energy [r]evolution

A SUSTAINABLE INDIA ENERGY OUTLOOK

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report 2nd edition 2012 india 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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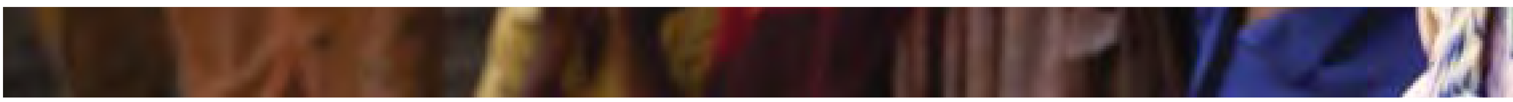

image WOMEN COLLECT WATER AT THE SOLAR-POWERED DESALINATION PLANT IN KOTRI VILLAGE, RAJASTHAN. BEFORE THE INSTALLATION OF THE PLANT THE LOCAL POPULATION WOULD DRINK SALINE GROUNDWATER, WITH HEALTH PROBLEMS AS A RESULT.

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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

Sometimes I wonder why do we need NGOs, why do we need Reports like these, why do we need protests and petitions and lobbying groups – why do we need anyone at all to tell us a truth that is so simple and obvious – traditional energy sources like coal and fossil will not remain forever!

All the statistics that point to this truth are already out there. They have occupied the headlines of the newspaper you have read with your morning cup of tea, they have impacted your household budgets too, month after month – rising petrol/diesel, LPG, electricity prices; yet day after day, month after month, you and I and our public institutions have done barely little to offset this challenge.

contents at a glance

image THE 100 KWP STAND-ALONE SOLAR PHOTOVOLTAIC POWER PLANT AT TANGTSE, DURBUK BLOCK, LADAKH. LOCATED AT 14,500 FEET IN THE HIMALAYA, THE PLANT SUPPLIES ELECTRICITY TO A CLINIC, A SCHOOL AND 347 HOUSES IN THIS REMOTE LOCATION, FOR AROUND FIVE HOURS EACH DAY.

As a country, we continue to lag behind in our actions and intent on using and promoting Renewable Energy (RE). The share of RE in the energy sector, as on March 2011, is a mere 10.63% of total generation capacity of India; this despite an abundance of Renewal Energy resources– sun, wind and water - available to us.

India's track record on RE is rather poor so far, and many people can tell you that through many set of numbers and viewpoints. Unfortunately/fortunately I am an optimist. So I would instead like to focus on the change in action and the change that needs to be action-ed.

In recent times, we have seen many committed citizens coming together across the country and making significant progress on the journey of sustainable energy. For example, in Bihar, where almost 80% of the population resides in rural areas with limited or no access to electricity, Husk Power Systems provides electricity to over 100,000 people using rice husk, which was essentially a waste product in the villages. Similarly near Andhra Pradesh border in Karnataka, Agriculture Development and Training Society, has built 5,500 biogas units across 339 villages providing clean cooking fuel and energy for heating water. In Delhi, Holy Family Hospital is saving up to 60% on its water heating bills due to solar systems set up on its roof, while Odanthurai panchayat in Tamil Nadu, has invested in wind turbines to provide better energy and public services for its citizens.

These cases may be far and few in between, but they are providing powerful RE implementation examples and patterns. What is needed now is for mainstream India to embrace these models in greater numbers. We need partnerships between government, corporates and communities to accelerate deployment and development of these sustainable models which promote access and use of Renewable Energy. Much can be done at an individual level too. We need to align the elements of sun, wind and water more intrinsically into our lifestyle - more glass windows, solar panels, water harvesting etc at our homes. These are all interventions that require minimum investment and effort and yet can yield great results.

Also, our governments and policy makers have to tap this opportunity whole heartedly and transform the Indian energy sector. Forums like Greenpeace are playing a crucial role in advocacy of this important imperative and more and more community-led paradigms are showing us the way forward.

However, these winds of change will not achieve a revolutionary velocity until every unit, every hand and every mind in our country starts thinking 'sustainable'!

So in conclusion, the only one message I want to leave with you is a reminder of our individual and collective responsibility – as an individual, a community member, a policy maker or a government functionary – each one of us have the power to change India's energy future...

I just hope we exercise this power before it's too late.

Vineet Nayar
VICE CHAIRMAN & CEO, HCL TECHNOLOGIES
NOVEMBER 2012

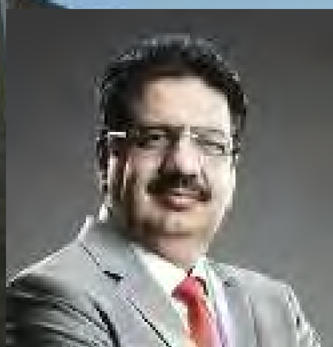

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image A WOMAN IN FRONT OF HER FLOODED HOUSE IN SATJELLIA ISLAND. DUE TO THE REMOTENESS OF THE SUNDARBANS ISLANDS, SOLAR PANELS ARE USED BY MANY VILLAGERS. AS A HIGH TIDE INVADES THE ISLAND, PEOPLE REMAIN ISOLATED SURROUNDED BY THE FLOODS.

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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 ODANTHURAI PANCHAYAT, AN ADMINISTRATIVE GROUPING OF ELEVEN VILLAGES IN THE SOUTH EAST INDIAN STATE OF TAMIL NADU, WHO DRIVEN BY THE NEED TO REDUCED ELECTRICITY BILLS HAVE BEGUN INSTALLING RENEWABLE ENERGY, INCLUDING SOLAR STREETLIGHTS, A BIOGAS PLANT, AND A 350KW WIND TURBINE.

This 2nd edition of the Energy [R]evolution for India which comes at a time of profound changes and challenges in the energy market. On the 25th anniversary of the Chernobyl catastrophe, another such nuclear incident underlined the urgent need to rethink over the energy strategies. The Fukushima disaster triggered a surge in global renewable energy and energy efficiency deals and made the government change their energy approach altogether. While the use of renewable energy increased, the global economic crisis showed its impact: the Eurozone debt crisis, overall decreasing investments resulting high unemployment, falling energy demand and decreasing global carbon prices.

In India the total gross inland consumption increased from about 18,800 PJ/a in 2000 to 29,000 PJ/a in 2009. Renewable energy provided 7,500 PJ/a or 25% of gross energy consumption in India in 2009. Despite the overall growth of renewable energy in India and worldwide and constant maturing of these technologies, there is an urgent need to implement renewable energy on a much larger scale.

Renewable energy resources and technologies are facing some critical barriers towards its development & deployment which are market-oriented, perception related, technology-biased and political in nature. To overcome these barriers, appropriate policy reforms at regulatory and market level must be ensured. The most important step is setting up an aggregate and stipulated generation based national renewable energy target of at least 20% by year 2020. This would help in consolidating the multiple targets for renewable energy. Furthermore, mandatory escalating Renewable energy Purchase Obligations (RPOs) target for each state must be set up based on logical and rational criteria and have strong compliance and monitoring regime. Further, decentralised renewable energy infrastructures should be prioritised as preferred option for rural/household electrification and therefore, half of financial allocations under national flag-ship rural electrification programme Rajiv Gandhi Gramin Vidhyutikaran Yojana (RGGVY) should be allocated for off-grid or grid-interactive renewable energy projects. Although, prices of renewable energy technologies in India is falling down, the sector needs certain fiscal supports such as a lending body, a Renewable Energy collateral fund and a public-private investment on research & development to further reduce its cost.

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.

If India has to ensure a sustainable and inclusive growth and not just "Economic growth at all cost", it needs to protect its forests, critical wildlife habitats and livelihood of the dependent communities from unmindful coal mining. The government should also put an immediate moratorium on new coal mining clearance till criteria for such clearances is developed. Before giving Clearance to new coal based power plant, in water starved areas, the Indian Government should do a cumulative water impact assessment.

India needs to plug smart power by imposing stringent and mandatory energy efficiency standard legislation on industrial and commercial usage, starting with the highest consumption area i.e. heavy industry. It also has to initiate technical roadmap for integration of ICT technologies in power grid to reduce perpetual Transmission and Distribution (T&D) loss which is globally the highest.

In India, there is a considerable inequity in energy distribution between rural and urban households. While the energy generating capacity in the country has increased , yet 40% of the households (mostly in the rural areas), don't have an access to electricity., The present centralised model of energy system may not be the right way forward. Since 2010 Greenpeace is working in the state of Bihar to challenge the dominant perception that only centralised system based on fossil fuel can deliver power to all. Through this campaign Greenpeace is trying to create political and policy champions who can support decentralized renewable energy as the empowered model which can provide energy access to all. To make decentralised renewable energy an important tool for energy access, huge investment opportunity exists within the state and Bihar has a potential to become a flag-bearer for national revolution for renewable energy. The "Bihar model" can offer a new negotiating leverage for global negotiation on climate change and represent a model of Decentralised Renewable Energy (DRE) development for many poor countries, especially in Africa, that have similar socioeconomic conditions.

From the business opportunities perspective , such a shift is advantageous as the renewable energy sector is well placed to develop and offer a wide range of solutions and applications. However, in Bihar the acceleration of such a process is constrained by certain barriers. These barriers could be related to the technical and financial viability, investments, support infrastructure and infrastructure bottle-necks and regulatory issues. Since the current state leadership has demonstrated a strong commitment towards renewable energy, it would be helpful in shaping the policy to enhance the investment at state level and also influencing similar policies at national level.

While the Energy [R]evolution scenario is for the entire country, many regional energy plans – like the Bihar Energy [R]evolution clusters – need to be developed on the basis of an overall plan.

The India Energy [R]evolution 2012 presents a roadmap to achieve sustainable energy system in India now and for generations to come. Such a profound change translates into a wide variety of skilled domestic green jobs. Renewable energy technologies are becoming increasingly competitive over conventional fuels (which have been heavily subsidized for decades), which will, in turn, save consumers money in the long run, at a time when financial stringency and planning has become an imperative for citizens at large.

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NOVEMBER 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 A SOLAR-POWERED REVERSE OSMOSIS PLANT IN KOTRI VILLAGE, RAJASTHAN, WHICH PRODUCES OVER 3000 LITRES OF DRINKING WATER PER DAY FROM THE BRACKISH GROUNDWATER.

The second edition of India Energy [R]evolution in 2012 provides a practical pathway for India to secure its energy particularly electricity supply to achieve its long-term ambitious economic growth along with providing access to modern electricity technology to over 300 million population who are still waiting to see light in their home while remaining significantly on low-carbon growth trajectory.

The previous edition of India Energy [R]evolution in 2010 has detailed employment analysis, and the current edition expands the research further to incorporate socio-economic effects of renewable heating and cooling 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

Rising energy juggernaut in India is putting pressure on fossil fuel supply and pushing coal mining in country's last remaining forests, threatening critical wildlife habitats and displacing millions of forest-dependent communities. This is aggravating water scarcity by diverting water from irrigation to power generation. The major challenge for India is to ensure high economic growth by accomplishing growing energy needs without compromising social and environmental justice. Phasing out fossil fuel particularly the new coal expansion in current economic crisis becomes far more important as in Government's own word, India needs to aspire for "Sustainable & inclusive evolution" and not "Economic growth at all cost". Shift from fossil fuels to renewables will provide substantial benefits like liberation from global volatile fossil fuel prices and ensures millions of new green jobs. Further, it can also provide swift access to electricity to those 300 million currently without having any access to energy. The India Energy [R]evolution 2012 also takes a closer glance at demand of energy reduction significantly through energy efficiency measures which eventually helps in meeting growing energy needs of the country withoutmaking any momentous fossil fuel expansion beyond 2015.

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."

energy security threat

India's fuel import deficit[1] has been rising substantially over the last few years, widening country's fiscal deficit placing the energy security of the country under serious threat. Coal is proposed to remain the principal energy source in the coming years. India holds almost 10% of the total global reserves of coal, the coal import has gone up from zero five years ago to over 50 million tonnes in the last fiscal year.[2] At current usage, India's coal reserves are projected to be depleted in 45 years.[3]

Moreover, with the increase in demand for coal in Asia, global coal prices are projected to rise, exerting greater pressure on India's power sector. The International Energy Agency (IEA) estimates that nominal prices of coal will likely to be triple during the next two decades. Simultaneously, coal, gas, and oil prices have seen considerable volatility in recent years, and the trend is likely to continue. Since India imports around 75%—80% of its crude oil requirements, vulnerability to international oil price volatility is another significant threat to India's energy security.

climate change and renewable energy

The threat of climate change, due to rising global temperature, is the most significant environmental challenge facing the world at the beginning of the 21st century. However, for India, implication of climate change does not limit itself to environmental arena only, but also seriously threaten its social and economic stability, its natural resources and its poor and marginalized communities' livelihood.

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 possibl, however the time is running out. To be 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 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[4] including India.

Energy planning in India is taking place in the context of impeding climate change resulting from global warming. India has pledged to reduce its economy's greenhouse gas (GHG) intensity by 20 to 25 percent by 2020 from 2005 levels, and has also pledged that its per capita emissions will not exceed those of developed nations. Currently, India is the fourth largest carbon emitter in the world and if its reliance on conventional energy continues, emissions will increase further.

There are multiple options for lowering GHG emissions from the energy system while still satisfying the demand for energy services. Historically, economic development has been strongly correlated with increasing energy use and growth of GHG emissions. Renewable energy can help decouple that correlation, contributing to sustainable development. Apart of from this, significant deployment of Renewable energy provide wide benefits such as significant contribution to social and economic development, energy access, a secure energy supply, and reducing negative impacts on the environment and health.

growth and development

Renewable energy has the potential to transform energy markets across the world but more so in case of India. Globally, the clean technology industry is considered to be the next big high-tech industry. India's wind turbine industry clearly shows that the country has developed into a global hub for manufacturing renewable energy equipment. Solar PV is the new technology buzz in India.

The potential of job generation and energy efficiency domain in Renewable energy can be two to three times that of conventional energy e.g. coal, oil. Currently India's renewable energy industry employs 0.2 million people.[5] However, this can escalate to 14 times by 2030 if Energy [R]evolution pathway is well implemented with appropriate policy and market measures.

Renewable energy development is also important for economic development in Indian states which are currently lagging behind in economic development but have high renewable energy potential. Developing renewable energy in these states can provide secure electricity supply to foster domestic industrial development, attract new investments, job creation, and create additional state income by allowing the states to sell renewable energy trading certificates to other states. Investments to develop the attractive renewable energy potential of these states would thus give a huge boost to their economies.

references

1 ACCORDING TO HSBC GLOBAL RESEARCH REPORT, IN 2008, INDIA IMPORTED 75% OIL, 11% COAL, 26% NATURAL GAS, LEADING TO AN IMPORT BILL OF 5.6% OF INDIA'S GDP.
2 HTTP://WWW.CEA.NIC.IN/REPORTS/MONTHLY/ELECT_ENERGY_GEN.PDF
3 HTTP://WWW.REN21.NET/PORTALS/97/DOCUMENTS/GSR/GSR2011_MASTER18.PDF
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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.[6] 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
- 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 is where power and heat are produced close to the point of final use which 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 almost two billion people around who currently don't have access to electricity.

the energy [r]evolution for the india– key results

Renewable energy sources account for 25% India's primary energy demand in 2009. The main source is traditional biomass, which is mostly used for cooking.

For electricity generation renewable energy contributes about 13.0% and for heat supply, around 55%, almost exclusive from traditional biomass. About 74% of the primary energy supply today still comes from fossil fuels and 0.7 % from nuclear energy.

The Energy [R]evolution scenario describes development pathways to 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 can be achieved through the following measures:

- **Curbing energy demand:** India's energy demand is projected by combining population development, GDP growth and energy intensity. Under the Reference scenario, total primary energy demand in India increases by 209% from the current 29,149 PJ/a to 89,948 PJ/a in 2050. In the Energy [R]evolution scenario, by contrast, energy demand increases by 78% compared to current consumption and it is expected to reach 52,006 PJ/a by 2050.
- **Controlling power demand:** 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 4.2). In the transport sector – for both freight and person – a shift towards electric trains and public transport as well as efficient electric vehicles is expected.
- **Reducing heating demand**: Efficiency gain in the heat supply sector is larger than in the electricity sector. Under the Energy [R]evolution scenario, final demand for heat supply can even be reduced significantly. Compared to the Reference scenario, consumption equivalent to 3,560 PJ/a is avoided through efficiency measures by 2050.
- **Development of industry energy demand**: Fossil fuels for industrial process and heat generation are also phase 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.

references
6 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.

- **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 phasing out of nuclear energy and reduce the number of fossil fuel based 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.
- **Future costs of electricity generation:** Under the Energy [R]evolution scenario the costs of electricity generation slightly increases the costs of electricity generation in India compared to the Reference scenario. This difference will be less than INR 0.5 ($ 1 cent)/kWh up to 2020, however due to 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 INR 3.7 ($ 7.2 cents)/kWh below those in the Reference version.
- **The future electricity bill:** 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 INR 5.2 trillion ($ 100 billion) per year to more than INR 48.2 trillion ($ 932 billion) in 2050. Figure 4.6 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.
- **Future investment in power generation:** It would require about INR 242 trillion ($ 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 INR 6.1 trillion ($ 117 billion) annually or INR 3.6 trillion ($ 69 billion) more than in the Reference scenario (INR 98.6 trillion/$ 1,905 billion). Under the Reference version, the level 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, 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 INR 6.1 trillion ($ 117 billion).
- **Fuel costs savings:** As renewable energy has no fuel costs, however, the fuel cost savings in the Energy [R]evolution scenario reach a total of INR 285 trillion ($ 5,500 billion) up to 2050, or INR 7.1 trillion ($ 138 billion) per year. The total fuel cost savings therefore 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 the national economy.
- **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. 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.
- **Future investments in the heat sector:** In the heat sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially the not 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 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 INR 66.9 trillion ($ 1,293 billion) to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately INR 1.7 trillion ($ 32 billion) per year.

- **Future employment in the energy sector**: The Energy [R]evolution scenario results in more number of jobs in India's energy sector by 2015 and 2020. In 2030, job numbers remain 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. Finally by 2030, there are 1.5 million jobs in the Energy [R]evolution scenario and the Reference scenario.
- **Transport**: In the transport sector, it is assumed under the Energy [R]evolution scenario the 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. 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%.
- **Primary energy consumption**: 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 has been 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.
- **Development of CO_2 emissions**: Whilst India's emissions of CO_2 will increase by 251% under the Reference scenario, however, under the Energy [R]evolution scenario it 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 gain and the increased use of renewable electricity in vehicles will also significantly reduce the emission 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 will be 72% of 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. India should have an aggregate target of at least 20% renewable energy in the national grid by 2020.
2. Each state should have an ambitious but mandatory Renewable energy obligation (RPO) target based on Renewable energy potential, consumer profile and economic status of the state. The RPO should have stringent compliance mechanism for effective implementation.
3. Enabling bottom up energy/electricity infrastructure and top-down financing as key principle for household / rural electrification.
4. Recognizing Decentralized Renewable Energy- both grid-interactive and off-grid, as preferred option in all government policies and scheme for energy access.
5. A transparent public consultation process should be held to arrive at the criteria for determining which forests should be permanently closed to mining.
6. Increase public investment in innovation through support for research and development.
7. The existing environment clearances for coal based power plants must be re-examined on the basis of a cumulative water impact.
8. Create a dedicated Renewable Energy Collateral fund for significant deployment of renewable energy.
9. Declare Renewable energy sector as priority lending sector and ensure nationalized banks and government financial institutions should provide easy soft loans to decentralized renewable energy projects.
10. Ensure better monitoring and management, first through smart meters at consumer's level and then by integrating more advanced ICTs technologies like energy internet.

climate and energy policy

THE UNFCCC AND THE KYOTO PROTOCOL | INTERNATIONAL ENERGY POLICY | RENEWABLE ENERGY TARGETS | INDIA POLICY RECOMMENDATIONS

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.[7]

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.

reference
7 UNEP EMISSIONS GAP REPORT.

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.

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.

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,[8] the European Solar Thermal Power Industry Association[9] and the Global Wind Energy Council,[10] 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 india policy recommendations

With an increasing demand for electricity, India is facing formidable challenges to build up its energy infrastructure to meet its economic and social targets. The current and foreseeable coal crisis at the domestic front, coupled with price rise of imported coal and natural gas strongly advocates for fundamental rethinking and restructuring of India's power infrastructure and energy dependencies. India needs to shift its current energy policy based on over-dependence on unviable fossil fuel & nuclear energy to sustainable and economically efficient renewable energy resources along with improved energy efficiency measures.

Therefore to ensure that India is able to achieve its twin imperatives of providing access to modern energy to over 300 million people without electricity and sustaining its long-term high economic and development growth aspiration, Greenpeace recommends that Government of India should implement the following policy reforms in power, energy and allied sectors.

1. **Renewable energy: Sustaining India's energy demand.** India is enriched with natural resources and able to generate electricity from renewable energy sources. While on the other hand the country faces acute power deficit of over 10% resulting approximately $58 billion of loss.

   Renewable energy provides not just a bridging solution to present power crisis but can also be a permanent fix to India's increasing electricity requirements. This will boost India's high economic growth aspiration and also benefit millions awaiting to have an electricity access along with positive effect on environment.

   In order to tap the benefits of renewable energy and to bridge the demand and supply gap in the power sector, Government of India needs to have an ambitious, logical but stipulated National generation based Renewable Energy target. Currently, there are multiple targets put forth by different agencies. The most ambitious target is from National Action Plan for Climate Change (NAPCC). The NAPCC released in year 2008, set for15% generation from renewable energy by 2020. Due to the massive churning in power sector coupled with price reduction in major renewable energy technologies, both globally and domestically, this target also looks highly conservative. It is logical to revise the current target under NAPCC on high potential, rapid growth and economic efficiency of renewable energy and therefore, further scale up.

   Therefore, Greenpeace recommends the Government of India to set up an aggregate and stipulated generation based national renewable energy target of at least 20 % by year 2020.Having this as the national target would consolidate the multiple targets for renewable energy. This target means having a total of 319TWh/a of electricity being produced from renewable energy excluding large hydro power plant by year 2020. This would translate into having an installed capacity of 147 GW of renewable energy dominated by Wind and Solar PV technology.

2. **Implementing national renewable target: Obligation and Responsibility.** A national target would help to build investors' confidence, whereas a Renewable energy purchase obligation (RPOs) would help in creating a permanent domestic market for renewable energy. With each state being mandated to buy renewable energy, projects developers would be assured of a buyer. RPOs will also help in regulating the market by ensuring renewable energy projects producing electricity and are not there as tax evasion models.

   Currently in India, RPOs range from 1% to 10% in various states. Central Electricity Regulatory Commission (CERC) recommended a standardized RPO across all states, starting with 5% in year 2010 with linear progress of 1% every year to reach 15% by year 2020. With the solar mission, there is also a national solar RPO of 0.25 % for all states increasing to 3% by year 2022.

   The Electricity Act 2003, under section 86 1(e) and the National Tariff Policy paragraph 6.4 suggests the state regulators to assign renewable energy purchase obligation for states however, do not specify a quantum and are only prescriptive and falling short of being mandatory. RPO targets were assigned to electricity utilities by their respective State Electricity Regulatory Commissions (SERCs) without fixing any specific criteria and also lack rationality and logic.

references
8 'SOLARGENERATION IV', SEPTEMBER 2009.
9 'GLOBAL CONCENTRATED SOLAR POWER OUTLOOK – WHY RENEWABLES ARE HOT!' MAY, 2009.
10 'GLOBAL WIND ENERGY OUTLOOK 2008', OCTOBER 2008.

There is no compliance mechanism in place to monitor the performance of electricity utilities on assigned targets. There are also instances where targets are arbitrarily reduced on request of obligated entities like utilities.

The Government of India through CERC and SERCs should ensure effective implementation of Renewable Purchase Obligation (RPOs) through following policy reforms:

- CERC should frame a guideline on differential RPO target for all states based on state's own renewable energy potential based on existing technology, consumer profile and financial status of state.
- The SERCs, on the basis of assessment in accordance with prescribed criteria, should assign a logical but specific RPO target for its state which matches state's potential and profile.
- SERCs should also ensure that all captive power producers and Open Access entities should have ambitious RPO target as part of their obligation.
- CERCs should also enforce a mandatory uniform compliance code for RPO which shall be adopted by all States across the country. The compliance code should have element of penalty and reward system which will encourage State electricity utilities to meet the target. This will help in ensuring effective implementation of RPO regime across the country.

3. **Energy Access through Decentralized Renewable Energy.** India's energy future will need to be driven, not just by large-scale generating facilities to power aspirational economic growth but also by providing access to over 300 million who currently have no access to electricity. It is a well-known fact that India suffers from "energy poverty". Planning commission report has accepted that providing subsidence level of electricity access to every person in the country requires only 12,000 MW of power generation. However, the dream of lighting every home in the country still distant despite addition of massive power generation capacity in last few years.

Renewable energy technologies are well-suited to meet India's need for power in remote areas that lack grid and road infrastructure due to the distributed nature of resources and the scalability of system design. With Decentralized micro-grids based on renewable energy generation, India could plug in the terawatt challenge and provide quality electricity supply to million. While it is true that grid extension has a significant role to play in rural electrification, an integrated approach with a mix of grid extension, grid interactive and off-grid systems to meet the rural electricity requirements should be developed.

To ensure sustainable and equitable development through affordable, economical and quality access of electricity for all, the Government of India should ensure following policy reforms at earliest:

- Enabling bottom up energy/electricity infrastructure and top-down financing as key principle for household / rural electrification
- Recognizing Decentralized Renewable Energy- both grid-interactive and off-grid, as preferred option in all government policies and scheme for energy access.
- Social audit of Rajiv Gandhi Gramin Vidyutikaran Yojana (RGGVY) brings up the fact that extension of centralized grid to provide electricity access in many areas is cost-prohibitive while seldom electricity reaches to such people when its needed the most. Therefore, Government of India should allocate 50% of financial allocation under RGVVY to Grid-interactive and off-grid Decentralized Renewable Energy for ensuring quality, economical and affordable access to electricity for rural population.
- Reducing load on centralized grid and ensuring quality access of electricity at affordable rate in urban areas, Government of India should enact a national Solar rooftop policy with Feed-in-tariff mechanism, even for small quantum of excess supply to the grid from the building.

4. **Investments in coal power: decimating forests and worsening water scarcity.** decimating forests and worsening water scarcity. There are many reasons behind the increasing dependence on coal for energy and it is not a wise choice as it leads to energy insecurity, greenhouse gas emissions, climate change, public health implications and the inability of to deliver power to remote locations. The implications of coal mining will be on the Indian forests, their water sources, endangered species and millions of impoverished forest-dependent communities. The government should put an immediate moratorium on further forest clearances for coal.

Coal based thermal power is also an extremely water intensive way to produce energy. About 220 GW of the proposed coal power plants are located on the land which will have an impact on the livelihoods farmers. It also cause serious environmental pollution in these regions. When the irrigation waters are diverted to service coal power plants, the reliability of power generation from these regions remains unpredictable due to water scarcity. The present trend of coal-based power generation brings multiple risks to national energy security by depending on imported coal and conflicted water, as well as by increasing health and environmental damage.

Both coal mining and coal based power projects are becoming increasingly risky investments in the long term conflicts on the water, land and livelihood fronts.

Greenpeace recommends the Government of India to enforce an immediate moratorium on any further forest clearances for coal mining and on environmental clearances granted to inland coal-based thermal power projects and implement the following policy recommendations at the earliest.

- A transparent public consultation process must be initiated to arrive at the criteria for identifying forests which should be permanently closed to mining. These criteria need to take into account biodiversity, livelihood dependence, hydrological values and the value of intact landscapes.

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.

- The existing environment clearances for coal based power plants must be re-examined on the basis of a cumulative water impact and availability assessment in the river basins so that water conflicts between various users can be avoided and irrigation requirements of farmers are not jeopardized.

5. **Renewable Energy innovation and deployment: Supportive fiscal measures.** Renewable energy technologies are not just on the cusp of being deemed mature technologies but the price for exploitation of these technologies are also falling rapidly. Renewable energy technologies fare decently well on learning rate standards. The cost of a technology which has a learning rate of 0.90 is expected to fall by 10% every time the cumulative output from the technology doubles.

   To further reduce the cost of renewable energy technologies and to increase deployment, the government should track the following policy measures:

- Establish a renewable energy collateral fund which spreads the financial risk for businesses and individuals who want to invest in renewable energy technologies. The fund can support the initial high capital cost through soft loan for installation of renewable energy technologies for private and individual players.
- In order to fast-track the uptake of renewable energy in India, the Government of India along with corporate sector should increase the R & D spending on the sector and also incentivize the private sector to encourage innovation.
- Provision of higher capital subsidy for solar application, especially in off grid areas along with better institutionalization of capital subsidy through accessible institutional structures.
- The introduction of a digression rate in feed in tariffs for renewable energy, where FIT reduce over time in order to incentivize introduction of state of the art renewable energy technologies in India.
- Declare Renewable energy sector as priority lending sector and ensure nationalized banks and government financial institutions should provide easy soft loans to decentralized renewable energy projects.
- Reforms in the banking sector to ensure that energy efficiency projects are made financially viable.

6. **Energy Efficiency: Plugging the smart Power.** Energy Efficiency and energy modesty should be priority for the national and state energy policy as energy saved is as good as energy produced. The July electricity black-out has brought back the debate on improved demand-side management of electricity along with urgent critical reform in our power grid infrastructure. Indian power grid is currently one of the world's most inefficient power grid in transmission and distribution (T&D) loss amounting one-quarter of total electricity generated in the country despite some incremental efficiency improvement in last few years.

   Demand-side management and urgent grid reforms become critical from the facts that while we need to balance economic growth and domestic consumption of electricity, similarly, we also need to protect millions of critical forest areas, endangered species' habitats and livelihood of millions of forest-dependent communities from unmindful coal mining. From renewable energy deployment perspective as well, the grid infrastructure reform has become critical as our current power grid is inflexible to allow significant amount of renewable energy evacuation.

   Therefore, to create mandatory level of energy efficiency of all domestic and commercial usage and providing incentives and mechanisms that support this shift at the earliest; Government of India should ensure following policy reforms:

- Existing efficiency measures from grid improvement to demand side management should be incorporated through specific state level targets, involving SERCs and utilities, depending on the capacity, existing efficiency levels and grid strength of the state.
- Enabling T&D losses in India's power grid at par with global standard, better monitoring and management should be ensured, first through smart meters at consumer's level and then by integrating more advanced ICTs technologies like energy internet.
- Performance, Achieve and Trade (PAT) under National Mission of Enhanced Energy Efficiency (NMEEE) should be extended to all industry and commercial uses with progressive standard and targets along with mandatory compliances.
- Improve demand-side management with special focus on appliance efficiency in the residential and commercial sector, encompassing broad range of appliances with emphasis on consumer awareness and introduction of standardised efficient appliances in the market

the energy [r]evolution concept

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.[11] 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 1.7 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.

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.[12]

   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

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

2.2 the "3 step implementation"

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 energyefficiency 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, is valuable as a transition fuel, and can also drive cost-effective decentralisation of the energy infrastructure.

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.

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.

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

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.

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.

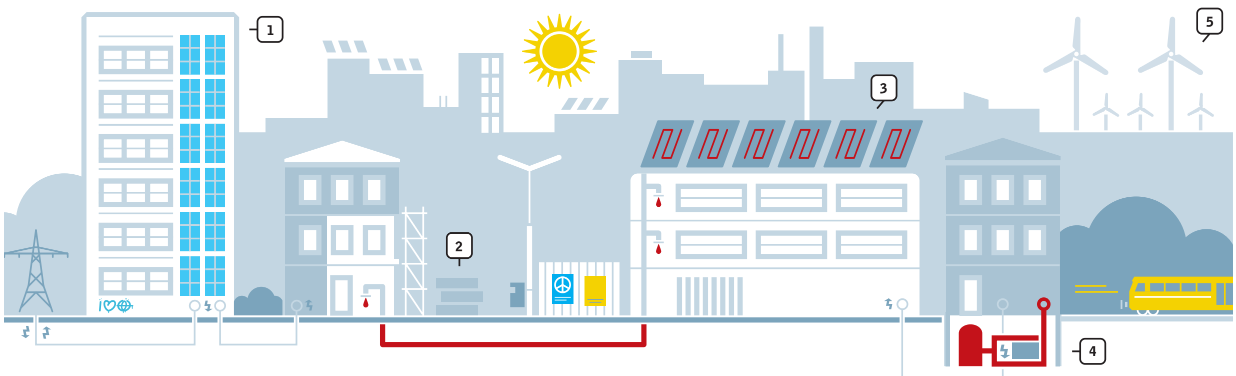
Renewable electricity The electricity sector will be the pioneer of renewable energy utilisation. Many renewable electricity technologies have been experiencing steady growth over the past 20 to 30 years of up to 35% annually and are expected to consolidate at a high level between 2030 and 2050. By 2050, 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.

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.

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.

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. 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.

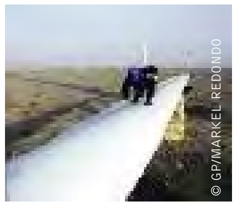
The current model is a relatively small number of large power plants that are owned and operated by utilities or their subsidiaries, generating electricity for the population. Under the Energy [R]evolution scenario, around 60 to 70% of electricity will be made by small but numerous decentralised power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

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							■

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



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.

The role of sustainable, clean renewable energy To achieve security of supply and independs from fossil fuels a massive uptake of renewable energy is required. Targets for renewable energy are needed both to substitute for fossil fuel and nuclear generation and to create the necessary economies of scale necessary for the needed expansion of the renewable industry. 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'.[13] 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.

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

13 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.

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.

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

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.[14] 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.[15] 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.[16] Together the combination ensures sufficient electricity supply to cover demand.

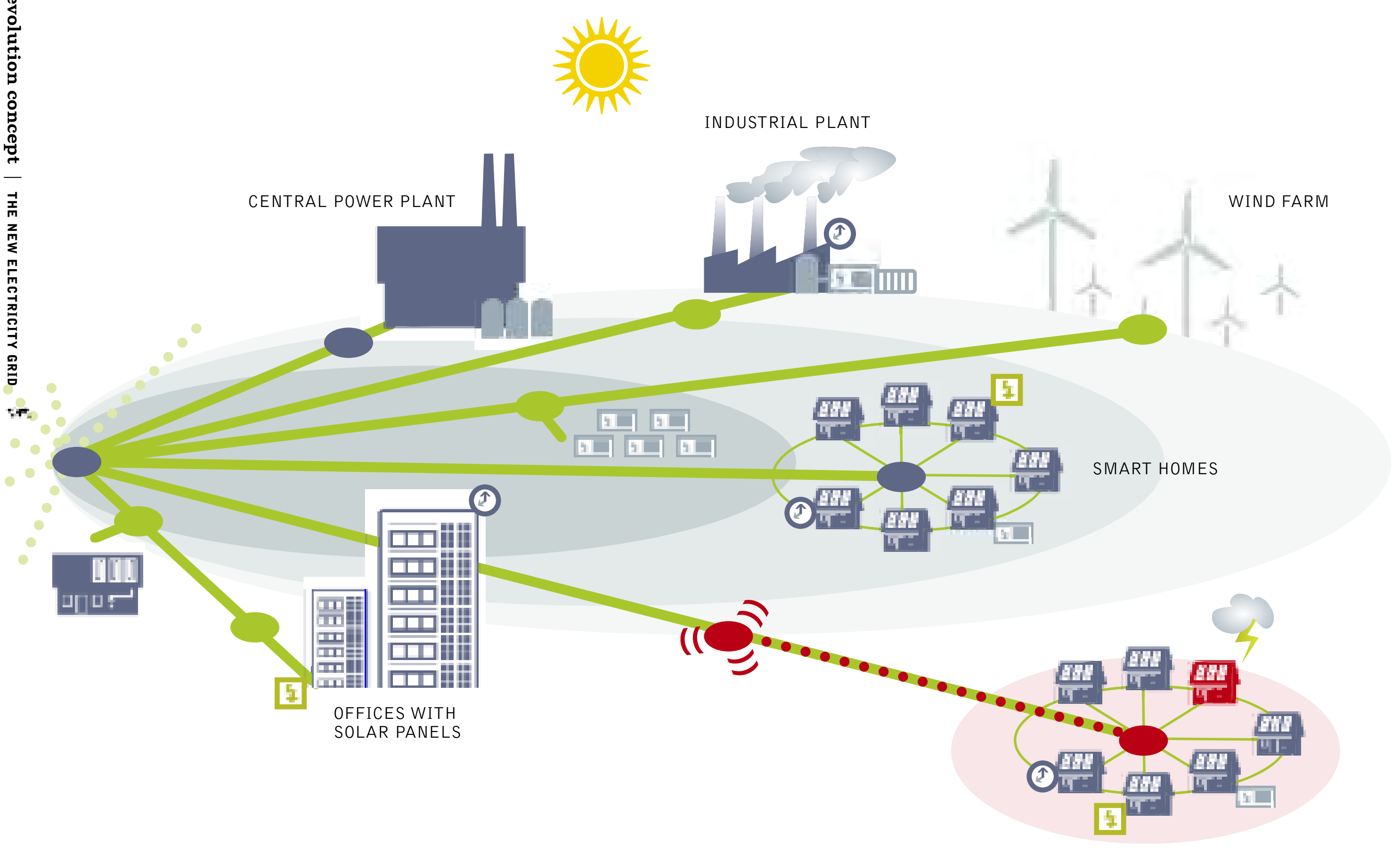
Electricity storage options. Pumped storage is the most established technology for storing energy from a type of hydroelectric power station. Water is pumped from a lower elevation reservoir to a higher elevation during times of low cost, off-peak electricity. During periods of high electrical demand, 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

14 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.
15 SEE ALSO HTTP://WWW.KOMBIKRAFTWERK.DE/INDEX.PHP?ID=27.
16 SEE ALSO HTTP://WWW.SOLARSERVER.DE/SOLARMAGAZIN/ANLAGEJANUAR2008_E.HTML.

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

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

© GP/MARKEL REDONDO

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 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. 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.

box 2.3: do we need baseload power plants?[17]

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.

references
17 BATTLE OF THE GRIDS, GREENPEACE INTERNATIONAL, FEBRUARY 2011.

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

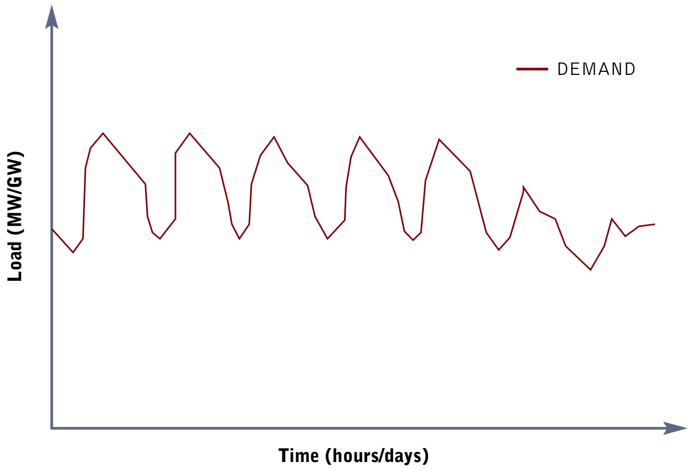
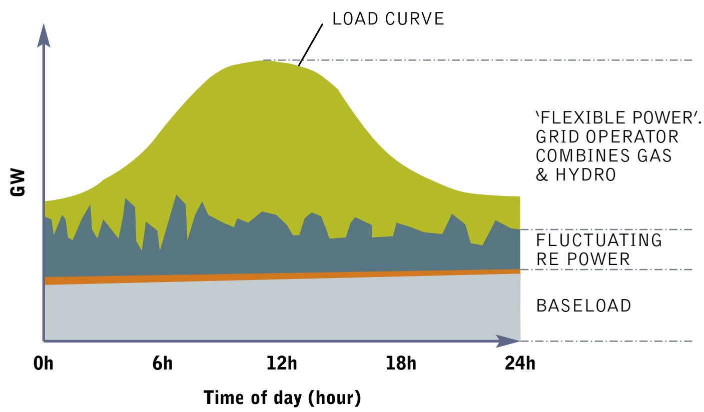


figure 2.5: the evolving approach to grids

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.

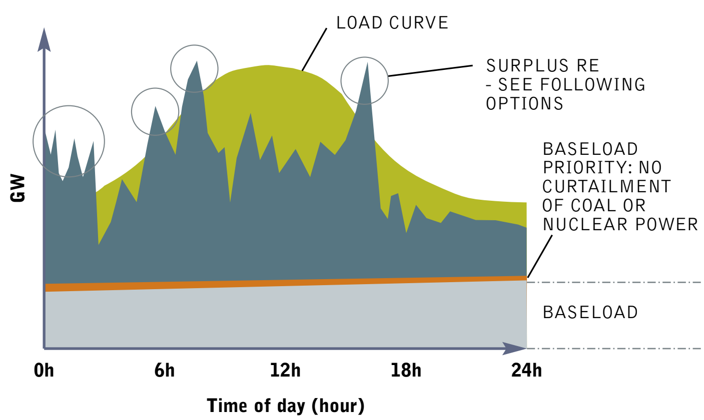


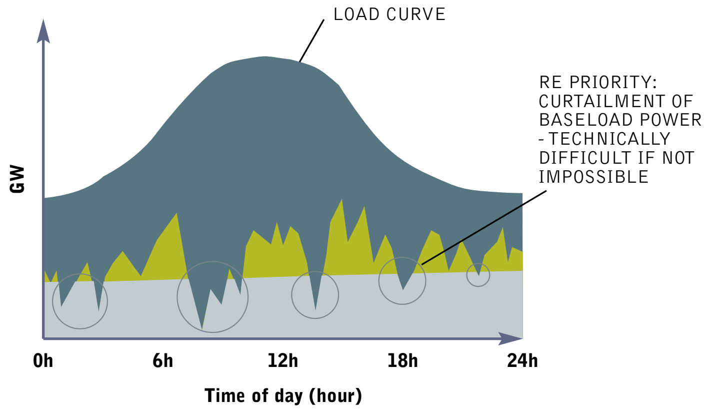
image GREENPEACE OPENS A SOLAR ENERGY WORKSHOP IN BOMA. A MOBILE PHONE GETS CHARGED BY A SOLAR ENERGY POWERED CHARGER.

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.

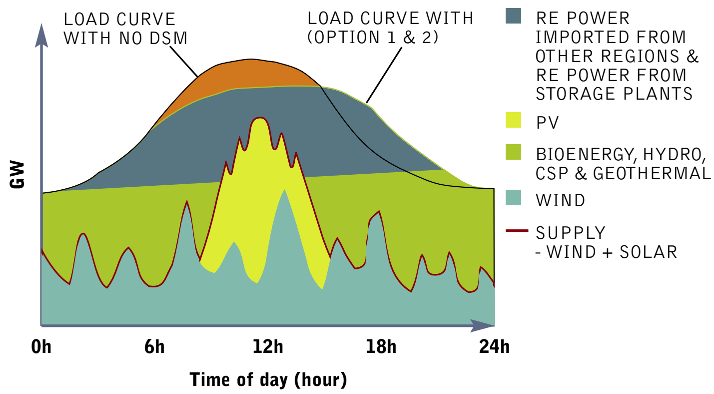
Technically difficult, not a solution.



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.

2.4 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.

2.4.1 methodology

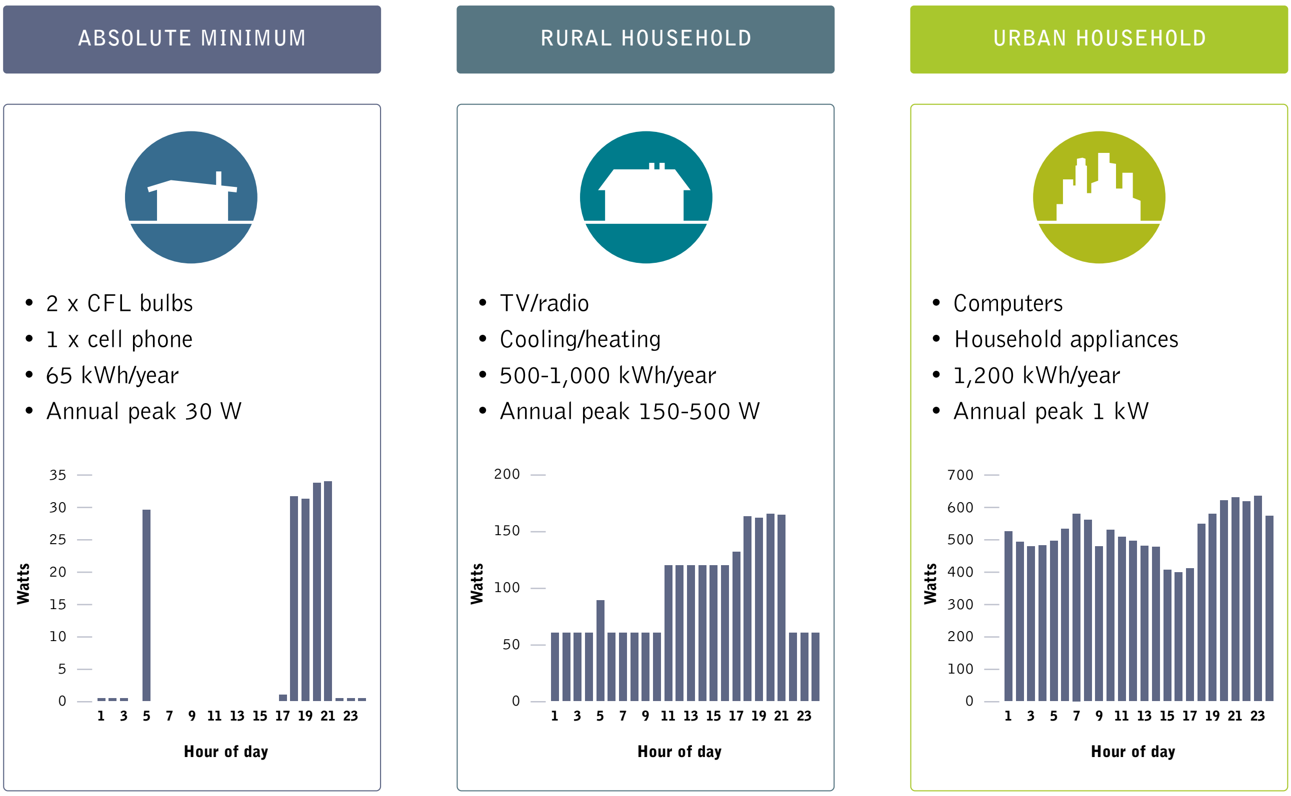
The first step is to **assess the resources** available in the area. In Bihar, these are biomass, hydro and solar PV power.

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.[18] (Figure 2.7)
- 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[19] which tests system behaviour under different operating conditions. (Figure 2.8)

figure 2.6: development of household demand



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

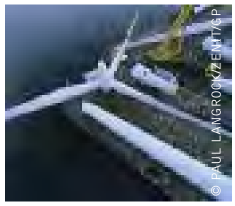
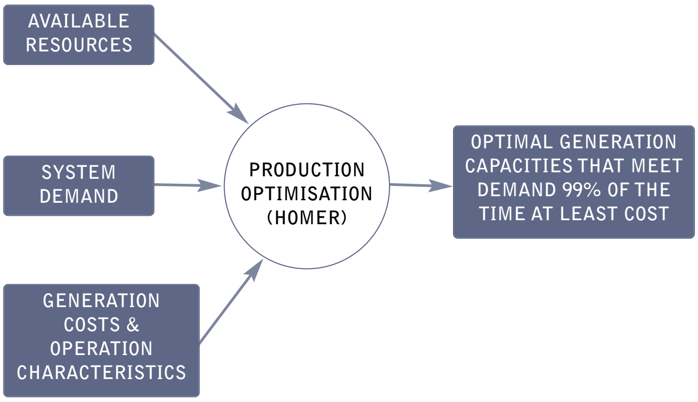


image CONSTRUCTION OF THE OFFSHORE WINDFARM AT MIDDELGRUNDEN NEAR COPENHAGEN, DENMARK.

- 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.

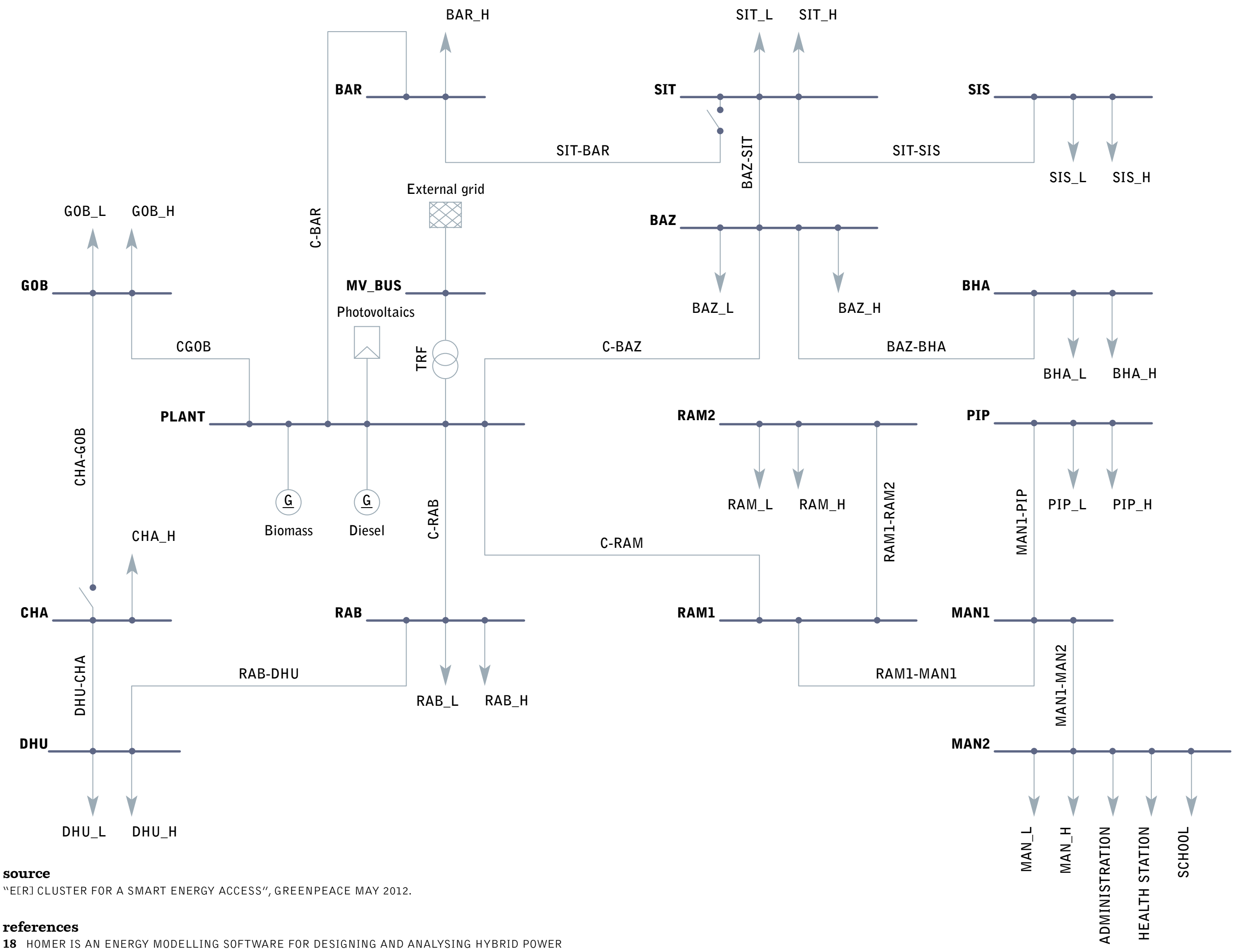
The *Smart Energy Access Concept* method can be used to develop roadmap visions and general strategy directions. It must be noted however, that detailed resource assessments, cost evaluations, demand profile forecasts and power system simulations are always required to ensure that a specific microgrid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

figure 2.7: process overview of supply system design by production optimisation



source ENERGYNAUTICS

figure 2.8: screenshot of the PowerFactory grid model.



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

source ENERGYNAUTICS

references

18 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/

19 POWERFACTORY IS A POWER SYSTEM SIMULATION SOFTWARE FOR DESIGNING AND ANALYSING POWER SYSTEMS. IT IS A LICENSED PRODUCT DEVELOPED BY DIGSILENT.

2.4.2 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[20], 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.

2.4.3 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
20 WWW.HUSKPOWERSYSTEMS.COM

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

2.5 greenpeace proposal to support a renewable energy cluster

This energy cluster system builds upon Greenpeace's Energy [R]evolution scenario[21] 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 2.2: 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
21 ENERGY [R]EVOLUTION – A SUSTAINABLE ENERG Y WORLD ENERGY OUTLOOK 2012, GREENPEACE INTERNATIONAL, AMSTERDAM – THE NETHERLANDS, JUNE 2012.

2.5.1 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.

2.6 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,[22] 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 2.6.

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[23], 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.

references

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

23 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.[24] 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 2.3: 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
24 POWER FACTORY IS A POWER SYSTEM SIMULATION SOFTWARE FOR DESIGNING AND ANALYSING POWER SYSTEMS. IT IS A LICENSED PRODUCT DEVELOPED BY DIGSILENT.

"investments in renewables are investments in the future."

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).

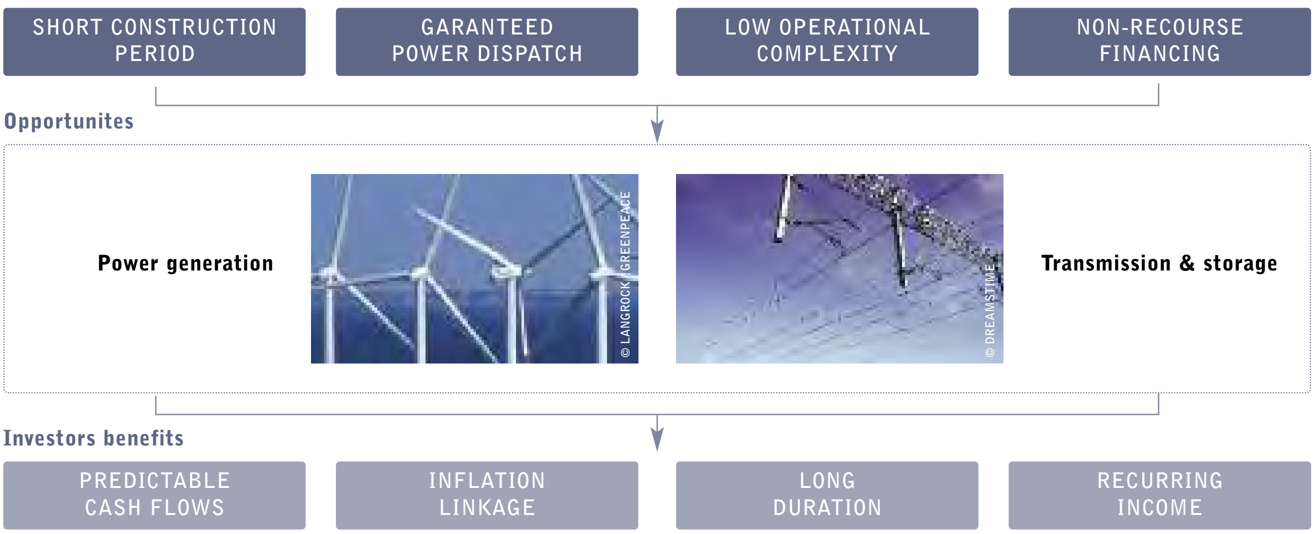
P = Project developer, **M** = Meteorological Experts, **I** = Investor, **U** = utility.

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 financing, 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 $63M^2$ 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.

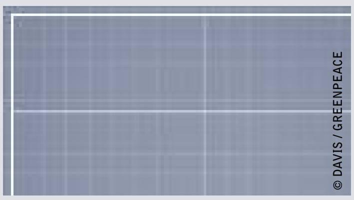
figure 3.3: investment stages of renewable energy projects

RISKS

Higher — Lower

Stage

DEVELOPMENT	CONSTRUCTION	OPERATIONS



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

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

- Operations
- Maintenance
- Refinancing
- Refurbishment/Repowering

Strategy

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

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.

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[25] 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.

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[26] 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.[27]
- 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.

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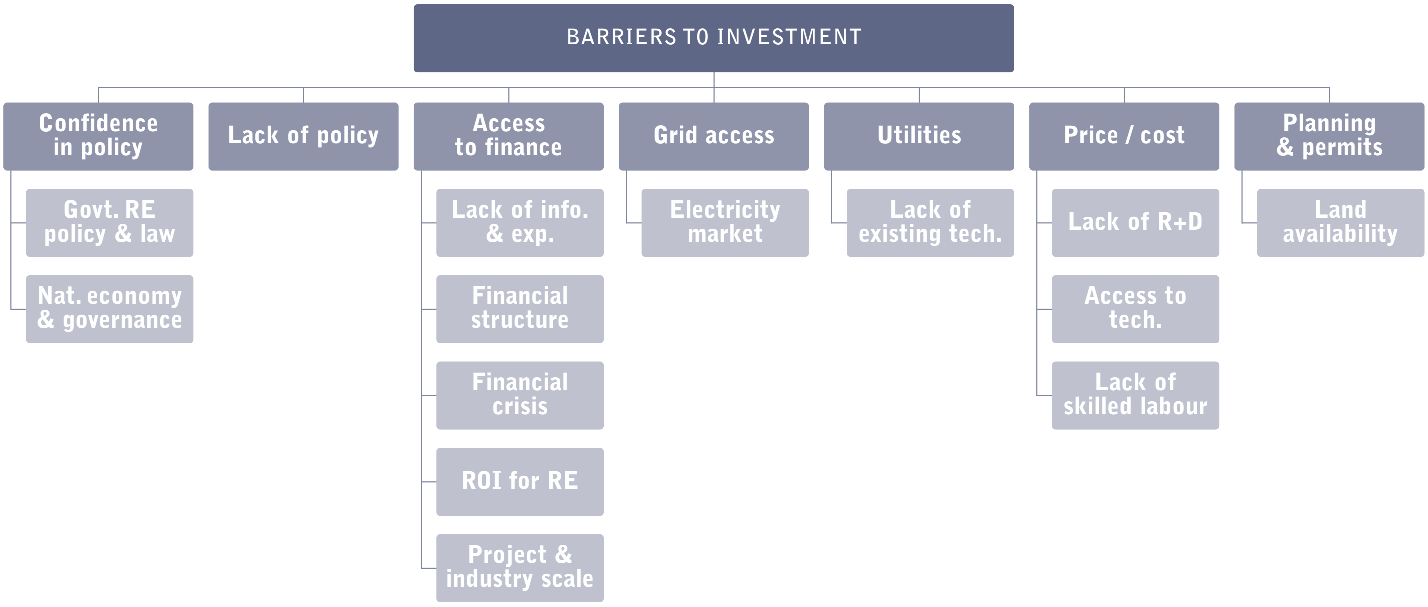
25 SOURCES INCLUDE: INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) (2011) SPECIAL REPORT ON RENEWABLE ENERGY SOURCES AND CLIMATE CHANGE MITIGATION (SRREN), 15TH JUNE 2011. UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP), BLOOMBERG NEW ENERGY FINANCE (BNEF) (2011). GLOBAL TRENDS IN RENEWABLE ENERGY INVESTMENT 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.
26 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.
27 CLIMATE POLICY INITIATIVE (2011):THE IMPACTS OF POLICY ON THE FINANCING OF RENEWABLE PROJECTS: A CASE STUDY ANALYSIS, 3 OCTOBER 2011.

figure 3.4: key barriers to renewable energy investment



key results of the india energy [r]evolution scenario

ENERGY DEMAND BY SECTOR

ELECTRICITY GENERATION

FUTURE COSTS OF ELECTRICITY GENERATION

FUTURE INVESTMENTS IN THE POWER SECTOR

HEATING SUPPLY

FUTURE INVESTMENTS IN THE HEAT SECTOR

FUTURE EMPLOYMENT IN THE ENERGY SECTOR

TRANSPORT

DEVELOPMENT OF CO_2 EMISSIONS

PRIMARY ENERGY CONSUMPTION

“exceptionally strong growth in renewable energy”

image THE AIR OVER THE TIBETAN PLATEAU TO THE NORTH OF THE HIMALAYAS IS VERY CLEAR, WHEREAS THE VIEW OF THE LAND SURFACE SOUTH OF THE MOUNTAINS IS OBSTRUCTED BY A BROWNISH HAZE. MOST OF THIS AIR POLLUTION COMES FROM HUMAN ACTIVITIES. THE AEROSOL OVER THIS REGION IS NOTORIOUSLY RICH IN SULFATES, NITRATES, ORGANIC AND BLACK CARBON, AND FLY ASH. THESE PARTICLES NOT ONLY REPRESENT A HEALTH HAZARD TO THOSE PEOPLE LIVING IN THE REGION, BUT SCIENTISTS HAVE ALSO RECENTLY FOUND THAT THEY CAN HAVE A SIGNIFICANT IMPACT ON THE REGION’S HYDROLOGICAL CYCLE AND CLIMATE.

energy demand by sector

The future development pathways for India's energy demand are shown in Figure 4.1 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 4.2). 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 4.4). Compared to the Reference scenario, consumption equivalent to 3,560 PJ/a is avoided through efficiency measures by 2050.

figure 4.1: total final energy demand by sector under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

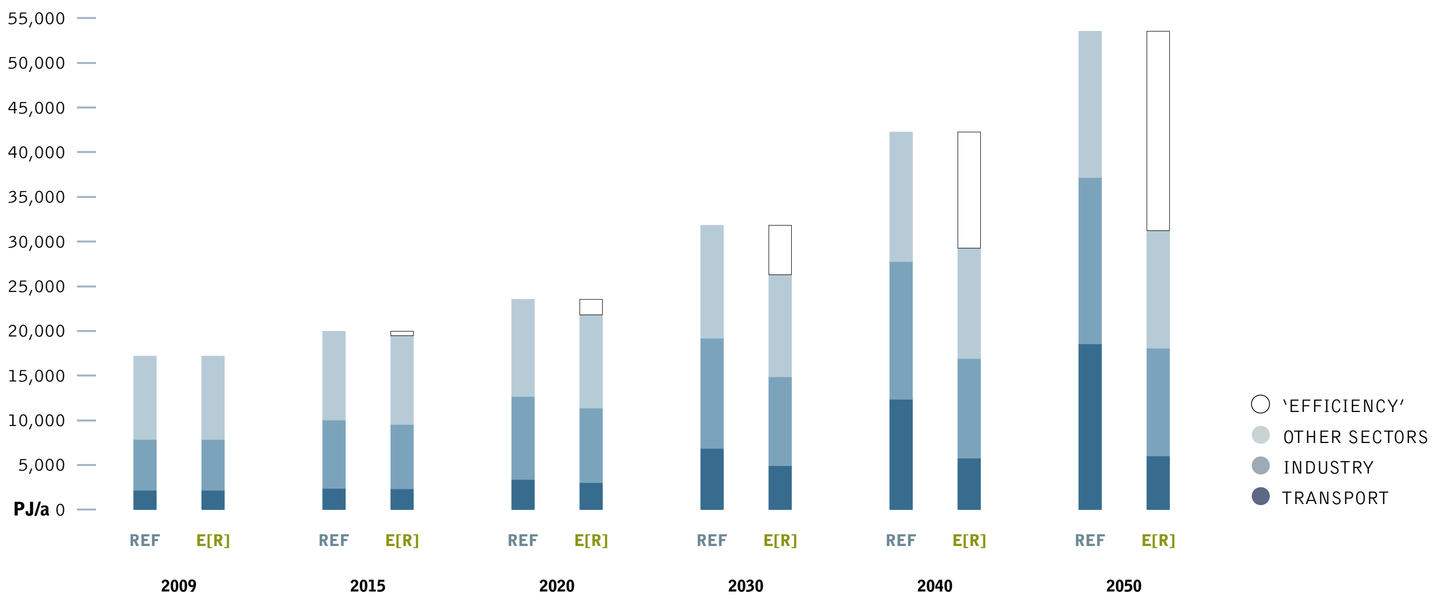


image AJIT DAS LIVES IN GHORAMARA ISLAND AND IS ONE OF THE MANY PEOPLE AFFECTED BY SEA LEVEL RISE: "WE CANNOT STAY HERE BECAUSE OF THE GANGA'S FLOODING. WE HAVE MANY PROBLEMS. WE DON'T KNOW WHERE WE WILL GO OR WHAT WE WILL DO. WE CANNOT BRING OUR GRANDCHILDREN UP HERE. WHATEVER THE GOVERNMENT DECIDES 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 4.2: development of electricity demand by sector in the energy [r]evolution scenario

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

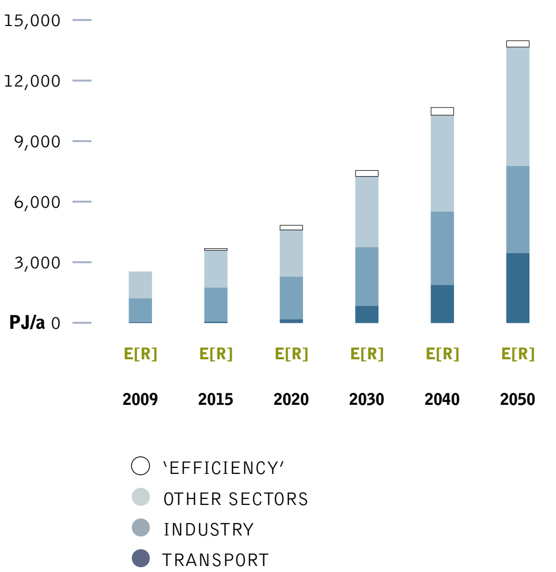


figure 4.4: development of heat demand by sector in the energy [r]evolution scenario

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

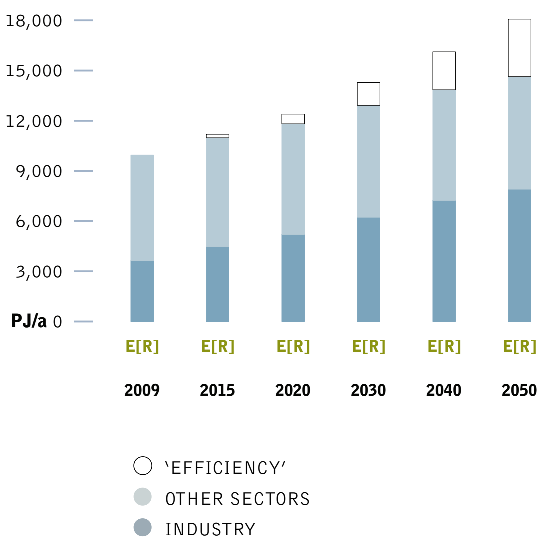
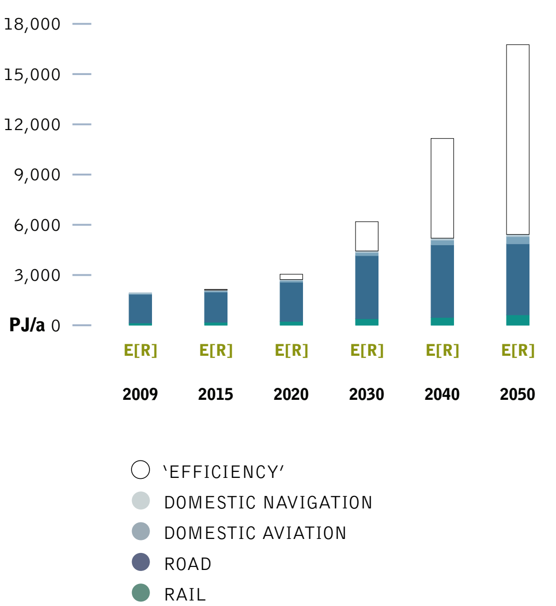


figure 4.3: development of the transport demand by sector in the energy [r]evolution scenario



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 4.1 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 4.1: 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 4.5: electricity generation structure under the reference scenario and the energy [r]evolution scenario (INCLUDING ELECTRICITY FOR ELECTROMOBILITY, HEAT PUMPS AND HYDROGEN GENERATION)

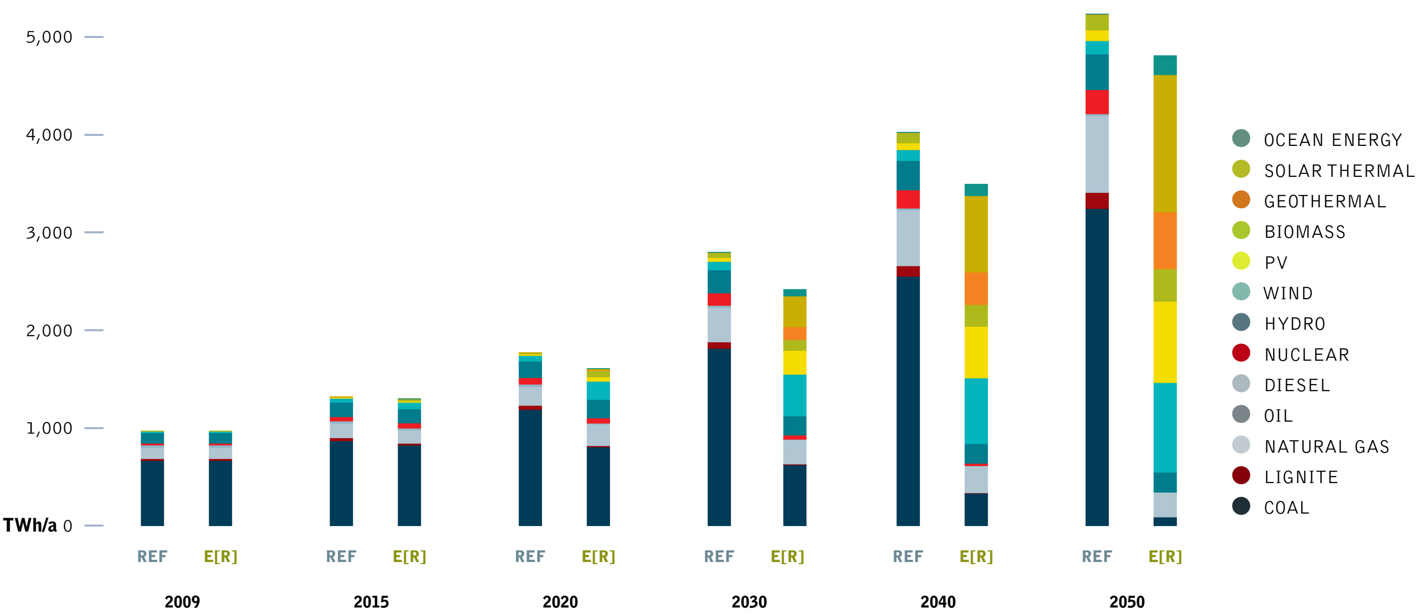


image A LOCAL BENGALI WOMAN PLANTS A MANGROVE (SUNDARI) SAPLING ON SAGAR ISLAND IN THE ECOLOGICALLY SENSITIVE SUNDERBANS RIVER DELTA REGION, IN WEST BENGAL. THOUSANDS OF LOCAL PEOPLE WILL JOIN THE MANGROVE PLANTING INITIATIVE LED BY PROFESSOR SUGATA HAZRA FROM JADAVAPUR UNIVERSITY, WHICH WILL HELP TO PROTECT THE COAST FROM EROSION AND WILL ALSO PROVIDE NUTRIENTS FOR FISH AND CAPTURE CARBON IN THEIR EXTENSIVE ROOT SYSTEMS.

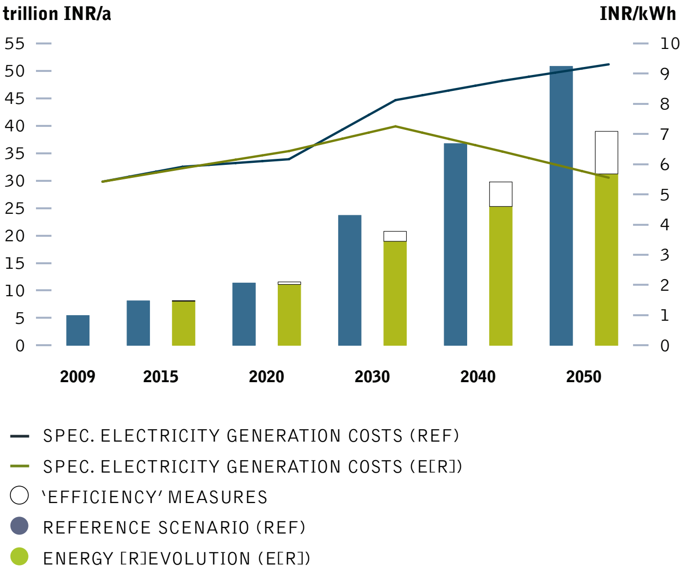
image FEMALE WORKER CLEANING A SOLAR OVEN AT A COLLEGE IN TILONIA, RAJASTHAN, INDIA.

future costs of electricity generation

Figure 4.6 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 INR 0.5 ($ 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 INR 3.7 ($ 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 INR 5.2 trillion ($ 100 billion) per year to more than INR 48.2 trillion ($ 932 billion) in 2050. Figure 4.6 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 4.6: total electricity supply costs and specific electricity generation costs under two scenarios

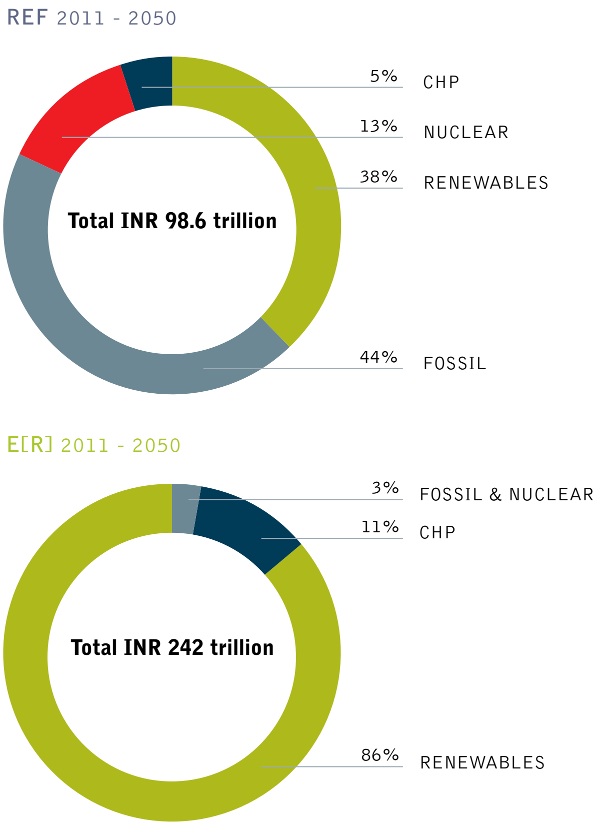


future investments in the power sector

It would require about INR 242 trillion ($ 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 INR 6.1 trillion ($ 117 billion) annually or INR 3.6 trillion ($ 69 billion) more than in the Reference scenario (INR 98.6 trillion/$ 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 INR 6.1 trillion ($ 117 billion).

Because renewable energy has no fuel costs, however, the fuel cost savings in the Energy [R]evolution scenario reach a total of INR 285 trillion ($ 5,500 billion) up to 2050, or INR 7.1 trillion ($ 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 4.7: investment shares - reference scenario versus energy [r]evolution scenario



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 4.2 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 4.2: 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 4.8: heat supply structure under the reference scenario and the energy [r]evolution scenario

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

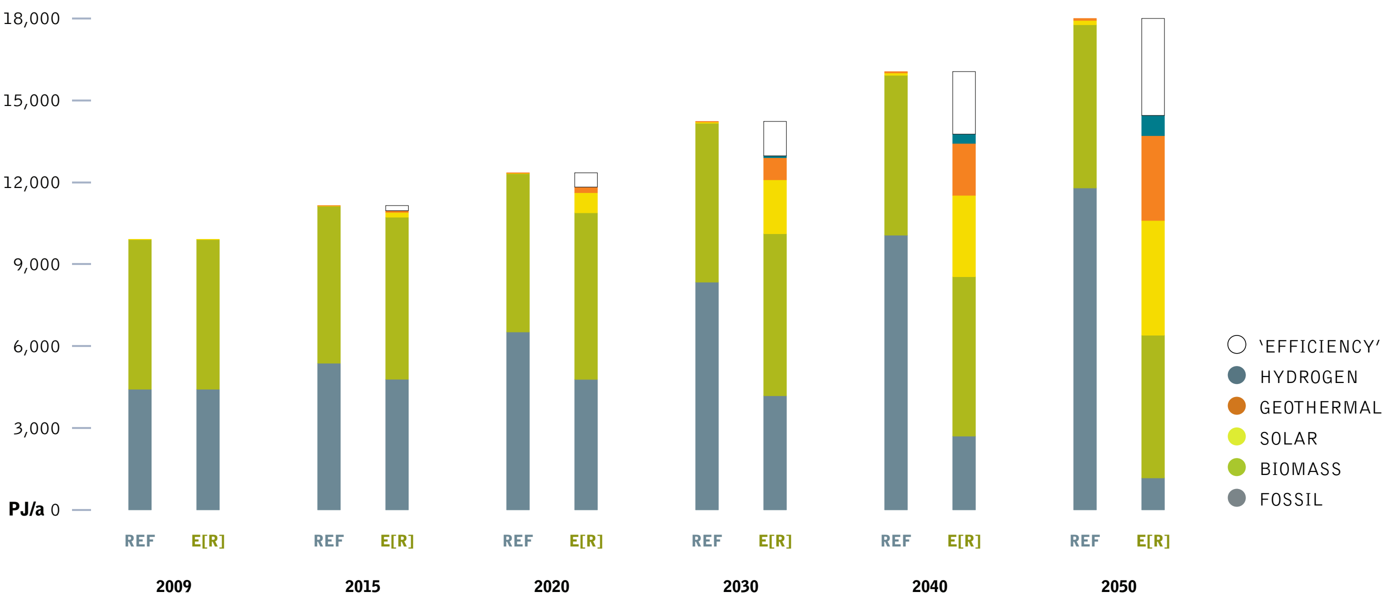
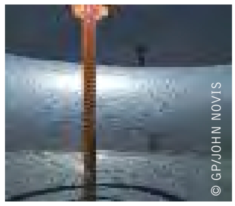


image NANLINIKANT BISWAS, FARMER AGE 43. FIFTEEN YEARS AGO NANLINIKANT'S FAMILY ONCE LIVED WHERE THE SEA IS NOW. THEY WERE AFFLUENT AND OWNED FOUR ACRES OF LAND. BUT RISING SEAWATER INCREASED THE SALINITY OF THE SOIL UNTIL THEY COULD NO LONGER CULTIVATE IT, KANHAPUR, ORISSA, INDIA.

image A SOLAR DISH WHICH IS ON TOP OF THE SOLAR KITCHEN AT AUROVILLE, TAMIL NADU, INDIA.



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.

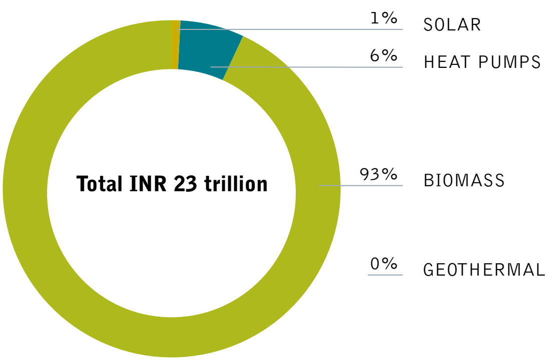
Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar thermal district heating plants with seasonal storage. Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around INR 66.9 trillion ($ 1,293 billion) to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately INR 1.7 ($ 32 billion) per year.

table 4.3: renewable heat generation capacities under the reference scenario and the energy [r]evolution scenario IN GW

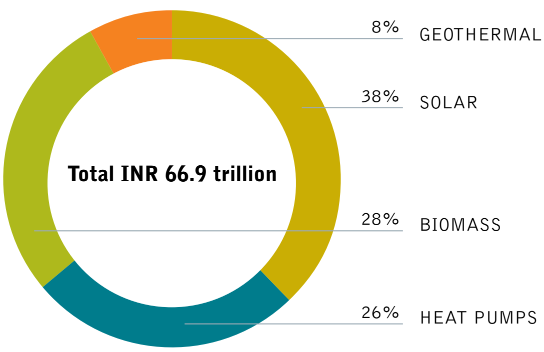
		2009	2020	2030	2040	2050
Biomass	REF	2,082	2,197	2,176	2,127	2,082
	E[R]	2,082	2,173	1,954	1,699	1,333
Geothermal	REF	0	0	0	0	0
	E[R]	0	11	23	65	120
Solar thermal	REF	3	6	11	21	37
	E[R]	3	170	452	669	927
Heat pumps	REF	0	1	4	9	14
	E[R]	0	17	62	100	141
Total	**REF**	**2,084**	**2,205**	**2,191**	**2,157**	**2,132**
	E[R]	**2,084**	**2,370**	**2,491**	**2,533**	**2,521**

figure 4.9: investments for renewable heat generation technologies under the reference scenario and the energy [r]evolution scenario

REF 2011 - 2050



E[R] 2011 - 2050



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 4.10 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 4.10: employment in the energy scenario under the reference and energy [r]evolution scenarios

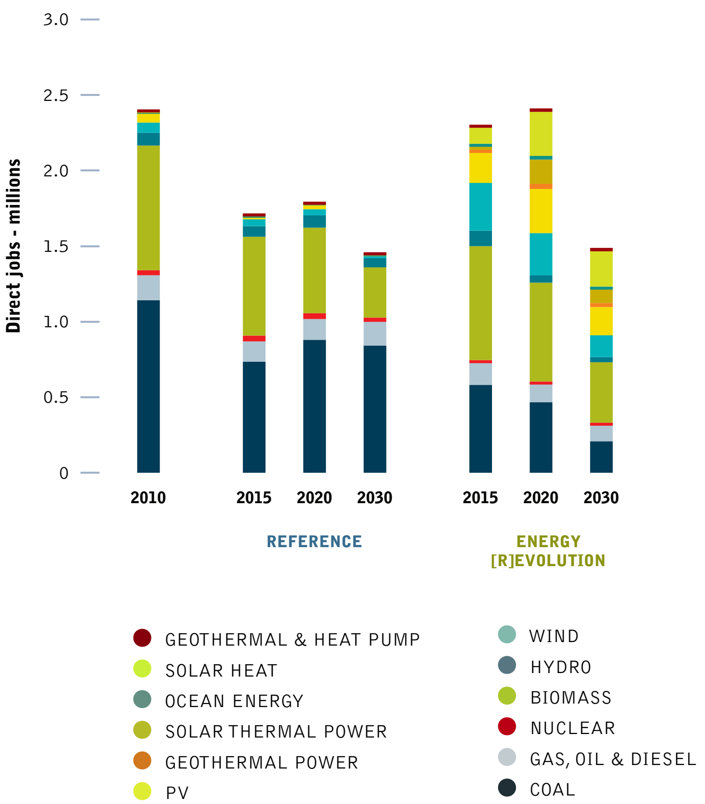


table 4.4: total employment in the energy sector THOUSAND JOBS

		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.

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.

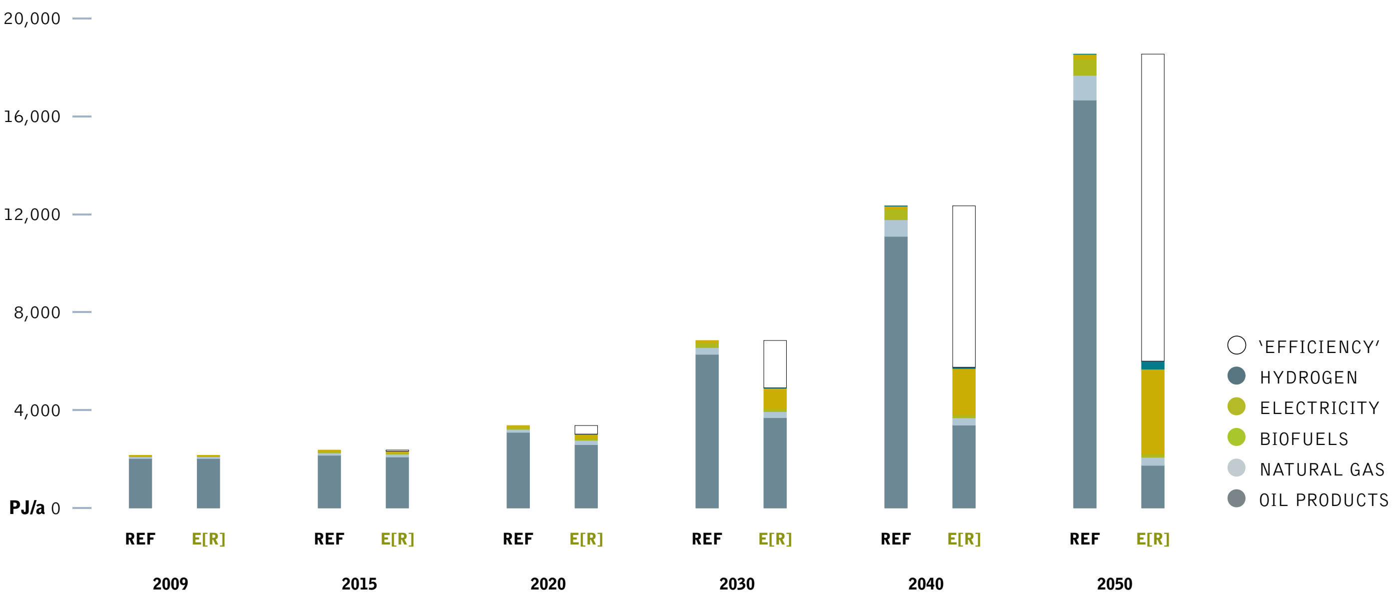
A shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains and a reduction of vehicle kilometres travelled by 0.25% per year leads to significant energy savings. In 2030, electricity will provide 17% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 58%.

table 4.5: 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 4.11: final energy consumption for transport under the reference scenario and the energy [r]evolution scenario



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.

primary energy consumption

Taking into account the above assumptions, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 4.13. 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 4.12: development of CO_2 emissions by sector under the energy [r]evolution scenario
('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

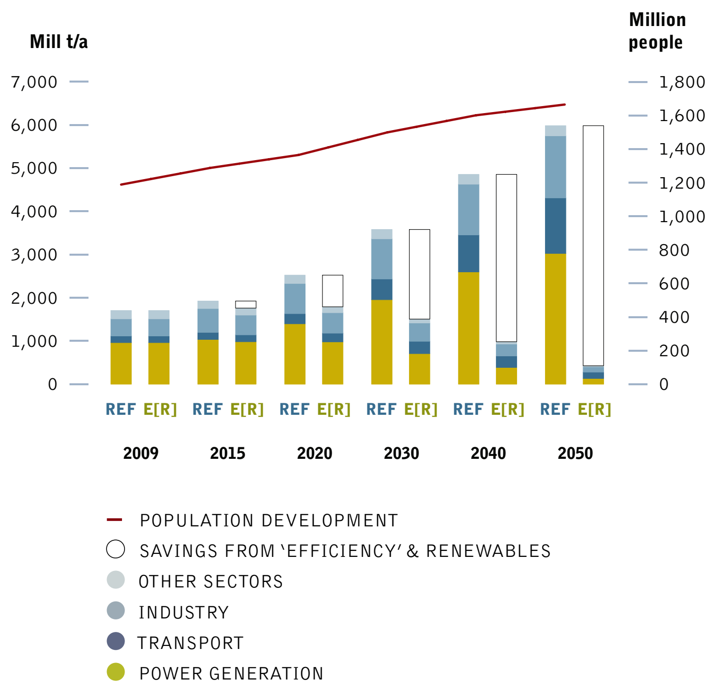


figure 4.13: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

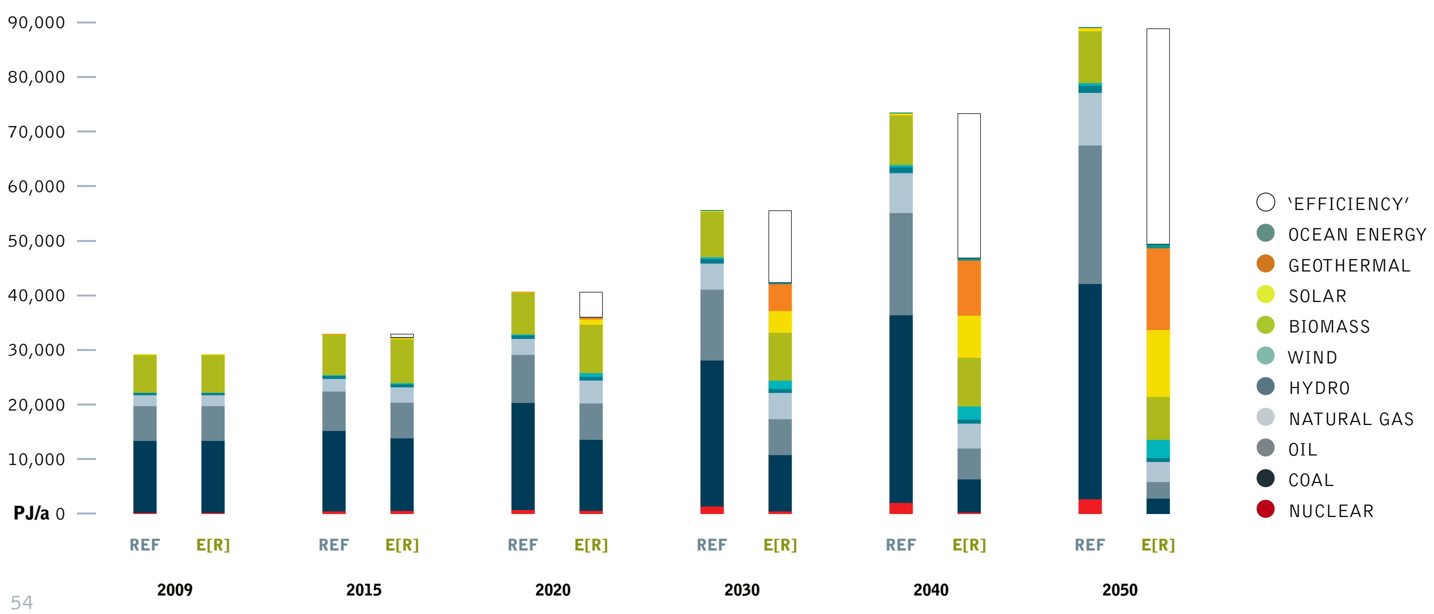


image ANANTHAMMA, A LOCAL WOMAN, RUNS A SMALL SHOP FROM HER HOME IN VADIGERE VILLAGE, AN ACTIVITY ENABLED DUE TO THE TIME SAVED BY RUNNING HER KITCHEN ON BIOGAS. THE COMMUNITY IN BAGEPALLI HAS PIONEERED THE USE OF RENEWABLE ENERGY IN ITS DAILY LIFE THANKS TO THE BIOGAS CLEAN DEVELOPMENT MECHANISM (CDM) 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.

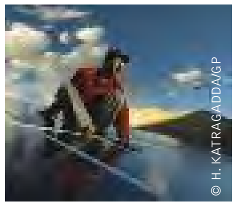


table 4.6: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

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 $	-4.50	-12.79	-16.07	-16.07	51.85	-1.29
Renewables	billion $	12.58	49.17	54.60	54.60	195.25	4.88
Total	billion $	**8.07**	**36.39**	**38.53**	**38.53**	**143.39**	**3.59**

CUMULATIVE FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion $/a	1.11	4.09	4.47	3.49	13.17	0.33
Gas	billion $/a	-1.95	-0.94	16.33	44.51	57.94	1.45
Hard coal	billion $/a	4.38	30.50	68.48	107.47	210.83	5.27
Lignite	billion $/a	0.15	0.47	0.86	1.42	2.89	0.07
Total	billion $/a	**3.70**	**34.11**	**90.14**	**156.89**	**284.84**	**7.12**

5

employment projections

"economy and ecology goes hand in hand with new employment."

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.

5.1 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.[28] 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 5.1.

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 5.1: 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
28 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.

5.2 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 5.2 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[29] 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.[30] 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 5.2: summary of employment factors used in global analysis 2012

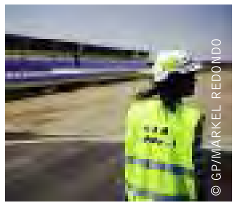
FUEL	CONSTRUCTION & INSTALLATION *Job years/MW*	MANUFACTURING *Jobs/MW*	OPERATION & MAINTENANCE *Jobs/MW*	FUEL – PRIMARY ENERGY DEMAND *Jobs/PJ*
Coal	7.7	3.5	0.1	regional
Gas	1.7	1.0	0.08	22
Nuclear	14	1.3	0.3	0.001 jobs per GWh (final energy demand)
Biomass	14	2.9	1.5	32
Hydro-large	6.0	1.5	0.3	
Hydro-small	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

29 INTERNATIONAL ENERGY AGENCY STATISTICS, AVAILABLE FROM HTTP://WWW.IEA.ORG/STATS/INDEX.ASP
30 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.



5.3 regional adjustments

More details of all the regional adjustments, including their derivation, can be found in the detailed methodology document.[31]

5.3.1 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 5.4.

5.3.2 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.

5.3.3 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.

5.3.4 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 5.4: 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 5.3: 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
31 JAY RUTOVITZ AND STEPHEN HARRIS. 2012. CALCULATING GLOBAL ENERGY SECTOR JOBS: 2012 METHODOLOGY.

table 5.5: 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 5.1: proportion of fossil fuel and renewable employment at 2010 and 2030

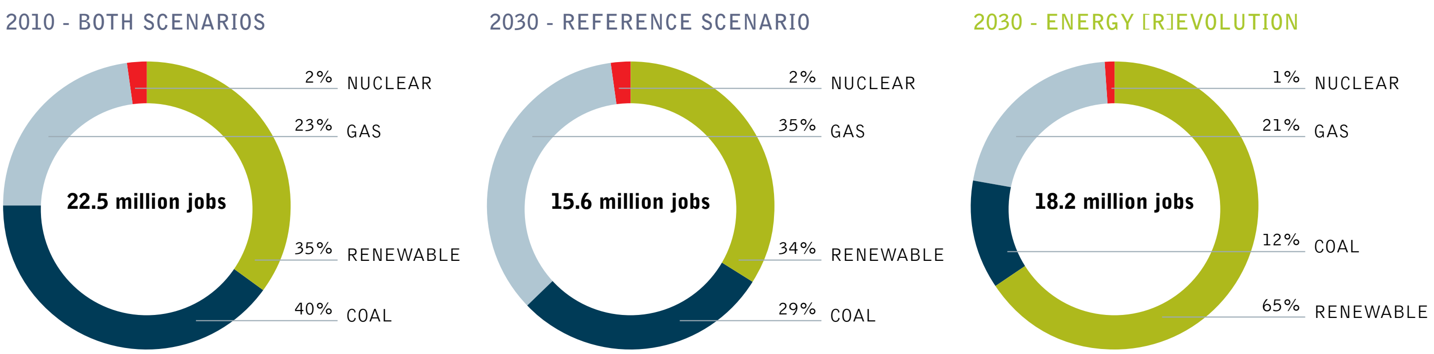


image A WORKER STANDS BETWEEN WIND TURBINE ROTORS AT GANSU JINFENG WIND POWER EQUIPMENT CO. LTD. IN JIUQUAN, GANSU PROVINCE, CHINA.

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5.4 fossil fuels and nuclear energy - employment, investment, and capacities

5.4.1 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.

5.4.2 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.

5.4.3 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 5.6: 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

5.5 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.

5.5.1 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.

5.5.2 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 5.7: 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 5.8: 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.

5.5.3 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.

5.5.4 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 5.9: 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 5.10: 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

5.5.5 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.

5.5.6 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 5.11: 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 5.12: 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.

5.6 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.

5.6.1 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.

5.6.2 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.

5.6.3 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 5.13: 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 5.14: 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 5.15: 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

THE GLOBAL RENEWABLE ENERGY MARKET

THE GLOBAL POWER PLANT MARKET

6

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.

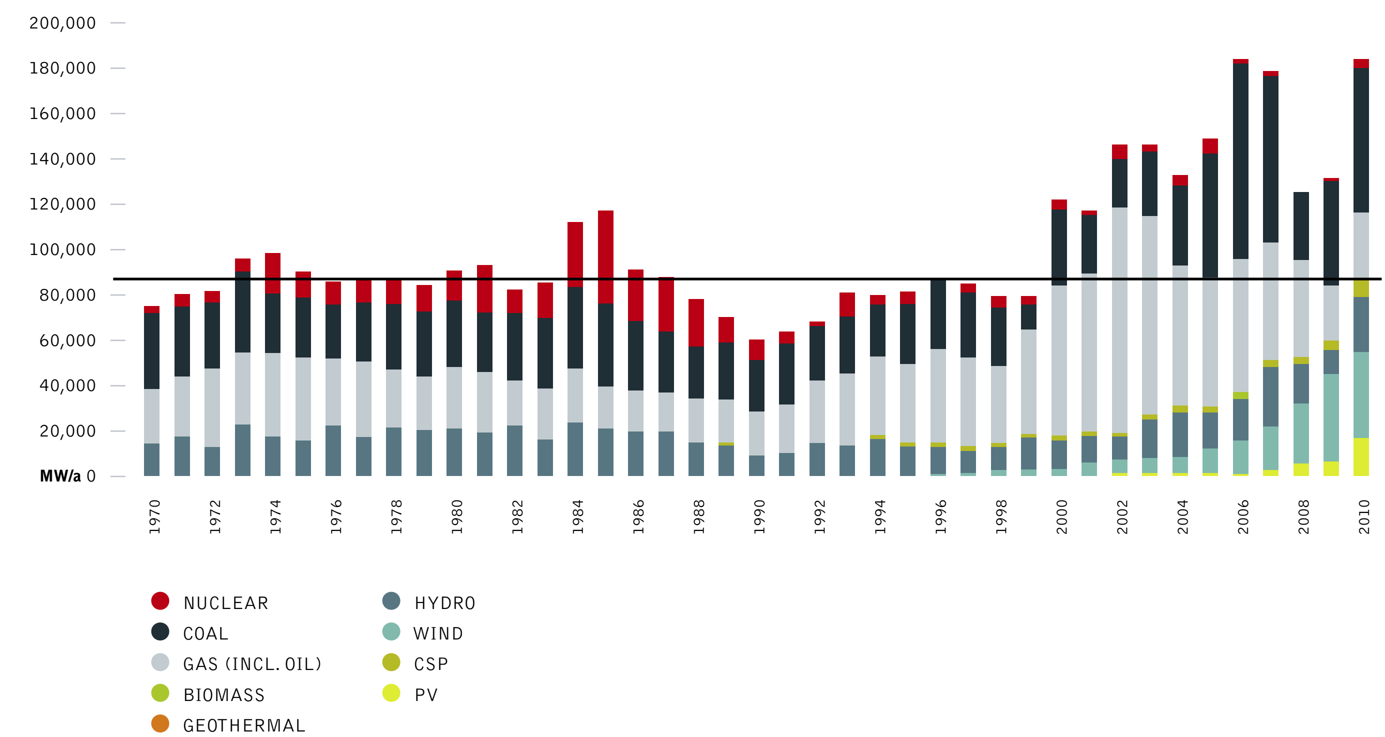
The global market volume of renewable energies in 2010 was on average, equal the total global energy market volume each year between 1970 and 2000. There is a window of opportunity for new renewable energy installations to replace old plants in OECD countries and for electrification in developing countries. 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[32] 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.

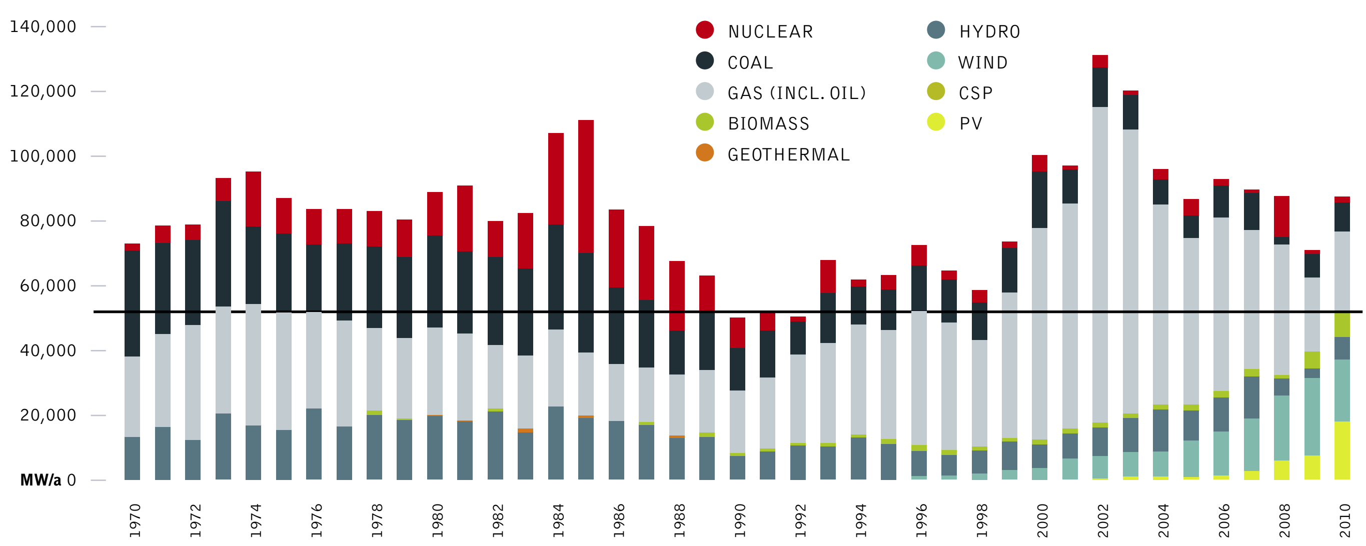
figure 6.1: global power plant market 1970-2010



source
Platts, IEA, Breyer, Teske.

reference
32 ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT.

figure 6.2: global power plant market 1970-2010, excluding china



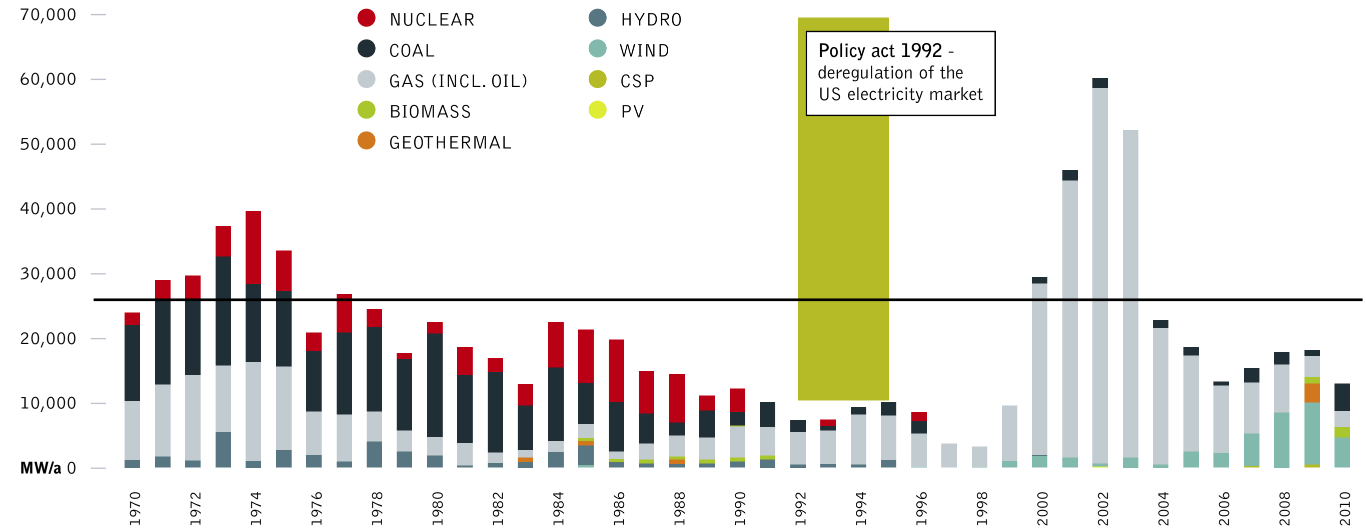
source
Platts, IEA, Breyer, Teske.

6.1 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 6.3: 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.

India: Since the late 1990th, India economy grows steady and the demand for power increased significantly. However the power plant market is very volatile, but dominated from new coal power plants as well as large scale hydro power plants. Compared to China, the power plant market is up to factor 10 smaller. Also the market for wind energy is not at all as developed as in China, where the annula market doubled every year between 2003 and 2010. China installed twice a s much wind capacity in 2010, than India installed all new power plants - including coal - combined. Between 2000 and 2010, 35% of all new power plants were based on coal, 18% on gas and only 22% new renewables. Nuclear reamins marginal and the additional new nuclear capacity is still irrelevant compared to the overall power porduction.

figure 6.4: india: power plant market 1970-2010

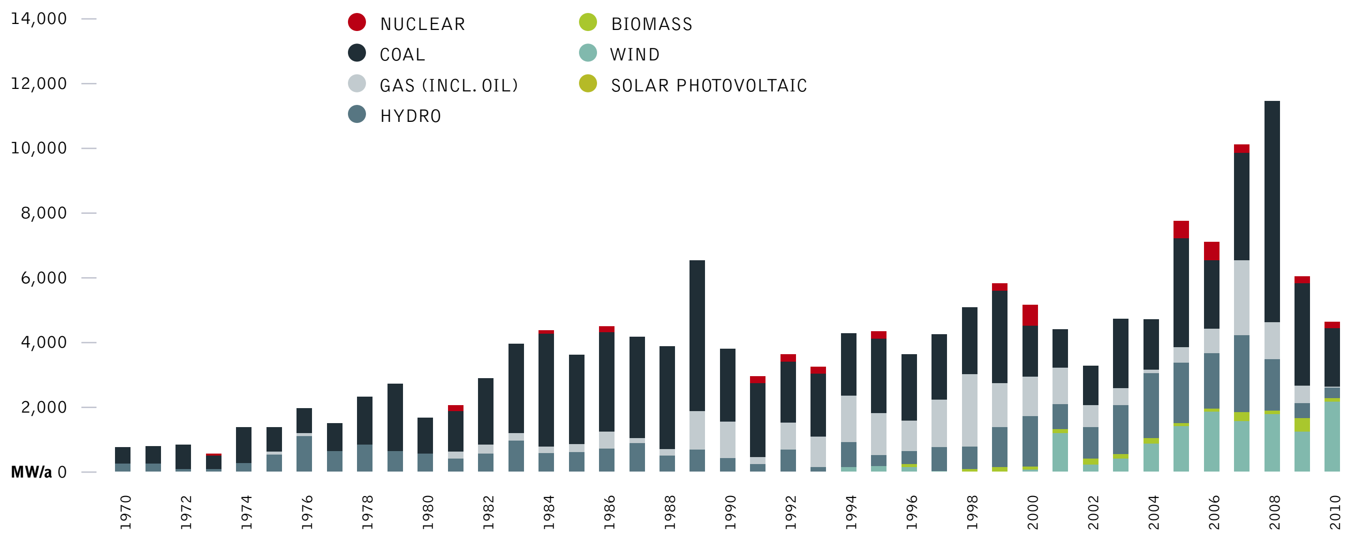
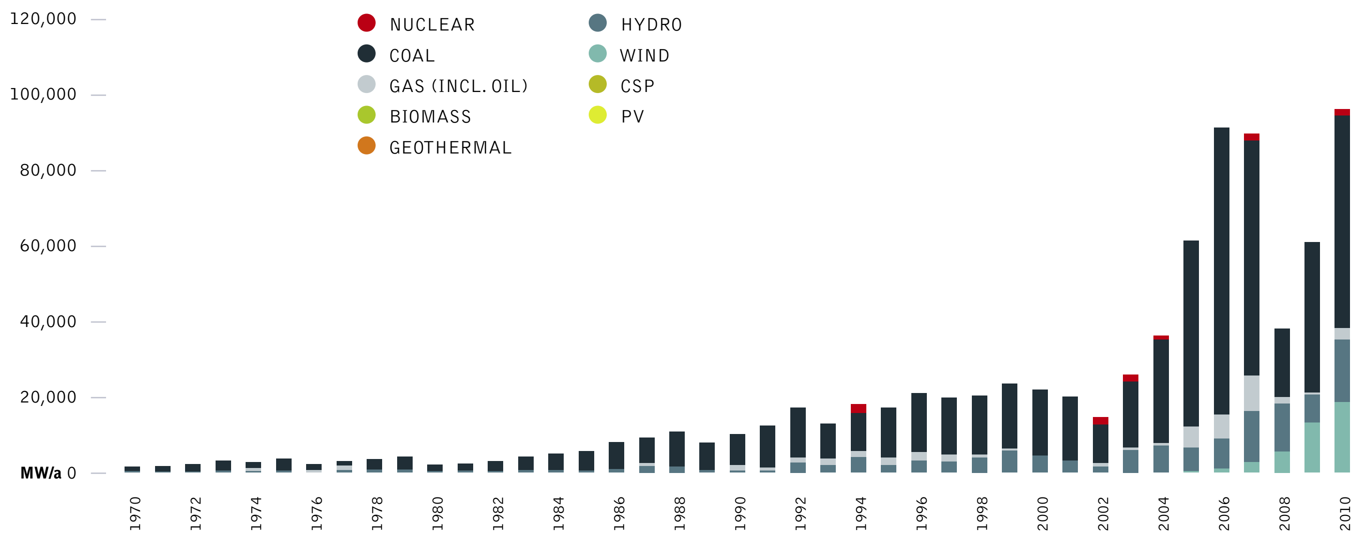


figure 6.5: china: power plant market 1970-2010



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[33] 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.

6.2 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.

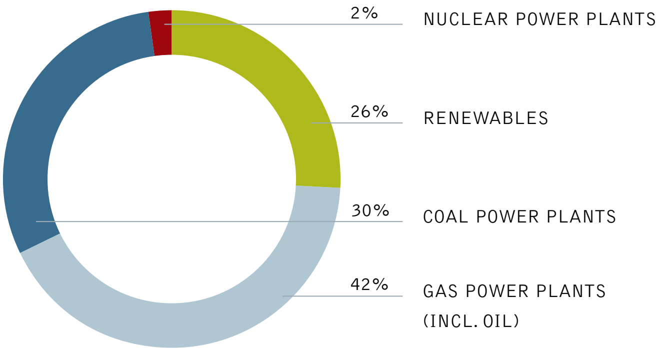
reference

33 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.

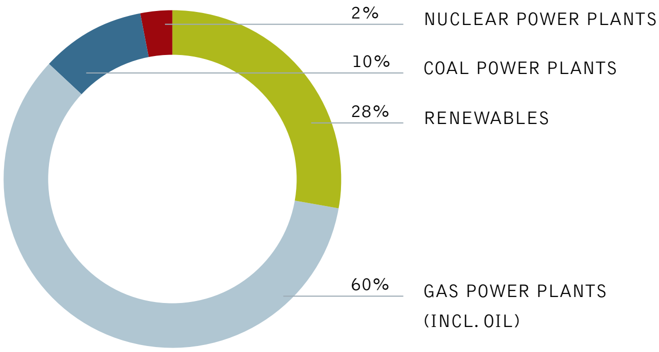
image WITNESSES FROM FUKUSHIMA, JAPAN, KANAKO NISHIKATA, HER TWO CHILDREN KAITO AND FUU AND TATSUKO OGAWARA VISIT A WIND FARM IN KLENNOW IN WENDLAND.

figure 6.6: power plant market shares

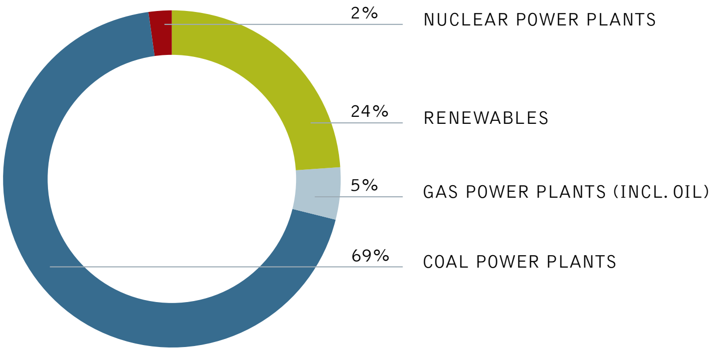
global power plant market shares 2000-2010



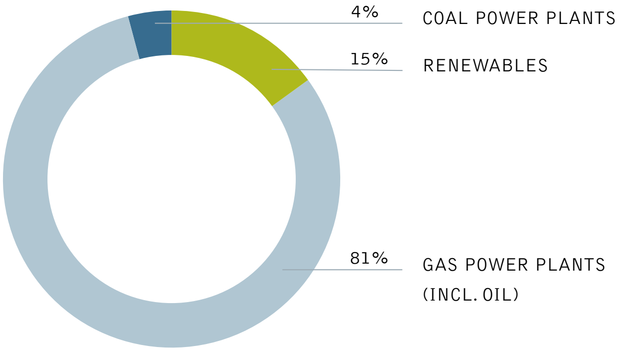
global power plant market shares 2000-2010 - excluding china



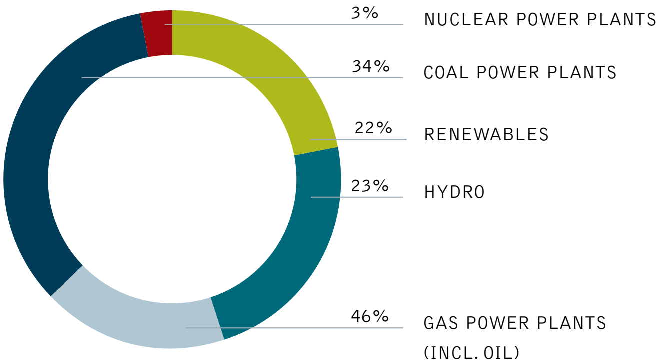
china: power plant market shares 2000-2010



usa: power plant market shares 2000-2010



india: power plant market shares 2000-2010



source PLATTS, IEA, BREYER, TESKE, GWAC, EPIA.

6.3 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.

6.4 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 6.1: 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 6.9: global power plant market 2011

NEW POWER PLANTS BY TECHNOLOGY INSTALLED & UNDER CONSTRUCTION IN 2011

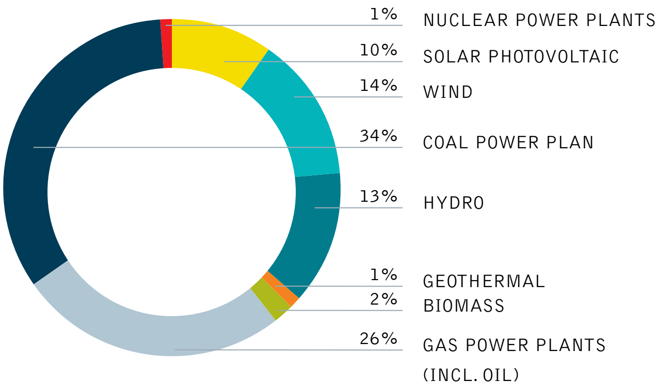
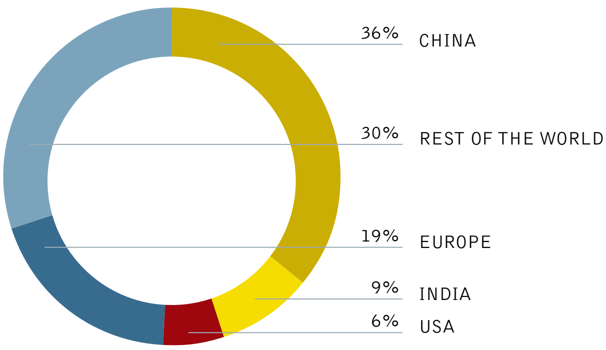


figure 6.8: global power plant by region

NEW INSTALLATIONS IN 2011



glossary & appendix

GLOSSARY OF COMMONLY USED TERMS AND ABBREVIATIONS

DEFINITION OF SECTORS

“because we use such inefficient lighting, 80 coal fired power plants are running day and night to produce the energy that is wasted.”

© NASA/JESSE ALLEN, ROBERT SIMMON

image ICEBERGS FLOATING IN MACKENZIE BAY ON THE THE NORTHEASTERN EDGE OF ANTARCTICA’S AMERY ICE SHELF, EARLY FEBRUARY 2012.

7.1 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 7.1: 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 7.2: 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

7.2 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")

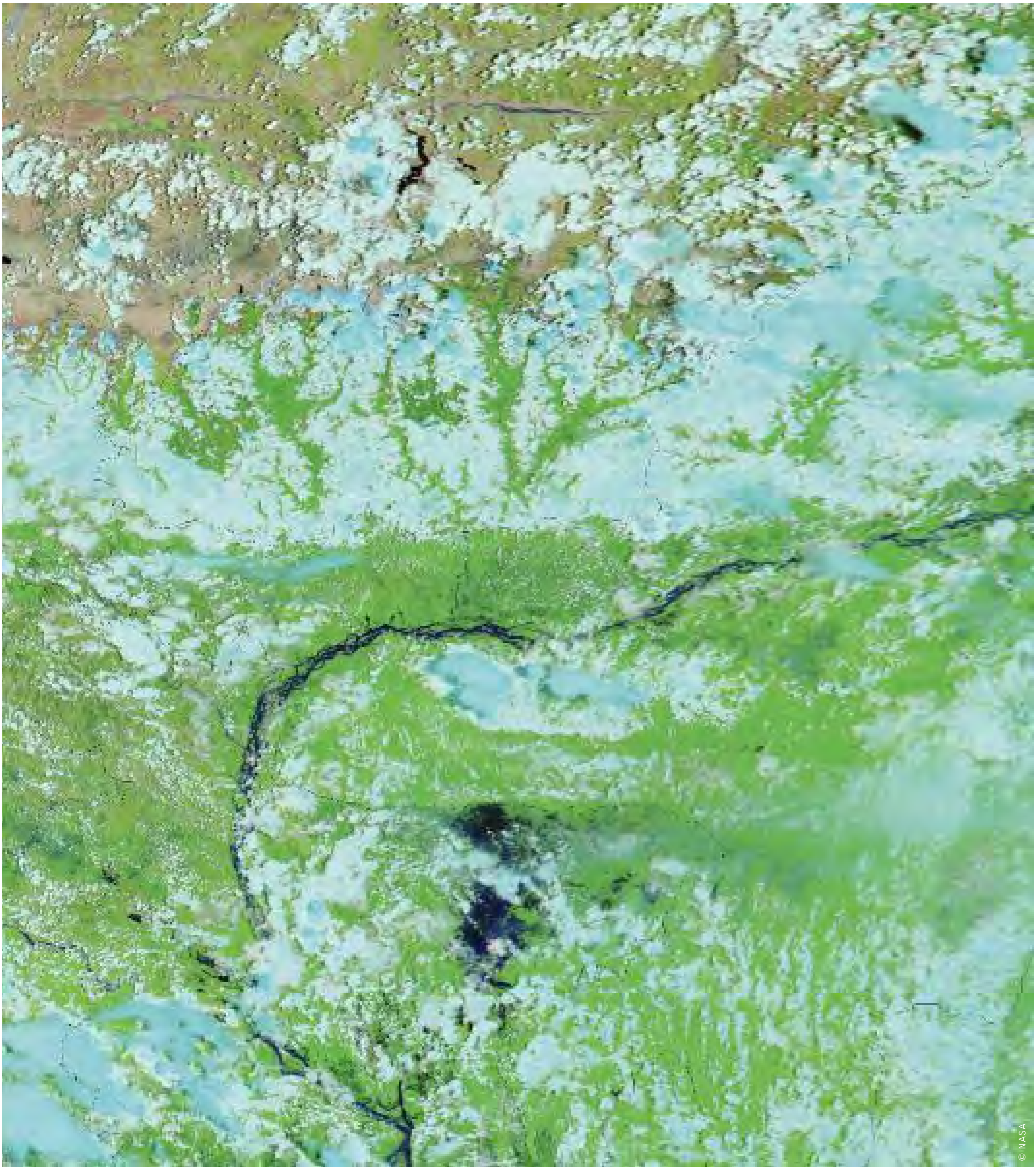
- Iron and steel industry
- Chemical industry
- Non-metallic mineral products e.g. glass, ceramic, cement etc.
- Transport equipment
- Machinery
- Mining
- Food and tobacco
- Paper, pulp and print
- Wood and wood products (other than pulp and paper)
- Construction
- Textile and Leather

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.

india: scenario results data



© NASA

image HIGH SEASONAL WATERS ALONG THE INDIA-NEPAL BORDER, 2009.

india: investment & employment

table 7.2: 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 7.3: 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 7.4: 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**

india: reference scenario

table 7.5: 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 7.6: 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 7.7: 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 7.8: 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 7.9: 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 7.10: 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 7.11: 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 7.12: 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 7.13: 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 7.14: 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 7.15: 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 7.16: 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

GREENPEACE

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image ON MARCH 20, 2012, A GIANT DUST PLUME STRETCHED ACROSS THE ARABIAN SEA FROM THE COAST OF OMAN TO INDIA. THIS EXTENSIVE PLUME FOLLOWED DAYS OF DUST-STORM ACTIVITY OVER THE ARABIAN PENINSULA AND SOUTHWEST ASIA. **front cover images** INDIA. © NASA, JEFF SCHMALTZ ©SHARBENDU DE/GREENPEACE, © SELVAPRAKASH LAKSHMANAN / GREENPEACE.