKEMEIER, G. HANSEN, S. SCHLÖMER, C. VON STECHOW (EDS)]. CAMBRIDGE UNIVERSITY PRESS, CAMBRIDGE, UNITED KINGDOM AND NEW YORK, NY, USA.

83 FAO 2010. WHAT WOODFUELS CAN DO TO MITIGATE CLIMATE CHANGE. FAO FORESTRY PAPER 162. FAO, ROME . HTTP://WWW.FAO.ORG/DOCREP/013/I1756E/I1756E00.PDF

Current studies estimating the amount of biomass give the following ranges:

- IPCC (2011) pg. 223. Estimates "From the expert review of available scientific literature, potential deployment levels of biomass for energy by 2050 could be in the range of 100 to 300 EJ. However, there are large uncertainties in this potential such as market and policy conditions, and it strongly depends on the rate of improvement in the production of food and fodder as well as wood and pulp products."
- WWF (2011) Ecofys Energy Scenario (for WWF) found a 2050 total potential of 209 EJ per year with a share of waste/residue-based bioenergy of 101 EJ per year (for 2050), a quarter of which is agricultural residues like cereal straw. Other major sources include wet waste/residues like sugar beet/ potato, oil palm, sugar cane/cassava processing residues or manure (35 EJ), wood processing residues and wood waste (20 EJ) and non-recyclable renewable dry municipal solid waste (11 EJ).[84] However, it's not always clear how some of the numbers were calculated.
- Beringer et al. (2011) estimate a global bioenergy potential of 130-270 EJ per year in 2050 of which 100 EJ per year is waste/residue based.[85]
- WBGU (2009) estimate a global bioenergy potential of 80-170 EJ per year in 2050 of which 50 EJ per year is waste/residue based.[86]
- Deutsches Biomasse Forschungs Zentrum (DBFZ), 2008 did a survey for Greenpeace International where the sustainable bio energy potentials for residuals have been estimated at 87.6 EJ/a and energy crops at a level of 10 to 15 EJ/a (depending on the assumptions for food production). The DBFZ technical and sustainable potential for growing energy crops has been calculated on the assumption that demand for food takes priority. As a first step the demand for arable and grassland for food production has been calculated for each of 133 countries in different scenarios. These scenarios are:

  Business as usual (BAU) scenario: Present agricultural activity continues for the foreseeable future

  Basic scenario: No forest clearing; reduced use of fallow areas for agriculture

  Sub-scenario 1: Basic scenario plus expanded ecological protection areas and reduced crop yields

  Sub-scenario 2: Basic scenario plus food consumption reduced in industrialised countries

  Sub-scenario 3: Combination of sub-scenarios 1 and 2.

In a next step the surpluses of agricultural areas were classified either as arable land or grassland. On grassland, hay and grass silage are produced, on arable land fodder silage and Short Rotation Coppice (such as fast-growing willow or poplar) are cultivated. Silage of green fodder and grass are assumed to be used for biogas production, wood from SRC and hay from grasslands for the production of heat, electricity and synthetic fuels. Country specific yield variations were taken into consideration. The result is that the global biomass potential from energy crops in 2050 falls within a range from 6 EJ in Sub-scenario 1 up to 97 EJ in the BAU scenario.

Greenpeace's vision of ecological agriculture means that low input agriculture is not an option, but a pre-requisite. This means strongly reduced dependence on capital intensive inputs. The shift to eco-ag increases the importance of agricultural residues as synthetic fertilisers are phased out and animal feed production and water use (irrigation and other) are reduced. We will need optimal use of residues as fertilizer, animal feed, and to increase soil organic carbon and the water retention function of the soils etc. to make agriculture more resilient to climate impacts (droughts, floods) and to help mitigate climate change.

references

84 WWF 2011. WWF ENERGY REPORT 2011. PRODUCED IN COLLABORATION WITH ECOFYS AND OMA. HTTP://WWF.PANDA.ORG/WHAT_WE_DO/FOOTPRINT/CLIMATE_CARBON_ENERGY/ENERGY_SOLUTIONS/RENEWABLE_ENERGY/SUSTAINABLE_ENERGY_REPORT/. SOURCES FOR BIOENERGY ARE ON PGS. 183-18.
85 BERINGER, T. ET AL. 2011. BIOENERGY PRODUCTION POTENTIAL OF GLOBAL BIOMASS PLANTATIONS UNDER ENVIRONMENTAL AND AGRICULTURAL CONSTRAINTS. GCB BIOENERGY, 3:299–312. DOI:10.1111/J.1757-1707.2010.01088.X
86 WBGU 2009. FUTURE BIOENERGY AND SUSTAINABLE LAND USE. EARTHSCAN, LONDON AND STERLING, VA

energy technologies

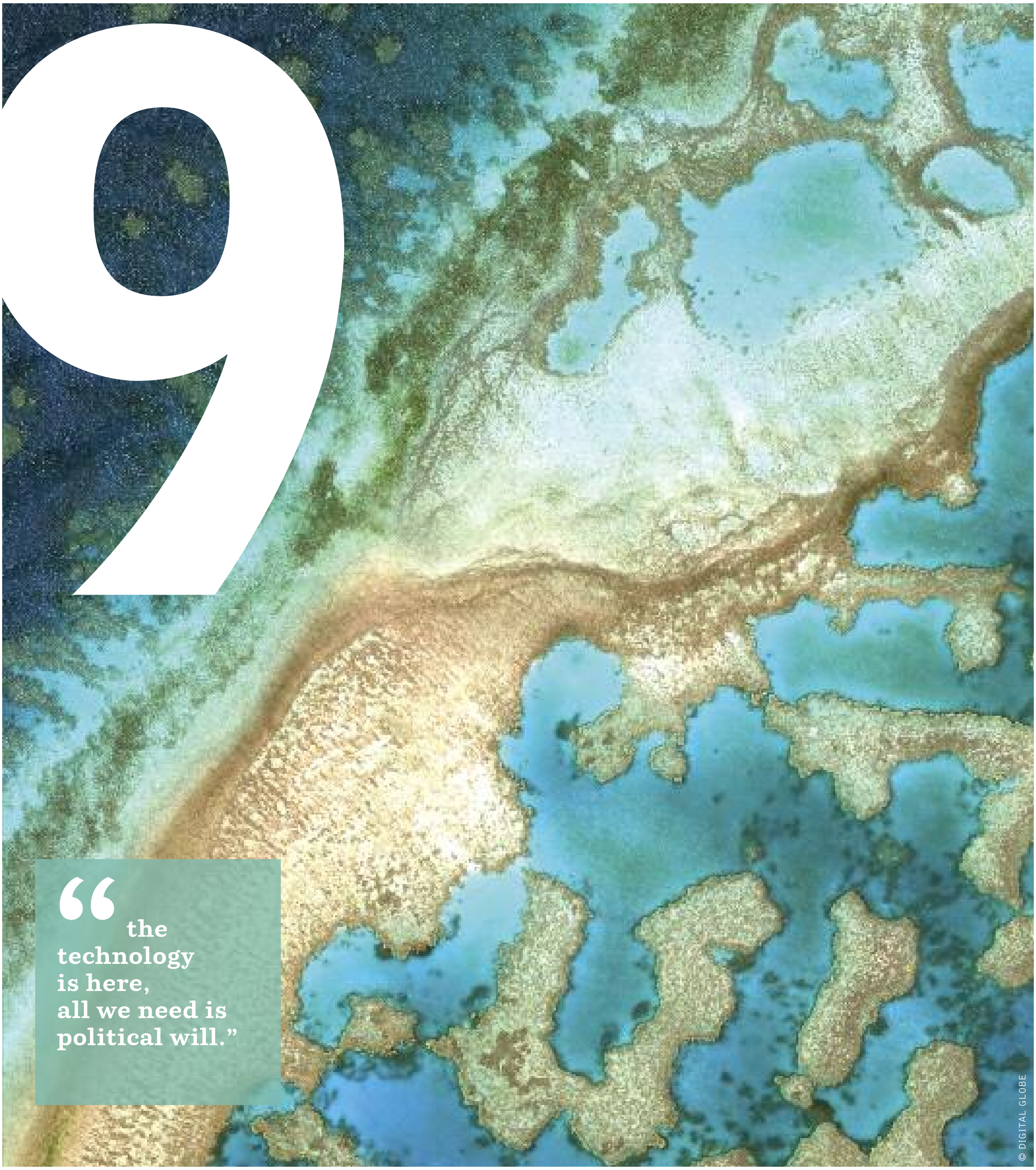


image THE GREAT BARRIER REEF CAN BE SEEN FROM OUTER SPACE AND IS THE WORLD'S BIGGEST SINGLE STRUCTURE MADE BY LIVING ORGANISMS. THIS REEF STRUCTURE IS COMPOSED OF AND BUILT BY BILLIONS OF TINY ORGANISMS, KNOWN AS CORAL POLYPS. IT SUPPORTS A WIDE DIVERSITY OF LIFE AND WAS SELECTED AS A WORLD HERITAGE SITE IN 1981.

This chapter describes the range of technologies available now and in the future to satisfy the world's energy demand. The Energy [R]evolution scenario is focused on the potential for energy savings and renewable sources, primarily in the electricity and heat generating sectors.

9.1 fossil fuel technologies

The most commonly used fossil fuels for power generation around the world are coal and gas. Oil is still used where other fuels are not readily available, for example islands or remote sites, or where there is an indigenous resource. Together, coal and gas currently account for over half of global electricity supply.

9.1.1 coal combustion technologies

In a conventional coal-fired power station, pulverised or powdered coal is blown into a combustion chamber where it is burned at high temperature. The resulting heat is used to convert water flowing through pipes lining the boiler into steam. This drives a steam turbine and generates electricity. Over 90% of global coal-fired capacity uses this system. Coal power stations can vary in capacity from a few hundred megawatts up to several thousand.

A number of technologies have been introduced to improve the environmental performance of conventional coal combustion. These include coal cleaning (to reduce the ash content) and various 'bolt-on' or 'end-of-pipe' technologies to reduce emissions of particulates, sulphur dioxide and nitrogen oxide, the main pollutants resulting from coal firing apart from carbon dioxide. Flue gas desulphurisation (FGD), for example, most commonly involves 'scrubbing' the flue gases using an alkaline sorbent slurry, which is predominantly lime or limestone based.

More fundamental changes have been made to the way coal is burned both to improve its efficiency and further reduce emissions of pollutants. These include:

- **Integrated Gasification Combined Cycle:** Coal is not burned directly but reacted with oxygen and steam to form a synthetic gas composed mainly of hydrogen and carbon monoxide. This is cleaned and then burned in a gas turbine to generate electricity and produce steam to drive a steam turbine. IGCC improves the efficiency of coal combustion from 38-40% up to 50%.
- **Supercritical and Ultrasupercritical:** These power plants operate at higher temperatures than conventional combustion, again increasing efficiency towards 50%.
- **Fluidised Bed Combustion:** Coal is burned in a reactor comprised of a bed through which gas is fed to keep the fuel in a turbulent state. This improves combustion, heat transfer and the recovery of waste products. By elevating pressures within a bed, a high-pressure gas stream can be used to drive a gas turbine, generating electricity. Emissions of both sulphur dioxide and nitrogen oxide can be reduced substantially.
- **Pressurised Pulverised Coal Combustion:** Mainly being developed in Germany, this is based on the combustion of a finely ground cloud of coal particles creating high pressure, high temperature steam for power generation. The hot flue gases are used to generate electricity in a similar way to the combined cycle system.

Other potential future technologies involve the increased use of coal gasification. Underground Coal Gasification, for example, involves converting deep underground unworked coal into a combustible gas which can be used for industrial heating, power generation or the manufacture of hydrogen, synthetic natural gas or other chemicals. The gas can be processed to remove CO_2 before it is passed on to end users. Demonstration projects are underway in Australia, Europe, China and Japan.

9.1.2 gas combustion technologies

Natural gas can be used for electricity generation through the use of either gas or steam turbines. For the equivalent amount of heat, gas produces about 45% less carbon dioxide during its combustion than coal.

Gas turbine plants use the heat from gases to directly operate the turbine. Natural gas fuelled turbines can start rapidly, and are therefore often used to supply energy during periods of peak demand, although at higher cost than baseload plants.

Particularly high efficiencies can be achieved through combining gas turbines with a steam turbine in combined cycle mode. In a combined cycle gas turbine (CCGT) plant, a gas turbine generator produces electricity and the exhaust gases from the turbine are then used to make steam to generate additional electricity. The efficiency of modern CCGT power stations can be more than 50%. Most new gas power plants built since the 1990s have been of this type.

At least until the recent increase in global gas prices, CCGT power stations have been the cheapest option for electricity generation in many countries. Capital costs have been substantially lower than for coal and nuclear plants and construction time shorter.

9.1.3 carbon reduction technologies

Whenever a fossil fuel is burned, carbon dioxide (CO_2) is produced. Depending on the type of power plant, a large quantity of the gas will dissipate into the atmosphere and contribute to climate change. A hard coal power plant discharges roughly 720 grammes of carbon dioxide per kilowatt hour, a modern gas-fired plant about 370g CO_2/kWh. One method, currently under development, to mitigate the CO_2 impact of fossil fuel combustion is called carbon capture and storage (CCS). It involves capturing CO_2 from power plant smokestacks, compressing the captured gas for transport via pipeline or ship and pumping it into underground geological formations for permanent storage.

While frequently touted as the solution to the carbon problem inherent in fossil fuel combustion, CCS for coal-fired power stations is unlikely to be ready for at least another decade. Despite the 'proof of concept' experiments currently in progress, the technology remains unproven as a fully integrated process in

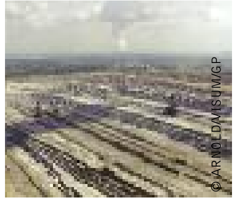


image BROWN COAL SURFACE MINING IN HAMBACH, GERMANY. GIANT COAL EXCAVATOR AND SPOIL PILE.

relation to all of its operational components. Suitable and effective capture technology has not been developed and is unlikely to be commercially available any time soon; effective and safe long-term storage on the scale necessary has not been demonstrated; and serious concerns attach to the safety aspects of transport and injection of CO_2 into designated formations, while long term retention cannot reliably be assured.

Deploying the technology on coal power plants is likely to double construction costs, increase fuel consumption by 10-40%, consume more water, generate more pollutants and ultimately require the public sector to ensure that the CO_2 stays where it has been buried. In a similar way to the disposal of nuclear waste, CCS envisages creating a scheme whereby future generations monitor in perpetuity the climate pollution produced by their predecessors.

9.1.4 carbon dioxide storage

In order to benefit the climate, captured CO_2 has to be stored somewhere permanently. Current thinking is that it can be pumped under the earth's surface at a depth of over 3,000 feet into geological formations, such as saline aquifers. However, the volume of CO_2 that would need to be captured and stored is enormous - a single coal-fired power plant can produce 7 million tonnes of CO_2 annually. It is estimated that a single 'stabilisation wedge' of CCS (enough to reduce carbon emissions by 1 billion metric tons per year by 2050) would require a flow of CO_2 into the ground equal to the current flow out of the ground - and in addition to the associated infrastructure to compress, transport and pump it underground. It is still not clear that it will be technically feasible to capture and bury this much carbon, both in terms of the number of storage sites and whether they will be located close enough to power plants.

Even if it is feasible to bury hundreds of thousands of megatons of CO_2 there is no way to guarantee that storage locations will be appropriately designed and managed over the timescales required. The world has limited experience of storing CO_2 underground; the longest running storage project at Sleipner in the Norweigian North Sea began operation only in 1996. This is particularly concerning because as long as CO_2 is present in geological sites, there is a risk of leakage. Although leakages are unlikely to occur in well managed and monitored sites, permanent storage stability cannot be guaranteed since tectonic activity and natural leakage over long timeframes are impossible to predict.

Sudden leakage of CO_2 can be fatal. Carbon dioxide is not itself poisonous, and is contained (approx. 0.04 %) in the air we breathe. But as concentrations increase it displaces the vital oxygen in the air. Air with concentrations of 7 to 8% CO_2 by volume causes death by suffocation after 30 to 60 minutes.

There are also health hazards when large amounts of CO_2 are explosively released. Although the gas normally disperses quickly after leaking, it can accumulate in depressions in the landscape or closed buildings, since carbon dioxide is heavier than air. It is equally dangerous when it escapes more slowly and without being noticed in residential areas, for example in cellars below houses.

The dangers from such leaks are known from natural volcanic CO_2 degassing. Gas escaping at the Lake Nyos crater lake in Cameroon, Africa in 1986 killed over 1,700 people. At least ten people have died in the Lazio region of Italy in the last 20 years as a result of CO_2 being released.

9.1.5 carbon storage and climate change targets

Can carbon storage contribute to climate change reduction targets? In order to avoid dangerous climate change, global greenhouse gas emissions need to peak by between 2015 and 2020 and fall dramatically thereafter. However, power plants capable of capturing and storing CO_2 are still being developed and won't become a reality for at least another decade, if ever. This means that even if CCS works, the technology would not make any substantial contribution towards protecting the climate before 2020.

Power plant CO_2 storage will also not be of any great help in attaining the goal of at least an 80% greenhouse gas reduction by 2050 in OECD countries. Even if CCS were to be available in 2020, most of the world's new power plants will have just finished being modernised. All that could then be done would be for existing power plants to be retrofitted and CO_2 captured from the waste gas flow. Retrofitting power plants would be an extremely expensive exercise. 'Capture ready' power plants are equally unlikely to increase the likelihood of retrofitting existing fleets with capture technology.

The conclusion reached in the Energy [R]evolution scenario is that renewable energy sources are already available, in many cases cheaper, and lack the negative environmental impacts associated with fossil fuel exploitation, transport and processing. It is renewable energy together with energy efficiency and energy conservation – and not carbon capture and storage – that has to increase worldwide so that the primary cause of climate change – the burning of fossil fuels like coal, oil and gas – is stopped.

Greenpeace opposes any CCS efforts which lead to:

- public financial support to CCS at the expense of funding renewable energy development and investment in energy efficiency.
- stagnation of renewable energy, energy efficiency and energy conservation improvements.
- inclusion of CCS in the Kyoto Protocol's Clean Development Mechanism (CDM) as it would divert funds away from the stated intention of the mechanism, and cannot be considered clean development under any coherent definition of this term.
- promotion of this possible future technology as the only major solution to climate change, thereby leading to new fossil fuel developments – especially lignite and black coal-fired power plants, and an increase in emissions in the short to medium term.

9.2 nuclear technologies

Generating electricity from nuclear power involves transferring the heat produced by a controlled nuclear fission reaction into a conventional steam turbine generator. The nuclear reaction takes place inside a core and surrounded by a containment vessel of varying design and structure. Heat is removed from the core by a coolant (gas or water) and the reaction controlled by a moderating element or "moderator".

Across the world over the last two decades there has been a general slowdown in building new nuclear power stations. This has been caused by a variety of factors: fear of a nuclear accident, following the events at Three Mile Island, Chernobyl, Monju and Fukushima, increased scrutiny of economics and environmental factors, such as waste management and radioactive discharges.

9.2.1 nuclear reactor designs: evolution and safety issues

At the beginning of 2005 there were 441 nuclear power reactors operating in 31 countries around the world. Although there are dozens of different reactor designs and sizes, there are three broad categories either currently deployed or under development. These are:

Generation I: Prototype commercial reactors developed in the 1950s and 1960s as modified or enlarged military reactors, originally either for submarine propulsion or plutonium production.

Generation II: Mainstream reactor designs in commercial operation worldwide.

Generation III: New generation reactors now being built.

Generation III reactors include the so-called Advanced Reactors, three of which are already in operation in Japan, with more under construction or planned. About 20 different designs are reported to be under development,[87] most of them 'evolutionary' designs developed from Generation II reactor types with some modifications, but without introducing drastic changes. Some of them represent more innovative approaches. According to the World Nuclear Association, reactors of Generation III are characterised by the following:

- a standardised design for each type to expedite licensing, reduce capital cost and construction time
- a simpler and more rugged design, making them easier to operate and less vulnerable to operational upsets
- higher availability and longer operating life, typically 60 years
- reduced possibility of core melt accidents
- minimal effect on the environment
- higher burn-up to reduce fuel use and the amount of waste
- burnable absorbers ('poisons') to extend fuel life

To what extent these goals address issues of higher safety standards, as opposed to improved economics, remains unclear. Of the new reactor types, the European Pressurised Water Reactor (EPR) has been developed from the most recent Generation II designs to start operation in France and Germany.[88] Its stated goals are to improve safety levels - in particular to reduce the probability of a severe accident by a factor of ten, achieve mitigation from severe accidents by restricting their consequences to the plant itself, and reduce costs. Compared to its predecessors, however, the EPR displays several modifications which constitute a reduction of safety margins, including:

- The volume of the reactor building has been reduced by simplifying the layout of the emergency core cooling system, and by using the results of new calculations which predict less hydrogen development during an accident.
- The thermal output of the plant has been increased by 15% relative to existing French reactors by increasing core outlet temperature, letting the main coolant pumps run at higher capacity and modifying the steam generators.
- The EPR has fewer redundant pathways in its safety systems than a German Generation II reactor.

Several other modifications are hailed as substantial safety improvements, including a 'core catcher' system to control a meltdown accident. Nonetheless, in spite of the changes being envisaged, there is no guarantee that the safety level of the EPR actually represents a significant improvement. In particular, reduction of the expected core melt probability by a factor of ten is not proven. Furthermore, there are serious doubts as to whether the mitigation and control of a core melt accident with the core catcher concept will actually work.

Finally, Generation IV reactors are currently being developed with the aim of commercialisation in 20-30 years.

references
87 IAEA 2004; WNO 2004A.
88 HAINZ 2004.

image SOLAR PROJECT IN PHITSANULOK, THAILAND. SOLAR FACILITY OF THE INTERNATIONAL INSTITUTE AND SCHOOL FOR RENEWABLE ENERGY.

image SOLAR PANELS ON CONISTON STATION, NORTH WEST OF ALICE SPRINGS, NORTHERN TERRITORY.

9.3 renewable energy technologies

Renewable energy covers a range of natural sources which are constantly renewed and therefore, unlike fossil fuels and uranium, will never be exhausted. Most of them derive from the effect of the sun and moon on the earth's weather patterns. They also produce none of the harmful emissions and pollution associated with 'conventional' fuels. Although hydroelectric power has been used on an industrial scale since the middle of the last century, the serious exploitation of other renewable sources has a more recent history.

box 9.1: definition of renewable energy by the ipcc

"Renewable energy is any form of energy from solar, geophysical or biological sources that is replenished by natural processes at a rate that equals or exceeds its rate of use. RE is obtained from the continuing or repetitive flows of energy occurring in the natural environment and includes resources such as biomass, solar energy, geothermal heat, hydropower, tide and waves and ocean thermal energy, and wind energy. However, it is possible to utilise biomass at a greater rate than it can grow, or to draw heat from a geothermal field at a faster rate than heat flows can replenish it. On the other hand, the rate of utilisation of direct solar energy has no bearing on the rate at which it reaches the Earth. Fossil fuels (coal, oil, natural gas) do not fall under this definition, as they are not replenished within a time frame that is short relative to their rate of utilisation."

source
IPCC, SPECIAL REPORT RENEWABLE ENERGY /SRREN RENEWABLES FOR POWER GENERATION.

9.3.1 solar power (photovoltaics)

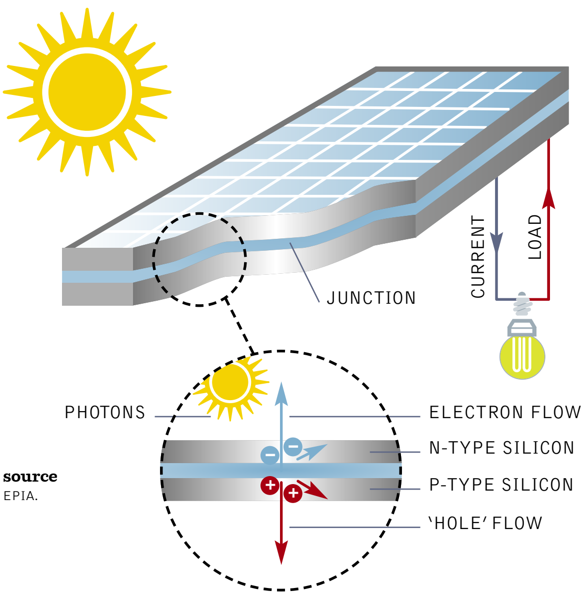
There is more than enough solar radiation available all over the world to satisfy a vastly increased demand for solar power systems. The sunlight which reaches the earth's surface is enough to provide 7,900 times as much energy as we can currently use. On a global average, each square metre of land is exposed to enough sunlight to produce 1,700 kWh of power every year. The average irradiation in Europe is about 1,000 kWh per square metre and 1,800 kWh in the Middle East.

Photovoltaic (PV) technology is the generation of electricity from light. Photovoltaic systems contain cells that convert sunlight into electricity. Inside each cell there are layers of a semi-conducting material. Light falling on the cell creates an electric field across the layers, causing electricity to flow. The intensity of the light determines the amount of electrical power each cell generates. A photovoltaic system does not need direct sunlight in order to operate. It can also generate electricity on cloudy and rainy days but with lower output.

Solar PV is different from a solar thermal collecting system (see below) where the sun's rays are used to generate heat, usually for hot water in a house, swimming pool, or other domestic applications.

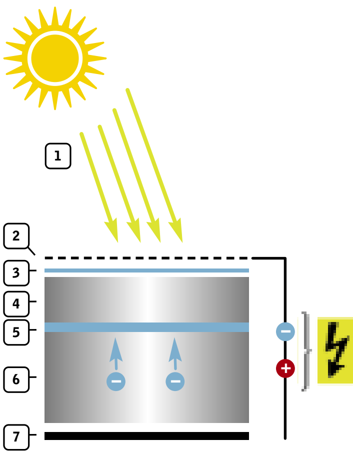
The most important parts of a PV system are the cells which form the basic building blocks, the modules which bring together large numbers of cells into a unit, and, in some situations, the inverters used to convert the electricity generated into a form suitable for everyday use. When a PV installation is described as having a capacity of 3 kWp (peak), this refers to the output of the system under standard testing conditions, allowing comparison between different modules. In central Europe a 3 kWp rated solar electricity system, with a surface area of approximately 27 square metres, would produce enough power to meet the electricity demand of an energy conscious household.

figure 9.1: example of the photovoltaic effect



source
EPIA.

figure 9.2: photovoltaic technology



1. LIGHT (PHOTONS)
2. FRONT CONTACT GRID
3. ANTI-REFLECTION COATING
4. N-TYPE SEMICONDUCTOR
5. BOARDER LAYOUT
6. P-TYPE SEMICONDUCTOR
7. BACK CONTACT

There are several different PV technologies and types of installed system. PV systems can provide clean power for small or large applications. They are already installed and generating energy around the world on individual homes, housing developments, offices and public buildings.

Today, fully functioning solar PV installations operate in both built environments and remote areas where it is difficult to connect to the grid or where there is no energy infrastructure. PV installations that operate in isolated locations are known as stand-alone systems. In built areas, PV systems can be mounted on top of roofs (known as Building Adapted PV systems – or BAPV) or can be integrated into the roof or building facade (known as Building Integrated PV systems – or BIPV).

Modern PV systems are not restricted to square and flat panel arrays. They can be curved, flexible and shaped to the building's design. Innovative architects and engineers are constantly finding new ways to integrate PV into their designs, creating buildings that are dynamic, beautiful and provide free, clean energy throughout their life.

Technologies

Crystalline silicon technology: Crystalline silicon cells are made from thin slices cut from a single crystal of silicon (mono crystalline) or from a block of silicon crystals (polycrystalline or multi crystalline). This is the most common technology, representing about 80% of the market today. In addition, this technology also exists in the form of ribbon sheets.

Thin film technology: Thin film modules are constructed by depositing extremely thin layers of photosensitive materials onto a substrate such as glass, stainless steel or flexible plastic. The latter opens up a range of applications, especially for building integration (roof tiles) and end-consumer purposes. Four types of thin film modules are commercially available at the moment: Amorphous Silicon, Cadmium Telluride, Copper Indium/Gallium Diselenide/Disulphide and multi-junction cells.

Other emerging cell technologies (at the development or early commercial stage): These include Concentrated Photovoltaic, consisting of cells built into concentrating collectors that use a lens to focus the concentrated sunlight onto the cells, and Organic Solar Cells, whereby the active material consists at least partially of organic dye, small, volatile organic molecules or polymer.

Systems

Industrial and utility-scale power plants: Large industrial PV systems can produce enormous quantities of electricity at a single point. These types of electricity generation plants can produce from many hundreds of kilowatts (kW) to several megawatts (MW).The solar panels for industrial systems are usually mounted on frames on the ground. However, they can also be installed on large industrial buildings such as warehouses, airport terminals or railways stations. The system can make double-use of an urban space and put electricity into the grid where energy-intensive consumers are located.

Residential and commercial systems: **Grid Connected** Grid connected are the most popular type of solar PV systems for homes and businesses in the developed world. Connection to the local electricity network, allows any excess power produced to be sold to the utility. When solar energy is not available, electricity can be drawn from the grid. An inverter converts the DC power produced by the system to AC power for running normal electrical equipment. This type of PV system is referred to as being 'on-grid.' A 'grid support' system can be connected to the local electricity network as well as a back-up battery. Any excess solar electricity produced after the battery has been charged is then sold to the network. This system is ideal for use in areas of unreliable power supply.

Stand-alone, off-grid systems Off-grid PV systems have no connection to an electricity grid. An off-grid system usually has batteries, so power can still be used at night or after several days of low sun. An inverter is needed to convert the DC power generated into AC power for use in appliances. Typical off-grid applications are:

- Off-grid systems for rural electrification: Typical off-grid installations bring electricity to remote areas or developing countries. They can be small home systems which cover a household's basic electricity needs, or larger solar mini-grids which provide enough power for several homes, a community or small business use.
- Off-grid industrial applications: Off-grid industrial systems are used in remote areas to power repeater stations for mobile telephones (enabling communications), traffic signals, marine navigational aids, remote lighting, highway signs and water treatment plants among others. Both full PV and hybrid systems are used. Hybrid systems are powered by the sun when

table 9.1: typical type and size of applications per market segment

MARKET SEGMENT TYPE OF APPLICATION	RESIDENTIAL < 10 kWp	COMMERCIAL 10 kWp - 100 kWp	INDUSTRIAL 100 kWp - 1 MWp	UTILITY-SCALE > 1 MWp
Ground-mounted	-	-	•	•
Roof-top	•	•	•	
Integrated to facade/roof	•	•	-	

image LA DEHESA, 50 MW PARABOLIC TROUGH SOLAR THERMAL POWER PLANT WITH MOLTEN SALTS STORAGE. COMPLETED IN FEBRUARY 2011, IT IS LOCATED IN LA GAROVILLA (BADAJOZ), SPAIN, AND IT IS OWNED BY RENOVABLES SAMCA. WITH AN ANNUAL PRODUCTION OF 160 MILLION KWH, LA DEHESA WILL BE ABLE TO COVER THE ELECTRICITY NEEDS OF MORE THAN 45,000 HOMES, PREVENTING THE EMISSION OF 160,000 TONS OF CARBON. THE 220 H PLANT HAS 225,792 MIRRORS ARRANGED IN ROWS AND 672 SOLAR COLLECTORS WHICH OCCUPY A TOTAL LENGTH OF 100KM.

it is available and by other fuel sources during the night and extended cloudy periods. Off-grid industrial systems provide a cost-effective way to bring power to areas that are very remote from existing grids. The high cost of installing cabling makes off-grid solar power an economical choice.

Consumer goods: PV cells are now found in many everyday electrical appliances such as watches, calculators, toys, and battery chargers (for instance embedded in clothes and bags). Services such as water sprinklers, road signs, lighting and telephone boxes also often rely on individual PV systems.

Hybrid Systems: A solar system can be combined with another source of power – e.g. a biomass generator, a wind turbine or diesel generator - to ensure a consistent supply of electricity. A hybrid system can be grid connected, stand alone or grid support.

9.3.2 concentrating solar power (CSP)

The majority of the world's electricity today—whether generated by coal, gas, nuclear, oil or biomass—comes from creating a hot fluid. Concentrating Solar Power (CSP) technologies produce electricity by concentrating direct-beam solar irradiance to heat a liquid, solid or gas that is then used in a downstream process for electricity generation. CSP simply provides an alternative heat source.

Thus, CSP plants, also called solar thermal power plants, produce electricity in much the same way as conventional power stations. They obtain their energy input by concentrating solar radiation and converting it to high temperature steam or gas to drive a turbine or motor engine. Large mirrors concentrate sunlight into a single line or point. The heat created there is used to generate steam. This hot, highly pressurised steam is used to power turbines which generate electricity. In sun-drenched regions, CSP plants can guarantee a large proportion of electricity production. An attraction of this technology is that it builds on much of the current know-how on power generation in the world today. It will benefit from ongoing advances in solar concentrator technology and as improvements continue to be made in steam and gas turbine cycles.

Some of the key advantages of CSP include:

- it can be installed in a range of capacities to suit varying applications and conditions, from tens of kW (dish/Stirling systems) to multiple MWs (tower and trough systems)
- it can integrate thermal storage for peaking loads (less than one hour) and intermediate loads (three to six hours) or base load (15-20 hours) just as required by demand
- it has modular and scalable components,
- it does not require exotic materials.
- hybrid operation with biomass or fossil fuel guarantees firm and flexible power capacity on demand.

Systems

All systems require four main elements: a concentrator, a receiver, some form of transfer medium or storage and power conversion. Many different types of system are possible, including combinations with other renewable and non-renewable technologies, but there are four main groups of solar thermal technologies:

Parabolic trough: Parabolic trough plants use rows of parabolic trough collectors, each of which reflect the solar radiation into an absorber tube. The troughs track the Sun around one axis, typically oriented north-south. Synthetic oil circulates through the tubes, heating up to approximately 400°C. The hot oil from numerous rows of troughs is passed through a heat exchanger to generate steam for a conventional steam turbine generator to generate electricity. Some of the plants under construction have been designed to produce power not only during sunny hours but also to store energy, allowing the plant to produce an additional 7.5 hours of nominal power after sunset, which dramatically improves their integration into the grid. Molten salts are normally used as storage fluid in a hot-and-cold two-tank concept. Plants in operation in Europe: Andasol 1 and 2 (50 MW +7.5 hour storage each); Puertollano (50 MW); Alvarado (50 MW) and Extresol 1 (50 MW + 7.5 hour storage). Land requirements are of the order of 2 km^2 for a 100-MWe plant, depending on the collector technology and assuming no storage is provided.

Linear Fresnel Systems: Collectors resemble parabolic troughs, with a similar power generation technology, using long lines of flat or nearly flat Fresnel reflectors to form a field of horizontally mounted flat mirror strips, collectively or individually tracking the sun. These are cheaper to install than trough systems but not as efficient. There is one plant currently in operation in Europe: Puerto Errado (2 MW).

Central receiver or solar tower: Central receivers (or "power towers") are point-focus collectors that are able to generate much higher temperatures than troughs and linear Fresnel reflectors. This technology uses a circular array of mirrors (heliostats) where each mirror tracks the Sun, reflecting the light onto a fixed receiver on top of a tower. Temperatures of more than 1,000°C can be reached. A heat-transfer medium absorbs the highly concentrated radiation reflected by the heliostats and converts it into thermal energy to be used for the subsequent generation of superheated steam for turbine operation. To date, the heat transfer media demonstrated include water/steam, molten salts, liquid sodium and air. If pressurised gas or air is used at very high temperatures of about 1,000°C or more as the heat transfer medium, it can even be used to directly replace natural gas in a gas turbine, thus making use of the excellent efficiency (60%+) of modern gas and steam combined cycles.

After an intermediate scaling up to 30 MW capacity, solar tower developers now feel confident that grid-connected tower power plants can be built up to a capacity of 200 MWe solar-only units. Use of heat storage will increase their flexibility. Although solar tower plants are considered to be further from commercialisation than parabolic trough systems, they have good longer-term prospects for high conversion efficiencies. Projects are being developed in Spain, South Africa and Australia.

Parabolic dish: A dish-shaped reflector is used to concentrate sunlight on to a receiver located at its focal point. The receiver moves with the dish. The concentrated beam radiation is absorbed into the receiver to heat a fluid or gas to approximately 750°C. This is then used to generate electricity in a small piston, Stirling engine or micro turbine attached to the receiver. Dishes have been used to power Stirling engines up to 900°C, and also for steam generation. The largest solar dishes have a 485-m^2 aperture and are in research facilities or demonstration plants. Currently the capacity of each Stirling engine is small — in the order of 10 to 25 kWelectric. There is now significant operational experience with dish/Stirling engine systems and the technology has been under development for many years, with advances in dish structures, high-temperature receivers, use of hydrogen as the circulating working fluid, as well as some experiments with liquid metals and improvements in Stirling engines — all bringing the technology closer to commercial deployment. Although the individual unit size may only be of the order of tens of kWe, power stations of up to 800 MWe have been proposed by aggregating many modules. Because each dish represents a stand-alone electricity generator, there is great flexibility in the capacity and rate at which units are installed to the grid. However, the dish technology is less likely to integrate thermal storage. The potential of parabolic dishes lies primarily for decentralised power supply and remote, stand-alone power systems. Projects are currently planned in the United States, Australia and Europe.

Thermal Storage: Thermal energy storage integrated into a system is an important attribute of CSP. Until recently, this has been primarily for operational purposes, providing 30 minutes to one hour of full-load storage. This eases the impact of thermal transients such as clouds on the plant, assists start-up and shut-down, and provides benefits to the grid. Trough plants are now designed for 6 to 7.5 hours of storage, which is enough to allow operation well into the evening when peak demand can occur and tariffs are high.

In thermal storage, the heat from the solar field is stored before reaching the turbine. The solar field needs to be oversized so that enough heat can be supplied to both operate the turbine during the day and, charge the thermal storage. Thermal storage for CSP systems needs to be generally between 400°C and 600°C, higher than the temperature of the working fluid. Temperatures are also dictated by the limits of the media available. Examples of storage media include molten salt (presently comprising separate hot and cold tanks), steam accumulators (for short-term storage only), solid ceramic particles, high-temperature phase-change materials, graphite, and high-temperature concrete. The heat can then be drawn from the storage to generate steam for a turbine, when needed. Another type of storage associated with high-temperature CSP is thermochemical storage, where solar energy is stored chemically. Trough plants in Spain are now operating with molten-salt storage. In the USA, Abengoa Solar's 280-MW Solana trough project, planned to be operational by 2013, intends to integrate six hours of thermal storage. Towers, with their higher temperatures, can charge and store molten salt more efficiently. Gemasolar, a 19-MWe solar tower project operating in Spain, is designed for 15 hours of storage, giving a 75% annual capacity factor (Arce et al., 2011).

figures 9.3: csp technologies: parabolic trough, central receiver/solar tower and parabolic dish

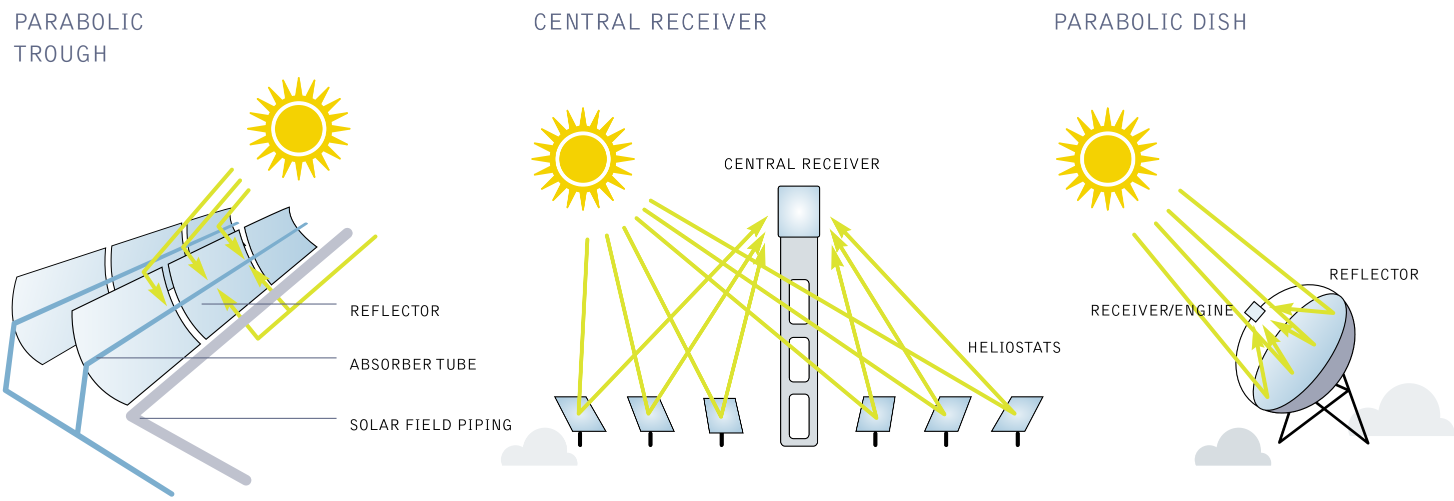


image SOLAR PANELS FEATURED IN A RENEWABLE ENERGY EXHIBIT ON BORACAY ISLAND, ONE OF THE PHILIPPINES' PREMIER TOURIST DESTINATIONS.

image VESTAS VM 80 WIND TURBINES AT AN OFFSHORE WIND PARK IN THE WESTERN PART OF DENMARK.

box 9.2: centralised CSP

Centralised CSP benefits from the economies of scale offered by large-scale plants. Based on conventional steam and gas turbine cycles, much of the technological know-how of large power station design and practice is already in place. While larger capacity has significant cost benefits, it has also tended to be an inhibitor until recently because of the much larger investment commitment required from investors. In addition, larger power stations require strong infrastructural support, and new or augmented transmission capacity may be needed. The earliest commercial CSP plants were the 354 MW of Solar Electric Generating Stations in California — deployed between 1985 and 1991 — that continue to operate commercially today. As a result of the positive experiences and lessons learned from these early plants, the trough systems tend to be the technology most often applied today as the CSP industry grows. In Spain, regulations to date have mandated that the largest capacity unit that can be installed is 50 MWe to help stimulate industry competition. In the USA, this limitation does not exist, and proposals are in place for much larger plants — 280 MWe in the case of troughs and 400 MWe plants (made up of four modules) based on towers. There are presently two operational solar towers of 10 and 20 MWe, and all tower developers plan to increase capacity in line with technology development, regulations and investment capital. Multiple dishes have also been proposed as a source of aggregated heat, rather than distributed-generation Stirling or Brayton units. CSP or PV electricity can also be used to power reverse-osmosis plants for desalination. Dedicated CSP desalination cycles based on pressure and temperature are also being developed for desalination.

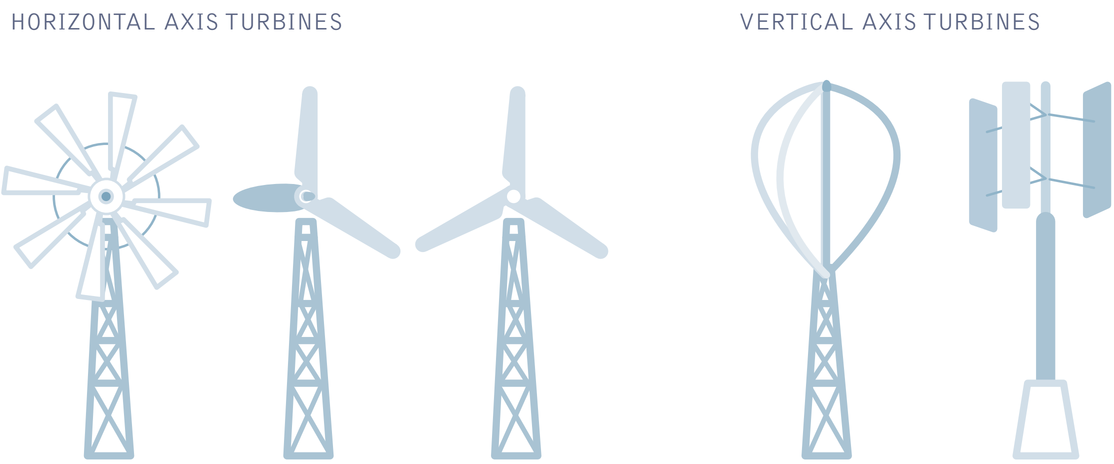
9.3.3 wind power

Wind energy has grown faster than all other electricity sources in the last 20 years and turbine technology has advanced sufficiency that a single machine can power about 5,000 homes. In Europe, wind farms are generally well integrated into the environment and accepted by the public. Smaller models can produce electricity for areas that are not connected to a central grid, through use of battery storage.

Wind speeds and patterns are good enough for this technology on all continents, on both coastlines and inland. The wind resource out at sea is particularly productive and is now being harnessed by offshore wind parks with foundations embedded in the ocean floor.

Wind turbine design: Modern wind technology is available for low and high wind speeds, and in a variety of climates. A variety of onshore wind turbine configurations have been investigated, including both horizontal and vertical axis designs (see Figure 9.4 below). Now, the horizontal axis design dominates, and most designs now centre on the three-blade, upwind rotor; locating the turbine blades upwind of the tower prevents the tower from blocking wind flow and avoids extra aerodynamic noise and loading.[89]

figure 9.4: early wind turbine designs, including horizontal and vertical axis turbines



reference
89 EWEA.

The blades are attached to a hub and main shaft, which transfers power to a generator, sometimes via a gearbox, depending on design, to a generator. The electricity output is channelled down the tower to a transformer and eventually into the local grid network. The main shaft and main bearings, gearbox, generator and control system are contained within a housing called the nacelle (Figure 9.5).

Turbine size has increased over time and the turbine output is controlled by pitching (i.e., rotating) the blades along their long axis.[90] Reduced cost of power electronics allows variable speed wind turbine operation which helps maintain production in variable and gusty winds and also keep large wind power plants generating during electrical faults, and providing reactive power.

Modern wind turbines typically operate at variable speeds using full-span blade pitch control. Over the past 30 years, average wind turbine size has grown significantly (Figure 9.6), with the largest fraction of onshore wind turbines installed globally in 2011 having a rated capacity of 3.5 to 7.5 MW; the average size of turbines installed in 2011 was around 2–2.5 MW.

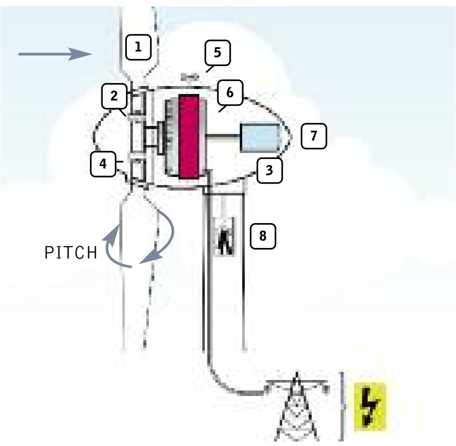
As of 2010, wind turbines used on land typically have 50 to 100 m high towers, with rotors between 50 to 100 m in diameter. Some commercial machines have diameters and tower heights above 125 m, and even larger models are being developed. Modern turbines spin at 12 to 20 revolutions per minute (RPM), which is much slower than the models from the 1980s models which spun at 60 RPM. Later rotors are slower, less visually disruptive and less noisy.

Onshore wind turbines are typically grouped together into wind power plants, with between 5-300 MW generating capacity, and are sometimes also called wind farms. Turbines have been getting larger to help reduce the cost of generation (reach better quality wind), reduce investment per unit of capacity and reduce operation and maintenance costs.[91]

For turbines on land, there will be engineering and logistical constraints to size because the components have to travel by road.

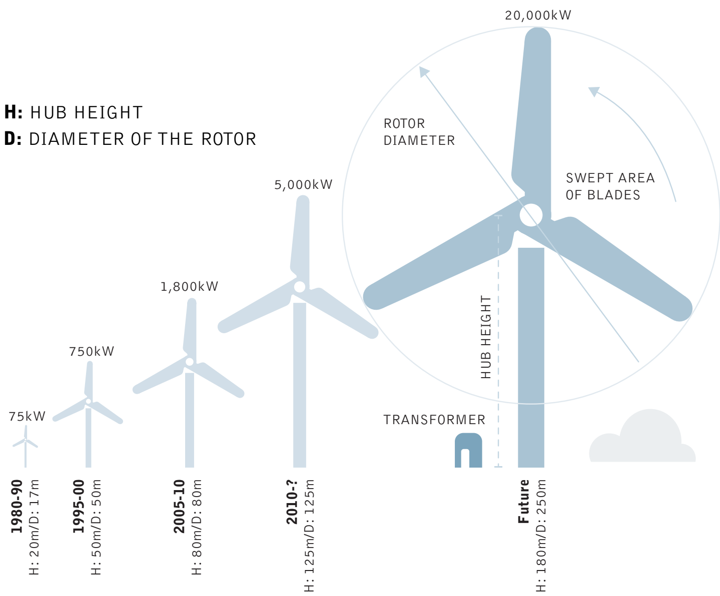
Modern wind turbines have nearly reached their theoretical maximum of aerodynamic efficiency, measured by the coefficient of performance (0.44 in the 1980s to about 0.50 by the mid 2000s).

figure 9.5: basic components of a modern, horizontal axis wind turbine with a gearbox



1. ROTOR BLADE
2. BLADE ADJUSTMENT
3. NACELL
4. ROTOR SHAFT
5. ANEMOMETER
6. GENERATOR
7. SYSTEM CONTROL
8. LIFT INSIDE THE TOWER

figure 9.6: growth in size of typical commercial wind turbines



source
IPCC 2012: SPECIAL REPORT ON RENEWABLE ENERGY SOURCES AND CLIMATE CHANGE MITIGATION. PREPARED BY WORKING GROUP III OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, FIGURE(S).... CAMBRIDGE UNIVERSITY PRESS.

references
90 EWEA.
91 EWEA.

image FOREST CREEK WIND FARM PRODUCING 2.3 MW WITH WIND TURBINES MADE BY SIEMENS. WORKERS WORKING ON TOP OF WIND TURBINE.

Offshore wind energy technology: The existing offshore market makes up just 1.3% of the world's land-based installed wind capacity, however, the potential at sea is driving the latest developments in wind technology, size in particular.

The first offshore wind power plant was built in 1991 in Denmark, consisting of eleven 450 kW wind turbines. By the end of 2009, global installed wind power capacity 2,100 MW.[92]

By going offshore, wind energy can use stronger winds and provide clean energy to countries where there is less technical potential for land-based wind energy development or where it would be in conflict with other land uses. Offshore wind energy also makes use lower 'shear' near hub height and greater economies of scale from large turbines that can be transported by ship. Offshore wind farms also reduce the need for new, long-distance, land-based transmission infrastructure that wind farms on land can require.[93]

There is considerable interest in offshore wind energy technology in the EU and, increasingly in other regions, despite the typically higher costs relative to onshore wind energy.

Offshore wind turbines built between 2007 and 2009 typically have nameplate capacity ratings of 2 to 5 MW and larger turbines are under development. Offshore wind power plants installed from 2007 to 2009 were typically 20 to 120 MW in size, and often installed in water between 10 and 20 m deep. Distance to shore is mostly less than 20 km, but average distance has increased over time.[94] Offshore wind is likely to be installed at greater depths, and with larger turbines (5 to 10 MW or larger) as experience is gained and for greater economies of scale.

Offshore wind turbine technology has been very similar to onshore designs, with some structural modifications and with special foundations.[95] Other design features include marine navigational equipment and monitoring and infrastructure to minimise expensive servicing.

9.3.4 biomass energy

Biomass is a broad term used to describe material of recent biological origin that can be used as a source of energy. This includes wood, crops, algae and other plants as well as agricultural and forest residues. Biomass can be used for a variety of end uses: heating, electricity generation or as fuel for transportation. The term 'bio energy' is used for biomass energy systems that produce heat and/or electricity and 'biofuels' for liquid fuels used in transport. Biodiesel manufactured from various crops has become increasingly used as vehicle fuel, especially as the cost of oil has risen.

Biological power sources are renewable, easily stored and, if sustainably harvested, CO_2 neutral. This is because the gas emitted during their transfer into useful energy is balanced by the carbon dioxide absorbed when they were growing plants.

Electricity generating biomass power plants work just like natural gas or coal power stations, except that the fuel must be processed before it can be burned. These power plants are generally not as large as coal power stations because their fuel supply needs to grow as near as possible to the plant. Heat generation from biomass power plants can result either from utilising a Combined Heat and Power (CHP) system, piping the heat to nearby homes or industry, or through dedicated heating systems. Small heating systems using specially produced pellets made from waste wood, for example, can be used to heat single family homes instead of natural gas or oil.

Biomass technology

A number of processes can be used to convert energy from biomass. These divide into thermochemical processes (direct combustion of solids, liquids or a gas via pyrolysis or gasification), and biological systems, (decomposition of solid biomass to liquid or gaseous fuels by processes such as anaerobic digestion and fermentation).

Thermochemical processes: **Direct combustion** Direct biomass combustion is the most common way of converting biomass into energy for both heat and electricity, accounting for over 90% of biomass generation. Combustion processes are well understood, in essence when carbon and hydrogen in the fuel react with excess oxygen to form CO_2 and water and release heat. In rural areas, many forms are biomass are burned for cooking. Wood and charcoal are also used as a fuel in industry. A wide range of existing commercial technologies are tailored to the characteristics of the biomass and the scale of their applications.

Technologies types are fixed bed, fluidised bed or entrained flow combustion. In fixed bed combustion, such as a grate furnace, air first passes through a fixed bed for drying, gasification and charcoal combustion. The combustible gases produced are burned after the addition of secondary air, usually in a zone separated from the fuel bed. In fluidised bed combustion, the primary combustion air is injected from the bottom of the furnace with such high velocity that the material inside the furnace becomes a seething mass of particles and bubbles. Entrained flow combustion is suitable for fuels available as small particles, such as sawdust or fine shavings, which are pneumatically injected into the furnace.

references

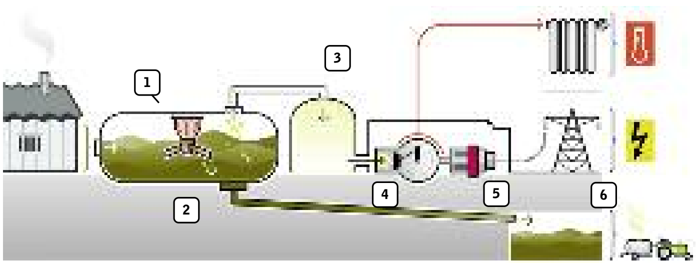
92 GWEC, 2010A.
93 CARBON TRUST, 2008B; SNYDER AND KAISER, 2009B; TWIDELL AND GAUDIOSI, 2009.
94 (EWEA, 2010A).
95 MUSIAL, 2007; CARBON TRUST, 2008B.

Gasification Biomass fuels are increasingly being used with advanced conversion technologies, such as gasification systems, which are more efficient than conventional power generation. Biomass gasification occurs when a partial oxidation of biomass happens upon heating. This produces a combustible gas mixture (called producer gas or fuel gas) rich in CO and hydrogen (H2) that has an energy content of 5 to 20 MJ/Nm^3 (depending on the type of biomass and whether gasification is conducted with air, oxygen or through indirect heating). This energy content is roughly 10 to 45% of the heating value of natural gas.

Fuel gas can then be upgraded to a higher-quality gas mixture called biomass synthesis gas or syngas.[96] A gas turbine, a boiler or a steam turbine are options to employ unconverted gas fractions for electricity co-production. Coupled with electricity generators, syngas can be used as a fuel in place of diesel in suitably designed or adapted internal combustion engines. Most commonly available gasifiers use wood or woody biomass, Specially designed gasifiers can convert non-woody biomass materials.[97] Compared to combustion, gasification is more efficient, providing better controlled heating, higher efficiencies in power production and the possibility for co-producing chemicals and fuels.[98] Gasification can also decrease emission levels compared to power production with direct combustion and a steam cycle.

Pyrolysis Pyrolysis is the thermal decomposition of biomass occurring in the absence of oxygen (anaerobic environment) that produces a solid (charcoal), a liquid (pyrolysis oil or bio-oil) and a gas product. The relative amounts of the three co-products depend on the operating temperature and the residence time used in the process. Lower temperatures produce more solid and liquid products and higher temperatures more biogas. Heating the biomass feedstocks to moderate temperatures (450°C to 550°C) produce oxygenated oils as the major products (70 to 80%), with the remainder split between a biochar and gases.

figure 9.7: biogas technology



1. HEATED MIXER
2. CONTAINMENT FOR FERMENTATION
3. BIOGAS STORAGE
4. COMBUSTION ENGINE
5. GENERATOR
6. WASTE CONTAINMENT

Biological systems: These processes are suitable for very wet biomass materials such as food or agricultural wastes, including farm animal slurry.

Anaerobic digestion Anaerobic digestion means the breakdown of organic waste by bacteria in an oxygen-free environment. This produces a biogas typically made up of 65% methane and 35% carbon dioxide. Purified biogas can then be used both for heating and electricity generation.

Fermentation Fermentation is the process by which growing plants with a high sugar and starch content are broken down with the help of micro-organisms to produce ethanol and methanol. The end product is a combustible fuel that can be used in vehicles.

Biomass power station capacities typically range up to 15 MW, but larger plants are possible. However bio mass power station should use the heat as well, in order to use the energy of the biomass as much as possible, and therefore the size should not be much larger than 25 MW (electric). This size could be supplied by local bio energy and avoid unsustainable long distance fuel supply.

Biofuels Converting crops into ethanol and bio diesel made from rapeseed methyl ester (RME) currently takes place mainly in Brazil, the USA and Europe. Processes for obtaining synthetic fuels from 'biogenic synthesis' gases will also play a larger role in the future. Theoretically biofuels can be produced from any biological carbon source, although the most common are photosynthetic plants. Various plants and plant-derived materials are used for biofuel production.

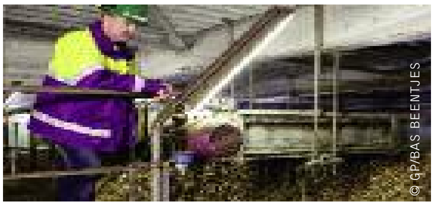
Globally biofuels are most commonly used to power vehicles, but can also be used for other purposes. The production and use of biofuels must result in a net reduction in carbon emissions compared to the use of traditional fossil fuels to have a positive effect in climate change mitigation. Sustainable biofuels can reduce the dependency on petroleum and thereby enhance energy security.

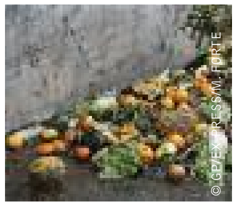
- Bio ethanol is a fuel manufactured through the fermentation of sugars. This is done by accessing sugars directly (sugar cane or beet) or by breaking down starch in grains such as wheat, rye, barley or maize. In the European Union bio ethanol is mainly produced from grains, with wheat as the dominant feedstock. In Brazil the preferred feedstock is sugar cane, whereas in the USA it is corn (maize). Bio ethanol produced from cereals has a by-product, a protein-rich animal feed called Dried Distillers Grains with Solubles (DDGS). For every tonne of cereals used for ethanol production, on average one third will enter the animal feed stream as DDGS. Because of its high protein level this is currently used as a replacement for soy cake. Bio ethanol can either be blended into gasoline (petrol) directly or be used in the form of ETBE (Ethyl Tertiary Butyl Ether).

references
96 FAAIJ, 2006.
97 YOKOYAMA AND MATSUMURA, 2008.
98 KIRKELS AND VERBONG, 2011).

image THROUGH BURNING OF WOOD CHIPS THE POWER PLANT GENERATES ELECTRICITY, ENERGY OR HEAT. HERE WE SEE THE STOCK OF WOOD CHIPS WITH A CAPACITY OF 1000 M³ ON WHICH THE PLANT CAN RUN, UNMANNED, FOR ABOUT FOUR DAYS. LELYSTAD, THE NETHERLANDS.

image FOOD WASTE FOR THE BIOGAS PLANT. THE FARMER PETER WYSS PRODUCES ON HIS FARM WITH A BIOGAS PLANT GREEN ELECTRICITY WITH DUNG FROM COWS, LIQUID MANURE AND WASTE FROM THE FOOD PRODUCTION.





- Bio diesel is a fuel produced from vegetable oil sourced from rapeseed, sunflower seeds or soybeans as well as used cooking oils or animal fats. If used vegetable oils are recycled as feedstock for bio diesel production this can reduce pollution from discarded oil and provides a new way of transforming a waste product into transport energy. Blends of bio diesel and conventional hydrocarbon-based diesel are the most common products distributed in the retail transport fuel market.
- Most countries use a labelling system to explain the proportion of bio diesel in any fuel mix. Fuel containing 20% biodiesel is labelled B20, while pure bio diesel is referred to as B100. Blends of 20 % bio diesel with 80 % petroleum diesel (B20) can generally be used in unmodified diesel engines. Used in its pure form (B100) an engine may require certain modifications. Bio diesel can also be used as a heating fuel in domestic and commercial boilers. Older furnaces may contain rubber parts that would be affected by bio diesel's solvent properties, but can otherwise burn it without any conversion.

The amount of bio energy used in this report is based on bio energy potential surveys which are drawn from existing studies, but not necessarily reflecting all the ecological assumptions that Greenpeace would use. For more details see Chapter 8, page 212.

9.3.5 geothermal energy

Geothermal energy is heat derived from underneath the earth's crust. In most areas, this heat is generated a long way down and has mostly dissipated by the time it reaches the surface, but in some places the geothermal resources are relatively close to the surface and can be used as non-polluting sources of energy. These "hotspots" include the western part of the USA, west and central Eastern Europe, Iceland, Asia and New Zealand.

The uses of geothermal energy depend on the temperatures. Low and moderate areas temperature areas at (less than 90°C or between 90°C and 150°C) can be used for their heat directly and the highest temperature resources (above 150°C) is suitable only for electric power generation. Today's total global geothermal generation is approximately 10,700 MW, with nearly one-third in USA (over 3,000 MW), and the next biggest share in Philippines (1,900 MW) and Indonesia (1,200 MW).

Technology and applications

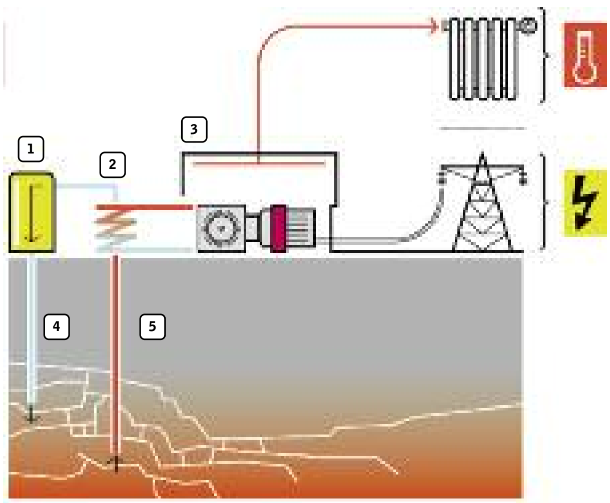
Geothermal energy is currently extracted using wells or other means that produce hot fluids from either hydrothermal reservoirs with naturally high permeability; or reservoirs that are engineered and fractured to extract heat. See below for more information on these "enhanced geothermal systems". Production wells discharge hot water and/or steam.

In high-temperature hydrothermal reservoirs, water occurs naturally underground under pressure in liquid from. As it is extracted the pressure drops and the water is converted to steam which is piped to a turbine to generate electricity. Remaining hot water may go through the process again to obtain more steam. The remaining salty water is sent back to the reservoir through injection wells, sometimes via another system to use the remaining heat. A few reservoirs, such as The Geysers in the USA, Larderello in Italy, Matsukawa in Japan, and some Indonesian fields, produce steam vapour naturally that can be used in a turbine. Hot water produced from intermediate-temperature hydrothermal or Enhanced Geothermal Systems (EGS) reservoirs can also be used in heat exchangers to generate power in a binary cycle, or in direct use applications. Recovered fluids are also injected back into the reservoir.[99] Key technologies are:

Exploration and drilling includes estimating where the resource is, its size and depth with geophysical methods and then drilling exploration wells to test the resource. Today, geothermal wells are drilled over a range of depths down to 5 km using methods similar to those used for oil and gas. Advances in exploration and drilling can technology can be expected. For example if several wells are drilled from the same pad, it can access more heat resources and minimise the surface impact.[100]

Reservoir engineering is focused on determining the volume of geothermal resource and the optimal plant size. The optimum has to consider sustainable use of the resources and safe and efficient operation. The modern method of estimating reserves and sizing power plants through 'reservoir simulation' – a process that starts with a conceptual model followed by a calibrated, numerical representation.[101] Then future behaviour is forecast under selected load conditions using an algorithm (e.g., TOUGH2) to select the plant size. Injection management looks after the production zones and uses data to make sure the hot reservoir rock is re-charged sufficiently.

figure 9.8: geothermal energy



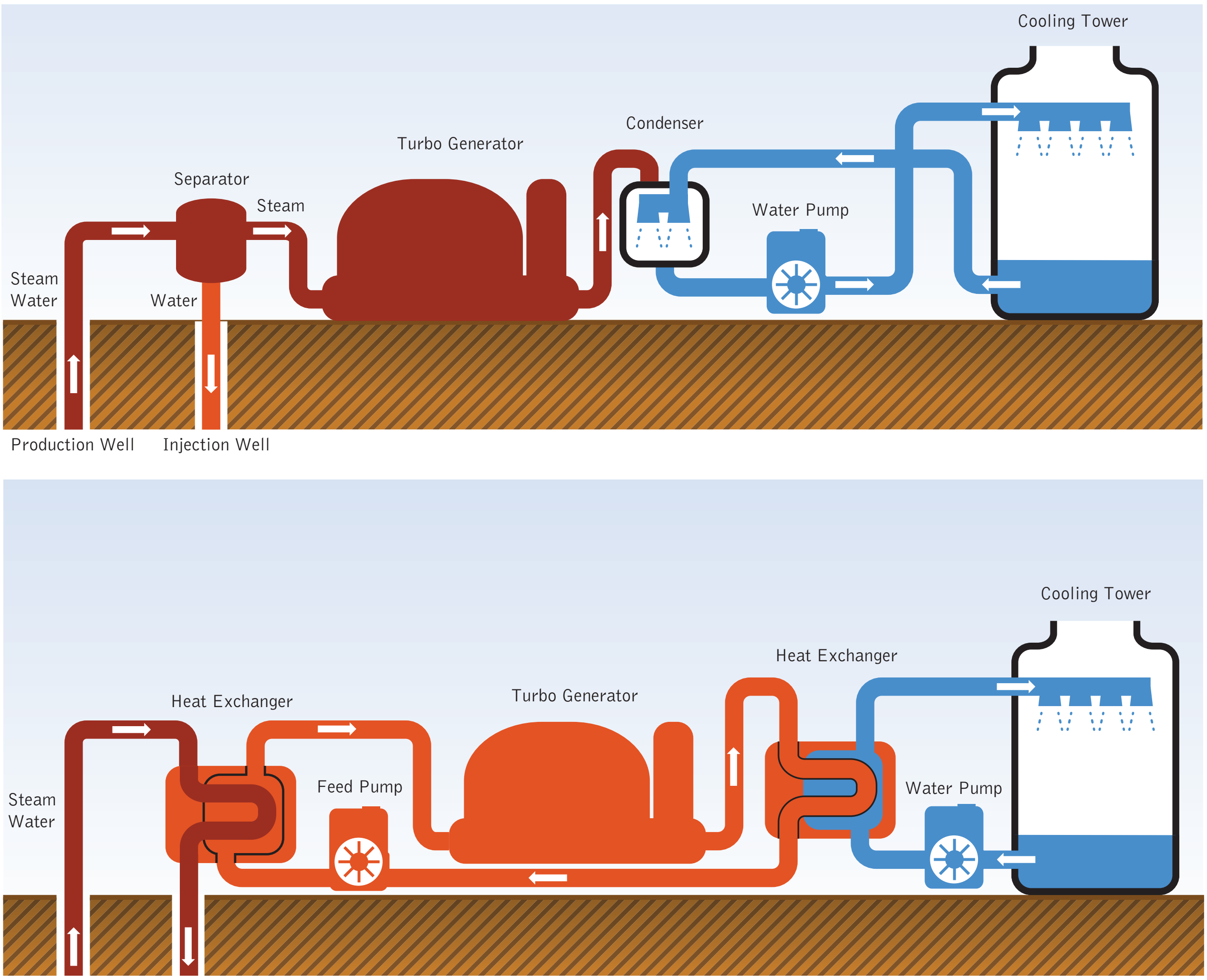
1. PUMP
2. HEAT EXCHANGER
3. GAS TURBINE & GENERATOR
4. DRILLING HOLE FOR COLD WATER INJECTION
5. DRILLING HOLE FOR WARM WATER EXTRACTION

references
99 ARMSTEAD AND TESTER, 1987; DICKSON AND FANELLI, 2003; DIPIPPO, 2008.
100 IPCC, SRREN 2011.
101 GRANT ET AL., 1982.

Geothermal power plants uses the steam created from heating water via natural underground sources to power a turbine which produces electricity. The technique has been used for decades in USA, New Zealand and Iceland this technique, and is under trial in Germany, where it is necessary to drill many kilometres down to reach the high temperature zones temperatures. The basic types of geothermal power plants in use today are steam condensing turbines, binary cycle units and cogeneration plants.

- Steam condensing turbines can be used in flash or dry-steam plants operating at sites with intermediate- and high-temperature resources (≥150°C). The power units are usually 20 to 110 MWe[102], and may utilise a multiple flash system, obtaining steam successively lower pressures, to get as much energy as possible from the geothermal fluid. A dry-steam plant does not require brine separation, resulting in a simpler and cheaper design.
- Binary-cycle plants, typically organic Rankine cycle (ORC) units, typically extract heat from low- and intermediate-temperature geothermal fluids from hydrothermal- and EGS-type reservoirs. Binary plants are more complex than condensing ones since the geothermal fluid (water, steam or both) passes through a heat exchanger to heat another working fluid (e.g. isopentane or isobutene) which vaporises, drives a turbine, and then is air cooled or condensed with water. Binary plants are often constructed as smaller, linked modular units (a few MWe each).
- Combined or hybrid plants comprise two or more of the above basic types to improve versatility, increase overall thermal efficiency, improve load-following capability, and efficiently cover a wide resource temperature range.

figure 9.9: schematic diagram of a geothermal condensing steam power plant (top) and a binary cycle power plant (bottom)



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102 DIPIPPO, 2008.

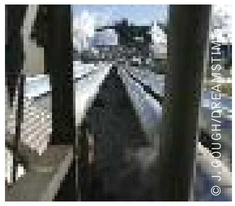
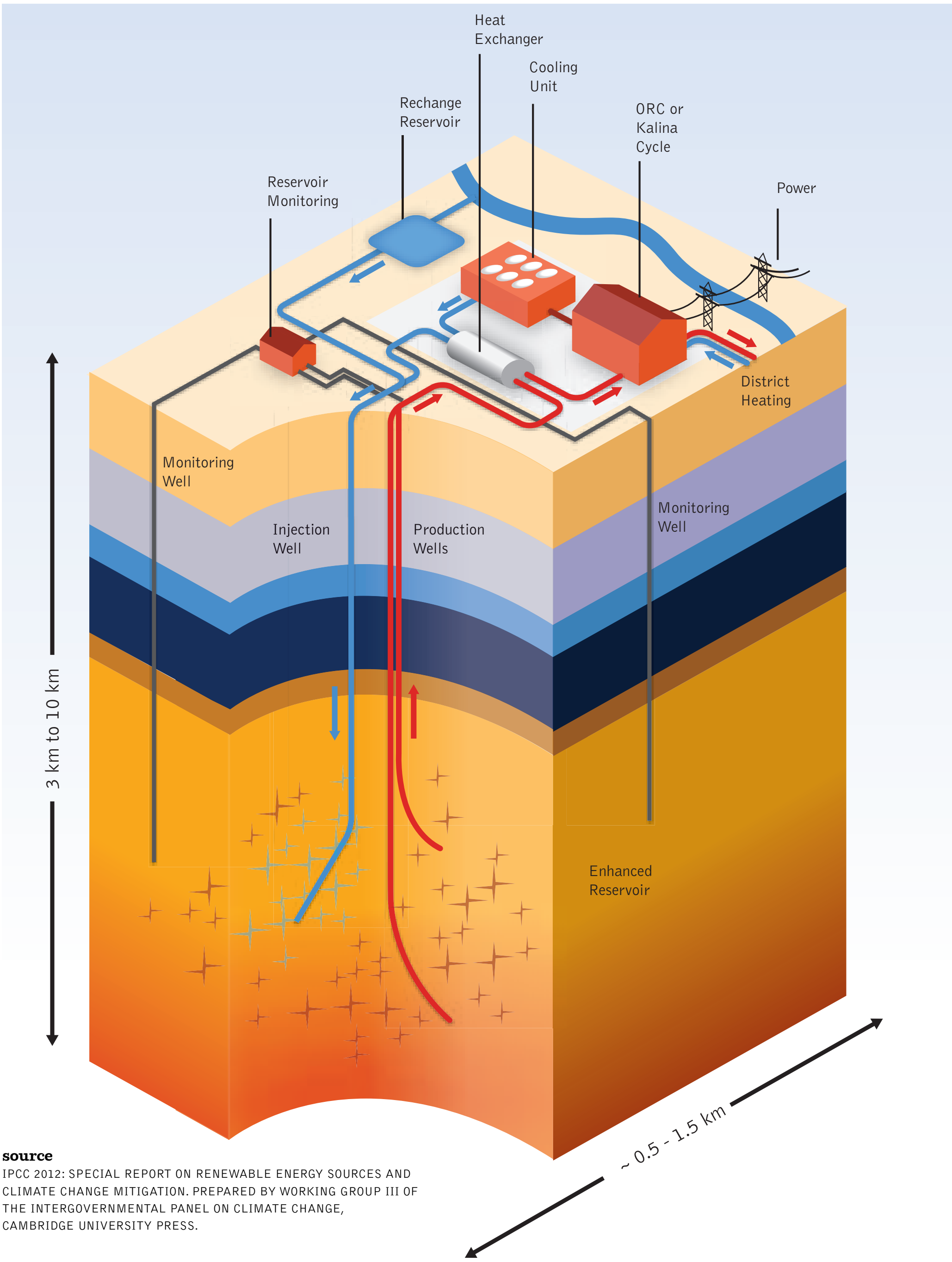


image GEOTHERMAL POWER STATION, NORTH ISLAND, NEW ZEALAND.

- Cogeneration plants, or combined or cascaded heat and power plants (CHP), produce both electricity and hot water for direct use. They can be used in relatively small industries and communities of a few thousand people. Iceland for example, has three geothermal runs geothermal cogeneration plants with a combined capacity of 580 MWth.[103] At the Oregon Institute of Technology, a CHP plant provides most of the electricity needs and all the heat demand.[104]

Enhanced Geothermal Systems (EGS): In some areas, the subsurface regions are 'stimulated' to make use of geothermal energy for power generation. This means making a reservoir by creating or enhancing a network of fractures in the rock underground. This allows fluid to move between the injection point and where power is produced (production wells) (see Figure below 9.10). Heat is extracted by circulating water through the reservoir in a closed loop and can be used for power generation or heating via the technologies described above. Recently developed models provide insights useful for geothermal exploration and production. EGS projects are currently at a demonstration and experimental stage in a number of countries. The technology's key challenges are creating enough reservoirs with sufficient volumes for commercial rates of energy production, while taking care of the water resources and avoiding instability of the earth or seismicity (earthquake activity).[105]

figure 9.10: scheme showing conductive EGS resources



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103 HJARTARSON AND EINARSSON, 2010.
104 LUND AND BOYD, 2009.
105 TESTER ET AL., 2006.

9.3.6 hydro power

Water has been used to produce electricity for about a century and even today it is used to generate around one fifth of the world's electricity. The main requirement for hydro power is to create an artificial head of water, that when it is diverted into a channel or pipe it has sufficient energy to power a turbine.

Classification by head and size

The 'head' in hydro power refers to the difference between the upstream and the downstream water levels, determining the water pressure on the turbines which, along with discharge, decide what type of hydraulic turbine is used. The classification of 'high head' and 'low head' varies from country to country, and there is no generally accepted scale.

Broadly, Pelton impulse turbines are used for high heads (where a jet of water hits a turbine and reverses direction), Francis reaction turbines are used to exploit medium heads (which run full of water and in effect generate hydrodynamic 'lift' to propel the turbine blades) and for low heads, Kaplan and Bulb turbines are applied.

Classification according to refers to installed capacity measured in MW. Small-scale hydropower plants are more likely to be run-of-river facilities than are larger hydropower plants, but reservoir (storage) hydropower stations of all sizes use the same basic components and technologies. It typically takes less time and effort to construct and integrate small hydropower schemes into local environments[106] so their deployment is increasing in many parts of the world. Small schemes are often considered in remote areas where other energy sources are not viable or are not economically attractive.

Greenpeace supports the sustainability criteria developed by the International Rivers Network (www.internationalrivers.org)

Classification by facility type

Hydropower plants are also classified in the following categories according to operation and type of flow:

- run-of-river
- storage (reservoir)
- pumped storage, and
- in-stream technology, which is a young and less-developed technology.

Run-of-River: These plants draw the energy for electricity mainly from the available flow of the river and do not collect significant amounts of stored water. They may include some short-term storage (hourly, daily), but the generation profile will generally be dictated by local river flow conditions. Because generation depends on rainfall it may have substantial daily, monthly or seasonal variations, especially when located in small rivers or streams that with widely varying flows. In a typical plant, a portion of the river water might be diverted to a channel or pipeline (penstock) to convey the water to a hydraulic turbine, which is connected to an electricity generator (see Figure 9.11). RoR projects may form cascades along a river valley, often with a reservoir-type hydro power plants in the upper reaches of the valley. Run-of-river installation is relatively inexpensive and facilities typically have fewer environmental impacts than similar-sized storage hydropower plants.

figure 9.11: run-of-river hydropower plant

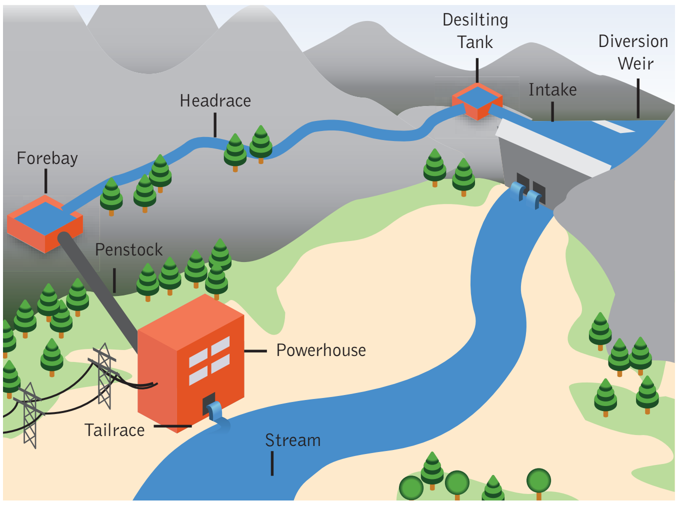

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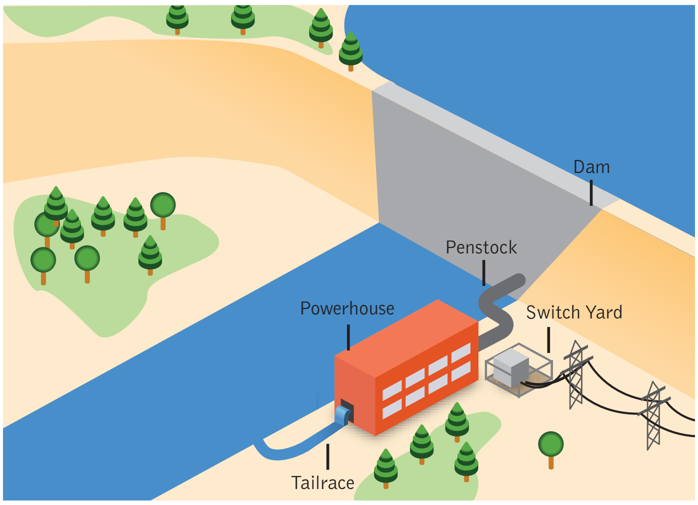
figure 9.12: typical hydropower plant with resevoir



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reference
106 EGRE AND MILEWSKI, 2002

image MOTUP TASHI, OPERATOR OF THE 30KVA MICRO-HYDRO POWER UNIT ABOVE UDMAROO VILLAGE, NUBRA BLOCK, LADAKH. FOR NINE MONTHS OF THE YEAR, THE MICRO-HYDRO POWER UNIT SUPPLIES 90 HOUSES AND SOME SMALL ENTERPRISES WITH ELECTRICITY.

image LIGHTS ARE TURNED ON AT PUSHPAVATHY'S HOME IN CHEMBU, WITH THE HELP OF THEIR PICO HYDRO UNIT. RESIDENTS OF CHEMBU WITH LAND AND ACCESS TO FLOWING WATER HAVE BEGUN TO INSTALL THEIR OWN PRIVATE PICO-HYDRO SYSTEMS TO BRING ELECTRICITY. THIRTY FIVE I KW SYSTEMS HAVE BEEN INSTALLED IN THE PANCHAYAT BY NISARGA ENVIRONMENT TECHNOLOGIES.

Storage Hydropower: Hydropower projects with a reservoir are also called storage hydropower. The reservoir reduces dependence on the variability of inflow and the generating stations are located at the dam toe or further downstream, connected to the reservoir through tunnels or pipelines. (Figure 9.12). Reservoirs are designed according to the landscape and in many parts of the world river valleys are inundated to make an artificial lake. In geographies with mountain plateaus, high-altitude lakes make up another kind of reservoir that retains many of the properties of the original lake. In these settings, the generating station is often connected to the reservoir lake via tunnels (lake tapping). For example, in Scandinavia, natural high-altitude lakes create high pressure systems where the heads may reach over 1,000 m. A storage power plant may have tunnels coming from several reservoirs and may also be connected to neighbouring watersheds or rivers. Large hydroelectric power plants with concrete dams and extensive collecting lakes often have very negative effects on the environment, requiring the flooding of habitable areas.

Pumped storage: Pumped storage plants are not generating electricity but are energy storage devices. In such a system, water is pumped from a lower reservoir into an upper reservoir (Figure below 9.13), usually during off-peak hours when electricity is cheap. The flow is reversed to generate electricity during the daily peak load period or at other times of need. The plant is a net energy consumer overall, because it uses power to pump water, however the plant provides system benefits by helping to meet fluctuating demand profiles. Pumped storage is the largest-capacity form of grid energy storage now readily available worldwide.

In-stream technology using existing facilities: To optimise existing facilities like weirs, barrages, canals or falls, small turbines or hydrokinetic turbines can be installed for electricity generation. These basically function like a run-of-river scheme, as shown in Figure 9.14. Hydrokinetic devices are also being developed to capture energy from tides and currents may also be deployed inland for free-flowing rivers and engineered waterways.

Greenpeace does not support large hydro power stations which require large dams and flooding areas, but supports small scale run of river power plants.

figure 9.13: **typical pumped storage project**

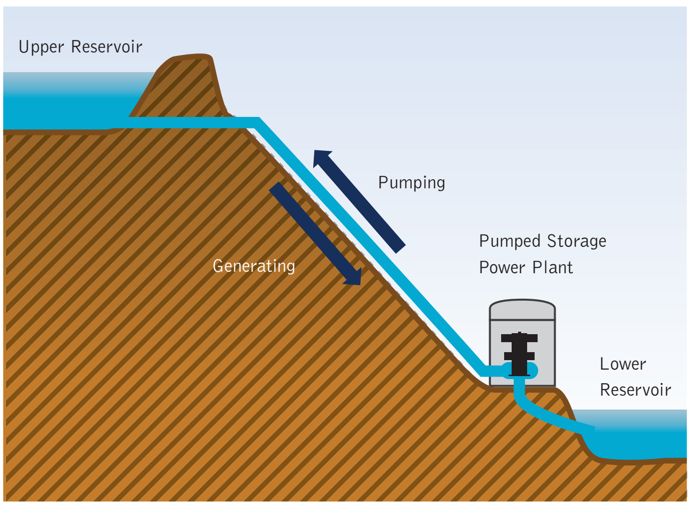

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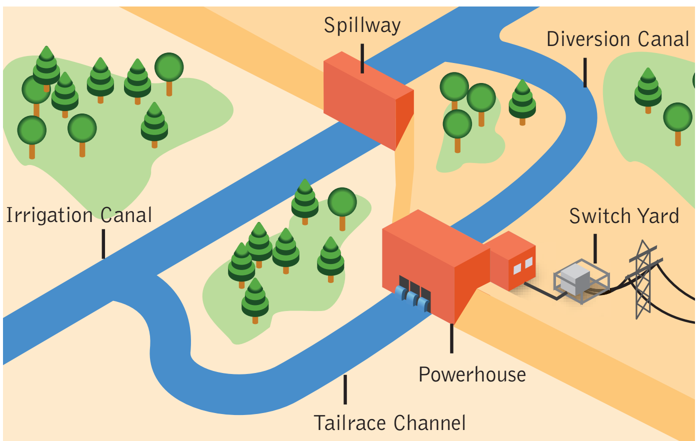
figure 9.14: **typical in-stream hydropower project using existing facilities**



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9.3.7 ocean energy

Wave energy

In wave power generation, a structure interacts with the incoming waves, converting this energy to electricity through a hydraulic, mechanical or pneumatic power take-off system. The structure is moored or placed directly on the seabed/seashore. Power is transmitted to the seabed by a flexible submerged electrical cable and to shore by a sub-sea cable. Wave power can potentially provide a predictable supply of energy and does not create much visual impact.

Many wave energy technologies are at an early phase of conceptual development and testing. Power plants designs vary to deal with different wave motion (heaving, surging, pitching) water depths (deep, intermediate, shallow) and distance from shore (shoreline, nearshore, offshore).

Shoreline devices are fixed to the coast or embedded in the shoreline, near shore devices work at depths of 20-25 m up to ~500 m from the shore where there are stronger, more productive waves and offshore devices exploit the more powerful waves in water over 25 m deep.

No particular technology is leading for wave power and several different systems are being prototyped and tested at sea, with the most development being carried out in UK. The largest grid-connected system installed to date is the 2.25 MW Pelamis, with linked semi-submerged cylindrical sections, operating off the coast of Portugal.

A generic scheme for characterising ocean wave energy generation devices consists of primary, secondary and tertiary conversion stages[107], which refer to the conversions of kinetic energy (in water) to mechanical energy, and then to electrical energy in the generator. Recent reviews have identified more than 50 wave energy devices at various stages of development[108], and we have not explored the limits of size in practice.

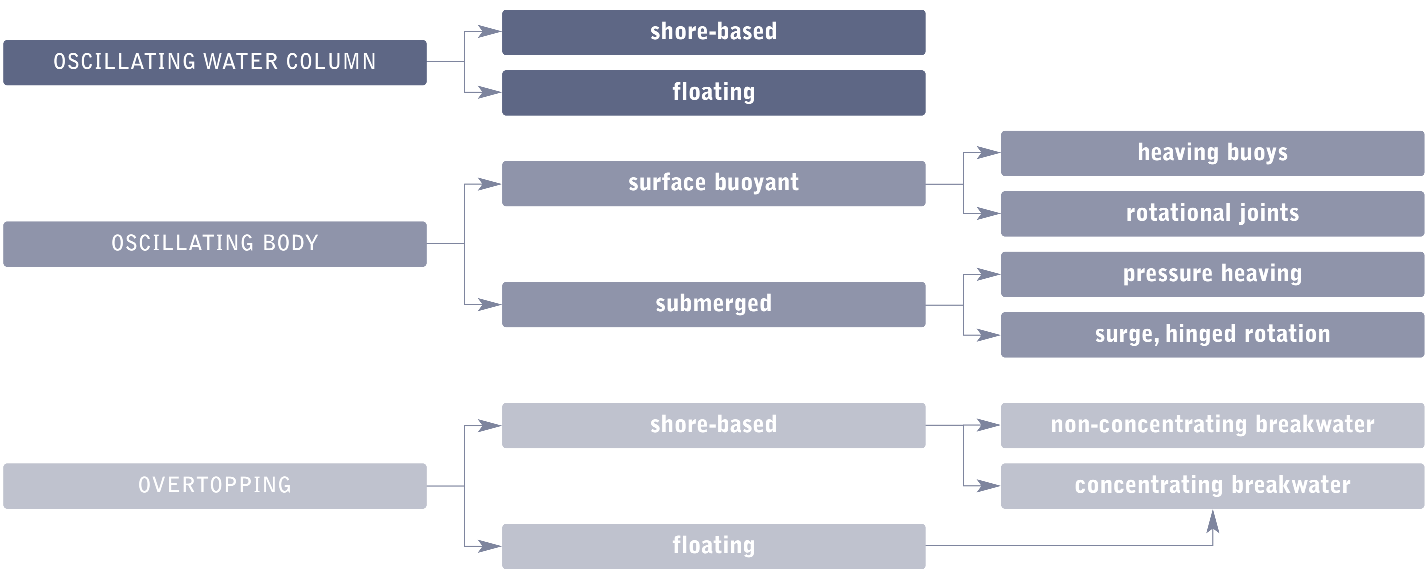
Utility-scale electricity generation from wave energy will require arrays of devices, and like wind turbines, devices are likely to be chosen for specific site conditions. Wave power converters can be made up from connected groups of smaller generator units of 100 – 500 kW, or several mechanical or hydraulically interconnected modules can supply a single larger turbine generator unit of 2 – 20 MW. However, large waves needed to make the technology more cost effective are mostly a long way from shore which would require costly sub-sea cables to transmit the power. The converters themselves also take up large amounts of space.

Wave energy systems may be categorised by their genus, location and principle of operation as shown in Figure 9.15.

Oscillating water columns use wave motion to induce different pressure levels between the air-filled chamber and the atmosphere.[109] Air is pushed at high speed through an air turbine coupled to an electrical generator (Figure 9.16), creating a pulse when the wave advances and recedes, as the air flows in two directions. The air turbine rotates in the same direction, regardless of the flow. A device can be a fixed structure above the breaking waves (cliff-mounted or part of a breakwater), bottom mounted near shore or it can be a floating system moored in deeper waters.

Oscillating-body systems use the incident wave motion to make two bodies move in oscillation; which is then used to drive the power take-off system.[110] They can be surface devices or, more rarely, fully submerged. Surface flotation devices are generally referred to

figure 9.15: wave energy technologies: classification based on principles of operation



source
FALCAO 2009.

references
107 KHAN ET AL., 2009.
108 FALCAO, 2009; KHAN AND BHUYAN, 2009; US DOE, 2010.
109 FALCAO ET AL., 2000; FALCAO, 2009.
110 FALCAO, 2009.

image TESTING THE SCOTRENEWABLES TIDAL TURBINE OFF KIRWALL IN THE ORKNEY ISLANDS.

as 'point absorbers', because they are nondirectional. Some oscillating body devices are fully submerged and rely on oscillating hydrodynamic pressure to extract the wave energy. Lastly, there are hinged devices, which sit on the seabed relatively close to shore and harness the horizontal surge energy of incoming waves.

Overtopping devices: convert wave energy into potential energy by collecting surging waves into a water reservoir at a level above the free water surface.[111] The reservoir drains down through a conventional low-head hydraulic turbine. These systems can float offshore or be incorporated into shorelines or man-made breakwaters (Figure 9.18).

Power take-off systems are used to convert the kinetic energy, air flow or water flow generated by the wave energy device into a useful form, usually electricity. There large number of different options for technology are described in the literature.[112] However, the overall concept is that real-time wave oscillations will produce corresponding electrical power oscillations. In practice, some method of short-term energy storage (durations of seconds) may be needed to smooth energy delivery. These devices would probably deployed in arrays because the cumulative power generated by several devices will be smoother than from a single device.

figure 9.16: oscillating water columns

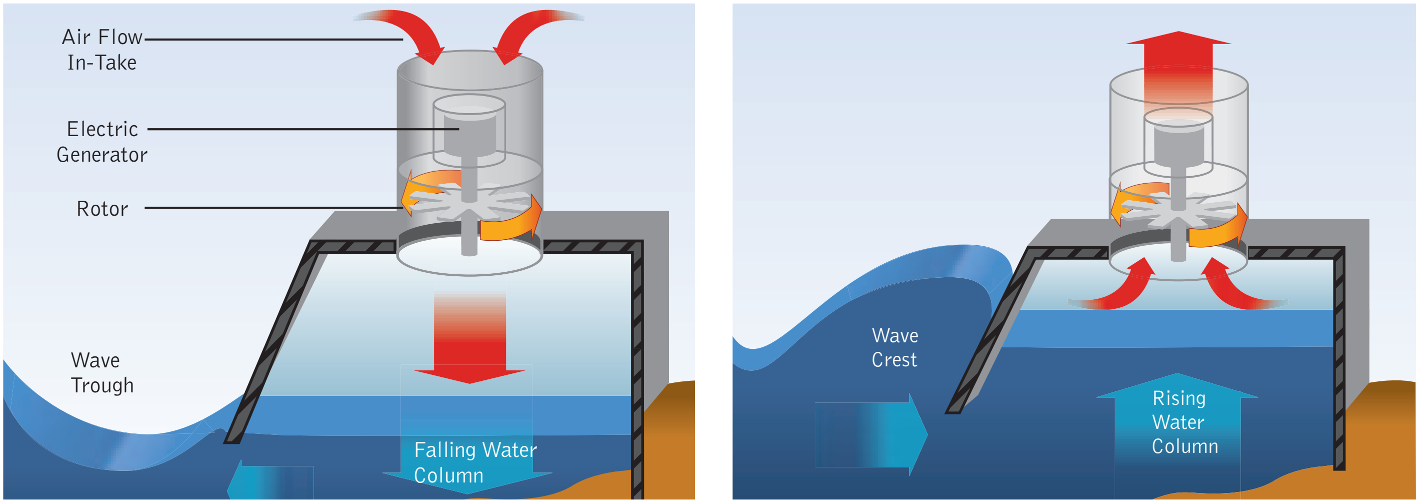


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figure 9.17: oscillating body systems

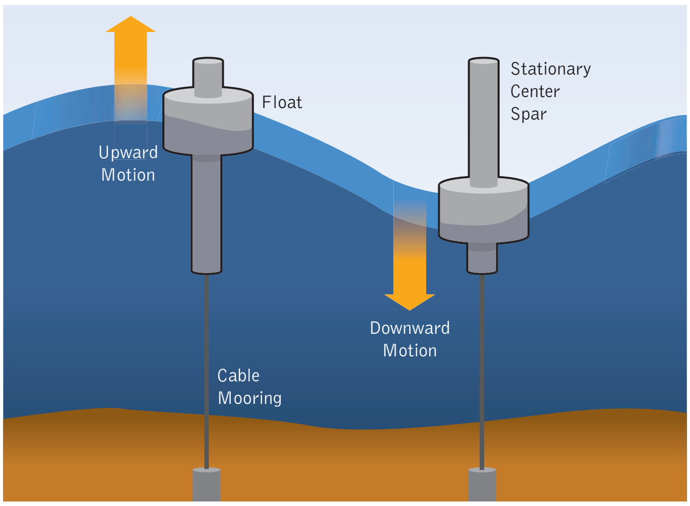

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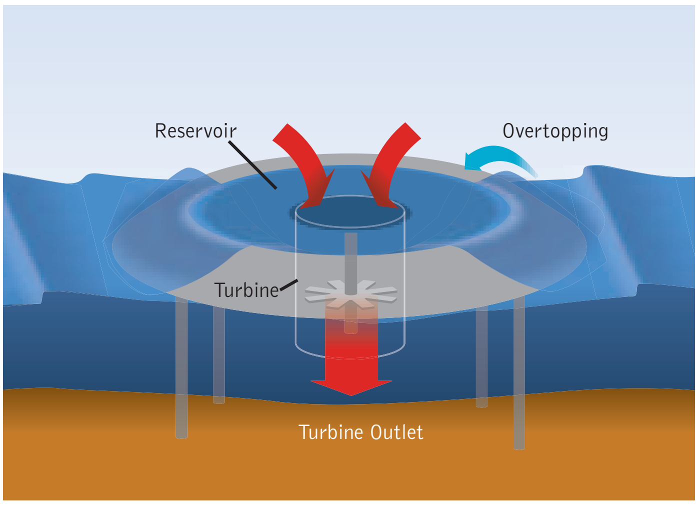
figure 9.18: overtopping devices



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Tidal range

Tidal range hydropower has been tried in estuarine developments where a barrage encloses an estuary, which creates a single reservoir (basin) behind it with conventional low-head hydro turbines in the barrage. Alternative configurations of multiple barrages have been proposed where basins are filled and emptied at different times with turbines located between the basins. Multi-basin schemes may offer more flexible power generation availability than normal schemes, because they could generate power almost continuously.

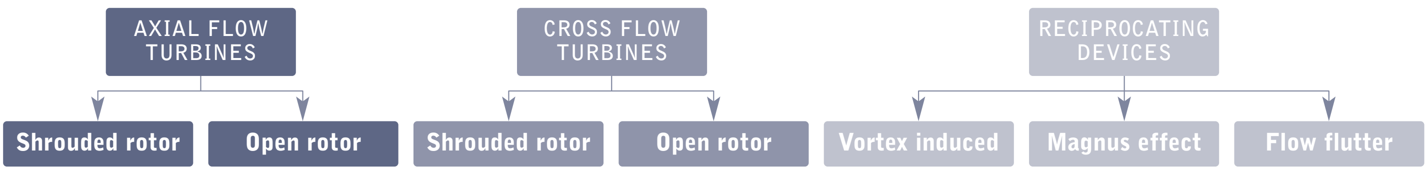
Recent developments focus on single or multiple offshore basins, away from estuaries, called 'tidal lagoons' which could provide more flexible capacity and output with little or no impact on delicate estuarine environments. This technology uses commercially available systems and the conversion mechanism most widely used to produce electricity from tidal range is the bulb-turbine.[113] Examples of power plants with bulb turbines technology include a 240 MW power plant at La Rance in northern France[114] and the 254 MW Sihwa Barrage in the Republic of Korea, which is nearing completion.[115]

Some favourable sites with very gradually sloping coastlines, are well suited to tidal range power plants, such as the Severn Estuary between southwest England and South Wales. Current feasibility studies there include options such as barrages and tidal lagoons. The average capacity factor for tidal power stations has been estimated from 22.5% to 35%.[116]

Tidal and ocean currents

A device can be fitted underwater to a column fixed to the sea bed with a rotor to generate electricity from fast-moving currents, to capture energy from tidal currents. The technologies that extract kinetic energy from tidal and ocean currents are under development, and tidal energy converters the most common to date, designed to generate as the tide travels in both directions. Devices types are, such as axial-flow turbines, cross-flow turbines and reciprocating devices Axial-flow turbines (Figure 9.20 see below) work on a horizontal axis whilst cross-flow turbines may operate about a vertical axis (Figure 9.21 see below) or a horizontal axis with or without a shroud to accentuate the flow. Designs can have multiple turbines on a single device (Figure 9.22).

figure 9.19: classification of current tidal and ocean energy technologies (principles of operation)



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IPCC 2012.

figure 9.20: twin turbine horizontal axis device

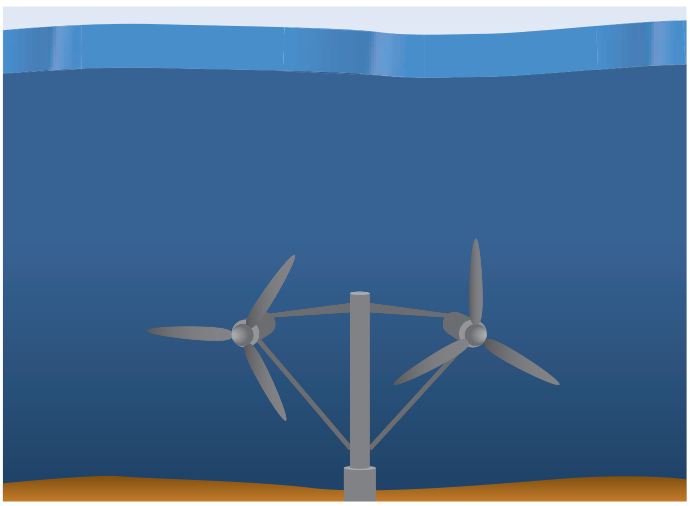

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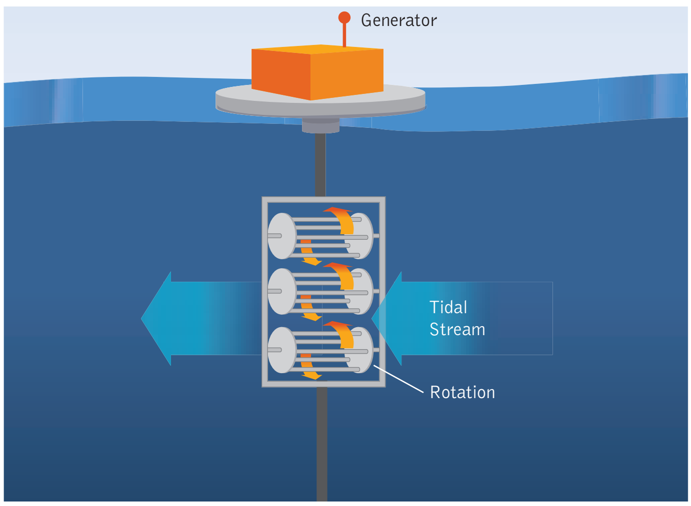
figure 9.21: cross flow device



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113 BOSC, 1997.
114 ANDRE, 1976; DE LALEU, 2009.
115 PAIK, 2008.
116 CHARLIER, 2003; ETSAP 2010B.

image THE PELAMIS WAVE POWER MACHINE IN ORKNEY - ALONGSIDE IN LYNESS - THE MACHINE IS THE P2 . THE PELAMIS ABSORBS THE ENERGY OF OCEAN WAVES AND CONVERTS IT INTO ELECTRICITY. ALL GENERATION SYSTEMS ARE SEALED AND DRY INSIDE THE MACHINES AND POWER IS TRANSMITTED TO SHORE USING STANDARD SUBSEA CABLES AND EQUIPMENT.

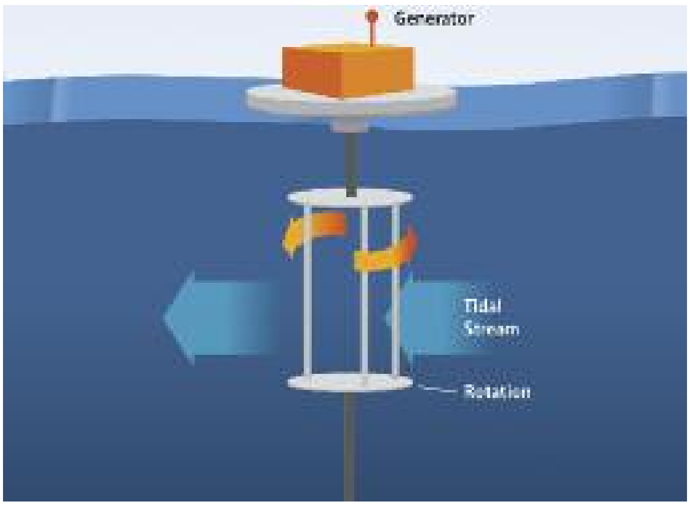
image OCEAN ENERGY.

Marine turbine designs look somewhat like wind turbines but they must contend with reversing flows, cavitation and harsh underwater marine conditions (e.g. salt water corrosion, debris, fouling, etc). Axial flow turbines must be able to respond to reversing flow directions, while cross-flow turbines continue to operate regardless of current flow direction. Rotor shrouds (also known as cowlings or ducts) can enhance hydrodynamic performance by increasing the speed of water through the rotor and reducing losses at the tips. Some technologies in the conceptual stage of development are based on reciprocating devices incorporating hydrofoils or tidal sails. Two prototype oscillating devices have been trialled at open sea locations in the UK.[117]

The development of the tidal current resource will require multiple machines deployed in a similar fashion to a wind farm, and siting will need to take into account wake effects.[118]

Capturing the energy of open-ocean current systems is likely to require the same basic technology as for tidal flows but with some different infrastructure. Deep-water applications may requre neutrally buoyant turbine/generator modules with mooring lines and anchor systems or they could be attached to other structures, such as offshore platforms.[119] These modules will also have hydrodynamic lifting designs to allow optimal and flexible vertical positioning.[120] Systems to capture energy from open ocean current systems may have larger rotors, as there is no restriction based on the channel size.

figure 9.22: vertical axis device



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120 VENEZIA AND HOLT, 1995; RAYE, 2001; VANZWIETEN ET AL., 2005.
121 WEISS ET AL. 2011.

9.3.8 renewable heating and cooling technologies

Renewable heating and cooling has a long tradition in human culture. Heat can come from the sun (solar thermal), the earth (geothermal), ambient heat and plant matter (biomass). Using solar heat for drying processes and or wood stoves for cooking have been done for so long that they labeled "traditional", but today's technologies are far from old-fashioned. Over the last decade there have been improvements to a range of traditional applications many of which are already economical competitive with fossil-fuel based technologies or starting to be.

This chapter presents the current range of renewable heating and cooling technologies and gives a short outlook of the most sophisticated technologies, integrating multiple suppliers and users in heat networks or even across various renewable energy sources in integrated heating and cooling systems. Some of the emerging areas for this technology are building heating and cooling and industrial process heat.

Solar Thermal Technologies

Solar thermal energy has been used for the production of heat for centuries but has become more popular and developed commercially for the last thirty years. Solar thermal collecting systems are based on a centuries-old principle: the sun heats up water contained in a dark vessel.

The technologies on the market now are efficient and highly reliable, providing energy for a wide range of applications in domestic and commercial buildings, swimming pools, for industrial process heat, in cooling and the desalination for drinking water.

Although mature products exist to provide domestic hot water and space heating using solar energy, in most countries they are not yet the norm. A big step towards an Energy [R]evolution is integrating solar thermal technologies into buildings at the design stage or when the heating (and cooling) system is being replaced, lowering the installation cost.

Swimming pool heating: Pools can make simple use of free heating, using unglazed water collectors. They are mostly made of plastic, have no insulation and reach temperatures just a few degrees above ambient temperature. Collectors used for heating swimming pools and are either installed on the ground or on a nearby rooftop and they word by pumping swimming pool water through the collector directly. The size of such a system depends on the size of the pool as well as the seasons in which the pool is used. The collector area needed is about 50 % to 70 % of the pool surface. The average size of an unglazed water collector system installed in Europe is about 200 m^2.[121]

Domestic hot water systems: The major application of solar thermal heating so far is for domestic hot water systems. Depending on the conditions and the system's configuration, most of a building's hot water requirements can be provided by solar energy. Larger systems can additionally cover a substantial part of the energy needed for space heating. Two major collector types are:

Vacuum tubes The absorber inside the vacuum tube absorbs radiation from the sun and heats up the fluid inside. Additional radiation is picked up from the reflector behind the tubes. Whatever the angle of the sun, the round shape of the vacuum tube allows it to reach the absorber. Even on a cloudy day, when the light is coming from many angles at once, the vacuum tube collector can still be effective. Most of the world's installed systems are this type, they are applied in the largest world market - China. This collector type consists of a row of evacuated glass tubes with the absorber placed inside. Due to the evacuated environment there are fewer heat losses. The systems can reach operating temperature levels of at least 120 °C, however, the typical use of this collector type is in the range of 60°C to 80°C. Evacuated tube collectors are more efficient than standard flat-plate collectors but generally also more costly.

Flat plate or flat panel This is basically a box with a glass cover which sits on the roof like a skylight. Inside is a series of copper or aluminium tubes with copper fins attached. The entire structure is coated in a black substance designed to capture the sun's rays. In general, flat plate collectors are not evacuated. They can reach temperatures of about 30°C to 80°C[122] and are the most common collector type in Europe.

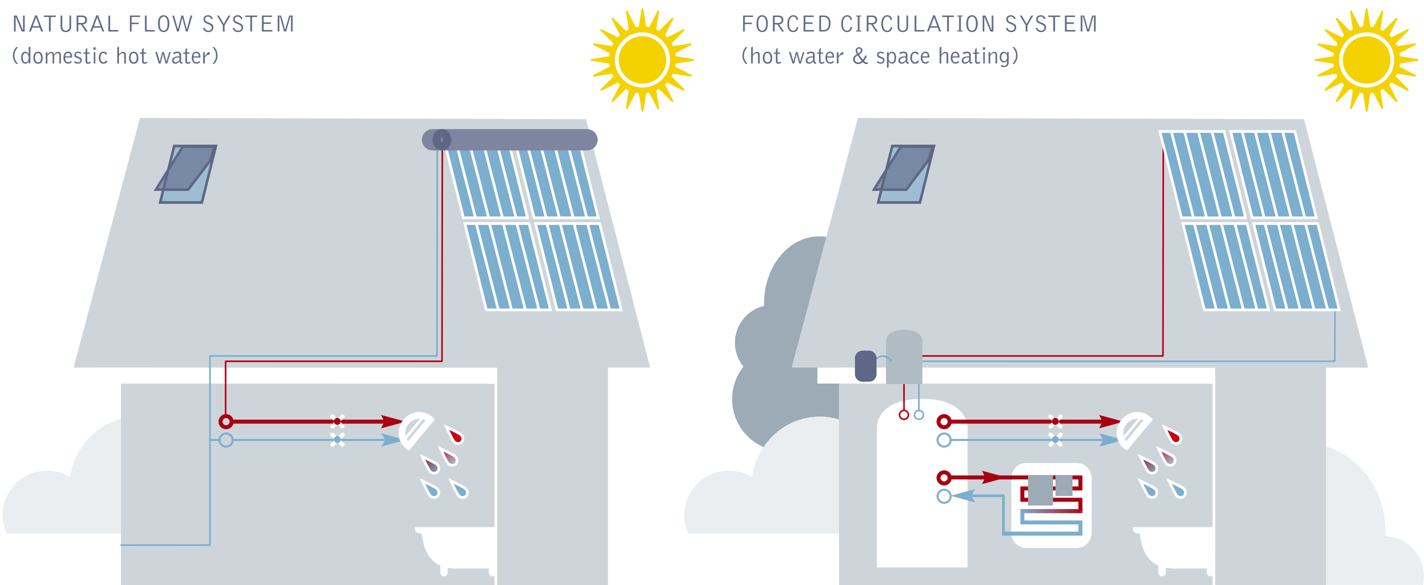
There are two different system types for solar how water, which influence the overall system costs.

Thermosiphon systems The simple form of a thermosiphon solar thermal system uses gravity as a natural way to transfer hot water from the collector to the storage tank. No pump or control station is needed and many are applied as direct systems without a heat exchanger, which reduces system costs. The thermosiphon is relatively compact, making installation and maintenance quite easy. The storage tank of a thermosiphon system is usually applied right above the collector on the rooftop and it is directly exposed to the seasons. These systems are typical in warm climates, due to their lower efficiency compared with forced circulation systems. The most common problems are heat losses and the risk of freeze so they are not suitable for areas where temperatures drop below freezing point. In southern Europe, a system like this is capable of providing almost the total hot water demand of a household. However, the largest market for thermosiphon systems is China. In Europe, thermosiphon solar hot water systems are 95% of private installations in Greece[123], followed by 25% and 15% of newly installed systems in Italy and Spain newly in 2009.[124]

Pumped systems The majority of systems installed in Europe are forced circulation (pumped) systems, which are far more complex and expensive than thermosiphon systems. Typically the storage tank is situated inside the house (for instance in the cellar). An automatic control pump circulates the water between the storage tank and the collector. Forced circulation systems are normally installed with a heat exchanger, which means they have two circuits. They are mostly used in areas with low outside temperatures, and antifreeze additives might have to be added to the solar circuit to protect the water from freezing and destroying the collector.

Even though forced circulation systems are more efficient than thermosiphon systems, they are mostly not capable of supplying the full hot water demand in cold areas and are usually combined with a back-up system, such as heat pumps, pellet heaters or conventional gas or oil boilers. The solar coverage of a system is the share of energy provided by the solar system in relation to total heat consumption, e.g. space heating or hot water. Solar coverage levels depend on the heat demand, the outside temperature and the system design. For hot water production, a solar coverage of 60% in central Europe is common at the current state of technology development. The typical collector area installed for a domestic hot water system in a single family house in the EU 27 is 3-6 m². For multifamily houses and hotels, the size of installations is much bigger, with a typical size of 50 m².[125]

figure 9.23: natural flow systems vs. forced circulation systems



reference
122 WEISS ET AL. 2011.
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image THE SOLAR THERMAL PLANT SET UP BY TRANS SOLAR TECHNOLOGIES, IN COLLABORATION WITH THE HOLY FAMILY HOSPITAL, NEW DELHI. A PERFECT EXAMPLE OF A SMALL SCALE, DECENTRALIZED-RENEWABLE ENERGY PROJECT, THE PLANT SUPPLIES 22,000 LITRES OF HOT WATER EVERYDAY TO THE HOSPITAL FOR ITS VARIOUS NEEDS. SUNNY GEORGE, THE HOSPITAL'S MAINTENANCE OFFICER IS ON THE ROOF.

Domestic heat systems: Besides domestic hot water systems, solar thermal energy for space heating systems is becoming increasingly relevant in European countries. In fact, the EU 27 is the largest market for this application at the moment, with Germany and Austria as the main driving forces. The collectors used for this area of operation are the same as for domestic hot water systems, however, for solar space heating purposes, only pumped systems are applicable. Effectively most systems used are so called combi-systems that provide space as well as water heating.

So far the majority of installations are applied to single-family houses with a typical system size between 6 and 16 m^2 and a typical annual solar coverage of 25 % in central Europe.[126]

Solar combi-systems for multiple family houses are not yet used very frequently. These systems are about 50 m^2, cost approximately 470-550 €/m^2 and an have annual solar coverage of 25% in central Europe.[127] Large scale solar thermal applications that are connected to a local or district heating grid with a collector area above 500 m^2 are not so common. However, since 1985, system installation rates have increased in the EU with a typical annual solar coverage of 15% in central Europe.[128] To get a significant solar share a large storage needs to be applied. The typical solar coverage of such a system including storage is around 50% today. With seasonal storage the coverage may be increased to about 80%.[129] Another option for domestic heating systems is air collector systems which are not explicitly described here. The largest market for air collectors are in North America and Asia, and have a very small penetration to the European market though it has been increasing in recent years.

Process heat: Solar thermal use for industrial process heat is receiving some attention for development, although it is hardly in use today. Standardised systems are not available because industrial processes are often individually designed. Also solar thermal applications are mostly not capable of providing 100% of the heat required over a year, so another non-solar heat source would be necessary for commercial use.

Depending on the temperature level needed, different collectors have been developed to serve the requirements for process heat. Flat plates or evacuated tube collectors provide a temperature range up to 80 °C a and a large number are available on the market. For temperatures between 80°C and 120°C advanced flat-plate collectors are available e.g. with multiple glassing, antireflective coating, evacuated or using an inert gas filling. Other options are flat-plate and evacuated tube collectors with compound parabolic concentrators. These collectors can be stationary and are generally constructed to concentrate solar radiation by a factor of 1 to 2. They can use most of the diffuse radiation which makes them especially attractive for areas with low direct solar radiation.

There are a few conceptual designs to reach higher temperatures between 80°C and 180°C, primarily using a parabolic trough or linear concentrating Fresnel collectors.[130] These collector types have a higher concentration factor than CPC collectors, are only capable of using direct solar radiation and have to be combined with sun tracking systems. The collectors especially designed for heat use are most suitable for a temperature range between 150°C and 250°C.[131] Air collector systems for process heat are limited to lower temperatures, being mostly used for to drying purposes (e.g. hay) and are not discussed here.

Cooling: Solar chillers use thermal energy to produce cooling and/or dehumidify the air in a similar way to a refrigerator or conventional air-conditioning. This application is well-suited to solar thermal energy, as the demand for cooling is often greatest when there is most sunshine. Solar cooling has been successfully demonstrated and large-scale use can be expected in the future, but is still not widely used.

The option to use solar heat this way makes sense because hot regions require more cooling for comfort. Solar thermal cooling is mostly designed as a closed-loop sorption system (see box 9.3). The most common application, however, is a solar absorption cooling unit. The system requires temperatures above 80°C which requires evacuated tube collectors, advanced flat-plate collectors and compound parabolic concentrators. The solar field required for a cooling unit is about 4 m^2 per kW of cooling capacity.

reference
125 WEISS ET AL. 2011; NITSCH ET AL. 2010; JAGER ET AL. 2011.
126 WEISS ET AL. 2011; NITSCH ET AL. 2010; JAGER ET AL. 2011.
127 WEISS ET AL. 2011; NITSCH ET AL. 2010; JAGER ET AL. 2011.
128 WEISS ET AL. 2011; NITSCH ET AL. 2010; JAGER ET AL. 2011.
129 NITSCH ET AL. 2010.
130 THESE COLLECTOR TYPES ARE PRIMARILY USED IN SOLAR THERMAL POWER PLANTS AND REACH TEMPERATURE LEVELS AROUND 400°C. FOR THE SEGMENT OF PROCESS HEAT THESE COLLECTOR TYPES WHERE DEVELOPED FURTHER TO MEET THE SPECIFIC REQUIREMENTS OF THIS SEGMENT WITH TEMPERATURE LEVELS UP TO 250°C.
131 WEISS ET AL. 2011; NITSCH ET AL. 2010; JAGER ET AL. 2011.

box 9.3: sorption cooling units

A thermo-chemical refrigerant cycle (sorption) provides cold by either ab- or adsorption cooling. Absorption occurs when a gaseous or liquid substance is taken up by another substance, e.g. the solution of a gas in a liquid. Adsorption takes place when a liquid or gaseous substance is bound to the surface of a solid material.

The absorption cooling circle can be described as follows: A liquid refrigerant with a very low boiling point is vaporised at low pressure withdrawing heat from its environment and therefore providing the desired cool. The gaseous refrigerant is then absorbed by a liquid solvent, mostly water. The refrigerant and solvent are separated again by adding (renewable) heat to the system, making use of the different boiling points. The gaseous refrigerant is now condensed, released and returned to the beginning of the process. The heat, which is needed in the process, can be provided e.g. by firing natural gas, combined heat and power plants or solar thermal collectors.

9.3.9 geothermal, hydrothermal and aerothermal energy

The three categories of environmental heat are geothermal, hydrothermal and aerothermal energy. Geothermal energy is the energy stored in the Earth's crust, i.e. in rock and subsurface fluids. The main source of geothermal energy is the internal heat flow from the Earth's mantle and core into the crust, which itself is replenished mainly by heat from the decay of radioactive isotopes. At depths of a few meters, the soil is also warmed by the atmosphere. Geothermal energy is available all year round, 24 hours a day and is independent from climatic conditions. Hydrothermal energy is the energy stored in surface waters - rivers, lakes, and the sea. Hydrothermal energy is available permanently at temperature level similar to that of shallow geothermal energy. Aerothermal energy is the thermal energy stored in the Earth's atmosphere, which originally comes from the sun, but has been buffered by the atmosphere. Aerothermal energy is available uninterruptedly, albeit with variations in energy content due to climatic and regional differences.

Deep geothermal energy (geothermal reservoirs)

On average, the crust's temperature increases by 25-30°C per km, reaching around 100°C at 3 km depth in most regions of the world. High temperature fields with that reach over 180°C can be found at this depth in areas with volcanic activity. "Deep geothermal reservoirs" generally refer to geothermal reservoirs more than 400m depth, where reservoir temperatures typically exceed 50°C. Depending on reservoir temperature, deep geothermal energy is used to generate electricity and/or to supply hot water for various thermal applications, e.g. for district heat, balneology etc. Temperatures in geothermal reservoirs less that 400m deep are typically below 30°C which is too low for most direct use applications or electricity production. In these shallow fields, heat pumps are applied to increase the temperature level of the heat extracted from shallow geothermal reservoirs.

The use of geothermal energy for heating purposes or for the generation of electricity depends on the availability of steam or hot water as a heat transfer medium. In hydrothermal systems, hot water or water vapour can be tapped directly from the reservoir. Technologies to exploit hydrothermal systems are already well established and are in operation in many parts of the world. However, the there is limited availability of aquifers with sufficient temperature and water production rate at favourable depth. In Europe, high temperature (above 180°C) hydrothermal reservoirs, generally containing steam, are found in Iceland and Italy.

Hydrothermal systems with aquifer lowers temperatures (below 180°C) can also be used to produce electricity and heat in other regions. They contain warm water or a water-steam mixture. In contrast to hydrothermal systems, EGS systems do not require a hot aquifer; the heat carrier is the rock itself. They can thus virtually found everywhere. The natural permeability of these reservoirs generally does not allow a sufficient water flow from the injection to the production well, so energy projects require the artificial injection of water into the reservoir, which they do by fracturing rock underground. Water is injected from the surface into the reservoir, where the surrounding rock acts as a heat exchanger. The heated water is pumped back to the surface to supply a power plant or a heating network. While enhanced geothermal systems promise large potentials both for electricity generation and direct use, they are still in the pre-commercialisation phase.

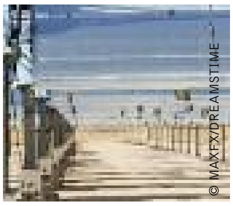
Direct use of geothermal energy

(Deep) geothermal heat from aquifers or deep reservoirs can be used directly in hydrothermal heating plants to supply heat demand nearby or in a district heating network. Networks provide space heat, hot water in households and health facilities or low temperature process heat (industry, agriculture and services). In the surface unit, hot water from the production well is either directly fed into a heat distribution network ("open loop system"). Alternatively, heat is transferred from the geothermal fluid to a secondary heat distribution network via heat exchangers ("closed loop system"). Heating network temperatures are typically in the range 60-100°C. However, higher temperatures are possible if wet or dry steam reservoirs are exploited or if heat pumps are switched into the heat distribution circuit. In these cases, geothermal energy may also supply process heat applications which require temperatures above 100°C.

Alternatively, deep borehole heat exchangers can exploit the relatively high temperature at depths between 300 and 3,000m (20 – 110°C) by circulating a working fluid in a borehole in a heat exchanger between the surface and the depth. Heat pumps can be used to increase the temperature of the useful heat, if required. The overall efficiency of geothermal heat use can be raised if several thermal direct-use applications with successive lower temperature levels are connected in series (concept of

image CONCENTRATING SOLAR POWER (CSP).

image HOUSEHOLD HEAT PUMP CONNECTED TO A SHALLOW BOREHOLE HEAT EXCHANGER IN SWEDEN.



cascaded use). For example, dry steam at 250°C can be fed to a cogeneration plant for electricity, the co-generated heat then fed into a district heating network at 80°C, and the waste heat at 40°C used to warm fishing ponds. The main costs for deep geothermal projects are in drilling.

Simultaneous production of electricity and heat

In many cases, geothermal power plants also produce heat to supply a district heating network. There are two different options for using heat; one where the geothermal fluid is separated into two streams which are separately used either for power production or to feed the heat network. Alternatively, a heat exchanger transfers thermal energy from the geothermal fluid to the working fluid which feeds the turbines. After the heat exchange process, the leftover heat from the geothermal fluid can be used for heating purposes. In both cases, after the electricity production in the turbines waste heat is not captured as it is for cogeneration (CHP), but released into the environment.

Heat pump technology

Heat pumps use the refrigeration cycle to provide heating, cooling and sanitary hot water. They employ renewable energy from ground, water and air to move heat from a relatively low temperature reservoir (the "source") to the temperature level of the desired thermal application (the "output"). Heat pumps commonly use two types of refrigeration cycles:

- Compression heat pumps use mechanical energy, most commonly electric motors or combustion engines to drive the compressor in the unit. Consequently, electricity, gas or oil is used as auxiliary energy.
- Thermally-driven heat pumps use thermal energy to drive the sorption process - either adsorption or absorption - to make ambient heat useful. Different energy sources can be used as auxiliary energy: waste energy, biomass, solar thermal energy or conventional fuels.

Compression heat pump are most commonly used today, however thermally driven units are seen as a promising future technology.

The "efficiency" of a heat pump is described by the seasonal performance factor (SPF) - the ratio between the annual useful heat output and the annual auxiliary energy consumption of the unit. In the residential market, heat pumps work best for relatively warm heat sources and low-temperature applications such as space heating and sanitary hot water. They are less efficient for providing higher temperature heat and can't be used for heat over 90°C. For industrial applications, different refrigerants can be used to provide heat from 80°C to 90°C efficiently, so they are only suitable for part of the energy requirements of industry.

Heat pumps are generally distinguished by the heat source they exploit:

- Ground source heat pumps use the energy stored in the ground at depths from around hundred meter to the surface, they are used for deep borehole heat exchangers (300 – 3,000m), shallow borehole heat exchangers (50-250m) and horizontal borehole heat exchangers (a few meters deep).
- Water source heat pumps are coupled to a (relatively warm) water reservoir of around 10°C, e.g. wells, ponds, rivers, the sea.
- Aerothermal heat pumps use the outside air as heat source. As outside temperatures during the heating period are generally lower than soil and water temperature, ground source and water source heat pumps typically more efficient than aerothermal heat pumps.

figure 9.24: examples for heat pump systems

LEFT: AIR SOURCE HEAT PUMP, MIDDLE: GROUND SOURCE HEAT PUMP WITH HORIZONTAL COLLECTOR, RIGHT: WATER SOURCE HEAT PUMP (OPEN LOOP SYSTEM WITH TWO WELLS)

source
© GERMAN HEAT PUMP ASSOCIATION (BWP).

Heat pumps require additional energy apart from the environmental heat extracted from the heat source, so their environmental benefit depends on both their efficiency and the emissions related to the production of the working energy. Where the heat pump technology has low SPF and a high share of electricity from coal power plants, for example, carbon dioxide emissions relative to useful heat production might higher than conventional gas condensing boilers. On the other hand, efficient heat pumps powered with "green" electricity are 100% emission-free solutions that contribute significantly to the reduction of greenhouse gas emissions when used in place of fossil-fuel fired heating systems.

box 9.4: typical heat pump specifications

Usually provide hot water or space heat at lower temperatures, around 35°C

Example uses: underfloor/wall heating

Typical size for space heating a single family house purposes: approx 5-10 kWth

Typical size for space heating a large office building: >100 kWth.

Aerothermal heat pumps do not require drilling which significantly reduces system costs compared to other types.

If waste heat from fossil fuel fired processes is used as heat source for this technology, the heat provided cannot be classified as "renewable" - it becomes merely an efficient way of making better use of energy otherwise wasted.

Heat pumps for cooling

Reversible heat pumps can be operated both in heating and in cooling mode. When running in cooling mode in summer, heat is extracted from the building and "pumped" into the underground reservoir which is then heated. In this way, the temperature of the warm reservoir in the ground is restored after its exploitation in winter.

Alternatively, renewable cooling could be provided by circulating a cooling fluid through the relatively cool ground before being distributed in a building's heating/cooling system ("free cooling"). However this cooling fluid must not be based on chemicals that are damaging to the upper atmosphere such as HFC's (a strong greenhouse gas) or CFC's (ozone-depleting gas).

In principle, high enthalpy geothermal heat might provide the energy needed to drive an absorption chiller (see Box 9.3: Sorption cooling units). However, only a very limited number of geothermal absorption chillers are in operation world-wide.

box 9.5: district heat networks

Heat networks are preferably used in populated areas such as large cities. Their advantages include reduction of local emissions, higher efficiency (in particular with cogeneration), or a lesser need for infrastructures that go along with individual heating solutions. Generally heat from all sources can be used in heat networks. However, there are some applications like cogeneration technologies that have a special need for a secure heat demand provided by heat networks to be able to operate economically.

Managing the variations in heat supply and demand is vital for high shares of renewables, which is more challenging for space heat and hot water than for electricity. Heat networks help even out peaks in demand by connecting a large number of clients, and supply can be adjusted by tapping various renewable sources and relatively cheap storage options. The use of an existing heat network for renewable heat depends on the competitiveness of the new heat applications or plants. The development of new grids however is not an easy task.

The relevant factors to assess whether a new heat network is economically competitive compared to other heating or cooling options are:

- Heat density (heat demand per area) of building infrastructure, depending on housing density and the specific heat demand of the buildings
- Obligation to connect to the network (leads to higher effective heat density)
- Existing buildings' infrastructure or newly developed areas, where grid installation can be integrated in building site preparation
- Existence of competing infrastructures such as gas grids
- Size of the heat network and distance to the remotest client

The combination and interdependence of these factors mean the costs of a heat network are highly variable and project-specific so no general indication of investment cost can be made. A German example in 2009 was the development of heat networks under the market incentive program which had average investment costs (including building connection) in the range of 350 to 460 €/kW.

image BIOMASS ENERGY PLANT NEAR VARNAMO, SMÅLAND, SWEDEN.

9.3.10 biomass heating technologies

There is a broad portfolio of technologies for heat production available from biomass, a traditional fuel source. A need for more sustainable energy supply has lead to the development of modern biomass technologies. A high variety of new or modernised technologies or technology combinations can serve space and warm water needs but eventually also provide process heat even for industrial processes.

Biomass can provide a large temperature range of heat and can be transported over long distances, which is an advantage compared to solar thermal or geothermal heat. However, sustainable biomass imposes limits on volume and transport distance. Another disadvantage of bioenergy is the production of exhaust emissions and the risk of greenhouse gas emissions from energy crop cultivation.

These facts lead to two approaches to biomass development:

- Towards improved, relatively small-scale, decentralised systems for space heat and hot water.
- Development of various highly efficient and upgraded biomass cogeneration systems for industry and district heating.

Small applications for space heat and hot water in buildings

In the residential sector, the traditional applications of biomass technologies have been strongly improved over the last decades for efficient and comfortable space heating and warm water supply. The standard application is direct combustion of solid biomass (wood), for example in familiar but improved wood log stoves that supply single rooms. For average single homes and small apartment houses, log wood or pellet boilers are an option to provide space heat and hot water. Wood is easy to handle and a standardized quality and the pellet systems can be automated along the whole chain, meaning that operation activities can be reduced to a few times a year. Automatically-fed systems are more easily adaptable to variations in heat demand e.g. between summer and winter. Another advantage is lower emissions of air pollutants from pellet appliances compared to log wood.[132] Pellet heating systems are gaining importance in Europe.

Handfed systems are common for smaller applications below 50 kW. Small applications for single rooms (around 5kW capacity) are usually hand fed wood stoves with rather low efficiency and low costs. Technologies are available for central heating in single and semi-detached houses and are also an option for apartment houses. Wood boilers provide better combustion with operating efficiencies of 70-85% and fewer emissions than stoves with a typical sizes of 10-50 kW.[133] Larger wood boilers can heat large buildings such as apartment blocks, office buildings or other large buildings in service, commerce and industry with space heat and hot water.

Direct heating technologies: Large applications for district or process heat rely on automatic feeding technologies, due to constant heat demand at a defined temperature. Direct combustion of biomass can provide temperatures up to 1,000°C, with higher temperatures for wood and lower temperatures e.g. for straw. Automatically fed appliances are available for wood chips and pellets as well as for straw. Three combustion types, after Kaltschmitt et al. 2009 are:

Cogeneration technologies Cogeneration increases the efficiency of using biomass, if the provided heat can be used efficiently. The size of a plant is limited due to the lower energy content of biomass compared to fossil fuels and resulting difficulties in the fuel logistics. Selection of the appropriate cogeneration technology depends on the available biomass. In several Scandinavian countries – with an extraordinarily high potential of forest biomass - solid biomass is already a main fuel for cogeneration processes. Finland derives already over 30% and Sweden even 70% of its co-generated -electricity from biomass.[134]

Direct combustion technologies The cogeneration processes can be based on direct combustion types (fixed bed combustion, fluidised bed combustion, pulverised fuel combustion). While steam engines are available from 50 kWel, steam turbines normally cover the range above 2 MWel, with special applications available from 0.5 MWel. The heat is typically generated at 60- 70% efficiency depending on the efficiency of the power production process, which in total can add up to 90%.[135] Thus, small and medium cogeneration plants provide three to five times more heat than power, with local heat demand often being the limiting factor for the plant size.

Upgraded biomass Besides direct combustion, there are various conversion technologies use to upgrade biomass products for use in specific applications and for higher temperatures. Common currently available technologies are (upgraded) biogas production and gasification, and other technologies like pyrolysis and production of synthetic gases or oils are under development.

Gasification is especially valuable in the case of biomass with low caloric value or when it includes moisture. Partial oxidation of the biomass fuel provides a combustible gas mixture mainly consisting of carbon monoxide (CO). Gasification can provide higher efficiency along the whole biomass chain, however at the expense of additional investments for the more sophisticated technology. There are many different gasification systems based on varying fuel input, gasification technology and combination with gas turbines. Available literature shows a large cost range for gasification cogeneration plants. Assumptions on costs of the gasification processes vary strongly.

reference

132 GEMIS 2011.
133 NITSCH ET AL. 2010; GEMIS 2011; AEBIOM 2011B.
134 THESE COLLECTOR TYPES ARE PRIMARILY USED IN SOLAR THERMAL POWER PLANTS AND REACH TEMPERATURE LEVELS AROUND 400°C. FOR THE SEGMENT OF PROCESS HEAT THESE COLLECTOR TYPES WHERE DEVELOPED FURTHER TO MEET THE SPECIFIC REQUIREMENTS OF THIS SEGMENT WITH TEMPERATURE LEVELS UP TO 250°C.
135 IBID.

Other upgrading processes are biogas upgrading for feed-in to the natural gas grid or the production of liquid biomass, such as plant oil, ethanol or second generation fuels. Those technologies can be easily exchangeable with fossil fuels, but the low efficiency of the overall process and energy input needed to produce energy crops are disadvantages for sustainability.

Biogas

Biogas plants use anaerobic digestion of bacteria for conversion of various biomass substrates into biogas. This gas mainly consists of methane, a gas of high caloric value, CO_2 and water. Anaerobic digestion can be used to upgrade organic matter with low energy density, such as organic waste and manure. These substrates usually contain large water contents and appear liquid. "Dry" substrates need additional water.

Liquid residues like wastes and excrements would be energetically unused and biogas taps into their calorific potential. The residue of the digestion process is used as a fertiliser, which has higher availability of nitrogen and is more valuable than the input substrates.[139]

Methane is a strong greenhouse gas, so biogas plants need airtight covers for the digestate, to maintain low emissions.[137] Residues and wastes are preferable for biogas compared with energy crops such as corn silage which require energy and fertilizer inputs while growing which themselves create greenhouse gas emissions.

Biogas plants usually consist of a digester for biogas production and a cogeneration plant. Planst are range of sizes and are normally fed by a mixture of substrates for example manure mixed with maize silage, grass silage, other energy crops and/or organic wastes.[138]

Normally biogas is normally used in cogeneration. In Germany, the feed-in tariff means biogas production currently is mostly for power and the majority of biogas plants are on farms in rural areas. Small biogas plants often use the produced heat for local space heating or to provide process heat e.g. for drying processes. Larger biogas plants need access to a heat network to make good use of all the available heat. However, network access is often not available in rural areas so there is still untapped potential of heat consumption from biogas. Monitoring of German biogas plants showed that 50% of available heat was actually wasted.[139] The conditioning and enriching of biogas and subsequent feed in into the gas grid has been promoted lately and should become an option to use biogas directly at the location of heat demand.

Upgrading technologies for biomass do bear the risk of additional methane emissions so tight emission standards are necessary to achieve real reductions in greenhouse gas emissions.[140]

9.3.11 storage technologies

As the share of electricity provided by renewable sources increases around the world the technologies and policies required to handle their variability is also advancing. Along with the grid-related and forecasting solutions discussed in Chapter 3, energy storage is a key part of the Energy [R]evolution.

Once the share of electricity from variable renewable sources exceeds 30-35%, energy storage is necessary in order to compensate for generation shortages or to store possible surplus electricity generated during windy and sunny periods. Today storage technology is available for different stages of development, scales of projects, and for meeting both short- and long-term energy storage needs. Short-term storage technologies can compensate for output fluctuations that last only a few hours, whereas longer term or seasonal storage technologies can bridge the gap over several weeks.

Short-term options include batteries, flywheels, compressed air power plants and pump storage power stations with high efficiency factors. The later is also used for long term storage. Perhaps the most promising of these options is electric vehicles (EVs) with Vehicle-to-Grid (V2G) capability, which can increase flexibility of the power system by charging when there is surplus renewable generation and discharging while parked to take up peaking capacity or ancillary services to the power system. Vehicles are often parked close to main load centres during peak times (e.g., outside factories) so there would be no network issues. However battery costs are currently very high and significant logistical challenges remain.

Seasonal storage technologies include hydro pumped storage and the production of hydrogen or renewable methane. While the latter two options are currently in the development with several demonstration projects mainly in Germany, pumped storage has been in use around the world for more than a century.

reference
136 KALTSCHMITT ET AL. 2009.
137 PEHNT ET AL. 2007.
138 IEA 2007; NITSCH ET AL. 2010.
139 DBFZ 2010.
140 GÄRTNER ET AL. 2008.

image BIOMASS.

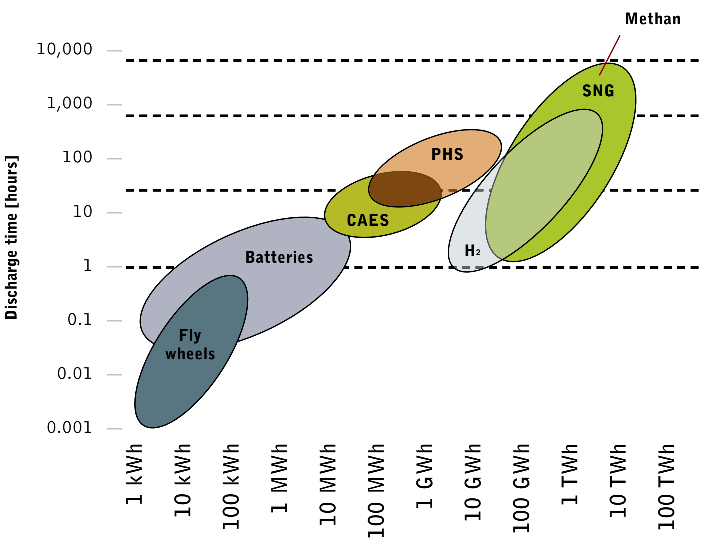
image A VILLAGER NAGARATHNAMMA LOADING THE BIOGAS UNIT WITH A MIXTURE OF COW DUNG AND WATER. THE COMMUNITY IN BAGEPALLI HAS PIONEERED THE USE OF RENEWABLE ENERGY IN ITS DAILY LIFE THANKS TO THE BIOGAS CLEAN DEVELOPMENT MECHANISM (CDM) PROJECT STARTED IN 2006.

Pumped Storage

Pumped Storage Pumped storage is the largest-capacity form of grid energy storage now available and currently the most important technology to manage high shares of wind and solar electricity. It is a type of hydroelectric power generation[141] that stores energy by pumping water from a lower elevation reservoir to a higher elevation during times of low-cost, off-peak electricity and releasing it through turbines during high demand periods. While pumped storage is currently the most cost-effective means of storing large amounts of electrical energy on an operating basis, capital costs and appropriate geography are critical decision factors in building new infrastructure. Losses associated with the pumping and water storage process make such plants net consumers of energy; accounting for evaporation and conversion losses, approximately 70-85% of the electrical energy used to pump water into the elevated reservoir can be recaptured when it is released.

Renewable Methane Both gas plants and cogeneration units can be converted to operate on renewable methane, which can be made from renewable electricity and used to effectively store energy from the sun and wind. Renewable methane can be stored and transported via existing natural gas infrastructure, and can supply electricity when needed. Gas storage capacities can close electricity supply gaps of up to two months, and the smart link between power grid and gas network can allow for grid stabilisation. Expanding local heat networks, in connection with power grids or gas networks, would enable the electricity stored as methane to be used in cogeneration units with high overall efficiency factors, providing both heat and power.[142] There are currently several pilot projects in Germany in the range of one to two- Megawatt size, but not in a larger commercial scale yet. If those pilot projects are successful, a commercial scale can be expected between 2015 and 2020. However, policy support, to encourage the commercialisation of storage is still lacking.

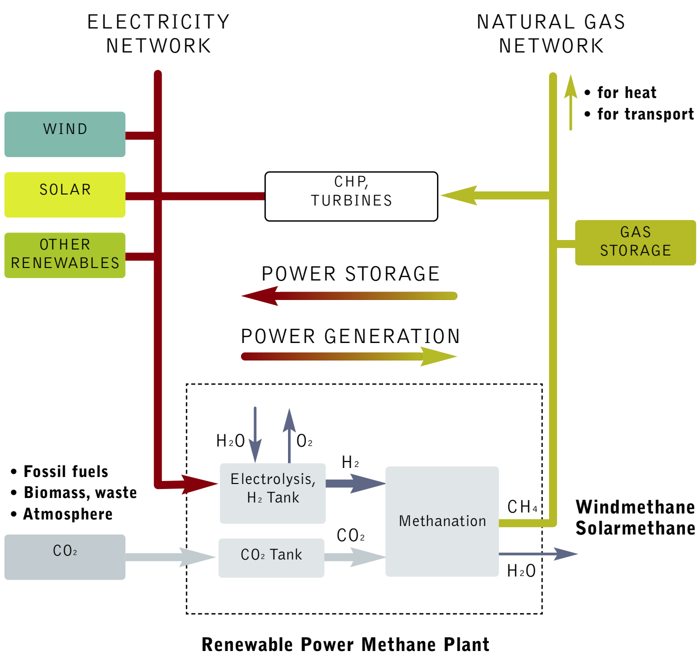
figure 9.25: overview storage capacity of different energy storage systems



source
FRAUNHOFER INSTITUT, 2010.

figure 9.26: renewable (power) (to) methane - renewable gas

STORING RENEWABLE POWER AS RENEWABLE AS NATURAL GAS BY LINKING ELECTRICITY AND NATURAL GAS NETWORKS



source
IWES ZSW.

references

141 CONVENTIONAL HYDROELECTRIC PLANTS THAT HAVE SIGNIFICANT STORAGE CAPACITY MAY BE ABLE TO PLAY A SIMILAR ROLE IN THE ELECTRICAL GRID AS PUMPED STORAGE, BY DEFERRING OUTPUT UNTIL NEEDED.

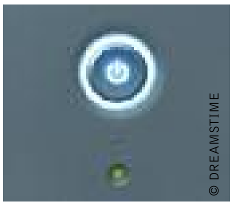
142 FRAUNHOFER IWS, ERNEUERBARES METHAN KOPPLUNG VON STROM- UND GASNETZ M.SC. MAREIKE JENTSCH, DR. MICHAEL STERNER (IWES), DR. MICHAEL SPECHT (ZSW), TU CHEMNITZ, SPEICHERWORKSHOP CHEMNITZ, 28.10.2010.

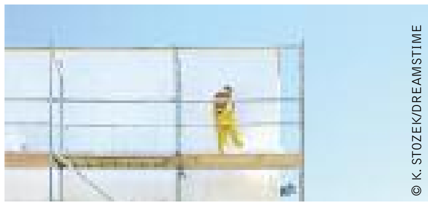
energy efficiency – more with less

image THE SUNDARBANS OF INDIA AND BANGLADESH IS THE LARGEST REMAINING TRACT OF MANGROVE FOREST IN THE WORLD. A TAPESTRY OF WATERWAYS, MUDFLATS, AND FORESTED ISLANDS AT THE EDGE OF THE BAY OF BENGAL. HOME TO THE ENDANGERED BENGAL TIGER, SHARKS, CROCODILES, AND FRESHWATER DOLPHINS, AS WELL AS NEARLY TWO HUNDRED BIRD SPECIES, THIS LOW-LYING PLAIN IS PART OF THE MOUTHS OF THE GANGES. THE AREA HAS BEEN PROTECTED FOR DECADES BY THE TWO COUNTRIES AS A NATIONAL PARK.

image STANDBY.

image WORK TEAM APPLYING STYROFOAM WALL INSULATION TO A NEWLY CONSTRUCTED BUILDING.





Using energy efficiently is cheaper than producing new energy from scratch and often has many other benefits. An efficient clothes washing machine or dishwasher, for example, uses less power and saves water too. Efficiency in buildings doesn't mean going without – it should provide a higher level of comfort. A well-insulated house, will feel warmer in the winter, cooler in the summer and be healthier to live in. An efficient refrigerator is quieter, has no frost inside, no condensation outside and will probably last longer. Efficient lighting offers more light where you need it. Efficiency is thus really better described as 'more with less'.

There are very simple steps to efficiency both at home and in business, through updating or replacing separate systems or appliances, that will save both money and energy. But the biggest savings don't come from incremental steps but from rethinking the whole concept - 'the whole house', 'the whole car' or even 'the whole transport system'. In this way, energy needs can often be cut back by four to ten times.

In order to find out the global and regional energy efficiency potential, the Dutch institute Ecofys developed energy demand scenarios for the Greenpeace Energy [R]evolution analysis in 2008, which have now been updated by the Utrecht University for the 2012 model. These scenarios cover energy demand over the period 2009-2050 for ten world regions. In contrast to the Reference scenario, based on the IEA World Energy Outlook 2011 (WEO 2011), a low energy demand scenario for energy efficiency improvements has been defined. In this edition, the transport sector has been separated from the stationary energy research. The efficiency scenario is based on the best technical energy efficiency potentials and takes into account into account implementation constraints including costs and other barriers. This scenario is called 'ER' and has been compared to the IEA's 450ppm scenario – published in the WEO 2011. The main results of the study are summarised below.

10.1 methodology for the energy demand projections

This section explains the methodology for developing the energy demand projections. The approach includes two steps:

1. Definition of reference energy demand
2. Development of low energy demand scenarios including potentials for energy-efficiency improvement

Step 1: definition of reference scenario

In order to estimate potentials for energy-efficiency improvement in 2050 a detailed reference scenario is required that projects the development of energy demand when current trends continue. In the Reference scenario – the World Energy Outlook 2011 "Current policy"[143] only currently adopted energy and climate change policies are implemented. Technological change including efficiency improvement is slow but substantial and mainly triggered by increased energy prices.[144] The Reference scenario covers energy demand development in the period 2009-2050 for ten world regions and three sectors:

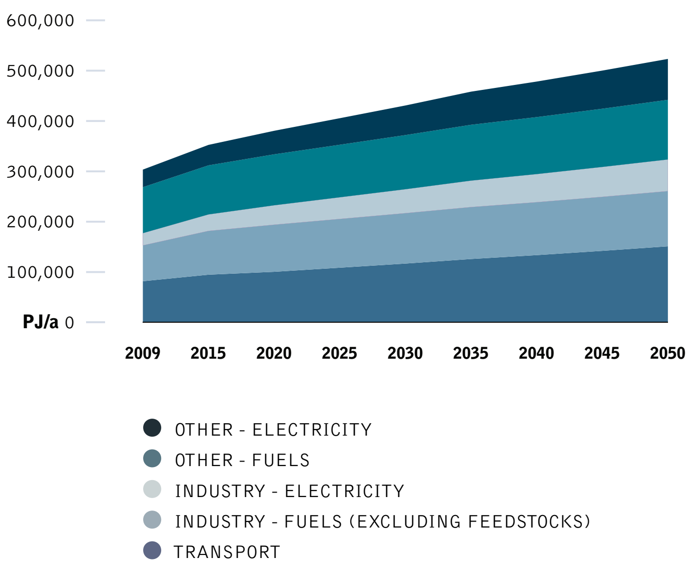
- Transport
- Industry
- Other (also referred to as "buildings and agriculture").

Within the energy industry and other sectors a distinction is made between electricity demand and fuel and heat demand. Heat demand mainly consists of district heating from heat plants and from combined heat and power plants. Fuel and heat demand is referred to as 'fuel demand' in the figures that follow. The energy demand scenario focuses only on energy-related fuel, power and heat use. This means that feedstock consumption in industries is excluded from the analysis. Total final consumption data in WEO includes non-energy use. By assuming that the share of non-energy use remains the same as in the base year 2009 we determine the energy-related fuel use beyond 2009.

Transport efficiencies were calculated by the DLR Institute of Vehicle Concepts and are documented in chapter 11.

Figure 10.1 shows the Reference scenario for final energy demand for the world per sector.

figure 10.1: final energy demand (PJ) in reference scenario per sector worldwide



Worldwide final energy demand is expected to grow by 75%, from 304 ExaJoule (EJ) in 2009 to 523 EJ in 2050. The transport sector has the largest relative growth, with energy demand expected to grow from 82 EJ in 2009 to 151 EJ in 2050. Fuel demand in others sectors is expected to grow slowest from 91 EJ in 2009 to 119 EJ in 2050.

references
143 IEA WEO 2011, NOV 2011, PARIS/FRANCE.
144 IEA WEO 2011, NOV 2011, PARIS/FRANCE.

figure 10.2: final energy demand (PJ) in reference scenario per region

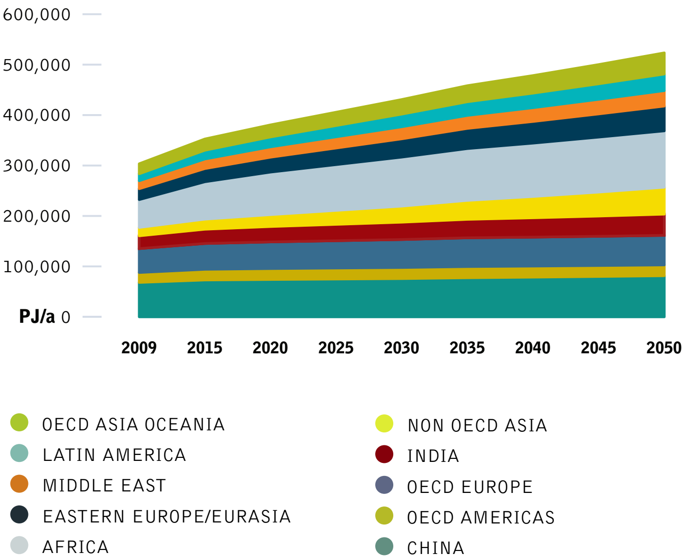


Figure 10.2 shows the final energy demand per region in the Reference scenario.

In the Reference scenario, final energy demand in 2050 will be largest in China (112 EJ), followed by OECD Americas (81 EJ) and OECD Europe (59 EJ). Final energy demand in OECD Asia Oceania and Latin America will be lowest (21 EJ and 31 EJ respectively).

Figure 10.3 shows the development of final energy demand per capita per region.

There would still be large differences between regions for final energy demand per capita in 2050 in the Reference scenario. Energy demand per capita is expected to be highest in OECD Americas and Eastern Europe/Eurasia (130 GJ/capita), followed by OECD Asia Oceania and OECD Europe (111 and 98 GJ/capita respectively). Final energy demand in Africa, India, Non OECD Asia, and Latin America is expected to be lowest, ranging from 19-56 GJ/capita.

Step 2: development of low energy demand scenarios

The low energy demand scenarios are based on literature studies and new calculations. The scenarios take into account:

- The implementation of best practice technologies and a certain share of emerging technologies.
- No behavioral changes or loss in comfort levels.
- No structural changes in the economy, other than occurring in the Reference scenario.
- Equipment and installations are replaced at the end of their (economic) lifetime, so no early retirement.

The selection of measures is based on the current worldwide energy use per sector and sub sector. Figure 10.4 shows a breakdown of final energy demand in the world by the most important sub-sectors in the base year 2009.

figure 10.3: final energy demand per capita in reference scenario

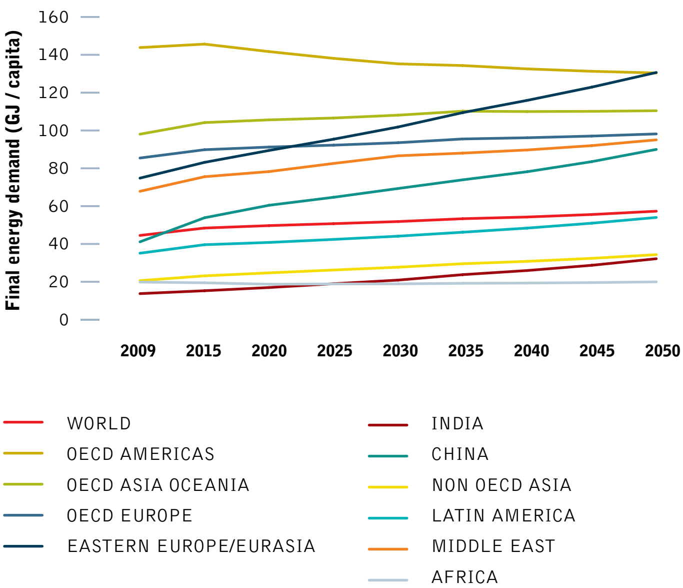


figure 10.4: final energy demand for the world by sub sector and fuel source in 2009 (IEA ENERGY BALANCES 2011)

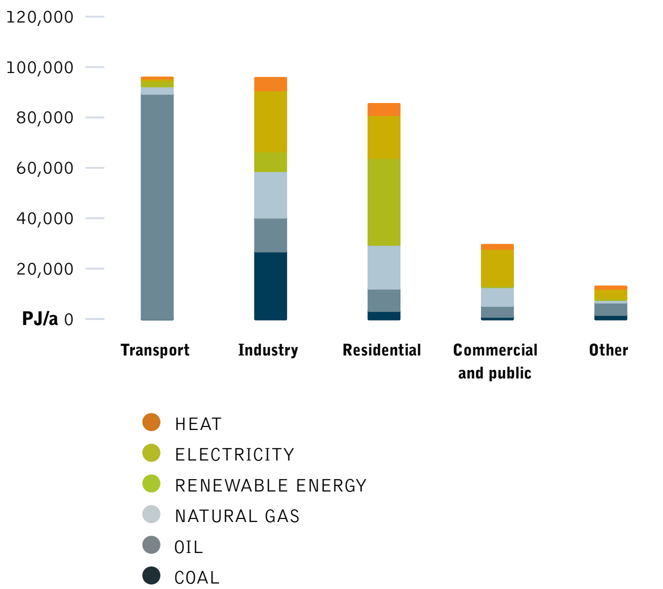


image A ROOM AT A NEWLY CONSTRUCTED HOME IS SPRAYED WITH LIQUID INSULATING FOAM BEFORE THE DRYWALL IS ADDED.

image FUTURISTIC SOLAR HEATED HOME MADE FROM CEMENT AND PARTIALLY COVERED IN THE EARTH.

10.2 efficiency in industry

10.2.1 energy demand reference scenario: industry

Figure 10.5 gives the reference scenario for final energy demand in industries in the period 2009-2050. As can be seen, the energy demand in Chinese industries is expected to be huge in 2050 and amount to 54 EJ. The energy demand in all other regions together is expected to be 118 EJ, meaning that China accounts for 31% of worldwide energy demand in industries in 2050.

Figure 10.7 shows a breakdown of final energy demand by sub sector in industry worldwide for the base year 2009. The largest energy consuming sectors in industry are chemical and petrochemical industry, iron and steel and non-metallic minerals. Together the sectors consume about 50% of industrial energy demand. Since these three sectors are relatively large we look at them in detail. Also we look at aluminium production in detail, which is in the category of non-ferrous metals. This is because the share of aluminium production makes up nearly 11% of total industrial energy demand in 2009.

figure 10.5: projection of industrial energy demand in period 2009-2050 per region

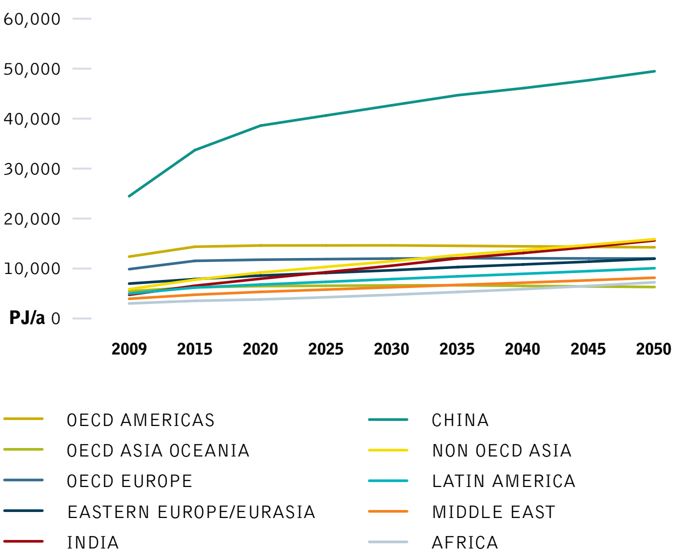


figure 10.7: breakdown of final energy consumption in 2009 by sub sector for industry (IEA ENERGY BALANCES 2011)

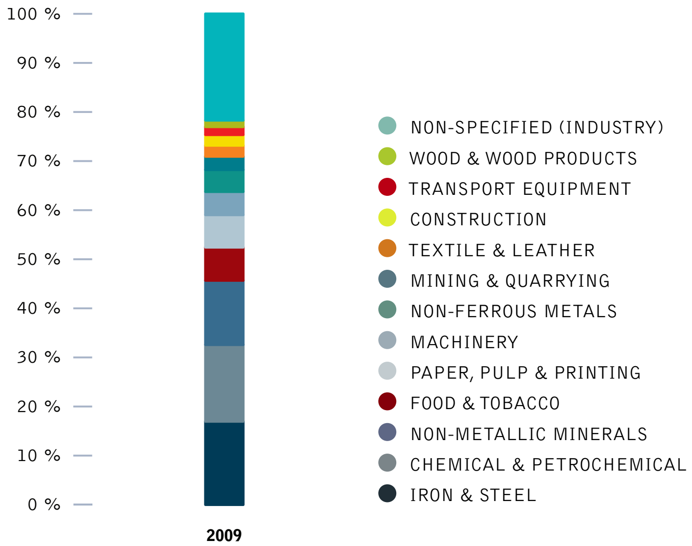
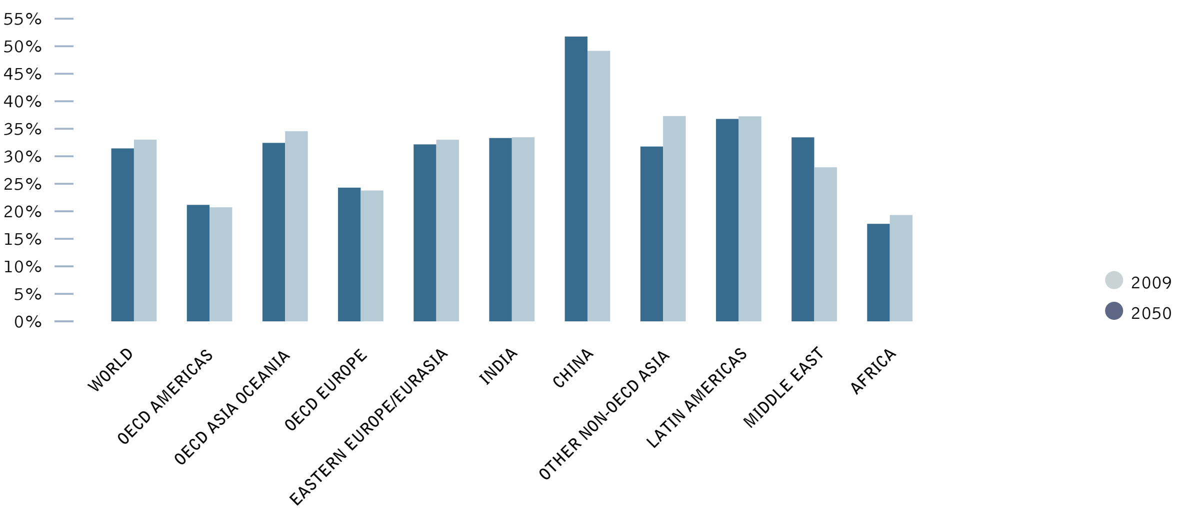


Figure 10.6 shows the share of industrial energy use in total energy demand per region for the years 2009 and 2050. Worldwide, industry consumers about 30% of total final energy demand on average, both in 2009 as in 2050. The share in Africa is lowest with 20% in 2050. The share in China is highest with 48% in 2050.

For all sectors we look at implementing best practice technologies, increased recycling and increased material efficiency. Where possible the potentials are based on specific energy consumption data in physical units (MJ/tonne steel, MJ/tonne aluminium etc.).

figure 10.6: share of industry in total final energy demand per region in 2009 and 2050



10.3 low energy demand scenario: industry

The overall technical potential is estimated after identifying the most significant energy-efficiency improvements. In the Reference scenario, some of these energy-efficiency improvements have already been implemented (autonomous and policy induced energy-efficiency improvement). However, the level of energy-efficiency improvement in the Reference scenario is unknown, we therefore assume that it is equal to 1% per year for all regions, based on historical developments of energy-efficiency.[145] Therefore, the technical potential in the low energy demand scenarios is the technical potential identified that has not already been implemented in the Reference scenario.

Table 10.1 shows the resulting savings potential for industry compared to the Reference scenario per region in 2050. These are based on the technical potentials with the subtraction of the energy-efficiency improvement already included in the Reference scenario.

table 10.1: reduction of energy use in comparison to the reference scenario per sector in 2050

	IRON & STEEL		ALUMINIUM PRODUCTION		CHEMICAL INDUSTRY		NON-METALLIC MINERALS		PULP & PAPER		OTHER INDUSTRIES	
	Industry fuels	Industry electricity	Industry fuels	Industry electricity	Industry fuels	Industry electricity	Industry fuels	Industry electricity	Industry fuels	Industry electricity	Industry fuels	Industry electricity
OECD Europe	45%	45%	40%	38%	32%	7%	0.6%	0.6%	10%	10%	48%	48%
OECD North America	64%	64%	40%	38%	32%	7%	0.6%	0.6%	10%	10%	48%	48%
OECD Asia Oceania	51%	51%	40%	38%	32%	7%	0.6%	0.6%	10%	10%	48%	48%
China	69%	69%	40%	38%	32%	7%	0.6%	0.6%	10%	10%	48%	48%
Latin America	79%	79%	40%	38%	32%	7%	0.6%	0.6%	10%	10%	48%	48%
Africa	70%	70%	40%	38%	32%	7%	0.6%	0.6%	10%	10%	48%	48%
Middle East	52%	52%	0%	38%	32%	7%	0.6%	0.6%	10%	10%	48%	48%
Eastern Europe/Eurasia	79%	79%	40%	38%	32%	7%	0.6%	0.6%	10%	10%	48%	48%
India	63%	63%	40%	38%	32%	7%	0.6%	0.6%	10%	10%	48%	48%
Non OECD Asia	33%	33%	40%	38%	32%	7%	0.6%	0.6%	10%	10%	48%	48%
World	**66%**	**66%**	**40%**	**38%**	**32%**	**7%**	**0.6%**	**0.6%**	**10%**	**10%**	**48%**	**48%**

table 10.2: share of technical potentials implemented in the energy [r]evolution scenario

INDUSTRY - FUELS	2009	2015	2020	2025	2030	2035	2040	2045	2050
OECD North America	90%	90%	90%	90%	90%	90%	90%	90%	90%
OECD Asia Oceania	90%	90%	90%	90%	90%	90%	90%	90%	90%
OECD Europe	85%	85%	85%	85%	85%	85%	85%	85%	85%
Eastern Europe/Eurasia	95%	95%	95%	95%	95%	95%	95%	95%	95%
India	80%	80%	80%	80%	80%	80%	80%	80%	80%
China	85%	85%	85%	85%	85%	85%	85%	85%	85%
Non OECD Asia	95%	95%	95%	95%	95%	95%	95%	95%	95%
Latin America	90%	90%	90%	90%	90%	90%	90%	90%	90%
Middle East	70%	70%	70%	70%	70%	70%	70%	70%	70%
Africa	70%	70%	70%	70%	70%	70%	70%	70%	70%
World	**80%**	**80%**	**80%**	**80%**	**80%**	**80%**	**80%**	**80%**	**80%**
INDUSTRY ELECTRICITY									
OECD North America	80%	80%	80%	80%	80%	80%	80%	80%	80%
OECD Asia Oceania	70%	70%	70%	70%	70%	70%	70%	70%	70%
OECD Europe	80%	80%	80%	80%	80%	80%	80%	80%	80%
Eastern Europe/Eurasia	80%	80%	80%	80%	80%	80%	80%	80%	80%
India	70%	70%	70%	70%	70%	70%	70%	70%	70%
China	70%	70%	70%	70%	70%	70%	70%	70%	70%
Non OECD Asia	70%	70%	70%	70%	70%	70%	70%	70%	70%
Latin America	70%	70%	70%	70%	70%	70%	70%	70%	70%
Middle East	80%	80%	80%	80%	80%	80%	80%	80%	80%
Africa	70%	70%	70%	70%	70%	70%	70%	70%	70%
World	**80%**	**80%**	**80%**	**80%**	**80%**	**80%**	**80%**	**80%**	**80%**

reference
145 ECOFYS (2005), BLOK (2005), ODYSSEE (2005), IEA (2011C).

images POWER SOCKETS AND SWITCH.

For the Energy [R]evolution scenarios we assume that a certain share of these potentials is implemented. This share is different per region as shown in Table 10.2.

10.4 results for industry: efficiency pathway of the energy [r]evolution

Figure 10.8 shows the energy demand scenarios for the sector industry on a global level. Energy demand in electricity can be reduced by 33% and 35% for fuel use, in comparison to the reference level in 2050. In comparison to 2009, global fuel use in industry increases slightly from 71 EJ to 72 EJ and electricity use shows a stronger increase from 24 EJ to 43 EJ.

Figures 10.9, 10.10 and 10.11 show the final energy demand in the sector industries per region for total energy demand, fuel use and electricity use, respectively.

figure 10.8: global final energy use in the period 2009-2050 in industry

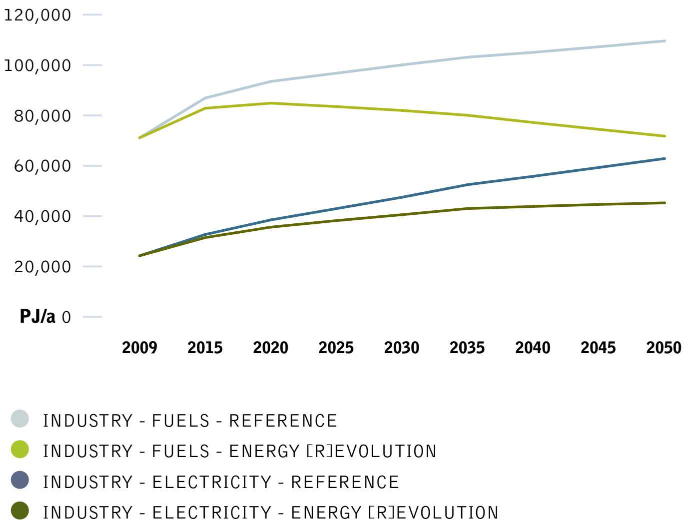


figure 10.10: fuel/heat use in sector industries

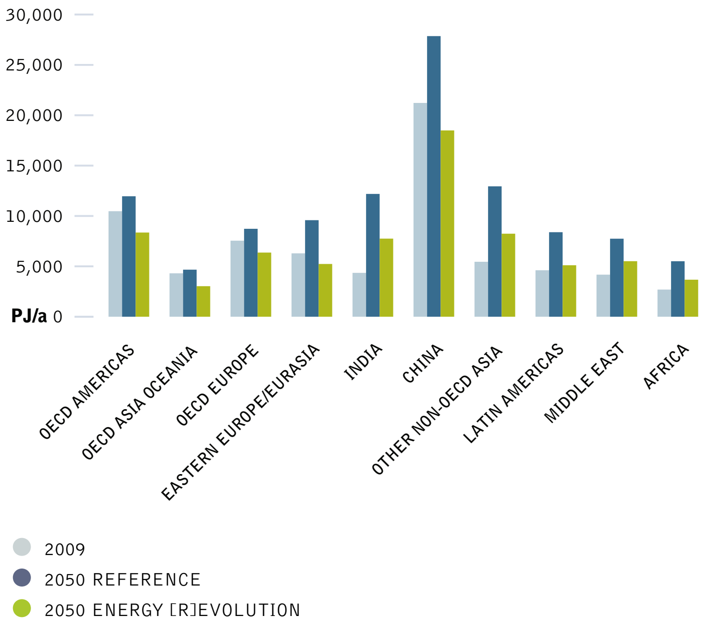


figure 10.9: final energy use in sector industries

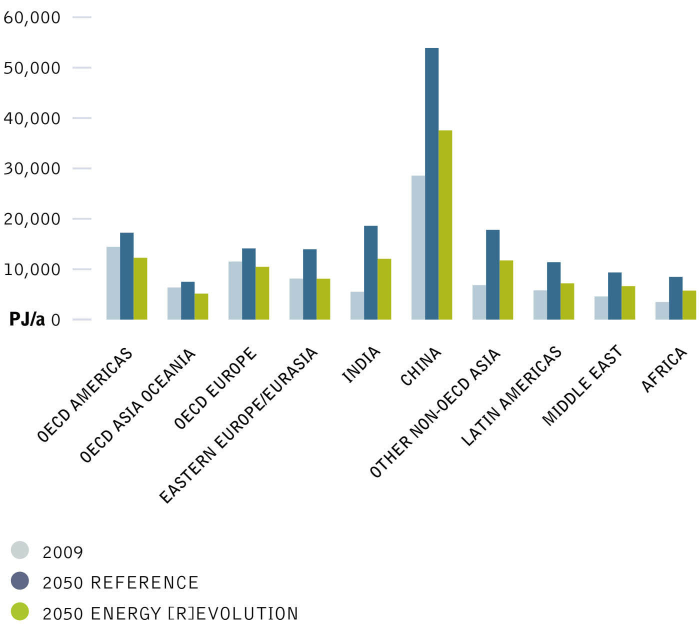
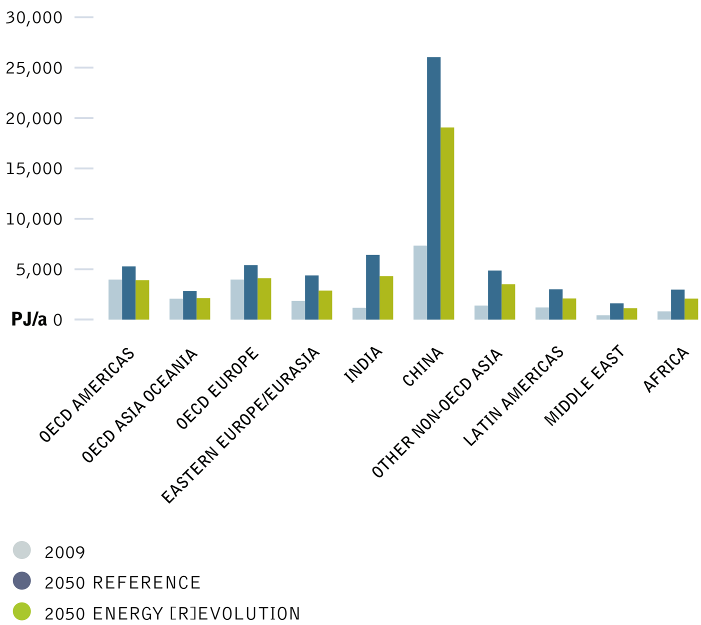


figure 10.11: electricity use in sector industries



10.5 buildings and agriculture

10.5.1 energy demand reference scenario: buildings and agriculture

Energy consumed in buildings and agriculture (summarized as "Other Sectors") represents 40% of global energy consumption in 2009 (see Figure 10.12). In most regions the share of residential energy demand is larger than the share of commercial and public services energy demand (except in OECD Asia Oceania). Since energy use in agriculture is relatively small (globally only 6% of this sector) we do not look at this sector in detail but assume the same energy saving potentials as in residential and commercial combined.

In the Reference scenario, energy demand in buildings and agriculture is forecasted to grow considerably (see Figure 10.14).

Figure 10.13 shows that energy demand in buildings and agriculture in 2050 is highest in OECD Americas, followed by China and OECD Europe. Latin America, OECD Asia Oceania and Middle East have the lowest energy demand for buildings and agriculture.

The share of fuel and electricity use by buildings and agriculture in total energy demand in 2009 and 2050 are shown in Figure 10.14. India and Africa have the highest share of buildings and agriculture in total final energy demand. Until 2050, a sharp decrease is expected in India. Globally it is expected that electricity use in this sector will be relatively more important in 2050 than in 2009 (16% instead of 12%) and fuel use will be relatively less important (23% instead of 30%).

figure 10.12: breakdown of energy demand in buildings and agriculture in 2009 (IEA ENERGY BALANCES 2011)

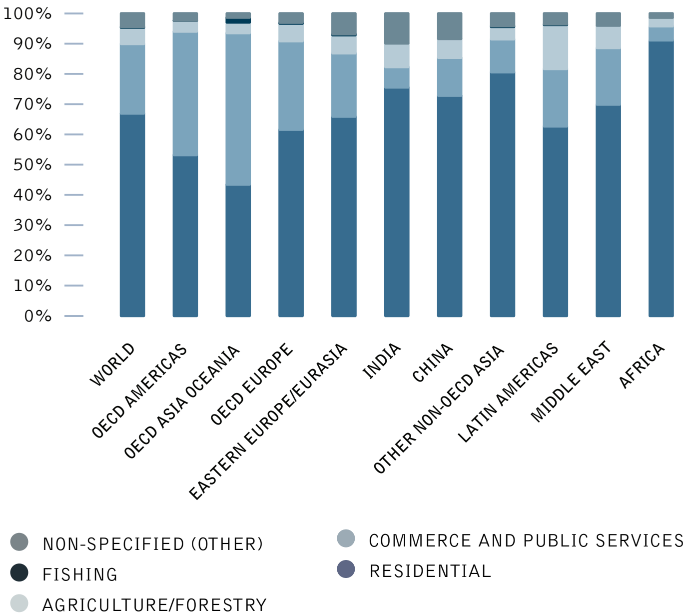


figure 10.13: energy demand in buildings and agriculture in reference scenario per region

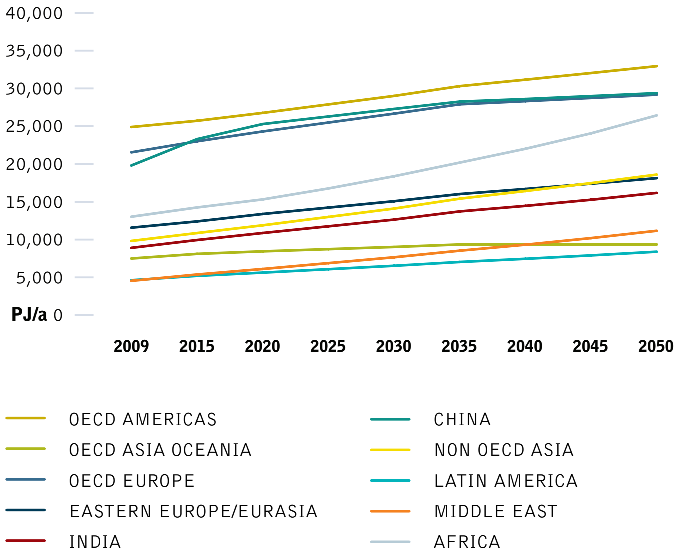


figure 10.14: share electricity and fuel consumption by buildings and agriculture in total final energy demand in 2009 and 2050 in the reference scenario

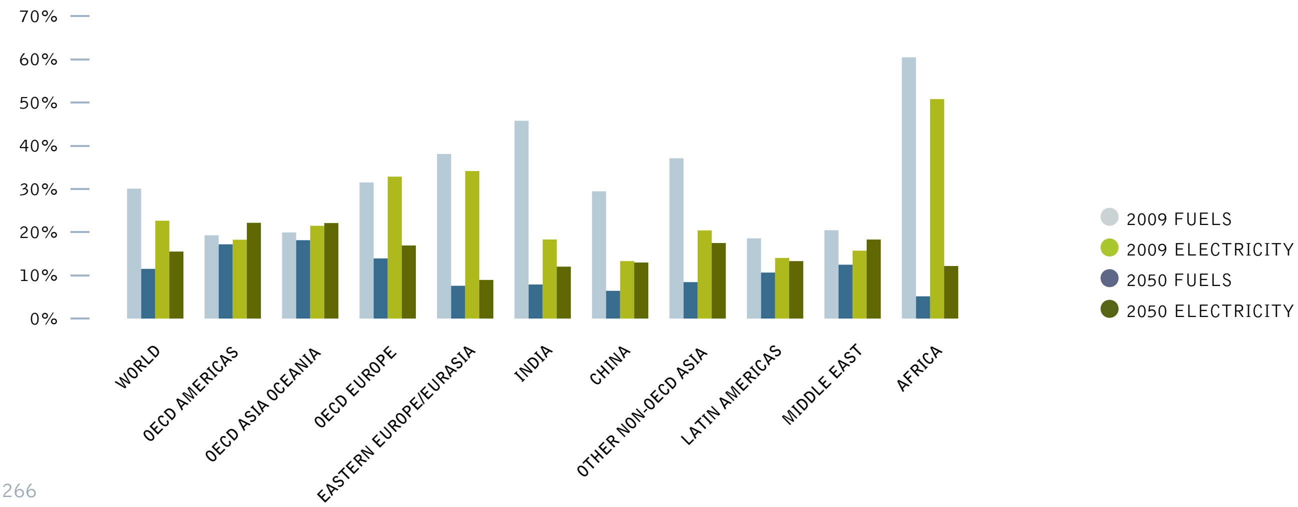
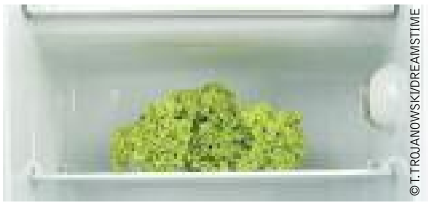
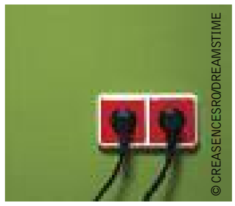


image FRIDGE.

image POWER PLUGS.





10.5.2 fuel and heat use

Fuels and heat use represent the largest share of total final energy use in this sector, see Figure 10.15. The share ranges from 52% for OECD Asia Oceania to 92% for Africa.

The residential sector has the largest end-use for fuels and heat use, see Figure 10.16. Its share ranges from 45% in OECD Asia Oceania to 94% in Africa.

Currently the largest share of fuel and heat use in this sector is used for space heating. The breakdown of fuel use per function is different per region. In the [R]evolution scenario a convergence is assumed for the different types of fuel demand per region. The following breakdown for fuel use in 2050 is assumed for most regions:[145]

- space heating (80%)
- hot water (15%)
- cooking (5%)

A summary of possible energy saving measures for each of the three types of fuel/heat use is provided here.

Space heating Energy-efficiency improvement for space heating is indicated by the energy demand per m^2 floor area per heating degree day (HDD). Heating degree day is the number of degrees that a day's average temperature is below 18°C. Typical current heating demand for dwellings in OECD countries is 70-120 kJ/m^2/HDD (based on IEA, 2007) but those with better efficiency consume below 32 kJ/m^2/HDD.[147] An example of a household with low energy use is given in Figure 10.17 on the following page.

Technologies to reduce energy demand of new dwellings are;[148]

- Triple-glazed windows with low-emittance coatings. These windows reduce heat loss to 40% compared to windows with one layer. The low-emittance coating prevents energy waves in sunlight coming in and thereby reduces cooling need.
- Insulation of roofs, walls, floors and basement. Proper insulation reduces heating and cooling demand by 50% in comparison to average energy demand.
- Passive solar energy. Good building design can make use of solar energy design, through orientation of the building's site and windows. The term "passive" indicates that no mechanical equipment is used. Because solar gains are brought in through windows or shading keeps the heat out in summer.
- Balanced ventilation with heat recovery. Heated indoor air passes to a heat recovery unit and is used to heat incoming outdoor air.

For existing buildings, retrofits help reduce energy use. Important retrofit options are more efficient windows and insulation, which can save 39% and 32% of space heating or cooling demand, respectively, according to IEA.[149] IEA[150] reports that average energy consumption in current buildings in Europe can decrease overall by more than 50%.

figure 10.15: breakdown of final energy demand in 2009 for electricity and fuels/heat in 'others' (IEA ENERGY BALANCES 2011)

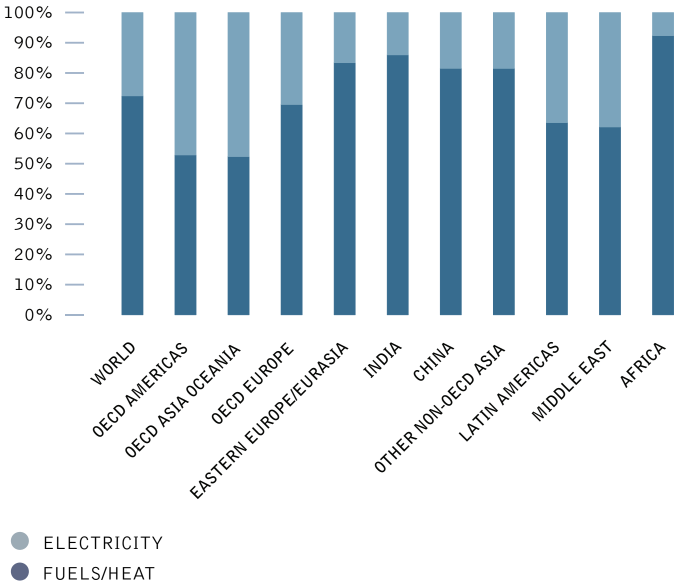
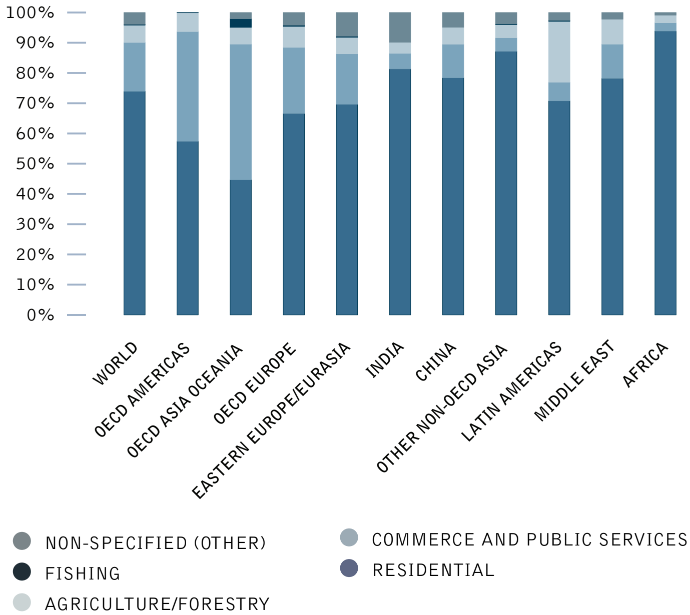


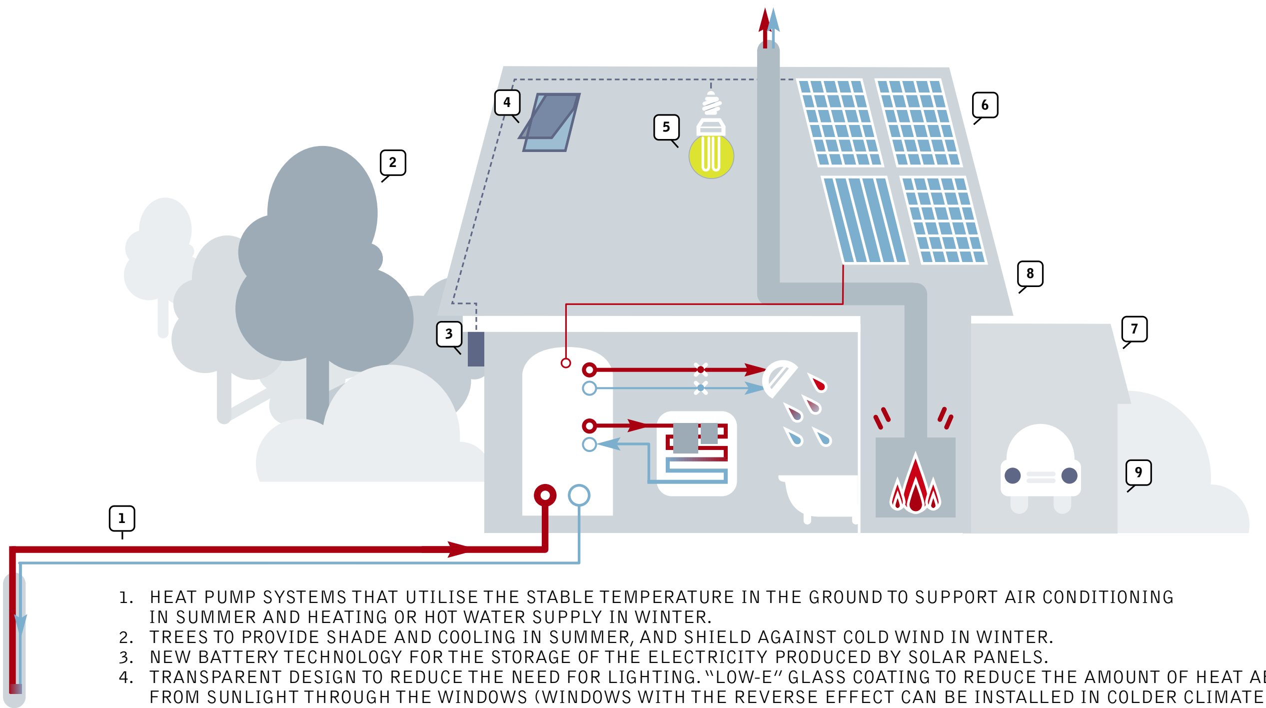
figure 10.16: breakdown of fuel and heat use in 'others' in 2009 (IEA ENERGY BALANCES 2011)



reference

146 BERTOLDI & ATANASIU (2006), IEA (2006), IEA (2007) AND WBCSD (2005).
147 THIS IS BASED ON A NUMBER OF ZERO-ENERGY DWELLING IN THE NETHERLANDS AND GERMANY, CONSUMING 400-500 M3 NATURAL GAS PER YEAR, WITH A FLOOR SURFACE BETWEEN 120 AND 150 M^2. THIS RESULTS IN 0.1 GJ/M^2/YR AND IS CONVERTED BY 3100 HEATING DEGREE DAYS TO 32 KJ/M^2/HDD.
148 (WBCSD (2005), IEA (2006), JOOSEN ET AL (2002).
149 IEA, LIGHT´S LABOUR´S LOST, 2006, PARIS/FRANCE.
150 IEA, LIGHT´S LABOUR´S LOST, 2006, PARIS/FRANCE.

figure 10.17: elements of new building design that can substantially reduce energy use (WBCSD, 2005)



1. HEAT PUMP SYSTEMS THAT UTILISE THE STABLE TEMPERATURE IN THE GROUND TO SUPPORT AIR CONDITIONING IN SUMMER AND HEATING OR HOT WATER SUPPLY IN WINTER.
2. TREES TO PROVIDE SHADE AND COOLING IN SUMMER, AND SHIELD AGAINST COLD WIND IN WINTER.
3. NEW BATTERY TECHNOLOGY FOR THE STORAGE OF THE ELECTRICITY PRODUCED BY SOLAR PANELS.
4. TRANSPARENT DESIGN TO REDUCE THE NEED FOR LIGHTING. "LOW-E" GLASS COATING TO REDUCE THE AMOUNT OF HEAT ABSORBED FROM SUNLIGHT THROUGH THE WINDOWS (WINDOWS WITH THE REVERSE EFFECT CAN BE INSTALLED IN COLDER CLIMATES).
5. EFFICIENT LIGHT BULBS.
6. SOLAR PHOTOVOLTAIC PANELS FOR ELECTRICITY PRODUCTION AND SOLAR THERMAL PANELS FOR WATER HEATING.
7. ROOMS THAT ARE NOT NORMALLY HEATED (E.G. A GARAGE) SERVING AS ADDITIONAL INSULATION.
8. VENTILATED DOUBLE SKIN FAÇADES TO REDUCE HEATING AND COOLING REQUIREMENTS.
9. WOOD AS A BUILDING MATERIAL WITH ADVANTAGEOUS INSULATION PROPERTIES, WHICH ALSO STORES CARBON AND IS OFTEN PRODUCED WITH BIOMASS ENERGY.

To improve the efficiency of existing heating systems, an option is to install new thermostatic valves which can save 15% of energy required for heating. On average, this option is installed in an estimated 40% of systems in Europe.[151]

Besides reducing the demand for heating, another option is to improve the conversion of efficiency of heat supply. A number of options are available such as high efficiency boilers that can achieve efficiencies of 107%, based on lower heating value. Another option is the use of heat pumps (see section 3.1.2).

Space heating Energy savings options for hot water include pipe insulation and high efficiency boilers. Another option is heat recovery units that capture the waste heat from water going down the drain and use it to preheat cold water before it enters the household water heater. A heat recovery system can recover as much as 70% of this heat and recycle it back for immediate use.[152] Furthermore, water saving shower heads and flow inhibitors can be implemented. The typical saving rate (in terms of energy) for shower heads is 12,5% and 25% for flow inhibitors.[153] In developing regions, improved coke stoves can be an important energy-efficiency option, which consume less energy than conventional ones.[154]

10.5.2 electricity use

While residential buildings use a bigger share of fuel and heat, for electricity, the consumption is more evenly spread over the sub-sector "commerce and public services" and residential. Globally, 49% of electricity is used in residential buildings and 41% in commerce and public services (also referred to as services). The use of electricity in the services sector strongly depends on the region and ranges from 17% in India to 56% in OECD Asia Oceania, see Figure 10.18.

The breakdown of electricity use per type of appliance is different per region. In the Energy [R]evolution scenario a convergence is assumed for the different types of electricity demand per region in 2050. Based on data in the literature[155], the overall breakdown of electricity use per type is:

- Space heating 10%
- Hot water 10%
- Lighting 20%
- ICT and home entertainment (HE) 12%
- Other appliances 30%
- Air conditioning 18%

Electricity savings option per application are discussed in the following.

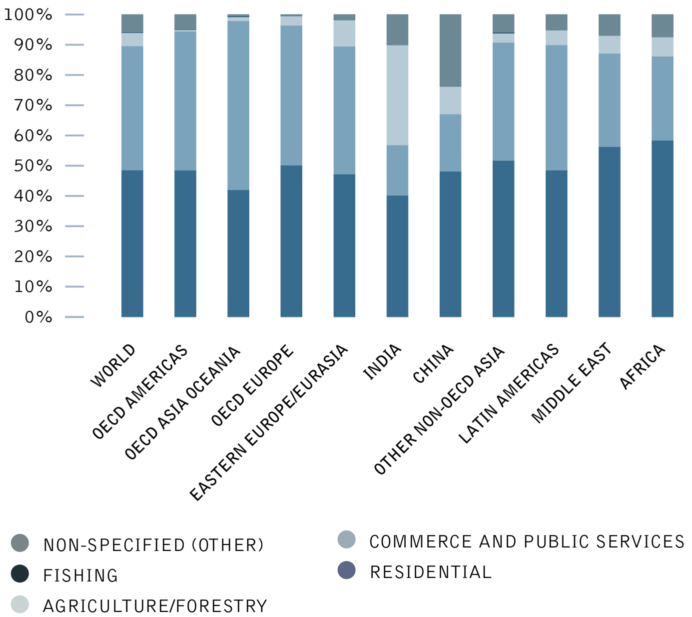
Space heating and hot water Measures to reduce electricity use for space heating and hot water are similar to measures for heating by fuels (see section 3.1.1). Changing the building shell can reduce the need for heat, and the other approach is to improve the conversion efficiency of heat supply. This can be done for example with heat pumps to provide both cooling and space and water heating, and are discussed extensively in Chapter 9 – Energy Technologies.

references
151 BETTGENHÄUSER ET AL. 2009.
152 ENVIROHARVEST, 2008.
153 BETTGENHÄUSER ET AL. 2009.
154 REEEP, 2009.
155 IEA (2009), IEA (2007) AND IPCC (2007A).

image COMPACT FLUORESCENT LAMP LIGHT BULB.

image WASHING MACHINE.

figure 10.18: breakdown of electricity use by sub sector in sector 'others' in 2009 (IEA ENERGY BALANCES 2011)



Technologies Typically, heat pumps can produce from 2.5 to 4 times as much useful heat as the amount of high-grade energy input, with variations due to seasonal performance. The sales of heat pumps in a number of major European markets experienced strong growth in recent years. Total annual sales in Austria, Finland, France, Germany, Italy, Norway, Sweden and Switzerland reached 576,000 in 2008, almost 50% more than in 2005.[156] Data suggests that heat pumps may be beginning to achieve a critical mass for space and water heating in a number of European countries.

Lighting Incandescent bulbs have been the most common lamps for a more than 100 years but also the most inefficient type since up to 95% of the electricity is lost as heat.[157] Incandescent lamps have a relatively short life-span (average value approximately 1,000 hours), but have a low initial cost and attractive light colour. Compact Fluorescent Light Bulbs (CFLs) are more expensive than incandescent, but they use about a quarter of the energy and last about 10 times longer.[158] In recent years many policies have been implemented that reduce or ban the use of incandescent light bulbs in various countries.

It is important to realise however that lighting energy savings are not just a question of using more efficient lamps, but also involve other approaches: reducing light absorption of luminaries (the fixture in which the lamp is housed), optimise lighting levels (which commonly exceed values recommended by IEA),[159] use of automatic controls like movement and daylight sensors, and retrofitting buildings to make better use of daylight. Buildings designed to optimize daylight can receive up to 70% of their annual illumination needs from daylight while a typical building will only get 20 to 25%.[160]

The IEA publication Light's Labour's Lost (2006) projects at least 38% of lighting electricity consumption could be cut in cost-effective ways, disregarding newer and promising technologies such as light emitted diodes (LEDs).

ICT and home entertainment equipment Information and communication technologies (ICT) and home entertainment consist of a growing number of appliances in both residential and commercial buildings, such as computers, (smart) phones, televisions, set-top boxes, games consoles, printers, copiers and servers. ICT and consumer electronics account for about 15% of residential electricity consumption now.[161] Globally a rise of 3 times is expected for ICT and consumer electronics, from 776 TWh in 2010 to 1,700 TWh in 2030. One of the main options for reducing energy use in ICT and home entertainment is using best available technology. IEA (2009b) estimates that a reduction is possible from 1,700 TWh to 775 TWh in 2030 by applying best available technology and to 1,220 TWh by least life-cycle costs measures, which do not impose additional costs on consumers. Below we discuss other energy savings options for ICT and home entertainment.

Other appliances Other appliances include cold appliances (freezers and refrigerators), washing machines, dryers, dish washers, ovens and other kitchen equipment. Electricity use for cold appliances depends on average per household storage capacities, the ratio of frozen to fresh food storage capacity, ambient temperatures and humidity, and food storage temperatures and control.[162] European and Japanese households typically have one combined refrigerator-freezer in the kitchen or they have a refrigerator and a separate freezer, due to having less space in the home. In OECD North America and Australia where houses are larger, almost all households have a refrigerator-freezer and many also have a separate freezer and occasionally a separate refrigerator.[163] It is estimated that by improving the energy-efficiency of cold appliances on average 45% of electricity use could be saved for EU-27.[164] For "wet appliances" they estimate a potential of 40-60% savings by implementing best practice technology (see Table 10.3).

table 10.3: reference and best practice electricity use by "wet appliances"

Washing machine*	
Reference (kWh/dwelling/yr)	231
Best practice (kWh/dwelling/yr)	116
Improvement (%)	50
Dryer*	
Reference (kWh/dwelling/yr)	440
Best practice (kWh/dwelling/yr)	210-140
Improvement (%)	60
Dish washers*, **	
Reference (kWh/dwelling/yr)	305
Best practice (kWh/dwelling/yr)	209-163
Improvement (%)	40

notes
* WWW.MILIEUCENTRAAL.NL
** ESTIMATE OF 163 DERIVED FROM VHK, 2005.

references
156 IEA, 2010.
157 HENDEL-BLACKFORD ET AL., 2007.
158 ENERGY STAR, 2008.
159 IEA, LIGHT´S LABOUR´S LOST, 2006, PARIS/FRANCE.
160 IEA, LIGHT´S LABOUR´S LOST, 2006, PARIS/FRANCE.
161 IEA, 2009B
162 IEA , COOL APPLIANCES, 2003, PARIS/FRANCE.
163 IEA , COOL APPLIANCES, 2003, PARIS/FRANCE.
164 BETTGENHAUSER ET AL. (2009).

Air conditioning There are several options for technological savings from air conditioning equipment; one is using a different refrigerant. Tests with the refrigerant Ikon B show possible energy consumption reductions of 20-25% compared to regularly used refrigerants.[165]

Also geothermal cooling is an important option which is explained in Chapter 9 - Renewable Heating and Cooling. Of several technical concepts available, the highest energy savings can be achieved with two storage reservoirs in aquifers where in summer time cold water is used from the cold reservoir. The hot reservoir can be used with a heat pump for heating in winter.

Solar energy can also be used for heating and cooling, the different types are also discussed in the previous chapter. Heat pumps and air conditioners that can be powered by solar photovoltaic systems[166] for example uses only 0.05 kW of electricity is instead of 0.35 kW for regular air conditioning.[167]

As well as using efficient air conditioning equipment, it is as important to reduce the need for air conditioning. The ways to reduce cooling demand are to use insulation to prevent heat from entering the building, reduce the amount of inefficient appliances present in the house (such as incandescent lamps, old refrigerators, etc.) that give off heat, use cool exterior finishes (such as cool roof technology[168] or light-coloured paint on the walls) to reduce the peak cooling demand as much as 10-15%[169], improve windows and use vegetation to reduce the amount of heat that comes into the house, and use ventilation instead of air conditioning units.

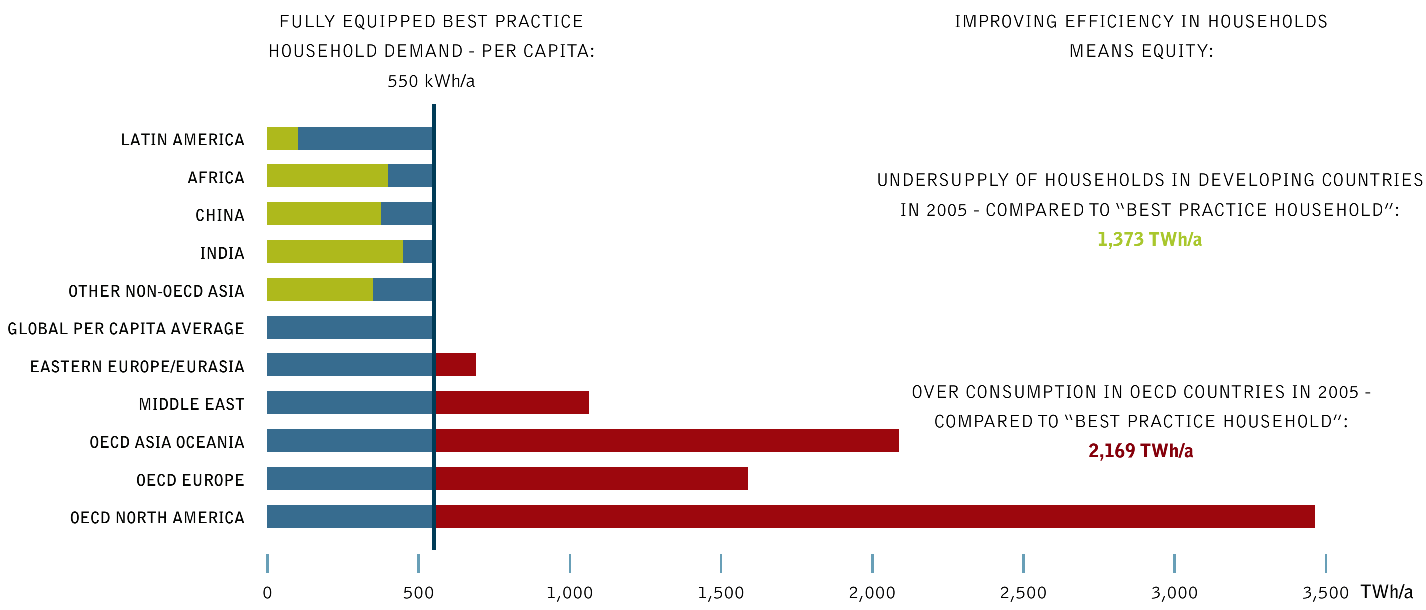
10.6 the standard household concept

In order to enable a specific level of energy demand as a basic "right" for all people in the world, we have developed the model of an efficient Standard Household. A fully equipped OECD household (including fridge, oven, TV, radio, music centre, computer, lights etc.) currently consumes between 1,500 and 3,400 kWh per year per person. With an average of two to four people per household the total consumption is therefore between 3,000 and 12,000 kWh/a. This demand could be reduced to about 550 kWh/year per person just by using the most efficient appliances available on the market today, without any significant lifestyle changes.

Based on this assumption, the 'over-consumption' of all households in OECD countries totals more than 2,100 billion kilowatt-hours. Comparing this figure with the current per capita consumption in developing countries, they would have the 'right' to use about 1,350 billion kilowatt-hours more. The current 'oversupply' to OECD households could therefore fill the gap in energy supply to developing countries one and a half times over.

By implementing a strict technical standard for all electrical appliances, in order to achieve a level of 550 kWh/a per capita consumption, it would be possible to switch off more than 340 coal power plants in OECD countries.

figure 10.19: efficiency in households - electricity demand per capita IN TWH/A

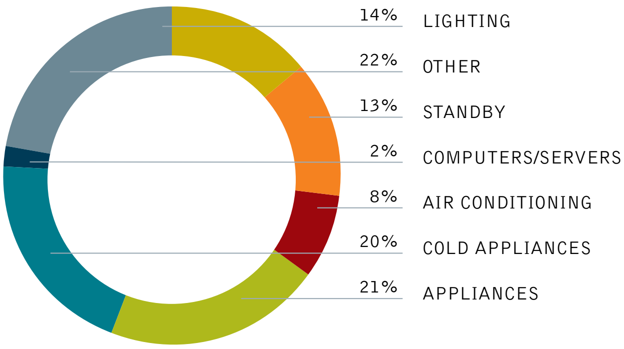


reference
165 US DOE EERE, 2008.
166 DARLING, 2005.
167 AUSTRIAN ENERGY AGENCY, 2006 - NOTE THAT SOLAR COOLING AND GEOTHERMAL COOLING MAY REDUCE THE NEED FOR HIGH GRADE ENERGY SUCH AS NATURAL GAS AND ELECTRICITY. ON THE OTHER HAND THEY INCREASE THE USE OF RENEWABLE ENERGY. THE ENERGY SAVINGS ACHIEVED BY REDUCING THE NEED OF HIGH GRADE ENERGY WILL BE PARTLY COMPENSATED BY AN INCREASE OF RENEWABLE ENERGY.
168 US EPA, 2007.
169 ACEEE (2007).

image WASHING MACHINE.

image COMPUTER.

figure 10.20: electricity savings in households (energy [r]evolution versus reference) in 2050



note
BY 2050, STRICT ENERGY EFFICIENCY STANDARDS, WOULD MEAN ALL GLOBAL HOUSEHOLDS COULD SAVE OVER 4,000 TWH COMPARED TO THE REFERENCE SCENARIO. THIS WOULD TAKE OVER 570 COAL POWER PLANTS OFF THE GRID.

Setting energy efficiency standards for electrical equipment could have a huge impact on the world's power sector. A large number of power plants could be switched off if strict technical standards were brought into force. The table below provides an overview of the theoretical potential for using efficiency standards based on currently available technology.

The Energy [R]evolution scenario has not been calculated on the basis of this potential. However, this overview illustrates how many power plants producing electricity would not be needed if all global appliances were brought up to the highest efficiency standards.

table 10.4: effect on number of global operating power plants of introducing strict energy efficiency standards based on currently available technology

	ELECTRICITY LIGHTING	ELECTRICITY STANDBY	ELECTRICITY AIR CONDITIONING	ELECTRICITY SET TOP BOXES	ELECTRICITY OTHER APPLIANCES	ELECTRICITY COLD APPLIANCES	ELECTRICITY COMPUTERS/ SERVERS	ELECTRICITY OTHER
OECD Europe	16	11	11	2	27	15	2	23
OECD Americas	32	19	19	3	47	26	4	42
OECD Asia Oceania	5	5	5	1	13	7	1	11
China	3	3	3	1	7	4	1	6
Latin America	5	2	3	0	6	3	1	6
Africa	3	2	2	0	4	2	0	4
Middle East	5	2	3	0	6	3	1	6
Eastern Europe/Eurasia	6	3	3	1	7	4	1	7
India	2	1	1	0	3	2	0	3
Other Non-OECD Asia	4	2	2	0	6	3	1	5
World	**80**	**50**	**52**	**9**	**126**	**69**	**11**	**113**

	ELECTRICITY SERVICES - COMPUTERS	ELECTRICITY SERVICES - LIGHTING	ELECTRICITY SERVICES - AIR CONDITIONING	ELECTRICITY SERVICES - COLD APPLIANCES	ELECTRICITY SERVICES - OTHER APPLIANCES	ELECTRICITY - AGRICULTURE	NUMBER OF COAL POWER PLANTS PHASED OUT	INDUSTRY	**TOTAL** INCLUDING INDUSTRY
OECD Europe	8	30	18	6	33	7	209	106	315
OECD Americas	15	62	34	11	60	21	397	107	503
OECD Asia Oceania	5	11	10	3	18	1	96	52	148
China	1	3	3	1	5	21	61	144	205
Latin America	2	8	4	1	7	3	52	39	90
Africa	1	3	1	0	2	6	30	23	53
Middle East	1	6	3	1	5	10	51	8	59
Eastern Europe/Eurasia	2	9	4	1	7	8	62	63	125
India	0	2	1	0	1	14	31	23	54
Other Non-OECD Asia	2	7	3	1	6	6	50	33	83
World	**37**	**140**	**81**	**27**	**144**	**98**	**1,038**	**613**	**1,651**

10.7 low energy demand scenario: buildings and agriculture

The level of energy savings and the percentage reduction below the baseline vary significantly between regions. The largest percentage reductions occur in China (38%), the economies in transition (38%) and OECD Europe (37%).

China's reduction in 2050 comes from both improved efficiency and switching away from the inefficient use of traditional biomass in buildings to modern bioenergy (biofuels, biogas and bio-dimethyl ether) and commercial fuels. The smallest percentage reduction below the baseline occurs in India and is due to a rebound effect in which some increased consumption is triggered by some of the energy efficiency measures in the period to 2050. The largest absolute reductions occur in China, OECD Europe and OECD North America. Figure 10.21 shows which types of energy use have the highest share in the savings in the baseline (IEA BLUE Map scenario).

10.8 results for buildings and agriculture: the efficiency pathway for the energy [r]evolution

The Energy [R]evolution scenario for the agriculture and buildings sector ("other") is based on a combination of the IEA 450 ppm scenario, the Blue map scenario and other assumptions. We assume that policies to improve energy-efficiency in this sector are implemented in 2013 and will lead to energy savings from 2014 onwards. Table 10.5 shows the annual reductions of energy demand compared to the Reference scenario. For electricity use in OECD countries we use savings potentials as calculated in the SERPEC-CC study for EU-27 (Bettgenhäuser et al. 2009). In this study, potentials have been calculated for energy savings from all types of energy-efficiency improvement options. This bottom-up study estimated a savings potential of 2.5% per year for electricity use in buildings in comparison to frozen technology levels, for a 25 year period.

figure 10.21: breakdown of energy savings in BLUE Map scenario for sector 'others' (IEA, 2010)

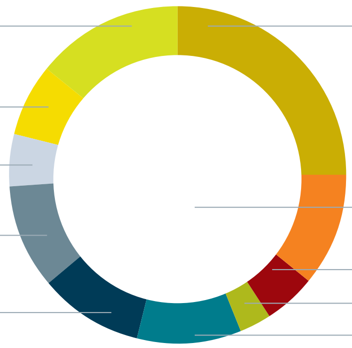


table 10.5: annual reduction of energy demand in 'others' sector in energy [r]evolution scenario in comparison to the corresponding reference scenario

	ENERGY [R]EVOLUTION – ENERGY SAVINGS IN %/YR PERIOD 2013-2050[170]		450 PPM SCENARIO %/YR[171]		BLUE MAP - ENERGY SAVINGS IN %/YR[172]	
	Fuel/heat	Electricity	Fuel/heat	Electricity	Fuel/heat	Electricity
OECD Americas	0.4%	1.5%	0.1%	0.7%	0.9%	1.1%
OECD Asia Oceania	0.8%	1.5%	0.3%	1.0%	0.7%	0.8%
OECD Europe	1.6%	1.5%	0.6%	0.8%	1.6%	1.1%
Eastern Europe/Eurasia	1.6%	0.9%	1.1%	1.4%	1.6%	0.9%
India	0.6%	0.6%	0.6%	1.4%	0.5%	1.0%
China	0.4%	1.1%	0.3%	2.2%	1.4%	1.4%
Non OECD Asia	0.4%	1.0%	0.2%	1.0%	0.4%	0.9%
Latin America	0.8%	1.0%	0.3%	1.0%	0.8%	0.6%
Middle East	0.9%	1.0%	0.9%	1.2%	1.6%	1.0%
Africa	1.0%	0.5%	0.2%	0.8%	1.4%	0.5%
World	**0.9%**	**1.3%**	**0.3%**	**1.3%**	**1.3%**	**1.0%**

references
170 IN COMPARISON TO REFERENCE SCENARIO (EXTRAPOLATED WEO CURRENT POLICIES SCENARIO)
171 IN COMPARISON TO WEO CURRENT POLICIES SCENARIO.
172 IN COMPARISON TO BLUE MAP REFERENCE SCENARIO.

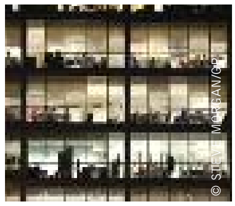


image OFFICE BUILDINGS AT NIGHT IN LEEDS. MOST OF AN OFFICE BUILDINGS ENERGY CONSUMPTION OVER ITS LIFETIME IS IN LIGHTING, LIFTS, HEATING, COOLING AND COMPUTER USAGE. LIGHTING IS RESPONSIBLE FOR ONE-FOURTH OF ALL ELECTRICITY CONSUMPTION WORLDWIDE. BUILDINGS CAN BE MADE MORE SUSTAINABLE BY ARCHITECTURE THAT RESPONDS TO THE CONDITIONS OF A SITE WITH INTEGRATED STRUCTURE AND BUILDING SERVICES. EFFECTIVE USE OF PASSIVE SOLAR HEAT AND THE THERMAL MASS OF THE BUILDING, HIGH INSULATION LEVELS, NATURAL DAYLIGHTING AND WIND POWER CAN ALL HELP TO MINIMIZE FOSSIL ENERGY USE.

We assume that this annual efficiency improvement rate can be achieved in OECD countries for the period 2013-2050. As mentioned in chapter 4, we assume that autonomous energy-efficiency improvement in the Reference scenario equals 1% per year. This means that electricity savings of 1.5% per year in OECD countries can be made on top of the references scenario. This potential for electricity use in OECD countries is within the technical potentials for electricity savings as calculated by Graus et al.[173], which gives a technical potential of 3% saving per year for electricity use in buildings against frozen technology level.

Table 10.6 shows the final energy consumption in absolute values for the Energy [R]evolution scenario, the BLUE Map scenario and 450 ppm scenarios as comparison. Table 10.6 shows the underlying Reference scenarios for all three scenarios.

It should be noted that the BLUE Map scenario for buildings covers a lower share of the energy demand than the sector buildings and agriculture sector in the Energy [R]evolution scenario and in the IEA WEO scenario; about 90% of energy demand. Still it becomes clear that the Energy [R]evolution scenario for this sector is slightly below the 450 ppm scenario and reasonably in line with the IEA BLUE Map scenario, in terms of the level of energy demand.

In order to achieve the Energy [R]evolution low energy demand scenario the following measure needs to be achieved:

- **Tighter building standards and codes for new residential and commercial buildings.** Regulatory standards for new residential buildings in cold climates are tightened to between 15 and 30 kWh/m^2/year for heating purposes, with little or no increase in cooling load. In hot climates, cooling loads are reduced by around one-third. For commercial buildings, standards are introduced which halve the consumption for heating and cooling compared to 2007. This will mean less heating and cooling equipment is required.
- **Large-scale refurbishment of residential buildings in the OECD**. Around 60% of residential dwellings in the OECD which will still be standing in 2050 will need to be refurbished to a low-energy standard (approximately 50 kWh/m^2/ year), which also means they require less heating equipment. This represents the refurbishment of around 210 million residential dwellings in the OECD between 2010 and 2050.
- **Highly efficient heating, cooling and ventilation systems**. These systems need to be both efficient and cost-effective. The coefficient of performance (COP) of installed cooling systems doubles from today's level.
- **Improved lighting efficiency.** Notwithstanding recent improvements, many driven by policy changes, there remains considerable potential to reduce lighting demand worldwide through the use of the most efficient options.
- **Improved appliance efficiency**. Appliance standards are assumed to shift rapidly to least life-cycle cost levels, and to the current BAT levels by 2030.
- **The deployment of heat pumps for space and water heating**. This occurs predominantly in OECD countries, and depends on the relative economics of different abatement options. And the deployment of micro- and mini-cogeneration for space and water heating, and electricity generation.

Results: Energy efficiency pathway of the Energy [R]evolution scenario in the building and agricultural sector

table 10.6: global final energy consumption for sector 'others' (EJ) in 2030 and 2050

			2030			2050
	Heat/fuels	Electricity	Total	Heat/fuels	Electricity	Total
Energy [R]evolution	91.4	48.4	139.8	84.4	54.6	138.9
IEA Blue map	76.6	42.0	118.6	73.2	52.4	125.4
IEA WEO - 450 ppm scenario	97.7	49.8	147.5	-	-	-

table 10.7: global final energy consumption for sector 'others' (EJ) in 2030 and 2050 in underlying baseline scenarios

			2030			2050
	Heat/fuels	Electricity	Total	Heat/fuels	Electricity	Total
Reference scenario - Energy [R]evolution	106.5	59.5	166.0	116.6	82.9	199.5
Reference scenario - BLUE Map	96.1	53.2	149.3	107.6	76.9	184.5
IEA WEO – current policies scenario	108.0	59.0	167.0	-	-	-

references

173 ENERGY DEMAND PROJECTIONS FOR ENERGY [R]EVOLUTION 2012,WINA GRAUS, KATERINA KERMELI, UTRECHT UNIVERSITY, MARCH 2012.

Figure 10.22 shows the energy demand scenarios for the buildings and agriculture sector on a global level. Energy demand for electricity is reduced by 36% and for fuel by 28%, in comparison to the reference level in 2050. In comparison to 2009, global fuel use in this sector decreases slightly from 92 EJto 84 EJ while electricity use shows a strong increase from 35 EJ to 55 EJ.

Figure 10.23, 10.24 and 10.25 show the final energy demand in the buildings and agriculture sector per region for total energy demand, fuel use and electricity use, respectively.

figure 10.22: global final energy use in the period 2009-2050 in sector 'others'

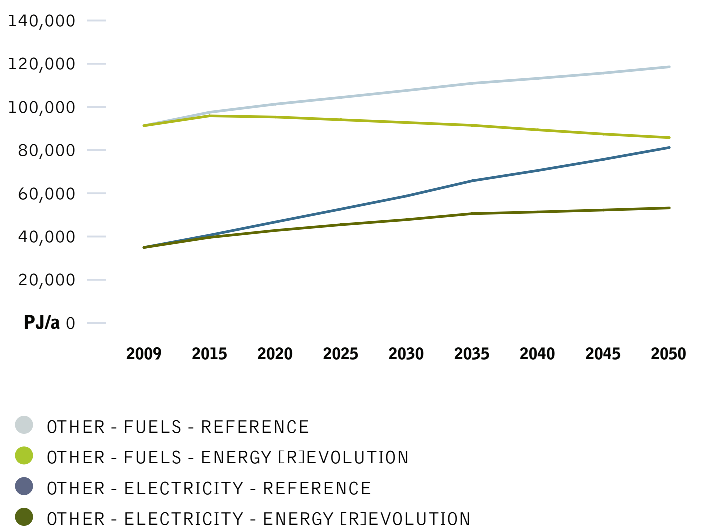


figure 10.24: fuel/heat use in sector 'others'

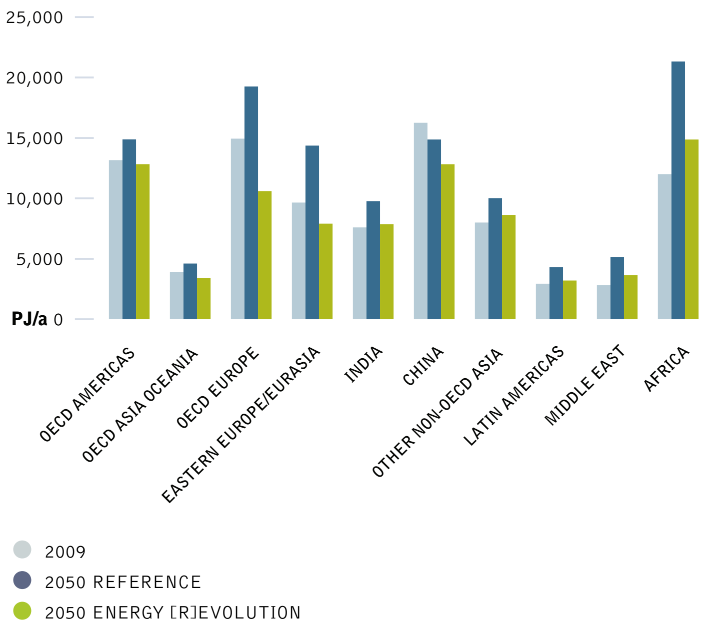


figure 10.23: final energy use in sector 'others'

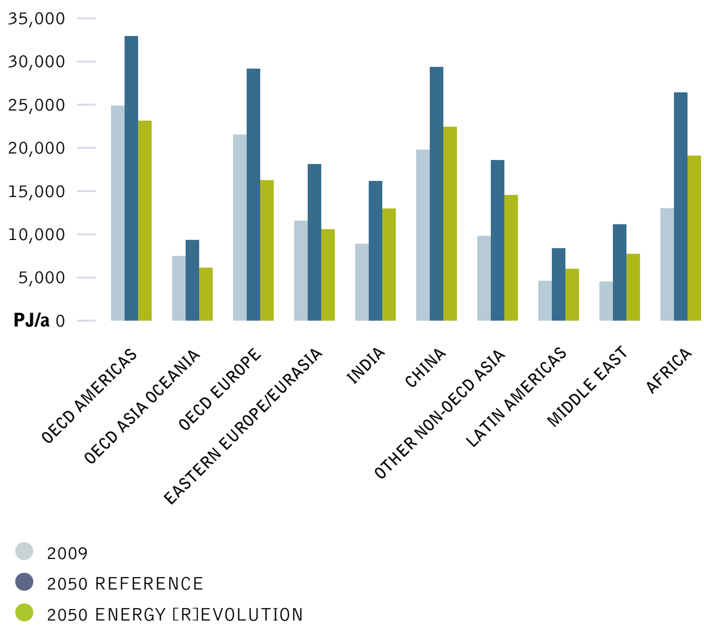
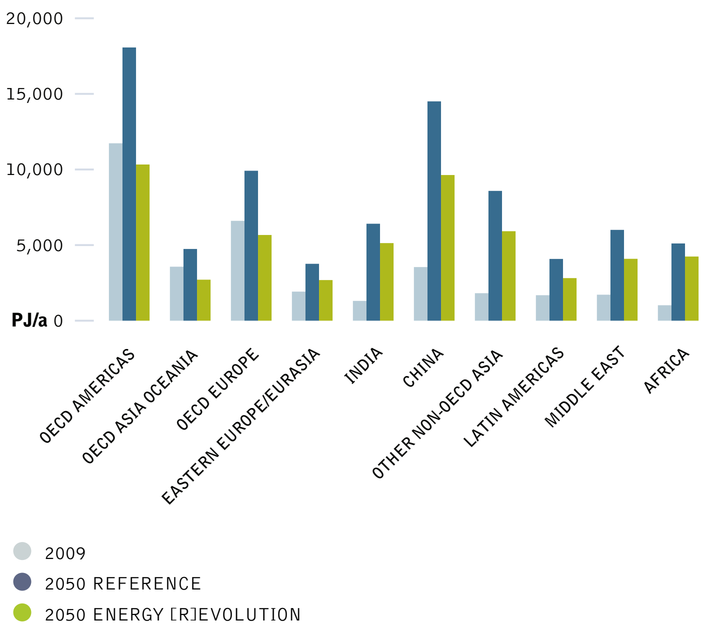


figure 10.25: electricity use in sector 'others'



transport

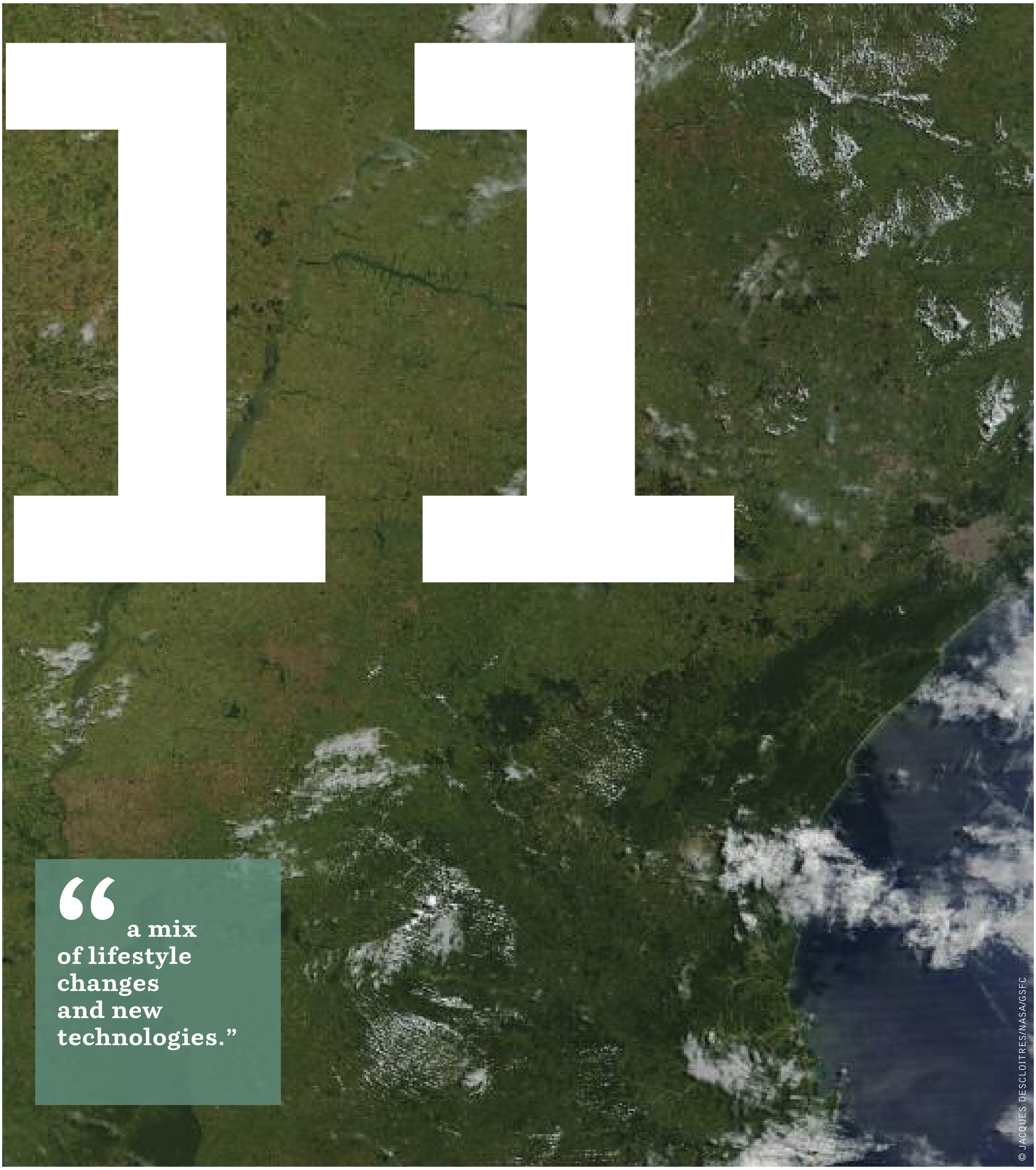
THE FUTURE OF THE TRANSPORT SECTOR IN THE E[R] SCENARIO

TECHNICAL AND BEHAVIOURAL MEASURES

PROJECTION OF THE FUTURE LDV VECHICAL MARKET

CONCLUSION

11



"a mix of lifestyle changes and new technologies."

image THE PENINSULAR, NORTHEASTERN ARM OF ARGENTINA IS HOME TO SOME OF THE LAST REMAINING REMNANTS OF A SOUTH AMERICAN ECOSYSTEM KNOWN AS ATLANTIC RAINFOREST, WHICH USED TO RUN ALL ALONG BRAZIL'S COAST FROM THE STATE OF RIO GRANDE DO NORTE THOUSANDS OF MILES SOUTH TO RIO GRANDE DO SUL.

Sustainable transport is needed to reduce the level of greenhouse gases in the atmosphere, just as much as a shift to renewable electricity and heat production. Today, nearly a third (27%) of current energy use comes from the transport sector, including road and rail, aviation and sea transport. In order to assess the present status of global transport, including its carbon footprint, a special study was undertaken for the 2012 Energy [R]evolution report by the German Aerospace Centre (DLR) Institute of Vehicle Concepts.

The demand projections for the Reference and this Energy [R]evolution scenario have been based on this analysis, although the reference year has been updated on the basis of IEA WEO 2011 (to 2009 figures).

This chapter provides an overview of the selected measures required to develop a more energy efficient and sustainable transport system in the future, with a focus on:

- reducing transport demand,
- shifting transport 'modes' (from high to low energy intensity), and
- energy efficiency improvements from technology development.

The section provides assumptions for the transport sector energy demand calculations used in the Reference and the Energy [R]evolution scenarios including projections for the passenger vehicle market (Light Duty Vehicles).

Overall, some technologies will have to be adapted for greater energy efficiency. In other situations, a simple modification will not be enough. The transport of people in megacities and urban areas will have to be almost entirely reorganised and individual transport must be complemented or even substituted by public transport systems. Car sharing and public transport on demand are only the beginning of the transition needed for a system that carries more people more quickly and conveniently to their destination while using less energy.

For the 2012 Energy [R]evolution scenario, the German DLR Institute of Vehicle Concepts undertook analyses of the entire global transport sector, broken down to the ten IEA regions. This report outlines the key findings of the analysis' calculations.

11.1 the future of the transport sector in the energy [r]evolution scenario

As for electricity projections, a detailed Reference scenario is required for transport. The scenario constructed includes detailed shares and energy intensity data per mode of transport and per region up to 2050 (sources: WBSCD, EU studies). Based on the Reference scenario, deviating transport performance and technical parameters are applied to create the ambitious Energy [R]evolution scenario for reducing energy consumption. Traffic performance is assumed to decline for the high energy intensity modes and further energy reduction potentials were assumed from further efficiency gains, alternative power trains and fuels.

International shipping has been left out whilst calculating the baseline figures, because it spreads across all regions of the world. The total is therefore made up of Light Duty Vehicles (LDVs), Heavy and Medium Duty Freight Trucks, rail, air, and national marine transport (Inland Navigation). Although energy use from international marine bunkers (international shipping fuel suppliers) is not included in these calculations, it is still estimated to account for 9% of today's worldwide transport final energy demand and 7% by 2050. A recent UN report concluded that carbon dioxide emissions from shipping are much greater than initially thought and increasing at an alarming rate. It is therefore very important to improve the energy efficiency of international shipping. Possible options are examined later in this chapter.

The definitions of the transport modes for the scenarios[174] are:

- Light duty vehicles (LDV) are four-wheel vehicles used primarily for personal passenger road travel. These are typically cars, Sports Utility Vehicles (SUVs), small passenger vans (up to eight seats) and personal pickup trucks. Light Duty Vehicles are also simply called 'cars' within this chapter.
- Heavy Duty Vehicles (HDV) are as long haul trucks operating almost exclusively on diesel fuel. These trucks carry large loads with lower energy intensity (energy use per tonne-kilometre of haulage) than Medium Duty Vehicles such as delivery trucks.
- Medium Duty Vehicles (MDV) include medium haul trucks and delivery vehicles.
- Aviation in each region denotes domestic air travel (intraregional and international air travel is provided as one figure).
- Inland Navigation denotes freight shipping with vessels operating on rivers and canals or in coastal areas for domestic transport purposes.

reference
174 FULTON & EADS (2004).

image TRAIN SIGNALS.

The figure below shows the breakdown of final energy demand for the transport modes in 2009 and 2050 in the Reference scenario.

As can be seen from the above figures, the largest share of energy demand comes from passenger road transport (mainly transport by car), although it decreases from 56% in 2009 to 46% in 2050. The share of domestic air transport increases from 6% to 8%. Of particular note is the high share of road transport in total transport energy demand: 89% in 2009 and 86% in 2050.

In the Reference scenario, overall energy demand in the transport sector adds up to 82 EJ in 2009. It is projected to increase to 151 EJ in 2050.

In the ambitious Energy [R]evolution scenario, implying the implementation of all efficiency and behavioural measures described, we calculated in fact a decrease of energy demand to 61 EJ, which means a lower annual energy consumption than in 2009.

Figure 11.1 shows world final energy use for the transport sector in 2009 and 2050 in the Reference scenario.

Today, energy consumption is comprised by nearly half of the total amount by OECD America and OECD Europe. In 2050, the picture looks more fragmented. In particular China and India form a much bigger portion of the world transport energy demand whereas OECD America remains the largest energy consumer.

figure 11.1: world final energy use per transport mode 2009/2050 – reference scenario

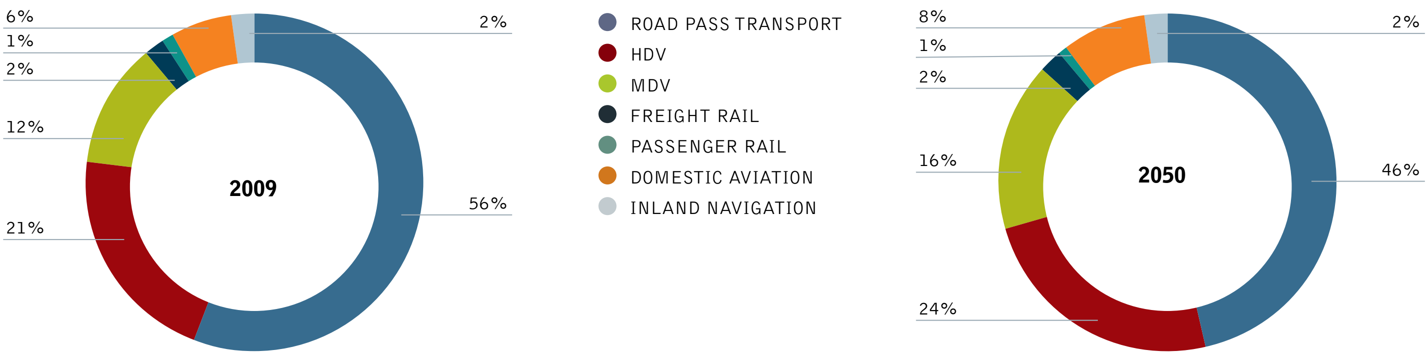


figure 11.2: world transport final energy use by region 2009/2050 – reference scenario

11.2 technical and behavioural measures to reduce transport energy consumption

The following section describes how the transport modes contribute to total and relative energy demand. Then, a selection of measures for reducing total and specific energy transport consumption are put forward for each mode. Measures are grouped as either behavioural or technical.

The three ways to decrease energy demand in the transport sector examined are:

- reduction of transport demand of high energy intensity modes
- modal shift from high energy intensive transport to low energy intensity modes
- energy efficiency improvements.

Table 11.1 summarises these options and the indicators used to quantify them.

11.2.1 step 1: reduction of transport demand

To use less transport overall means reducing the amount of 'passenger-km (p-km)' travelled per capita and reducing freight transport demand. The amount of freight transport is to a large extent linked to GDP development and therefore difficult to influence. However, by improved logistics, for example optimal load profiles for trucks or a shift to regionally-produced and shipped goods, demand can be limited.

Passenger transport The study focussed on the change in passenger-km per capita of high-energy intensity air transport and personal vehicles modes. Passenger transport by Light duty vehicles (LDV), for example, is energy demanding both in absolute and relative terms. Policy measures that enforce a reduction of passenger-km travelled by individual transport modes are an effective means to reduce transport energy demand.

Policy measures for reducing passenger transport demand in general could include:

- charge and tax policies that increase transport costs for individual transport
- price incentives for using public transport modes
- installation or upgrading of public transport systems
- incentives for working from home
- stimulating the use of video conferencing in business
- improved cycle paths in cities.

Table 11.2 shows the p-km for light duty vehicle transport in 2009 against the assumed p-km in the Reference scenario and in the Energy [R]evolution scenario in 2050, broken down for all regions.

table 11.2: LDV passenger-km per capita

REGION	2009	2050 REF	2050 E[R]
OECD Europe	9,061	10,518	7,390
OECD North America	9,401	11,940	8,211
OECD Asia Oceania	9,924	11,861	10,893
Latin America	3,045	6,235	5,468
Non OECD Asia	1,289	3,708	2,673
Eastern Europe/Eurasia	4,385	13,074	10,361
China	1,051	5,462	3,364
Middle East	4,749	14,383	8,358
India	335	6,196	5,011
Africa	726	1,346	834

table 11.1: selection of measures and indicators

MEASURE	REDUCTION OPTION	INDICATOR
Reduction of transport demand	Reduction in volume of passenger transport in comparison to the Reference scenario	Passenger-km/capita
	Reduction in volume of freight transport in comparison to the Reference scenario	Ton-km/unit of GDP
Modal shift	Modal shift from trucks to rail	MJ/tonne-km
	Modal shift from cars to public transport	MJ/Passenger-km
Energy efficiency improvements	Shift to energy efficient passenger car drive trains (battery electric vehicles, hybrid and fuel cell hydrogen cars) and trucks (fuel cell hydrogen, battery electric, catenary or inductive supplied)	MJ/Passenger-km, MJ/Ton-km
	Shift to powertrain modes that may be fuelled by renewable energy (electric, fuel cell hydrogen)	MJ/Passenger-km, MJ/Ton-km
	Autonomous efficiency improvements of LDV, HDV, trains, airplanes over time	MJ/Passenger-km, MJ/Ton-km

image ITALIAN EUROSTAR TRAIN.

image TRUCK.

In the Reference scenario, there is a forecast increase in passenger-km in all regions up to 2050. For the 2050 Energy [R]evolution scenario there is still a rise, but this would be much flatter and for OECD Europe and OECD America there will even be a decline in individual transport on a per capita basis.

The reduction in passenger-km per capita in the Energy [R]evolution scenario compared to the Reference scenario comes with a general reduction in car use due to behavioural and traffic policy changes and partly with a shift of transport to public modes.

A shift from energy-intensive individual transport to low-energy demand public transport goes align with an increase in low-energy public transport p-km.

Freight transport It is difficult to estimate a reduction in freight transport and the Energy [R]evolution scenario does not include a model for reduced frieght transport.

11.2.2 step 2: changes in transport mode

In order to figure out which vehicles or transport modes are the most efficient for each purpose requires an analysis of the transport modes' technologies. Then, the energy use and intensity for each type of transport is used to calculate energy savings resulting from a transport mode shift. The following information is required:

- Passenger transport: Energy demand per passenger kilometre, measured in MJ/p-km.
- Freight transport: Energy demand per kilometre of transported tonne of goods, measured in MJ/tonne-km.

For this study passenger transport includes Light Duty Vehicles, passenger rail and air transport. Freight transport includes Medium Duty Vehicles, Heavy DutyVehicles, Inland Navigation, marine transport and freight rail. WBCSD 2004 data was used as baseline data and updated where more recent information was available.

Passenger transport Travelling by rail is the most efficient – but car transport improves strongly. Figure 11.3 shows the worldwide average specific energy consumption (energy intensity) by transport mode in 2009 and in the Energy [R]evolution scenario in 2050. This data differs for each region. There is a large difference in specific energy consumption among the transport modes. Passenger transport by rail will consume on a per p-km basis 28% less energy in 2050 than car transport and 85% less than aviation which shows that shifting from road to rail can make large energy savings.

From Figure 11.3 we can conclude that in order to reduce transport energy demand, passengers will need to shift from cars and especially air transport to the lower energy-intensive passenger rail transport.

In the Energy [R]evolution scenario it is assumed that a certain portion of passenger-kilometer of domestic air traffic and intraregional air traffic (i. e., traffic among two countries of one IEA region) is suitable to be substituted by high speed rail (HSR). For international aviation there is obviously no substitution potential to other modes whatsoever.

Table 11.3 displays the relative model shifts used in the calculation of the Energy [R]evolution scenario. Where the shares are higher it means that the cites are closer, so a substitution by high speed trains is a more realistic option (i. e. distances of up to 800 – 1,000 km, compared to countries where they are far apart).

figure 11.3: world average (stock-weighted) passenger transport energy intensity for 2009 and 2050

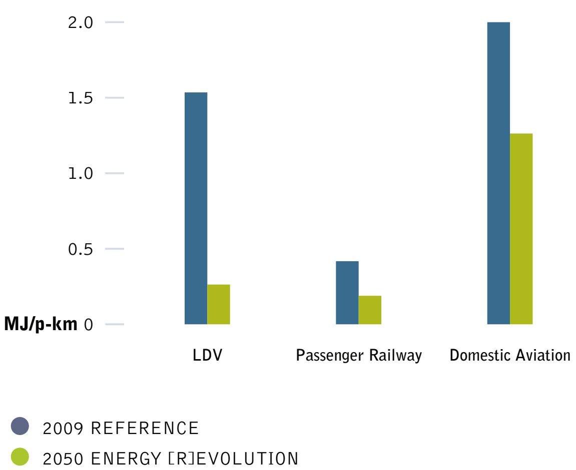


table 11.3: air traffic substitution potential of high speed rail (HSR)

REGION	RELATIVE SUBSTITUTION OF AIR TRAFFIC TO HSR IN 2050 (ALT)	
	DOMESTIC	INTRAREGIONAL
OECD Europe	30 %	15 %
OECD North America	20 %	10 %
OECD Asia Oceania	20 %	10 %
Latin America	30 %	10 %
Non OECD Asia	20 %	10 %
Eastern Europe/Eurasia	10 %	10 %
China	20 %	10 %
Middle East	30 %	10 %
India	20 %	10 %
Africa	20 %	10 %

Figure 11.4 and 11.5 show how passenger-km of both domestic aviation and rail passenger traffic would change due to modal shift in the Energy [R]evolution scenario against the Reference scenario (the Rail passenger-km includes, besides the modal shift, a general increase in rail passenger-km as people use rail over individual transport as well).

Figure 11.6 and Figure 11.7 show the resulting passenger-km of all modes in the Reference and Energy [R]evolution scenario; including the decreasing LDV passenger-km compared to the Reference scenario.

figure 11.4: aviation passenger-km in the reference and energy [r]evolution scenarios

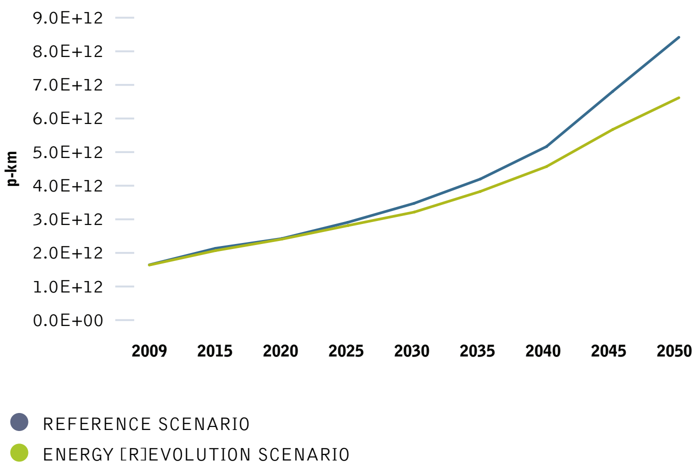


figure 11.6: passenger-km over time in the reference scenario

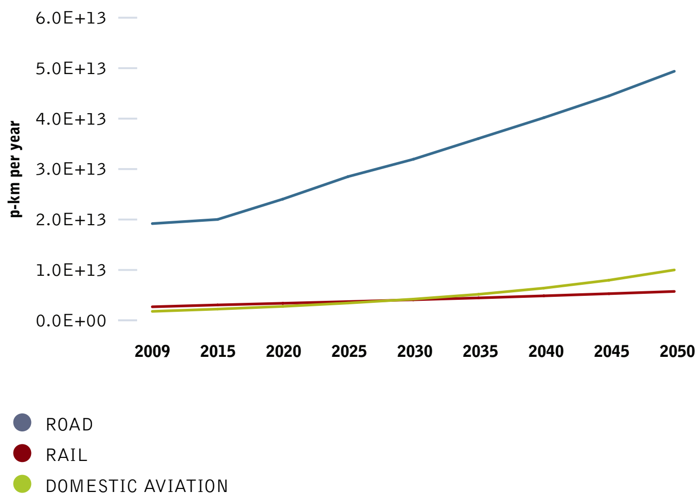


figure 11.5: rail passenger-km in the reference and energy [r]evolution scenarios

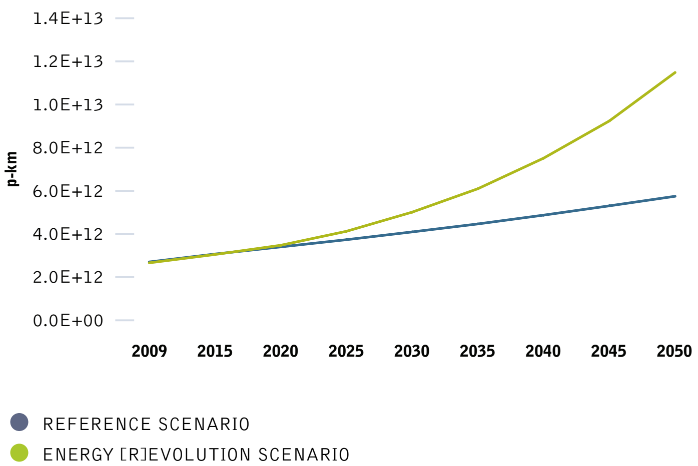


figure 11.7: passenger-km over time in the energy [r]evolution scenario

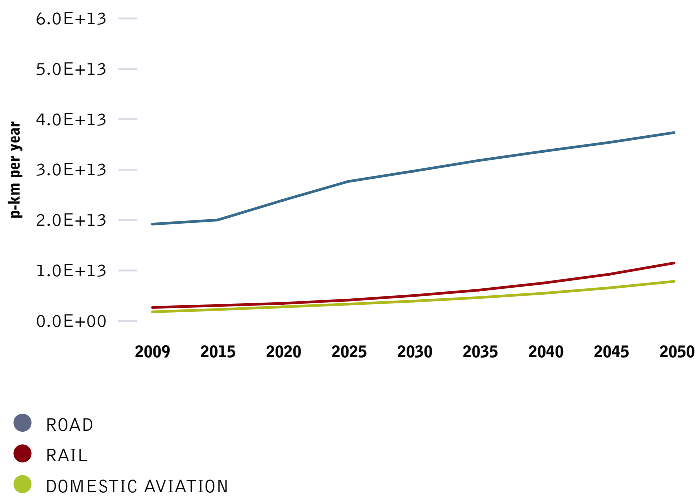
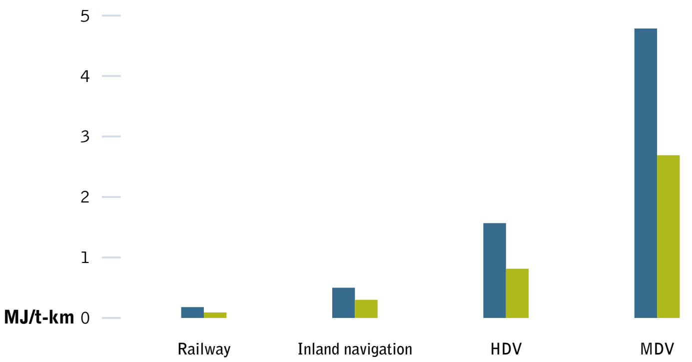


image TRANSPORT POLLUTION.

Freight transport Similar to Figure 11.3 which showed average specific energy consumption for passenger transport modes, Figure 11.8 shows the respective energy consumption for various freight transport modes in 2009 and in the Energy [R]evolution scenario 2050, the values are weighted according to stock-and-traffic performance.

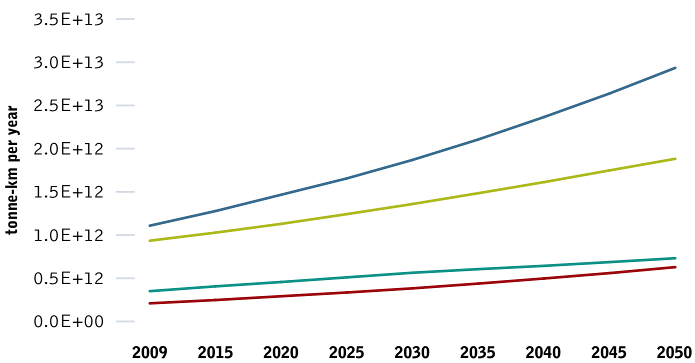
Energy intensity for all modes of transport is expected to decrease by 2050. In absolute terms, road transport has the largest efficiency gains whereas transport on rail and on water remain the modes with the lowest relative energy demand per tonne-km. Rail freight transport will consume 89% less energy per tonne-km in 2050 than long haul HDV. This means that large energy savings can be made following a shift from road to rail.

figure 11.8: world average (stock-weighted) freight transport energy intensities for 2005 and 2050



2009 REFERENCE
2050 ENERGY [R]EVOLUTION

figure 11.9: tonne-km over time in the reference scenario



HEAVY DUTY VEHICLES
MEDIUM DUTY VEHICLES
RAIL FREIGHT
INLAND NAVIGATION

Modal shifts for transporting goods in the Energy [R]evolution scenario The figures above indicate that as much road freight as possible should be shifted from road freight transport to less energy intensive freight rail, to gain maximum energy savings from modal shifts.

Since the use of ships largely depends on the geography of the country, a modal shift is not proposed for national ships but instead a shift towards freight rail. As the goods transported by medium duty vehicles are mainly going to regional destinations (and are therefore not suitable for the long distance nature of freight rail transport), no modal shift to rail is assumed for this transport type.

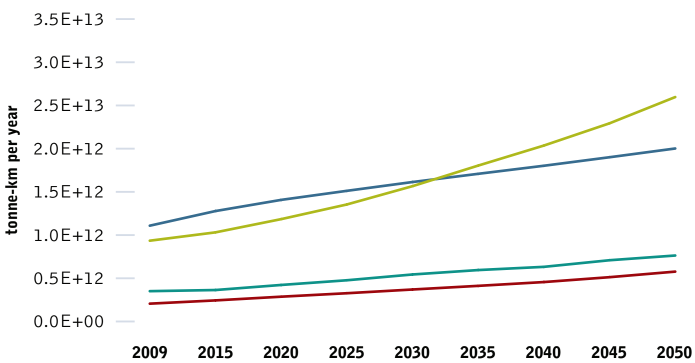
For long-haul heavy duty vehicles transport, however, especially low value density, heavy goods that are transported on a long range are suitable for a modal shift to railways.[175] We assumed the following relative modal shifts in the Energy [R]evolution scenario:

table 11.4: modal shift of HDV tonne-km to freight rail in 2050

REGION	MODAL SHIFT TO FREIGHT RAIL IN 2050 ENERGY [R]EVOLUTION
OECD Europe	25 %
OECD North America	23 %
All other regions	30 %

Figure 11.9 and Figure 11.10 show the resulting tonne-km of the modes in the Reference scenario and Energy [R]evolution scenario. In the Energy [R]evolution scenario freight transported by rail is larger in absolute numbers than freight transported by heavy duty vehicles.

figure 11.10: tonne-km over time in the energy [r]evolution scenario



HEAVY DUTY VEHICLES
MEDIUM DUTY VEHICLES
RAIL FREIGHT
INLAND NAVIGATION

reference
175 TAVASSZY AND VAN MEIJEREN 2011.

11.2.3 step 3: efficiency improvements

Energy efficiency improvements are the third important way of reducing transport energy demand. This section explains ways for improving energy efficiency up to 2050 for each type of transport, namely:

- air transport
- passenger and freight trains
- trucks
- inland navigation and marine transport
- cars.

In general, an integral part of an energy reduction scheme is an increase in the load factor – this applies both for freight and passenger transport. As the load factor increases, less vehicles need to be employed and thus the energy intensity decreases when measured per passenger-km or tonne-km.

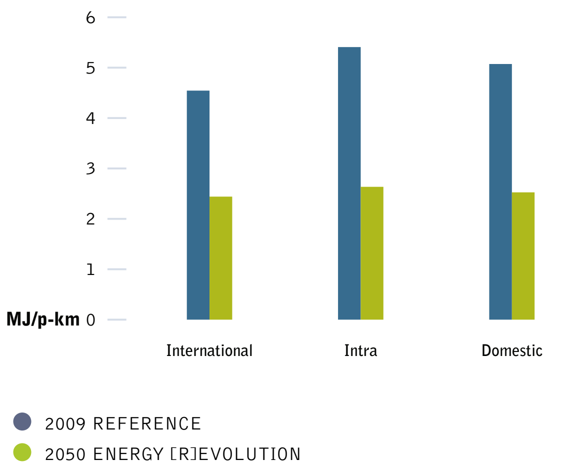
In aviation there are already sophisticated efforts to optimise the load factor, however for other modes such as road and rail freight transport there is still room for improvement. Lifting the load factor may be achieved through improved logistics and supply chain planning for freight transport and in enhanced capacity utilisation in passenger transport.

Air transport A study conducted by NASA (2011) shows that energy use of new subsonic aicrafts can be reduced by up to 58% up to 2035. Potentially, up to 81% reduction in CO_2 emissions are achievable when using biofuels.[176] Akerman (2005) reports that a 65% reduction in fuel use is technically feasible by 2050. Technologies to reduce fuel consumption of aircrafts mainly comprise:

- Aerodynamic adaptations to reduce the drag of the aircraft, for example by improved control of laminar flow, the use of riblets and multi-functional structures, the reduction in fasteners, flap fairings and the tail size as well as by advanced supercritical airfoil technologies.
- Structural technologies to reduce the weight of the aircraft while at the same time increasing the stiffness. Examples include the use of new lightweight materials like advanced metals, composites and ceramics, the use of improved coatings as well as the optimised design of multi-functional, integrated structures.
- Subsystem technologies including, for example, advanced power management and generation as well as optimised flight avionics and wiring.
- Propulsion technologies like advanced gas turbines for powering the aircraft more efficiently; this could also include:
  - improved combustion emission measures, improvements in cold and hot section materials, and the use of turbine blade/vane technology;
  - investigation of all-electric, fuel-cell gas turbine and electric gas turbine hybrid propulsion devices;
  - the usage of electric propulsion technologies comprise advanced lightweight motors, motor controllers and power conditioning equipment.[177]

The scenario projects a 50% improvement in specific energy consumption on a per passenger-km basis for future aircrafts in 2050 based on 2009 energy intensities. Figure 11.11 shows the energy intensities in the Energy [R]evolution scenario for international, intraregional and domestic aviation.

figure 11.11: energy intensities (MJ/p-km) for air transport in the energy [r]evolution scenario



All regions have the same energy intensities due to a lack of regionally-differentiated data. Numbers shown are the global average.

Passenger and freight trains Transport of passengers and freight by rail is currently one of the most energy efficient means of transport. However, there is still potential to reduce the specific energy consumption of trains. Apart from operational and policy measures to reduce energy consumption like raising the load factor of trains, technological measures to reduce energy consumption of future trains are necessary, too. Key technologies are:

- reducing the total weight of a train is seen as the most significant measure to reduce traction energy consumption. By using lightweight structures and lightweight materials, the energy needed to overcome inertial and grade resistances as well as friction from tractive resistances can be reduced.
- aerodynamic improvements to reduce aerodynamic drag, especially important when running on high velocity. A reduction of aerodynamic drag is typically achieved by streamlining the profile of the train.
- switch from diesel-fuelled to more energy efficient electrically driven trains.

references
176 BRADLEY & DRONEY, 2011.
177 IBIDEM.

image DEUTSCHE BAHN AG IN GERMANY, USING RENEWABLE ENERGY. WIND PARK MAERKISCH LINDEN (BRANDENBURG) RUN BY THE DEUTSCHE BAHN AG.

image CYCLING THROUGH FRANKFURT.

- improvements in the traction system to further reduce frictional losses. Technical options include improvements of the major components as well as improvements in the energy management software of the system.
- regenerative braking to recover waste energy. The energy can either be transferred back into the grid or stored on-board in an energy storage device. Regenerative braking is especially effective in regional traffic with frequent stops.
- improved space utilisation to achieve a more efficient energy consumption per passenger kilometre. The simplest way to achieve this is to transport more passengers per train. This can either be achieved by a higher average load factor, more flexible and shorter trainsets or by the use of double-decker trains on highly frequented routes.
- improved accessory functions, e.g. for passenger comfort. The highest amount of energy in a train is used is to ensure the comfort of the train's passengers by heating and cooling. Some strategies for efficiency include djustments to the cabin design, changes to air intakes and using waste heat from traction.

By research on technologies for advanced high-speed trains, DLR's 'Next Generation Train' project aims to reduce the specific energy consumption per passenger kilometre by 50% relative to existing high speed trains in the future.

The Energy [R]evolution scenario uses energy intensity data of TOSCA, 2011 for electric and diesel fuelled train in Europe as input for our calculations. These data were available for 2009 and as forecasts for 2025 and 2050.

The region-specific efficiency factors and shares of diesel/electric traction traffic performance were used to calculate energy intensity data per region (MJ/p-km) for 2009 and up to 2050. The same methodology was applied for rail freight transport.

Figure 11.12 shows the weighted average share of electric and diesel traction today and as of 2030 and 2050 in the Energy [R]evolution scenario.

Electric trains as of today are about 2 to 3.5 times less energy intensive than diesel trains depending on the specific type of rail transport, so the projections to 2050 include a massive shift away from diesel to electric traction in the Energy [R]evolution 2050 scenario.

The region-specific efficiency factors for passenger rail take into account higher load factors for example in China and India. Energy intensity for freight rail is based on the assumptions that regions with longer average distances for freight rail (such as the US and Former Soviet Union), and where more raw materials are transported (such as coal), show a lower energy intensity than other regions (Fulton & Eads, 2004). Future projections use ten year historic IEA data.

figure 11.12: fuel share of electric and diesel rail traction for passenger transport

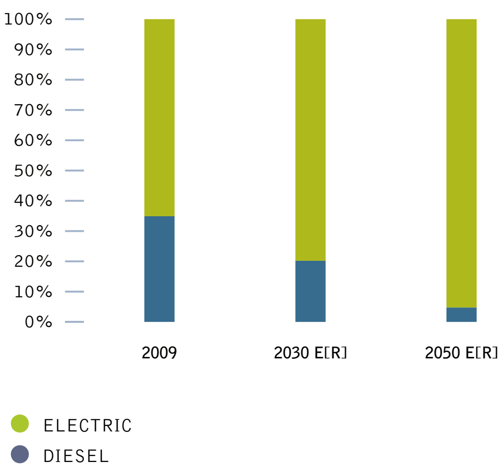


figure 11.13: fuel share of electric and diesel rail traction for freight transport

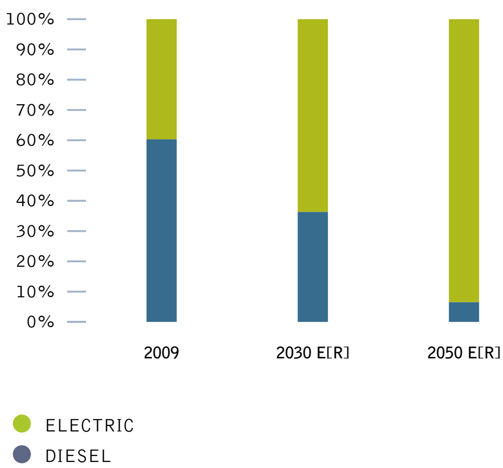


Figure 11.14 shows the energy intensity per region in the Energy [R]evolution scenario for passenger rail and Figure 11.15 shows the energy intensity per region in the Energy [R]evolution scenario for freight rail.

Heavy and medium duty vehicles (freight by road) Freight transport on the road forms the backbone of logistics in many regions of the world. But it is, apart from air freight transport, the most energy intensive way of moving goods around. However, gradual progress is being made in the fields of drivetrain efficiency, lightweight construction, alternative power trains and fuels and so on.

This study projected a major shift in drivetrain market share of medium and heavy duty vehicles in our Energy [R]evolution scenario in the future. As of today, the great majority of MDV and HDV is powered by internal combustion engines, fuelled mainly by diesel and in MDV as well by a small share of gasoline and gas (CNG and LPG). The Energy [R]evolution model includes a considerable shift to electric and fuel cell hydrogen powered vehicles (FCV) until 2050.

The electric MDV stock in the model will be mainly composed of battery electric vehicles (BEV), and a relevant share of hybrid electric vehicles (HEV). Hybrid electric vehicles will have also displaced conventional internal combustion engines in heavy duty vehicles. In addition to this, both electric vehicles supplied with current via overhead catenary lines and BEV are modeled in the Energy [R]evolution scenario for HDV applications. Siemens has proved the technical feasibility of the catenary technology for trucks with experimental vehicles in its eHighway project (Figure 11.16). The trucks are equipped with a hybrid diesel powertrain to be able to operate when not connected to the overhead line. When under a catenary line, the trucks can operate fully electric at speeds of up to 90 km/h.

Apart from electrically operated trucks fed by an overhead catenary, also inductive power supply via induction loops under the pavement could become an option. In addition to the electric truck fleet in the Energy [R]evolution scenario, HDV and MDV powered by fuel cells (FCV) were integrated into the vehicle stock, too.

FCV are beneficial especially for long haul transports where no overhead catenary lines are available and the driving range of BEV would not be sufficient.

figure 11.16: HDV operating fully electrically under a catenary[178]

figure 11.14: energy intensities for passenger rail transport in the energy [r]evolution scenario

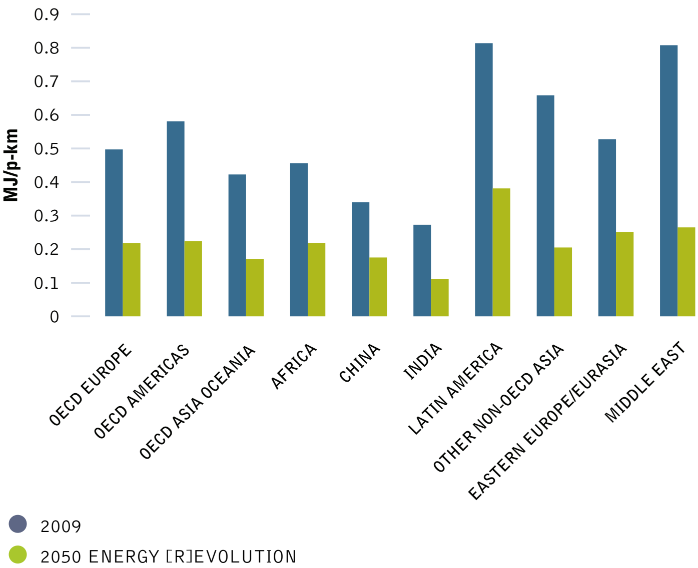
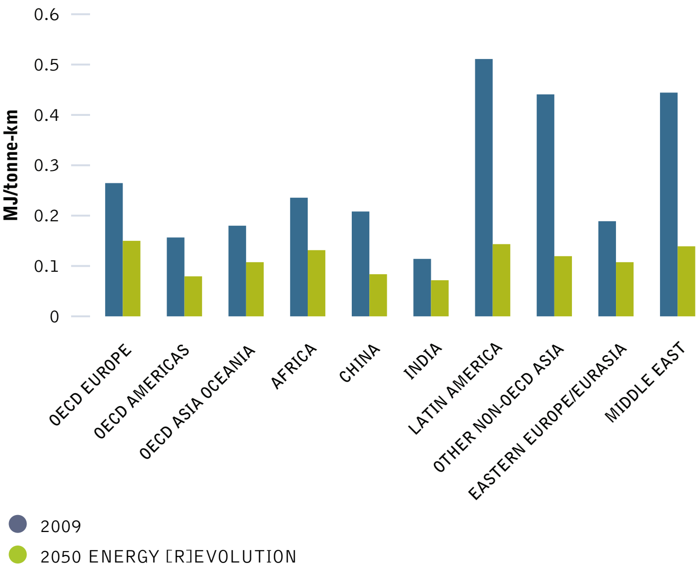


figure 11.15: energy intensities for freight rail transport in the energy [r]evolution scenario



references

178 SOURCE: HTTP://WWW.GREENTECHMEDIA.COM/ARTICLES/READ/SIEMENS-PLANS-TO-CLEAN-UP-TRUCKING-WITH-A-TROLLEY-LINE/

image CHARGING AN ELECTRIC CAR.

Figure 11.17 and Figure 11.18 show the market shares of the power train technologies discussed here for MDV and HDV in 2009, in 2030 Energy [R]evolution and in 2050 Energy [R]evolution. These figures form the basis of the energy consumption calculation in the Energy [R]evolution scenario.

Figure 11.19 shows the energy consumption, based on efficiency ratios of various HDV and MDV power trains relative to diesel powered vehicles.

Energy [R]evolution fleet average transport energy intensities for MDV and HDV were derived using region-specific IEA energy intensity data of MDV and HDV transport until 2050[179], with the specific energy consumption factors of Figure 11.19 applied to the IEA data and matched with the region-specific market shares of the power train technologies.

table 11.5: the world average energy intensities for MDV and HDV in 2009 and 2050 energy [r]evolution

	2009	2050 E[R]
MDV	5,02 MJ/t-km	2,18 MJ/t-km
HDV	1,53 MJ/t-km	0,74 MJ/t-km

The reduction between 2009 and 2050 Energy [R]evolution on a per ton-km basis is then 57% for MDV and 52% for HDV.

The DLR's Institute of Vehicle Concepts conducted a special study to look at future vehicle concepts to see what the potential might be for reducing the overall energy consumption of existing and future trucks when applying energy efficient technologies. The approach will show the potential of different technologies influencing the energy efficiency of future trucks and will also indicate possible cost developments.

figure 11.17: fuel share of medium duty vehicles (global average) by transport performance (ton-km)

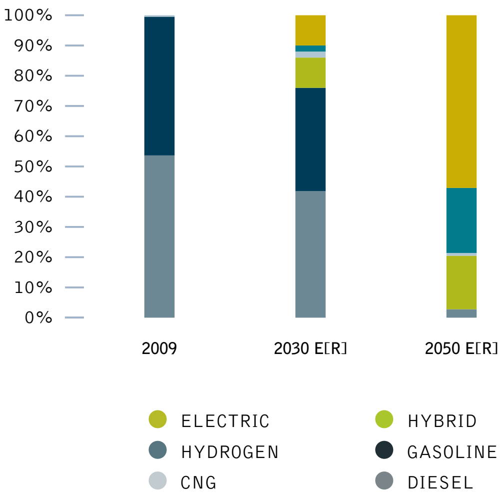


figure 11.18: fuel share of heavy duty vehicles (global average) by transport performance (ton-km)

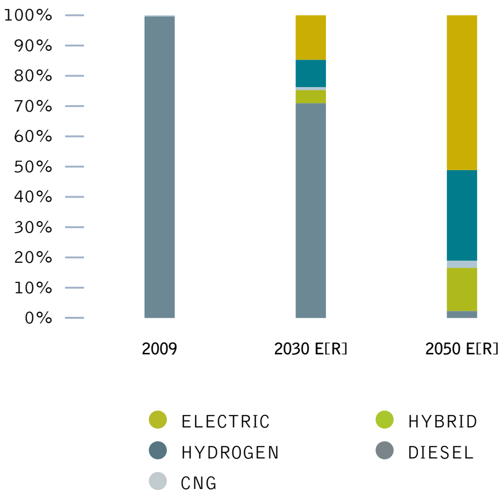
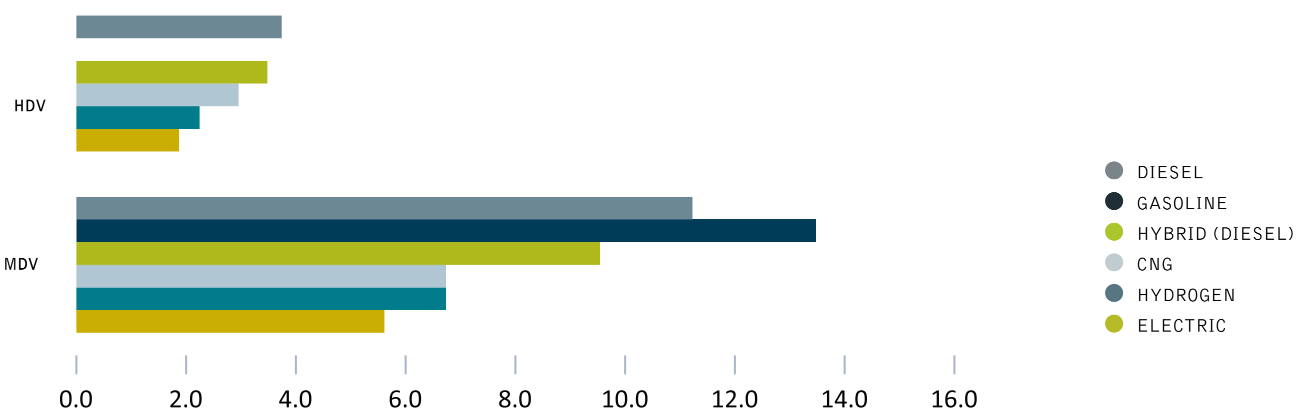


figure 11.19: specific energy consumption of HDV and MDV in litres of gasoline equivalent per 100 tkm in 2050



reference
179 WBSCD 2004.

Inland Navigation Technical measures to reduce energy consumption of inland vessels include:[180]

- aerodynamic improvements to the hull to reduce friction resistance
- improving the propeller design to increase efficiency
- enhancing engine efficiency.

For inland navigation we assumed a reduction of 40% of global averaged energy intensity in relation to a 2009 value of 0.5 MJ/t-km. This means a reduction to 0.3 MJ/t-km.

Marine Transport Several technological measures can be applied to new vessels in order to reduce overall fuel consumption in national and international marine transport. These technologies comprise for example:

- weather routing to optimise the vessel's route
- autopilot adjustments to minimise steering
- improved hull coatings to reduce friction losses
- improved hull openings to optimise water flow
- air lubrication systems to reduce water resistances
- improvements in the design and shape of the hull and rudder
- waste heat recovery systems to increase overall efficiency
- improvement of the diesel engine (e.g. common-rail technology)
- installing towing kites and wind engines to use wind energy for propulsion
- using solar energy for onboard power demand

Adding each technology effectiveness figure stated by ICCT (2011), these technologies have a potential to improve energy efficiency of new vessels between 18.4% and about 57%. Another option to reduce energy demand of ships is simply to reduce operating speeds. Up to 36% of fuel consumption can be saved by reducing the vessel's speed by 20%.[181] Eyring et al. (2005) report that a 25% reduction of fuel consumption for an international marine diesel fleet is achievable by using more efficient alternative propulsion devices only.[182] Up to 30% reduction in energy demand is reported by Marintek (2000) only by optimising the hull shape and propulsion devices of new vessels.[183]

The model assumes a total of 40% energy efficiency improvement potential for international shipping.

box 11.1: case study: wind powered ships

Introduced to commercial operation in 2007, the SkySails system uses wind power, which has no fuel costs, to contribute to the motion of large freight-carrying ships, which currently use increasingly expensive and environmentally damaging oil. Instead of a traditional sail fitted to a mast, the system uses large towing kites to contribute to the ship's propulsion. Shaped like paragliders, they are tethered to the vessel by ropes and can be controlled automatically, responding to wind conditions and the ship's trajectory.

The kites can operate at altitudes of between 100 and 300 metres, where there are stronger and more stable winds. With dynamic flight patterns, the SkySails are able to generate five times more power per square metre of sail area than conventional sails. Depending on the prevailing winds, the company claims that a ship's average annual fuel costs can be reduced by 10% to 35%. Under oprimal wind conditions, fuel consumption can temporarily be cut by 50%.

On the first voyage of the Beluga SkySails, a 133m long specially-built cargo ship, the towing kite propulsion system was able to temporarily substitute for approximately 20% of the vessel's main engine power, even in moderate winds. The company is now planning a kite twice the size of this 160m^2 pilot.

The designers say that virtually all sea-going cargo vessels can be retro- or outfitted with the SkySails propulsion sytsem without extensive modifications. If 1,600 ships were equipped with these sails by 2015, it would save over 146 million tonnes of CO_2 a year, equivalent to about 15% of Germany's total emissions.

references
180 BASED ON VAN ROMPUY, 2010.
181 ICCT, 2011.
182 EYRING ET AL., 2005.
183 MARINTEK, 2000.

image A SIGN PROMOTES A HYDROGEN REFUELING STATION IN REYKJAVIK. THESE STATIONS ARE PART OF A PLAN TO TRY AND MAKE ICELAND A 'HYDROGEN ECONOMY.'

image PARKING SPACE FOR HYBRIDS ONLY.

Passenger cars This section draws on the future vehicle technologies study conducted by the DLR's Institute of Vehicle Concepts. The approach shows the potential of different technologies influencing the energy efficiency of future cars.

Many technologies can be used to improve the fuel efficiency of passenger cars. Examples include improvements in engines, weight reduction as well as friction and drag reduction.[184] The impact of the various measures on fuel efficiency can be substantial. Hybrid vehicles, combining a conventional combustion engine with an electric engine, have relatively low fuel consumption. The most well-known is the Toyota Prius, which originally had a fuel efficiency of about 5 litres of gasoline-equivalent per 100 km (litre ge/100 km). Toyota has recently presented an improved version with a lower fuel consumption of 4.3 litres ge/100 km. Applying new lightweight materials, in combination with new propulsion technologies, can bring fuel consumption levels down to 1 litre ge/100 km.

The figure below gives the energy intensities calculated using power train market shares and efficiency improvements for LDV in the Reference scenario and in the Energy [R]evolution scenario.

The energy intensities for car passenger transport are currently highest in OECD North America and lowest in OECD Europe. The Reference scenario shows a decrease in energy intensities in all regions, but the division between highest and lowest will remain the same, although there will be some convergence. We have assumed that the occupancy rate for cars remains nearly the same as in 2009, as shown in the figure below.

Table 11.6 summarises the energy efficiency improvement for passenger transport in the Energy [R]evolution 2050 scenario and Table 11.7 shows the energy efficiency improvement for freight transport in the Energy [R]evolution 2050 scenario.

table 11.6: technical efficiency potential for world passenger transport

MJ/P-KM	2009	2050 E[R]
LDV	1.5	0.3
Air (Domestic)	2.5	1.2
Buses	0.5	0.3
Mini-buses	0.5	0.3
Two wheels	0.5	0.3
Three wheels	0.7	0.5
Passenger rail	0.4	0.2

table 11.7: technical efficiency potential for world freight transport

MJ/T-KM	2009	2050 E[R]
MDV	4.8	2.7
HDV	1.6	0.8
Freight rail	0.2	0.1
Inland Navigation	0.5	0.3

figure 11.20: energy intensities for freight rail transport in the energy [r]evolution scenario

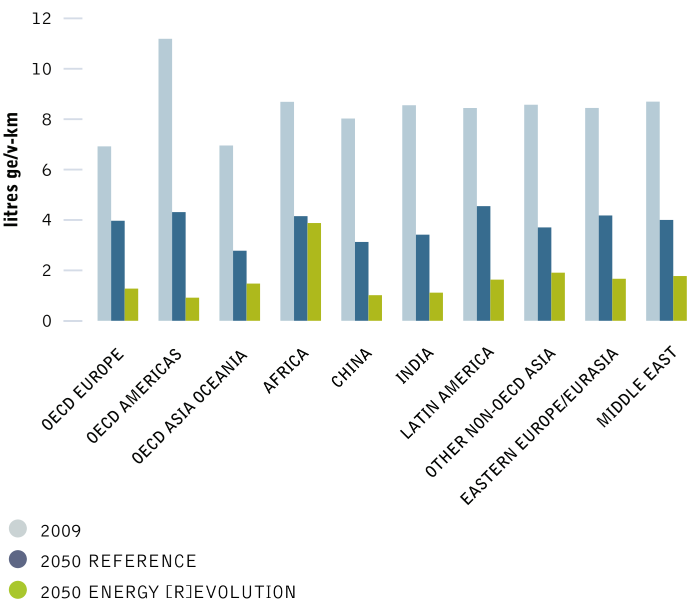
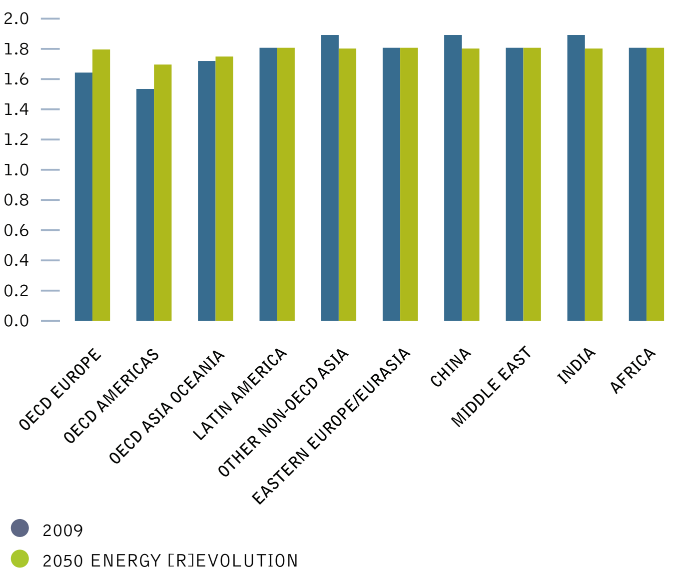


figure 11.21: LDV occupancy rates in 2009 and in the energy [r]evolution 2050



references

184 DECICCO ET AL., 2001.

11.3 projection of the future LDV market

11.3.1 projection of the future technology mix

To achieve the substantial CO_2-reduction targets in the Energy [R]evolution scenario would require a radical shift in fuels for cars and other light duty vehicles. It would mean that conventional fossil fueled cars are no longer used in 2050 in almost all world regions except for Africa. For viable, full electrification based on renewable energy sources, the model assumes that petrol and diesel fuelled autonomous hybrids and plug-in hybrids that we have today are phased out already by 2050. That is, two generations of hybrid technologies will pave the way for the complete transformation to light duty vehicles with full battery electric or hydrogen fuel cell powertrains. This is the only way that is efficient enough for the use of renewable energy to reach the CO_2-targets in the LDV sector.

In the future it may not be possible to power LDVs for all purposes by rechargeable batteries only. Therefore, hydrogen is required as a renewable fuel especially for larger LDVs including light commercial vehicles. Biofuels and remaining oil will be used in other applications where a substitution is even harder than for LDVs. Figure 11.22 shows the share of fuel cell vehicles (autonomous hybrids) and full battery electric vehicles (grid-connectable) in 2050 in the new vehicle market.

11.3.2 projection of the future vehicle segment split

For future vehicle segment split the scenario is constructed to disaggregate the light-duty vehicle sales into three segments: small, medium and large vehicles. In this way, the model shows the effect of 'driving small urban cars', to see if they are suitable for megacities of the future. The size and CO_2 emissions of the vehicles are particularly interesting in the light of the enormous growth predicted in the LDV stock. For our purposes we could divide up the numerous car types as follows:

- The very small car bracket includes city, supermini, minicompact cars as well as one and two seaters.
- The small sized bracket includes compact and subcompact cars, micro and subcompact vans and small SUVs.
- The medium sized bracket includes car derived vans and small station wagons, upper medium class, midsize cars and station wagons, executive class, compact passenger vans, car derived pickups, medium SUVs, 2WD and 4WD.
- The large car bracket includes all kinds of luxury class, luxury multi purpose vehicles, medium and heavy vans, compact and full-size pickup trucks (2WD, 4WD), standard and luxury SUVs. In addition, we looked at light duty trucks in North America and light commercial vehicles in China separately.

In examining the segment split, we have focused most strongly on the two world regions which will be the largest emitters of CO_2 from cars in 2050: North America and China. In North America today the small vehicle segment is almost non-existant. We found it necessary to introduce here small cars substantially up to a sales share of 50% in 2050, triggered by rising fuel prices and possibly vehicle taxes. For China, we have anticipated a similar share of the mature car market as for Europe and projected that the small segment will grow by 3% per year at the expenses of the larger segments in the light of rising mass mobility. The segment split is shown in Figure 11.23.

figure 11.22: sales share of conventional ICE, autonomous hybrid and grid-connectable vehicles in 2050

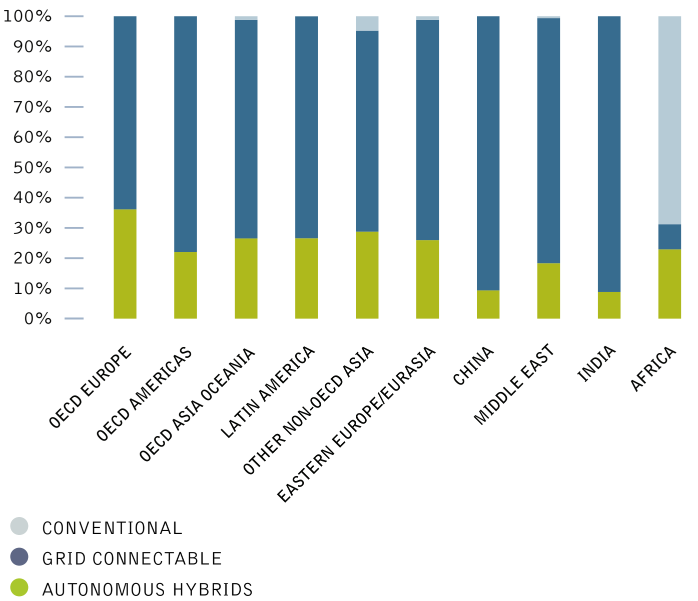
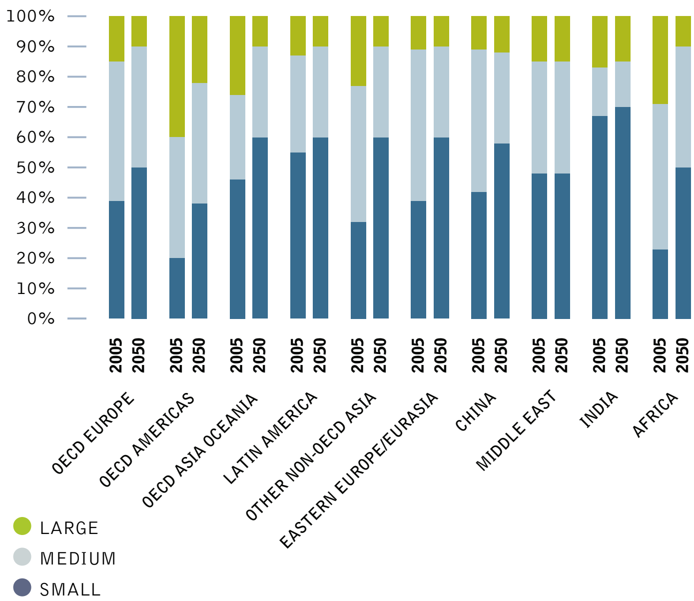


figure 11.23: vehicle sales by segment in 2009 and 2050 in the energy [r]evolution scenario



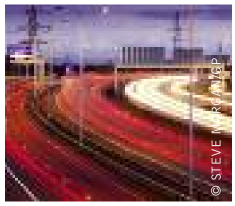
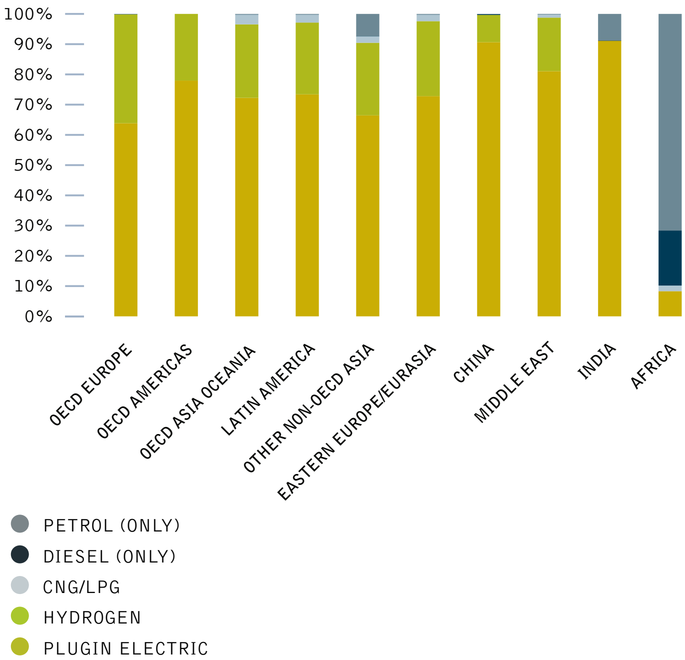


image CARS ON THE ROAD NEAR MANCHESTER. ROAD TRANSPORT IS ONE OF THE BIGGEST SOURCES OF POLLUTION IN THE UK, CONTRIBUTING TO POOR AIR QUALITY, CLIMATE CHANGE, CONGESTION AND NOISE DISTURBANCE. OF THE 33 MILLION VEHICLES ON OUR ROADS, 27 MILLION ARE CARS.

11.3.3 projection of the future switch to alternative fuels

A switch to renewable fuels in the car fleet is one of the cornerstones of the low CO_2 car scenario, with the most prominent element the direct use of renewable electricity in cars. The different types of electric and hybrid cars, such as battery electric and plug-in hybrid, are summarised as 'plug-in electric'. Their introduction will start in industrialised countries in 2015, following an s-curve pattern, and are projected to reach about 40% of total LDV sales in the EU, North America and the Pacific OECD by 2050. Due to the higher costs of the technology and renewable electricity availability, we have slightly delayed progress in other countries. More cautious targets are applied for Africa. The sales split in vehicles by fuel is presented in Figure 11.24 for 2005 and 2050.

figure 11.24: fuel split in vehicle sales for 2050 energy [r]evolution by world region



11.3.4 projection of the global vehicle stock development

There are huge differences in forecasts for the growth of vehicle sales in developing countries. In general, the increase in sales and thus vehicle stock and ownersip is linked to the forecast of GDP growth, which is a well established correlation in the science community. However, this scenario analysis found that technology shift in LDVs alone – although linked to enormous efficiency gains and fuel switch - is not enough to fulfil the ambitious Energy [R]evolution CO_2 targets. A slow down of vehicle sales growth and a limitation or even reduction in vehicle ownership per capita compared to the reference scenario was thus required.

Global urbanisation, the on-going rise of megacities, where space for parking is scarce, and the trend starting today that ownership of cars might not be seen as desirable as in the past supports, draws a different scenario of the future compared to the reference case. Going against the global pattern of a century, this development would have to be supported by massive policy intervention to promote modal shift and alternative forms of car usage. The development of the global car market is shown in Figure 11.25 and 11.26.

figure 11.25: development of the global LDV stock under the reference scenario

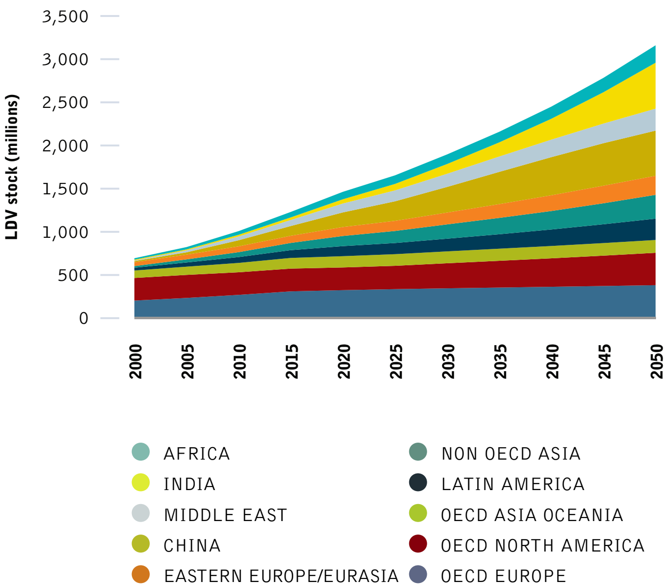
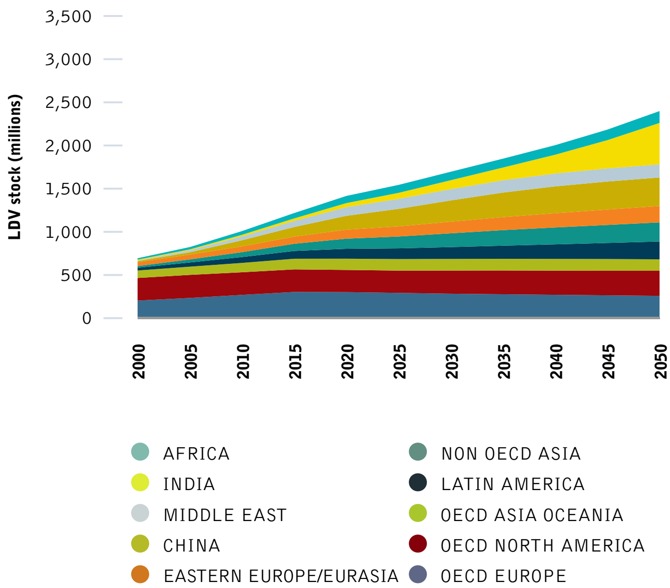


figure 11.26: development of the global LDV stock under the energy [r]evolution scenario

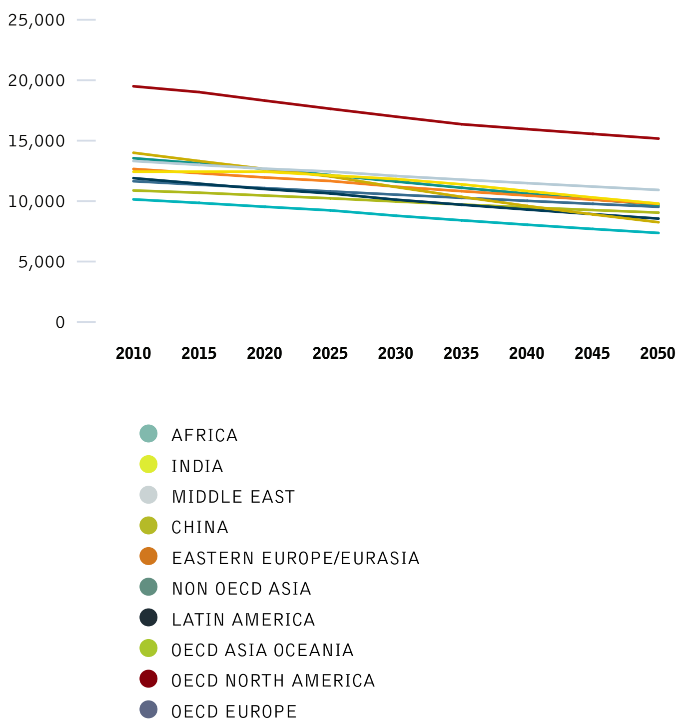


11.3.5 projection of the future kilometres driven per year

Until a full shift from fossil to renewable fuels has taken place, driving on the road will create CO_2 emissions. Thus driving less contributes to our target for emissions reduction. However, this shift does not have to mean reduced mobility because there are many excellent opportunities for shifts from individual passenger road transport towards less CO_2 intense public or non-motorised transport.

Data on average annual kilometres driven are uncertain in many world regions except for North America, Europe and recently China. The scenario starts from the state-of-the-art knowledge on how LDVs are driven in the different world regions and then projects a decline in car usage. This is a further major building block in the low carbon strategy of the Energy [R]evolution scenario, which goes hand in hand with new mobility concepts like co-modality and car-sharing concepts. In 2050, policies supporting the use of public transport and environmental friendly modes are anticipated to be in place in all world regions. Our scenario of annual kilometres driven (AKD) by LDVs is shown in Figure 11.27. In total, AKD fall almost by one quarter until 2050 compared to 2010.

figure 11.27: average annual LDV kilometres driven per world region



11.4 conclusion

In a business as usual world we project a high rise of transport energy demand until 2050 in all world regions in the Reference scenario, which is fuelled especially by fast developing countries like China and India.

The aim of this chapter was therefore to show ways to reduce energy demand in general and the dependency on climate-damaging fossil fuels in the transport sector.

The findings of our scenario calculations show that in order to reach the ambitious energy reduction goals of the Energy [R]evolution scenario a combination of behavioral changes and tremendous technical efforts is needed:

- a decrease of passenger and freight kilometers on a per capita base
- a massive shift to electrically and hydrogen powered vehicles whose energy sources may be produced by renewables
- a gradual decrease of all modes' energy intensities by technological progress
- a modal shift from aviation to high speed rail and from road freight to rail freight.

These measures must of course be accompanied by major efforts in the installation and extension of the necessary infrastructures as for example in railway networks hydrogen and battery charging infrastructure for electric vehicles and an electrification of highways.

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glossary & appendix

GLOSSARY OF COMMONLY USED TERMS AND ABBREVIATIONS

DEFINITION OF SECTORS

image ICEBERGS FLOATING IN MACKENZIE BAY ON THE THE NORTHEASTERN EDGE OF ANTARCTICA'S AMERY ICE SHELF, EARLY FEBRUARY 2012.

12

12.1 glossary of commonly used terms and abbreviations

CHP Combined Heat and Power
CO_2 Carbon dioxide, the main greenhouse gas
GDP Gross Domestic Product (means of assessing a country's wealth)
PPP Purchasing Power Parity (adjustment to GDP assessment to reflect comparable standard of living)
IEA International Energy Agency

J Joule, a measure of energy:
kJ (Kilojoule) = 1,000 Joules
MJ (Megajoule) = 1 million Joules
GJ (Gigajoule) = 1 billion Joules
PJ (Petajoule) = 10^{15} Joules
EJ (Exajoule) = 10^{18} Joules

W Watt, measure of electrical capacity:
kW (Kilowatt) = 1,000 watts
MW (Megawatt) = 1 million watts
GW (Gigawatt) = 1 billion watts
TW (Terawatt) = 1^{12} watts

kWh Kilowatt-hour, measure of electrical output:
kWh (Kilowatt-hour) = 1,000 watt-hours
TWh (Terawatt-hour) = 10^{12} watt-hours

t Tonnes, measure of weight:
t = 1 tonne
Gt = 1 billion tonnes

table 12.1: conversion factors - fossil fuels

FUEL				
Coal	23.03	MJ/kg	1 cubic	0.0283 m^3
Lignite	8.45	MJ/kg	1 barrel	159 liter
Oil	6.12	GJ/barrel	1 US gallon	3.785 liter
Gas	38000.00	kJ/m^3	1 UK gallon	4.546 liter

table 12.2: conversion factors - different energy units

FROM / TO: MULTIPLY BY	TJ	Gcal	Mtoe	Mbtu	GWh
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	$10^{(-7)}$	3.968	1.163×10^{-3}
Mtoe	4.1868×10^{4}	10^{7}	1	3968×10^{7}	11630
Mbtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-5}	3412	1

12.2 definition of sectors

The definition of different sectors follows the sectorial break down of the IEA World Energy Outlook series.

All definitions below are from the IEA Key World Energy Statistics.

Industry sector: Consumption in the industry sector includes the following subsectors (energy used for transport by industry is not included -> see under "Transport")

- Iron and steel industry
- Chemical industry
- Non-metallic mineral products e.g. glass, ceramic, cement etc.
- Transport equipment
- Machinery
- Mining
- Food and tobacco
- Paper, pulp and print
- Wood and wood products (other than pulp and paper)
- Construction
- Textile and Leather

Transport sector: The Transport sector includes all fuels from transport such as road, railway, aviation, domestic navigation. Fuel used for ocean, coastal and inland fishing is included in "Other Sectors".

Other sectors: "Other Sectors" covers agriculture, forestry, fishing, residential, commercial and public services.

Non-energy use: Covers use of other petroleum products such as paraffin waxes, lubricants, bitumen etc.

global: scenario results data

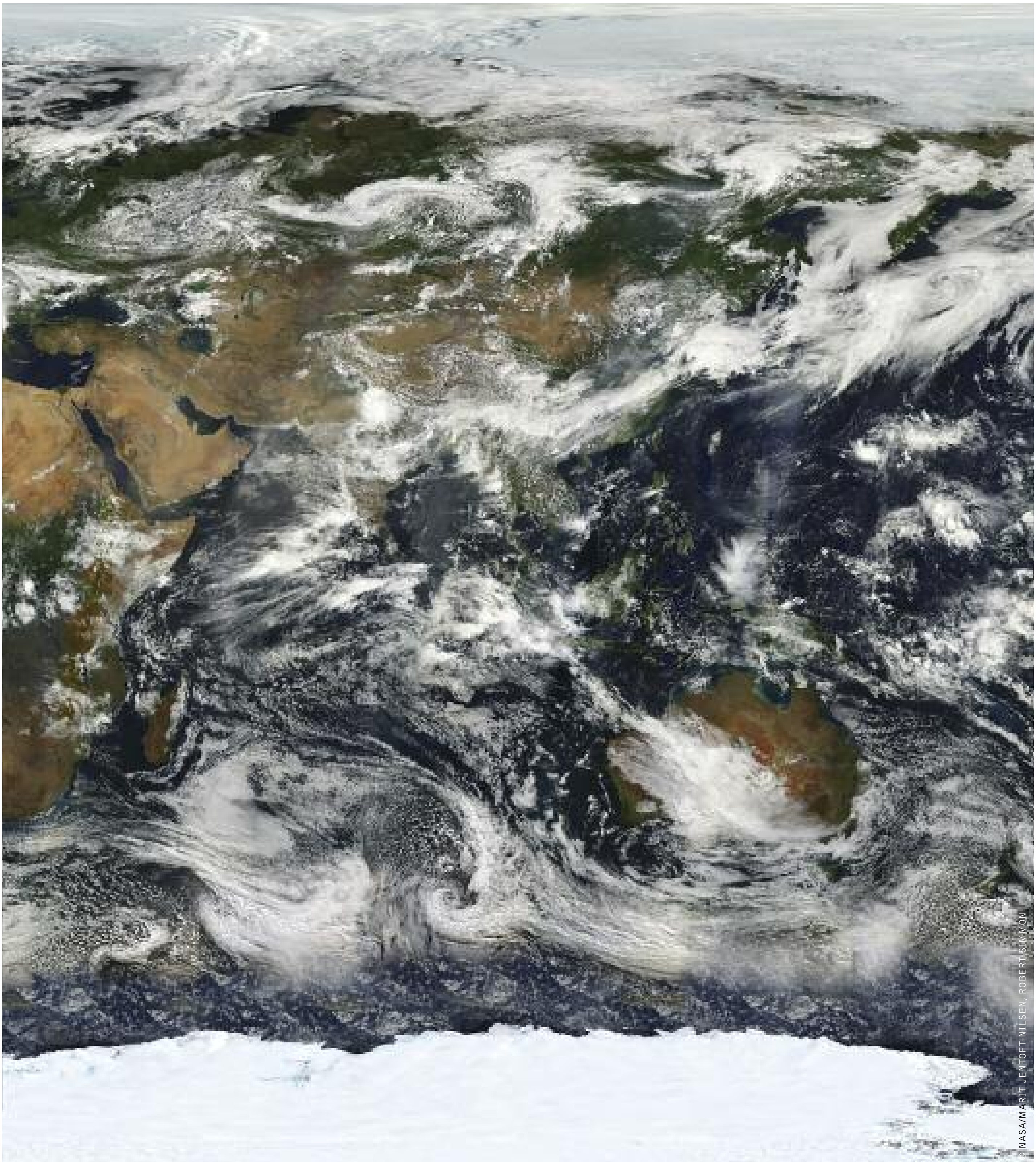


image THE EARTH ON JULY 11, 2005 AS SEEN BY NASA'S EARTH OBSERVING SYSTEM, A COORDINATED SERIES OF SATELLITES THAT MONITOR HOW EARTH IS CHANGING. THEY DOCUMENT EARTH'S BIOSPHERE, CARBON MONOXIDE, AEROSOLS, ELEVATION, AND NET RADIATION.

global: reference scenario

table 12.3: global: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**18,064**	**22,352**	**26,071**	**32,646**	**39,045**	**44,804**
Coal	5,698	7,802	9,543	12,796	15,731	17,898
Lignite	1,712	1,706	1,650	1,416	1,243	1,147
Gas	3,280	4,027	4,641	6,107	7,943	9,923
Oil	825	669	601	479	404	360
Diesel	107	91	83	73	71	68
Nuclear	2,676	2,949	3,495	3,938	4,058	4,183
Biomass	180	296	401	696	1,012	1,297
Hydro	3,226	3,791	4,223	4,834	5,325	5,780
Wind	273	806	1,127	1,710	2,298	2,838
of which wind offshore	0	9	51	214	392	559
PV	20	108	158	341	548	746
Geothermal	65	91	113	163	225	283
Solar thermal power plants	1	15	35	81	143	222
Ocean energy	1	1	2	13	43	58
Combined heat & power plants	**1,992**	**2,237**	**2,420**	**2,815**	**3,181**	**3,512**
Coal	488	584	675	815	939	1,060
Lignite	185	180	170	161	152	146
Gas	1,131	1,260	1,336	1,542	1,724	1,867
Oil	83	72	60	47	45	40
Biomass	104	137	173	241	307	378
Geothermal	2	4	5	9	14	20
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	1,451	1,566	1,623	1,776	1,913	2,028
Autoproducers	542	672	797	1,039	1,268	1,484
Total generation	**20,056**	**24,589**	**28,490**	**35,461**	**42,226**	**48,316**
Fossil	13,509	16,392	18,759	23,436	28,253	32,511
Coal	6,186	8,386	10,218	13,611	16,670	18,959
Lignite	1,897	1,886	1,820	1,576	1,395	1,294
Gas	4,410	5,287	5,977	7,649	9,667	11,790
Oil	908	741	661	526	449	401
Diesel	107	91	83	73	71	68
Nuclear	2,676	2,949	3,495	3,938	4,058	4,183
Hydrogen	0	0	0	0	0	0
Renewables	**3,872**	**5,249**	**6,237**	**8,088**	**9,915**	**11,623**
Hydro	3,226	3,791	4,223	4,834	5,325	5,780
Wind	273	806	1,127	1,710	2,298	2,838
of which wind offshore	0	9	51	214	392	559
PV	20	108	158	341	548	746
Biomass	284	433	574	937	1,319	1,675
Geothermal	67	94	118	172	238	303
Solar thermal	1	15	35	81	143	222
Ocean energy	1	1	2	13	43	58
Distribution losses	1,682	1,863	2,123	2,578	3,061	3,515
Own consumption electricity	1,692	1,974	2,232	2,671	3,083	3,481
Electricity for hydrogen production	0	0	0	1	2	3
Final energy consumption (electricity)	**16,707**	**20,744**	**24,128**	**30,201**	**36,060**	**41,293**
Fluctuating RES (PV, Wind, Ocean)	294	915	1,286	2,064	2,889	3,643
Share of fluctuating RES	1.5%	3.7%	4.5%	5.8%	6.8%	7.5%
RES share (domestic generation)	**19.3%**	**21.3%**	**21.9%**	**22.8%**	**23.5%**	**24.1%**

table 12.4: global: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**6,598**	**6,946**	**7,417**	**7,498**	**7,716**	**8,170**
Fossil fuels	6,331	6,568	6,937	6,894	7,110	7,591
Biomass	265	374	475	598	600	574
Solar collectors	0	0	0	1	1	0
Geothermal	3	4	4	5	5	5
Heat from CHP	**6,303**	**7,074**	**7,676**	**8,463**	**9,124**	**10,036**
Fossil fuels	5,938	6,661	7,174	7,834	8,338	9,046
Biomass	355	390	471	582	712	871
Geothermal	10	23	31	47	75	119
Hydrogen	0	0	0	0	0	0
Direct heating[1]	**124,373**	**142,878**	**151,410**	**162,652**	**172,640**	**181,464**
Fossil fuels	90,033	105,883	113,457	122,561	129,024	133,997
Biomass	33,465	35,699	36,365	37,675	40,044	42,935
Solar collectors	545	883	1,099	1,742	2,542	3,255
Geothermal[2]	329	411	489	673	1,030	1,277
Total heat supply[1]	**137,274**	**156,898**	**166,502**	**178,613**	**189,480**	**199,670**
Fossil fuels	102,302	119,112	127,567	137,289	144,472	150,634
Biomass	34,085	36,464	37,311	38,856	41,356	44,380
Solar collectors	546	884	1,100	1,743	2,543	3,255
Geothermal[2]	342	438	525	725	1,110	1,400
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**25.5%**	**24.1%**	**23.4%**	**23.1%**	**23.8%**	**24.6%**

1) heat from electricity (direct) not included; 2) including heat pumps.

table 12.5: global: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**10,117**	**12,073**	**13,568**	**16,177**	**18,507**	**19,343**
Coal	6,090	7,865	9,273	11,712	13,507	14,029
Lignite	1,757	1,752	1,663	1,319	1,163	1,080
Gas	1,529	1,850	2,082	2,714	3,475	3,922
Oil	659	540	490	379	312	263
Diesel	82	66	60	52	51	49
Combined heat & power production	**1,779**	**1,784**	**1,781**	**1,851**	**1,946**	**2,045**
Coal	591	670	703	760	820	881
Lignite	246	202	175	166	156	153
Gas	851	834	835	871	924	976
Oil	92	78	69	55	45	35
CO_2 emissions power generation (incl. CHP public)	**11,896**	**13,856**	**15,349**	**18,028**	**20,454**	**21,388**
Coal	6,681	8,535	9,975	12,472	14,327	14,910
Lignite	2,002	1,954	1,837	1,484	1,320	1,233
Gas	2,379	2,684	2,917	3,585	4,399	4,897
Oil & diesel	833	684	619	487	408	347
CO_2 emissions by sector	**27,925**	**31,951**	**34,751**	**39,192**	**42,968**	**45,267**
% of 1990 emissions	133%	153%	166%	187%	205%	216%
Industry[1]	4,674	5,873	6,393	6,774	6,997	7,185
Other sectors[1]	3,380	3,617	3,761	3,967	4,055	4,097
Transport	5516	6299	6673	7716	8733	9847
Power generation[2]	11,526	13,401	14,835	17,430	19,782	20,650
District heating & other conversion	2,829	2,761	3,089	3,306	3,401	3,487
Population (Mill.)	6,818	7,284	7,668	8,372	8,978	9,469
CO_2 emissions per capita (t/capita)	**4.1**	**4.4**	**4.5**	**4.7**	**4.8**	**4.8**

1) including CHP autoproducers. 2) including CHP public

table 12.6: global: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**4,387**	**5,543**	**6,294**	**7,635**	**8,991**	**10,267**
Coal	1,138	1,559	1,826	2,350	2,798	3,124
Lignite	297	292	287	232	196	182
Gas	987	1,238	1,400	1,698	2,117	2,584
Oil	319	282	247	187	159	133
Diesel	46	54	49	46	45	42
Nuclear	395	420	485	539	549	565
Biomass	34	57	71	117	167	211
Hydro	995	1,137	1,250	1,425	1,564	1,695
Wind	147	397	525	754	959	1,135
of which wind offshore	0	3	17	68	116	160
PV	19	88	124	234	351	471
Geothermal	11	14	18	25	35	44
Solar thermal power plants	0	5	11	24	40	62
Ocean energy	0	1	1	4	13	18
Combined heat & power production	**521**	**553**	**578**	**633**	**698**	**761**
Coal	125	134	149	169	190	217
Lignite	40	35	32	27	24	23
Gas	286	308	328	372	409	434
Oil	52	53	40	25	24	23
Biomass	18	22	27	38	49	60
Geothermal	0	1	1	1	2	3
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	399	397	400	404	421	443
Autoproducers	122	156	178	229	278	317
Total generation	**4,908**	**6,096**	**6,872**	**8,268**	**9,690**	**11,028**
Fossil	3,290	3,954	4,359	5,106	5,962	6,763
Coal	1,263	1,693	1,975	2,519	2,988	3,342
Lignite	338	327	318	259	220	205
Gas	1,273	1,545	1,729	2,070	2,526	3,018
Oil	372	335	288	212	183	156
Diesel	46	54	49	46	45	42
Nuclear	395	420	485	539	549	565
Hydrogen	0	0	0	0	0	0
Renewables	**1,224**	**1,721**	**2,028**	**2,622**	**3,179**	**3,699**
Hydro	995	1,137	1,250	1,425	1,564	1,695
Wind	147	397	525	754	959	1,135
of which wind offshore	0	3	17	68	116	160
PV	19	88	124	234	351	471
Biomass	51	79	98	155	215	272
Geothermal	11	15	18	27	37	47
Solar thermal	0	5	11	24	40	62
Ocean energy	0	1	1	4	13	18
Fluctuating RES (PV, Wind, Ocean)	165.8	485.6	649.7	992	1322	1624
Share of fluctuating RES	3.4%	8.0%	9.5%	12.0%	13.6%	14.7%
RES share (domestic generation)	**24.9%**	**28.2%**	**29.5%**	**31.7%**	**32.8%**	**33.5%**

table 12.7: global: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**498,243**	**568,874**	**615,685**	**693,951**	**760,603**	**805,253**
Fossil	**401,126**	**457,556**	**491,659**	**550,601**	**601,888**	**633,413**
Hard coal	120,811	147,912	166,399	192,304	209,391	212,151
Lignite	21,649	21,418	20,343	16,891	15,096	14,094
Natural gas	107,498	121,067	131,682	155,412	179,878	195,804
Crude oil	151,168	167,159	173,236	185,993	197,522	211,365
Nuclear	**29,215**	**32,169**	**38,125**	**42,958**	**44,275**	**45,636**
Renewables	**67,902**	**79,149**	**85,900**	**100,393**	**114,440**	**126,204**
Hydro	11,617	13,650	15,205	17,403	19,173	20,811
Wind	983	2,902	4,057	6,155	8,275	10,219
Solar	626	1,397	1,960	3,614	5,629	7,718
Biomass	52,040	58,099	61,077	68,443	75,248	80,503
Geothermal/ambient heat	2,634	3,095	3,593	4,728	5,961	6,744
Ocean energy	2	5	7	48	155	209
RES share	**13.6%**	**13.9%**	**13.9%**	**14.4%**	**15.0%**	**15.6%**

table 12.8: global: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**335,013**	**386,456**	**416,436**	**469,241**	**517,946**	**564,280**
Total (energy use)	**303,800**	**351,445**	**379,485**	**429,613**	**476,674**	**521,892**
Transport	**81,577**	**94,462**	**100,181**	**116,457**	**132,881**	**150,478**
Oil products	75,529	86,100	90,821	103,949	116,650	131,366
Natural gas	2,923	3,614	3,836	4,973	6,597	7,984
Biofuels	2,158	3,472	4,070	5,612	7,129	8,018
Electricity	967	1,276	1,455	1,920	2,500	3,102
RES electricity	187	272	318	438	587	746
Hydrogen	0	0	0	3	5	9
RES share Transport	**2.9%**	**4.0%**	**4.4%**	**5.2%**	**5.8%**	**5.8%**
Industry	**95,202**	**119,107**	**131,613**	**147,134**	**160,379**	**171,874**
Electricity	24,131	32,563	38,348	47,330	55,620	62,635
RES electricity	4,658	6,951	8,395	10,795	13,059	15,067
District heat	4,607	5,200	5,674	5,857	6,073	6,565
RES district heat	110	293	366	446	492	550
Coal	22,026	31,535	35,220	36,111	35,677	34,758
Oil products	13,290	14,600	15,029	15,185	15,202	15,508
Gas	23,403	25,707	27,405	31,513	35,342	38,732
Solar	0	4	7	11	22	64
Biomass and waste	7,731	9,481	9,913	11,108	12,421	13,582
Geothermal/ambient heat	15	16	17	19	22	31
Hydrogen	0	0	0	0	0	0
RES share Industry	**13.1%**	**14.1%**	**14.2%**	**15.2%**	**16.2%**	**17.0%**
Other Sectors	**127,021**	**137,875**	**147,690**	**166,022**	**183,415**	**199,540**
Electricity	35,049	40,839	47,058	59,474	71,697	82,919
RES electricity	6,766	8,717	10,302	13,564	16,834	19,946
District heat	5,974	6,338	6,794	7,392	7,952	8,642
RES district heat	126	328	407	513	554	571
Coal	5,995	5,750	5,453	4,867	3,690	2,492
Oil products	18,070	19,333	20,004	19,978	19,503	19,003
Gas	26,030	28,914	31,050	35,724	39,875	43,240
Solar	545	879	1,092	1,732	2,520	3,191
Biomass and waste	35,151	35,552	35,908	36,358	37,320	38,959
Geothermal/ambient heat	207	270	330	497	858	1,094
RES share Other Sectors	**33.7%**	**33.2%**	**32.5%**	**31.7%**	**31.7%**	**32.0%**
Total RES	**57,653**	**66,234**	**71,125**	**81,093**	**91,821**	**101,821**
RES share	**19.0%**	**18.8%**	**18.7%**	**18.9%**	**19.3%**	**19.5%**
Non energy use	**31,213**	**35,012**	**36,952**	**39,627**	**41,271**	**42,388**
Oil	23,979	26,109	27,354	28,976	29,834	30,463
Gas	5,692	7,018	7,581	8,499	9,226	9,725
Coal	1,542	1,885	2,017	2,152	2,211	2,201

global: energy [r]evolution scenario

table 12.9: global: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**18,064**	**21,648**	**23,766**	**29,082**	**36,131**	**41,258**
Coal	5,698	7,135	7,154	5,731	3,218	152
Lignite	1,712	1,669	1,042	130	8	0
Gas	3,280	3,984	4,254	3,740	2,429	672
Oil	825	648	318	95	22	4
Diesel	107	77	59	31	17	10
Nuclear	2,676	2,226	1,623	557	182	0
Biomass	180	274	310	359	371	355
Hydro	3,226	3,771	4,192	4,542	4,818	5,009
Wind	273	1,320	2,989	6,971	10,822	13,767
of which wind offshore	0	45	190	1,243	2,345	3,160
PV	20	289	878	2,634	5,242	7,290
Geothermal	65	144	342	1,062	1,923	2,599
Solar thermal power plants	1	92	466	2,672	5,988	9,348
Ocean energy	1	19	139	560	1,089	2,053
Combined heat & power plants	**1,992**	**2,379**	**2,959**	**3,959**	**4,825**	**5,315**
Coal	488	528	518	562	346	77
Lignite	185	121	87	20	0	0
Gas	1,131	1,378	1,631	1,935	1,890	1,484
Oil	83	63	37	10	4	2
Biomass	104	274	621	1,162	1,823	2,336
Geothermal	2	14	58	239	658	1,167
Hydrogen	0	0	7	31	104	249
CHP by producer						
Main activity producers	1,451	1,609	1,852	2,210	2,436	2,429
Autoproducers	542	770	1,107	1,749	2,389	2,885
Total generation	**20,056**	**24,028**	**26,725**	**33,041**	**40,955**	**46,573**
Fossil	13,509	15,604	15,099	12,253	7,934	2,401
Coal	6,186	7,664	7,671	6,292	3,564	229
Lignite	1,897	1,791	1,129	149	8	0
Gas	4,410	5,362	5,885	5,675	4,318	2,156
Oil	908	711	355	105	27	6
Diesel	107	77	59	31	17	10
Nuclear	2,676	2,226	1,623	557	182	0
Hydrogen	0	0	7	31	104	249
Renewables	**3,872**	**6,198**	**9,996**	**20,201**	**32,735**	**43,923**
Hydro	3,226	3,771	4,192	4,542	4,818	5,009
Wind	273	1,320	2,989	6,971	10,822	13,767
of which wind offshore	0	45	190	1,243	2,345	3,160
PV	20	289	878	2,634	5,242	7,290
Biomass	284	548	932	1,521	2,194	2,691
Geothermal	67	159	400	1,301	2,581	3,765
Solar thermal	1	92	466	2,672	5,988	9,348
Ocean energy	1	19	139	560	1,089	2,053
Distribution losses	1,682	1,834	1,899	2,037	2,075	2,113
Own consumption electricity	1,692	1,864	1,928	1,950	1,864	1,791
Electricity for hydrogen production	0	2	477	2,114	5,236	7,923
Final energy consumption (electricity)	**16,707**	**20,321**	**22,387**	**26,892**	**31,756**	**34,749**
Fluctuating RES (PV, Wind, Ocean)	294	1,628	4,006	10,166	17,154	23,109
Share of fluctuating RES	1.5%	6.8%	15.0%	30.8%	41.9%	49.6%
RES share (domestic generation)	**19.3%**	**25.8%**	**37.4%**	**61.1%**	**79.9%**	**94.3%**
'Efficiency' savings (compared to Ref.)	**0**	**446**	**1,905**	**5,000**	**8,715**	**12,776**

table 12.10: global: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**6,598**	**7,882**	**9,734**	**12,028**	**14,184**	**16,611**
Fossil fuels	6,331	6,798	6,716	5,158	2,368	270
Biomass	265	725	1,524	2,428	3,013	3,336
Solar collectors	0	158	820	2,476	4,851	6,974
Geothermal	3	200	674	1,966	3,952	6,031
Heat from CHP	**6,303**	**9,005**	**11,610**	**17,114**	**22,237**	**25,299**
Fossil fuels	5,938	7,798	8,546	9,858	8,219	5,371
Biomass	355	1,085	2,594	5,163	8,036	9,512
Geothermal	10	122	444	1,912	5,388	9,148
Hydrogen	0	0	26	180	595	1,268
Direct heating[1]	**124,373**	**136,902**	**135,432**	**128,261**	**120,328**	**111,289**
Fossil fuels	90,033	96,094	86,846	61,818	31,154	8,267
Biomass	33,465	36,421	36,279	34,981	32,556	27,520
Solar collectors	545	2,707	6,904	17,527	30,385	38,118
Geothermal[2]	329	1,680	4,824	12,060	22,683	32,309
Hydrogen	0	0	579	1,874	3,550	5,075
Total heat supply[1]	**137,274**	**153,788**	**156,775**	**157,402**	**156,750**	**153,200**
Fossil fuels	102,302	110,690	102,108	76,834	41,741	13,908
Biomass	34,085	38,232	40,397	42,573	43,605	40,368
Solar collectors	546	2,865	7,724	20,004	35,236	45,092
Geothermal[1]	342	2,001	5,942	15,938	32,023	47,488
Hydrogen	0	0	604	2,054	4,145	6,343
RES share (including RES electricity)	**25.5%**	**28.0%**	**34.6%**	**50.7%**	**72.8%**	**90.7%**
'Efficiency' savings (compared to Ref.)	**0**	**3,110**	**9,727**	**21,211**	**32,730**	**46,470**

1) heat from electricity (direct) not included; geothermal includes heat pumps

table 12.11: global: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**10,117**	**11,197**	**10,116**	**7,077**	**3,825**	**393**
Coal	6,090	7,118	6,917	5,278	2,787	124
Lignite	1,757	1,699	1,031	129	7	0
Gas	1,529	1,814	1,875	1,576	1,001	258
Oil	659	510	249	72	16	4
Diesel	82	56	44	23	13	8
Combined heat & power production	**1,779**	**1,791**	**1,749**	**1,668**	**1,248**	**736**
Coal	591	608	550	525	277	52
Lignite	246	147	101	23	0	0
Gas	851	974	1,065	1,110	967	681
Oil	92	62	33	10	4	3
CO_2 emissions power generation (incl. CHP public)	**11,896**	**12,988**	**11,865**	**8,746**	**5,073**	**1,129**
Coal	6,681	7,726	7,468	5,803	3,064	175
Lignite	2,002	1,845	1,132	152	7	0
Gas	2,379	2,788	2,940	2,686	1,968	939
Oil & diesel	833	628	326	105	34	14
CO_2 emissions by sector						
% of 1990 emissions	**27,925**	**29,659**	**27,337**	**20,007**	**10,482**	**3,076**
Industry[1]	133%	142%	131%	96%	50%	15%
Other sectors[1]	4,674	5,295	5,007	3,827	2,019	742
Transport	3,380	3,335	2,853	1,912	1,003	352
Power generation[2]	5516	5,794	5,630	4,274	2,124	1,015
District heating & other conversion	11,526	12,464	11,273	8,082	4,491	721
	2,829	2,771	2,575	1,911	845	247
Population (Mill.)	6,818	7,284	7,668	8,372	8,978	9,469
CO_2 emissions per capita (t/capita)	**4.1**	**4.1**	**3.6**	2.4	1.2	**0.3**
'Efficiency' savings (compared to Ref.)	**0**	**2,292**	**7,413**	**19,185**	**32,486**	**42,191**

1) including CHP autoproducers. 2) including CHP public

table 12.12: global: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**4,387**	**5,519**	**6,741**	**9,513**	**12,644**	**14,803**
Coal	1,138	1,327	1,335	1,069	649	34
Lignite	297	283	180	22	1	0
Gas	987	1,180	1,234	1,139	801	309
Oil	319	254	131	45	10	3
Diesel	46	38	29	16	10	5
Nuclear	395	314	225	75	24	0
Biomass	34	53	56	62	65	65
Hydro	995	1,132	1,246	1,347	1,428	1,484
Wind	147	638	1,357	2,908	4,287	5,236
of which wind offshore	0	14	61	391	688	892
PV	19	234	674	1,764	3,335	4,548
Geothermal	11	24	54	174	325	456
Solar thermal power plants	0	34	166	714	1,362	2,054
Ocean energy	0	9	54	176	345	610
Combined heat & power production	**521**	**585**	**685**	**893**	**1,044**	**1,104**
Coal	125	122	113	114	71	25
Lignite	40	26	18	4	0	0
Gas	286	340	411	518	506	394
Oil	52	47	24	2	1	0
Biomass	18	48	106	203	325	425
Geothermal	0	3	11	45	121	210
Hydrogen	0	0	1	7	21	49
CHP by producer						
Main activity producers	399	408	450	522	543	508
Autoproducers	122	177	234	371	501	596
Total generation	**4,908**	**6,104**	**7,426**	**10,406**	**13,688**	**15,907**
Fossil	3,290	3,617	3,475	2,931	2,049	770
Coal	1,263	1,449	1,448	1,184	720	60
Lignite	338	309	199	26	1	0
Gas	1,273	1,520	1,645	1,657	1,306	703
Oil	372	300	154	48	11	3
Diesel	46	38	29	16	10	5
Nuclear	395	314	225	75	24	0
Hydrogen	0	0	1	7	21	49
Renewables	**1,224**	**2,174**	**3,724**	**7,392**	**11,594**	**15,087**
Hydro	995	1,132	1,246	1,347	1,428	1,484
Wind	147	638	1,357	2,908	4,287	5,236
of which wind offshore	0	14	61	391	688	892
PV	19	234	674	1,764	3,335	4,548
Biomass	51	101	162	265	390	490
Geothermal	11	26	65	219	446	666
Solar thermal	0	34	166	714	1,362	2,054
Ocean energy	0	9	54	176	345	610
Fluctuating RES (PV, Wind, Ocean)	165.8	880	2,085	4,847	7,968	10,394
Share of fluctuating RES	3.4%	14.4%	28.1%	46.6%	58.2%	65.3%
RES share (domestic generation)	**24.9%**	**35.6%**	**50.2%**	**71.0%**	**84.7%**	**94.8%**

table 12.13: global: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**498,243**	**542,460**	**544,209**	**526,958**	**504,731**	**481,039**
Fossil	**401,126**	**427,789**	**400,614**	**306,616**	**185,214**	**84,984**
Hard coal	120,811	135,310	130,599	103,376	58,655	19,484
Lignite	21,649	19,621	12,234	1,843	77	0
Natural gas	107,498	120,861	124,069	106,228	73,452	35,557
Crude oil	151,168	151,996	133,712	95,169	53,030	29,942
Nuclear	**29,215**	**24,289**	**17,714**	**6,079**	**1,984**	**0**
Renewables	**67,902**	**90,383**	**125,880**	**214,262**	**317,533**	**396,055**
Hydro	11,617	13,578	15,092	16,352	17,347	18,036
Wind	983	4,751	10,763	25,102	38,968	49,571
Solar	626	4,604	14,322	47,498	94,221	134,099
Biomass	52,040	61,054	68,827	75,352	76,967	71,590
Geothermal/ambient heat	2,634	6,326	16,376	47,943	86,110	115,369
Ocean energy	2	70	500	2,016	3,920	7,389
RES share	**13.6%**	**16.6%**	**23.1%**	**40.6%**	**62.9%**	**82.3%**
'Efficiency' savings (compared to Ref.)	**0**	**26,543**	**72,106**	**167,666**	**256,332**	**324,507**

table 12.14: global: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**335,013**	**371,184**	**378,684**	**375,580**	**362,042**	**350,884**
Total (energy use)	**303,800**	**337,325**	**344,158**	**340,070**	**326,095**	**316,157**
Transport	**81,577**	**86,812**	**86,758**	**78,014**	**65,025**	**60,529**
Oil products	75,529	79,106	76,358	57,177	27,672	12,436
Natural gas	2,923	3,214	3,297	3,123	2,831	2,636
Biofuels	2,158	3,125	4,521	6,421	7,116	6,730
Electricity	967	1,362	2,321	9,110	20,022	26,454
RES electricity	187	351	868	5,570	16,003	24,949
Hydrogen	0	4	262	2,183	7,385	12,273
RES share Transport	**2.9%**	**4.0%**	**6.3%**	**17.1%**	**44.6%**	**71.5%**
Industry	**95,202**	**113,924**	**120,112**	**122,222**	**120,719**	**116,679**
Electricity	24,131	31,327	35,470	40,372	43,617	45,001
RES electricity	4,658	8,081	13,266	24,683	34,863	42,441
District heat	4,607	7,317	9,853	14,428	18,931	22,267
RES district heat	110	989	2,790	7,003	13,498	19,400
Coal	22,026	26,314	25,397	17,701	5,633	685
Oil products	13,290	12,447	9,302	4,810	2,467	864
Gas	23,403	25,999	25,780	22,599	14,890	5,075
Solar	0	790	2,030	5,229	11,102	14,086
Biomass and waste	7,731	9,183	9,988	10,648	10,642	9,384
Geothermal/ambient heat	15	547	1,652	4,354	9,565	13,849
Hydrogen	0	0	640	2,080	3,872	5,468
RES share Industry	**13.1%**	**17.2%**	**24.9%**	**43.5%**	**68.6%**	**89.4%**
Other Sectors	**127,021**	**136,589**	**137,288**	**139,834**	**140,351**	**138,949**
Electricity	35,049	40,468	43,078	48,432	52,326	54,558
RES electricity	6,766	10,438	16,112	29,611	41,824	51,454
District heat	5,974	7,115	8,712	11,921	14,607	16,908
RES district heat	126	920	2,429	5,832	10,731	15,378
Coal	5,995	5,628	5,068	3,408	1,119	76
Oil products	18,070	17,153	12,482	7,086	3,512	708
Gas	26,030	26,704	24,910	17,510	9,652	3,886
Solar	545	1,918	4,874	12,298	19,293	24,032
Biomass and waste	35,151	36,684	35,549	33,040	29,492	24,166
Geothermal/ambient heat	207	917	2,615	6,139	10,350	14,615
RES share Other Sectors	**33.7%**	**37.2%**	**44.9%**	**62.2%**	**79.6%**	**93.3%**
Total RES	**57,653**	**73,944**	**97,031**	**153,434**	**223,475**	**277,214**
RES share	**19.0%**	**21.9%**	**28.2%**	**45.1%**	**68.5%**	**87.7%**
Non energy use	**31,213**	**33,859**	**34,525**	**35,510**	**35,947**	**34,727**
Oil	23,979	24,310	22,500	19,367	16,636	14,894
Gas	5,692	6,970	7,849	8,282	8,105	7,294
Coal	1,542	2,580	4,177	7,861	11,206	12,539

global: investment & employment

table 12.15: global: total investment in power sector

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Conventional (fossil & nuclear)	**3,544,417**	**3,070,771**	**2,706,206**	**2,542,435**	**11,863,829**	**296,596**
Renewables	**2,509,308**	**2,394,831**	**2,625,579**	**2,797,442**	**10,327,161**	**258,179**
Biomass	218,239	259,591	292,374	316,776	1,086,980	27,174
Hydro	1,303,574	1,166,960	1,084,725	1,330,598	4,885,857	122,146
Wind	620,265	602,406	802,946	653,506	2,679,123	66,978
PV	201,839	200,919	231,962	238,426	873,146	21,829
Geothermal	85,675	70,854	79,430	67,772	303,731	7,593
Solar thermal power plants	76,846	84,228	113,367	178,545	452,986	11,325
Ocean energy	2,871	9,873	20,776	11,820	45,339	1,133
Energy [R]evolution						
Conventional (fossil & nuclear)	**1,764,842**	**760,668**	**598,289**	**232,280**	**3,356,079**	**83,902**
Renewables	**7,105,239**	**10,482,264**	**13,521,260**	**15,938,599**	**47,047,362**	**1,176,184**
Biomass	553,980	482,998	837,382	709,201	2,583,560	64,589
Hydro	1,289,703	903,228	863,906	1,059,272	4,116,108	102,903
Wind	2,030,088	2,921,960	3,886,064	4,001,478	12,839,589	320,990
PV	1,319,654	1,558,646	2,482,138	2,373,033	7,733,471	193,337
Geothermal	471,399	1,021,317	1,440,129	1,681,827	4,614,673	115,367
Solar thermal power plants	1,224,562	3,260,292	3,640,288	5,453,715	13,578,857	339,471
Ocean energy	215,854	333,823	371,352	660,074	1,581,103	39,528

table 12.16: global: total investment in renewable heating only

(EXCLUDING INVESTMENTS IN FOSSIL FUELS)

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Renewables	**1,472,062**	**1.311.491**	**871.856**	**14.516**	**4.417.055**	**110.426**
Biomass	1,238,045	1.009.996	460.941	415.196	3.124.179	78.104
Geothermal	5,197	21.887	60.511	40.769	128.364	3.209
Solar	118,306	168.581	212.445	196.654	695.986	17.400
Heat pumps	110,514	111.026	137.960	109.026	468.526	11.713
Energy [R]evolution scenario						
Renewables	**4,519,868**	**4,770,720**	**9.164.235**	**8.401.514**	**26.856.337**	**671.408**
Biomass	1,251,532	367,121	278.267	135.444	2.032.365	50.809
Geothermal	921,250	542,221	2.750.750	2.389.920	6.604.140	165.103
Solar	1,354,208	2,218,173	3.585.699	2.774.025	9.932.105	248.303
Heat pumps	992,878	1,643,204	2.549.520	3.102.125	8.287.728	207.193

table 12.17: global: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	3,257	1,946	1,699	1,219	4,471	4,668	3,952
Manufacturing	1,669	906	788	565	2,702	2,701	2,243
Operations and maintenance	1,713	1,834	1,951	1,905	1,934	2,317	2,604
Fuel supply (domestic)	14,717	12,729	11,857	10,738	12,885	11,667	8,772
Coal and gas export	1,129	1,308	1,452	1,216	1,345	1,249	589
Total jobs	**22,485**	**18,722**	**17,746**	**15,644**	**23,337**	**22,602**	**18,161**
By technology							
Coal	9,087	6,705	5,820	4,588	5,513	4,074	2,123
Gas, oil & diesel	5,072	5,162	5,296	5,440	5,358	5,281	3,891
Nuclear	537	500	413	290	258	269	270
Total renewables	**7,789**	**6,356**	**6,217**	**5,326**	**12,208**	**12,978**	**11,876**
Biomass	*5,205*	*4,652*	*4,557*	*3,980*	*5,077*	*4,995*	*4,549*
Hydro	*1,035*	*944*	*913*	*853*	*925*	*738*	*669*
Wind	*728*	*408*	*382*	*235*	*1,842*	*1,865*	*1,723*
PV	*374*	*182*	*210*	*124*	*1,991*	*1,635*	*1,528*
Geothermal power	*21*	*16*	*13*	*11*	*122*	*173*	*165*
Solar thermal power	*14*	*23*	*35*	*30*	*504*	*855*	*826*
Ocean	*1*	*1*	*2*	*5*	*107*	*121*	*105*
Solar - heat	*383*	*121*	*92*	*75*	*1,352*	*2,036*	*1,692*
Geothermal & heat pump	*30*	*10*	*13*	*13*	*288*	*561*	*619*
Total jobs	**22,485**	**18,722**	**17,746**	**15,644**	**23,337**	**22,602**	**18,161**

oecd north america: scenario results data

image BLOOMING PHYTOPLANKTON AND COASTAL FORESTS IN THE PACIFIC NORTHWEST, AUGUST 9, 2001. SHOWING PORTIONS OF WASHINGTON STATE, OREGON, AND THE CANADIAN PROVINCE OF BRITISH COLUMBIA. VANCOUVER ISLAND IS LOCATED IN THE UPPER CENTER OF THE IMAGE. THE CASCADE RANGE BLOCKS MOISTURE COMING IN FROM THE PACIFIC OCEAN, CREATING THE ARID CONDITIONS OF THE COLUMBIA PLATEAU TO THE EAST.

oecd north america: reference scenario

table 12.18: oecd north america: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**4,719**	**5,154**	**5,479**	**6,021**	**6,461**	**6,833**
Coal	914	1,077	1,258	1,617	1,932	2,087
Lignite	1,052	1,014	946	724	476	296
Gas	917	1,019	1,082	1,216	1,323	1,444
Oil	80	41	28	13	7	0
Diesel	9	10	9	6	5	4
Nuclear	931	998	1,037	1,074	1,099	1,125
Biomass	44	51	74	139	208	256
Hydro	666	701	714	734	747	767
Wind	79	187	248	358	474	599
of which wind offshore	0	0	2	20	54	92
PV	2	19	32	60	80	87
Geothermal	24	30	38	51	59	72
Solar thermal power plants	1	7	12	27	46	87
Ocean energy	0	0	0	3	5	10
Combined heat & power plants	**314**	**359**	**372**	**435**	**484**	**527**
Coal	42	58	63	80	95	106
Lignite	7	5	3	2	0	0
Gas	212	222	223	249	269	286
Oil	16	18	17	16	14	11
Biomass	38	55	64	85	101	117
Geothermal	0	1	2	4	5	7
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	174	205	212	264	299	329
Autoproducers	140	155	160	171	186	198
Total generation	**5,032**	**5,514**	**5,851**	**6,456**	**6,945**	**7,360**
Fossil	3,247	3,464	3,629	3,922	4,121	4,235
Coal	956	1,135	1,321	1,697	2,027	2,193
Lignite	1,058	1,019	949	726	476	296
Gas	1,129	1,241	1,306	1,465	1,592	1,730
Oil	95	59	45	29	21	12
Diesel	9	10	9	6	5	4
Nuclear	931	998	1,037	1,074	1,099	1,125
Hydrogen	0	0	0	0	0	0
Renewables	**854**	**1,052**	**1,185**	**1,460**	**1,725**	**2,001**
Hydro	666	701	714	734	747	767
Wind	79	187	248	358	474	599
of which wind offshore	0	0	2	20	54	92
PV	2	19	32	60	80	87
Biomass	82	106	138	224	309	372
Geothermal	24	31	41	55	64	79
Solar thermal	1	7	12	27	46	87
Ocean energy	0	0	0	3	5	10
Distribution losses	351	391	409	433	463	495
Own consumption electricity	359	354	368	388	411	433
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**4,321**	**4,759**	**5,065**	**5,625**	**6,061**	6,423
Fluctuating RES (PV, Wind, Ocean)	81	207	280	420	559	695
Share of fluctuating RES	1.6%	3.8%	4.8%	6.5%	8.0%	9.4%
RES share (domestic generation)	**17.0%**	**19.1%**	**20.2%**	**22.6%**	**24.8%**	**27.2%**

table 12.19: oecd north america: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**85**	**156**	**143**	**137**	**123**	**106**
Fossil fuels	79	149	135	126	116	103
Biomass	6	6	8	9	6	2
Solar collectors	0	0	0	1	0	0
Geothermal	0	0	0	1	1	0
Heat from CHP	**463**	**413**	**395**	**301**	**242**	**205**
Fossil fuels	423	344	313	221	169	135
Biomass	40	64	75	73	68	65
Geothermal	0	5	7	6	5	5
Hydrogen	0	0	0	0	0	0
Direct heating[1]	**19,460**	**21,898**	**22,129**	**22,524**	**23,027**	**23,843**
Fossil fuels	17,376	19,180	19,246	19,131	19,013	19,416
Biomass	2,006	2,598	2,706	3,011	3,257	3,443
Solar collectors	64	101	154	330	620	795
Geothermal[2]	14	19	24	53	137	188
Total heat supply[1]	**20,008**	**22,467**	**22,667**	**22,961**	**23,392**	**24,153**
Fossil fuels	17,878	19,673	19,694	19,478	19,298	19,654
Biomass	2,052	2,668	2,788	3,093	3,331	3,511
Solar collectors	64	101	154	330	620	796
Geothermal[2]	14	24	31	60	143	193
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**10.6%**	**12.4%**	**13.1%**	**15.2%**	**17.5%**	**18.6%**

1) heat from electricity (direct) not included; 2) including heat pumps.

table 12.20: oecd north america: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**2,247**	**2,332**	**2,380**	**2,429**	**2,416**	**2,363**
Coal	834	968	1,093	1,332	1,495	1,542
Lignite	954	907	820	597	381	237
Gas	389	418	439	487	532	580
Oil	63	31	21	9	5	0
Diesel	7	7	7	4	4	3
Combined heat & power production	**171**	**161**	**160**	**178**	**194**	**207**
Coal	44	52	55	66	76	85
Lignite	5	4	3	1	0	0
Gas	109	91	91	100	108	115
Oil	12	14	12	11	10	8
CO_2 emissions power generation (incl. CHP public)	**2,418**	**2,493**	**2,541**	**2,607**	**2,610**	**2,570**
Coal	878	1,021	1,148	1,398	1,571	1,627
Lignite	959	911	823	598	381	237
Gas	499	509	530	586	640	695
Oil & diesel	82	52	40	25	18	11
CO_2 emissions by sector	**6,119**	**6,356**	**6,373**	**6,323**	**6,297**	**6,256**
% of 1990 emissions	121%	125%	126%	125%	124%	123%
Industry[1]	567	638	639	614	585	586
Other sectors[1]	731	732	729	720	713	716
Transport	1980	2068	2038	1970	1975	1953
Power generation[2]	2,353	2,431	2,478	2,546	2,547	2,508
District heating & other conversion	487	488	487	474	476	494
Population (Mill.)	457.6	483.7	504.4	541.2	571.1	594.9
CO_2 emissions per capita (t/capita)	**13.4**	**13.1**	**12.6**	**11.7**	**11.0**	**10.5**

1) including CHP autoproducers. 2) including CHP public

table 12.21: oecd north america: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**1,147**	**1,242**	**1,306**	**1,409**	**1,505**	**1,613**
Coal	161	184	222	271	303	327
Lignite	183	171	165	119	74	46
Gas	374	398	407	438	473	506
Oil	58	39	18	7	4	0
Diesel	10	13	10	5	4	3
Nuclear	121	128	133	138	141	144
Biomass	8	10	13	23	33	41
Hydro	187	193	197	204	208	214
Wind	39	85	109	150	192	241
of which wind offshore	0	0	1	7	18	31
PV	2	14	22	39	51	55
Geothermal	4	5	6	8	9	11
Solar thermal power plants	0	2	3	7	12	22
Ocean energy	0	0	0	1	1	2
Combined heat & power production	**97**	**104**	**102**	**117**	**129**	**140**
Coal	8	11	13	15	17	19
Lignite	1	1	1	0	0	0
Gas	69	70	69	78	86	90
Oil	11	12	10	10	10	11
Biomass	7	9	10	13	16	18
Geothermal	0	0	0	1	1	1
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	72	76	74	86	94	102
Autoproducers	25	27	28	32	35	37
Total generation	**1,244**	**1,345**	**1,408**	**1,526**	**1,634**	**1,753**
Fossil	875	899	914	943	970	1,003
Coal	169	195	235	286	320	346
Lignite	184	172	165	120	74	46
Gas	443	469	476	516	558	597
Oil	69	51	28	17	14	11
Diesel	10	13	10	5	4	3
Nuclear	121	128	133	138	141	144
Hydrogen	0	0	0	0	0	0
Renewables	**247**	**318**	**361**	**445**	**523**	**606**
Hydro	187	193	197	204	208	214
Wind	39	85	109	150	192	241
of which wind offshore	0	0	1	7	18	31
PV	2	14	22	39	51	55
Biomass	15	18	23	36	49	59
Geothermal	4	5	6	9	10	12
Solar thermal	0	2	3	7	12	22
Ocean energy	0	0	0	1	1	2
Fluctuating RES (PV, Wind, Ocean)	41	99	132	189	245	299
Share of fluctuating RES	3.3%	7.4%	9.3%	12.4%	15.0%	17.0%
RES share (domestic generation)	**19.9%**	**23.6%**	**25.7%**	**29.1%**	**32.0%**	**34.6%**

table 12.22: oecd north america: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**108,449**	**116,014**	**117,675**	**119,852**	**122,517**	**125,321**
Fossil	**90,047**	**94,714**	**94,675**	**93,582**	**92,976**	**92,857**
Hard coal	10,998	12,782	14,228	16,927	18,848	19,405
Lignite	10,337	9,806	8,874	6,463	4,117	2,558
Natural gas	27,790	28,895	29,528	30,728	31,982	33,814
Crude oil	40,923	43,230	42,045	39,464	38,030	37,080
Nuclear	**10,160**	**10,865**	**11,294**	**11,694**	**11,964**	**12,249**
Renewables	**8,242**	**10,435**	**11,706**	**14,576**	**17,576**	**20,216**
Hydro	2,399	2,523	2,571	2,642	2,690	2,763
Wind	286	675	892	1,288	1,707	2,157
Solar	78	235	377	776	1,301	1,862
Biomass	4,894	6,298	6,993	8,687	10,393	11,670
Geothermal/ambient heat	585	704	873	1,174	1,467	1,730
Ocean energy	0	0	0	10	18	34
RES share	**7.6%**	**9.0%**	**9.9%**	**12.1%**	**14.3%**	**16.1%**

table 12.23: oecd north america: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**73,972**	**79,228**	**80,295**	**81,884**	**84,189**	**86,717**
Total (energy use)	**67,352**	**72,081**	**73,044**	**74,609**	**77,299**	**79,905**
Transport	**28,615**	**30,269**	**29,947**	**29,340**	**30,102**	**30,760**
Oil products	26,883	28,004	27,352	25,944	25,682	25,370
Natural gas	726	764	804	923	1,274	1,833
Biofuels	961	1,438	1,722	2,388	3,028	3,395
Electricity	45	63	69	85	118	162
RES electricity	8	12	14	19	29	44
Hydrogen	0	0	0	0	0	0
RES share Transport	**3.4%**	**4.8%**	**5.8%**	**8.2%**	**10.2%**	**11.2%**
Industry	**14,102**	**16,380**	**16,643**	**16,618**	**16,452**	**16,672**
Electricity	3,840	4,597	4,785	4,922	4,974	5,053
RES electricity	652	877	969	1,113	1,235	1,374
District heat	251	271	269	246	236	230
RES district heat	10	36	45	50	51	53
Coal	972	1,237	1,245	1,163	1,116	1,102
Oil products	1,590	1,704	1,687	1,588	1,436	1,387
Gas	5,868	6,559	6,591	6,478	6,368	6,506
Solar	0	1	1	1	2	13
Biomass and waste	1,577	2,007	2,061	2,215	2,314	2,367
Geothermal/ambient heat	4	5	5	5	6	15
Hydrogen	0	0	0	0	0	0
RES share Industry	**15.9%**	**17.9%**	**18.5%**	**20.4%**	**21.9%**	**22.9%**
Other Sectors	**24,634**	**25,431**	**26,454**	**28,651**	**30,744**	**32,473**
Electricity	11,672	12,473	13,379	15,243	16,729	17,908
RES electricity	1,980	2,380	2,709	3,447	4,155	4,868
District heat	62	58	51	33	24	22
RES district heat	1	5	7	5	3	2
Coal	68	68	71	66	59	49
Oil products	3,118	3,027	2,869	2,537	2,354	2,304
Gas	8,762	8,776	8,928	9,208	9,393	9,621
Solar	64	100	153	329	618	783
Biomass and waste	885	920	987	1,169	1,350	1,495
Geothermal/ambient heat	5	10	15	65	217	292
RES share Other Sectors	**11.9%**	**13.4%**	**14.6%**	**17.5%**	**20.6%**	**22.9%**
Total RES	**6,147**	**7,791**	**8,687**	**10,807**	**13,010**	**14,699**
RES share	**9.1%**	**10.8%**	**11.9%**	**14.5%**	**16.8%**	**18.4%**
Non energy use	**6,621**	**7,147**	**7,251**	**7,275**	**6,890**	**6,811**
Oil	6,026	6,342	6,430	6,446	6,092	6,017
Gas	585	790	805	812	780	777
Coal	9	16	16	17	17	18

oecd north america: energy [r]evolution scenario

table 12.24: oecd north america: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**4,719**	**5,056**	**5,065**	**5,588**	**6,513**	**7,024**
Coal	914	953	878	357	25	0
Lignite	1,052	1,060	673	27	0	0
Gas	917	909	847	692	294	4
Oil	80	61	27	4	3	2
Diesel	9	7	4	2	1	0
Nuclear	931	792	410	53	0	0
Biomass	44	33	25	10	3	1
Hydro	666	725	784	816	818	819
Wind	79	355	878	1,826	2,382	2,500
of which wind offshore	0	0	16	107	283	305
PV	2	52	188	583	857	989
Geothermal	24	57	127	308	419	392
Solar thermal power plants	1	43	156	696	1,334	1,857
Ocean energy	0	11	69	216	376	460
Combined heat & power plants	**314**	**399**	**509**	**576**	**581**	**535**
Coal	42	46	42	34	0	0
Lignite	7	0	0	0	0	0
Gas	212	274	348	340	265	126
Oil	16	16	13	6	4	1
Biomass	38	59	88	133	172	194
Geothermal	0	2	11	39	92	158
Hydrogen	0	0	6	25	48	57
CHP by producer						
Main activity producers	174	224	276	287	286	271
Autoproducers	140	175	233	289	295	264
Total generation	**5,032**	**5,455**	**5,573**	**6,164**	**7,093**	**7,559**
Fossil	3,247	3,326	2,833	1,460	592	133
Coal	956	999	921	390	25	0
Lignite	1,058	1,060	673	27	0	0
Gas	1,129	1,183	1,195	1,031	560	130
Oil	95	76	40	10	6	4
Diesel	9	7	4	2	1	0
Nuclear	931	792	410	53	0	0
Hydrogen	0	0	6	25	48	57
Renewables	**854**	**1,337**	**2,324**	**4,626**	**6,453**	**7,369**
Hydro	666	725	784	816	818	819
Wind	79	355	878	1,826	2,382	2,500
of which wind offshore	0	0	16	107	283	305
PV	2	52	188	583	857	989
Biomass	82	92	112	143	176	195
Geothermal	24	59	138	347	511	550
Solar thermal	1	43	156	696	1,334	1,857
Ocean energy	0	11	69	216	376	460
Distribution losses	351	386	412	442	457	446
Own consumption electricity	359	352	374	399	415	405
Electricity for hydrogen production	0	0	232	910	1,923	2,616
Final energy consumption (electricity)	**4,321**	**4,707**	**4,546**	**4,404**	**4,288**	**4,082**
Fluctuating RES (PV, Wind, Ocean)	81	418	1,135	2,625	3,614	3,948
Share of fluctuating RES	1.6%	7.7%	20.4%	42.6%	51.0%	52.2%
RES share (domestic generation)	**17.0%**	**24.5%**	**41.7%**	**75.1%**	**91.0%**	**97.5%**
'Efficiency' savings (compared to Ref.)	**0**	**45**	**465**	**1,144**	**1,831**	**2,495**

table 12.25: oecd north america: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**85**	**356**	**993**	**2,754**	**3,917**	**3,770**
Fossil fuels	79	101	242	397	316	17
Biomass	6	140	242	401	496	522
Solar collectors	0	53	264	1,094	1,699	1,787
Geothermal	0	63	245	863	1,407	1,444
Heat from CHP	**463**	**1,024**	**1,555**	**2,398**	**2,855**	**3,179**
Fossil fuels	423	849	1,109	1,201	822	390
Biomass	40	154	337	693	903	1,013
Geothermal	0	21	87	354	843	1,438
Hydrogen	0	0	22	150	288	339
Direct heating[1]	**19,460**	**20,813**	**19,459**	**16,904**	**15,317**	**14,921**
Fossil fuels	17,376	17,894	15,180	8,704	3,306	317
Biomass	2,006	2,326	2,126	1,742	1,365	754
Solar collectors	64	342	1,008	3,209	5,052	6,087
Geothermal[2]	14	251	895	2,526	4,278	6,126
Hydrogen	0	0	249	723	1,317	1,637
Total heat supply[1]	**20,008**	**22,194**	**22,007**	**22,056**	**22,090**	**21,870**
Fossil fuels	17,878	18,843	16,531	10,302	4,443	724
Biomass	2,052	2,620	2,705	2,837	2,764	2,288
Solar collectors	64	395	1,272	4,303	6,751	7,874
Geothermal[1]	14	335	1,227	3,742	6,527	9,007
Hydrogen	0	0	271	873	1,605	1,976
RES share (including RES electricity)	**10.6%**	**15.1%**	**24.2%**	**52.3%**	**79.2%**	**96.5%**
'Efficiency' savings (compared to Ref.)	**0**	**273**	**660**	**905**	**1,302**	**2,283**

1) heat from electricity (direct) not included; geothermal includes heat pumps

table 12.26: oecd north america: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**2,247**	**2,227**	**1,713**	**596**	**140**	**3**
Coal	834	855	762	293	20	0
Lignite	954	948	583	22	0	0
Gas	389	373	344	277	118	2
Oil	63	46	21	3	2	2
Diesel	7	6	3	1	1	0
Combined heat & power production	**171**	**166**	**188**	**168**	**109**	**52**
Coal	44	42	37	28	0	0
Lignite	5	0	0	0	0	0
Gas	109	113	141	136	107	51
Oil	12	12	9	4	3	1
CO_2 emissions power generation (incl. CHP public)	**2,418**	**2,393**	**1,900**	**764**	**249**	**55**
Coal	878	897	799	321	20	0
Lignite	959	948	583	22	0	0
Gas	499	486	485	413	225	52
Oil & diesel	82	63	33	8	5	3
CO_2 emissions by sector	**6,119**	**6,180**	**5,174**	**2,724**	**977**	**204**
% of 1990 emissions	121%	122%	102%	54%	19%	4%
Industry[1]	567	595	504	302	131	27
Other sectors[1]	731	696	615	362	149	37
Transport	1980	1,982	1,792	1,106	382	87
Power generation[2]	2,353	2,329	1,824	689	200	26
District heating & other conversion	487	578	439	266	116	28
Population (Mill.)	457.6	484	504	541	571	595
CO_2 emissions per capita (t/capita)	**13.4**	**12.8**	**10.3**	**5.0**	**1.7**	**0.3**
'Efficiency' savings (compared to Ref.)	**0**	**176**	**1,198**	**3,599**	**5,320**	**6,052**

1) including CHP autoproducers. 2) including CHP public

table 12.27: oecd north america: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**1,147**	**1,302**	**1,523**	**2,086**	**2,537**	**2,713**
Coal	161	162	155	59	4	0
Lignite	183	179	117	4	0	0
Gas	374	369	349	323	162	1
Oil	58	46	18	2	1	1
Diesel	10	10	6	2	1	0
Nuclear	121	101	52	7	0	0
Biomass	8	6	4	2	1	0
Hydro	187	201	217	224	224	224
Wind	39	162	386	759	961	1,011
of which wind offshore	0	0	6	35	90	98
PV	2	40	132	384	552	639
Geothermal	4	10	21	52	75	77
Solar thermal power plants	0	13	46	218	467	651
Ocean energy	0	3	20	51	89	108
Combined heat & power production	**97**	**116**	**141**	**153**	**152**	**120**
Coal	8	9	8	7	0	0
Lignite	1	0	0	0	0	0
Gas	69	86	107	108	90	39
Oil	11	11	7	1	1	0
Biomass	7	10	15	24	33	40
Geothermal	0	1	2	8	18	30
Hydrogen	0	0	1	5	10	11
CHP by producer						
Main activity producers	72	86	98	92	86	60
Autoproducers	25	30	43	61	66	60
Total generation	**1,244**	**1,419**	**1,664**	**2,240**	**2,689**	**2,833**
Fossil	875	872	768	507	259	41
Coal	169	171	164	66	4	0
Lignite	184	179	117	4	0	0
Gas	443	455	456	430	251	40
Oil	69	57	25	3	2	1
Diesel	10	10	6	2	1	0
Nuclear	121	101	52	7	0	0
Hydrogen	0	0	1	5	10	11
Renewables	**247**	**445**	**843**	**1,721**	**2,420**	**2,780**
Hydro	187	201	217	224	224	224
Wind	39	162	386	759	961	1,011
of which wind offshore	0	0	6	35	90	98
PV	2	40	132	384	552	639
Biomass	15	16	20	26	34	40
Geothermal	4	10	23	59	93	107
Solar thermal	0	13	46	218	467	651
Ocean energy	0	3	20	51	89	108
Fluctuating RES (PV, Wind, Ocean)	41	205	538	1,194	1,601	1,758
Share of fluctuating RES	3.3%	14.5%	32.3%	53.3%	59.6%	62.1%
RES share (domestic generation)	**19.9%**	**31.4%**	**50.7%**	**76.8%**	**90.0%**	**98.1%**

table 12.28: oecd north america: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**108,449**	**110,746**	**101,837**	**85,423**	**76,814**	**73,029**
Fossil	**90,047**	**90,304**	**78,304**	**45,988**	**21,090**	**9,158**
Hard coal	10,998	11,913	11,451	6,511	3,596	3,405
Lignite	10,337	10,102	6,237	237	0	0
Natural gas	27,790	27,045	24,548	17,593	8,889	2,559
Crude oil	40,923	41,245	36,068	21,647	8,604	3,193
Nuclear	**10,160**	**8,623**	**4,464**	**577**	**0**	**0**
Renewables	**8,242**	**11,819**	**19,069**	**38,858**	**55,724**	**63,871**
Hydro	2,399	2,610	2,822	2,938	2,945	2,947
Wind	286	1,278	3,160	6,573	8,576	9,001
Solar	78	916	3,227	12,111	20,713	26,543
Biomass	4,894	5,479	5,698	6,075	6,117	5,775
Geothermal/ambient heat	585	1,497	3,914	10,384	16,020	17,949
Ocean energy	0	39	248	778	1,354	1,656
RES share	**7.6%**	**10.7%**	**18.7%**	**45.5%**	**72.5%**	**87.5%**
'Efficiency' savings (compared to Ref.)	**0**	**5,298**	**15,833**	**34,438**	**45,731**	**52,342**

table 12.29: oecd north america: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**73,972**	**76,760**	**73,009**	**62,799**	**53,625**	**49,874**
Total (energy use)	**67,352**	**69,889**	**66,354**	**56,737**	**47,885**	**44,210**
Transport	**28,615**	**28,713**	**26,237**	**18,300**	**11,361**	**9,554**
Oil products	26,883	26,842	24,063	14,534	4,865	934
Natural gas	726	728	690	597	554	517
Biofuels	961	1,108	1,277	1,724	1,855	1,989
Electricity	45	35	161	960	2,480	3,181
RES electricity	8	9	67	720	2,256	3,101
Hydrogen	0	0	46	486	1,606	2,932
RES share Transport	**3.4%**	**3.9%**	**5.2%**	**15.3%**	**49.1%**	**83.2%**
Industry	**14,102**	**15,745**	**15,367**	**14,123**	**12,822**	**11,862**
Electricity	3,840	4,436	4,454	4,256	3,986	3,744
RES electricity	652	1,087	1,857	3,194	3,626	3,649
District heat	251	547	1,152	2,110	2,516	2,392
RES district heat	10	171	544	1,496	2,140	2,290
Coal	972	1,477	1,422	508	0	0
Oil products	1,590	1,509	1,039	503	211	55
Gas	5,868	5,866	4,977	3,448	1,684	224
Solar	0	181	375	850	1,124	1,445
Biomass and waste	1,577	1,693	1,438	1,162	901	611
Geothermal/ambient heat	4	35	248	534	1,048	1,728
Hydrogen	0	0	261	751	1,352	1,664
RES share Industry	**15.9%**	**20.1%**	**29.7%**	**55.2%**	**78.5%**	**95.6%**
Other Sectors	**24,634**	**25,431**	**24,750**	**24,314**	**23,702**	**22,795**
Electricity	11,672	12,473	12,036	11,789	11,124	10,237
RES electricity	1,980	3,057	5,019	8,848	10,120	9,980
District heat	62	526	987	2,540	3,630	3,911
RES district heat	1	162	481	1,847	3,105	3,777
Coal	68	59	58	0	0	0
Oil products	3,118	2,852	2,536	1,365	597	98
Gas	8,762	8,277	7,029	3,961	1,323	206
Solar	64	162	633	2,359	3,938	4,642
Biomass and waste	885	940	978	810	644	229
Geothermal/ambient heat	5	143	493	1,490	2,445	3,471
RES share Other Sectors	**11.9%**	**17.6%**	**30.7%**	**63.1%**	**85.4%**	**96.9%**
Total RES	**6,147**	**8,748**	**13,539**	**25,963**	**35,894**	**41,393**
RES share	**9.1%**	**12.5%**	**20.4%**	**45.8%**	**75.0%**	**93.6%**
Non energy use	**6,621**	**6,871**	**6,656**	**6,062**	**5,740**	**5,664**
Oil	6,026	5,890	5,243	3,706	2,436	2,003
Gas	585	766	747	624	511	423
Coal	9	214	666	1,732	2,792	3,238

oecd north america: investment & employment

table 12.30: oecd north america: total investment in power sector

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Conventional (fossil & nuclear)	**785,271**	**658,974**	**517,372**	**367,632**	**2,329,249**	**58,231**
Renewables	**374,831**	**366,523**	**431,111**	**426,307**	**1,598,772**	**39,969**
Biomass	52,362	55,022	58,849	65,309	231,541	5,789
Hydro	137,475	134,497	134,397	123,197	529,565	13,239
Wind	123,494	124,038	166,977	146,050	560,559	14,014
PV	36,207	25,646	30,273	19,644	111,770	2,794
Geothermal	7,579	5,550	2,554	4,538	20,220	506
Solar thermal power plants	17,655	19,940	35,901	65,043	138,539	3,463
Ocean energy	61	1,830	2,159	2,527	6,577	164
Energy [R]evolution						
Conventional (fossil & nuclear)	**368,371**	**162,280**	**136,625**	**15,116**	**682,391**	**17,060**
Renewables	**1,499,785**	**2,219,690**	**2,784,348**	**2,613,842**	**9,117,666**	**227,942**
Biomass	51,732	39,674	48,043	39,706	179,155	4,479
Hydro	204,351	136,642	117,774	106,172	564,939	14,123
Wind	597,942	646,938	850,543	674,808	2,770,231	69,256
PV	233,395	321,047	296,899	311,964	1,163,305	29,083
Geothermal	41,554	55,224	50,520	49,535	196,833	4,921
Solar thermal power plants	291,652	934,884	1,336,107	1,341,305	3,903,948	97,599
Ocean energy	79,160	85,281	84,463	90,353	339,257	8,481

table 12.31: oecd north america: total investment in renewable heating only

(EXCLUDING INVESTMENTS IN FOSSIL FUELS)

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Renewables	**211,347**	**234,915**	**236,699**	**183,252**	**866,214**	**21,655**
Biomass	165,968	147,670	70,883	57,063	441,584	11,040
Geothermal	2,705	19,478	58,563	39,368	120,114	3,003
Solar	38,322	64,222	101,226	83,083	286,853	7,171
Heat pumps	4,353	3,545	6,026	3,738	17,663	442
Energy [R]evolution scenario						
Renewables	**927,612**	**1,340,326**	**2,091,634**	**1,939,363**	**6,298,936**	**157,473**
Biomass	99,522	11,606	21,965	6,971	140,064	3,502
Geothermal	218,819	76,614	553,689	296,956	1,146,079	28,652
Solar	337,238	752,325	821,653	782,241	2,693,456	67,336
Heat pumps	272,033	499,781	694,328	853,195	2,319,337	57,983

table 12.32: oecd north america: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	130	124	101	73	464	545	503
Manufacturing	64	65	60	40	332	407	299
Operations and maintenance	226	243	259	277	254	292	355
Fuel supply (domestic)	953	986	978	982	934	851	626
Coal and gas export	4.4	7.4	9.5	10	4.1	0.5	-
Total jobs	**1,377**	**1,425**	**1,408**	**1,383**	**1,987**	**2,095**	**1,782**
By technology							
Coal	181	228	193	171	131	102	34
Gas, oil & diesel	761	755	736	733	740	665	477
Nuclear	60	56	54	53	54	74	79
Total renewables	**375**	**386**	**424**	**426**	**1,062**	**1,255**	**1,193**
Biomass	*205*	*237*	262	*282*	*209*	*207*	*206*
Hydro	*62*	*64*	66	*72*	*84*	*77*	*75*
Wind	*54*	*46*	52	*38*	*305*	*324*	*250*
PV	*30*	*23*	23	*13*	*238*	*240*	*145*
Geothermal power	*2.8*	*3.5*	2.5	*1.5*	*24*	*30*	*21*
Solar thermal power	*2.2*	*2.3*	3.0	*3.2*	*47*	*74*	*137*
Ocean	*0.005*	*0.002*	0.35	*0.49*	*26*	*19*	*16*
Solar - heat	*19*	*10*	15	*13*	*95*	*190*	*212*
Geothermal & heat pump	*0.3*	*0.6*	0.7	*3.4*	*35*	*94*	*130*
Total jobs	**1,377**	**1,425**	**1,408**	**1,383**	**1,987**	**2,095**	**1,782**

latin america: scenario results data

image SURROUNDED BY DARKER, DEEPER OCEAN WATERS, CORAL ATOLLS OFTEN GLOW IN VIBRANT HUES OF TURQUOISE, TEAL, PEACOCK BLUE, OR AQUAMARINE. BELIZE'S LIGHTHOUSE REEF ATOLL FITS THIS DESCRIPTION, WITH ITS SHALLOW WATERS COVERING LIGHT-COLORED CORAL: THE COMBINATION OF WATER AND PALE CORALS CREATES VARYING SHADES OF BLUE-GREEN. WITHIN THIS SMALL SEA OF LIGHT COLORS, HOWEVER, LIES A GIANT CIRCLE OF DEEP BLUE. ROUGHLY 300 METERS (1,000 FEET) ACROSS AND 125 METERS (400 FEET) DEEP, THE FEATURE IS KNOWN AS THE GREAT BLUE HOLE.

latin america: reference scenario

table 12.33: latin america: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**1,005**	**1,180**	**1,328**	**1,597**	**1,919**	**2,292**
Coal	4	24	43	49	55	102
Lignite	5	5	5	5	5	5
Gas	142	199	245	359	542	764
Oil	110	99	89	56	48	39
Diesel	16	13	10	8	7	6
Nuclear	21	33	42	47	54	60
Biomass	32	38	43	54	63	73
Hydro	669	753	823	957	1,050	1,100
Wind	2	10	16	31	46	74
of which wind offshore	0	0	2	4	6	8
PV	0	3	5	16	25	36
Geothermal	3	5	7	11	16	20
Solar thermal power plants	0	0	0	3	9	13
Ocean energy	0	0	0	0	0	0
Combined heat & power plants	**0**	**10**	**20**	**55**	**75**	**85**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	10	19	51	68	76
Oil	0	0	0	0	0	0
Biomass	0	0	1	4	7	9
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	10	20	55	75	85
Total generation	**1,005**	**1,190**	**1,348**	**1,652**	**1,994**	**2,377**
Fossil	278	349	411	528	724	992
Coal	4	24	43	49	55	102
Lignite	5	5	5	5	5	5
Gas	142	208	264	410	610	839
Oil	110	99	89	56	48	39
Diesel	16	13	10	8	7	6
Nuclear	21	33	42	47	54	60
Hydrogen	0	0	0	0	0	0
Renewables	**705**	**809**	**894**	**1,076**	**1,216**	**1,325**
Hydro	669	753	823	957	1,050	1,100
Wind	2	10	16	31	46	74
of which wind offshore	0	0	2	4	6	8
PV	0	3	5	16	25	36
Biomass	32	38	44	58	70	82
Geothermal	3	5	7	11	16	20
Solar thermal	0	0	0	3	9	13
Ocean energy	0	0	0	0	0	0
Distribution losses	164	188	208	231	259	274
Own consumption electricity	34	44	52	65	81	96
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**807**	**958**	**1,087**	**1,353**	**1,637**	**1,986**
Fluctuating RES (PV, Wind, Ocean)	2	13	22	47	71	110
Share of fluctuating RES	0.2%	1.1%	1.6%	2.8%	3.6%	4.6%
RES share (domestic generation)	**70%**	**68%**	**66%**	**65%**	**61%**	**56%**

table 12.34: latin america: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**0**	**0**	**1**	**2**	**4**	**8**
Fossil fuels	0	0	1	2	4	8
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**4**	**14**	**40**	**82**	**155**
Fossil fuels	0	4	14	37	74	136
Biomass	0	0	1	3	8	19
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
Direct heating[1]	**5,565**	**6,630**	**7,142**	**8,057**	**8,812**	**9,387**
Fossil fuels	3,459	4,201	4,646	5,355	5,879	6,269
Biomass	2,089	2,399	2,451	2,623	2,793	2,883
Solar collectors	17	28	42	72	126	209
Geothermal[2]	0	2	3	7	15	25
Total heat supply[1]	**5,565**	**6,633**	**7,157**	**8,099**	**8,898**	**9,550**
Fossil fuels	3,459	4,205	4,660	5,394	5,956	6,413
Biomass	2,089	2,399	2,452	2,626	2,801	2,902
Solar collectors	17	28	42	72	126	209
Geothermal[2]	0	2	3	7	15	25
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**37.8%**	**36.6%**	**34.9%**	**33.4%**	**33.1%**	**32.8%**

1) heat from electricity (direct) not included; 2) including heat pumps.

table 12.35: latin america: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**159**	**195**	**198**	**214**	**283**	**397**
Coal	4	21	38	41	44	82
Lignite	6	6	5	5	5	5
Gas	67	96	92	129	200	283
Oil	71	64	57	35	30	24
Diesel	10	8	6	5	4	4
Combined heat & power production	**0**	**4**	**9**	**23**	**31**	**34**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	4	9	23	31	34
Oil	0	0	0	0	0	0
CO_2 emissions power generation (incl. CHP public)	**159**	**200**	**206**	**237**	**314**	**431**
Coal	4	21	38	41	44	82
Lignite	6	6	5	5	5	5
Gas	67	101	100	151	231	317
Oil & diesel	82	72	63	39	34	28
CO_2 emissions by sector	**972**	**1,165**	**1,274**	**1,449**	**1,627**	**1,872**
% of 1990 emissions	168%	202%	220%	251%	281%	324%
Industry[1]	202	253	282	333	367	396
Other sectors[1]	115	138	153	176	191	198
Transport	342	415	436	496	549	660
Power generation[2]	159	195	198	214	283	397
District heating & other conversion	155	162	205	230	236	221
Population (Mill.)	468	499	522	562	589	603
CO_2 emissions per capita (t/capita)	**2.1**	**2.3**	**2.4**	**2.6**	**2.8**	**3.1**

1) including CHP autoproducers. 2) including CHP public

table 12.36: latin america: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**227**	**271**	**305**	**371**	**451**	**545**
Coal	1	5	7	8	9	17
Lignite	1	1	1	1	1	1
Gas	42	58	69	96	142	201
Oil	29	28	31	25	23	19
Diesel	4	4	3	4	3	3
Nuclear	3	4	6	7	7	8
Biomass	5	6	6	8	9	11
Hydro	142	158	170	198	218	228
Wind	1	4	6	11	17	27
of which wind offshore	0	0	1	1	2	2
PV	0	2	4	11	17	25
Geothermal	1	1	1	2	2	3
Solar thermal power plants	0	0	0	1	2	3
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**2**	**3**	**10**	**15**	**17**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	2	3	9	14	15
Oil	0	0	0	0	0	0
Biomass	0	0	0	1	1	1
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	2	3	10	15	17
Total generation	**227**	**272**	**308**	**381**	**466**	**561**
Fossil	77	97	115	143	192	255
Coal	1	5	7	8	9	17
Lignite	1	1	1	1	1	1
Gas	42	59	72	105	156	216
Oil	29	28	31	25	23	19
Diesel	4	4	3	4	3	3
Nuclear	3	4	6	7	7	8
Hydrogen	0	0	0	0	0	0
Renewables	**148**	**171**	**188**	**231**	**266**	**298**
Hydro	142	158	170	198	218	228
Wind	1	4	6	11	17	27
of which wind offshore	0	0	1	1	2	2
PV	0	2	4	11	17	25
Biomass	5	6	7	9	10	12
Geothermal	1	1	1	2	2	3
Solar thermal	0	0	0	1	2	3
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	1	7	10	22	34	52
Share of fluctuating RES	0%	2%	3%	6%	7%	9%
RES share (domestic generation)	**65%**	**63%**	**61%**	**61%**	**57%**	**53%**

table 12.37: latin america: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**22,045**	**26,355**	**28,150**	**32,407**	**36,456**	**40,850**
Fossil	**14,876**	**17,816**	**18,930**	**21,446**	**24,242**	**28,072**
Hard coal	664	960	1,249	1,305	1,273	1,684
Lignite	72	69	62	59	58	58
Natural gas	4,539	5,667	6,172	7,795	9,710	11,441
Crude oil	9,600	11,121	11,447	12,288	13,202	14,890
Nuclear	**230**	**357**	**462**	**517**	**589**	**655**
Renewables	**6,939**	**8,182**	**8,758**	**10,444**	**11,625**	**12,124**
Hydro	2,408	2,710	2,962	3,446	3,780	3,960
Wind	7	35	58	111	166	266
Solar	17	39	61	155	297	456
Biomass	4,399	5,219	5,438	6,398	7,011	7,062
Geothermal/ambient heat	108	180	239	333	371	379
Ocean energy	0	0	0	0	0	0
RES share	**31.5%**	**30.9%**	**31.0%**	**32.1%**	**31.8%**	**29.6%**

table 12.38: latin america: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**17,190**	**20,654**	**22,306**	**25,927**	**29,245**	**33,139**
Total (energy use)	**15,835**	**19,040**	**20,561**	**23,949**	**27,062**	**30,801**
Transport	**5,381**	**6,622**	**7,007**	**8,221**	**9,300**	**11,000**
Oil products	4,592	5,568	5,834	6,574	7,201	8,667
Natural gas	217	286	307	444	583	692
Biofuels	562	754	851	1,183	1,486	1,591
Electricity	10	13	15	20	29	50
RES electricity	7	9	10	13	18	28
Hydrogen	0	0	0	0	0	0
RES share Transport	**10.6%**	**11.5%**	**12.3%**	**14.5%**	**16.2%**	**14.7%**
Industry	**5,828**	**7,221**	**7,925**	**9,195**	**10,356**	**11,404**
Electricity	1,210	1,508	1,716	2,105	2,523	3,013
RES electricity	850	1,024	1,139	1,371	1,538	1,680
District heat	0	4	14	40	82	155
RES district heat	0	0	1	3	8	18
Coal	282	393	507	538	479	495
Oil products	1,334	1,674	1,667	1,800	1,955	2,089
Gas	1,348	1,549	1,815	2,229	2,596	2,847
Solar	0	0	0	0	0	0
Biomass and waste	1,655	2,093	2,206	2,482	2,721	2,805
Geothermal/ambient heat	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**43.0%**	**43.2%**	**42.2%**	**41.9%**	**41.2%**	**39.5%**
Other Sectors	**4,626**	**5,198**	**5,629**	**6,533**	**7,406**	**8,397**
Electricity	1,686	1,930	2,184	2,746	3,341	4,085
RES electricity	1,184	1,311	1,449	1,789	2,037	2,277
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	4	5	9	10	12	14
Oil products	1,173	1,412	1,559	1,774	1,886	1,913
Gas	488	578	632	767	879	963
Solar	17	28	42	72	126	209
Biomass and waste	1,259	1,243	1,202	1,158	1,151	1,193
Geothermal/ambient heat	0	1	2	5	11	19
RES share Other Sectors	**53.2%**	**49.7%**	**47.9%**	**46.3%**	**44.9%**	**44.0%**
Total RES	**5,533**	**6,463**	**6,901**	**8,077**	**9,096**	**9,820**
RES share	**34.9%**	**33.9%**	**33.6%**	**33.7%**	**33.6%**	**31.9%**
Non energy use	**1,355**	**1,614**	**1,745**	**1,978**	**2,183**	**2,338**
Oil	839	999	1,080	1,225	1,351	1,448
Gas	510	608	657	745	822	880
Coal	6	7	8	9	10	10

latin america: energy [r]evolution scenario

table 12.39: latin america: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**1,005**	**1,156**	**1,263**	**1,683**	**2,275**	**2,639**
Coal	4	15	14	6	0	0
Lignite	5	4	2	0	0	0
Gas	142	158	162	189	257	121
Oil	110	103	41	18	11	1
Diesel	16	10	6	2	1	1
Nuclear	21	18	18	0	0	0
Biomass	32	48	51	92	137	175
Hydro	669	745	768	806	814	823
Wind	2	35	130	354	580	745
of which wind offshore	0	0	0	100	220	300
PV	0	8	45	105	221	354
Geothermal	3	7	6	12	19	22
Solar thermal power plants	0	6	20	89	200	345
Ocean energy	0	0	1	10	35	52
Combined heat & power plants	**0**	**21**	**75**	**180**	**251**	**320**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	12	28	48	27	15
Oil	0	0	0	0	0	0
Biomass	0	9	43	118	173	215
Geothermal	0	0	4	13	46	83
Hydrogen	0	0	0	1	4	7
CHP by producer						
Main activity producers	0	3	10	35	48	60
Autoproducers	0	18	65	145	203	260
Total generation	**1,005**	**1,177**	**1,338**	**1,863**	**2,526**	**2,959**
Fossil	278	302	253	263	296	139
Coal	4	15	14	6	0	0
Lignite	5	4	2	0	0	0
Gas	142	170	190	237	284	137
Oil	110	103	41	18	11	1
Diesel	16	10	6	2	1	1
Nuclear	21	18	18	0	0	0
Hydrogen	0	0	0	1	4	7
Renewables	**705**	**858**	**1,067**	**1,599**	**2,226**	**2,814**
Hydro	669	745	768	806	814	823
Wind	2	35	130	354	580	745
of which wind offshore	0	0	0	100	220	300
PV	0	8	45	105	221	354
Biomass	32	57	93	210	310	390
Geothermal	3	7	11	25	65	105
Solar thermal	0	6	20	89	200	345
Ocean energy	0	0	1	10	35	52
Distribution losses	164	190	201	228	254	296
Own consumption electricity	34	42	44	47	45	37
Electricity for hydrogen production	0	0	47	213	452	601
Final energy consumption (electricity)	**807**	**945**	**1,045**	**1,376**	**1,774**	**2,026**
Fluctuating RES (PV, Wind, Ocean)	2	43	176	469	836	1,151
Share of fluctuating RES	0.2%	3.7%	13.2%	25.2%	33.1%	38.9%
RES share (domestic generation)	**70%**	**73%**	**80%**	**86%**	**88%**	**95%**
'Efficiency' savings (compared to Ref.)	**0**	**18**	**81**	**214**	**374**	**605**

table 12.40: latin america: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**0**	**2**	**9**	**16**	**23**	**19**
Fossil fuels	0	0	0	0	0	0
Biomass	0	2	7	12	15	10
Solar collectors	0	0	1	2	5	5
Geothermal	0	0	1	2	3	4
Heat from CHP	**0**	**43**	**251**	**1,060**	**1,831**	**2,379**
Fossil fuels	0	24	91	266	173	110
Biomass	0	19	143	689	1,214	1,474
Geothermal	0	0	17	98	417	744
Hydrogen	0	0	0	6	28	50
Direct heating[1)]	**5,565**	**6,373**	**6,347**	**5,993**	**5,373**	**4,782**
Fossil fuels	3,459	3,666	3,050	2,022	728	95
Biomass	2,089	2,447	2,528	2,417	2,300	1,966
Solar collectors	17	163	460	837	1,258	1,460
Geothermal[2)]	0	96	239	463	793	1,009
Hydrogen		0	71	254	295	253
Total heat supply[1)]	**5,565**	**6,418**	**6,607**	**7,070**	**7,228**	**7,180**
Fossil fuels	3,459	3,690	3,140	2,289	901	205
Biomass	2,089	2,468	2,679	3,117	3,529	3,451
Solar collectors	17	163	461	840	1,262	1,465
Geothermal[1)]	0	97	257	563	1,213	1,757
Hydrogen	0	0	71	261	322	303
RES share (including RES electricity)	**37.8%**	**43%**	**52%**	**67%**	**87%**	**97%**
'Efficiency' savings (compared to Ref.)	**0**	**216**	**550**	**1,029**	**1,670**	**2,369**

1) heat from electricity (direct) not included; geothermal includes heat pumps

table 12.41: latin america: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**159**	**167**	**105**	**85**	**102**	**46**
Coal	4	13	12	5	0	0
Lignite	6	5	2	0	0	0
Gas	67	76	61	68	95	45
Oil	71	66	26	11	7	1
Diesel	10	6	4	1	1	1
Combined heat & power production	**0**	**13**	**29**	**44**	**19**	**11**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	13	29	44	19	11
Oil	0	0	0	0	0	0
CO_2 emissions power generation (incl. CHP public)	**159**	**180**	**133**	**129**	**121**	**57**
Coal	4	13	12	5	0	0
Lignite	6	5	2	0	0	0
Gas	67	90	89	111	114	56
Oil & diesel	82	73	30	12	7	1
CO_2 emissions by sector	**972**	**1,004**	**880**	**660**	**358**	**155**
% of 1990 emissions	168%	174%	152%	114%	62%	27%
Industry[1)]	202	220	195	140	46	12
Other sectors[1)]	115	122	101	74	39	20
Transport	342	371	365	264	132	58
Power generation[2)]	159	168	107	90	107	46
District heating & other conversion	155	123	112	93	35	18
Population (Mill.)	468	499	522	562	589	603
CO_2 emissions per capita (t/capita)	**2.1**	**2.0**	**1.7**	**1.2**	**0.6**	**0.3**
'Efficiency' savings (compared to Ref.)	**0**	**161**	**394**	**788**	**1,268**	**1,718**

1) including CHP autoproducers. 2) including CHP public

table 12.42: latin america: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**227**	**275**	**326**	**475**	**691**	**858**
Coal	1	3	2	1	0	0
Lignite	1	1	0	0	0	0
Gas	42	46	46	50	67	43
Oil	29	29	14	8	5	0
Diesel	4	3	2	1	0	0
Nuclear	3	2	2	0	0	0
Biomass	5	7	8	15	23	32
Hydro	142	157	159	167	169	170
Wind	1	16	49	130	202	258
of which wind offshore	0	0	0	35	69	93
PV	0	6	33	74	152	243
Geothermal	1	1	1	2	3	4
Solar thermal power plants	0	5	8	21	44	69
Ocean energy	0	0	1	7	25	37
Combined heat & power production	**0**	**4**	**13**	**32**	**43**	**54**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	2	5	10	6	3
Oil	0	0	0	0	0	0
Biomass	0	1	7	19	27	34
Geothermal	0	0	1	3	9	16
Hydrogen	0	0	0	0	1	1
CHP by producer						
Main activity producers	0	1	2	6	8	9
Autoproducers	0	3	11	25	35	45
Total generation	**227**	**279**	**338**	**507**	**734**	**912**
Fossil	77	84	70	70	79	47
Coal	1	3	2	1	0	0
Lignite	1	1	0	0	0	0
Gas	42	48	51	60	73	46
Oil	29	29	14	8	5	0
Diesel	4	3	2	1	0	0
Nuclear	3	2	2	0	0	0
Hydrogen	0	0	0	0	1	1
Renewables	**148**	**193**	**266**	**436**	**654**	**863**
Hydro	142	157	159	167	169	170
Wind	1	16	49	130	202	258
of which wind offshore	0	0	0	35	69	93
PV	0	6	33	74	152	243
Biomass	5	8	15	33	50	66
Geothermal	1	1	2	4	12	19
Solar thermal	0	5	8	21	44	69
Ocean energy	0	0	1	7	25	37
Fluctuating RES (PV, Wind, Ocean)	1	22	83	210	379	538
Share of fluctuating RES	0%	8%	25%	42%	52%	59%
RES share (domestic generation)	**65%**	**69%**	**79%**	**86%**	**89%**	**95%**

table 12.43: latin america: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**22,045**	**25,115**	**25,822**	**27,501**	**28,599**	**29,506**
Fossil	**14,876**	**16,090**	**14,551**	**11,705**	**7,813**	**4,433**
Hard coal	664	787	897	959	959	873
Lignite	72	44	19	0	0	0
Natural gas	4,539	5,580	5,589	5,511	4,277	2,373
Crude oil	9,600	9,679	8,045	5,235	2,577	1,186
Nuclear	**230**	**191**	**191**	**0**	**0**	**0**
Renewables	**6,939**	**8,835**	**11,080**	**15,796**	**20,786**	**25,073**
Hydro	2,408	2,683	2,763	2,903	2,932	2,962
Wind	7	126	468	1,275	2,089	2,683
Solar	17	246	803	2,017	3,858	5,845
Biomass	4,399	5,378	6,245	7,883	8,215	8,097
Geothermal/ambient heat	108	401	798	1,682	3,565	5,299
Ocean energy	0	0	4	36	126	187
RES share	**31.5%**	**35.1%**	**42.9%**	**57.4%**	**72.7%**	**85.0%**
'Efficiency' savings (compared to Ref.)	**0**	**1,244**	**2,359**	**4,923**	**7,784**	**11,236**

table 12.44: latin america: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**17,190**	**19,609**	**20,293**	**21,071**	**21,143**	**20,807**
Total (energy use)	**15,835**	**18,027**	**18,636**	**19,192**	**19,113**	**18,890**
Transport	**5,381**	**5,979**	**6,200**	**6,000**	**5,600**	**5,400**
Oil products	4,592	4,975	4,866	3,444	1,597	583
Natural gas	217	259	278	310	322	306
Biofuels	562	718	877	1,166	1,049	934
Electricity	10	28	153	865	1,846	2,322
RES electricity	7	20	122	742	1,626	2,208
Hydrogen	0	0	27	216	786	1,255
RES share Transport	**10.6%**	**12.3%**	**16.5%**	**34.9%**	**60.1%**	**80.3%**
Industry	**5,828**	**6,850**	**7,125**	**7,500**	**7,551**	**7,351**
Electricity	1,210	1,444	1,574	1,767	1,933	2,102
RES electricity	850	1,053	1,256	1,517	1,704	1,999
District heat	0	25	180	736	1,328	1,729
RES district heat	0	12	122	583	1,272	1,725
Coal	282	274	268	21	0	0
Oil products	1,334	1,140	721	362	123	48
Gas	1,348	1,748	1,688	1,480	600	146
Solar	0	82	250	441	671	790
Biomass and waste	1,655	2,040	2,166	2,034	1,841	1,430
Geothermal/ambient heat	0	96	191	341	687	790
Hydrogen	0	0	88	318	368	316
RES share Industry	**43.0%**	**47.9%**	**56.9%**	**69.2%**	**86.1%**	**95.7%**
Other Sectors	**4,626**	**5,198**	**5,311**	**5,693**	**5,962**	**6,139**
Electricity	1,686	1,930	2,035	2,315	2,585	2,816
RES electricity	1,184	1,406	1,624	1,987	2,278	2,678
District heat	0	18	68	290	439	557
RES district heat	0	10	42	210	352	553
Coal	4	3	0	0	0	0
Oil products	1,173	1,207	892	556	188	38
Gas	488	537	541	382	241	114
Solar	17	81	210	396	587	670
Biomass and waste	1,259	1,368	1,353	1,332	1,366	1,317
Geothermal/ambient heat	0	54	212	423	556	627
RES share Other Sectors	**53.2%**	**56.2%**	**64.8%**	**76.4%**	**86.2%**	**95.2%**
Total RES	**5,533**	**6,941**	**8,516**	**11,629**	**15,005**	**17,215**
RES share	**34.9%**	**38.5%**	**45.7%**	**60.6%**	**78.5%**	**91.1%**
Non energy use	**1,355**	**1,582**	**1,657**	**1,879**	**2,030**	**1,917**
Oil	839	949	845	545	507	479
Gas	510	601	646	770	873	863
Coal	6	32	166	564	650	575

latin america: investment & employment

table 12.45: latin america: total investment in power sector

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Conventional (fossil & nuclear)	**74,917**	**50,616**	**68,713**	**90,432**	**284,678**	**7,117**
Renewables	**193,193**	**222,430**	**199,952**	**207,146**	**822,720**	**20,568**
Biomass	9,791	14,508	9,890	11,072	45,261	1,132
Hydro	160,684	176,381	150,476	149,319	636,860	15,921
Wind	8,617	10,617	13,796	22,078	55,108	1,378
PV	7,706	10,939	11,140	15,149	44,933	1,123
Geothermal	6,396	5,753	6,322	4,476	22,948	574
Solar thermal power plants	0	4,232	8,327	5,052	17,611	440
Ocean energy	0	0	0	0	0	0
Energy [R]evolution						
Conventional (fossil & nuclear)	**27,494**	**21,961**	**23,491**	**4,277**	**77,224**	**1,931**
Renewables	**390,432**	**540,588**	**760,405**	**891,985**	**2,583,410**	**64,585**
Biomass	43,834	72,046	83,880	102,590	302,349	7,559
Hydro	121,449	105,031	85,110	115,939	427,530	10,688
Wind	67,993	179,694	205,060	251,987	704,735	17,618
PV	65,797	59,370	126,064	138,285	389,516	9,738
Geothermal	19,114	24,245	68,927	62,747	175,033	4,376
Solar thermal power plants	69,511	83,438	153,236	194,524	500,709	12,518
Ocean energy	2,734	16,764	38,127	25,913	83,538	2,088

table 12.46: latin america: total investment in renewable heating only

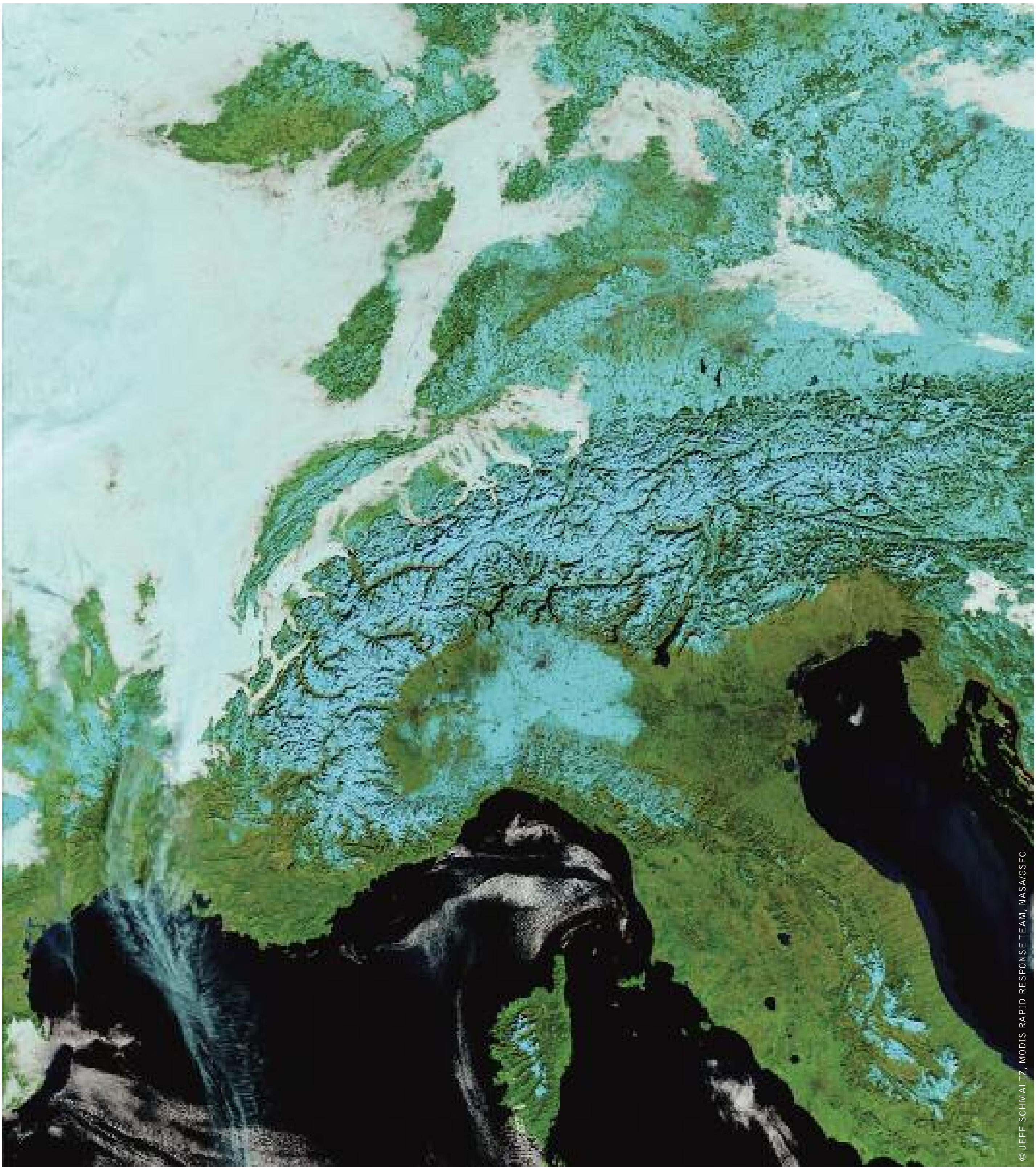
(EXCLUDING INVESTMENTS IN FOSSIL FUELS)

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Renewables	**94,606**	**66,114**	**46,134**	**27,505**	**234,359**	**5,859**
Biomass	92,841	62,947	40,223	19,227	215,239	5,381
Geothermal	0	0	0	0	0	0
Solar	1,122	1,384	2,705	4,018	9,229	231
Heat pumps	642	1,783	3,205	4,260	9,891	247
Energy [R]evolution scenario						
Renewables	**231,844**	**99,876**	**242,323**	**124,344**	**698,387**	**17,460**
Biomass	112,181	13,783	10,529	0	136,493	3,412
Geothermal	40,832	25,034	86,304	8,228	160,398	4,010
Solar	64,740	45,409	102,915	59,707	272,771	6,819
Heat pumps	14,091	15,650	42,574	56,409	128,725	3,218

table 12.47: latin america: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	112	96	98	87	331	380	303
Manufacturing	35	32	37	34	142	185	175
Operations and maintenance	166	178	196	224	198	247	338
Fuel supply (domestic)	767	811	816	830	807	801	809
Coal and gas export	84.7	90.9	106.3	103.5	72.7	53.0	21.0
Total jobs	**1,165**	**1,208**	**1,252**	**1,279**	**1,551**	**1,666**	**1,646**
By technology							
Coal	69	86	91	102	44	24	22
Gas, oil & diesel	414	441	457	491	422	392	336
Nuclear	14	11	8	9	3	3	4
Total renewables	**668**	**670**	**697**	**677**	**1,082**	**1,247**	**1,284**
Biomass	*454*	*463*	*453*	*425*	*521*	*578*	*667*
Hydro	*184*	*178*	*199*	*218*	*135*	*149*	*141*
Wind	*7*	*8*	*11*	*11*	*91*	*131*	*127*
PV	*13*	*12*	*23*	*13*	*166*	*108*	*141*
Geothermal power	*1.6*	*1.2*	*1.0*	*1.3*	*4.7*	*5.9*	*9.1*
Solar thermal power	*0.1*	*0.0*	*0.1*	*3.0*	*20*	*47*	*51*
Ocean	*-*	*-*	*-*	*-*	*2.9*	*4.4*	*20*
Solar - heat	*6.4*	*7.5*	*8.8*	*5.0*	*109*	*166*	*91*
Geothermal & heat pump	*2.0*	*0.2*	*0.3*	*0.6*	*33*	*59*	*37*
Total jobs	**1,165**	**1,208**	**1,252**	**1,279**	**1,551**	**1,666**	**1,646**

oecd europe: scenario results data



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oecd europe: reference scenario

table 12.48: oecd europe: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**2,814**	**3,153**	**3,360**	**3,759**	**4,005**	**4,156**
Coal	275	414	458	569	495	382
Lignite	342	305	270	250	240	231
Gas	529	578	628	762	881	982
Oil	47	31	20	16	14	10
Diesel	9	7	6	5	4	3
Nuclear	874	847	824	727	671	635
Biomass	66	89	99	121	151	183
Hydro	515	543	576	606	626	647
Wind	135	284	409	568	706	804
of which wind offshore	0	3	22	85	145	210
PV	14	40	48	93	140	185
Geothermal	9	12	14	20	24	29
Solar thermal power plants	0	2	8	15	20	27
Ocean energy	0	1	2	8	31	37
Combined heat & power plants	**643**	**671**	**691**	**732**	**773**	**798**
Coal	149	147	149	145	138	128
Lignite	84	85	82	78	76	76
Gas	311	335	346	376	411	435
Oil	36	28	19	11	11	10
Biomass	61	74	94	121	135	148
Geothermal	2	2	2	2	2	2
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	450	470	485	515	545	560
Autoproducers	193	201	206	217	228	238
Total generation	**3,457**	**3,823**	**4,051**	**4,491**	**4,778**	**4,954**
Fossil	1,781	1,931	1,977	2,211	2,270	2,256
Coal	424	562	607	713	633	509
Lignite	426	390	352	328	316	307
Gas	840	913	974	1,138	1,292	1,417
Oil	83	59	39	26	25	20
Diesel	9	7	6	5	4	3
Nuclear	874	847	824	727	671	635
Hydrogen	0	0	0	0	0	0
Renewables	**802**	**1,046**	**1,250**	**1,554**	**1,837**	**2,063**
Hydro	515	543	576	606	626	647
Wind	135	284	409	568	706	804
of which wind offshore	0	3	22	85	145	210
PV	14	40	48	93	140	185
Biomass	127	163	192	242	287	332
Geothermal	11	13	16	21	26	31
Solar thermal	0	2	8	15	20	27
Ocean energy	0	1	2	8	31	37
Distribution losses	218	214	216	225	229	236
Own consumption electricity	285	295	298	311	316	326
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**2,967**	**3,330**	**3,554**	**3,974**	**4,254**	**4,414**
Fluctuating RES (PV, Wind, Ocean)	149	325	458	670	877	1,026
Share of fluctuating RES	4.3%	8.5%	11.3%	14.9%	18.4%	20.7%
RES share (domestic generation)	**23.2%**	**27.4%**	**30.8%**	**34.6%**	**38.4%**	**41.6%**

table 12.49: oecd europe: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**557**	**689**	**772**	**827**	**854**	**840**
Fossil fuels	418	517	579	620	641	630
Biomass	135	169	190	203	210	206
Solar collectors	0	0	0	0	0	0
Geothermal	3	3	4	4	4	4
Heat from CHP	**1,694**	**1,831**	**1,926**	**2,187**	**2,508**	**2,795**
Fossil fuels	1,396	1,536	1,587	1,801	2,077	2,333
Biomass	288	280	324	369	414	444
Geothermal	10	14	15	16	17	17
Hydrogen	0	0	0	0	0	0
Direct heating[1]	**17,104**	**20,157**	**21,002**	**21,934**	**22,465**	**22,811**
Fossil fuels	14,878	17,199	17,778	17,992	17,720	17,422
Biomass	1,989	2,607	2,778	3,293	3,832	4,256
Solar collectors	64	140	204	332	459	586
Geothermal[2]	173	211	243	317	454	547
Total heat supply[1]	**19,355**	**22,676**	**23,700**	**24,947**	**25,827**	**26,446**
Fossil fuels	16,693	19,251	19,944	20,414	20,437	20,386
Biomass	2,413	3,057	3,291	3,865	4,456	4,907
Solar collectors	64	140	204	332	459	586
Geothermal[2]	186	229	261	336	475	568
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**13.8%**	**15.1%**	**15.8%**	**18.2%**	**20.9%**	**22.9%**

1) heat from electricity (direct) not included; 2) including heat pumps.

table 12.50: oecd europe: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**1,005**	**1,080**	**1,069**	**1,078**	**993**	**880**
Coal	274	391	413	480	385	284
Lignite	456	406	360	244	223	205
Gas	228	251	275	337	370	381
Oil	40	27	18	13	12	8
Diesel	6	5	4	3	3	2
Combined heat & power production	**438**	**384**	**342**	**339**	**356**	**361**
Coal	154	145	120	110	114	104
Lignite	105	77	62	65	66	69
Gas	147	143	148	157	169	181
Oil	32	20	12	7	7	6
CO_2 emissions power generation (incl. CHP public)	**1,442**	**1,465**	**1,412**	**1,417**	**1,349**	**1,241**
Coal	428	536	533	591	500	388
Lignite	561	483	422	309	289	274
Gas	375	394	422	494	540	562
Oil & diesel	79	51	34	23	21	17
CO_2 emissions by sector	**3,778**	**3,881**	**3,874**	**3,905**	**3,771**	**3,621**
% of 1990 emissions	97%	100%	100%	101%	97%	93%
Industry[1]	485	530	534	505	461	435
Other sectors[1]	765	806	824	840	836	828
Transport	957	965	965	950	958	961
Power generation[2]	1,357	1,391	1,348	1,360	1,291	1,184
District heating & other conversion	214	188	203	251	225	213
Population (Mill.)	555	570	579	593	599	600
CO_2 emissions per capita (t/capita)	**6.8**	**6.8**	**6.7**	**6.6**	**6.3**	**6.0**

1) including CHP autoproducers. 2) including CHP public

table 12.51: oecd europe: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**730**	**872**	**952**	**1,065**	**1,158**	**1,226**
Coal	79	111	117	114	96	78
Lignite	48	41	36	32	30	29
Gas	129	153	178	212	243	271
Oil	38	32	26	18	16	12
Diesel	4	3	3	2	2	1
Nuclear	136	128	121	105	94	89
Biomass	11	14	15	19	23	26
Hydro	193	201	210	220	227	234
Wind	76	147	195	256	295	313
of which wind offshore	0	1	7	26	40	55
PV	14	38	45	79	115	152
Geothermal	2	2	2	3	4	5
Solar thermal power plants	0	1	2	4	5	6
Ocean energy	0	0	0	2	9	11
Combined heat & power production	**165**	**175**	**177**	**172**	**176**	**174**
Coal	41	36	36	30	28	27
Lignite	12	12	11	10	10	10
Gas	77	89	98	104	108	107
Oil	25	26	18	9	9	8
Biomass	10	12	14	19	21	23
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	111	112	117	116	119	119
Autoproducers	54	62	60	56	56	55
Total generation	**895**	**1,046**	**1,129**	**1,237**	**1,334**	**1,400**
Fossil	452	503	523	531	541	541
Coal	119	147	153	144	124	105
Lignite	60	53	47	42	40	38
Gas	206	242	276	316	351	377
Oil	63	57	44	26	25	19
Diesel	4	3	3	2	2	1
Nuclear	136	128	121	105	94	89
Hydrogen	0	0	0	0	0	0
Renewables	**306**	**415**	**486**	**602**	**699**	**770**
Hydro	193	201	210	220	227	234
Wind	76	147	195	256	295	313
of which wind offshore	0	1	7	26	40	55
PV	14	38	45	79	115	152
Biomass	21	26	30	37	43	49
Geothermal	2	2	3	3	4	5
Solar thermal	0	1	2	4	5	6
Ocean energy	0	0	0	2	9	11
Fluctuating RES (PV, Wind, Ocean)	90	186	241	337	419	476
Share of fluctuating RES	10.1%	17.7%	21.3%	27.2%	31.4%	34.0%
RES share (domestic generation)	**34.2%**	**39.7%**	**43.0%**	**48.6%**	**52.4%**	**55.0%**

table 12.52: oecd europe: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**74,707**	**79,255**	**80,539**	**82,162**	**82,364**	**81,169**
Fossil	**56,844**	**59,273**	**59,414**	**59,745**	**58,671**	**56,889**
Hard coal	7,666	9,029	9,034	9,300	7,852	6,466
Lignite	5,468	4,813	4,285	3,291	3,090	2,952
Natural gas	18,249	20,025	21,185	23,351	24,694	25,308
Crude oil	25,462	25,405	24,910	23,802	23,034	22,163
Nuclear	**9,536**	**9,238**	**8,990**	**7,927**	**7,321**	**6,929**
Renewables	**8,327**	**10,744**	**12,136**	**14,489**	**16,372**	**17,351**
Hydro	1,854	1,955	2,073	2,182	2,255	2,329
Wind	485	1,023	1,471	2,046	2,542	2,894
Solar	115	300	449	802	1,143	1,495
Biomass	5,382	6,833	7,401	8,497	9,332	9,493
Geothermal/ambient heat	490	629	737	933	986	1,006
Ocean energy	2	4	5	30	113	134
RES share	**10.8%**	**13.2%**	**14.6%**	**17.1%**	**19.3%**	**20.7%**

table 12.53: oecd europe: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**51,374**	**55,542**	**57,448**	**60,031**	**61,860**	**62,885**
Total (energy use)	**46,881**	**51,013**	**52,869**	**55,496**	**57,412**	**58,604**
Transport	**14,107**	**14,700**	**14,833**	**14,835**	**15,138**	**15,287**
Oil products	13,260	13,354	13,355	13,108	13,195	13,241
Natural gas	89	125	131	175	222	227
Biofuels	497	916	1,005	1,140	1,230	1,242
Electricity	260	305	342	411	491	576
RES electricity	60	83	106	142	189	240
Hydrogen	0	0	0	0	0	0
RES share Transport	**4.0%**	**6.8%**	**7.5%**	**8.6%**	**9.4%**	**9.7%**
Industry	**11,475**	**13,308**	**13,730**	**13,997**	**13,954**	**14,136**
Electricity	3,936	4,638	4,842	5,137	5,302	5,408
RES electricity	913	1,269	1,494	1,777	2,038	2,252
District heat	639	705	721	731	760	811
RES district heat	62	131	143	143	145	149
Coal	964	1,275	1,470	1,352	1,052	928
Oil products	1,594	1,552	1,431	1,258	1,041	868
Gas	3,411	3,963	4,039	4,081	4,061	4,041
Solar	0	2	3	5	8	11
Biomass and waste	929	1,172	1,222	1,430	1,727	2,065
Geothermal/ambient heat	1	2	2	3	3	3
Hydrogen	0	0	0	0	0	0
RES share Industry	**16.6%**	**19.3%**	**20.8%**	**24.0%**	**28.1%**	**31.7%**
Other Sectors	**21,300**	**23,005**	**24,306**	**26,664**	**28,320**	**29,181**
Electricity	6,484	7,047	7,609	8,759	9,521	9,906
RES electricity	1,504	1,927	2,347	3,030	3,660	4,125
District heat	1,303	1,469	1,607	1,870	2,140	2,324
RES district heat	125	265	298	330	362	360
Coal	797	834	768	662	569	572
Oil products	3,679	3,682	3,645	3,452	3,182	2,900
Gas	7,300	7,966	8,444	9,142	9,596	9,833
Solar	64	138	201	327	451	575
Biomass and waste	1,557	1,725	1,866	2,229	2,532	2,664
Geothermal/ambient heat	116	143	167	224	330	407
RES share Other Sectors	**15.8%**	**18.3%**	**20.1%**	**23.0%**	**25.9%**	**27.9%**
Total RES	**5,828**	**7,774**	**8,852**	**10,780**	**12,674**	**14,093**
RES share	**12.4%**	**15.2%**	**16.7%**	**19.4%**	**22.1%**	**24.0%**
Non energy use	**4,493**	**4,529**	**4,579**	**4,535**	**4,448**	**4,281**
Oil	3,984	3,985	4,029	3,990	3,914	3,767
Gas	462	498	504	499	489	471
Coal	47	46	46	46	45	43

oecd europe: energy [r]evolution scenario

table 12.54: oecd europe: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**2,814**	**2,980**	**2,946**	**3,040**	**3,430**	**3,515**
Coal	275	267	227	96	44	0
Lignite	342	306	163	25	0	0
Gas	529	534	537	477	248	49
Oil	47	9	5	2	0	0
Diesel	9	7	5	3	1	0
Nuclear	874	755	460	78	0	0
Biomass	66	71	71	55	41	21
Hydro	515	543	566	591	602	605
Wind	135	370	609	1,045	1,356	1,485
of which wind offshore	0	43	122	484	682	755
PV	14	97	210	319	597	632
Geothermal	9	13	37	144	166	172
Solar thermal power plants	0	7	46	143	265	411
Ocean energy	0	1	10	63	110	140
Combined heat & power plants	**643**	**699**	**765**	**810**	**790**	**710**
Coal	149	148	91	51	0	0
Lignite	84	34	21	3	0	0
Gas	311	349	388	379	251	101
Oil	36	29	14	0	0	0
Biomass	61	135	240	337	429	435
Geothermal	2	4	11	39	108	149
Hydrogen	0	0	0	0	2	25
CHP by producer						
Main activity producers	450	485	520	540	515	460
Autoproducers	193	214	245	270	275	250
Total generation	**3,457**	**3,679**	**3,711**	**3,850**	**4,220**	**4,225**
Fossil	1,781	1,683	1,451	1,036	544	149
Coal	424	415	318	147	44	0
Lignite	426	340	184	28	0	0
Gas	840	883	925	856	499	149
Oil	83	38	19	2	0	0
Diesel	9	7	5	3	1	0
Nuclear	874	755	460	78	0	0
Hydrogen	0	0	0	0	2	25
Renewables	**802**	**1,241**	**1,800**	**2,736**	**3,674**	**4,051**
Hydro	515	543	566	591	602	605
Wind	135	370	609	1,045	1,356	1,485
of which wind offshore	0	43	122	484	682	755
PV	14	97	210	319	597	632
Biomass	127	206	312	392	470	456
Geothermal	11	17	48	183	274	322
Solar thermal	0	7	46	143	265	411
Ocean energy	0	1	10	63	110	140
Distribution losses	218	216	212	208	203	201
Own consumption electricity	285	274	259	217	173	134
Electricity for hydrogen production	0	0	14	158	567	817
Final energy consumption (electricity)	**2,967**	**3,209**	**3,272**	**3,441**	**3,589**	**3,470**
Fluctuating RES (PV, Wind, Ocean)	149	468	829	1,427	2,063	2,257
Share of fluctuating RES	4.3%	12.7%	22.3%	37.1%	48.9%	53.4%
RES share (domestic generation)	**23.2%**	**33.7%**	**48.5%**	**71.1%**	**87.1%**	**95.9%**
'Efficiency' savings (compared to Ref.)	**0**	**128**	**304**	**742**	**1,175**	**1,563**

table 12.55: oecd europe: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**557**	**763**	**1,479**	**2,087**	**2,743**	**3,135**
Fossil fuels	418	534	713	657	263	125
Biomass	135	191	500	574	576	533
Solar collectors	0	23	178	532	1,289	1,818
Geothermal	3	15	89	324	615	658
Heat from CHP	**1,694**	**2,526**	**2,855**	**2,965**	**3,183**	**3,085**
Fossil fuels	1,396	1,925	1,822	1,531	856	351
Biomass	288	562	938	1,084	1,352	1,304
Geothermal	10	39	95	350	969	1,335
Hydrogen	0	0	0	1	6	94
Direct heating[1)]	**17,104**	**18,875**	**17,304**	**15,285**	**13,055**	**11,306**
Fossil fuels	14,878	15,461	12,635	8,406	4,311	849
Biomass	1,989	2,712	2,731	2,607	2,133	1,743
Solar collectors	64	296	777	2,165	3,152	3,856
Geothermal[2)]	173	405	1,161	2,107	3,428	4,748
Hydrogen	0	0	0	0	31	110
Total heat supply[1)]	**19,355**	**22,164**	**21,639**	**20,338**	**18,981**	**17,525**
Fossil fuels	16,693	17,919	15,170	10,594	5,430	1,326
Biomass	2,413	3,466	4,170	4,265	4,061	3,580
Solar collectors	64	319	954	2,697	4,441	5,675
Geothermal[1)]	186	460	1,345	2,781	5,012	6,741
Hydrogen	0	0	0	1	37	204
RES share (including RES electricity)	**13.8%**	**19.2%**	**29.9%**	**47.9%**	**71.4%**	**92.4%**
'Efficiency' savings (compared to Ref.)	**0**	**512**	**2,062**	**4,609**	**6,846**	**8,921**

1) heat from electricity (direct) not included; geothermal includes heat pumps

table 12.56: oecd europe: co_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**1,005**	**904**	**664**	**320**	**139**	**19**
Coal	274	251	205	81	35	0
Lignite	456	408	217	24	0	0
Gas	228	232	235	211	104	19
Oil	40	8	4	1	0	0
Diesel	6	5	3	2	1	0
Combined heat & power production	**438**	**401**	**320**	**237**	**115**	**43**
Coal	154	146	74	39	0	0
Lignite	105	31	16	2	0	0
Gas	147	204	222	196	115	43
Oil	32	20	9	0	0	0
CO_2 emissions power generation (incl. CHP public)	**1,442**	**1,305**	**984**	**557**	**255**	**62**
Coal	428	397	278	120	35	0
Lignite	561	439	233	27	0	0
Gas	375	436	457	407	220	62
Oil & diesel	79	33	16	4	1	0
CO_2 emissions by sector	**3,778**	**3,539**	**2,814**	**1,744**	**765**	**192**
% of 1990 emissions	97%	91%	72%	45%	20%	5%
Industry[1)]	485	510	425	292	158	38
Other sectors[1)]	765	742	568	354	186	54
Transport	957	926	795	515	178	45
Power generation[2)]	1,357	1,178	861	464	195	41
District heating & other conversion	214	184	166	119	47	15
Population (Mill.)	555	570	579	593	599	600
CO_2 emissions per capita (t/capita)	**6.8**	**6.2**	**4.9**	**2.9**	**1.3**	**0.3**
'Efficiency' savings (compared to Ref.)	**0**	**342**	**1,061**	**2,161**	**3,006**	**3,429**

1) including CHP autoproducers. 2) including CHP public

table 12.57: oecd europe: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**730**	**872**	**1,019**	**1,169**	**1,411**	**1,446**
Coal	79	69	65	27	13	0
Lignite	48	42	22	3	0	0
Gas	129	138	145	144	75	40
Oil	38	12	7	2	0	0
Diesel	4	3	2	1	0	0
Nuclear	136	114	68	11	0	0
Biomass	11	11	11	8	6	3
Hydro	193	201	207	215	218	219
Wind	76	183	276	414	496	516
of which wind offshore	0	13	38	147	189	199
PV	14	94	197	270	489	518
Geothermal	2	2	6	23	26	27
Solar thermal power plants	0	2	12	32	55	82
Ocean energy	0	0	3	18	31	40
Combined heat & power production	**165**	**181**	**184**	**174**	**146**	**127**
Coal	41	36	22	11	0	0
Lignite	12	5	3	0	0	0
Gas	77	92	108	104	61	29
Oil	25	26	13	0	0	0
Biomass	10	21	37	52	66	66
Geothermal	0	1	2	7	19	26
Hydrogen	0	0	0	0	0	5
CHP by producer						
Main activity producers	111	116	118	113	95	82
Autoproducers	54	65	66	62	51	44
Total generation	**895**	**1,053**	**1,204**	**1,343**	**1,556**	**1,573**
Fossil	452	423	386	294	149	70
Coal	119	106	87	38	13	0
Lignite	60	46	25	4	0	0
Gas	206	230	253	249	136	70
Oil	63	38	20	2	0	0
Diesel	4	3	2	1	0	0
Nuclear	136	114	68	11	0	0
Hydrogen	0	0	0	0	0	5
Renewables	**306**	**516**	**750**	**1,038**	**1,407**	**1,498**
Hydro	193	201	207	215	218	219
Wind	76	183	276	414	496	516
of which wind offshore	0	13	38	147	189	199
PV	14	94	197	270	489	518
Biomass	21	32	48	60	72	70
Geothermal	2	3	8	30	45	53
Solar thermal	0	2	12	32	55	82
Ocean energy	0	0	3	18	31	40
Fluctuating RES (PV, Wind, Ocean)	90	277	476	702	1,017	1,074
Share of fluctuating RES	10.1%	26.4%	39.5%	52.2%	65.3%	68.3%
RES share (domestic generation)	**34.2%**	**49.0%**	**62.3%**	**77.3%**	**90.4%**	**95.2%**

table 12.58: oecd europe: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**74,707**	**75,318**	**68,826**	**60,441**	**52,248**	**46,316**
Fossil	**56,844**	**55,245**	**46,467**	**31,929**	**16,669**	**7,091**
Hard coal	7,666	7,243	5,026	2,424	1,322	874
Lignite	5,468	4,167	2,281	252	0	0
Natural gas	18,249	19,853	20,258	16,709	9,455	3,176
Crude oil	25,462	23,982	18,903	12,545	5,891	3,042
Nuclear	**9,536**	**8,238**	**5,019**	**851**	**0**	**0**
Renewables	**8,327**	**11,836**	**17,340**	**27,661**	**35,580**	**39,224**
Hydro	1,854	1,955	2,037	2,128	2,167	2,177
Wind	485	1,332	2,193	3,763	4,882	5,347
Solar	115	731	2,124	5,133	8,976	11,649
Biomass	5,382	6,853	8,105	8,004	7,680	6,582
Geothermal/ambient heat	490	959	2,844	8,407	11,479	12,965
Ocean energy	2	4	36	227	396	504
RES share	**10.8%**	**15.2%**	**25.3%**	**46.1%**	**68.5%**	**85.0%**
'Efficiency' savings (compared to Ref.)	**0**	**3,828**	**12,159**	**21,743**	**29,732**	**34,284**

table 12.59: oecd europe: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**51,374**	**53,594**	**50,617**	**45,373**	**40,176**	**36,226**
Total (energy use)	**46,881**	**49,072**	**46,221**	**41,244**	**36,214**	**32,482**
Transport	**14,107**	**13,888**	**12,196**	**9,289**	**6,792**	**5,815**
Oil products	13,260	12,820	10,993	7,094	2,382	519
Natural gas	89	108	112	129	146	152
Biofuels	497	630	633	502	500	498
Electricity	260	329	424	1,162	2,316	2,655
RES electricity	60	111	206	826	2,016	2,545
Hydrogen	0	0	34	402	1,448	1,991
RES share Transport	**4.0%**	**5.3%**	**7.0%**	**17.4%**	**55.6%**	**85.2%**
Industry	**11,475**	**12,981**	**12,766**	**12,071**	**11,130**	**10,393**
Electricity	3,936	4,478	4,511	4,450	4,262	4,025
RES electricity	913	1,510	2,188	3,162	3,711	3,859
District heat	639	1,412	1,750	1,921	2,236	2,463
RES district heat	62	356	727	1,091	1,817	2,277
Coal	964	854	522	112	42	0
Oil products	1,594	1,399	718	288	104	28
Gas	3,411	3,622	3,643	3,080	1,641	321
Solar	0	70	241	544	943	1,327
Biomass and waste	929	1,066	1,079	1,096	820	766
Geothermal/ambient heat	1	80	303	579	1,048	1,348
Hydrogen	0	0	0	0	33	115
RES share Industry	**16.6%**	**23.7%**	**35.5%**	**53.6%**	**75.2%**	**93.2%**
Other Sectors	**21,300**	**22,203**	**21,259**	**19,884**	**18,292**	**16,275**
Electricity	6,484	6,747	6,845	6,774	6,331	5,663
RES electricity	1,504	2,275	3,320	4,814	5,512	5,430
District heat	1,303	1,563	2,155	2,670	3,223	3,316
RES district heat	125	468	1,036	1,641	2,755	3,110
Coal	797	725	388	0	0	0
Oil products	3,679	3,432	1,885	1,164	402	57
Gas	7,300	7,319	6,844	4,686	2,709	825
Solar	64	226	536	1,621	2,209	2,529
Biomass and waste	1,557	1,948	1,956	1,801	1,550	1,171
Geothermal/ambient heat	116	243	651	1,168	1,868	2,713
RES share Other Sectors	**15.8%**	**23.2%**	**35.3%**	**55.5%**	**76.0%**	**91.9%**
Total RES	**5,828**	**8,984**	**12,892**	**19,131**	**26,038**	**29,592**
RES share	**12.4%**	**18.3%**	**27.9%**	**46.4%**	**71.9%**	**91.1%**
Non energy use	**4,493**	**4,522**	**4,396**	**4,129**	**3,961**	**3,744**
Oil	3,984	3,898	3,680	3,203	2,776	2,399
Gas	462	507	515	533	551	596
Coal	47	117	202	392	634	749

oecd europe: investment & employment

table 12.60: oecd europe: total investment in power sector

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Conventional (fossil & nuclear)	**483,686**	**371,581**	**317,913**	**211,739**	**1,384,919**	**34,623**
Renewables	**517,270**	**510,484**	**507,414**	**415,209**	**1,950,377**	**48,759**
Biomass	62,643	66,304	44,875	39,159	212,981	5,325
Hydro	157,019	145,445	140,893	129,413	572,770	14,319
Wind	212,642	192,472	220,923	143,639	769,676	19,242
PV	53,956	77,798	67,280	73,942	272,976	6,824
Geothermal	13,314	11,248	9,697	7,095	41,354	1,034
Solar thermal power plants	16,252	11,598	9,369	16,926	54,145	1,354
Ocean energy	1,444	5,619	14,377	5,034	26,475	662
Energy [R]evolution						
Conventional (fossil & nuclear)	**174,672**	**102,573**	**96,463**	**6,000**	**379,709**	**9,493**
Renewables	**1,302,801**	**1,187,749**	**1,503,680**	**1,027,221**	**5,021,450**	**125,536**
Biomass	159,750	89,145	149,851	52,745	451,492	11,287
Hydro	144,375	138,925	127,954	104,651	515,904	12,898
Wind	443,353	476,027	471,695	348,294	1,739,369	43,484
PV	381,812	134,810	452,095	106,126	1,074,843	26,871
Geothermal	74,348	182,393	133,984	144,736	535,461	13,387
Solar thermal power plants	88,366	124,680	139,783	237,216	590,046	14,751
Ocean energy	10,795	41,770	28,318	33,452	114,335	2,858

table 12.61: oecd europe: total investment in renewable heating only

(EXCLUDING INVESTMENTS IN FOSSIL FUELS)

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Renewables	**350,297**	**329,064**	**266,312**	**217,121**	**1,162,794**	**29,070**
Biomass	233,695	218,885	123,465	98,812	674,857	16,871
Geothermal	1,812	114	662	41	2,630	66
Solar	60,340	55,957	77,398	67,417	261,111	6,528
Heat pumps	54,451	54,108	64,787	50,850	224,196	5,605
Energy [R]evolution scenario						
Renewables	**854,958**	**785,744**	**1,232,260**	**1,022,761**	**3,895,723**	**97,393**
Biomass	266,389	37,133	6,511	1,103	311,137	7,778
Geothermal	112,524	41,099	307,864	132,572	594,058	14,851
Solar	285,141	511,565	615,092	536,262	1,948,060	48,701
Heat pumps	190,904	195,948	302,794	352,823	1,042,468	26,062

table 12.62: oecd europe: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	161	114	97	83	415	370	391
Manufacturing	158	103	72	44	421	330	263
Operations and maintenance	222	239	254	253	262	293	289
Fuel supply (domestic)	717	708	662	642	696	629	498
Coal and gas export	-	-	-	-	-	-	-
Total jobs	**1,258**	**1,164**	**1,085**	**1,022**	**1,794**	**1,623**	**1,442**
By technology							
Coal	387	326	269	211	278	177	91
Gas, oil & diesel	264	261	241	286	272	265	226
Nuclear	55	58	60	62	66	84	91
Total renewables	**552**	**519**	**516**	**463**	**1,177**	**1,097**	**1,034**
Biomass	*241*	*264*	*276*	*271*	*312*	*331*	*317*
Hydro	*65*	*74*	*73*	*78*	*69*	*71*	*78*
Wind	*140*	*115*	*90*	*60*	*283*	*232*	*160*
PV	*69*	*31*	*46*	*30*	*349*	*157*	*206*
Geothermal power	*2.0*	*1.5*	*1.2*	*0.9*	*13*	*19*	*14*
Solar thermal power	*2.6*	*5.9*	*4.8*	*3.1*	*41*	*45*	*42*
Ocean	*0.3*	*0.3*	*1.1*	*3.7*	*4.7*	*10*	*6*
Solar - heat	*29*	*24*	*21*	*12*	*83*	*152*	*156*
Geothermal & heat pump	*2.7*	*3.5*	*3.2*	*3.7*	*23*	*78*	*56*
Total jobs	**1,258**	**1,164**	**1,085**	**1,022**	**1,794**	**1,623**	**1,442**

africa: scenario results data

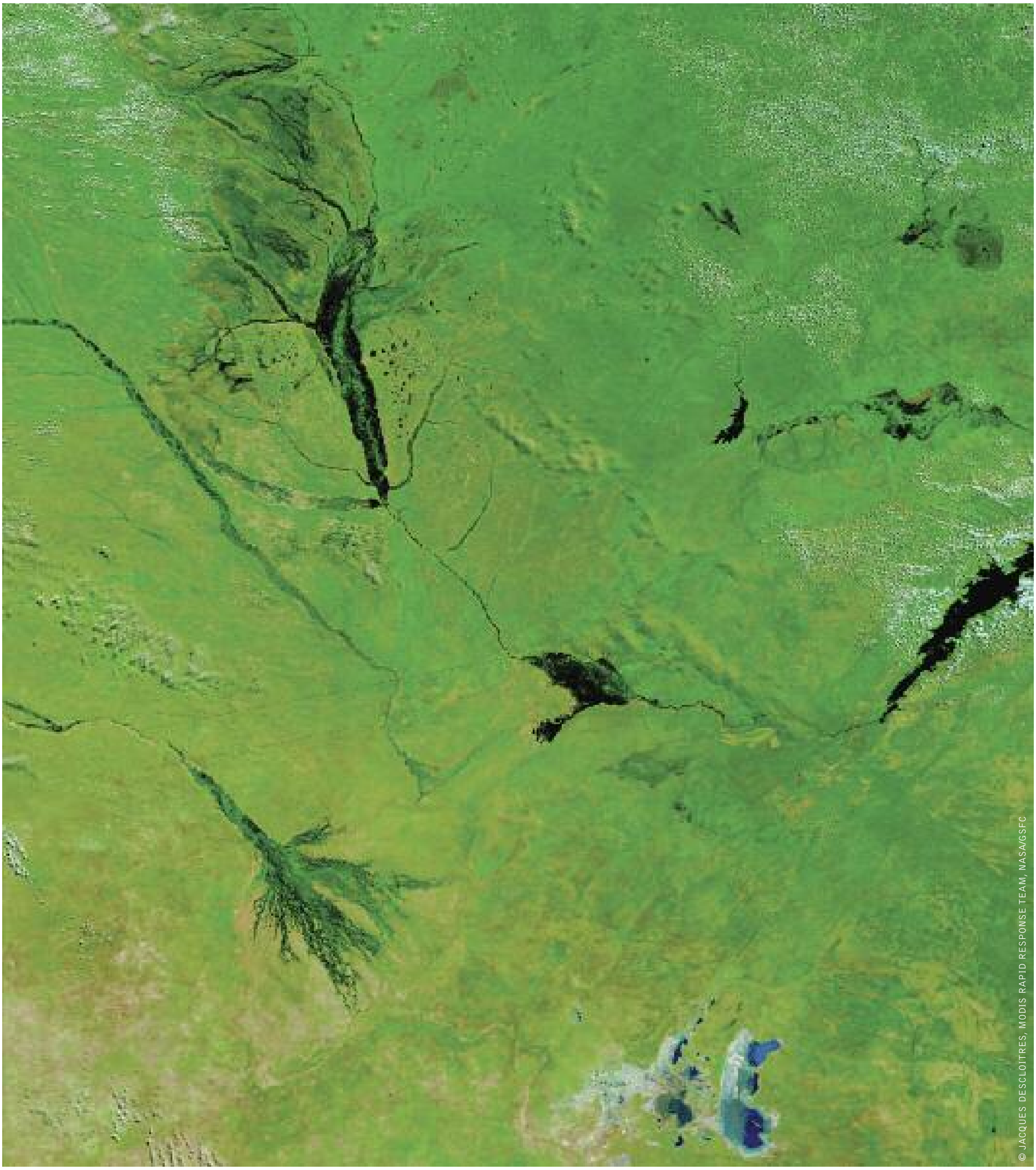

image THREE REGIONS OF SEASONAL FLOODING ARE SHOWN. THE NORTH-SOUTH-RUNNING ZAMBEZI RIVER RUNS THROUGH ZAMBIA BEFORE CURVING EAST IN NAMIBIA. THE OKAVANGO RIVER DELTA, WHICH RESEMBLES THE TANGLED ROOTS OF A PLANT. THE DARK WATER SPREADING BEYOND THE GREEN BANKS OF THE RIVER SUGGESTS THAT THE OKAVANGO DELTA MAY ALSO BE FLOODED.

africa: reference scenario

table 12.63: africa: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**630**	**769**	**913**	**1,273**	**1,813**	**2,616**
Coal	250	282	338	480	720	1,224
Lignite	0	0	0	0	0	0
Gas	186	257	316	417	547	677
Oil	68	61	56	31	22	14
Diesel	11	13	14	16	18	20
Nuclear	13	13	13	32	37	42
Biomass	1	6	10	30	58	86
Hydro	98	122	142	206	283	361
Wind	2	6	10	21	35	50
of which wind offshore	0	0	1	3	5	7
PV	0	5	9	28	67	100
Geothermal	1	3	4	8	15	23
Solar thermal power plants	0	0	1	5	10	20
Ocean energy	0	0	0	0	0	0
Combined heat & power plants	**0**	**1**	**3**	**16**	**29**	**42**
Coal	0	1	2	10	19	29
Lignite	0	0	0	0	0	0
Gas	0	0	1	5	8	11
Oil	0	0	0	0	0	0
Biomass	0	0	0	0	1	2
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	1	3	16	29	42
Total generation	**630**	**770**	**916**	**1,289**	**1,842**	**2,658**
Fossil	515	614	727	960	1,336	1,975
Coal	250	283	340	490	739	1,253
Lignite	0	0	0	0	0	0
Gas	186	257	317	422	556	689
Oil	68	61	56	32	23	14
Diesel	11	13	14	16	18	20
Nuclear	13	13	13	32	37	42
Hydrogen	0	0	0	0	0	0
Renewables	**102**	**142**	**176**	**298**	**470**	**642**
Hydro	98	122	142	206	283	361
Wind	2	6	10	21	35	50
of which wind offshore	0	0	1	3	5	7
PV	0	5	9	28	67	100
Biomass	1	6	10	30	59	87
Geothermal	1	3	4	8	15	23
Solar thermal	0	0	1	5	10	20
Ocean energy	0	0	0	0	0	0
Distribution losses	76	89	101	121	160	230
Own consumption electricity	45	53	60	72	95	136
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**518**	**631**	**761**	**1,103**	**1,595**	**2,302**
Fluctuating RES (PV, Wind, Ocean)	2	12	19	49	102	151
Share of fluctuating RES	0.3%	1.6%	2.1%	3.8%	5.5%	5.7%
RES share (domestic generation)	**16%**	**19%**	**19%**	**23%**	**26%**	**24%**

table 12.64: africa: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**0**	**0**	**0**	**0**	**0**	**0**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**4**	**13**	**59**	**85**	**129**
Fossil fuels	0	4	13	57	82	124
Biomass	0	0	0	2	3	5
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
Direct heating[1]	**11,637**	**12,533**	**13,248**	**15,524**	**18,037**	**20,838**
Fossil fuels	2,487	2,875	3,070	3,948	4,725	5,766
Biomass	9,148	9,653	10,169	11,515	13,193	14,894
Solar collectors	3	6	8	57	111	166
Geothermal[2]	0	0	0	4	9	12
Total heat supply[1]	**11,637**	**12,537**	**13,261**	**15,583**	**18,123**	**20,967**
Fossil fuels	2,487	2,878	3,083	4,005	4,807	5,890
Biomass	9,148	9,653	10,169	11,517	13,196	14,900
Solar collectors	3	6	8	57	111	166
Geothermal[2]	0	0	0	4	9	12
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**78.6%**	**77.0%**	**76.8%**	**74.3%**	**73.5%**	**71.9%**

1) heat from electricity (direct) not included; 2) including heat pumps.

table 12.65: africa: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**407**	**454**	**517**	**557**	**890**	**1,256**
Coal	251	277	325	352	626	964
Lignite	0	0	0	0	0	0
Gas	95	121	139	170	235	268
Oil	53	48	44	25	17	11
Diesel	8	9	9	10	12	13
Combined heat & power production	**0**	**1**	**3**	**12**	**19**	**24**
Coal	0	1	2	8	14	19
Lignite	0	0	0	0	0	0
Gas	0	0	1	3	4	5
Oil	0	0	0	0	0	0
CO_2 emissions power generation (incl. CHP public)	**407**	**456**	**520**	**569**	**909**	**1,279**
Coal	251	278	327	360	640	983
Lignite	0	0	0	0	0	0
Gas	95	122	141	174	240	273
Oil & diesel	61	56	53	35	29	24
CO_2 emissions by sector	**928**	**1,058**	**1,165**	**1,350**	**1,834**	**2,383**
% of 1990 emissions	170%	194%	214%	248%	336%	437%
Industry[1]	107	132	138	176	213	259
Other sectors[1]	117	132	146	192	228	285
Transport	233	276	293	348	411	484
Power generation[2]	407	454	517	557	890	1,256
District heating & other conversion	63	64	71	77	92	100
Population (Mill.)	999	1,145	1,278	1,562	1,870	2,192
CO_2 emissions per capita (t/capita)	**0.9**	**0.9**	**0.9**	**0.9**	**1.0**	**1.1**

1) including CHP autoproducers. 2) including CHP public

table 12.66: africa: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**142**	**179**	**215**	**280**	**380**	**529**
Coal	41	48	58	72	105	178
Lignite	0	0	0	0	0	0
Gas	47	63	77	99	122	151
Oil	21	21	21	13	9	6
Diesel	6	6	7	8	9	10
Nuclear	2	2	2	4	5	6
Biomass	0	1	2	5	10	14
Hydro	25	31	37	53	73	93
Wind	1	3	5	9	15	21
of which wind offshore	0	0	0	1	1	2
PV	0	3	4	11	22	33
Geothermal	0	0	1	1	3	4
Solar thermal power plants	0	0	1	4	8	14
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**0**	**1**	**4**	**7**	**9**
Coal	0	0	0	2	4	6
Lignite	0	0	0	0	0	0
Gas	0	0	0	1	2	3
Oil	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	0	1	4	7	9
Total generation	**142**	**179**	**216**	**284**	**387**	**538**
Fossil	114	139	165	196	251	353
Coal	41	48	59	74	108	184
Lignite	0	0	0	0	0	0
Gas	47	64	78	100	124	154
Oil	21	21	21	14	10	6
Diesel	6	6	7	8	9	10
Nuclear	2	2	2	4	5	6
Hydrogen	0	0	0	0	0	0
Renewables	**26**	**39**	**49**	**84**	**131**	**179**
Hydro	25	31	37	53	73	93
Wind	1	3	5	9	15	21
of which wind offshore	0	0	0	1	1	2
PV	0	3	4	11	22	33
Biomass	0	1	2	5	10	15
Geothermal	0	0	1	1	3	4
Solar thermal	0	0	1	4	8	14
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	1	6	9	20	37	54
Share of fluctuating RES	1%	3%	4%	7%	10%	10%
RES share (domestic generation)	**18%**	**22%**	**23%**	**29%**	**34%**	**33%**

table 12.67: africa: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**27,553**	**29,724**	**32,096**	**37,567**	**46,714**	**56,330**
Fossil	**14,225**	**15,386**	**16,880**	**19,643**	**25,818**	**32,228**
Hard coal	4,413	4,142	4,761	5,639	9,054	13,493
Lignite	0	0	0	0	0	0
Natural gas	3,452	4,057	4,479	5,714	7,663	8,697
Crude oil	6,359	7,187	7,641	8,290	9,101	10,037
Nuclear	**140**	**140**	**145**	**346**	**400**	**453**
Renewables	**13,189**	**14,198**	**15,070**	**17,578**	**20,496**	**23,649**
Hydro	353	439	510	741	1,021	1,300
Wind	6	23	38	75	128	181
Solar	3	25	50	203	441	707
Biomass	12,778	13,616	14,341	16,307	18,536	21,043
Geothermal/ambient heat	49	94	133	252	371	419
Ocean energy	0	0	0	0	0	0
RES share	**47.6%**	**47.6%**	**46.7%**	**46.5%**	**43.6%**	**41.8%**

table 12.68: africa: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**20,864**	**23,041**	**24,746**	**29,854**	**35,860**	**43,095**
Total (energy use)	**20,143**	**22,281**	**23,914**	**28,918**	**34,844**	**42,019**
Transport	**3,301**	**3,905**	**4,149**	**4,991**	**5,947**	**7,044**
Oil products	3,230	3,824	4,060	4,623	5,311	6,281
Natural gas	52	54	55	327	571	654
Biofuels	0	4	8	13	18	22
Electricity	19	23	26	28	45	88
RES electricity	3	4	5	6	12	21
Hydrogen	0	0	0	0	0	0
RES share Transport	**0.1%**	**0.2%**	**0.3%**	**0.4%**	**0.5%**	**0.6%**
Industry	**3,518**	**4,127**	**4,452**	**5,537**	**6,856**	**8,486**
Electricity	823	975	1,119	1,564	2,165	2,979
RES electricity	133	180	215	361	552	719
District heat	0	4	13	59	85	129
RES district heat	0	0	0	2	3	5
Coal	320	538	559	731	891	1,225
Oil products	515	559	592	624	644	583
Gas	696	692	688	878	1,132	1,383
Solar	0	0	0	0	0	0
Biomass and waste	1,163	1,359	1,481	1,682	1,938	2,188
Geothermal/ambient heat	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**36.8%**	**37.3%**	**38.1%**	**36.9%**	**36.4%**	**34.3%**
Other Sectors	**13,324**	**14,250**	**15,313**	**18,390**	**22,041**	**26,488**
Electricity	1,022	1,275	1,593	2,378	3,533	5,220
RES electricity	166	236	306	549	901	1,260
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	323	331	346	502	652	1,025
Oil products	974	1,140	1,301	1,490	1,591	1,694
Gas	257	274	288	609	868	1,127
Solar	3	6	8	57	111	166
Biomass and waste	10,745	11,224	11,778	13,350	15,280	17,248
Geothermal/ambient heat	0	0	0	3	6	9
RES share Other Sectors	**81.9%**	**80.5%**	**79.0%**	**75.9%**	**73.9%**	**70.5%**
Total RES	**12,212**	**13,013**	**13,801**	**16,024**	**18,821**	**21,638**
RES share	**60.6%**	**58.4%**	**57.7%**	**55.4%**	**54.0%**	**51.5%**
Non energy use	**720**	**760**	**832**	**937**	**1,017**	**1,077**
Oil	396	418	458	515	559	592
Gas	277	292	320	360	391	414
Coal	47	50	54	61	66	70

africa: energy [r]evolution scenario

table 12.69: africa: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**630**	**756**	**893**	**1,250**	**1,930**	**2,763**
Coal	250	257	250	189	129	35
Lignite	0	0	0	0	0	0
Gas	186	256	288	246	177	82
Oil	68	52	43	21	7	0
Diesel	11	7	5	4	4	3
Nuclear	13	13	8	0	0	0
Biomass	1	5	10	10	9	6
Hydro	98	128	150	175	190	195
Wind	2	26	54	224	362	613
of which wind offshore	0	0	3	85	184	283
PV	0	6	29	125	272	473
Geothermal	1	4	17	66	125	208
Solar thermal power plants	0	1	32	167	606	1,047
Ocean energy	0	0	7	24	51	102
Combined heat & power plants	**0**	**4**	**20**	**98**	**145**	**170**
Coal	0	2	5	12	23	20
Lignite	0	0	0	0	0	0
Gas	0	1	6	44	65	77
Oil	0	0	0	0	0	0
Biomass	0	1	9	37	44	51
Geothermal	0	0	0	4	12	17
Hydrogen	0	0	0	0	1	5
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	4	20	98	145	170
Total generation	**630**	**760**	**913**	**1,348**	**2,075**	**2,933**
Fossil	515	576	597	516	404	216
Coal	250	260	255	201	152	55
Lignite	0	0	0	0	0	0
Gas	186	257	294	290	242	158
Oil	68	52	43	21	7	0
Diesel	11	7	5	4	4	3
Nuclear	13	13	8	0	0	0
Hydrogen	0	0	0	0	1	5
Renewables	**102**	**171**	**308**	**832**	**1,670**	**2,712**
Hydro	98	128	150	175	190	195
Wind	2	26	54	224	362	613
of which wind offshore	0	0	3	85	184	283
PV	0	6	29	125	272	473
Biomass	1	6	19	47	52	57
Geothermal	1	4	17	70	137	225
Solar thermal	0	1	32	167	606	1,047
Ocean energy	0	0	7	24	51	102
Distribution losses	76	89	98	122	161	223
Own consumption electricity	45	53	58	61	73	83
Electricity for hydrogen production	0	2	6	37	163	332
Final energy consumption (electricity)	**518**	**620**	**726**	**1,019**	**1,469**	**2,039**
Fluctuating RES (PV, Wind, Ocean)	2	33	90	373	685	1,188
Share of fluctuating RES	0.3%	4.3%	9.9%	27.7%	33.0%	40.5%
RES share (domestic generation)	**16%**	**22.5%**	**33.7%**	**61.7%**	**80.5%**	**92.4%**
'Efficiency' savings (compared to Ref.)	**0**	**12**	**42**	**125**	**265**	**493**

table 12.70: africa: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**0**	**0**	**0**	**0**	**0**	**0**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**15**	**75**	**349**	**538**	**624**
Fossil fuels	0	12	40	195	293	298
Biomass	0	2	35	127	146	157
Geothermal	0	0	1	26	94	153
Hydrogen	0	0	0	0	5	16
Direct heating[1]	**11,637**	**12,463**	**12,405**	**13,370**	**14,390**	**15,523**
Fossil fuels	2,487	2,825	2,614	1,947	1,339	771
Biomass	9,148	9,321	8,963	8,791	8,552	7,736
Solar collectors	3	315	791	2,143	3,306	5,004
Geothermal[2]	0	2	36	490	1,180	1,819
Hydrogen	0	0	0	0	13	193
Total heat supply[1]	**11,637**	**12,478**	**12,480**	**13,719**	**14,927**	**16,146**
Fossil fuels	2,487	2,837	2,653	2,142	1,631	1,069
Biomass	9,148	9,323	8,999	8,918	8,698	7,893
Solar collectors	3	315	791	2,143	3,306	5,004
Geothermal[1]	0	2	37	517	1,274	1,972
Hydrogen	0	0	0	0	18	208
RES share (including RES electricity)	**78.6%**	**77%**	**79%**	**84%**	**89%**	**93%**
'Efficiency' savings (compared to Ref.)	**0**	**59**	**781**	**1,864**	**3,196**	**4,821**

1) heat from electricity (direct) not included; geothermal includes heat pumps

table 12.71: africa: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**407**	**418**	**404**	**258**	**195**	**62**
Coal	251	252	240	139	112	28
Lignite	0	0	0	0	0	0
Gas	95	121	127	100	76	32
Oil	53	40	33	16	5	0
Diesel	8	5	3	3	2	2
Combined heat & power production	**0**	**4**	**11**	**41**	**50**	**44**
Coal	0	3	5	10	17	13
Lignite	0	0	0	0	0	0
Gas	0	1	6	30	33	31
Oil	0	0	0	0	0	0
CO_2 emissions power generation (incl. CHP public)	**407**	**422**	**415**	**298**	**246**	**106**
Coal	251	255	245	149	129	41
Lignite	0	0	0	0	0	0
Gas	95	122	133	131	110	63
Oil & diesel	61	45	37	19	7	2
CO_2 emissions by sector	**928**	**980**	**983**	**790**	**621**	**381**
% of 1990 emissions	170%	180%	180%	145%	114%	70%
Industry[1]	107	125	121	117	112	72
Other sectors[1]	117	130	116	85	50	36
Transport	233	243	275	277	234	196
Power generation[2]	407	418	404	258	195	62
District heating & other conversion	63	64	66	53	31	15
Population (Mill.)	999	1,145	1,278	1,562	1,870	2,192
CO_2 emissions per capita (t/capita)	**0.9**	**0.9**	**0.8**	**0.5**	**0.3**	**0.2**
'Efficiency' savings (compared to Ref.)	**0**	**78**	**182**	**560**	**1,213**	**2,002**

1) including CHP autoproducers. 2) including CHP public

table 12.72: africa: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**142**	**180**	**226**	**340**	**476**	**672**
Coal	41	43	43	28	29	10
Lignite	0	0	0	0	0	0
Gas	47	63	68	58	42	33
Oil	21	18	16	9	3	0
Diesel	6	3	2	2	2	1
Nuclear	2	2	1	0	0	0
Biomass	0	1	2	2	1	1
Hydro	25	33	39	45	49	50
Wind	1	13	25	89	125	200
of which wind offshore	0	0	1	25	51	72
PV	0	3	12	49	90	155
Geothermal	0	1	3	11	21	35
Solar thermal power plants	0	1	13	42	101	161
Ocean energy	0	0	2	6	13	26
Combined heat & power production	**0**	**1**	**5**	**22**	**32**	**39**
Coal	0	1	1	2	5	7
Lignite	0	0	0	0	0	0
Gas	0	0	2	12	17	19
Oil	0	0	0	0	0	0
Biomass	0	0	2	7	8	9
Geothermal	0	0	0	1	2	3
Hydrogen	0	0	0	0	0	1
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	1	5	22	32	39
Total generation	**142**	**182**	**231**	**362**	**508**	**710**
Fossil	114	129	133	112	97	70
Coal	41	44	44	31	33	17
Lignite	0	0	0	0	0	0
Gas	47	64	69	70	59	52
Oil	21	18	17	9	3	0
Diesel	6	3	2	2	2	1
Nuclear	2	2	1	0	0	0
Hydrogen	0	0	0	0	0	1
Renewables	**26**	**51**	**97**	**250**	**410**	**639**
Hydro	25	33	39	45	49	50
Wind	1	13	25	89	125	200
of which wind offshore	0	0	1	25	51	72
PV	0	3	12	49	90	155
Biomass	0	1	4	8	9	10
Geothermal	0	1	3	12	23	38
Solar thermal	0	1	13	42	101	161
Ocean energy	0	0	2	6	13	26
Fluctuating RES (PV, Wind, Ocean)	1	16	39	143	228	380
Share of fluctuating RES	1%	9%	17%	40%	45%	54%
RES share (domestic generation)	**18%**	**28%**	**42%**	**69%**	**81%**	**90%**

table 12.73: africa: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**27,553**	**28,864**	**30,371**	**33,642**	**38,719**	**43,270**
Fossil	**14,225**	**14,465**	**14,787**	**12,458**	**10,193**	**6,923**
Hard coal	4,413	3,840	3,756	2,454	2,087	921
Lignite	0	0	0	0	0	0
Natural gas	3,452	4,390	4,982	4,667	3,932	2,604
Crude oil	6,359	6,235	6,049	5,337	4,174	3,398
Nuclear	**140**	**140**	**87**	**0**	**0**	**0**
Renewables	**13,189**	**14,259**	**15,497**	**21,184**	**28,526**	**36,347**
Hydro	353	461	540	630	684	702
Wind	6	95	194	807	1,303	2,207
Solar	3	345	1,184	4,096	9,739	16,128
Biomass	12,778	13,224	12,909	12,893	12,335	11,246
Geothermal/ambient heat	49	132	645	2,672	4,281	5,697
Ocean energy	0	1	25	86	184	367
RES share	**47.6%**	**49.5%**	**51.0%**	**62.8%**	**73.4%**	**83.8%**
'Efficiency' savings (compared to Ref.)	**0**	**939**	**1,942**	**4,522**	**8,982**	**14,191**

table 12.74: africa: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**20,864**	**22,378**	**23,166**	**25,482**	**27,810**	**30,445**
Total (energy use)	**20,143**	**21,618**	**22,333**	**24,546**	**26,793**	**29,369**
Transport	**3,301**	**3,444**	**3,952**	**4,251**	**4,369**	**4,441**
Oil products	3,230	3,362	3,807	3,821	3,189	2,637
Natural gas	52	54	56	75	109	126
Biofuels	0	1	23	85	126	130
Electricity	19	24	51	176	540	897
RES electricity	3	6	17	108	435	829
Hydrogen	0	4	15	95	405	651
RES share Transport	**0.1%**	**0.2%**	**1.1%**	**5.9%**	**20.3%**	**35.1%**
Industry	**3,518**	**3,924**	**4,028**	**4,544**	**5,111**	**5,761**
Electricity	823	932	1,023	1,308	1,656	2,086
RES electricity	133	210	345	807	1,333	1,929
District heat	0	15	75	349	538	624
RES district heat	0	2	36	154	244	324
Coal	320	415	413	200	128	19
Oil products	515	500	336	163	77	25
Gas	696	810	832	825	788	448
Solar	0	25	73	321	558	1,007
Biomass and waste	1,163	1,225	1,242	1,235	1,055	787
Geothermal/ambient heat	0	2	33	142	296	539
Hydrogen	0	0	0	0	16	227
RES share Industry	**36.8%**	**37.3%**	**42.9%**	**58.5%**	**68.4%**	**83.2%**
Other Sectors	**13,324**	**14,250**	**14,354**	**15,751**	**17,313**	**19,167**
Electricity	1,022	1,275	1,538	2,184	3,086	4,336
RES electricity	166	287	519	1,348	2,483	4,009
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	323	383	375	270	197	75
Oil products	974	936	568	270	54	28
Gas	257	431	701	719	498	487
Solar	3	290	719	1,822	2,748	3,997
Biomass and waste	10,745	10,935	10,454	10,251	10,123	9,340
Geothermal/ambient heat	0	0	0	234	606	904
RES share Other Sectors	**81.9%**	**80.8%**	**81.5%**	**86.7%**	**92.2%**	**95.2%**
Total RES	**12,212**	**12,984**	**13,466**	**16,565**	**20,346**	**24,605**
RES share	**60.6%**	**60.1%**	**60.3%**	**67.5%**	**75.9%**	**83.8%**
Non energy use	**720**	**760**	**832**	**937**	**1,017**	**1,077**
Oil	396	410	441	478	498	506
Gas	277	292	320	360	391	414
Coal	47	57	71	99	127	156

africa: investment & employment

table 12.75: africa: total investment in power sector

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Conventional (fossil & nuclear)	**74,874**	**81,368**	**105,498**	**157,832**	**419,572**	**10,489**
Renewables	**81,812**	**124,139**	**170,522**	**201,476**	**577,950**	**14,449**
Biomass	6,441	9,702	18,093	20,609	54,846	1,371
Hydro	50,374	71,722	88,062	96,318	306,476	7,662
Wind	6,525	8,304	13,410	14,406	42,645	1,066
PV	7,773	10,866	16,530	18,911	54,080	1,352
Geothermal	5,081	5,642	8,966	8,913	28,602	715
Solar thermal power plants	5,618	17,903	25,460	42,320	91,300	2,283
Ocean energy	0	0	0	0	0	0
Energy [R]evolution						
Conventional (fossil & nuclear)	**47,875**	**17,250**	**35,591**	**17,737**	**118,452**	**2,961**
Renewables	**264,716**	**499,997**	**633,736**	**958,161**	**2,356,611**	**58,915**
Biomass	13,939	20,921	13,981	21,706	70,547	1,764
Hydro	57,826	35,277	28,109	24,397	145,608	3,640
Wind	38,140	132,881	119,104	236,401	526,526	13,163
PV	24,127	53,484	58,730	106,672	243,013	6,075
Geothermal	27,744	67,630	71,520	99,271	266,166	6,654
Solar thermal power plants	96,112	178,020	328,017	439,784	1,041,933	26,048
Ocean energy	6,827	11,785	14,275	29,930	62,818	1,570

table 12.76: africa: total investment in renewable heating only

(EXCLUDING INVESTMENTS IN FOSSIL FUELS)

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Renewables	**326,234**	**324,557**	**152,238**	**174,308**	**977,336**	**24,433**
Biomass	326,044	321,622	149,109	169,067	965,841	24,146
Geothermal	0	0	0	0	0	0
Solar	189	1,469	1,729	3,022	6,410	160
Heat pumps	0	1,466	1,400	2,219	5,085	127
Energy [R]evolution scenario						
Renewables	**200,348**	**231,017**	**296,638**	**441,778**	**1,169,781**	**29,245**
Biomass	157,544	19,624	0	0	177,168	4,429
Geothermal	5,765	14,176	13,789	42,064	75,794	1,895
Solar	34,841	74,251	95,646	162,356	367,094	9,177
Heat pumps	2,197	122,967	187,202	237,358	549,725	13,743

table 12.77: africa: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	100	110	142	164	514	614	595
Manufacturing	46	59	51	78	149	186	241
Operations and maintenance	42	56	73	108	63	114	219
Fuel supply (domestic)	2,123	2,096	2,217	2,336	2,091	2,048	2,049
Coal and gas export	397.8	484.9	530.8	466.4	645.0	704.5	374.3
Total jobs	**2,709**	**2,806**	**3,014**	3,153	**3,461**	**3,667**	**3,478**
By technology							
Coal	106	143	134	181	76	65	53
Gas, oil & diesel	723	837	901	888	1,076	1,187	881
Nuclear	1	9	17	7	1	3	5
Total renewables	**1,880**	**1,816**	**1,962**	**2,077**	**2,309**	**2,412**	**2,539**
Biomass	*1,807*	1,749	*1,853*	*1,925*	*1,680*	*1,622*	*1,606*
Hydro	*36*	37	*58*	*80*	*41*	*23*	*17*
Wind	*8*	8	*11*	*15*	*49*	*100*	*136*
PV	*23*	12	*26*	*25*	*81*	*125*	*59*
Geothermal power	*1.5*	1.5	*1.7*	*2.7*	*13*	*13*	*20*
Solar thermal power	-	4.9	*9.7*	*14.6*	*79*	*94*	*180*
Ocean	-	-	-	-	*10*	*11*	*10*
Solar - heat	*4.0*	3.1	*2.6*	*13*	*355*	*417*	*395*
Geothermal & heat pump	-	-	-	*1.6*	*0.6*	*7.7*	*115*
Total jobs	**2,709**	**2,806**	**3,014**	**3,153**	**3,461**	**3,667**	**3,478**

middle east: scenario results data

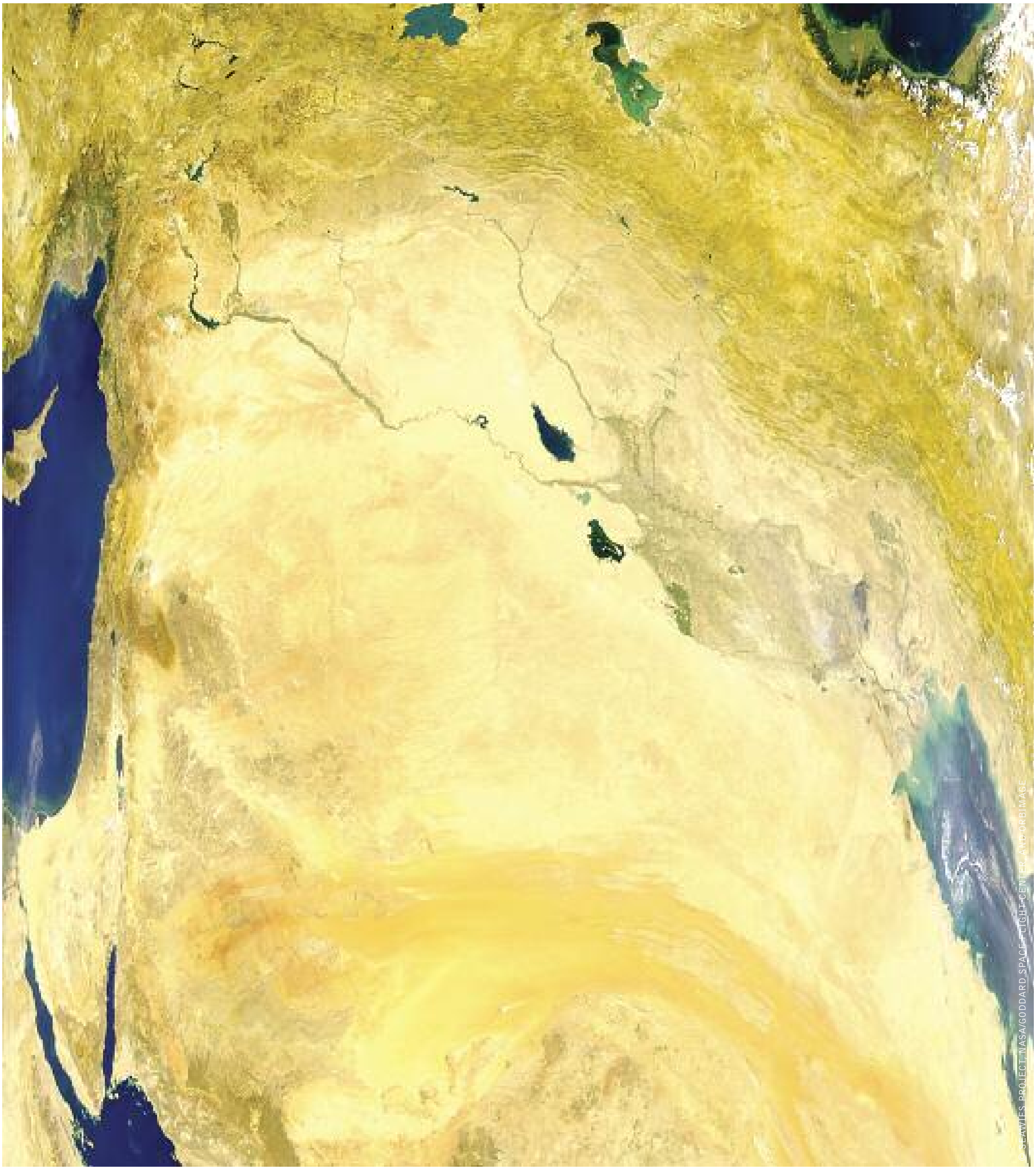

image VIEW OVER THE MIDDLE EAST, 1999

middle east: reference scenario

table 12.78: middle east: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**743**	**949**	**1,138**	**1,569**	**1,985**	**2,497**
Coal	1	4	4	4	5	7
Lignite	0	0	0	0	0	0
Gas	428	599	763	1,141	1,589	2,063
Oil	276	286	289	278	239	238
Diesel	25	15	10	5	4	3
Nuclear	0	7	18	41	12	14
Biomass	0	2	3	7	10	13
Hydro	13	32	38	50	52	59
Wind	0.2	3	6	15	27	37
of which wind offshore	0	0	0	4	6	8
PV	0	1	4	14	20	30
Geothermal	0	0	0	0	0	0
Solar thermal power plants	0	1	3	14	27	33
Ocean energy	0	0	0	0	0	0
Combined heat & power plants	**0**	**3**	**7**	**15**	**25**	**30**
Coal	0	0	0	1	1	1
Lignite	0	0	0	0	0	0
Gas	0	1	3	8	13	15
Oil	0	2	3	5	9	10
Biomass	0	0	1	2	3	4
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	3	7	15	25	30
Total generation	**743**	**952**	**1,145**	**1,584**	**2,010**	**2,527**
Fossil	730	905	1,072	1,441	1,859	2,337
Coal	1	4	4	5	6	8
Lignite	0	0	0	0	0	0
Gas	428	599	766	1,149	1602	2,078
Oil	276	287	292	283	248	248
Diesel	25	15	10	5	4	3
Nuclear	0	7	18	41	12	14
Hydrogen	0	0	0	0	0	0
Renewables	**13**	**39**	**55**	**101**	**139**	**176**
Hydro	13	32	38	50	52	59
Wind	0.2	3	6	15	27	37
of which wind offshore	0	0	0	4	6	8
PV	0	1	4	14	20	30
Biomass	0	2	4	9	13	17
Geothermal	0	0	0	0	0	0
Solar thermal	0	1	3	14	27	33
Ocean energy	0	0	0	0	0	0
Distribution losses	112	101	115	146	146	160
Own consumption electricity	55	86	109	156	180	212
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**599**	**768**	**925**	**1,289**	**1,693**	**2,165**
Fluctuating RES (PV, Wind, Ocean)	0	3	10	29	47	67
Share of fluctuating RES	0.0%	0.4%	0.9%	1.8%	2.3%	2.7%
RES share (domestic generation)	**1.8%**	**4.1%**	**4.8%**	**6.4%**	**6.9%**	**7.0%**

table 12.79: middle east: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**0**	**0**	**0**	**0**	**0**	**0**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**0**	**0**	**0**	**0**	**0**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
Direct heating[1)]	**5,834**	**6,645**	**7,304**	**8,338**	**9,358**	**10,365**
Fossil fuels	5,807	6,564	7,208	8,192	9,161	10,098
Biomass	20	26	32	48	69	77
Solar collectors	5	52	62	90	113	151
Geothermal[2)]	1	2	3	7	14	39
Total heat supply[1)]	**5,834**	**6,645**	**7,304**	**8,338**	**9,358**	**10,365**
Fossil fuels	5,807	6,564	7,208	8,192	9,161	10,098
Biomass	20	26	32	48	69	77
Solar collectors	5	52	62	90	113	151
Geothermal[2)]	1	2	3	7	14	39
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**0.5**	**1.2**	**1.3**	**1.7**	**2.1**	**2.6**

1) heat from electricity (direct) not included; 2) including heat pumps.

table 12.80: middle east: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**492**	**536**	**590**	**716**	**864**	**1,001**
Coal	1	4	4	4	5	6
Lignite	0	0	0	0	0	0
Gas	246	287	346	496	682	832
Oil	225	233	232	213	174	161
Diesel	20	12	8	4	3	2
Combined heat & power production	**0**	**2**	**4**	**8**	**13**	**15**
Coal	0	0	0	1	1	1
Lignite	0	0	0	0	0	0
Gas	0	0	2	3	5	7
Oil	0	1	2	4	6	8
CO_2 emissions power generation (incl. CHP public)	**492**	**538**	**594**	**724**	**876**	**1,016**
Coal	1	5	4	4	6	7
Lignite	0	0	0	0	0	0
Gas	246	288	347	499	687	838
Oil & diesel	245	246	242	220	184	170
CO_2 emissions by sector	**1,510**	**1,778**	**1,992**	**2,452**	**2,779**	**3,081**
% of 1990 emissions	271%	319%	358%	440%	499%	553%
Industry[1)]	266	320	356	408	457	504
Other sectors[1)]	177	197	213	238	265	291
Transport	334	457	519	723	801	876
Power generation[2)]	492	536	590	716	864	1,001
District heating & other conversion	241	268	315	367	393	409
Population (Mill.)	203	229	250	289	326	358
CO_2 emissions per capita (t/capita)	**7.4**	**7.8**	**8.0**	**8.5**	**8.5**	**8.6**

1) including CHP autoproducers. 2) including CHP public

table 12.81: middle east: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**198**	**289**	**325**	**380**	**462**	**579**
Coal	1	1	1	1	1	1
Lignite	0	0	0	0	0	0
Gas	126	197	216	258	344	447
Oil	60	71	78	71	60	60
Diesel	5	4	3	1	1	1
Nuclear	0	1	2	6	2	2
Biomass	0	0	1	1	2	2
Hydro	6	13	18	24	25	28
Wind	0.1	1	2	5	10	14
of which wind offshore	0	0	0	1	2	3
PV	0	0	2	8	11	16
Geothermal	0	0	0	0	0	0
Solar thermal power plants	0	1	1	3	4	6
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**1**	**1**	**3**	**5**	**6**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	0	0	1	3	3
Oil	0	0	1	1	2	2
Biomass	0	0	0	0	0	1
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	1	1	3	5	6
Total generation	**198**	**290**	**327**	**383**	**466**	**585**
Fossil	192	274	299	334	410	513
Coal	1	2	1	1	1	1
Lignite	0	0	0	0	0	0
Gas	126	197	217	259	346	450
Oil	60	72	79	72	62	62
Diesel	5	4	3	1	1	1
Nuclear	0	1	2	6	2	2
Hydrogen	0	0	0	0	0	0
Renewables	**6**	**15**	**25**	**43**	**54**	**70**
Hydro	6	13	18	24	25	28
Wind	0.1	1	2	5	10	14
of which wind offshore	0	0	0	1	2	3
PV	0	0	2	8	11	16
Biomass	0	0	1	1	2	3
Geothermal	0	0	0	0	0	0
Solar thermal	0	1	1	3	4	6
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	0	1	5	13	21	31
Share of fluctuating RES	0.0%	0.5%	1.4%	3.5%	4.6%	5.2%
RES share (domestic generation)	**3.1%**	**5.2%**	**7.6%**	**11.3%**	**11.7%**	**11.9%**

table 12.82: middle east: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**24,516**	**29,554**	**33,377**	**41,075**	**46,089**	**50,527**
Fossil	**24,432**	**29,223**	**32,840**	**40,027**	**45,151**	**49,348**
Hard coal	134	106	109	112	119	116
Lignite	0	0	0	0	0	0
Natural gas	11,836	13,878	16,270	20,527	24,697	27,512
Crude oil	12,463	15,239	16,461	19,389	20,335	21,720
Nuclear	**0**	**82**	**196**	**449**	**131**	**153**
Renewables	**84**	**249**	**342**	**599**	**806**	**1,026**
Hydro	47	114	137	179	187	212
Wind	1	10	21	52	97	133
Solar	5	59	89	192	282	378
Biomass	30	65	93	170	229	273
Geothermal/ambient heat	1	2	2	5	11	29
Ocean energy	0	0	0	0	0	0
RES share	**0.4%**	**0.9%**	**1.0%**	**1.5%**	**1.8%**	**2.1%**

table 12.83: middle east: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**16,475**	**20,681**	**23,329**	**29,393**	**33,655**	**37,874**
Total (energy use)	**13,812**	**17,328**	**19,594**	**25,063**	**28,865**	**32,862**
Transport	**4,676**	**6,395**	**7,264**	**10,116**	**11,222**	**12,293**
Oil products	4,539	6,226	7,078	9,874	10,923	11,941
Natural gas	136	168	185	240	296	334
Biofuels	0	0	0	0	2	17
Electricity	1	1	1	1	1	1
RES electricity	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Transport	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.1%**
Industry	**4,595**	**5,553**	**6,220**	**7,289**	**8,312**	**9,368**
Electricity	437	562	681	951	1,260	1,622
RES electricity	8	23	33	61	87	113
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	13	19	22	28	22	5
Oil products	1,748	2,029	2,221	2,375	2,594	2,983
Gas	2,388	2,932	3,283	3,922	4,422	4,744
Solar	0	0	0	0	0	0
Biomass and waste	9	11	12	13	14	14
Geothermal/ambient heat	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**0.4%**	**0.6%**	**0.7%**	**1.0%**	**1.2%**	**1.4%**
Other Sectors	**4,541**	**5,380**	**6,109**	**7,657**	**9,331**	**11,202**
Electricity	1,720	2,201	2,648	3,689	4,835	6,173
RES electricity	31	89	128	236	334	430
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	0	0	0	0	0	0
Oil products	1,106	1,243	1,296	1,304	1,291	1,291
Gas	1,693	1,860	2,074	2,522	3,012	3,479
Solar	5	52	61	90	113	151
Biomass and waste	16	22	28	47	70	78
Geothermal/ambient heat	1	1	2	5	10	29
RES share Other Sectors	**1.2%**	**3.1%**	**3.6%**	**4.9%**	**5.7%**	**6.1%**
Total RES	**70**	**199**	**265**	**453**	**631**	**832**
RES share	**0.5%**	**1.1%**	**1.4%**	**1.8%**	**2.2%**	**2.5%**
Non energy use	**2,663**	**3,353**	**3,736**	**4,330**	**4,789**	**5,012**
Oil	1,649	1,780	1,983	2,298	2,542	2,660
Gas	1,014	1,573	1,753	2,032	2,247	2,351
Coal	0	0	0	0	0	0

middle east: energy [r]evolution scenario

table 12.84: middle east: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**743**	**945**	**1,166**	**1,824**	**2,582**	**3,179**
Coal	1	1	1	0	0	0
Lignite	0	0	0	0	0	0
Gas	428	581	730	679	353	55
Oil	276	255	118	15	2	1
Diesel	25	14	10	4	3	1
Nuclear	0	3	3	3	0	0
Biomass	0	1	5	14	15	18
Hydro	13	32	38	50	52	59
Wind	0.2	26	78	280	480	755
of which wind offshore	0	0	0	70	160	280
PV	0	20	83	290	619	863
Geothermal	0	0	8	15	67	72
Solar thermal power plants	0	12	85	460	948	1,294
Ocean energy	0	0	6	14	43	61
Combined heat & power plants	**0**	**7**	**15**	**30**	**55**	**85**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	1	3	5	7	11
Oil	0	1	1	1	0	0
Biomass	0	4	7	14	23	27
Geothermal	0	1	3	9	22	38
Hydrogen	0	0	0	1	3	9
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	7	15	30	55	85
Total generation	**743**	**952**	**1,181**	**1,854**	**2,637**	**3,264**
Fossil	730	853	864	704	365	69
Coal	1	1	1	0	0	0
Lignite	0	0	0	0	0	0
Gas	428	582	733	684	361	67
Oil	276	256	120	16	2	1
Diesel	25	14	10	4	3	1
Nuclear	0	3	3	3	0	0
Hydrogen	0	0	0	1	3	9
Renewables	**13**	**96**	**313**	**1,146**	**2,269**	**3,187**
Hydro	13	32	38	50	52	59
Wind	0.2	26	78	280	480	755
of which wind offshore	0	0	0	70	160	280
PV	0	20	83	290	619	863
Biomass	0	5	12	28	38	45
Geothermal	0	1	11	24	89	111
Solar thermal	0	12	85	460	948	1,294
Ocean energy	0	0	6	14	43	61
Distribution losses	112	99	96	95	95	103
Own consumption electricity	55	84	90	102	117	137
Electricity for hydrogen production	0	0	95	361	715	922
Final energy consumption (electricity)	**599**	**772**	**880**	**1,215**	**1,600**	**1,958**
Fluctuating RES (PV, Wind, Ocean)	0	46	167	584	1,142	1,679
Share of fluctuating RES	0.0%	4.8%	14.1%	31.5%	43.3%	51.4%
RES share (domestic generation)	**1.8%**	**10%**	**27%**	**62%**	**86%**	**98%**
'Efficiency' savings (compared to Ref.)	**0**	**6**	**67**	**207**	**409**	**681**

table 12.85: middle east: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**0**	**2**	**10**	**66**	**131**	**219**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Solar collectors	0	2	9	60	118	197
Geothermal	0	0	1	7	13	22
Heat from CHP	**0**	**3**	**12**	**122**	**454**	**703**
Fossil fuels	0	1	3	21	51	80
Biomass	0	2	6	57	185	218
Geothermal	0	0	3	41	198	344
Hydrogen	0	0	0	4	20	61
Direct heating[1]	**5,834**	**6,476**	**6,854**	**7,240**	**7,439**	**7,504**
Fossil fuels	5,807	6,084	5,840	4,713	2,845	815
Biomass	20	62	94	146	209	290
Solar collectors	5	246	562	1,389	2,836	4,228
Geothermal[2]	1	84	212	491	815	1,342
Hydrogen	0	0	145	500	734	829
Total heat supply[1]	**5,834**	**6,481**	**6,875**	**7,428**	**8,024**	**8,426**
Fossil fuels	5,807	6,085	5,843	4,734	2,897	895
Biomass	20	63	100	203	394	508
Solar collectors	5	248	571	1,449	2,954	4,426
Geothermal[1]	1	85	216	538	1,026	1,708
Hydrogen	0	0	145	504	754	890
RES share (including RES electricity)	**0**	**6%**	**13%**	**34%**	**63%**	**89%**
'Efficiency' savings (compared to Ref.)	**0**	**164**	**429**	**909**	**1,334**	**1,939**

1) heat from electricity (direct) not included; geothermal includes heat pumps

table 12.86: middle east: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**492**	**499**	**435**	**281**	**140**	**22**
Coal	1	1	1	0	0	0
Lignite	0	0	0	0	0	0
Gas	246	279	331	266	137	21
Oil	225	208	95	12	2	1
Diesel	20	11	8	3	2	1
Combined heat & power production	**0**	**3**	**5**	**7**	**9**	**14**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	2	4	6	9	14
Oil	0	1	1	1	0	0
CO_2 emissions power generation (incl. CHP public)	**492**	**502**	**440**	**288**	**149**	**36**
Coal	1	1	1	0.1	0	0
Lignite	0	0	0	0	0	0
Gas	246	280	335	273	146	35
Oil & diesel	245	220	104	15	3	1
CO_2 emissions by sector	**1,510**	**1,633**	**1,580**	**1,150**	**571**	**173**
% of 1990 emissions	271%	293%	284%	207%	102%	31%
Industry[1]	266	289	270	209	122	34
Other sectors[1]	177	189	174	146	98	48
Transport	334	400	403	304	147	49
Power generation[2]	492	499	435	281	140	22
District heating & other conversion	241	257	297	210	63	20
Population (Mill.)	203	229	250	289	326	358
CO_2 emissions per capita (t/capita)	**7.4**	**7.1**	**6.3**	**4.0**	**1.8**	**0.5**
'Efficiency' savings (compared to Ref.)	**0**	**145**	**413**	**1,302**	**2,209**	**2,908**

1) including CHP autoproducers. 2) including CHP public

table 12.87: middle east: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**198**	**298**	**358**	**567**	**853**	**1,121**
Coal	1	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	126	191	197	153	118	43
Oil	60	64	30	4	1	1
Diesel	5	4	3	1	1	0
Nuclear	0	0	0	0	0	0
Biomass	0	0	1	2	3	4
Hydro	6	13	18	24	25	28
Wind	0.1	10	31	106	181	283
of which wind offshore	0	0	0	25	57	100
PV	0	11	47	162	340	474
Geothermal	0	0	1	3	11	12
Solar thermal power plants	0	4	25	102	146	235
Ocean energy	0	0	4	9	29	41
Combined heat & power production	**0**	**1**	**3**	**5**	**10**	**16**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	0	0	1	1	2
Oil	0	0	0	0	0	0
Biomass	0	1	1	2	3	4
Geothermal	0	0	1	2	4	8
Hydrogen	0	0	0	0	1	2
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	1	3	5	10	16
Total generation	**198**	**299**	**361**	**572**	**863**	**1,136**
Fossil	192	259	231	160	121	46
Coal	1	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	126	191	198	154	119	45
Oil	60	64	30	4	1	1
Diesel	5	4	3	1	1	0
Nuclear	0	0	0	0	0	0
Hydrogen	0	0	0	0	1	2
Renewables	**6**	**39**	**130**	**412**	**742**	**1,089**
Hydro	6	13	18	24	25	28
Wind	0.1	10	31	106	181	283
of which wind offshore	0	0	0	25	57	100
PV	0	11	47	162	340	474
Biomass	0	1	2	4	6	8
Geothermal	0	0	2	4	16	20
Solar thermal	0	4	25	102	146	235
Ocean energy	0	0	4	9	29	41
Fluctuating RES (PV, Wind, Ocean)	0	21	82	277	550	798
Share of fluctuating RES	0.0%	7%	23%	48%	64%	70%
RES share (domestic generation)	**3.1%**	**13%**	**36%**	**72%**	**86%**	**96%**

table 12.88: middle east: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**24,516**	**28,089**	**29,839**	**29,264**	**28,577**	**27,647**
Fossil	**24,432**	**27,078**	**26,921**	**21,456**	**13,651**	**6,837**
Hard coal	134	99	126	450	597	637
Lignite	0	0	0	0	0	0
Natural gas	11,836	13,394	15,917	13,941	9,217	4,444
Crude oil	12,463	13,585	10,879	7,065	3,836	1,756
Nuclear	**0**	**33**	**33**	**33**	**0**	**0**
Renewables	**84**	**979**	**2,885**	**7,776**	**14,926**	**20,810**
Hydro	47	114	137	179	187	212
Wind	1	94	281	1,008	1,728	2,718
Solar	5	363	1,177	4,149	8,596	12,190
Biomass	30	237	668	1,122	1,196	1,210
Geothermal/ambient heat	1	171	600	1,268	3,064	4,259
Ocean energy	0	0	22	50	155	220
RES share	**0.4%**	**3.5%**	**9.5%**	**26.0%**	**51.7%**	**74.9%**
'Efficiency' savings (compared to Ref.)	**0**	**1,462**	**3,668**	**12,208**	**18,007**	**23,498**

table 12.89: middle east: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**16,475**	**19,651**	**21,008**	**22,209**	**22,469**	**22,566**
Total (energy use)	**13,812**	**16,399**	**17,459**	**18,095**	**18,158**	**18,557**
Transport	**4,676**	**5,692**	**6,029**	**5,451**	**4,560**	**4,137**
Oil products	4,539	5,450	5,485	4,103	1,902	521
Natural gas	136	146	159	174	190	213
Biofuels	0	56	247	373	354	298
Electricity	1	39	79	479	1,128	1,685
RES electricity	0	4	21	296	971	1,645
Hydrogen	0	0	60	322	986	1,420
RES share Transport	**0.0%**	**1.1%**	**4.7%**	**15.9%**	**47.6%**	**80.5%**
Industry	**4,595**	**5,328**	**5,724**	**6,164**	**6,447**	**6,650**
Electricity	437	538	626	801	969	1,137
RES electricity	8	54	166	495	834	1,110
District heat	0	5	20	158	518	796
RES district heat	0	4	17	139	470	726
Coal	13	16	4	0	0	0
Oil products	1,748	1,749	1,098	665	270	69
Gas	2,388	2,749	3,260	2,724	1,669	271
Solar	0	119	255	705	1,398	2,029
Biomass and waste	9	25	59	110	164	220
Geothermal/ambient heat	0	127	232	413	594	1,153
Hydrogen	0	0	171	589	864	975
RES share Industry	**0.4%**	**6.2%**	**13.5%**	**36.1%**	**65.2%**	**93.1%**
Other Sectors	**4,541**	**5,380**	**5,705**	**6,480**	**7,152**	**7,770**
Electricity	1,720	2,201	2,463	3,093	3,654	4,206
RES electricity	31	221	653	1,912	3,144	4,107
District heat	0	0	0	21	40	83
RES district heat	0	0	0	21	40	83
Coal	0	0	0	0	0	0
Oil products	1,106	1,154	884	491	329	121
Gas	1,693	1,835	1,937	1,950	1,311	688
Solar	5	127	307	685	1,437	2,199
Biomass and waste	16	53	59	69	89	125
Geothermal/ambient heat	1	9	55	171	292	349
RES share Other Sectors	**1.2%**	**7.6%**	**18.8%**	**44.1%**	**69.9%**	**88.3%**
Total RES	**70**	**799**	**2,132**	**5,952**	**11,378**	**16,382**
RES share	**0.5%**	**4.9%**	**12.2%**	**32.9%**	**62.7%**	**88.3%**
Non energy use	**2,663**	**3,252**	**3,549**	**4,114**	**4,310**	**4,009**
Oil	1,649	1,697	1,600	1,402	1,210	1,002
Gas	1,014	1,526	1,878	2,300	2,540	2,406
Coal	0	29	71	411	560	601

middle east: investment & employment

table 12.90: middle east: total investment in power sector

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Conventional (fossil & nuclear)	**136,531**	**90,385**	**145,212**	**109,075**	**481,203**	**12,030**
Renewables	**61,651**	**63,916**	**40,698**	**68,883**	**235,148**	**5,879**
Biomass	1,773	2,672	3,468	3,953	11,865	297
Hydro	44,338	28,426	12,780	19,098	104,641	2,616
Wind	2,641	7,795	9,551	11,895	31,883	797
PV	4,446	7,795	6,071	11,571	29,883	747
Geothermal	0	0	15	0	15	0
Solar thermal power plants	8,454	17,229	8,814	22,366	56,862	1,422
Ocean energy	0	0	0	0	0	0
Energy [R]evolution						
Conventional (fossil & nuclear)	**85,704**	**5,271**	**59,679**	**1,147**	**151,801**	**3,795**
Renewables	**429,310**	**864,904**	**851,722**	**1,542,690**	**3,688,626**	**92,216**
Biomass	7,428	9,009	11,555	12,064	40,056	1,001
Hydro	44,338	28,426	12,780	19,098	104,641	2,616
Wind	43,695	148,390	185,382	314,384	691,852	17,296
PV	97,647	160,930	260,195	260,120	778,892	19,472
Geothermal	22,055	21,433	76,486	43,084	163,058	4,076
Solar thermal power plants	198,835	481,226	263,801	857,205	1,801,067	45,027
Ocean energy	15,311	15,490	41,523	36,735	109,060	2,726

table 12.91: middle east: total investment in renewable heating only

(EXCLUDING INVESTMENTS IN FOSSIL FUELS)

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Renewables	**5,700**	**7,087**	**10,218**	**14,543**	**37,547**	**939**
Biomass	3,396	4,471	5,345	3,932	17,143	429
Geothermal	0	0	0	0	0	0
Solar	1,399	1,068	1,955	1,820	6,243	156
Heat pumps	905	1,548	2,917	8,791	14,161	354
Energy [R]evolution scenario						
Renewables	**152,248**	**159,509**	**305,457**	**333,630**	**950,843**	**23,771**
Biomass	11,833	6,112	15,240	12,158	45,342	1,134
Geothermal	51,846	32,843	62,093	89,063	235,845	5,896
Solar	55,360	57,392	127,816	111,994	352,561	8,814
Heat pumps	33,209	63,162	100,310	120,415	317,095	7,927

table 12.92: middle east: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	123	90	63	45	452	485	400
Manufacturing	50	27	21	21	119	126	109
Operations and maintenance	51	70	79	89	86	127	196
Fuel supply (domestic)	900	960	1,057	1,182	935	1,029	821
Coal and gas export	192.8	196.3	203.4	142.9	206.7	212.9	87.2
Total jobs	**1,317**	**1,344**	**1,422**	**1,479**	**1,798**	**1,980**	**1,613**
By technology							
Coal	7	2	1	1	1	1	1
Gas, oil & diesel	1,228	1,241	1,340	1,409	1,184	1,237	863
Nuclear	9	14	15	5	0	0	0
Total renewables	**73**	**87**	**66**	**64**	**613**	**742**	**749**
Biomass	*7*	*10*	*13*	*19*	*34*	*69*	*92*
Hydro	*27*	*36*	*28*	*24*	*36*	*27*	*25*
Wind	*2.0*	*3.0*	*5.3*	*5.7*	*46*	*84*	*113*
PV	*1.0*	*12*	*3.6*	*6.7*	*211*	*151*	*267*
Geothermal power	*0.0*	*0.0*	*0.0*	*0.0*	*7.0*	*4.6*	*10*
Solar thermal power	*3.1*	*2.6*	*10.8*	*3.9*	*96*	*214*	*113*
Ocean	*-*	*-*	*-*	*-*	*17*	*14*	*22*
Solar - heat	*33*	*24*	*5.0*	*3.7*	*143*	*143*	*77*
Geothermal & heat pump	*-*	*0.2*	*0.3*	*0.6*	*24*	*35*	*30*
Total jobs	**1,317**	**1,344**	**1,422**	**1,479**	**1,798**	**1,980**	**1,613**

eastern europe/eurasia: scenario results data

image LOCATED JUST 600 MILES (970 KILOMETERS) FROM THE NORTH POLE, FRANZ JOSEF LAND, RUSSIA, IS PERPETUALLY COATED WITH ICE. GLACIERS COVER ROUGHLY 85 PERCENT OF THE ARCHIPELAGO'S LAND MASSES, AND SEA ICE FLOATS IN THE CHANNELS BETWEEN ISLANDS EVEN IN THE SUMMERTIME.

eastern europe/eurasia: reference scenario

table 12.93: eastern europe/eurasia: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**758**	**967**	**1,169**	**1,550**	**1,915**	**2,305**
Coal	63	94	99	110	135	158
Lignite	63	103	126	167	234	279
Gas	48	132	217	427	577	791
Oil	12	9	8	3	4	4
Diesel	3	0	0	0	0	1
Nuclear	276	309	376	426	438	463
Biomass	0	3	6	21	35	46
Hydro	292	304	316	352	396	431
Wind	1	10	15	30	72	100
of which wind offshore	0	1	2	4	6	8
PV	0	1	2	3	9	13
Geothermal	0	3	5	9	15	19
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power plants	**850**	**890**	**901**	**916**	**932**	**947**
Coal	166	164	164	163	158	152
Lignite	84	79	73	70	67	61
Gas	573	626	643	668	693	719
Oil	24	16	14	8	4	2
Biomass	3	5	6	8	10	12
Geothermal	0	0	0	0	1	2
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	797	825	830	835	840	845
Autoproducers	53	65	71	81	92	102
Total generation	**1,608**	**1,857**	**2,069**	**2,466**	**2,847**	**3,252**
Fossil	1,035	1,224	1,344	1,616	1,871	2,166
Coal	229	258	263	273	292	310
Lignite	147	182	199	237	301	340
Gas	621	759	860	1,095	1,270	1,510
Oil	36	26	22	11	8	6
Diesel	3	0	0	0	0	1
Nuclear	276	309	376	426	438	463
Hydrogen	0	0	0	0	0	0
Renewables	**296**	**324**	**350**	**423**	**537**	**623**
Hydro	292	304	316	352	396	431
Wind	1	10	15	30	72	100
of which wind offshore	0	1	2	4	6	8
PV	0	1	2	3	9	13
Biomass	3	7	12	29	45	58
Geothermal	0	3	5	9	16	21
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Distribution losses	183	187	200	226	239	257
Own consumption electricity	248	287	307	347	366	394
Electricity for hydrogen production	0	0	0	1	2	2
Final energy consumption (electricity)	**1,154**	**1,357**	**1,537**	**1,867**	**2,218**	**2,577**
Fluctuating RES (PV, Wind, Ocean)	1	11	17	33	81	113
Share of fluctuating RES	0.0%	0.6%	0.8%	1.4%	2.8%	3.5%
RES share (domestic generation)	**18.4%**	**17.4%**	**16.9%**	**17.2%**	**18.9%**	**19.2%**

table 12.94: eastern europe/eurasia: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**3,320**	**3,308**	**3,549**	**3,989**	**4,591**	**5,621**
Fossil fuels	3,225	3,207	3,441	3,867	4,450	5,449
Biomass	95	101	109	122	140	172
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**3,866**	**3,974**	**4,011**	**4,059**	**4,108**	**4,159**
Fossil fuels	3,843	3,938	3,966	4,001	4,027	4,049
Biomass	23	36	45	58	73	90
Geothermal	0	0	0	0	8	20
Hydrogen	0	0	0	0	0	0
Direct heating[1)]	**9,102**	**10,053**	**10,926**	**12,270**	**13,534**	**14,321**
Fossil fuels	8,688	9,598	10,432	11,673	12,799	13,484
Biomass	404	445	481	576	672	763
Solar collectors	3	6	5	10	14	18
Geothermal[2)]	7	5	7	10	50	57
Total heat supply[1)]	**16,288**	**17,335**	**18,486**	**20,318**	**22,233**	**24,102**
Fossil fuels	15,755	16,742	17,839	19,541	21,276	22,982
Biomass	523	582	635	756	886	1,025
Solar collectors	3	6	6	10	14	18
Geothermal[2)]	7	5	7	10	58	77
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**3.3%**	**3.4%**	**3.5%**	**3.8%**	**4.3%**	**4.6%**

1) heat from electricity (direct) not included; 2) including heat pumps.

table 12.95: eastern europe/eurasia: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**233**	**403**	**489**	**673**	**826**	**802**
Coal	90	127	128	138	136	124
Lignite	69	138	164	210	286	340
Gas	48	117	177	313	388	319
Oil	21	20	19	12	15	17
Diesel	4	1	1	1	2	2
Combined heat & power production	**979**	**918**	**871**	**807**	**780**	**775**
Coal	237	221	214	205	193	185
Lignite	120	106	95	87	81	75
Gas	582	556	526	488	491	509
Oil	40	36	36	26	15	6
CO_2 emissions power generation (incl. CHP public)	**1,212**	**1,322**	**1,360**	**1,480**	**1,607**	**1,578**
Coal	327	347	342	343	329	310
Lignite	189	244	259	297	367	415
Gas	630	673	703	801	879	828
Oil & diesel	66	57	56	40	32	25
CO_2 emissions by sector	**2,483**	**2,671**	**2,812**	**3,113**	**3,415**	**3,557**
% of 1990 emissions	62%	66%	70%	77%	85%	88%
Industry[1)]	318	361	392	430	463	478
Other sectors[1)]	346	375	403	449	490	512
Transport	262	296	324	392	456	515
Power generation[2)]	1,158	1,259	1,296	1,412	1,533	1,502
District heating & other conversion	399	380	396	429	473	550
Population (Mill.)	339	340	341	337	331	324
CO_2 emissions per capita (t/capita)	**7.3**	**7.9**	**8.2**	**9.2**	**10.3**	**11.0**

1) including CHP autoproducers. 2) including CHP public

table 12.96: eastern europe/eurasia: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**188**	**230**	**265**	**330**	**409**	**496**
Coal	17	22	22	22	25	29
Lignite	17	25	28	33	43	51
Gas	11	29	47	85	110	150
Oil	8	8	6	2	3	3
Diesel	2	0	0	0	0	0
Nuclear	42	45	53	59	60	63
Biomass	0	1	1	4	6	8
Hydro	90	94	97	107	119	130
Wind	0	5	8	14	34	47
of which wind offshore	0	0	1	2	2	3
PV	0	1	1	3	7	10
Geothermal	0	0	1	2	3	3
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**218**	**204**	**199**	**183**	**177**	**180**
Coal	46	39	37	33	29	29
Lignite	23	19	16	14	12	11
Gas	134	133	135	132	132	137
Oil	14	12	10	4	1	0
Biomass	1	1	1	1	1	2
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	209	193	187	168	159	159
Autoproducers	9	11	12	15	18	20
Total generation	**406**	**434**	**463**	**513**	**586**	**675**
Fossil	273	287	301	324	356	412
Coal	63	62	59	54	54	58
Lignite	40	43	44	47	56	63
Gas	146	161	182	217	242	287
Oil	22	21	16	6	4	3
Diesel	2	0	0	0	0	0
Nuclear	42	45	53	59	60	63
Hydrogen	0	0	0	0	0	0
Renewables	**91**	**102**	**109**	**130**	**170**	**200**
Hydro	90	94	97	107	119	130
Wind	0	5	8	14	34	47
of which wind offshore	0	0	1	2	2	3
PV	0	1	1	3	7	10
Biomass	1	1	2	5	8	10
Geothermal	0	0	1	2	3	3
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	0	6	9	17	41	57
Share of fluctuating RES	0.1%	1.4%	2.0%	3.3%	7.0%	8.5%
RES share (domestic generation)	**22.4%**	**23.5%**	**23.6%**	**25.4%**	**29.0%**	**29.7%**

table 12.97: eastern europe/eurasia: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**47,315**	**51,607**	**55,034**	**61,444**	**66,948**	**69,239**
Fossil	**42,313**	**45,998**	**48,482**	**53,764**	**58,355**	**59,823**
Hard coal	7,138	7,941	8,086	8,417	8,322	7,959
Lignite	2,182	2,726	2,807	3,083	3,761	4,225
Natural gas	24,069	25,515	27,258	31,132	34,194	34,678
Crude oil	8,923	9,817	10,331	11,132	12,078	12,961
Nuclear	**3,031**	**3,387**	**4,118**	**4,665**	**4,794**	**5,068**
Renewables	**1,972**	**2,222**	**2,434**	**3,015**	**3,799**	**4,347**
Hydro	1,053	1,093	1,140	1,268	1,425	1,553
Wind	2	35	55	109	259	360
Solar	3	9	11	21	45	64
Biomass	893	1,003	1,088	1,390	1,691	1,947
Geothermal/ambient heat	22	82	140	227	378	424
Ocean energy	0	0	0	0	0	0
RES share	**4.1%**	**4.3%**	**4.4%**	**4.9%**	**5.7%**	**6.3%**

table 12.98: eastern europe/eurasia: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**28,213**	**31,288**	**33,712**	**38,036**	**42,387**	**46,401**
Total (energy use)	**25,320**	**28,284**	**30,493**	**34,371**	**38,355**	**42,162**
Transport	**5,598**	**6,678**	**7,084**	**8,027**	**9,007**	**9,959**
Oil products	3,823	4,379	4,717	5,421	6,155	6,950
Natural gas	1,375	1,780	1,834	1,972	2,078	2,120
Biofuels	28	53	51	59	66	74
Electricity	372	466	482	572	703	808
RES electricity	68	81	81	98	133	155
Hydrogen	0	0	0	3	4	7
RES share Transport	**1.7%**	**2.0%**	**1.9%**	**2.0%**	**2.2%**	**2.3%**
Industry	**8,144**	**9,202**	**10,022**	**11,269**	**12,623**	**13,972**
Electricity	1,858	2,324	2,640	3,181	3,765	4,388
RES electricity	343	406	447	546	711	840
District heat	2,098	2,100	2,122	2,249	2,470	2,889
RES district heat	17	39	43	50	63	83
Coal	525	1,229	1,304	1,364	1,322	1,139
Oil products	887	906	950	1,053	1,150	1,154
Gas	2,719	2,560	2,917	3,311	3,764	4,218
Solar	0	0	0	0	0	0
Biomass and waste	57	82	88	111	152	184
Geothermal/ambient heat	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**5.1%**	**5.7%**	**5.8%**	**6.3%**	**7.3%**	**7.9%**
Other Sectors	**11,577**	**12,404**	**13,387**	**15,075**	**16,725**	**18,230**
Electricity	1,923	2,097	2,413	2,968	3,517	4,080
RES electricity	355	366	408	509	664	781
District heat	3,699	3,774	3,978	4,244	4,547	5,000
RES district heat	25	59	65	73	88	111
Coal	368	369	399	431	389	207
Oil products	967	1,245	1,265	1,251	1,269	1,288
Gas	4,175	4,456	4,843	5,618	6,339	6,908
Solar	3	6	5	10	14	18
Biomass and waste	436	454	478	543	611	683
Geothermal/ambient heat	5	5	7	9	39	45
RES share Other Sectors	**7.1%**	**7.2%**	**7.2%**	**7.6%**	**8.5%**	**9.0%**
Total RES	**1,337**	**1,550**	**1,673**	**2,011**	**2,542**	**2,976**
RES share	**5.3%**	**5.5%**	**5.5%**	**5.8%**	**6.6%**	**7.1%**
Non energy use	**2,894**	**3,003**	**3,220**	**3,665**	**4,032**	**4,239**
Oil	1,384	1,399	1,499	1,706	1,878	1,974
Gas	1,439	1,512	1,621	1,845	2,030	2,135
Coal	70	92	99	113	124	131

eastern europe/eurasia: energy [r]evolution scenario

table 12.99: eastern europe/eurasia: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**758**	**954**	**1,143**	**1,590**	**2,158**	**2,594**
Coal	63	81	75	61	34	0
Lignite	63	73	64	18	0	0
Gas	48	103	137	145	74	19
Oil	12	9	3	2	0	0
Diesel	3	0	0	0	0	1
Nuclear	276	285	269	150	0	0
Biomass	0	16	25	46	46	20
Hydro	292	335	350	360	375	380
Wind	1	46	188	673	1,303	1,634
of which wind offshore	0	0	1	7	16	25
PV	0	1	8	71	198	327
Geothermal	0	3	8	28	60	133
Solar thermal power plants	0	0	1	5	24	36
Ocean energy	0	2	15	32	42	44
Combined heat & power plants	**850**	**891**	**891**	**847**	**747**	**620**
Coal	166	156	152	131	46	0
Lignite	84	77	59	15	0	0
Gas	573	629	611	524	366	181
Oil	24	11	3	1	0	0
Biomass	3	14	52	127	212	274
Geothermal	0	4	14	48	123	165
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	797	825	820	764	653	520
Autoproducers	53	66	71	83	94	100
Total generation	**1,608**	**1,845**	**2,034**	**2,437**	**2,905**	**3,214**
Fossil	1,035	1,139	1,105	896	521	201
Coal	229	237	228	191	80	0
Lignite	147	150	123	33	0	0
Gas	621	732	748	669	440	200
Oil	36	20	6	3	1	1
Diesel	3	0	0	0	0	1
Nuclear	276	285	269	150	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**296**	**421**	**661**	**1,390**	**2,383**	**3,013**
Hydro	292	335	350	360	375	380
Wind	1	46	188	673	1,303	1,634
of which wind offshore	0	0	1	7	16	25
PV	0	1	8	71	198	327
Biomass	3	30	77	173	258	294
Geothermal	0	7	22	76	183	297
Solar thermal	0	0	1	5	24	36
Ocean energy	0	2	15	32	42	44
Distribution losses	183	195	196	197	193	187
Own consumption electricity	248	299	302	303	297	288
Electricity for hydrogen production	0	0	56	170	385	595
Final energy consumption (electricity)	**1,154**	**1,325**	**1,455**	**1,742**	**2,007**	**2,122**
Fluctuating RES (PV, Wind, Ocean)	1	49	211	776	1,543	2,005
Share of fluctuating RES	0.0%	2.6%	10.4%	31.9%	53.1%	62.4%
RES share (domestic generation)	**18.4%**	**22.8%**	**32.5%**	**57.1%**	**82.1%**	**93.7%**
'Efficiency' savings (compared to Ref.)	**0**	**30**	**109**	**277**	**488**	**743**

table 12.100: eastern europe/eurasia: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**3,320**	**3,226**	**3,228**	**3,029**	**2,913**	**2,557**
Fossil fuels	3,225	2,936	2,550	1,727	816	128
Biomass	95	161	323	606	757	614
Solar collectors	0	32	97	212	320	537
Geothermal	0	97	258	485	1,019	1,279
Heat from CHP	**3,866**	**3,968**	**4,041**	**4,108**	**4,004**	**3,768**
Fossil fuels	3,843	3,845	3,616	2,959	1,720	763
Biomass	23	85	302	714	1,176	1,523
Geothermal	0	38	123	435	1,108	1,482
Hydrogen	0	0	0	0	0	0
Direct heating[1]	**9,102**	**9,485**	**9,409**	**8,916**	**8,401**	**7,748**
Fossil fuels	8,688	8,379	6,884	4,043	1,731	283
Biomass	404	634	1,174	1,779	1,725	1,507
Solar collectors	3	179	581	1,238	1,641	1,700
Geothermal[2]	7	294	656	1,540	2,684	3,402
Hydrogen	0	0	113	316	620	857
Total heat supply[1]	**16,288**	**16,680**	**16,678**	**16,053**	**15,318**	**14,074**
Fossil fuels	15,755	15,160	13,050	8,729	4,267	1,174
Biomass	523	880	1,799	3,098	3,659	3,643
Solar collectors	3	211	678	1,450	1,961	2,237
Geothermal[1]	7	428	1,038	2,460	4,811	6,162
Hydrogen	0	0	113	316	620	857
RES share (including RES electricity)	**3.3%**	**9%**	**21%**	**45%**	**71%**	**91%**
'Efficiency' savings (compared to Ref.)	**0**	**655**	**1,808**	**4,265**	**6,915**	**10,028**

1) heat from electricity (direct) not included; geothermal includes heat pumps

table 12.101: eastern europe/eurasia: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**233**	**279**	**258**	**168**	**69**	**11**
Coal	90	69	64	50	28	0
Lignite	69	99	84	22	0	0
Gas	48	91	102	88	38	9
Oil	21	19	7	6	1	1
Diesel	4	1	1	1	2	2
Combined heat & power production	**979**	**896**	**782**	**569**	**317**	**130**
Coal	237	210	198	164	56	0
Lignite	120	103	76	19	0	0
Gas	582	559	500	383	259	128
Oil	40	24	8	3	2	2
CO_2 emissions power generation (incl. CHP public)	**1,212**	**1,175**	**1,040**	**738**	**386**	**141**
Coal	327	279	262	214	84	0
Lignite	189	202	160	41	0	0
Gas	630	650	602	472	298	137
Oil & diesel	66	44	15	10	5	5
CO_2 emissions by sector	**2,483**	**2,353**	**2,062**	**1,392**	**695**	**243**
% of 1990 emissions	62%	58%	51%	34%	17%	6%
Industry[1]	318	308	253	165	93	44
Other sectors[1]	346	324	270	156	68	17
Transport	262	272	266	195	99	48
Power generation[2]	1,158	1,115	988	691	342	104
District heating & other conversion	399	334	284	185	93	30
Population (Mill.)	339	340	341	337	331	324
CO_2 emissions per capita (t/capita)	**7.3**	**6.9**	**6.0**	**4.1**	**2.1**	**0.7**
'Efficiency' savings (compared to Ref.)	**0**	**319**	**750**	**1,721**	**2,720**	**3,314**

1) including CHP autoproducers. 2) including CHP public

table 12.102: eastern europe/eurasia: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**188**	**242**	**327**	**598**	**966**	**1,227**
Coal	17	18	17	12	6	0
Lignite	17	18	14	4	0	0
Gas	11	22	30	36	19	5
Oil	8	8	2	1	0	0
Diesel	2	0	0	0	0	0
Nuclear	42	42	38	21	0	0
Biomass	0	4	5	9	9	4
Hydro	90	104	108	109	113	114
Wind	0	25	98	328	619	776
of which wind offshore	0	0	1	3	6	10
PV	0	1	7	60	163	270
Geothermal	0	0	1	5	11	27
Solar thermal power plants	0	0	0	2	8	12
Ocean energy	0	1	6	12	16	17
Combined heat & power production	**218**	**200**	**194**	**194**	**170**	**136**
Coal	46	37	34	26	8	0
Lignite	23	18	13	3	0	0
Gas	134	133	133	129	93	46
Oil	14	8	2	0	0	0
Biomass	1	3	11	27	48	62
Geothermal	0	1	2	8	21	28
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	209	189	182	176	147	112
Autoproducers	9	11	12	18	23	24
Total generation	**406**	**442**	**521**	**792**	**1,137**	**1,364**
Fossil	273	262	245	211	128	52
Coal	63	55	51	38	15	0
Lignite	40	36	27	7	0	0
Gas	146	155	163	165	112	51
Oil	22	16	4	1	0	0
Diesel	2	0	0	0	0	0
Nuclear	42	42	38	21	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**91**	**138**	**238**	**560**	**1,009**	**1,312**
Hydro	90	104	108	109	113	114
Wind	0	25	98	328	619	776
of which wind offshore	0	0	1	3	6	10
PV	0	1	7	60	163	270
Biomass	1	7	16	36	57	66
Geothermal	0	1	4	13	32	56
Solar thermal	0	0	0	2	8	12
Ocean energy	0	1	6	12	16	17
Fluctuating RES (PV, Wind, Ocean)	0	27	110	401	799	1,064
Share of fluctuating RES	0.1%	6.0%	21.2%	50.6%	70.3%	78.0%
RES share (domestic generation)	**22.4%**	**31.3%**	**45.6%**	**70.7%**	**88.8%**	**96.2%**

table 12.103: eastern europe/eurasia: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**47,315**	**48,934**	**48,539**	**44,397**	**40,402**	**37,321**
Fossil	**42,313**	**41,420**	**36,970**	**26,654**	**15,654**	**8,055**
Hard coal	7,138	6,689	6,523	5,701	4,261	3,274
Lignite	2,182	2,140	1,609	421	0	0
Natural gas	24,069	24,707	22,539	16,313	9,073	2,949
Crude oil	8,923	7,884	6,298	4,219	2,319	1,833
Nuclear	**3,031**	**3,125**	**2,947**	**1,642**	**0**	**0**
Renewables	**1,972**	**4,388**	**8,622**	**16,101**	**24,749**	**29,265**
Hydro	1,053	1,206	1,260	1,296	1,350	1,368
Wind	2	166	677	2,425	4,692	5,884
Solar	3	213	708	1,724	2,760	3,544
Biomass	893	2,160	4,237	6,490	7,702	7,630
Geothermal/ambient heat	22	636	1,686	4,051	8,093	10,681
Ocean energy	0	7	54	115	151	158
RES share	**4.1%**	**8.9%**	**17.7%**	**36.2%**	**61.2%**	**78.4%**
'Efficiency' savings (compared to Ref.)	**0**	**2,668**	**6,393**	**16,918**	**26,423**	**31,773**

table 12.104: eastern europe/eurasia: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**28,213**	**29,605**	**30,004**	**28,775**	**27,281**	**25,588**
Total (energy use)	**25,320**	**26,691**	**27,042**	**25,844**	**24,378**	**22,832**
Transport	**5,598**	**6,031**	**6,098**	**5,328**	**4,540**	**4,012**
Oil products	3,823	3,960	3,771	2,533	1,207	559
Natural gas	1,375	1,505	1,413	1,084	720	464
Biofuels	28	108	320	491	552	439
Electricity	372	458	577	1,119	1,702	1,845
RES electricity	68	104	187	638	1,396	1,730
Hydrogen	0	0	17	101	360	705
RES share Transport	**1.7%**	**3.5%**	**8.4%**	**22.3%**	**49.4%**	**70.5%**
Industry	**8,144**	**8,668**	**8,877**	**8,770**	**8,542**	**8,116**
Electricity	1,858	2,217	2,398	2,610	2,774	2,880
RES electricity	343	505	779	1,489	2,276	2,700
District heat	2,098	2,122	2,235	2,331	2,379	2,241
RES district heat	17	122	339	802	1,512	1,932
Coal	525	641	580	366	0	0
Oil products	887	692	410	91	79	35
Gas	2,719	2,699	2,268	1,531	815	117
Solar	0	39	116	293	430	450
Biomass and waste	57	199	615	998	978	842
Geothermal/ambient heat	0	60	136	218	434	648
Hydrogen	0	0	119	333	652	902
RES share Industry	**5.1%**	**10.7%**	**22.8%**	**45.5%**	**72.2%**	**91.4%**
Other Sectors	**11,577**	**11,992**	**12,067**	**11,746**	**11,296**	**10,705**
Electricity	1,923	2,097	2,264	2,542	2,751	2,914
RES electricity	355	478	735	1,450	2,257	2,731
District heat	3,699	3,753	3,751	3,645	3,513	3,286
RES district heat	25	210	556	1,267	2,318	2,978
Coal	368	348	289	135	32	0
Oil products	967	689	453	268	122	16
Gas	4,175	4,229	3,652	2,137	926	232
Solar	3	140	465	945	1,210	1,250
Biomass and waste	436	562	767	1,023	982	870
Geothermal/ambient heat	5	175	427	1,050	1,758	2,137
RES share Other Sectors	**7.1%**	**13.0%**	**24.4%**	**48.8%**	**75.5%**	**93.1%**
Total RES	**1,337**	**2,701**	**5,486**	**10,911**	**16,937**	**20,215**
RES share	**5.3%**	**10.1%**	**20.3%**	**42.2%**	**69.5%**	**88.5%**
Non energy use	**2,894**	**2,913**	**2,962**	**2,932**	**2,903**	**2,755**
Oil	1,384	1,165	889	879	697	1,102
Gas	1,439	1,602	1,777	1,466	1,045	551
Coal	70	146	296	586	1,161	1,102

eastern europe/eurasia: investment & employment

table 12.105: eastern europe/eurasia: total investment in power sector

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Conventional (fossil & nuclear)	**333,918**	**242,132**	**147,345**	**176,611**	**900,007**	**22,500**
Renewables	**105,603**	**124,879**	**166,502**	**127,160**	**524,144**	**13,104**
Biomass	6,200	9,687	11,676	13,570	41,132	1,028
Hydro	76,202	89,740	104,163	69,717	339,822	8,496
Wind	12,781	12,113	35,547	28,125	88,567	2,214
PV	2,360	3,832	6,213	4,761	17,166	429
Geothermal	8,059	5,618	8,819	8,016	30,512	763
Solar thermal power plants	0	3,831	38	2,953	6,822	171
Ocean energy	0	58	47	18	123	3
Energy [R]evolution						
Conventional (fossil & nuclear)	**172,558**	**83,685**	**8,278**	**5,625**	**270,146**	**6,754**
Renewables	**397,436**	**629,695**	**1,035,388**	**1,052,280**	**3,114,799**	**77,870**
Biomass	64,729	78,920	126,667	106,579	376,895	9,422
Hydro	110,837	61,205	72,014	41,878	285,935	7,148
Wind	139,127	302,537	504,055	517,731	1.463,450	36,586
PV	13,037	76,841	126,007	167,752	383,637	9,591
Geothermal	45,240	83,718	161,133	179,075	469,166	11,729
Solar thermal power plants	1,071	8,274	36,046	22,784	68,175	1,704
Ocean energy	23,395	18,201	9,466	16,481	67,543	1,689

table 12.106: eastern europe/eurasia: total investment in renewable heating only

(EXCLUDING INVESTMENTS IN FOSSIL FUELS)

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Renewables	**55,244**	**56,370**	**39,505**	**30,719**	**181,839**	**4,546**
Biomass	51,755	50,295	22,157	25,460	149,667	3,742
Geothermal	679	2,277	1,286	1,360	5,602	140
Solar	694	2,279	2,972	2,236	8,181	205
Heat pumps	2,116	1,519	13,090	1,664	18,388	460
Energy [R]evolution scenario						
Renewables	**784,705**	**651,084**	**1,329,036**	**883,465**	**3,648,291**	**91,207**
Biomass	149,937	122,700	35,551	0	308,189	7,705
Geothermal	322,882	106,511	653,677	341,123	1,424,192	35,605
Solar	203,350	204,078	280,324	182,759	870,511	21,763
Heat pumps	108,537	217,794	359,484	359,584	1,045,399	26,135

table 12.107: eastern europe/eurasia: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	125	75	57	42	330	413	325
Manufacturing	37	20	19	17	161	214	226
Operations and maintenance	187	177	171	146	203	232	262
Fuel supply (domestic)	975	911	849	819	920	866	653
Coal and gas export	362.9	407.8	446.6	372.5	350.9	268.7	103.9
Total jobs	**1,688**	**1,591**	**1,542**	**1,398**	**1,965**	**1,994**	**1,570**
By technology							
Coal	745	637	587	509	498	309	153
Gas, oil & diesel	692	727	742	709	715	660	386
Nuclear	75	69	52	33	32	32	32
Total renewables	**176**	**158**	**162**	**146**	**719**	**994**	**999**
Biomass	*78*	*75*	*76*	*67*	*220*	*332*	*369*
Hydro	*75*	*71*	*73*	*67*	*79*	*66*	*58*
Wind	*10*	*7.4*	*9.1*	*9.2*	*137*	*175*	*269*
PV	*3.5*	*2.6*	*0.4*	*1.3*	*29*	*75*	*91*
Geothermal power	*1.2*	*1.2*	*0.9*	*0.6*	*9*	*12*	*14*
Solar thermal power	*0.01*	*0.00*	*1.7*	*-*	*0.5*	*0.8*	*4.0*
Ocean	*-*	*-*	*0.02*	*0.02*	*16*	*8.8*	*3.1*
Solar - heat	*8.8*	*0.9*	*-*	*0.6*	*133*	*210*	*98*
Geothermal & heat pump	*-*	*0.2*	*0.5*	*0.2*	*95*	*114*	*92*
Total jobs	**1,688**	**1,591**	**1,542**	**1,398**	**1,965**	**1,994**	**1,570**

india: scenario results data

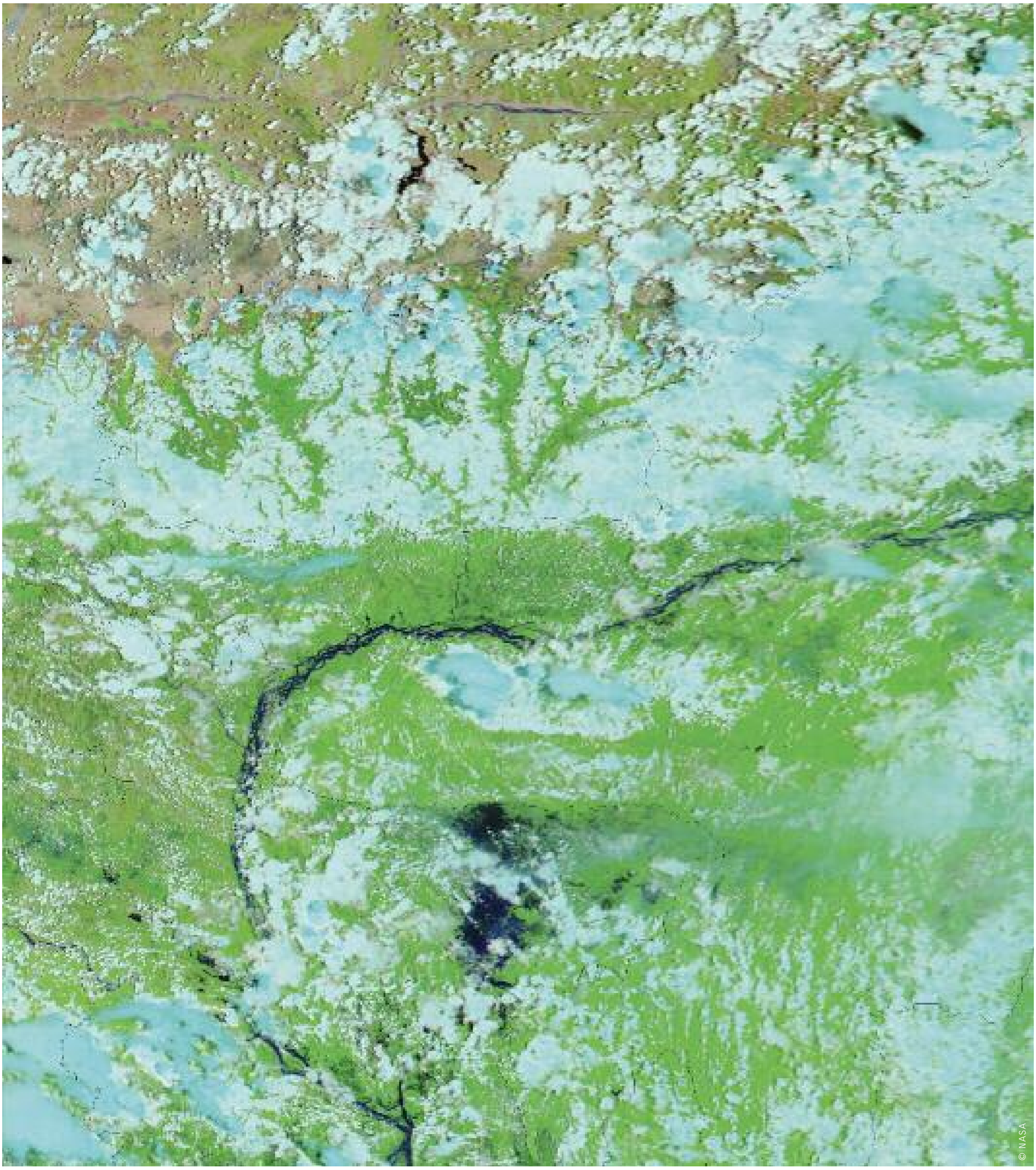

image HIGH SEASONAL WATERS ALONG THE INDIA-NEPAL BORDER, 2009.

india: reference scenario

table 12.108: india: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**970**	**1,298**	**1,724**	**2,712**	**3,900**	**5,070**
Coal	666	849	1,146	1,736	2,439	3,096
Lignite	20	31	42	66	107	164
Gas	112	146	187	343	556	770
Oil	26	24	25	23	20	18
Diesel	0	0	0	0	0	0
Nuclear	19	44	67	126	186	246
Biomass	2	7	15	56	108	159
Hydro	107	147	168	235	299	364
Wind	18	41	58	87	112	137
of which wind offshore	0	1	2	4	6	8
PV	0	10	15	40	69	109
Geothermal	0	0	0	1	1	1
Solar thermal power plants	0	0	0	0	1	3
Ocean energy	0	0	0	0	1	2
Combined heat & power plants	**0**	**21**	**45**	**84**	**123**	**162**
Coal	0	19	41	76	111	145
Lignite	0	0	0	0	0	0
Gas	0	2	5	8	12	16
Oil	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	21	45	84	123	162
Total generation	**970**	**1,319**	**1,769**	**2,796**	**4,022**	**5,231**
Fossil	824	1,070	1,446	2,252	3,245	4,209
Coal	666	868	1,187	1,812	2,549	3,242
Lignite	20	31	42	66	107	164
Gas	112	148	192	351	569	786
Oil	26	24	25	23	20	18
Diesel	0	0	0	0	0	0
Nuclear	19	44	67	126	186	246
Hydrogen	0	0	0	0	0	0
Renewables	**127**	**206**	**256**	**418**	**591**	**775**
Hydro	107	147	168	235	299	364
Wind	18	41	58	87	112	137
of which wind offshore	0	1	2	4	6	8
PV	0	10	15	40	69	109
Biomass	2	7	15	56	108	159
Geothermal	0	0	0	1	1	1
Solar thermal	0	0	0	0	1	3
Ocean energy	0	0	0	0	1	2
Distribution losses	220	240	337	532	781	966
Own consumption electricity	58	68	101	177	289	395
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**702**	**1,021**	**1,342**	**2,097**	**2,964**	**3,883**
Fluctuating RES (PV, Wind, Ocean)	18	52	73	126	182	248
Share of fluctuating RES	1.9%	3.9%	4.1%	4.5%	4.5%	4.7%
RES share (domestic generation)	**13%**	**16%**	**14%**	**15%**	**15%**	**15%**

table 12.109: india: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**0**	**0**	**0**	**0**	**0**	**0**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**2**	**7**	**24**	**53**	**93**
Fossil fuels	0	2	7	24	53	93
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
Direct heating[1)]	**9,940**	**11,175**	**12,373**	**14,243**	**16,045**	**17,956**
Fossil fuels	4,431	5,386	6,528	8,342	10,037	11,730
Biomass	5,497	5,763	5,813	5,833	5,868	5,994
Solar collectors	11	23	28	47	90	159
Geothermal[2)]	0	2	5	22	49	73
Total heat supply[1)]	**9,940**	**11,177**	**12,379**	**14,268**	**16,098**	**18,049**
Fossil fuels	4,431	5,388	6,534	8,366	10,090	11,823
Biomass	5,497	5,763	5,813	5,833	5,868	5,994
Solar collectors	11	23	28	47	90	159
Geothermal[2)]	0	2	5	22	49	73
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**55.4%**	**51.8%**	**47.2%**	**41.4%**	**37.3%**	**34.5%**

1) heat from electricity (direct) not included; 2) including heat pumps.

table 12.110: india: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**962**	**1,035**	**1,398**	**1,955**	**2,597**	**3,025**
Coal	848	908	1,241	1,725	2,258	2,580
Lignite	25	33	46	66	99	136
Gas	55	65	80	138	219	292
Oil	33	29	31	27	21	16
Diesel	0	0	0	0	0	0
Combined heat & power production	**0**	**21**	**46**	**79**	**112**	**148**
Coal	0	20	44	75	107	141
Lignite	0	0	0	0	0	0
Gas	0	1	2	4	5	7
Oil	0	0	0	0	0	0
CO_2 emissions power generation (incl. CHP public)	**962**	**1,056**	**1,444**	**2,034**	**2,710**	**3,172**
Coal	848	928	1,285	1,800	2,365	2,720
Lignite	25	33	46	66	99	136
Gas	55	66	82	142	224	299
Oil & diesel	33	29	31	27	21	16
CO_2 emissions by sector	**1,704**	**1,924**	**2,523**	**3,579**	**4,854**	**5,981**
% of 1990 emissions	287%	324%	425%	604%	819%	1009%
Industry[1)]	272	408	527	711	887	1,056
Other sectors[1)]	192	174	193	215	226	235
Transport	154	164	235	478	856	1,285
Power generation[2)]	962	1,035	1,398	1,955	2,597	3,025
District heating & other conversion	125	143	170	219	287	380
Population (Mill.)	1,208	1,308	1,387	1,523	1,627	1,692
CO_2 emissions per capita (t/capita)	**1.4**	**1.5**	**1.8**	**2.3**	**3.0**	**3.5**

1) including CHP autoproducers. 2) including CHP public

table 12.111: india: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**186**	**299**	**354**	**559**	**796**	**1,034**
Coal	99	164	186	289	408	518
Lignite	3	6	7	11	18	27
Gas	20	33	44	78	123	171
Oil	7	8	8	8	7	6
Diesel	0	0	0	0	0	0
Nuclear	5	7	10	19	27	36
Biomass	2	3	4	10	18	27
Hydro	39	49	55	77	98	119
Wind	11	23	30	42	51	60
of which wind offshore	0	0	1	1	2	2
PV	0	7	10	26	44	68
Geothermal	0	0	0	0	0	0
Solar thermal power plants	0	0	0	0	0	1
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**5**	**11**	**20**	**30**	**40**
Coal	0	5	10	19	27	36
Lignite	0	0	0	0	0	0
Gas	0	0	1	2	2	3
Oil	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	5	11	20	30	40
Total generation	**186**	**304**	**365**	**580**	**826**	**1,074**
Fossil	130	216	256	406	586	762
Coal	99	169	196	308	435	554
Lignite	3	6	7	11	18	27
Gas	20	34	45	79	126	174
Oil	7	8	8	8	7	6
Diesel	0	0	0	0	0	0
Nuclear	5	7	10	19	27	36
Hydrogen	0	0	0	0	0	0
Renewables	**52**	**81**	**99**	**155**	**213**	**276**
Hydro	39	49	55	77	98	119
Wind	11	23	30	42	51	60
of which wind offshore	0	0	1	1	2	2
PV	0	7	10	26	44	68
Biomass	2	3	4	10	18	27
Geothermal	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	1
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	11	30	40	68	96	128
Share of fluctuating RES	6%	10%	11%	12%	12%	12%
RES share (domestic generation)	**28%**	**27%**	**27%**	**27%**	**26%**	**26%**

table 12.112: india: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**29,049**	**32,803**	**40,509**	**55,458**	**73,308**	**88,950**
Fossil	**21,456**	**24,173**	**31,260**	**44,398**	**60,296**	**74,334**
Hard coal	12,758	14,195	18,964	25,905	33,192	37,869
Lignite	326	446	566	739	1,078	1,474
Natural gas	2,005	2,327	2,941	4,785	7,304	9,637
Crude oil	6,366	7,206	8,789	12,969	18,723	25,354
Nuclear	**203**	**483**	**726**	**1,377**	**2,033**	**2,689**
Renewables	**7,391**	**8,146**	**8,523**	**9,684**	**10,979**	**11,928**
Hydro	385	528	606	847	1,078	1,309
Wind	65	149	208	312	402	493
Solar	11	61	82	191	344	563
Biomass	6,930	7,401	7,614	8,299	9,094	9,481
Geothermal/ambient heat	0	7	13	34	57	76
Ocean energy	0	0	0	1	4	7
RES share	**25.4%**	**24.8%**	**21.0%**	**17.4%**	**15.0%**	**13.4%**

table 12.113: india: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**18,810**	**22,111**	**25,997**	**34,885**	**45,961**	**57,877**
Total (energy use)	**17,183**	**19,962**	**23,528**	**31,820**	**42,261**	**53,542**
Transport	**2,156**	**2,371**	**3,372**	**6,846**	**12,345**	**18,544**
Oil products	2,021	2,152	3,089	6,276	11,095	16,663
Natural gas	83	99	122	277	680	1,009
Biofuels	7	55	83	195	440	670
Electricity	45	65	77	98	131	201
RES electricity	6	10	11	15	19	30
Hydrogen	0	0	0	0	0	0
RES share Transport	**0.6%**	**2.7%**	**2.8%**	**3.1%**	**3.7%**	**3.8%**
Industry	**5,695**	**7,651**	**9,286**	**12,333**	**15,417**	**18,615**
Electricity	1,175	1,776	2,352	3,575	4,933	6,425
RES electricity	154	277	341	535	725	952
District heat	0	2	7	24	53	93
RES district heat	0	0	0	0	0	0
Coal	1,874	3,022	3,897	5,299	6,617	7,726
Oil products	982	1,180	1,272	1,409	1,525	1,775
Gas	469	358	480	675	900	1,122
Solar	0	0	0	0	6	33
Biomass and waste	1,195	1,313	1,279	1,350	1,383	1,442
Geothermal/ambient heat	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**23.7%**	**20.8%**	**17.4%**	**15.3%**	**13.7%**	**13.0%**
Other Sectors	**9,332**	**9,940**	**10,870**	**12,641**	**14,499**	**16,383**
Electricity	1,309	1,836	2,402	3,877	5,606	7,352
RES electricity	171	286	348	580	824	1,090
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	1,035	691	706	657	522	308
Oil products	1,294	1,474	1,688	1,972	2,173	2,410
Gas	7	24	55	166	322	523
Solar	11	23	28	47	84	126
Biomass and waste	5,676	5,891	5,987	5,907	5,757	5,610
Geothermal/ambient heat	0	2	3	16	36	55
RES share Other Sectors	**62.8%**	**62.4%**	**58.6%**	**51.8%**	**46.2%**	**42.0%**
Total RES	**7,220**	**7,856**	**8,080**	**8,644**	**9,273**	**10,007**
RES share	**42.0%**	**39.4%**	**34.3%**	**27.2%**	**21.9%**	**18.7%**
Non energy use	**1,627**	**2,149**	**2,469**	**3,065**	**3,700**	**4,335**
Oil	1,103	1,456	1,673	2,077	2,507	2,938
Gas	525	693	796	988	1,193	1,397
Coal	0	0	0	0	0	0

india: energy [r]evolution scenario

table 12.114: india: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**970**	**1,279**	**1,548**	**2,266**	**3,138**	**4,258**
Coal	666	824	805	622	332	89
Lignite	20	18	13	8	4	0
Gas	112	124	191	197	193	154
Oil	26	21	10	1	0	0
Diesel	0	0	0	0	0	0
Nuclear	19	52	53	43	24	0
Biomass	2	14	35	34	34	29
Hydro	107	144	189	195	201	204
Wind	18	67	187	427	672	917
of which wind offshore	0	0	6	121	253	397
PV	0	13	43	243	528	830
Geothermal	0	1	5	112	250	437
Solar thermal power plants	0	0	15	315	781	1,402
Ocean energy	0	0	3	69	120	197
Combined heat & power plants	**0**	**20**	**61**	**152**	**376**	**608**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	10	29	55	84	99
Oil	0	0	0	0	0	0
Biomass	0	10	30	76	188	304
Geothermal	0	0	1	20	81	144
Hydrogen	0	0	0	2	22	61
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	20	61	152	376	608
Total generation	**970**	**1,299**	**1,608**	**2,418**	**3,514**	**4,866**
Fossil	824	997	1,048	883	613	342
Coal	666	824	805	622	332	89
Lignite	20	18	13	8	4	0
Gas	112	134	220	252	277	253
Oil	26	21	10	1	0	0
Diesel	0	0	0	0	0	0
Nuclear	19	52	53	43	24	0
Hydrogen	0	0	0	2	22	61
Renewables	**127**	**249**	**508**	**1,490**	**2,855**	**4,464**
Hydro	107	144	189	195	201	204
Wind	18	67	187	427	672	917
of which wind offshore	0	0	6	121	253	397
PV	0	13	43	243	528	830
Biomass	2	24	65	110	222	333
Geothermal	0	1	6	131	331	581
Solar thermal	0	0	15	315	781	1,402
Ocean energy	0	0	3	69	120	197
Distribution losses	220	240	260	284	305	305
Own consumption electricity	58	68	78	95	113	125
Electricity for hydrogen production	0	0	1	36	180	451
Final energy consumption (electricity)	**702**	**997**	**1,278**	**2,022**	**2,953**	**4,053**
Fluctuating RES (PV, Wind, Ocean)	18	80	233	739	1,320	1,944
Share of fluctuating RES	1.9%	6.2%	14.5%	30.6%	37.6%	39.9%
RES share (domestic generation)	**13%**	**19%**	**32%**	**62%**	**81%**	**92%**
'Efficiency' savings (compared to Ref.)	**0**	**25**	**93**	**290**	**593**	**993**

table 12.115: india: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**0**	**25**	**89**	**272**	**570**	**892**
Fossil fuels	0	0	0	0	0	0
Biomass	0	20	71	190	257	223
Solar collectors	0	5	18	68	251	526
Geothermal	0	0	0	14	63	143
Heat from CHP	**0**	**152**	**438**	**860**	**1,983**	**3,085**
Fossil fuels	0	72	210	283	337	358
Biomass	0	80	217	390	752	995
Geothermal	0	0	11	176	733	1,296
Hydrogen	0	0	0	11	161	436
Direct heating[1]	**9,940**	**10,811**	**11,330**	**11,870**	**11,248**	**10,510**
Fossil fuels	4,431	4,725	4,583	3,907	2,374	815
Biomass	5,497	5,853	5,829	5,371	4,844	4,024
Solar collectors	11	171	724	1,913	2,738	3,689
Geothermal[2]	0	62	194	624	1,113	1,677
Hydrogen		0	0	55	180	305
Total heat supply[1]	**9,940**	**10,988**	**11,856**	**13,002**	**13,801**	**14,487**
Fossil fuels	4,431	4,797	4,792	4,191	2,711	1,173
Biomass	5,497	5,954	6,117	5,951	5,852	5,242
Solar collectors	11	176	742	1,981	2,989	4,215
Geothermal[1]	0	62	205	814	1,908	3,116
Hydrogen	0	0	0	65	341	741
RES share (including RES electricity)	**55.4%**	**56%**	**60%**	**68%**	**80%**	**91%**
'Efficiency' savings (compared to Ref.)	**0**	**188**	**523**	**1,266**	**2,297**	**3,563**

1) heat from electricity (direct) not included; geothermal includes heat pumps

table 12.116: india: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**962**	**983**	**979**	**707**	**387**	**132**
Coal	848	882	872	618	308	74
Lignite	25	19	14	8	4	0
Gas	55	56	81	80	76	58
Oil	33	26	12	1	0	0
Diesel	0	0	0	0	0	0
Combined heat & power production	**0**	**12**	**33**	**40**	**42**	**40**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	12	33	40	42	40
Oil	0	0	0	0	0	0
CO_2 emissions power generation (incl. CHP public)	**962**	**995**	**1,013**	**747**	**429**	**172**
Coal	848	882	872	618	308	74
Lignite	25	19	14	8	4	0
Gas	55	68	115	120	118	98
Oil & diesel	33	26	12	1	0	0
CO_2 emissions by sector	**1,704**	**1,760**	**1,790**	**1,506**	**983**	**426**
% of 1990 emissions	287%	297%	302%	254%	166%	72%
Industry[1]	272	327	349	321	204	89
Other sectors[1]	192	162	137	90	53	22
Transport	154	160	201	286	266	147
Power generation[2]	962	983	979	707	387	132
District heating & other conversion	125	128	124	103	72	37
Population (Mill.)	1,208	1,308	1,387	1,523	1,627	1,692
CO_2 emissions per capita (t/capita)	**1.4**	**1.3**	**1.3**	**1.0**	**0.6**	**0.3**
'Efficiency' savings (compared to Ref.)	**0**	**164**	**733**	**2,073**	**3,871**	**5,555**

1) including CHP autoproducers. 2) including CHP public

table 12.117: india: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**186**	**273**	**390**	**691**	**996**	**1,325**
Coal	99	127	128	104	56	15
Lignite	3	3	2	1	1	0
Gas	20	28	46	48	46	38
Oil	7	7	3	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	5	8	8	6	4	0
Biomass	2	5	9	7	7	6
Hydro	39	48	62	64	66	67
Wind	11	37	96	185	265	335
of which wind offshore	0	0	2	36	70	104
PV	0	9	30	161	338	519
Geothermal	0	0	1	20	44	74
Solar thermal power plants	0	0	4	79	142	223
Ocean energy	0	0	1	17	29	47
Combined heat & power production	**0**	**3**	**9**	**27**	**71**	**121**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	2	5	11	19	25
Oil	0	0	0	0	0	0
Biomass	0	2	4	11	30	55
Geothermal	0	0	0	4	16	29
Hydrogen	0	0	0	0	5	12
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	3	9	27	71	121
Total generation	**186**	**276**	**399**	**718**	**1,067**	**1,446**
Fossil	130	167	184	164	121	78
Coal	99	127	128	104	56	15
Lignite	3	3	2	1	1	0
Gas	20	30	51	58	65	63
Oil	7	7	3	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	5	8	8	6	4	0
Hydrogen	0	0	0	0	5	12
Renewables	**52**	**101**	**207**	**548**	**937**	**1,356**
Hydro	39	48	62	64	66	67
Wind	11	37	96	185	265	335
of which wind offshore	0	0	2	36	70	104
PV	0	9	30	161	338	519
Biomass	2	7	13	19	38	62
Geothermal	0	0	1	24	60	103
Solar thermal	0	0	4	79	142	223
Ocean energy	0	0	1	17	29	47
Fluctuating RES (PV, Wind, Ocean)	11	46	127	362	631	902
Share of fluctuating RES	6%	17%	32%	50%	59%	62%
RES share (domestic generation)	**28%**	**36%**	**52%**	**76%**	**88%**	**94%**

table 12.118: india: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**29,049**	**32,233**	**35,977**	**42,312**	**46,816**	**49,357**
Fossil	**21,456**	**22,590**	**23,855**	**21,694**	**16,275**	**9,527**
Hard coal	12,758	12,979	12,827	10,205	6,027	2,803
Lignite	326	258	164	86	40	0
Natural gas	2,005	2,832	4,207	4,820	4,558	3,700
Crude oil	6,366	6,521	6,657	6,583	5,650	3,024
Nuclear	**203**	**567**	**576**	**467**	**260**	**0**
Renewables	**7,391**	**9,076**	**11,546**	**20,151**	**30,282**	**39,830**
Hydro	385	518	679	702	724	734
Wind	65	240	672	1,536	2,418	3,300
Solar	11	225	952	3,991	7,703	12,252
Biomass	6,930	8,009	8,855	8,775	8,925	7,869
Geothermal/ambient heat	0	84	378	4,899	10,081	14,966
Ocean energy	0	0	11	248	432	709
RES share	**25.4%**	**28.1%**	**32.1%**	**47.7%**	**64.8%**	**80.8%**
'Efficiency' savings (compared to Ref.)	**0**	**605**	**4,584**	**13,168**	**26,453**	**39,458**

table 12.119: india: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**18,810**	**21,564**	**24,216**	**29,206**	**32,524**	**34,513**
Total (energy use)	**17,183**	**19,465**	**21,797**	**26,291**	**29,262**	**31,224**
Transport	**2,156**	**2,321**	**3,022**	**4,910**	**5,754**	**6,002**
Oil products	2,021	2,083	2,588	3,688	3,386	1,741
Natural gas	83	119	181	250	297	328
Biofuels	7	50	71	113	128	139
Electricity	45	69	180	846	1,884	3,464
RES electricity	6	13	57	521	1,530	3,178
Hydrogen	0	0	3	14	59	329
RES share Transport	**0.6%**	**2.7%**	**4.2%**	**13.1%**	**29.7%**	**60.3%**
Industry	**5,695**	**7,204**	**8,345**	**9,949**	**11,154**	**12,069**
Electricity	1,175	1,685	2,118	2,908	3,640	4,316
RES electricity	154	323	668	1,792	2,957	3,959
District heat	0	156	460	984	2,269	3,476
RES district heat	0	93	278	737	1,950	3,141
Coal	1,874	2,136	2,042	1,760	885	171
Oil products	982	1,011	989	688	398	121
Gas	469	770	965	1,204	943	455
Solar	0	86	262	537	843	1,079
Biomass and waste	1,195	1,351	1,429	1,506	1,460	1,309
Geothermal/ambient heat	0	9	81	300	520	823
Hydrogen	0	0	0	62	196	318
RES share Industry	**23.7%**	**25.9%**	**32.6%**	**49.4%**	**70.7%**	**87.9%**
Other Sectors	**9,332**	**9,940**	**10,430**	**11,432**	**12,355**	**13,153**
Electricity	1,309	1,836	2,303	3,500	4,765	5,884
RES electricity	171	352	727	2,157	3,871	5,397
District heat	0	0	10	47	104	290
RES district heat	0	0	10	47	104	290
Coal	1,035	736	590	384	0	0
Oil products	1,294	1,241	1,042	625	508	29
Gas	7	39	87	139	263	323
Solar	11	84	462	1,376	1,895	2,609
Biomass and waste	5,676	5,966	5,857	5,169	4,429	3,424
Geothermal/ambient heat	0	39	79	192	393	592
RES share Other Sectors	**62.8%**	**64.8%**	**68.4%**	**78.2%**	**86.5%**	**93.6%**
Total RES	**7,220**	**8,367**	**9,981**	**14,493**	**20,286**	**26,535**
RES share	**42.0%**	**43.0%**	**45.8%**	**55.1%**	**69.3%**	**85.0%**
Non energy use	**1,627**	**2,099**	**2,419**	**2,915**	**3,261**	**3,289**
Oil	1,103	1,338	1,397	1,130	1,036	1,012
Gas	525	676	780	940	921	896
Coal	0	84	242	845	1,304	1,381

india: investment & employment

table 12.120: india: total investment in power sector

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Conventional (fossil & nuclear)	**179,759**	**261,422**	**334,311**	**399,127**	**1,174,620**	**29,365**
Renewables	**134,112**	**174,109**	**199,066**	**222,817**	**730,105**	**18,253**
Biomass	7,857	19,992	27,261	40,348	95,457	2,386
Hydro	71,946	99,718	102,263	108,381	382,307	9,558
Wind	30,853	29,349	35,931	28,403	124,537	3,113
PV	22,333	24,099	31,512	41,661	119,604	2,990
Geothermal	544	395	458	482	1,878	47
Solar thermal power plants	580	389	1,213	3,118	5,300	133
Ocean energy	0	168	429	423	1,021	26
Energy [R]evolution						
Conventional (fossil & nuclear)	**92,723**	**14,356**	**23,806**	**41,744**	**172,628**	**4,316**
Renewables	**377,116**	**1,124,349**	**1,254,043**	**1,747,500**	**4,503,008**	**112,575**
Biomass	44,763	28,519	104,128	109,809	287,219	**7,180**
Hydro	95,184	28,391	31,039	46,703	201,317	5,033
Wind	127,929	196,461	266,757	290,619	881,766	22,044
PV	61,847	187,397	235,120	327,627	811,991	20,300
Geothermal	12,690	181,149	241,948	301,348	737,135	18,428
Solar thermal power plants	31,920	458,107	349,741	621,621	1,461,389	36,535
Ocean energy	2,783	44,324	25,309	49,773	122,190	3,055

table 12.121: india: total investment in renewable heating only

(EXCLUDING INVESTMENTS IN FOSSIL FUELS)

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Renewables	**169,347**	**43,535**	**212,883**	**18,636**	**444,401**	**11,110**
Biomass	167,492	36,244	203,736	5,938	413,410	10,335
Geothermal	0	0	0	0	0	0
Solar	682	838	1,520	2,776	5,817	145
Heat pumps	1,173	6,454	7,627	9,921	25,175	629
Energy [R]evolution scenario						
Renewables	**248,578**	**232,932**	**481,510**	**329,781**	1,292,801	**32,320**
Biomass	131,060	44,147	175,207	15,894	366,307	9,158
Geothermal	11,397	13,627	25,024	57,992	108,039	2,701
Solar	74,003	90,290	164,293	160,500	489,086	12,227
Heat pumps	32,118	84,868	116,986	95,396	329,368	8,234

table 12.122: india: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	494	221	327	227	404	591	393
Manufacturing	246	111	155	99	428	496	274
Operations and maintenance	135	152	154	147	161	200	190
Fuel supply (domestic)	1,530	1,233	1,159	987	1,310	1,125	632
Coal and gas export	-	-	-	-	-	-	-
Total jobs	**2,405**	**1,716**	**1,794**	**1,460**	**2,304**	**2,412**	**1,488**
By technology							
Coal	1,142	735	880	842	582	467	208
Gas, oil & diesel	165	134	138	156	156	131	120
Nuclear	33	39	39	29	8	7	3
Total renewables	**1,064**	**809**	**738**	**432**	**1,558**	**1,808**	**1,157**
Biomass	*825*	*654*	*566*	*332*	*754*	*654*	*400*
Hydro	*85*	*70*	*82*	*64*	*103*	*48*	*34*
Wind	*67*	*45*	*40*	*17*	*316*	*280*	*145*
PV	*77*	*29*	*45*	*14*	*210*	*292*	*187*
Geothermal power	*0.9*	*0.5*	*0.3*	*0.1*	*8*	*34*	*26*
Solar thermal power	*1.3*	*1.0*	*1.1*	*0.3*	*37*	*161*	*102*
Ocean	*0.01*	*0.01*	*0.08*	*0.1*	*3.9*	*24.4*	*6.9*
Solar - heat	*5.5*	*7.5*	*2.6*	*3.9*	*109*	*292*	*233*
Geothermal & heat pump	*3.1*	*0.3*	*0.6*	*0.8*	*17*	*23*	*23*
Total jobs	**2,405**	**1,716**	**1,794**	**1,460**	**2,304**	**2,412**	**1,488**

non oecd asia: scenario results data

image THE IRRAWADDY DELTA, BURMA.

non oecd asia: reference scenario

table 12.123: non oecd asia: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**985**	**1,281**	**1,593**	**2,319**	**3,199**	**4,154**
Coal	162	350	595	1,065	1,581	2,173
Lignite	94	103	110	118	125	133
Gas	406	453	459	540	716	891
Oil	84	31	26	12	7	1
Diesel	28	28	28	28	28	28
Nuclear	44	67	70	93	92	90
Biomass	9	19	28	57	90	123
Hydro	136	194	227	300	368	435
Wind	1	5	12	43	103	162
of which wind offshore	0	0	1	5	9	13
PV	0	2	5	15	24	33
Geothermal	20	28	33	48	66	84
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power plants	**41**	**47**	**50**	**60**	**70**	**87**
Coal	34	36	38	45	53	66
Lignite	4	5	6	6	7	7
Gas	0	3	3	4	5	6
Oil	3	3	3	4	5	6
Biomass	0	0	0	0	1	2
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	7	9	10	11	12	13
Autoproducers	34	38	40	49	58	74
Total generation	**1,025**	**1,328**	**1,643**	**2,378**	**3,269**	**4,240**
Fossil	815	1,012	1,269	1,822	2,526	3,311
Coal	196	386	633	1,110	1,634	2,239
Lignite	98	108	116	124	132	140
Gas	406	456	462	544	720	897
Oil	87	34	30	16	11	7
Diesel	28	28	28	28	28	28
Nuclear	44	67	70	93	92	90
Hydrogen	0	0	0	0	0	0
Renewables	**166**	**249**	**304**	**463**	**651**	**839**
Hydro	136	194	227	300	368	435
Wind	1	5	12	43	103	162
of which wind offshore	0	0	1	5	9	13
PV	0	2	5	15	24	33
Biomass	9	19	28	57	91	125
Geothermal	20	28	33	48	66	84
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Distribution losses	82	105	129	173	226	293
Own consumption electricity	48	61	75	101	132	171
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**895**	**1,162**	**1,439**	**2,101**	**2,908**	**3,773**
Fluctuating RES (PV, Wind, Ocean)	1	7	17	58	126	195
Share of fluctuating RES	0.1%	0.6%	1.0%	2.4%	3.9%	4.6%
RES share (domestic generation)	**16%**	**19%**	**19%**	**19%**	**20%**	**20%**

table 12.124: non oecd asia: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**0**	**0**	**0**	**3**	**18**	**34**
Fossil fuels	0	0	0	3	18	34
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**35**	**40**	**52**	**66**	**71**	**75**
Fossil fuels	35	40	52	66	70	75
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
Direct heating[1)]	**10,361**	**12,031**	**13,483**	**15,746**	**18,157**	**19,854**
Fossil fuels	5,184	6,671	7,957	9,977	11,723	12,779
Biomass	5,173	5,328	5,489	5,691	6,295	6,876
Solar collectors	4	22	37	77	134	190
Geothermal[2)]	0	10	0	0	5	9
Total heat supply[1)]	**10,395**	**12,072**	**13,535**	**15,814**	**18,246**	**19,963**
Fossil fuels	5,219	6,711	8,009	10,046	11,812	12,887
Biomass	5,173	5,328	5,489	5,691	6,295	6,876
Solar collectors	4	22	37	77	134	190
Geothermal[2)]	0	10	0	0	5	9
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**49.8%**	**44.4%**	**40.8%**	**36.5%**	**35.3%**	**35.4%**

1) heat from electricity (direct) not included; 2) including heat pumps.

table 12.125: non oecd asia: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**542**	**697**	**906**	**1,323**	**1,812**	**2,135**
Coal	164	340	548	936	1,342	1,640
Lignite	95	100	102	104	108	114
Gas	194	212	214	252	334	358
Oil	67	24	21	9	5	1
Diesel	22	22	22	22	22	22
Combined heat & power production	**41**	**43**	**44**	**50**	**57**	**70**
Coal	34	35	35	40	46	57
Lignite	4	5	5	5	6	6
Gas	0	1	1	2	2	3
Oil	2	3	3	3	3	4
CO_2 emissions power generation (incl. CHP public)	**583**	**740**	**951**	**1,373**	**1,869**	**2,205**
Coal	198	374	583	976	1,388	1,697
Lignite	99	105	107	109	114	121
Gas	194	213	215	254	337	361
Oil & diesel	92	48	45	34	30	27
CO_2 emissions by sector	**1,514**	**1,903**	**2,300**	**2,978**	**3,691**	**4,201**
% of 1990 emissions	67%	85%	102%	133%	164%	187%
Industry[1)]	362	487	564	672	752	805
Other sectors[1)]	136	161	180	211	233	234
Transport	351	445	495	617	743	880
Power generation[2)]	549	706	916	1,333	1,822	2,146
District heating & other conversion	115	104	144	145	141	136
Population (Mill.)	1,046	1,128	1,194	1,307	1,392	1,445
CO_2 emissions per capita (t/capita)	**1.4**	**1.7**	**1.9**	**2.3**	**2.7**	**2.9**

1) including CHP autoproducers. 2) including CHP public

table 12.126: non oecd asia: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**246**	**313**	**374**	**520**	**701**	**899**
Coal	29	57	93	164	243	334
Lignite	17	17	17	18	19	20
Gas	98	112	121	143	188	235
Oil	32	21	18	10	5	1
Diesel	11	20	20	22	22	22
Nuclear	6	9	9	12	12	11
Biomass	3	5	6	11	16	22
Hydro	48	64	75	100	123	146
Wind	1	3	6	21	45	71
of which wind offshore	0	0	0	2	3	5
PV	0	2	4	11	17	24
Geothermal	3	4	5	7	10	13
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**9**	**10**	**11**	**13**	**15**	**19**
Coal	8	8	9	11	12	16
Lignite	1	1	1	1	1	1
Gas	0	0	1	1	1	1
Oil	1	1	1	1	1	1
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	1	1	2	2	2	2
Autoproducers	8	9	9	11	13	17
Total generation	**256**	**323**	**385**	**533**	**717**	**918**
Fossil	195	237	280	371	494	631
Coal	37	65	102	175	256	350
Lignite	17	18	18	19	20	22
Gas	98	112	121	144	189	236
Oil	32	22	19	10	6	2
Diesel	11	20	20	22	22	22
Nuclear	6	9	9	12	12	11
Hydrogen	0	0	0	0	0	0
Renewables	**55**	**78**	**96**	**150**	**211**	**275**
Hydro	48	64	75	100	123	146
Wind	1	3	6	21	45	71
of which wind offshore	0	0	0	2	3	5
PV	0	2	4	11	17	24
Biomass	3	5	6	11	17	23
Geothermal	3	4	5	7	10	13
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	1	5	10	32	62	94
Share of fluctuating RES	0%	1%	3%	6%	9%	10%
RES share (domestic generation)	**22%**	**24%**	**25%**	**28%**	**30%**	**30%**

table 12.127: non oecd asia: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**32,518**	**39,044**	**44,333**	**54,936**	**65,975**	**73,882**
Fossil	**23,050**	**28,452**	**33,214**	**42,302**	**52,035**	**58,591**
Hard coal	3,939	6,217	8,796	13,376	17,923	21,028
Lignite	1,719	1,936	2,095	2,311	2,395	2,418
Natural gas	6,757	8,403	9,495	11,826	15,005	16,561
Crude oil	10,634	11,897	12,827	14,789	16,713	18,585
Nuclear	**485**	**727**	**759**	**1,011**	**999**	**987**
Renewables	**8,983**	**9,865**	**10,360**	**11,622**	**12,942**	**14,304**
Hydro	490	700	818	1,081	1,324	1,567
Wind	3	19	42	155	369	583
Solar	5	29	55	131	220	309
Biomass	7,444	8,160	8,525	9,180	9,705	10,323
Geothermal/ambient heat	1,041	957	919	1,075	1,323	1,522
Ocean energy	0	0	0	0	0	0
RES share	**27.6%**	**25.2%**	**23.3%**	**21.1%**	**19.6%**	**19.4%**

table 12.128: non oecd asia: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**24,059**	**29,083**	**32,712**	**39,765**	**46,705**	**53,047**
Total (energy use)	**21,557**	**26,100**	**29,501**	**36,217**	**42,906**	**49,077**
Transport	**4,887**	**6,176**	**6,874**	**8,738**	**10,655**	**12,664**
Oil products	4,672	5,795	6,404	8,085	9,811	11,574
Natural gas	174	251	294	396	503	643
Biofuels	31	113	157	226	275	326
Electricity	9	16	20	31	66	121
RES electricity	2	3	4	6	13	24
Hydrogen	0	0	0	0	0	0
RES share Transport	**0.7%**	**1.9%**	**2.3%**	**2.7%**	**2.7%**	**2.8%**
Industry	**6,850**	**9,060**	**10,737**	**13,377**	**15,827**	**17,813**
Electricity	1,395	1,869	2,278	3,061	3,929	4,870
RES electricity	226	350	422	596	783	964
District heat	8	10	11	11	12	12
RES district heat	0	0	0	0	0	0
Coal	2,091	2,613	3,062	3,574	3,783	3,819
Oil products	1,133	1,289	1,347	1,377	1,410	1,438
Gas	1,387	2,173	2,835	3,946	4,981	5,659
Solar	0	0	0	0	0	0
Biomass and waste	835	1,106	1,204	1,408	1,712	2,015
Geothermal/ambient heat	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**15.5%**	**16.1%**	**15.1%**	**15.0%**	**15.8%**	**16.7%**
Other Sectors	**9,820**	**10,865**	**11,889**	**14,102**	**16,424**	**18,600**
Electricity	1,819	2,298	2,883	4,470	6,476	8,593
RES electricity	295	431	534	871	1,290	1,701
District heat	24	28	38	53	72	90
RES district heat	0	0	0	0	0	0
Coal	219	261	317	412	430	196
Oil products	1,253	1,385	1,466	1,524	1,442	1,355
Gas	430	570	728	1,070	1,535	2,001
Solar	4	22	37	77	134	190
Biomass and waste	6,070	6,294	6,419	6,496	6,332	6,168
Geothermal/ambient heat	0	7	0	0	3	7
RES share Other Sectors	**64.9%**	**62.2%**	**58.8%**	**52.8%**	**47.2%**	**43.4%**
Total RES	**7,463**	**8,327**	**8,777**	**9,681**	**10,542**	**11,395**
RES share	**34.6%**	**31.9%**	**29.8%**	**26.7%**	**24.6%**	**23.2%**
Non energy use	**2,503**	**2,983**	**3,211**	**3,548**	**3,799**	**3,970**
Oil	2,034	2,425	2,610	2,884	3,088	3,227
Gas	457	545	586	648	694	725
Coal	11	13	14	16	17	18

non oecd asia: energy [r]evolution scenario

table 12.129: non oecd asia: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**985**	**1,279**	**1,518**	**2,215**	**3,281**	**4,055**
Coal	162	306	300	232	91	0
Lignite	94	79	52	22	4	0
Gas	406	511	513	451	375	20
Oil	84	30	26	11	0	0
Diesel	28	28	26	13	5	1
Nuclear	44	45	40	30	12	0
Biomass	9	10	9	2	0	0
Hydro	136	175	208	240	263	286
Wind	1	54	173	473	910	1,275
of which wind offshore	0	0	2	20	51	97
PV	0	7	77	273	546	807
Geothermal	20	32	72	181	369	506
Solar thermal power plants	0	2	16	235	590	928
Ocean energy	0	0	7	52	117	232
Combined heat & power plants	**41**	**52**	**71**	**149**	**209**	**250**
Coal	34	35	34	33	12	5
Lignite	4	5	3	2	0	0
Gas	0	5	14	59	110	135
Oil	3	2	2	1	0	0
Biomass	0	5	11	33	52	63
Geothermal	0	1	6	21	34	47
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	7	9	10	11	12	15
Autoproducers	34	43	61	138	197	235
Total generation	**1,025**	**1,331**	**1,589**	**2,364**	**3,490**	**4,305**
Fossil	815	1,001	970	824	597	161
Coal	196	341	334	265	103	5
Lignite	98	83	55	24	4	0
Gas	406	515	527	510	485	155
Oil	87	32	28	13	0	0
Diesel	28	28	26	13	5	1
Nuclear	44	45	40	30	12	0
Hydrogen	0	0	0	0	0	0
Renewables	**166**	**285**	**579**	**1,511**	**2,881**	**4,144**
Hydro	136	175	208	240	263	286
Wind	1	54	173	473	910	1,275
of which wind offshore	0	0	2	20	51	97
PV	0	7	77	273	546	807
Biomass	9	15	20	36	52	63
Geothermal	20	33	78	202	403	553
Solar thermal	0	2	16	235	590	928
Ocean energy	0	0	7	52	117	232
Distribution losses	82	112	111	119	116	76
Own consumption electricity	48	74	91	146	215	302
Electricity for hydrogen production	0	0	9	77	412	719
Final energy consumption (electricity)	**895**	**1,145**	**1,377**	**2,019**	**2,746**	**3,205**
Fluctuating RES (PV, Wind, Ocean)	1	61	257	798	1,573	2,314
Share of fluctuating RES	0.1%	4.6%	16.2%	33.7%	45.1%	53.8%
RES share (domestic generation)	**16%**	**21%**	**36%**	**64%**	**83%**	**96%**
'Efficiency' savings (compared to Ref.)	**0**	**22**	**105**	**325**	**666**	**1,117**

table 12.130: non oecd asia: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**0**	**99**	**177**	**352**	**592**	**1,295**
Fossil fuels	0	21	14	12	3	0
Biomass	0	38	81	169	284	609
Solar collectors	0	20	39	81	148	337
Geothermal	0	21	42	90	157	350
Heat from CHP	**35**	**301**	**424**	**896**	**1,262**	**1,535**
Fossil fuels	35	252	275	434	526	595
Biomass	0	38	89	266	419	508
Geothermal	0	11	60	196	317	433
Hydrogen	0	0	0	0	0	0
Direct heating[1)]	**10,361**	**11,505**	**12,429**	**13,266**	**14,048**	**13,638**
Fossil fuels	5,184	6,128	6,549	6,028	4,400	1,719
Biomass	5,173	5,075	4,760	4,313	3,565	2,891
Solar collectors	4	220	695	1,897	3,591	4,702
Geothermal[2)]	0	82	424	1,028	2,255	4,002
Hydrogen	0	0	0	0	237	323
Total heat supply[1)]	**10,395**	**11,905**	**13,029**	**14,514**	**15,902**	**16,468**
Fossil fuels	5,219	6,400	6,839	6,474	4,929	2,314
Biomass	5,173	5,151	4,930	4,748	4,267	4,008
Solar collectors	4	240	734	1,978	3,739	5,038
Geothermal[1)]	0	114	526	1,314	2,729	4,784
Hydrogen	0	0	0	0	237	323
RES share (including RES electricity)	**49.8%**	**46%**	**48%**	**55%**	**69%**	**86%**
'Efficiency' savings (compared to Ref.)	**0**	**167**	**505**	**1,300**	**2,344**	**3,495**

1) heat from electricity (direct) not included; geothermal includes heat pumps

table 12.131: non oecd asia: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**542**	**608**	**570**	**432**	**252**	**9**
Coal	164	248	242	183	70	0
Lignite	95	76	48	19	3	0
Gas	194	238	239	211	175	8
Oil	67	23	20	9	0	0
Diesel	22	22	20	10	4	1
Combined heat & power production	**41**	**42**	**43**	**59**	**63**	**68**
Coal	34	34	32	29	11	4
Lignite	4	4	3	1	0	0
Gas	0	2	6	28	52	64
Oil	2	2	2	1	0	0
CO_2 emissions power generation (incl. CHP public)	**583**	**650**	**612**	**491**	**315**	**77**
Coal	198	282	274	212	81	4
Lignite	99	81	51	21	3	0
Gas	194	241	245	238	227	72
Oil & diesel	92	47	42	20	4	1
CO_2 emissions by sector	**1,514**	**1,693**	**1,708**	**1,377**	**836**	**278**
% of 1990 emissions	67%	75%	76%	61%	37%	12%
Industry[1)]	362	445	466	417	289	151
Other sectors[1)]	136	155	157	141	108	36
Transport	351	379	394	316	154	73
Power generation[2)]	549	615	576	436	255	11
District heating & other conversion	115	98	114	69	31	7
Population (Mill.)	1,046	1,128	1,194	1,307	1,392	1,445
CO_2 emissions per capita (t/capita)	**1.4**	**1.5**	**1.4**	**1.1**	**0.6**	**0.2**
'Efficiency' savings (compared to Ref.)	**0**	**210**	**591**	**1,600**	**2,855**	**3,923**

1) including CHP autoproducers. 2) including CHP public

table 12.132: non oecd asia: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**246**	**319**	**457**	**776**	**1,242**	**1,600**
Coal	29	50	47	36	14	0
Lignite	17	13	8	3	1	0
Gas	98	126	138	127	112	6
Oil	32	13	11	6	0	0
Diesel	11	12	11	7	3	1
Nuclear	6	6	5	4	2	0
Biomass	3	3	2	0	0	0
Hydro	48	58	69	80	88	96
Wind	1	30	90	210	372	478
of which wind offshore	0	0	1	9	14	25
PV	0	6	59	199	391	577
Geothermal	3	5	11	29	63	95
Solar thermal power plants	0	0	4	64	171	295
Ocean energy	0	0	2	12	27	53
Combined heat & power production	**9**	**11**	**15**	**33**	**52**	**63**
Coal	8	8	8	8	3	1
Lignite	1	1	0	0	0	0
Gas	0	1	2	13	30	37
Oil	1	0	0	0	0	0
Biomass	0	1	2	6	11	13
Geothermal	0	0	1	5	9	12
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	1	2	2	2	3	4
Autoproducers	8	10	13	30	49	59
Total generation	**256**	**331**	**472**	**809**	**1,294**	**1,663**
Fossil	195	223	227	200	162	45
Coal	37	58	55	44	17	1
Lignite	17	13	9	4	1	0
Gas	98	126	140	140	142	43
Oil	32	13	12	6	0	0
Diesel	11	12	11	7	3	1
Nuclear	6	6	5	4	2	0
Hydrogen	0	0	0	0	0	0
Renewables	**55**	**102**	**240**	**605**	**1,130**	**1,619**
Hydro	48	58	69	80	88	96
Wind	1	30	90	210	372	478
of which wind offshore	0	0	1	9	14	25
PV	0	6	59	199	391	577
Biomass	3	4	4	7	11	13
Geothermal	3	5	12	34	72	107
Solar thermal	0	0	4	64	171	295
Ocean energy	0	0	2	12	27	53
Fluctuating RES (PV, Wind, Ocean)	1	35	151	421	789	1,108
Share of fluctuating RES	0%	11%	32%	52%	61%	67%
RES share (domestic generation)	**22%**	**31%**	**51%**	**75%**	**87%**	**97%**

table 12.133: non oecd asia: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**32,518**	**36,356**	**39,633**	**43,696**	**46,926**	**47,038**
Fossil	**23,050**	**25,819**	**26,346**	**23,192**	**16,932**	**8,856**
Hard coal	3,939	5,210	5,290	4,313	2,556	1,754
Lignite	1,719	1,536	1,122	548	37	0
Natural gas	6,757	8,494	9,101	9,152	8,387	3,864
Crude oil	10,634	10,579	10,833	9,179	5,952	3,239
Nuclear	**485**	**491**	**436**	**327**	**131**	**0**
Renewables	**8,983**	**10,046**	**12,850**	**20,177**	**29,862**	**38,182**
Hydro	490	630	749	864	947	1,030
Wind	3	194	623	1,703	3,277	4,590
Solar	5	270	1,069	3,807	7,829	11,285
Biomass	7,444	7,726	7,732	7,988	6,985	6,248
Geothermal/ambient heat	1,041	1,225	2,652	5,627	10,403	14,194
Ocean energy	0	1	25	187	421	835
RES share	**27.6%**	**27.7%**	**32.4%**	**46.2%**	**63.6%**	**81.2%**
'Efficiency' savings (compared to Ref.)	**0**	**2,719**	**4,715**	**11,238**	**19,056**	**26,843**

table 12.134: non oecd asia: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**24,059**	**27,418**	**29,872**	**33,050**	**34,911**	**36,036**
Total (energy use)	**21,557**	**24,738**	**26,983**	**29,785**	**31,268**	**32,017**
Transport	**4,887**	**5,278**	**5,873**	**6,173**	**5,835**	**5,707**
Oil products	4,672	4,946	5,110	4,123	1,956	796
Natural gas	174	196	217	225	207	277
Biofuels	31	102	348	718	964	937
Electricity	9	34	176	909	1,881	2,096
RES electricity	2	7	64	580	1,553	2,018
Hydrogen	0	0	22	198	826	1,601
RES share Transport	**0.7%**	**2.1%**	**7.2%**	**23.1%**	**54.8%**	**78.8%**
Industry	**6,850**	**8,595**	**9,666**	**10,847**	**11,569**	**11,758**
Electricity	1,395	1,792	2,094	2,591	3,069	3,516
RES electricity	226	384	763	1,655	2,534	3,385
District heat	8	309	456	973	1,404	1,973
RES district heat	0	101	240	631	1,007	1,566
Coal	2,091	2,450	2,476	1,800	729	0
Oil products	1,133	1,249	1,322	880	497	115
Gas	1,387	1,772	2,049	2,555	2,371	1,440
Solar	0	92	209	678	1,377	1,860
Biomass and waste	835	878	879	847	780	674
Geothermal/ambient heat	0	53	180	523	1,086	1,839
Hydrogen	0	0	0	0	257	340
RES share Industry	**15.5%**	**17.5%**	**23.5%**	**40.0%**	**60.5%**	**82.1%**
Other Sectors	**9,820**	**10,865**	**11,444**	**12,765**	**13,865**	**14,552**
Electricity	1,819	2,298	2,687	3,768	4,937	5,924
RES electricity	295	493	979	2,407	4,075	5,704
District heat	24	82	131	234	403	783
RES district heat	0	47	102	215	390	771
Coal	219	218	213	150	48	0
Oil products	1,253	1,267	1,230	1,110	837	183
Gas	430	673	775	760	706	351
Solar	4	128	486	1,220	2,215	2,842
Biomass and waste	6,070	6,171	5,731	5,144	3,776	2,767
Geothermal/ambient heat	0	29	191	380	943	1,701
RES share Other Sectors	**64.9%**	**63.2%**	**65.4%**	**73.4%**	**82.2%**	**94.7%**
Total RES	**7,463**	**8,484**	**10,181**	**15,124**	**21,594**	**27,932**
RES share	**34.6%**	**34.3%**	**37.7%**	**50.8%**	**69.1%**	**87.2%**
Non energy use	**2,503**	**2,680**	**2,889**	**3,266**	**3,643**	**4,019**
Oil	2,034	2,170	2,282	2,547	2,477	2,090
Gas	457	482	520	425	364	322
Coal	11	27	87	294	801	1,608

non oecd asia: investment & employment

table 12.135: non oecd asia: total investment in power sector

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Conventional (fossil & nuclear)	**196,382**	**204,588**	**185,460**	**228,801**	**815,230**	**20,381**
Renewables	**167,201**	**192,000**	**211,598**	**258,529**	**829,328**	**20,733**
Biomass	13,544	17,109	24,186	28,344	83,183	2,080
Hydro	105,726	115,063	111,638	136,614	469,041	11,726
Wind	8,572	23,915	39,569	57,659	129,715	3,243
PV	8,176	10,256	11,385	14,099	43,916	1,098
Geothermal	31,183	25,656	24,820	21,813	103,472	2,587
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Energy [R]evolution						
Conventional (fossil & nuclear)	**107,256**	**46,124**	**38,865**	**32,072**	**224,317**	**5,608**
Renewables	**495,028**	**1,030,461**	**1,565,466**	**1,834,484**	**4,925,440**	**123,136**
Biomass	8,910	17,258	22,929	21,694	70,791	1,770
Hydro	84,366	65,821	55,696	79,028	284,910	7,123
Wind	131,005	171,115	332,084	318,849	953,053	23,826
PV	116,950	204,167	284,932	342,188	948,236	23,706
Geothermal	113,705	183,902	250,600	281,908	830,115	20,753
Solar thermal power plants	33,952	360,102	588,400	732,288	1,714,743	42,869
Ocean energy	6,139	28,098	30,827	58,529	123,593	3,090

table 12.136: non oecd asia: total investment in renewable heating only

(EXCLUDING INVESTMENTS IN FOSSIL FUELS)

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Renewables	**168,299**	**139,237**	**40,893**	**31,275**	**379,704**	**9,493**
Biomass	163,851	136,660	34,037	25,844	360,392	9,010
Geothermal	0	0	0	0	0	0
Solar	1,338	1,901	3,616	4,063	10,918	273
Heat pumps	3,110	677	3,240	1,368	8,394	210
Energy [R]evolution scenario						
Renewables	**332,081**	**327,405**	**817,621**	**981,798**	**2,458,905**	**61,473**
Biomass	75,681	5,721	12,101	23,854	117,357	2,934
Geothermal	107,240	86,766	361,002	382,479	937,486	23,437
Solar	86,103	153,647	284,996	273,206	797,952	19,949
Heat pumps	63,057	81,271	159,523	302,259	606,110	15,153

table 12.137: non oecd asia: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	230	206	196	141	492	555	385
Manufacturing	82	83	80	65	184	227	203
Operations and maintenance	125	125	132	129	125	156	173
Fuel supply (domestic)	1,339	1,184	1,156	1,006	1,117	978	668
Coal and gas export	83.8	115.9	149.6	114.7	63.5	8.5	2.0
Total jobs	**1,860**	**1,714**	**1,713**	**1,455**	**1,982**	**1,925**	**1,431**
By technology							
Coal	404	514	582	615	238	173	113
Gas, oil & diesel	537	466	451	386	479	431	295
Nuclear	19	13	15	5.9	4.8	4.2	3.4
Total renewables	**900**	**721**	**664**	**448**	**1,260**	**1,317**	**1,019**
Biomass	*753*	*600*	*535*	*346*	*550*	*457*	*310*
Hydro	*101*	*84*	*87*	*74*	*80*	*54*	*47*
Wind	*5.3*	*8.0*	*17*	*16*	*128*	*124*	*159*
PV	*11*	*11*	*13*	*5.7*	*262*	*276*	*164*
Geothermal power	*7.8*	*4.5*	*3.9*	*2.6*	*27*	*33*	*22*
Solar thermal power	-	-	-	-	*15*	*48*	*106*
Ocean	*0.1*	*0.0*	*0.0*	-	*5.3*	*11*	*6.8*
Solar - heat	*19*	*12*	*8.7*	*4.6*	*171*	*247*	*171*
Geothermal & heat pump	*2.8*	*2.1*	-	*0.0*	*22*	*66*	*32*
Total jobs	**1,860**	**1,714**	**1,713**	**1,455**	**1,982**	**1,925**	**1,431**

china: scenario results data

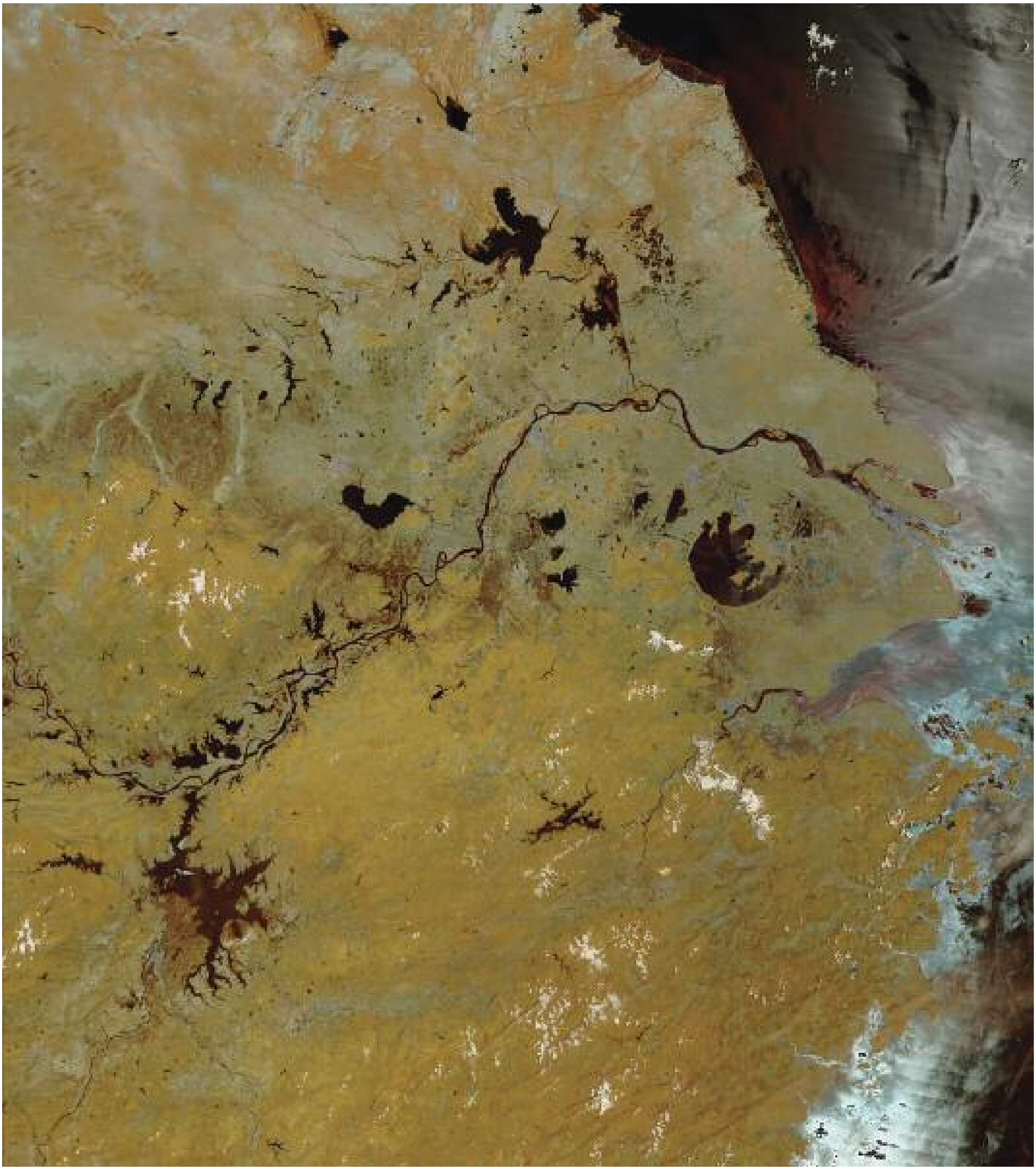

image YANGTZE RIVER, CENTRAL CHINA.

china: reference scenario

table 12.138: china: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**3,640**	**5,624**	**7,275**	**9,607**	**11,538**	**12,569**
Coal	2,826	4,111	4,984	6,483	7,702	8,020
Lignite	0	0	0	0	0	0
Gas	82	172	239	425	689	962
Oil	17	16	16	13	10	8
Diesel	0	0	0	0	0	0
Nuclear	70	149	520	723	820	918
Biomass	2	53	92	167	238	301
Hydro	616	868	1,079	1,249	1,355	1,461
Wind	27	235	318	492	629	765
of which wind offshore	0	2	15	75	130	170
PV	0	17	25	49	84	119
Geothermal	0	1	2	3	6	8
Solar thermal power plants	0	0	1	2	3	4
Ocean energy	0	0	0	1	2	4
Combined heat & power plants	**95**	**178**	**266**	**425**	**583**	**740**
Coal	95	156	214	292	361	430
Lignite	0	0	0	0	0	0
Gas	0	22	48	116	179	232
Oil	0	0	0	0	0	0
Biomass	0	1	4	16	40	73
Geothermal	0	0	1	2	3	4
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	30	56	117	179	241
Autoproducers	95	148	210	308	404	499
Total generation	**3,735**	**5,802**	**7,541**	**10,032**	**12,121**	**13,309**
Fossil	3,020	4,477	5,501	7,328	8,941	9,651
Coal	2,921	4,267	5,198	6,775	8,063	8,450
Lignite	0	0	0	0	0	0
Gas	82	194	286	541	867	1,194
Oil	17	16	16	13	10	8
Diesel	0	0	0	0	0	0
Nuclear	70	149	520	723	820	918
Hydrogen	0	0	0	0	0	0
Renewables	**645**	**1,176**	**1,521**	**1,981**	**2,360**	**2,740**
Hydro	616	868	1,079	1,249	1,355	1,461
Wind	27	235	318	492	629	765
of which wind offshore	0	2	15	75	130	170
PV	0	17	25	49	84	119
Biomass	2	53	95	183	279	374
Geothermal	0	1	2	5	9	12
Solar thermal	0	0	1	2	3	4
Ocean energy	0	0	0	1	2	4
Distribution losses	186	253	308	388	455	498
Own consumption electricity	439	595	726	914	1,072	1,174
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**3,106**	**4,950**	**6,502**	**8,720**	**10,578**	**11,612**
Fluctuating RES (PV, Wind, Ocean)	27	253	343	542	715	888
Share of fluctuating RES	0.7%	4.4%	4.5%	5.4%	5.9%	6.7%
RES share (domestic generation)	**17%**	**20%**	**20%**	**20%**	**19%**	**21%**

table 12.139: china: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**2,599**	**2,758**	**2,918**	**2,510**	**2,092**	**1,540**
Fossil fuels	2,587	2,675	2,763	2,259	1,862	1,355
Biomass	12	83	156	251	230	185
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**68**	**619**	**1,062**	**1,508**	**1,731**	**2,155**
Fossil fuels	68	617	1,042	1,438	1,589	1,897
Biomass	0	2	16	57	120	217
Geothermal	0	0	4	12	21	40
Hydrogen	0	0	0	0	0	0
Direct heating[1]	**28,734**	**34,541**	**36,404**	**36,388**	**35,536**	**34,529**
Fossil fuels	21,507	27,436	29,649	30,889	30,950	30,196
Biomass	6,822	6,532	6,075	4,645	3,565	3,195
Solar collectors	301	440	504	630	755	842
Geothermal[2]	104	132	177	224	267	295
Total heat supply[1]	**31,401**	**37,918**	**40,384**	**40,406**	**39,359**	**38,224**
Fossil fuels	24,162	30,728	33,454	34,586	34,401	33,449
Biomass	6,833	6,617	6,246	4,953	3,916	3,597
Solar collectors	301	440	504	631	755	842
Geothermal[2]	104	132	181	237	288	336
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**23.1%**	**19.0%**	**17.2%**	**14.4%**	**12.6%**	**12.5%**

1) heat from electricity (direct) not included; 2) including heat pumps.

table 12.140: china: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**3,214**	**4,398**	**5,082**	**6,352**	**6,999**	**6,700**
Coal	3,156	4,297	4,945	6,139	6,690	6,318
Lignite	0	0	0	0	0	0
Gas	35	79	115	196	296	373
Oil	23	22	22	17	13	9
Diesel	0	0	0	0	0	0
Combined heat & power production	**116**	**212**	**265**	**318**	**349**	**375**
Coal	116	189	225	247	264	283
Lignite	0	0	0	0	0	0
Gas	0	22	40	70	85	92
Oil	0	0	0	0	0	0
CO_2 emissions power generation (incl. CHP public)	**3,329**	**4,610**	**5,347**	**6,670**	**7,348**	**7,075**
Coal	3,271	4,486	5,170	6,386	6,954	6,601
Lignite	0	0	0	0	0	0
Gas	35	101	155	266	382	465
Oil & diesel	23	22	22	17	13	9
CO_2 emissions by sector	**6,875**	**9,067**	**10,287**	**12,007**	**12,772**	**12,492**
% of 1990 emissions	306%	404%	458%	535%	569%	557%
Industry[1]	1,794	2,399	2,602	2,571	2,474	2,347
Other sectors[1]	547	638	650	649	595	527
Transport	478	806	976	1379	1652	1935
Power generation[2]	3,214	4,432	5,135	6,439	7,110	6,830
District heating & other conversion	842	792	925	970	942	852
Population (Mill.)	1,342	1,377	1,407	1,452	1,474	1,468
CO_2 emissions per capita (t/capita)	**5.1**	**6.6**	**7.3**	**8.3**	**8.7**	**8.5**

1) including CHP autoproducers. 2) including CHP public

table 12.141: china: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**899**	**1,387**	**1,707**	**2,195**	**2,573**	**2,779**
Coal	629	877	1,028	1,305	1,507	1,542
Lignite	0	0	0	0	0	0
Gas	33	65	86	129	191	253
Oil	15	15	15	13	11	8
Diesel	0	0	0	0	0	0
Nuclear	11	21	68	94	107	120
Biomass	1	13	17	30	41	50
Hydro	197	266	320	370	402	433
Wind	13	115	150	222	266	305
of which wind offshore	0	1	5	23	37	46
PV	0	15	22	30	45	62
Geothermal	0	0	0	1	1	1
Solar thermal power plants	0	0	1	2	2	3
Ocean energy	0	0	0	0	1	1
Combined heat & power production	**21**	**41**	**59**	**95**	**127**	**159**
Coal	21	33	44	59	71	85
Lignite	0	0	0	0	0	0
Gas	0	7	14	33	48	61
Oil	0	0	0	0	0	0
Biomass	0	0	1	3	7	13
Geothermal	0	0	0	0	0	1
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	7	13	26	39	54
Autoproducers	21	34	46	68	88	105
Total generation	**920**	**1,428**	**1,766**	**2,290**	**2,700**	**2,938**
Fossil	698	997	1,187	1,538	1,829	1,949
Coal	650	910	1,072	1,364	1,578	1,627
Lignite	0	0	0	0	0	0
Gas	33	72	100	162	239	314
Oil	15	15	15	13	11	8
Diesel	0	0	0	0	0	0
Nuclear	11	21	68	94	107	120
Hydrogen	0	0	0	0	0	0
Renewables	**212**	**410**	**511**	**657**	**765**	**869**
Hydro	197	266	320	370	402	433
Wind	13	115	150	222	266	305
of which wind offshore	0	1	5	23	37	46
PV	0	15	22	30	45	62
Biomass	1	13	18	32	48	63
Geothermal	0	0	0	1	1	2
Solar thermal	0	0	1	2	2	3
Ocean energy	0	0	0	0	1	1
Fluctuating RES (PV, Wind, Ocean)	14	130	172	252	311	368
Share of fluctuating RES	1%	9%	10%	11%	12%	13%
RES share (domestic generation)	**23%**	**29%**	**29%**	**29%**	**28%**	**30%**

table 12.142: china: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**96,013**	**126,467**	**145,111**	**169,614**	**181,344**	**181,526**
Fossil	**83,978**	**111,505**	**124,862**	**145,811**	**155,636**	**153,724**
Hard coal	65,408	83,765	92,105	102,062	104,219	96,223
Lignite	0	0	0	0	0	0
Natural gas	2,783	5,710	7,469	12,585	17,063	20,135
Crude oil	15,787	22,030	25,287	31,165	34,355	37,366
Nuclear	**765**	**1,626**	**5,671**	**7,885**	**8,951**	**10,017**
Renewables	**11,270**	**13,336**	**14,578**	**15,918**	**16,757**	**17,784**
Hydro	2,217	3,127	3,885	4,498	4,879	5,259
Wind	97	848	1,144	1,771	2,263	2,756
Solar	302	503	603	827	1,065	1,305
Biomass	8,579	8,716	8,735	8,492	8,093	7,950
Geothermal/ambient heat	76	142	212	328	428	499
Ocean energy	0	0	0	2	9	16
RES share	**11.7%**	**10.5%**	**10.0%**	**9.4%**	**9.2%**	**9.8%**

table 12.143: china: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**60,369**	**80,155**	**90,807**	**104,025**	**112,796**	**118,593**
Total (energy use)	**55,503**	**74,149**	**84,365**	**97,171**	**105,790**	**111,665**
Transport	**6,816**	**11,542**	**14,042**	**20,101**	**24,313**	**28,532**
Oil products	6,631	11,188	13,546	19,089	22,785	26,653
Natural gas	16	20	23	101	220	306
Biofuels	52	115	168	381	555	652
Electricity	117	219	304	530	752	922
RES electricity	20	44	61	105	146	190
Hydrogen	0	0	0	0	0	1
RES share Transport	**1.1%**	**1.4%**	**1.6%**	**2.4%**	**2.9%**	**2.9%**
Industry	**28,565**	**39,314**	**45,036**	**49,785**	**52,905**	**53,900**
Electricity	7,341	11,789	15,251	20,004	23,904	26,041
RES electricity	1,268	2,389	3,075	3,950	4,655	5,360
District heat	1,497	1,990	2,401	2,379	2,245	2,111
RES district heat	3	49	102	181	207	236
Coal	13,932	19,545	21,244	20,211	18,660	16,832
Oil products	2,069	2,325	2,528	2,457	2,330	2,118
Gas	3,723	3,660	3,608	4,728	5,758	6,788
Solar	0	1	1	2	2	3
Biomass and waste	0	0	0	0	0	0
Geothermal/ambient heat	3	3	4	5	5	6
Hydrogen	0	0	0	0	0	0
RES share Industry	**4.5%**	**6.2%**	**7.1%**	**8.3%**	**9.2%**	**10.4%**
Other Sectors	**20,123**	**23,293**	**25,287**	**27,285**	**28,572**	**29,233**
Electricity	3,724	5,813	7,851	10,860	13,424	14,841
RES electricity	643	1,178	1,583	2,144	2,614	3,055
District heat	791	905	1,012	1,065	1,027	1,055
RES district heat	2	27	52	98	100	108
Coal	3,117	3,103	2,753	2,053	1,026	112
Oil products	2,478	2,712	2,872	2,626	2,232	1,838
Gas	1,224	2,548	3,113	4,557	5,823	6,660
Solar	301	440	503	629	753	839
Biomass and waste	8,422	7,685	7,064	5,339	4,098	3,673
Geothermal/ambient heat	68	88	120	156	190	215
RES share Other Sectors	**46.9%**	**40.4%**	**36.9%**	**30.7%**	**27.1%**	**27.0%**
Total RES	**10,782**	**12,019**	**12,733**	**12,989**	**13,325**	**14,336**
RES share	**19.4%**	**16.2%**	**15.1%**	**13.4%**	**12.6%**	**12.8%**
Non energy use	**4,867**	**6,006**	**6,441**	**6,854**	**7,006**	**6,928**
Oil	3,183	3,928	4,213	4,483	4,582	4,531
Gas	362	446	479	510	521	515
Coal	1,322	1,631	1,750	1,862	1,903	1,882

china: energy [r]evolution scenario

table 12.144: china: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**3,640**	**5,322**	**6,357**	**7,627**	**8,746**	**9,240**
Coal	2,826	3,881	4,212	3,850	2,441	28
Lignite	0	0	0	0	0	0
Gas	82	138	199	192	85	52
Oil	17	10	5	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	70	149	250	200	146	0
Biomass	2	39	44	55	34	31
Hydro	616	812	990	1,150	1,340	1,460
Wind	27	265	498	1,200	2,148	3,134
of which wind offshore	0	2	35	190	357	519
PV	0	25	95	365	1,014	1,525
Geothermal	0	2	8	97	313	512
Solar thermal power plants	0	1	55	482	1,115	1,858
Ocean energy	0	0	2	35	110	640
Combined heat & power plants	**95**	**219**	**429**	**955**	**1,467**	**1,772**
Coal	95	137	190	302	265	52
Lignite	0	0	0	0	0	0
Gas	0	47	113	384	636	721
Oil	0	0	0	0	0	0
Biomass	0	34	123	234	432	611
Geothermal	0	0	2	36	115	310
Hydrogen	0	0	0	0	19	78
CHP by producer						
Main activity producers	0	34	164	505	834	993
Autoproducers	95	185	265	450	633	779
Total generation	**3,735**	**5,541**	**6,786**	**8,582**	**10,213**	**11,012**
Fossil	3,020	4,213	4,719	4,728	3,427	853
Coal	2,921	4,018	4,402	4,152	2,706	80
Lignite	0	0	0	0	0	0
Gas	82	185	312	576	721	773
Oil	17	10	5	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	70	149	250	200	146	0
Hydrogen	0	0	0	0	19	78
Renewables	**645**	**1,179**	**1,817**	**3,654**	**6,621**	**10,081**
Hydro	616	812	990	1,150	1,340	1,460
Wind	27	265	498	1,200	2,148	3,134
of which wind offshore	0	2	35	190	357	519
PV	0	25	95	365	1,014	1,525
Biomass	2	73	167	290	466	642
Geothermal	0	2	10	133	428	822
Solar thermal	0	1	55	482	1,115	1,858
Ocean energy	0	0	2	35	110	640
Distribution losses	186	213	221	252	208	203
Own consumption electricity	439	497	515	468	312	187
Electricity for hydrogen production	0	0	6	55	241	556
Final energy consumption (electricity)	**3,106**	**4,827**	**6,038**	**7,797**	**9,436**	**10,041**
Fluctuating RES (PV, Wind, Ocean)	27	290	595	1,600	3,272	5,299
Share of fluctuating RES	0.7%	5.2%	8.8%	18.6%	32.0%	48.1%
RES share (domestic generation)	**17%**	**21%**	**27%**	**43%**	**65%**	**92%**
'Efficiency' savings (compared to Ref.)	**0**	**118**	**464**	**1,292**	**2,324**	**3,323**

table 12.145: china: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**2,599**	**3,321**	**3,566**	**2,925**	**2,646**	**4,120**
Fossil fuels	2,587	3,161	3,103	2,223	944	0
Biomass	12	133	214	234	291	536
Solar collectors	0	23	214	322	794	1,524
Geothermal	0	3	36	146	617	2,060
Heat from CHP	**68**	**775**	**1,653**	**3,962**	**5,534**	**6,049**
Fossil fuels	68	645	1,166	2,816	3,314	2,379
Biomass	0	130	477	991	1,611	1,880
Geothermal	0	0	11	155	538	1,551
Hydrogen	0	0	0	0	70	240
Direct heating[1]	**28,734**	**33,051**	**33,087**	**29,217**	**25,639**	**20,852**
Fossil fuels	21,507	24,705	24,049	18,560	8,137	2,050
Biomass	6,822	7,497	7,363	6,742	6,734	5,533
Solar collectors	301	605	985	1,961	5,766	6,152
Geothermal[2]	104	244	690	1,955	4,970	6,814
Hydrogen	0	0	0	0	32	303
Total heat supply[1]	**31,401**	**37,147**	**38,307**	**36,104**	**33,819**	**31,021**
Fossil fuels	24,162	28,512	28,317	23,598	12,395	4,429
Biomass	6,833	7,759	8,054	7,967	8,637	7,949
Solar collectors	301	628	1,199	2,283	6,560	7,676
Geothermal[1]	104	248	737	2,256	6,125	10,424
Hydrogen	0	0	0	0	102	543
RES share (including RES electricity)	**23.1%**	**23%**	**26%**	**35%**	**63%**	**86%**
'Efficiency' savings (compared to Ref.)	**0**	**771**	**2,078**	**4,303**	**5,540**	**7,203**

1) heat from electricity (direct) not included; geothermal includes heat pumps

table 12.146: china: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**3,214**	**4,015**	**4,230**	**3,730**	**2,157**	**42**
Coal	3,156	3,942	4,137	3,647	2,121	22
Lignite	0	0	0	0	0	0
Gas	35	59	85	83	36	20
Oil	23	14	7	0	0	0
Diesel	0	0	0	0	0	0
Combined heat & power production	**116**	**218**	**291**	**467**	**483**	**316**
Coal	116	167	200	255	193	34
Lignite	0	0	0	0	0	0
Gas	0	51	92	212	290	282
Oil	0	0	0	0	0	0
CO_2 emissions power generation (incl. CHP public)	**3,329**	**4,233**	**4,521**	**4,197**	**2,640**	**358**
Coal	3,271	4,109	4,337	3,903	2,314	56
Lignite	0	0	0	0	0	0
Gas	35	110	177	294	326	302
Oil & diesel	23	14	7	0	0	0
CO_2 emissions by sector	**6,875**	**8,300**	**8,584**	**7,531**	**4,122**	**860**
% of 1990 emissions	306%	370%	383%	336%	184%	38%
Industry[1]	1,794	2,182	2,216	1,857	780	252
Other sectors[1]	547	570	484	365	169	50
Transport	478	684	805	810	446	273
Power generation[2]	3,214	4,042	4,314	3,946	2,412	225
District heating & other conversion	842	822	765	553	316	61
Population (Mill.)	1,342	1,377	1,407	1,452	1,474	1,468
CO_2 emissions per capita (t/capita)	**5.1**	**6.0**	**6.1**	**5.2**	**2.8**	**0.6**
'Efficiency' savings (compared to Ref.)	**0**	**767**	**1,703**	**4,476**	**8,650**	**11,631**

1) including CHP autoproducers. 2) including CHP public

table 12.147: china: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**899**	**1,267**	**1,588**	**2,088**	**2,616**	**2,949**
Coal	629	776	823	755	498	9
Lignite	0	0	0	0	0	0
Gas	33	50	66	56	27	21
Oil	15	9	5	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	11	21	33	26	19	0
Biomass	1	10	8	10	6	5
Hydro	197	249	294	341	397	433
Wind	13	130	234	517	845	1,139
of which wind offshore	0	1	11	57	99	133
PV	0	22	83	221	542	803
Geothermal	0	0	1	16	51	83
Solar thermal power plants	0	1	42	138	203	295
Ocean energy	0	0	1	9	28	161
Combined heat & power production	**21**	**53**	**98**	**220**	**323**	**378**
Coal	21	29	39	61	55	17
Lignite	0	0	0	0	0	0
Gas	0	16	35	112	171	188
Oil	0	0	0	0	0	0
Biomass	0	8	23	42	75	107
Geothermal	0	0	0	6	19	50
Hydrogen	0	0	0	0	4	15
CHP by producer						
Main activity producers	0	8	39	120	183	216
Autoproducers	21	45	59	100	140	162
Total generation	**920**	**1,320**	**1,686**	**2,308**	**2,939**	**3,327**
Fossil	698	880	968	984	750	236
Coal	650	805	862	816	553	27
Lignite	0	0	0	0	0	0
Gas	33	65	102	168	198	209
Oil	15	9	5	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	11	21	33	26	19	0
Hydrogen	0	0	0	0	4	15
Renewables	**212**	**420**	**685**	**1,298**	**2,166**	**3,076**
Hydro	197	249	294	341	397	433
Wind	13	130	234	517	845	1,139
of which wind offshore	0	1	11	57	99	133
PV	0	22	83	221	542	803
Biomass	1	18	31	51	81	112
Geothermal	0	0	2	22	69	133
Solar thermal	0	1	42	138	203	295
Ocean energy	0	0	1	9	28	161
Fluctuating RES (PV, Wind, Ocean)	14	152	317	746	1,416	2,103
Share of fluctuating RES	1%	11%	19%	32%	48%	63%
RES share (domestic generation)	**23%**	**32%**	**41%**	**56%**	**74%**	**92%**

table 12.148: china: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**96,013**	**120,947**	**129,656**	**130,468**	**119,242**	**104,689**
Fossil	**83,978**	**103,899**	**106,212**	**93,385**	**55,978**	**19,203**
Hard coal	65,408	78,814	78,801	66,165	35,472	4,334
Lignite	0	0	0	0	0	0
Natural gas	2,783	6,100	8,137	10,004	9,817	7,586
Crude oil	15,787	18,985	19,274	17,216	10,688	7,283
Nuclear	**765**	**1,626**	**2,728**	**2,182**	**1,593**	**0**
Renewables	**11,270**	**15,423**	**20,716**	**34,901**	**61,671**	**85,486**
Hydro	2,217	2,924	3,565	4,141	4,825	5,257
Wind	97	956	1,793	4,321	7,734	11,284
Solar	302	727	2,036	7,935	20,245	29,888
Biomass	8,579	10,559	12,422	12,959	14,161	13,263
Geothermal/ambient heat	76	257	894	5,421	14,310	23,490
Ocean energy	0	0	7	126	396	2,304
RES share	**11.7%**	**12.7%**	**16.0%**	**26.7%**	**51.7%**	**81.6%**
'Efficiency' savings (compared to Ref.)	**0**	**5,543**	**15,465**	**39,133**	**62,054**	**76,747**

table 12.149: china: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**60,369**	**76,704**	**83,760**	**86,733**	**83,451**	**78,440**
Total (energy use)	**55,503**	**70,798**	**77,498**	**80,169**	**76,845**	**72,433**
Transport	**6,816**	**9,866**	**12,001**	**14,062**	**12,763**	**12,612**
Oil products	6,631	9,494	11,171	11,210	6,156	3,725
Natural gas	16	19	22	50	76	84
Biofuels	52	154	488	805	1,106	1,028
Electricity	117	198	306	1,856	4,908	6,886
RES electricity	20	42	82	790	3,182	6,304
Hydrogen	0	0	15	141	517	890
RES share Transport	**1.1%**	**2.0%**	**4.8%**	**11.8%**	**36.2%**	**64.6%**
Industry	**28,565**	**37,641**	**41,278**	**41,768**	**40,534**	**37,557**
Electricity	7,341	11,366	14,166	17,215	19,005	19,064
RES electricity	1,268	967	1,328	3,665	9,610	16,929
District heat	1,497	2,559	3,265	4,526	5,290	6,056
RES district heat	3	180	588	1,214	2,546	4,686
Coal	13,932	17,032	17,072	12,725	3,849	496
Oil products	2,069	1,837	1,376	533	371	312
Gas	3,723	4,484	4,547	4,356	3,458	1,338
Solar	0	84	175	602	3,423	3,706
Biomass and waste	0	264	547	979	1,947	2,180
Geothermal/ambient heat	3	15	129	832	3,157	4,086
Hydrogen	0	0	0	0	34	319
RES share Industry	**4.5%**	**4.0%**	**6.7%**	**17.5%**	**51.1%**	**84.9%**
Other Sectors	**20,123**	**23,291**	**24,219**	**24,339**	**23,548**	**22,263**
Electricity	3,724	5,813	7,266	8,998	9,958	9,857
RES electricity	643	2,688	4,411	7,497	9,166	9,547
District heat	791	1,059	1,390	1,910	2,492	3,736
RES district heat	2	58	232	517	1,283	3,020
Coal	3,117	3,096	3,108	2,446	841	0
Oil products	2,478	2,557	1,659	825	255	75
Gas	1,224	1,522	1,574	1,293	781	347
Solar	301	520	810	1,359	2,343	2,446
Biomass and waste	8,422	8,571	8,053	6,826	5,883	4,230
Geothermal/ambient heat	68	153	359	681	995	1,572
RES share Other Sectors	**46.9%**	**51.5%**	**57.2%**	**69.4%**	**83.5%**	**93.5%**
Total RES	**10,782**	**13,698**	**17,204**	**25,827**	**44,999**	**60,842**
RES share	**19.4%**	**19.3%**	**22.2%**	**32.2%**	**58.6%**	**84.0%**
Non energy use	**4,867**	**5,906**	**6,261**	**6,564**	**6,606**	**6,008**
Oil	3,183	3,627	3,707	3,571	3,396	2,908
Gas	362	439	465	488	491	447
Coal	1,322	1,840	2,089	2,505	2,719	2,653

china: investment & employment

table 12.150: china: total investment in power sector

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Conventional (fossil & nuclear)	**936,064**	**764,754**	**667,921**	**686,936**	**3,055,675**	**76,392**
Renewables	**746,995**	**504,812**	**566,273**	**784,066**	**2,602,146**	**65,054**
Biomass	44,370	52,976	83,543	83,985	264,873	6,622
Hydro	450,918	257,219	195,611	479,671	1,383,419	34,585
Wind	195,604	171,360	236,057	177,718	780,739	19,518
PV	46,136	14,596	39,992	26,693	127,417	3,185
Geothermal	4,299	3,660	5,908	5,475	19,342	484
Solar thermal power plants	5,618	4,648	4,153	9,545	23,964	599
Ocean energy	51	353	1,009	979	2,392	60
Energy [R]evolution						
Conventional (fossil & nuclear)	**515,540**	**230,401**	**112,714**	**105,623**	**964,278**	**24,107**
Renewables	**1,320,520**	**1,802,607**	**2,434,956**	**3,567,412**	**9,125,495**	**228,137**
Biomass	127,539	87,463	215,787	169,254	600,044	15,001
Hydro	361,317	246,561	288,897	495,708	1,392,482	34,812
Wind	332,908	501,949	760,645	857,503	2,453,004	61,325
PV	167,825	191,641	456,537	417,365	1,233,367	30,834
Geothermal	18,240	159,943	311,016	438,486	927,685	23,192
Solar thermal power plants	310,760	592,427	362,697	942,105	2,207,990	55,200
Ocean energy	1,932	22,623	39,376	246,991	310,922	7,773

table 12.151: china: total investment in renewable heating only

(EXCLUDING INVESTMENTS IN FOSSIL FUELS)

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Renewables	**64,831**	**62,628**	**45,316**	**33,209**	**205,984**	**5,150**
Biomass	11,127	9,928	0	0	21,055	526
Geothermal	0	18	0	0	18	0
Solar	13,561	16,438	12,389	10,483	52,870	1,322
Heat pumps	40,143	36,244	32,927	22,726	132,041	3,301
Energy [R]evolution scenario						
Renewables	**506,783**	**528,398**	**2,093,553**	**1,821,295**	**4,950,028**	**123,751**
Biomass	169,083	28,652	99,461	45,720	342,916	8,573
Geothermal	30,726	84,624	592,960	911,988	1,620,298	40,507
Solar	115,415	168,188	935,744	312,668	1,532,015	38,300
Heat pumps	191,558	246,934	465,388	550,919	1,454,798	36,370

table 12.152: china: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	1,725	868	571	339	883	514	499
Manufacturing	930	394	280	159	702	444	390
Operations and maintenance	478	504	539	429	495	554	459
Fuel supply (domestic)	5,318	3,730	2,842	1,836	3,957	3,229	1,888
Coal and gas export	-	-	-	-	-	-	-
Total jobs	**8,451**	**5,496**	**4,233**	**2,762**	**6,038**	**4,741**	**3,235**
By technology							
Coal	5,969	3,972	3,010	1,894	3,618	2,725	1,428
Gas, oil & diesel	223	223	213	302	250	263	262
Nuclear	231	185	101	53	40	18	9
Total renewables	**2,028**	**1,116**	**908**	**512**	**2,130**	**1,735**	**1,536**
Biomass	*802*	*563*	*486*	*275*	*733*	*662*	*454*
Hydro	*381*	*306*	*224*	*151*	*270*	*197*	*168*
Wind	*427*	*161*	*138*	*56*	*438*	*338*	*314*
PV	*137*	*44*	*23*	*11*	*370*	*104*	*195*
Geothermal power	*1.9*	*1.0*	*0.7*	*0.5*	*8*	*16*	*22*
Solar thermal power	*1.3*	*3.7*	*2.1*	*0.8*	*162*	*162*	*83*
Ocean	*0.04*	*0.03*	*0.11*	*0.16*	*2.1*	*7.2*	*6.2*
Solar - heat	*258*	*33*	*29*	*16*	*121*	*179*	*220*
Geothermal & heat pump	*18.6*	*3.0*	*7.2*	*2.4*	*26*	*71*	*75*
Total jobs	**8,451**	**5,496**	**4,233**	**2,762**	**6,038**	**4,741**	**3,235**

oecd asia oceania: scenario results data

image ON THE NORTHERN TIP OF NEW ZEALAND'S SOUTH ISLAND, FAREWELL SPIT STRETCHES 30 KILOMETERS EASTWARD INTO THE TASMAN SEA FROM THE CAPE FAREWELL MAINLAND. AN INTRICATE WETLAND ECOSYSTEM FACES SOUTH TOWARD GOLDEN BAY. ON THE SOUTHERN SIDE, THE SPIT IS PROTECTED BY SEVERAL KILOMETERS OF MUDFLATS, WHICH ARE ALTERNATELY EXPOSED AND INUNDATED WITH THE TIDAL RHYTHMS OF THE OCEAN. THE WETLANDS OF FAREWELL SPIT ARE ON THE RAMSAR LIST OF WETLANDS OF INTERNATIONAL SIGNIFICANCE.

oecd asia oceania: reference scenario

table 12.153: oecd asia oceania: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**1,801**	**1,976**	**2,092**	**2,239**	**2,310**	**2,313**
Coal	537	597	619	685	668	650
Lignite	137	145	150	85	55	40
Gas	429	473	506	476	524	579
Oil	106	71	43	33	33	28
Diesel	6	5	5	5	4	3
Nuclear	428	483	528	650	650	590
Biomass	24	29	33	43	51	57
Hydro	114	128	140	144	148	155
Wind	9	24	36	66	95	110
of which wind offshore	0	2	4	10	25	35
PV	4	9	12	23	30	35
Geothermal	8	9	11	13	22	27
Solar thermal power plants	0	4	9	15	27	35
Ocean energy	0	0	0	1	3	5
Combined heat & power plants	**51**	**57**	**64**	**78**	**87**	**94**
Coal	3	3	4	3	3	3
Lignite	6	6	6	5	3	3
Gas	35	39	45	58	66	71
Oil	5	5	4	4	3	2
Biomass	2	3	4	7	9	11
Geothermal	0	0	1	1	3	4
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	22	27	30	34	38	40
Autoproducers	28	30	34	44	49	54
Total generation	**1,851**	**2,034**	**2,156**	**2,317**	**2,397**	**2,408**
Fossil	1,263	1,344	1,382	1,354	1,359	1,379
Coal	540	600	622	688	671	653
Lignite	143	151	156	90	58	43
Gas	464	512	552	534	590	650
Oil	110	76	47	37	36	30
Diesel	6	5	5	5	4	3
Nuclear	428	483	528	650	650	590
Hydrogen	0	0	0	0	0	0
Renewables	**160**	**207**	**245**	**313**	**388**	**439**
Hydro	114	128	140	144	148	155
Wind	9	24	36	66	95	110
of which wind offshore	0	2	4	10	25	35
PV	4	9	12	23	30	35
Biomass	26	31	36	50	60	68
Geothermal	8	10	11	14	25	31
Solar thermal	0	4	9	15	27	35
Ocean energy	0	0	0	1	3	5
Distribution losses	89	96	101	103	104	105
Own consumption electricity	121	130	137	140	141	143
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**1,637**	**1,805**	**1,916**	**2,072**	**2,151**	**2,158**
Fluctuating RES (PV, Wind, Ocean)	13	33	48	90	128	150
Share of fluctuating RES	0.7%	1.6%	2.2%	3.9%	5.3%	6.2%
RES share (domestic generation)	**9%**	**10%**	**11%**	**14%**	**16%**	**18%**

table 12.154: oecd asia oceania: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**38**	**35**	**32**	**30**	**32**	**21**
Fossil fuels	21	20	18	17	18	12
Biomass	16	15	14	13	14	9
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**177**	**189**	**198**	**221**	**246**	**270**
Fossil fuels	173	177	181	189	197	204
Biomass	4	8	11	19	25	29
Geothermal	0	4	6	13	24	37
Hydrogen	0	0	0	0	0	0
Direct heating[1)]	**6,637**	**7,215**	**7,399**	**7,628**	**7,669**	**7,560**
Fossil fuels	6,216	6,774	6,944	7,061	7,018	6,836
Biomass	318	348	371	441	500	554
Solar collectors	74	65	57	96	121	138
Geothermal[2)]	28	28	28	29	30	32
Total heat supply[1)]	**6,851**	**7,439**	**7,629**	**7,879**	**7,947**	**7,851**
Fossil fuels	6,411	6,970	7,143	7,268	7,233	7,052
Biomass	338	372	396	473	539	592
Solar collectors	74	65	57	96	121	138
Geothermal[2)]	29	32	34	42	54	69
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**6.4%**	**6.3%**	**6.4%**	**7.8%**	**9.0%**	**10.2%**

1) heat from electricity (direct) not included; 2) including heat pumps.

table 12.155: oecd asia oceania: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**858**	**942**	**939**	**880**	**826**	**785**
Coal	469	533	538	566	526	489
Lignite	152	161	167	94	61	42
Gas	171	203	205	196	217	235
Oil	63	42	25	20	20	16
Diesel	4	3	3	3	2	2
Combined heat & power production	**34**	**36**	**37**	**37**	**36**	**36**
Coal	6	6	7	7	6	7
Lignite	11	10	10	6	4	3
Gas	12	14	16	20	23	24
Oil	5	5	4	4	3	2
CO_2 emissions power generation (incl. CHP public)	**892**	**977**	**975**	**917**	**863**	**821**
Coal	475	539	545	573	532	496
Lignite	163	171	176	101	65	45
Gas	183	216	221	216	241	260
Oil & diesel	71	50	33	26	25	20
CO_2 emissions by sector	**2,042**	**2,148**	**2,152**	**2,035**	**1,929**	**1,823**
% of 1990 emissions	130%	136%	137%	129%	123%	116%
Industry[1)]	301	345	358	354	338	320
Other sectors[1)]	253	264	270	276	278	271
Transport	425	407	391	363	332	299
Power generation[2)]	876	961	959	899	844	801
District heating & other conversion	187	171	173	144	136	132
Population (Mill.)	201	204	205	204	199	193
CO_2 emissions per capita (t/capita)	**10.2**	**10.6**	**10.5**	**10.0**	**9.7**	**9.5**

1) including CHP autoproducers. 2) including CHP public

table 12.156: oecd asia oceania: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**422**	**462**	**491**	**528**	**558**	**570**
Coal	82	89	91	104	102	100
Lignite	29	31	33	18	11	8
Gas	106	130	155	161	181	200
Oil	52	40	27	20	21	19
Diesel	3.9	3.3	3.3	3.3	2.7	2.0
Nuclear	70	75	80	96	94	86
Biomass	4	5	6	7	8	10
Hydro	67	68	70	72	72	70
Wind	4	10	14	24	33	37
of which wind offshore	0	0.7	1.4	3.2	8	10
PV	2.6	6.4	8.6	16	21	25
Geothermal	1.4	1.5	1.6	1.9	3.3	4.0
Solar thermal power plants	0.0	1.7	2.7	3.4	5.4	6.4
Ocean energy	0	0	0	1.0	2.1	3.2
Combined heat & power production	**11**	**12**	**13**	**16**	**18**	**19**
Coal	0.7	0.8	0.9	0.8	0.7	0.8
Lignite	3.1	2.9	2.7	1.4	0.9	0.7
Gas	5.6	6.3	7.3	10.5	12.6	13.7
Oil	1.4	1.4	1.1	0.9	0.7	0.5
Biomass	0	0.7	0.9	1.7	2.1	2.4
Geothermal	0	0	0	0	0	0.6
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	6.0	6.7	7.0	6.8	7.4	7.7
Autoproducers	5.2	5.5	6.0	8.7	10.2	11.0
Total generation	**433**	**474**	**504**	**543**	**576**	**589**
Fossil	283	305	321	320	333	345
Coal	83	90	92	104	103	101
Lignite	32	34	36	19	12	9
Gas	111	137	162	172	194	214
Oil	53	41	28	21	21	19
Diesel	3.9	3.3	3.3	3.3	2.7	2.0
Nuclear	70	75	80	96	94	86
Hydrogen	0	0	0	0	0	0
Renewables	**80**	**93**	**103**	**127**	**148**	**158**
Hydro	67	68	70	72	72	70
Wind	4	10	14	24	33	37
of which wind offshore	0	0.7	1.4	3.2	7.6	10.0
PV	2.6	6.4	8.6	16.4	21.4	25.0
Biomass	4.5	5.6	6.5	8.7	10.5	11.9
Geothermal	1.4	1.6	1.7	2.1	3.7	4.6
Solar thermal	0	1.7	2.7	3.4	5.4	6.4
Ocean energy	0	0	0.3	1.0	2.1	3.2
Fluctuating RES (PV, Wind, Ocean)	7	17	23	41	57	65
Share of fluctuating RES	2%	4%	4%	8%	10%	11%
RES share (domestic generation)	**19%**	**20%**	**21%**	**23%**	**26%**	**27%**

table 12.157: oecd asia oceania: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**36,076**	**38,051**	**38,861**	**39,437**	**38,888**	**37,460**
Fossil	**29,906**	**31,016**	**31,104**	**29,882**	**28,707**	**27,548**
Hard coal	7,692	8,775	9,066	9,262	8,590	7,908
Lignite	1,544	1,623	1,654	945	598	410
Natural gas	6,019	6,591	6,886	6,970	7,568	8,020
Crude oil	14,651	14,027	13,498	12,706	11,951	11,209
Nuclear	**4,665**	**5,265**	**5,765**	**7,088**	**7,092**	**6,438**
Renewables	**1,506**	**1,770**	**1,992**	**2,467**	**3,089**	**3,474**
Hydro	412	462	504	519	533	558
Wind	32	85	129	236	342	396
Solar	87	136	184	317	472	579
Biomass	711	788	850	1,024	1,162	1,263
Geothermal/ambient heat	263	299	325	367	569	660
Ocean energy	0	1	1	5	11	18
RES share	**4.2%**	**4.7%**	**5.1%**	**6.3%**	**7.9%**	**9.3%**

table 12.158: oecd asia oceania: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**23,686**	**24,674**	**25,083**	**25,440**	**25,288**	**24,652**
Total (energy use)	**20,216**	**21,207**	**21,615**	**22,000**	**21,880**	**21,254**
Transport	**6,040**	**5,804**	**5,610**	**5,243**	**4,852**	**4,395**
Oil products	5,878	5,609	5,385	4,954	4,491	4,028
Natural gas	54	67	79	117	169	166
Biofuels	19	23	26	28	28	29
Electricity	88	105	119	144	163	172
RES electricity	8	11	14	19	26	31
Hydrogen	0	0	0	0	0	0
RES share Transport	**0.4%**	**0.6%**	**0.7%**	**0.9%**	**1.1%**	**1.4%**
Industry	**6,431**	**7,293**	**7,562**	**7,733**	**7,676**	**7,507**
Electricity	2,115	2,524	2,683	2,830	2,865	2,836
RES electricity	183	256	305	383	464	517
District heat	113	115	117	119	130	134
RES district heat	5	15	16	22	30	36
Coal	1,053	1,664	1,910	1,851	1,735	1,486
Oil products	1,438	1,384	1,335	1,244	1,115	1,113
Gas	1,394	1,260	1,147	1,264	1,361	1,424
Solar	0	1	3	3	4	4
Biomass and waste	312	339	361	414	461	502
Geothermal/ambient heat	6	6	6	7	7	7
Hydrogen	0	0	0	0	0	0
RES share Industry	**7.9%**	**8.5%**	**9.1%**	**10.7%**	**12.6%**	**14.2%**
Other Sectors	**7,744**	**8,110**	**8,444**	**9,025**	**9,352**	**9,353**
Electricity	3,691	3,871	4,096	4,484	4,715	4,762
RES electricity	320	393	466	606	763	868
District heat	96	104	109	127	142	151
RES district heat	6	16	17	26	36	43
Coal	64	88	84	75	32	9
Oil products	2,028	2,013	2,044	2,048	2,085	2,011
Gas	1,694	1,863	1,945	2,063	2,106	2,123
Solar	74	64	54	93	117	134
Biomass and waste	85	93	99	121	139	147
Geothermal/ambient heat	13	13	13	14	15	17
RES share Other Sectors	**6.4%**	**7.1%**	**7.7%**	**9.5%**	**11.4%**	**12.9%**
Total RES	**1,031**	**1,231**	**1,381**	**1,737**	**2,091**	**2,336**
RES share	**5.1%**	**5.8%**	**6.4%**	**7.9%**	**9.6%**	**11.0%**
Non energy use	**3,471**	**3,468**	**3,468**	**3,440**	**3,408**	**3,398**
Oil	3,380	3,377	3,378	3,351	3,319	3,309
Gas	61	61	61	60	60	60
Coal	29	30	30	29	29	29

oecd asia oceania: energy [r]evolution scenario

table 12.159: oecd asia oceania: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**1,801**	**1,922**	**1,869**	**1,999**	**2,077**	**1,990**
Coal	537	550	392	318	121	0
Lignite	137	130	75	30	0	0
Gas	429	671	650	474	372	117
Oil	106	98	40	21	0	0
Diesel	6	3	3	3	3	3
Nuclear	428	115	113	0	0	0
Biomass	24	36	38	41	53	53
Hydro	114	132	150	159	163	180
Wind	9	75	195	470	630	710
of which wind offshore	0	0	5	60	140	200
PV	4	60	100	260	390	490
Geothermal	8	26	54	99	135	143
Solar thermal power plants	0	20	40	80	125	170
Ocean energy	0	5	19	45	85	125
Combined heat & power plants	**51**	**68**	**124**	**162**	**204**	**245**
Coal	3	3	2	0	0	0
Lignite	6	5	4	0	0	0
Gas	35	49	90	96	78	18
Oil	5	4	4	1	0	0
Biomass	2	5	17	52	97	162
Geothermal	0	2	6	11	25	57
Hydrogen	0	0	1	2	4	8
CHP by producer						
Main activity producers	22	30	52	68	88	110
Autoproducers	28	38	72	94	116	135
Total generation	**1,851**	**1,990**	**1,993**	**2,161**	**2,281**	**2,235**
Fossil	1,263	1,514	1,260	943	574	138
Coal	540	553	394	318	121	0
Lignite	143	135	79	30	0	0
Gas	464	720	740	570	450	135
Oil	110	102	44	22	0	0
Diesel	6	3	3	3	3	3
Nuclear	428	115	113	0	0	0
Hydrogen	0	0	1	2	4	8
Renewables	**160**	**361**	**619**	**1,217**	**1,703**	**2,089**
Hydro	114	132	150	159	163	180
Wind	9	75	195	470	630	710
of which wind offshore	0	0	5	60	140	200
PV	4	60	100	260	390	490
Biomass	26	41	55	93	150	215
Geothermal	8	28	60	110	160	200
Solar thermal	0	20	40	80	125	170
Ocean energy	0	5	19	45	85	125
Distribution losses	89	94	93	89	82	73
Own consumption electricity	121	120	118	114	105	93
Electricity for hydrogen production	0	0	11	98	199	314
Final energy consumption (electricity)	**1,637**	**1,774**	**1,770**	**1,858**	**1,894**	**1,754**
Fluctuating RES (PV, Wind, Ocean)	13	140	314	775	1,105	1,325
Share of fluctuating RES	0.7%	7.0%	15.8%	35.9%	48.4%	59.3%
RES share (domestic generation)	**9%**	**18%**	**31%**	**56%**	**75%**	**93%**
'Efficiency' savings (compared to Ref.)	**0**	**43**	**176**	**384**	**589**	**763**

table 12.160: oecd asia oceania: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**38**	**86**	**183**	**526**	**648**	**604**
Fossil fuels	21	45	93	142	26	0
Biomass	16	41	86	242	337	290
Solar collectors	0	0	1	105	227	242
Geothermal	0	0	2	37	58	72
Heat from CHP	**177**	**198**	**305**	**394**	**593**	**883**
Fossil fuels	173	174	215	152	127	47
Biomass	4	12	49	153	278	441
Geothermal	0	12	36	81	171	363
Hydrogen	0	0	4	8	17	31
Direct heating[1]	**6,637**	**7,049**	**6,810**	**6,199**	**5,419**	**4,506**
Fossil fuels	6,216	6,227	5,463	3,488	1,985	553
Biomass	318	494	710	1,074	1,130	1,076
Solar collectors	74	170	321	775	1,045	1,240
Geothermal[2]	28	158	316	835	1,168	1,371
Hydrogen		0	0	26	91	266
Total heat supply[1]	**6,851**	**7,333**	**7,297**	**7,119**	**6,660**	**5,993**
Fossil fuels	6,411	6,446	5,771	3,782	2,137	600
Biomass	338	547	845	1,469	1,745	1,808
Solar collectors	74	170	323	880	1,272	1,482
Geothermal[1]	29	170	354	953	1,398	1,806
Hydrogen	0	0	4	34	108	297
RES share (including RES electricity)	**6.4%**	**12%**	**21%**	**47%**	**67%**	**90%**
'Efficiency' savings (compared to Ref.)	**0**	**106**	**331**	**760**	**1,287**	**1,858**

1) heat from electricity (direct) not included; geothermal includes heat pumps

table 12.161: oecd asia oceania: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**858**	**980**	**708**	**496**	**241**	**46**
Coal	469	491	341	262	95	0
Lignite	152	144	83	33	0	0
Gas	171	285	258	186	144	45
Oil	63	58	24	13	0	0
Diesel	4	2	2	2	2	2
Combined heat & power production	**34**	**36**	**46**	**36**	**41**	**18**
Coal	6	6	5	0	0	0
Lignite	11	8	6	0	0	0
Gas	12	17	32	35	41	18
Oil	5	4	4	1	0	0
CO_2 emissions power generation (incl. CHP public)	**892**	**1,016**	**754**	**532**	**283**	**64**
Coal	475	497	346	263	95	0
Lignite	163	152	89	33	0	0
Gas	183	302	290	221	186	62
Oil & diesel	71	64	29	15	2	2
CO_2 emissions by sector	**2,042**	**2,097**	**1,697**	**1,117**	**556**	**164**
% of 1990 emissions	130%	133%	108%	71%	35%	10%
Industry[1]	301	294	258	158	86	23
Other sectors[1]	253	246	205	119	83	33
Transport	425	376	333	201	86	39
Power generation[2]	876	1,000	734	516	257	51
District heating & other conversion	187	181	167	123	44	17
Population (Mill.)	201	204	205	204	199	193
CO_2 emissions per capita (t/capita)	**10.2**	**10.3**	**8.3**	**5.5**	**2.8**	**0.9**
'Efficiency' savings (compared to Ref.)	**0**	**51**	**454**	**918**	**1,373**	**1,659**

1) including CHP autoproducers. 2) including CHP public

table 12.162: oecd asia oceania: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**422**	**491**	**528**	**721**	**857**	**892**
Coal	82	79	56	47	30	0
Lignite	29	28	17	6	0	0
Gas	106	148	148	144	133	78
Oil	52	49	25	13	0	0
Diesel	3.9	2	2	2	2	2
Nuclear	70	18	17	0	0	0
Biomass	4	6	6	7	9	9
Hydro	67	70	75	79	79	82
Wind	4	32	75	171	221	239
of which wind offshore	0	0	2	19	42	57
PV	2.6	43	71	186	279	350
Geothermal	1.4	4	8	15	20	21
Solar thermal power plants	0.0	8	11	18	25	31
Ocean energy	0	4	16	34	59	79
Combined heat & power production	**11**	**14**	**23**	**33**	**45**	**51**
Coal	0.7	1	1	0	0	0
Lignite	3.1	3	2	0	0	0
Gas	5.6	8	15	17	18	5
Oil	1.4	1	1	0	0	0
Biomass	0	1	4	13	23	35
Geothermal	0	0	1	2	4	9
Hydrogen	0	0	0	0	1	2
CHP by producer						
Main activity producers	6.0	7	10	13	21	25
Autoproducers	5.2	7	13	20	24	27
Total generation	**433**	**505**	**551**	**754**	**902**	**943**
Fossil	283	318	265	229	183	85
Coal	83	79	57	47	30	0
Lignite	32	31	18	6	0	0
Gas	111	156	162	161	151	83
Oil	53	50	26	13	0	0
Diesel	3.9	2	2	2	2	2
Nuclear	70	18	17	0	0	0
Hydrogen	0	0	0	0	1	2
Renewables	**80**	**169**	**268**	**524**	**718**	**856**
Hydro	67	70	75	79	79	82
Wind	4	32	75	171	221	239
of which wind offshore	0	0	2	19	42	57
PV	2.6	43	71	186	279	350
Biomass	4.5	7	11	20	32	44
Geothermal	1.4	5	9	17	24	31
Solar thermal	0	8	11	18	25	31
Ocean energy	0	4	16	34	59	79
Fluctuating RES (PV, Wind, Ocean)	7	80	162	391	558	669
Share of fluctuating RES	2%	16%	29%	52%	62%	71%
RES share (domestic generation)	**19%**	**33%**	**49%**	**70%**	**80%**	**91%**

table 12.163: oecd asia oceania: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**36,076**	**35,857**	**33,710**	**29,811**	**26,387**	**22,866**
Fossil	**29,906**	**30,880**	**26,203**	**18,154**	**10,959**	**4,899**
Hard coal	7,692	7,737	5,902	4,195	1,777	607
Lignite	1,544	1,375	803	300	0	0
Natural gas	6,019	8,467	8,791	7,517	5,846	2,302
Crude oil	14,651	13,302	10,707	6,143	3,337	1,990
Nuclear	**4,665**	**1,255**	**1,233**	**0**	**0**	**0**
Renewables	**1,506**	**3,722**	**6,274**	**11,657**	**15,427**	**17,966**
Hydro	412	476	539	571	586	647
Wind	32	270	702	1,692	2,268	2,556
Solar	87	566	1,043	2,536	3,801	4,776
Biomass	711	1,428	1,955	3,163	3,650	3,670
Geothermal/ambient heat	263	964	1,967	3,532	4,815	5,869
Ocean energy	0	18	68	162	306	448
RES share	**4.2%**	**10.4%**	**18.6%**	**39.1%**	**58.5%**	**78.6%**
'Efficiency' savings (compared to Ref.)	**0**	**2,193**	**5,147**	**9,619**	**12,494**	**14,586**

table 12.164: oecd asia oceania: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**23,686**	**23,902**	**22,740**	**20,879**	**18,653**	**16,387**
Total (energy use)	**20,216**	**20,626**	**19,836**	**18,166**	**16,177**	**14,143**
Transport	**6,040**	**5,600**	**5,150**	**4,250**	**3,450**	**2,850**
Oil products	5,878	5,175	4,505	2,628	1,031	422
Natural gas	54	80	169	228	210	170
Biofuels	19	198	239	445	482	338
Electricity	88	146	214	740	1,337	1,422
RES electricity	8	27	66	416	998	1,329
Hydrogen	0	0	23	209	390	498
RES share Transport	**0.4%**	**4.0%**	**6.1%**	**23.0%**	**51.3%**	**74.8%**
Industry	**6,431**	**6,987**	**6,936**	**6,487**	**5,859**	**5,163**
Electricity	2,115	2,440	2,507	2,466	2,322	2,130
RES electricity	183	443	778	1,388	1,733	1,991
District heat	113	167	259	340	454	518
RES district heat	5	39	94	230	397	501
Coal	1,053	1,018	597	208	0	0
Oil products	1,438	1,361	1,294	637	337	54
Gas	1,394	1,479	1,551	1,396	922	316
Solar	0	11	74	259	334	392
Biomass and waste	312	442	534	680	695	566
Geothermal/ambient heat	6	70	120	473	694	895
Hydrogen	0	0	0	28	100	292
RES share Industry	**7.9%**	**14.4%**	**23.1%**	**46.9%**	**67.1%**	**89.4%**
Other Sectors	**7,744**	**8,039**	**7,750**	**7,429**	**6,868**	**6,130**
Electricity	3,691	3,800	3,640	3,468	3,135	2,720
RES electricity	320	690	1,130	1,953	2,340	2,542
District heat	96	114	221	562	764	944
RES district heat	6	31	81	367	659	908
Coal	64	61	48	22	0	0
Oil products	2,028	1,819	1,334	410	220	63
Gas	1,694	1,843	1,770	1,484	892	313
Solar	74	159	247	517	711	848
Biomass and waste	85	170	341	615	650	693
Geothermal/ambient heat	13	73	149	351	494	549
RES share Other Sectors	**6.4%**	**14.0%**	**25.1%**	**51.2%**	**70.7%**	**90.4%**
Total RES	**1,031**	**2,352**	**3,861**	**7,827**	**10,554**	**12,291**
RES share	**5.1%**	**11.4%**	**19.5%**	**43.1%**	**65.2%**	**86.9%**
Non energy use	**3,471**	**3,276**	**2,904**	**2,713**	**2,477**	**2,245**
Oil	3,380	3,165	2,415	1,904	1,602	1,391
Gas	61	77	199	376	418	379
Coal	29	34	289	433	457	475

oecd asia oceania: investment & employment

table 12.165: oecd asia oceania: total investment in power sector

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Conventional (fossil & nuclear)	**343,014**	**344,952**	**216,460**	**114,250**	**1,018,676**	**25,467**
Renewables	**126,639**	**111,539**	**132,443**	**85,850**	**456,471**	**11,412**
Biomass	13,259	11,620	10,534	10,427	45,840	1,146
Hydro	48,894	48,749	44,443	18,870	160,956	4,024
Wind	18,584	22,443	31,206	23,532	95,766	2,394
PV	12,747	15,092	11,565	11,996	51,400	1,285
Geothermal	9,221	7,333	11,871	6,964	35,389	885
Solar thermal power plants	22,670	4,458	20,092	11,222	58,442	1,461
Ocean energy	1,265	1,844	2,732	2,838	8,679	217
Energy [R]evolution						
Conventional (fossil & nuclear)	**172,649**	**76,766**	**62,777**	**2,940**	**315,133**	**7,878**
Renewables	**628,095**	**582,223**	**697,515**	**703,024**	**2,610,856**	**65,271**
Biomass	31,356	40,043	60,561	73,054	205,013	5,125
Hydro	65,659	56,950	44,533	25,699	192,841	4,821
Wind	107,995	165,970	190,739	190,901	655,604	16,390
PV	157,219	168,960	185,559	194,934	706,671	17,667
Geothermal	96,708	61,682	73,995	81,637	314,021	7,851
Solar thermal power plants	102,382	39,131	82,460	64,884	288,858	7,221
Ocean energy	66,776	49,487	59,669	71,916	247,848	6,196

table 12.166: oecd asia oceania: total investment in renewable heating only

(EXCLUDING INVESTMENTS IN FOSSIL FUELS)

MILLION $	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Renewables	**26,156**	**47,984**	**15,906**	**14,516**	**114,425**	**2,861**
Biomass	21,877	21,275	9,783	9,143	62,078	1,552
Geothermal	0	0	0	0	0	0
Solar	659	23,026	5,678	14,359	43,721	1,093
Heat pumps	3,621	3,683	446	877	8,626	216
Energy [R]evolution scenario						
Renewables	**280,711**	**414,430**	**425,931**	**442,203**	**1,563,275**	**39,082**
Biomass	78,301	77,645	61,015	45,638	262,599	6,565
Geothermal	19,220	60,927	61,380	96,277	237,804	5,945
Solar	98,016	161,028	161,014	172,770	592,829	14,821
Heat pumps	85,175	114,830	142,522	127,518	470,044	11,751

table 12.167: oecd asia oceania: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	56	43	47	16	185	201	159
Manufacturing	21	13	14	8	64	85	63
Operations and maintenance	81	89	94	103	89	101	124
Fuel supply (domestic)	94	109	121	119	118	112	129
Coal and gas export	2.4	4.4	5.7	16.2	2.4	0.3	0.3
Total jobs	**255**	**258**	**282**	**262**	**458**	**500**	**477**
By technology							
Coal	77	62	73	71	47	32	21
Gas, oil & diesel	64	77	77	77	64	50	45
Nuclear	38	45	52	34	49	45	44
Total renewables	**75**	**74**	**80**	**80**	**298**	**372**	**367**
Biomass	*34*	*35*	*38*	*39*	*64*	*83*	*127*
Hydro	*20*	*24*	*23*	*24*	*29*	*27*	*27*
Wind	*7.1*	*5.9*	*8.2*	*6.7*	*49*	*76*	*51*
PV	*9.3*	*5.9*	*8.6*	*4.6*	*74*	*106*	*72*
Geothermal power	*0.8*	*0.6*	*0.6*	*0.5*	*8.3*	*5.7*	*5.1*
Solar thermal power	*3.6*	*2.3*	*1.3*	*1.2*	*8.8*	*8.1*	*7.4*
Ocean	*0.3*	*0.2*	*0.4*	*0.7*	*18*	*11*	*7.9*
Solar - heat	*-*	*-*	*-*	*3.3*	*34*	*40*	*39*
Geothermal & heat pump	*-*	*0.03*	*0.003*	*-*	*14*	*15*	*30*
Total jobs	**255**	**258**	**282**	**262**	**458**	**500**	**477**

2005 – 2012 development of energy [r]evolution scenarios

Greenpeace published the first Energy [R]evolution scenario in May 2005 for the EU-25 in conjunction with a 7-month long ship tour from Poland all the way down to Egypt. In five years the work has developed significantly. The very first scenario was launched on board of the ship with the support of former EREC Policy Director Oliver Schäfer, the start of a long-lasting fruitful Energy [R]evolution collaboration between Greenpeace International and EREC. The German Aerospace Center's Institute for Technical Thermodynamics under Dr. Wolfram Krewitt's leadership has been the scientific institution behind all published reports since then as well. Between 2005 and 2009, these three very different stakeholders managed to put together over 30 scenarios for countries from all continents and published two editions of the Global Energy [R]evolution scenario which became a well-respected, progressive, alternative energy blueprint. The work has been translated into over 15 different languages including Chinese, Japanese, Arabic, Hebrew, Spanish, Thai and Russian.

The concept of Energy [R]evolution scenario has been under constant development ever since and today we are able to calculate employment effects in parallel to the scenario development as well. The calculation program MESAP/PlaNet has been developed by software company seven2one and lots of features have been developed for this project. For the 2010 edition, we developed a standardised report tool, which provides us with a "ready to print" executive summary for each region and/or country we calculate and finally all regions interact with each other, so the global scenario is set up like a cascade. These innovative developments serve for an ever improving quality, faster development times and more user-friendly outputs.

In the past years, a team of about 20 scientists for all regions across the world formed to review regional and or country specific scenarios and to make sure that it has a basis within the region.

In some cases Energy [R]evolution scenarios have been the first-ever published, long-term energy scenario for a country, like the Turkish scenario published in 2009. Since the first Global Energy [R]evolution scenario published in January 2007, we have done side events on every single UNFCCC climate conference, countless energy conferences and panel debates. Over 200 presentations in more than 30 languages always had one message in common. "The Energy Revolution is possible; it is needed and pays off for future generations!"

Many high level meetings took place, for example on the 15th July 2009 when the Chilean President Michelle Bachelet attended our launch event for the Energy [R]evolution Chile.

The Energy [R]evolution work is a corner-stone of the Greenpeace climate and energy work worldwide and we would like to thank all involved stakeholders. Unfortunately, in October 2009, Dr Wolfram Krewitt from DLR passed away far too early and left a huge gap for everybody. His energy and dedication helped to make the energy revolution project a true success story. Arthouros Zervos and Christine Lins from EREC have been involved in this work from the very beginning and Sven Teske from Greenpeace International heads this work since the first development late 2004. The well-received layout of all Energy [R]evolution documents has been done – also from the very beginning – from Tania Dunster and Jens Christiansen from "onehemisphere" in Sweden with enormous passions especially in the final phase when the report goes to print.

The third version of the report, published in June 2010 in Berlin, reached out the scientific community to a much larger extent. The IPCC's Special Report Renewables (SRREN) chose the Energy [R]evolution as one of the four benchmark scenarios for climate mitigation energy scenarios (discussed in this edition Chapter 4). That Energy [R]evolution was the most ambitious scenario: combining an uptake of renewable energies and energy efficiency, and put forwards the highest renewable energy share by 2050. However, this high share resulted in a very strict efficiency strategy, and other scenarios actually had more renewables in terms of Exajoule by the year 2050. Following the publication of the SRREN in May 2011 in Abu Dhabi, the ER became a widely quoted energy scenario and is now part of many scientific debates and referenced in numerous scientific peer-reviewed literatures.

This new edition, the Energy [R]evolution 2012, takes into account the significantly changed situation of the global energy sector that has occurred in just two years. In Japan, the Fukushima Nuclear disaster following the devastating tsunami in Japan, triggered a faster phase-out of nuclear power in several countries. A serious oil spill occurred at the Deepwater Horizon drilling platform in the Gulf of Mexico in 2010, highlighting the damage that can be done to eco-systems, and some countries are indicating new oil exploration in ever-more sensitive environments like the Arctic Circle. There is an increase in shale gas, which is a particularly carbon-intensive way to obtain gas, and has required a more detailed analysis where the gas use projection in the Energy [R]evolution is coming from.

In the renewable energy sector, there has been a faster cost reduction in the photovoltaic and wind industries, creating earlier break-even points for these renewable energy investments. New and more detailed analysis of renewable energy potential is available and there are new storage technologies available, which could change the proportions of energy input types, for example, reduce the need for bio energy to make up the greenhouse gas reduction targets of the model.

Taking the above into account, this edition of the Energy [R]evolution includes:

- Detailed energy demand and technology investment pathways for power, heating and transport
- Detailed employment calculations for all sectors
- Detailed analysis of the needed fossil fuel infrastructure (gas, oil exploration and coal mining capacities)
- Detailed market analysis of the current power plant market

image MINOTI SINGH AND HER SON AWAIT FOR CLEAN WATER SUPPLY BY THE RIVERBANK IN DAYAPUR VILLAGE IN SATJELLIA ISLAND: "WE DO NOT HAVE CLEAN WATER AT THE MOMENT AND ONLY ONE TIME WE WERE LUCKY TO BE GIVEN SOME RELIEF. WE ARE NOW WAITING FOR THE GOVERNMENT TO SUPPLY US WITH WATER TANKS".

overview of the energy [r]evolution publications since 2005

A Global Energy [R]evolution scenario has been published in several scientific and peer-review journals like "Energy Policy". See below a selection of milestones from the Energy [R]evolution work between 2005 and June 2010.

June 2005: First Energy Revolution Scenario for EU 25 presented in Luxembourg for members of the EU's Environmental Council.

July – August 2005: National Energy Revolution scenarios for France, Poland and Hungary launched during an "Energy revolution" ship tour with a sailing vessel across Europe.

January 2007: First Global Energy revolution Scenario published parallel in Brussels and Berlin.

April 2007: Launch of the Turkish translation from the Global scenario.

July 2007: Launch of Futu[r]e Investment – An analysis of the needed global investment pathway for the Energy [R]evolution scenarios.

October 2008: Launch of the second edition of the Global Energy [R]evolution Report.

December 2008: Launch of a concept for specific feed in-tariff mechanism to implement the Global Energy [R]evolution Report in developing countries at a COP13 side event in Poznan, Poland.

September 2009: Launch of the first detailed Job Analysis "Working for the Climate" – based on the global Energy [R]evolution report in Sydney/Australia.

November 2009: Launch of "Renewable 24/7" a detailed analysis for the needed grid infrastructure in order to implement the Energy [R]evolution for Europe with 90% renewable power in Berlin / Germany.

June 2010: Launch of the third Global Energy [R]evolution edition in Berlin / Germany.

May 2011: The IPCC Special Report Renewable Energy (SRREN) published its find report in Abu Dhabi – the Energy [R]evolution 2010 has been chosen as one out of four benchmark scenarios.

June 2012: Launch of the fourth Global Energy [R]evolution edition in Berlin / Germany.

energy [r]evolution country analysis & launch dates

- November 2007: Energy [R]evolution for Indonesia
- January 2008: Energy [R]evolution for New Zealand
- March 2008: Energy [R]evolution for Brazil
- March 2008: Energy [R]evolution for China
- June 2008: Energy [R]evolution for Japan
- June 2008: Energy [R]evolution for Australia
- August 2008: Energy [R]evolution for the Philippines
- August 2008: Energy [R]evolution for Mexico
- December 2008: Energy [R]evolution for the EU-27
- March 2009: Energy [R]evolution for the USA
- March 2009: Energy [R]evolution for India
- April 2009: Energy [R]evolution for Russia
- May 2009: Energy [R]evolution for Canada
- June 2009: Energy [R]evolution for Greece
- June 2009: Energy [R]evolution for Italy
- July 2009: Energy [R]evolution for Chile
- July 2009: Energy [R]evolution for Argentina
- October 2009: Energy [R]evolution for South Africa
- November 2009: Energy [R]evolution for Turkey
- April 2010: Energy [R]evolution for Sweden
- May 2011: Energy [R]evolution South Africa
- September 2011: Energy [R]evolution Japan
- September 2011: Energy [R]evolution Argentina
- November 2011: Energy [R]evolution Hungary
- April 2012: Energy [R]evolution for South Korea
- June 2012: Energy [R]evolution for Czech Republic

GREENPEACE

Greenpeace is a global organisation that uses non-violent direct action to tackle the most crucial threats to our planet's biodiversity and environment. Greenpeace is a non-profit organisation, present in 40 countries across Europe, the Americas, Africa, Asia and the Pacific. It speaks for 2.8 million supporters worldwide, and inspires many millions more to take action every day. To maintain its independence, Greenpeace does not accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants. Greenpeace has been campaigning against environmental degradation since 1971 when a small boat of volunteers and journalists sailed into Amchitka, an area west of Alaska, where the US Government was conducting underground nuclear tests. This tradition of 'bearing witness' in a non-violent manner continues today, and ships are an important part of all its campaign work.

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The Global Wind Energy Council (GWEC) is the voice of the global wind energy sector. GWEC works at highest international political level to create better policy environment for wind power. GWEC's mission is to ensure that wind power established itself as the answer to today's energy challenges, producing substantial environmental and economic benefits. GWEC is a member based organisation that represents the entire wind energy sector. The members of GWEC represent over 1,500 companies, organisations and institutions in more than 70 countries, including manufacturers, developers, component suppliers, research institutes, national wind and renewables associations, electricity providers, finance and insurance companies.

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European Renewable Energy Council (EREC) Created in April 2000, the European Renewable Energy Council (EREC) is the umbrella organisation of the European renewable energy industry, trade and research associations active in the sectors of bioenergy, geothermal, ocean, small hydro power, solar electricity, solar thermal and wind energy. EREC thus represents the European renewable energy industry with an annual turnover of €70 billion and employing 550,000 people.

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image SATELLITE IMAGERY OF ANTARCTICA (22.5W, 90.0S.) BASED ON A COMBINATION OF DATA FROM THREE EARTH-OBSERVATION SATELLITE SYSTEMS. A MOSAIC OF THOUSANDS OF IMAGES TAKEN BY NOAA POLAR ORBITER WEATHER SATELLITES WAS COMBINED WITH 10 YEARS OF OCEAN COLOUR OBSERVATIONS FROM NASA'S NIMBUS 7 AND IMAGES OF THE POLAR ICE CAPS FROM THE US AIR FORCE DEFENSE METEOROLOGICAL SATELLITE PROGRAM. **front cover images** SATELLITE IMAGERY OF THE ARCTIC REGION (45.0E, 90.0N.) © PLANETARY VISIONS LIMITED, © MARKEL REDONDO/GREENPEACE, © FRANCISCO RIVOTTI/GREENPEACE.