energy

[r]evolution

A SUSTAINABLE TURKEY ENERGY OUTLOOK

GREENPEACE

report 2015 Turkey energy scenario

Greenpeace International

date May 2015

project manager & lead author Sven Teske, Greenpeace International

partners

Greenpeace International
Sven Teske

Greenpeace Turkey
Hilal Atici, İbrahim Çiftçi

researcher in Turkey
Zumrut Imamoglu, PhD
Research Associate, Betam
(Bahcesehir University Center for Economic and Social Research);
BETAM Osmanpasa Mektebi Sokak No:4-6; 34353 Besiktas, Istanbul, Turkey +90 212 381 5961

image PHOTOVOLTAIC SOLAR CELLS, TURKEY.

© JAHMAICAN/DREAMSTIME

research & co-authors
Overall modelling: DLR, Institute of Engineering Thermodynamics, Department of Systems Analysis and Technology Assessment, Stuttgart, Germany: Dr. Thomas Pregger, Christof Husenbeth, Dr. Tobias Naegler

Transport: DLR, Institute of Vehicle Concepts, Stuttgart, Germany: Dr. Stephan Schmid, Johannes Pagenkopf, Benjamin Frieske
Efficiency: Utrecht University, The Netherlands: Wina Graus, Katerina Kermeli
Fossil Fuel Resource Assessment: Ludwig-Bölkow Systemtechnik, Munich, Germany; Dr. Werner Zittel

Employment: Institute for Sustainable Futures, University of Technology, Sydney: Jay Rutovitz and Laura Wynne
Grid technology: energynautics GmbH, Langen/Germany; Dr. Thomas Ackermann, Rena Ruwahata, Nils Martensen

editor Alexandra Dawe, Rebecca Short, Crispin Aubrey (basic document).

design & layout **one**hemisphere, Sweden, www.onehemisphere.se

contacts
sven.teske@greenpeace.org

for further information about the global, regional and national scenarios please visit the Energy [R]evolution website: **www.energyblueprint.info/**
Published by Greenpeace International and EREC. (GPI reference number JN 439). Printed on 100% post consumer recycled chlorine-free paper.

foreword

Energy availability and use has been a driver of economic development worldwide for centuries. Until recently, it was the ultimately finite availability of many types of energy, such as the limited supply of fossil fuels or of water required for hydropower, that were considered a serious long term constraint on the use of energy. Over the last few decades the realization that the carbon emissions from energy use and other human activity were a cause of climate change because of their accumulation in the atmosphere, has led us to understand that the necessity to protect the planet's climate constitutes another fundamental constraint on the amount and on the type of energy we can all use.

There is uncertainty about the exact quantitative links between global carbon emissions and the speed of global warming. There exist optimistic as well as more pessimistic scenarios. But the fact that the emissions of carbon and other heat-trapping gases lead to climate change is now beyond reasonable doubt. There are of course other reasons to prefer "clean" energy, for example preventing air and water pollution leading to health problems. Climate change comes on top of such traditional and valid concerns as a universal and very challenging problem.

Why are these considerations important for Turkey and Turkey's development outlook?

contents at a glance

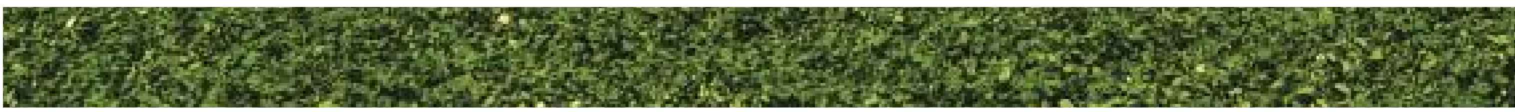


image WIND TURBINES AGAINST THE BLUE SKY, BEHIND GREEN COTTON FIELDS. SOKE, TURKEY.

The word as a whole has to embark on a radical and comprehensive clean energy revolution. Sooner or late all countries of significant size will have to participate in this revolution. The planet has to be saved from excessive climate change. The young, in particular, will demand policies and actions that will allow their children and grandchildren to live in a world where climate continues to allow a decent life and further economic development. All countries will participate in this effort to protect the planet and, by doing so, to protect their own future. The details will emerge over the next decade, and there will be a debate and negotiations on the actions to be undertaken and their speed. But no country will be able to stand aside.

Given this agreed need for an energy revolution, the countries that succeed in *planning ahead*, in moving towards clean energy gradually but decisively, in learning to use both the appropriate technologies as well as becoming adept at using the best regulatory and price policies, will develop an advantage over latecomers. They will be able to avoid sudden and disruptive change by acting early and they will develop a competitive advantage in the know-how relating to the energy revolution, perhaps contributing themselves to inventions that can lead to good economic and financial returns.

It is against this general background that this report on a sustainable energy outlook for Turkey has been prepared. It compares a "business as usual" Reference scenario to an "energy revolution" scenario that would move energy consumption in Turkey decisively towards clean renewables over the next 35 years. The report contains a wealth of information, analysis and careful projection work, based on modelling techniques that have proven useful in many other countries. One can of course question some of the assumptions and some of the parameters, as is the case with any such modelling. For example, the energy revolution scenario targets a reduction of carbon emissions from energy use in Turkey from 3.8 tons per capita now, to 0.7 tons by 2050. That is very ambitious but broadly in line with global models that target an average *per capita* emission of 2 tons worldwide by 2050, from all sources, energy and other. The world will indeed have to make huge efforts to reach that target.

The Report also considers any use of nuclear power as undesirable. As long as the security concerns around nuclear power are not reduced much more drastically, and as long as the problem of long run storage of radioactive nuclear waste, also, is not resolved much more convincingly, nuclear energy remains a questionable part of a sustainable energy future. The debate will continue on this, but what is important and interesting is that the energy revolution scenario proposed is one that would be able to meet Turkey's energy needs without nuclear power.

What is clear from the report is that there is huge potential to improve energy efficiency - a virtual "no net cost" instrument for reducing carbon emissions and pollution - and that there is also a large potential for increasing the share of solar, (photovoltaic and CSP), as well as of wind in total energy consumption over the coming decades. Efficient use of these resources will of course require a smart grid, appropriate feed-in tariffs and more generally energy pricing that fully reflects the cost of carbon emissions. Biomass and geothermal energy can also contribute to a more sustainable energy future.

An efficient, clean, sustainable energy sector will have to be a key component of an efficient and rapidly growing Turkish economy. Energy efficiency will contribute to a better balance of payments and greater competitiveness of Turkish industry. More energy independence thanks to reliance on domestic renewables will have benefits for Turkey's foreign policy. And a pro-active and pioneering role in combating climate change will raise Turkey's credibility and ability to project leadership, worldwide.

Kemal Dervis*

MAY 2015

© NUKHET BARLAS/DREAMSTIME

* Vice President and Director for Global Economy and Development, the Brookings Institution and Executive Committee Member of the Istanbul Policy Center-Merkator Initiative at Sabanci University. Former Minister of Economic Affairs of Turkey, and former Executive Head of UNDP.

contents

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.

list of figures

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

list of tables

introduction

"TURKEY'S ENERGY MODEL IS UNSUSTAINABLE. PUTTING ECONOMIC GROWTH AS THE SOLE INDICATOR OF PROGRESS CANNOT BE A JUSTIFICATION."

image SOLAR POWER PANELS ON A DOMESTIC BUILDING IN TURKEY.

2014 will be remembered in Turkey with the Soma mining tragedy, which has taken 301 lives and altered the lives of many families surrounding forever. Yet, few could see the energy policies that led us to the disaster and even fewer could raise the question if there is another way of producing our energy. The polarization of the society makes people talk more about the politics but less and less on how to ameliorate the quality of our lives. Meanwhile, many people die earlier due to the air pollution, loss of clean water and the augmented disasters that deepening climate change causes. Many others are forced to work in mines with minimum wages regardless of the lethal illnesses that they will carry throughout their lives.

Turkey's energy model is unsustainable. Putting economic growth as the sole indicator of progress cannot be a justification. This energy system doesn't only decrease significantly our quality of life, change the climate, decreases our ability to reach food and bring more air and water pollution and disrupts our healthy relation with the mother earth; it also leads the economy to have more deficit, more dependency on fossil and nuclear fuel imports.

This report proves that we have a choice. We can alter the energy policies by more economically viable options without compromising from the quality of our lives and economy. Three basic principles play important role in building this realistic dream:

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.

First one is 'Less is more'. With energy efficiency, it is possible to decouple economic growth from our need to energy. We can decrease our energy bills both for individuals and for industry and we can save billions of Dollars for better purposes.

Second principle is 'balanced clean energy first'. If we prioritize the access to our renewable energy sources in a balanced mix we can avoid pollution and we can protect people's access to water and food. This means we don't only focus on wind or any other renewable source but all of them keeping the balance of the economy and the assets that mother earth provide us. In a new system, renewables are not the accessories of a so-called 'base load' approach. This base load approach puts first the energy production from dangerous and dirty nuclear and coal, then generates the need to create consumers. In another mindset, renewables come first and can be complemented with flexible fossil fuels only when needed. This will help us to avoid the most dangerous impacts of climate change.

Third is 'power to the people'. This is scary for big energy companies/utilities especially after observing what is being experienced in Germany with 'energiewende'. People are not only considered as passive consumers of energy. They can be active consumers and producers with smart grid systems.

Energy [R]evolution is already happening in the world. The question is 'Will Turkey be a leader or a follower?' Let's not forget to note that the latter costs more for economy and for our lives. This report shows a comparison of what our energy system will look like if we continue the way we did under the Reference scenario and without compromising from the economic ambitions how better it can look if we choose the way to the Energy [R]evolution.

Ibrahim Çiftçi
CLIMATE & ENERGY UNIT
GREENPEACE TURKEY

Sven Teske
CLIMATE & ENERGY UNIT
GREENPEACE INTERNATIONAL

JUNE 2015

executive summary

"THE SCALE OF THE CHALLENGE REQUIRES A COMPLETE TRANSFORMATION OF THE WAY WE PRODUCE, CONSUME AND DISTRIBUTE ENERGY, WHILE MAINTAINING ECONOMIC GROWTH."

image WINDTURBINES AND BEACON AT AEGEAN SEA, BOZCAADA - TURKEY.

The expert consensus is that a 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.[1] The scale of the challenge requires a complete transformation of the way we produce, consume and distribute energy, while maintaining economic growth. The five key principles behind this Energy [R]evolution will be to:

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

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

the methodology

This report is based on the comparison of two scenarios. Reference scenario, describes in detail how our future look like if current energy policy and economic drivers and trends will continue. IEA forecasts have been taken as basis of the key data on energy. Bahcesehir University Center for Economic and Social Research (BETAM) provided GDP growth projections. The data has been then put on a model prepared by the energy systems analysis group of the German Aerospace Center (DLR) which extended the IEA forecasts until 2050. The outcomes of the model has been reviewed by BETAM researchers under the direction of Seyfettin Gürsel and by Ali Kerem Saysel from Bogaziçi University.

Based on the Reference scenario, the Energy [R]evolution scenario has been produced by DLR keeping the GDP and population growth projections constant. A review has been done again by BETAM experts (key economic and labor outcomes), Ali Kerem Saysel (energy projection outcomes) and Greenpeace experts (social and political outcomes).

Not only the possibility of two different energy pathways are assessed in this report, but also the impacts of these two pathways on future electricity costs, the creation of jobs and usage of water by the energy sector are calculated.

reference

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

image TEST WINDMILL N90 2500, BUILT BY THE GERMAN COMPANY NORDEX, IN THE HARBOUR OF ROSTOCK. THIS WINDMILL PRODUCES 2.5 MEGA WATT AND IS TESTED UNDER OFFSHORE CONDITIONS. TWO TECHNICIANS WORKING INSIDE THE TURBINE.

the energy [r]evolution for turkey – key results

Renewable energy sources account for 10% Turkey's primary energy demand in 2012. The main source is biomass, which is mostly used in the heat sector.

For electricity generation renewables contribute about 27% and for heat supply, around 15.3%, biomass but increasingly from geothermal heat pumps and solar thermal collectors as well. About 90% of the primary energy supply today still comes from fossil fuels energy.

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

- **Curbing energy demand:** Combining the projections on population development, GDP growth and energy intensity results in future development pathways for Turkey's final energy demand. Under the Reference scenario, total final energy demand increases by 92% from the current 3,359 PJ/a to 6,438 PJ/a in 2050. In the Energy [R]evolution scenario, final energy demand increases at a much lower rate by 25% compared to current consumption and it is expected to reach 4,184 PJ/a by 2050.
- **Controlling power demand:** Under the Energy [R]evolution scenario, due to economic growth, increasing living standards and electrification of the transport sector, electricity demand is expected to increase in both the industry sector, in the residential and service sectors as well as in the transport sector. Total electricity demand will rise from 193 TWh/a to 397 TWh/a by the year 2050. Compared to the Reference scenario, efficiency measures in the industry, residential and service sectors avoid the generation of about 132 TWh/a. This reduction can be achieved in particular by introducing highly efficient electric devices using the best available technology in all demand sectors.
- **Reducing heating demand:** Efficiency gains in the heating and cooling sector are even larger. Under the Energy [R]evolution scenario, demand for heating and cooling is expected to increase strongly until 2040 and remains rather constant afterwards. Compared to the Reference scenario, consumption equivalent to 783 PJ/a is avoided through efficiency gains by 2050. As a result of energy-related renovation of the existing stock of residential buildings, the introduction of low energy standards and 'passive climatisation' for new buildings, as well as highly efficient air conditioning systems, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.
- **Electricity generation:** The development of the electricity supply sector is charaterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the abstinence of nuclear power production in the Energy [R]evolution scenario and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 90% of the electricity produced in Turkey will come from renewable energy sources. 'New' renewables – mainly wind, geothermal energy and PV – will contribute 68% to the total electricity generation. Already by 2023 the share of renewable electricity production will be 47% and 65% by 2030. The installed capacity of renewables will reach 83 GW in 2030 and 156 GW by 2050. Up to 2023 wind and PV will become the main contributors of the growing market share. After 2023, the continuing growth of wind and PV will be complemented by electricity from biomass, solar thermal and geothermal energy. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 26% by 2030 and 42% by 2050, therefore the expansion of smart grids, demand side management (DSM) and storage capacity from the increased share of electric vehicles will be used for a better grid integration and power generation management.
- **Future costs of electricity generation:** The introduction of renewable technologies under the Energy [R]evolution scenario increase the future costs of electricity generation compared to the Reference scenario until 2018. This difference will be less than 1 €ct/kWh up to 2020, however. Because of high prices for conventional fuels and the lower CO_2 intensity of electricity generation, from 2023 on electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be 4.3 €ct/kWh below those in the Reference version.
- **The future electricity bill:** Under the Reference scenario, on the other hand, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO2 emissions result in total electricity supply costs rising from today's € 22 billion per year to more than € 63 billion in 2050, compared to € 46 billion in the Energy [R]evolution scenario. Figure 5.6 shows that the Energy [R]evolution scenario not only complies with Turkey's CO_2 reduction targets, but also helps to stabilise energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are more than 27% lower than in the Reference scenario.
- **Future investment in power generation:** It would require € 397 billion in investment for the Energy [R]evolution scenario to become reality within four decades until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately € 9.9 billion per year or € 157 billion more than in the Reference scenario (€ 240 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 47% while approximately 53% would be invested in renewable energy until 2050. Under the Energy [R]evolution scenario, however, Turkey would shift almost 92% of the entire investment towards renewables. Until 2030, the fossil fuel share of power sector investment would be focused mainly on gas power plants.
- **Fuel costs savings:** Because renewable energy has no fuel costs, the fuel cost savings in the Energy [R]evolution scenario reach a total of € 280 billion up to 2050, or € 7 billion per year. The total fuel cost savings therefore would cover 178% 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.

- **Heating supply:** Today, renewables meet 15% of Turkey's energy demand for heating and cooling, the main contribution coming from the use of biomass. Dedicated support instruments are required to ensure a dynamic development in particular for renewable cooling technologies (e.g. solar cooling) and renewable process heat production.In the Energy [R]evolution scenario, renewables provide 52% of Turkey's total heat demand in 2030 and 87% in 2050. Energy efficiency measures help to reduce the currently growing energy demand for heating and cooling by 25% in 2050 (relative to the Reference scenario), in spite of improving living standards and economic growth. In the industry sector solar collectors, geothermal energy (incl. heat pumps) as well as electricity from renewable sources are increasingly substituting for fossil fuel-fired systems. A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.
- **Future investments in the heat sector:** The heating and cooling sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially solar heating and cooling as well as geothermal and heat pump technologies need enormous increase in installations, if these potentials are to be tapped for the heat sector. Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar cooling systems.Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around € 358 billion to be invested in renewable heating technologies within four decades until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately € 9 billion per year.
- **Future employment in the energy sector:** Energy sector jobs in Turkey are higher in the Energy [R]evolution scenario at every stage of the projection. Jobs increase in both scenarios to 2015. Exceptionally strong growth in renewable energy in the Energy [R]evolution scenario takes jobs at 2020 to 126,000, 49% above 2012 levels with an additional 42,000 jobs created. Energy sector jobs continue to grow in the Energy [R]evolution scenario, and at 2030 reach 133,000, 58% above 2012 levels. Jobs in the Reference scenario also grow, but to a much lesser degree, reaching 102,000 in 2020, and then fall back to 98,000 by 2030. Renewable energy accounts for 74% of energy jobs in 2030, with biomass having the greatest share (29%), followed by solar heating.
- **Transport:** A key target in Turkey is to introduce incentives for people to drive smaller cars. In addition, it is vital to shift transport use to efficient modes like rail, light rail and buses, especially in the expanding large metropolitan areas. Together with rising prices for fossil fuels, these changes reduce the huge growth in car sales projected under the Reference scenario. Due to population increase, GDP growth and higher living standards, energy demand from the transport sector is expected to increase in the Energy [R]evolution scenario by 39% to 1,000 PJ/a in 2050, 279 PJ/a higher than today's levels (721 PJ/a). However, in 2050 efficiency measures and mode shifts will save 44% compared to the Reference scenario (1,785 PJ/a). Highly efficient propulsion technology with hybrid, plug-in hybrid and batteryelectric power trains will bring large efficiency gains. By 2030, electricity will provide 15% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 44%.
- **Primary energy consumption:** Under the Energy [R]evolution scenario, primary energy demand will increase by 15% from today's 4,956 PJ/a to 5,682 PJ/a. Compared to the Reference scenario, overall primary energy demand will be reduced by 37% in 2050 under the Energy [R]evolution scenario (Reference scenario is 9,095 PJ in 2050). The Energy [R]evolution version aims to phase out coal and oil as fast as technically and economically possible. This is made possible mainly by replacement of coal power plants with renewables and a fast introduction of very efficient electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 45% in 2030 and 79% in 2050. In contrast to the Reference scenario, no nuclear power plants will be built in Turkey in the Energy [R]evolution scenario.
- **Development of CO_2 emissions:** While Turkey's emissions of CO_2 will increase by 76% between 2012 and 2050 under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 278 million tonnes in 2012 to 59 million tonnes in 2050. Annual per capita emissions will drop from 3.7 tonnes to 0.6 tonnes. In spite of the abstinence of nuclear power production and increasing energy demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable in vehicles will reduce emissions also in the transport sector. With a share of 28% of CO_2, the transport sector will be the largest sources of emissions in 2050. By 2050, Turkey's CO_2 emissions are 54% below 1990 levels.

policy changes

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

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

climate and energy policy

THE UNFCC AND THE KYOTO PROTOCOL

INTERNATIONAL ENERGY POLICY

TURKEY ENERGY POLICY

RENEWABLE ENERGY TARGETS

POLICY CHANGES IN THE ENERGY SECTOR

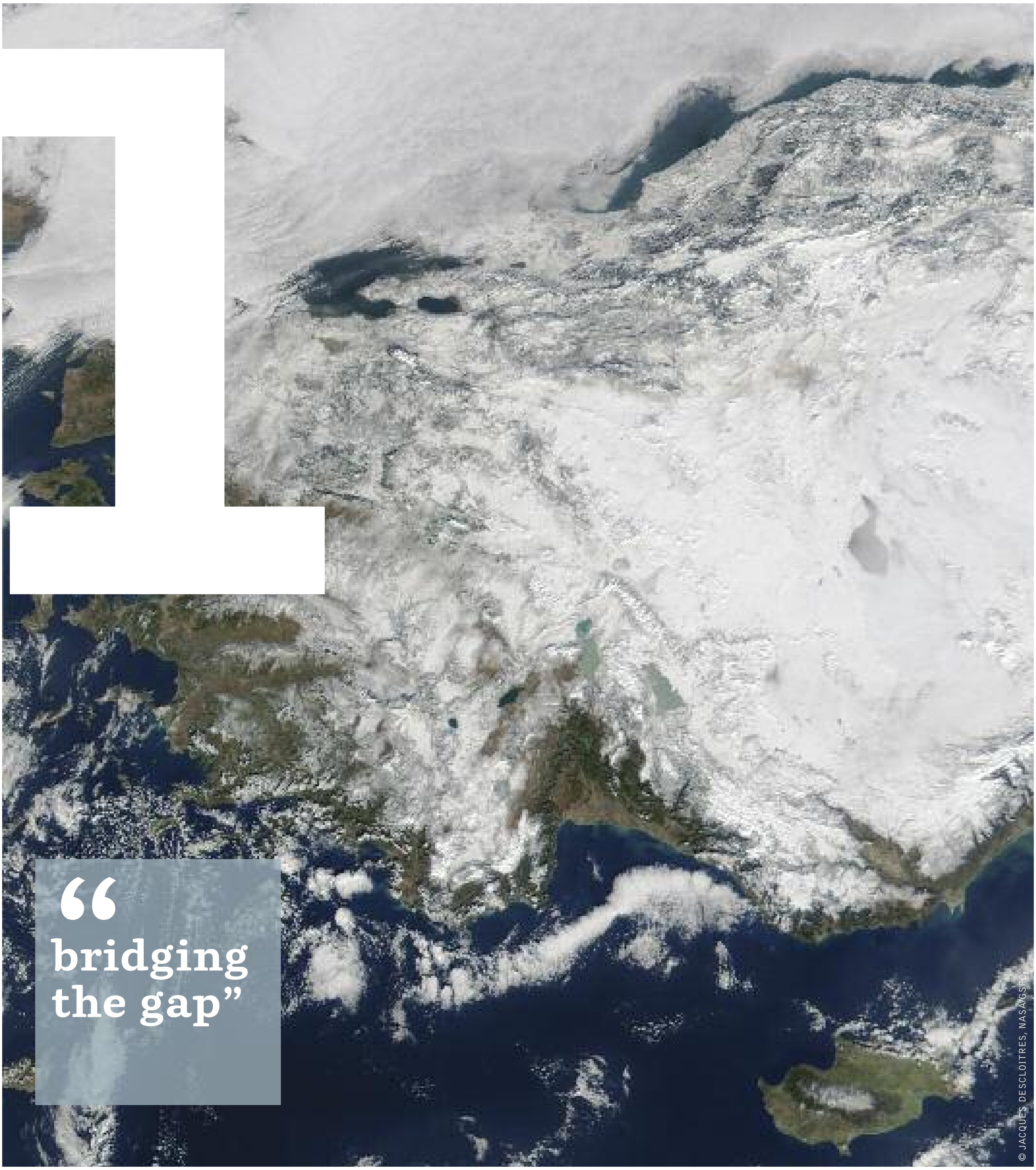


image THE PREDOMINANTLY MOUNTAINOUS TERRAIN OF THE REPUBLIC OF TURKEY IS COVERED BY SNOW. THE SNOW-LACED PEAKS OF THE KURE DAGLARI MOUNTAIN RANGE IN THE NORTH CAN BE SEEN AS THEY RANGE FROM THE UPPER MIDDLE OF THE IMAGE TO THE UPPER RIGHT. THE MOUNTAINS PARALLEL THE NORTHERN COASTLINE, WHICH OPENS TO THE BLACK SEA. ALSO VISIBLE IN THIS IMAGE, AT THE BOTTOM RIGHT, IS THE ISLAND OF CYPRUS.

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 United Nations Climate Convention

Recognizing 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 industrialized nation, the United States, has not ratified the protocol. In 2011, Canada announced its intention to withdraw from the protocol.

In Copenhagen in 2009, the 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.[2] 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:

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.

- That industrialized countries reduce their emissions on average by at least 40% by 2020 compared to their 1990 level.
- That industrialized 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 liberalizing their electricity markets, the increasing competitiveness of renewable energy should lead to higher demand. Without political support, however, renewable energy remains at a disadvantage, marginalized 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 turkey energy policy

Turkey has a fast developing energy market with little emphasis on long term planning. It is highly dependent with 88% of its fuel for energy being imported, mostly with the relatively big portion of gas usage in both electricity and heating sectors.

Given the economical situation of the country alongside the domestic reserves of coal and hydro potential, electricity had been generated from these two fuels in Turkey until 1980's. In 1987, Turkey became a natural gas consumer with 500mn m^3/a, where in 2000's, the use of natural gas escalated dramatically and reached to 36,8bn m^3/a level at 2008.

In order to fight the air pollution at Ankara and Istanbul, so called ''clean fuel'' natural gas started being used in district heating and specifically in 1997, debates about an energy shortage in near future, brought the CCGT into life and Blue Stream agreement signed in December '97 relatedly. Following Blue Stream and Turusgas agreements which also came with buy or pay agreements for huge amount of natural gas, many CCGT plants constructed by local/international energy companies either

reference
2 UNEP EMISSIONS GAP REPORT.

image PART-MADE WIND TURBINES FOR AN OFFSHORE WIND FARM AT MIDDELGRUNDEN, CLOSE TO COPENHAGEN, DENMARK

with BOT or BO models by the end of 1990's and off-take agreements were signed with these companies.

Coming to 2002, policy shaped to spreading the use of natural gas in industry and district heating, and construction of high-pressure transmission lines to major cities began. Today, the lines are approximately 11,400 kms long.

A commonly accepted fact about natural gas in Turkey is that this fuel must be the last source for electricity generation. For being the most expensive fuel, and no control over price stability nor on fuel supply, makes electricity generation from natural gas basically unreasonable. Even Russia, given the tremendous reserves of natural gas, does not use the reserves in electricity generation. Where, the energy policies have led Turkey to an account deficit problem mostly consisting of energy imports and a huge contribution of natural gas to it.

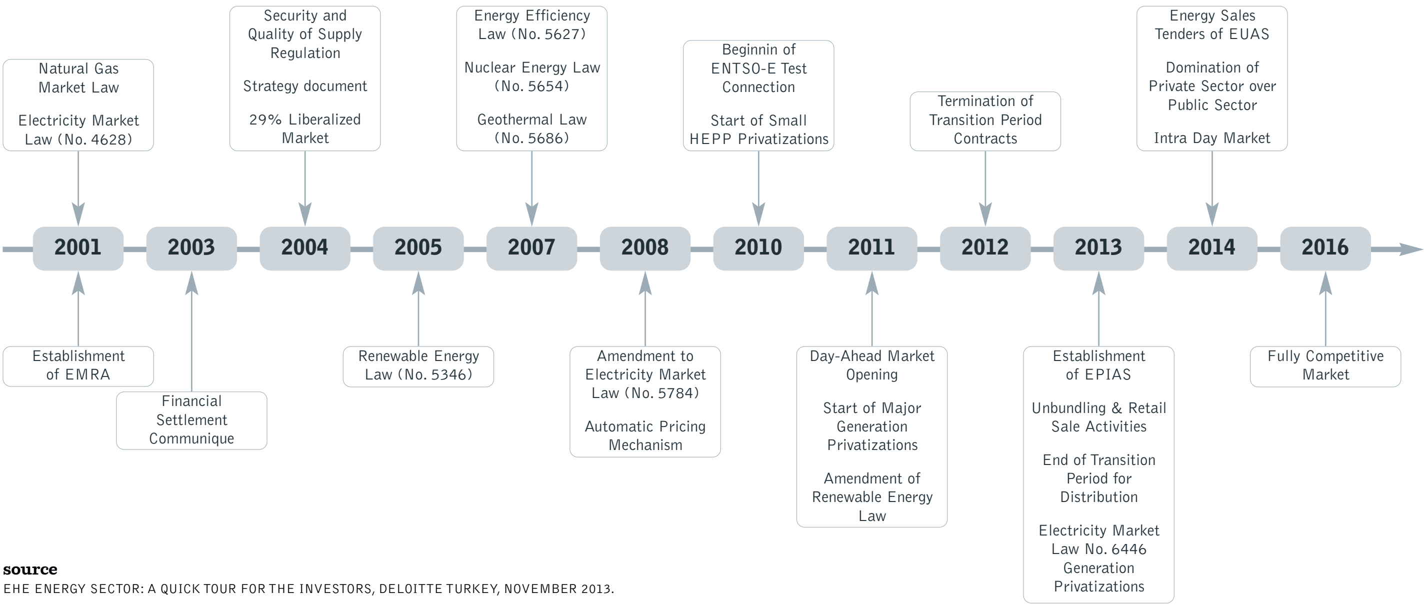
On the other hand Turkey, in the last years, has become one of the fastest growing energy markets in the world in parallel to its economic growth registered over the last ten years. The privatization program in that period – power distribution is completely privatized, while the privatization of power generation assets is set to be completed within the next few years – has given the country's energy sector a highly competitive structure. According to Ministry of Energy, total amount of investments required to meet the energy demand in Turkey by 2023 is estimated to be around USD 120 billion, more than double the total amount invested in the last decade.

Above timeline[3] shows the progression on Turkey energy Market, starting with the establishment of EMRA, Energy Market Regulatory Authority following with the privatization steps and each law regarding to energy.

Even though little attention given to long term energy planning, Turkish government's ambitious vision for 2023, the centennial foundation of the Republic, envisages grandiose targets for the energy sector in Turkey. These targets include:

- Lifting up installed power to 120,000 MW
- Increasing the share of renewables to 30 percent
- Maximizing the use of hydropower
- Increasing wind power installed capacity to 20,000 MW
- Installing power plants with 600 MW of geothermal and 3,000 MW of solar energy
- Extending the length of transmission lines to 60,717 km
- Reaching a power distribution unit capacity of 158,460 MVA
- Extending the use of smart grids
- Raising the natural gas storage capacity to 5 billion m^3
- Establishing an energy stock exchange
- Commissioning nuclear power plants (two operational nuclear power plants, with a third under construction by 2023)
- Building a coal-fired power plant with a capacity of 18,500 MW[4]

figure 1.1: timeline turkish energy policy



source
EHE ENERGY SECTOR: A QUICK TOUR FOR THE INVESTORS, DELOITTE TURKEY, NOVEMBER 2013.

references
3 THE ENERGY SECTOR: A QUICK TOUR FOR THE INVESTORS, DELOITTE TURKEY, NOVEMBER 2013.
4 HTTP://WWW.INVEST.GOV.TR/EN-US/SECTORS/PAGES/ENERGY.ASPX

As also the energy policy of Turkey takes into account; total installed capacity is expected to be doubled by 2023. Although the policy envisions segmentation and increasing the share of renewables, nuclear & fossil fuels still take a huge part in this strategy to cover the base load. Since the current account deficit of Turkey is thought to be mostly on natural gas and the deficit is planned to be decreased;

The coal fired power plants are supposed to take a big part on the agenda for 10 years henceforth. Even 1 out of 12 official target is to build an 18,500 MW coal fired PP and there are 90 projects on each phases of investment awaiting to be installed. But still, in contradiction to the plans of decreasing the current account deficit by using the local coal reserves, 34 of these projects are based on import coal whereas these 34 covers nearly half of the installed capacity of total proposed plants.

After creating a comparatively strong market, Turkey accelerated the long planned **nuclear projects** and a bilateral agreement with Russia was signed covering the installation of four nuclear reactors of 4,800 MW (Akkuyu) in Turkey by the Russian party. Alongside Akkuyu, another agreement with Japanese Government was signed and is now in front of the Japanese Parliament to sign off. Although the current feed-in tariff of Turkey only covers the renewables, the agreement of nuclear plant also comes with a long-term power purchase agreement. The agreement offers a 15 year purchasing guarantee for 12.35 USD cents per kwh which is around 40 to 50% higher than the current electricity spot market price.

In conclusion, the energy dependency of Turkey, and its fast growing market without long term vision is likely to affect the country in years.

The energy dependency will remain the same with the proposed imported coal fired power plants and less emphasis on energy efficiency and renewables. Changes in climate, and lack of cumulative impact on environmental impact assessments will have irreversible effects on climate and Turkish people on a large scale of areas from health to local economies.

1.4 renewable energy targets

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

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

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,[5] the European Solar Thermal Power Industry Association[6] and the Global Wind Energy Council,[7] 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.

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

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

1.5 policy changes in the energy sector

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

The main demands are:

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

Conventional energy sources receive an estimated $409 billion[8] in subsidies in 2010, resulting in heavily distorted markets. Subsidies artificially reduce the price of power, keep renewable energy out of the market place and prop up non-competitive technologies and fuels. Eliminating direct and indirect subsidies to fossil fuels and nuclear power would help move us towards a level playing field across the energy sector. Renewable energy would not need special provisions if markets factored in the cost of climate damage from greenhouse gas pollution. Subsidies to polluting technologies are perverse in that they are economically as well as environmentally detrimental. Removing subsidies from conventional electricity supply would not only save taxpayers' money, it would also dramatically reduce the need for renewable energy support.

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

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

The key requirements for an effective feed-in law are:

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

1. **Long term security for the investment** The investor needs to know if the energy policy will remain stable over the entire investment period (until the generator is paid off). Investors want a "good" return on investment and while there is no universal definition of a good return, it depends to a large extent on the inflation rate of the country. Germany, for example, has an average inflation rate of 2% per year and a minimum return of investment expected by the financial sector is 6% to 7%. Achieving 10 to 15% returns is seen as extremely good and everything above 20% is seen as suspicious.
2. **Long-term security for market conditions** The investor needs to know, if the electricity or heat from the power plant can be sold to the market for a price which guarantees a "good" return on investment (ROI). If the ROI is high, the financial sector will invest, it is low compared to other investments financial institutions will not invest.
3. **Transparent Planning Process** A transparent planning process is key for project developers, so they can sell the planned project to investors or utilities. The entire licensing process must be clear and transparent.
4. **Access to the grid** A fair access to the grid is essential for renewable power plants. If there is no grid connection available or if the costs to access the grid are too high the project will not be built. In order to operate a power plant it is essential for investors to know if the asset can reliably deliver and sell electricity to the grid. If a specific power plant (e.g. a wind farm) does not have priority access to the grid , the operator might have to switch the plant off when there is an over supply from other power plants or due to a bottleneck situation in the grid. This arrangement can add high risk to the project financing and it may not be financed or it will attract a "risk-premium" which will lower the ROI.

references
8 'IEA WORLD ENERGY OUTLOOK 2011', PARIS NOVEMBER 2011, CHAPTER 14, PAGE 507.

the energy [r]evolution concept

KEY PRINCIPLES THE "3 STEP IMPLEMENTATION" THE NEW ELECTRICITY GRID

2

"smart use, generation and distribution are at the core of the concept"

image THE DEEP BLUE LAKE ON THE LEFT IS TURKEY'S LAKE VAN. THE LAKE IS 120 KILOMETERS LONG AND 80 KILOMETERS WIDE. IT IS FED BY MOUNTAIN STREAMS, BUT HAS NO OUTLET EXCEPT EVAPORATION. THIS HAS ALLOWED SALTS AND MINERALS TO BUILD IN THE LAKE TO THE POINT THAT ONLY ONE SPECIES OF FISH CAN SURVIVE IN ITS WATERS. TO THE RIGHT OF LAKE VAN IS IRAN'S LAKE URMIA. LAKE URMIA IS SHALLOW, AND SEDIMENT COLORS ITS WATERS TURQUOISE COMPARED TO THE DEEP BLACK OF LAKE VAN. NORTH OF BOTH LAKES IS ARMENIA'S LAKE SEVANA.

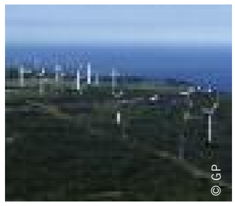


image LE NORDAIS WINDMILL PARK, ONE OF THE MOST IMPORTANT IN AMERICA, LOCATED ON THE GASPÈ PENINSULA IN CAP-CHAT, QUEBEC, CANADA.

The expert consensus is that a 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.[9] 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 have formed the 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 develop 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 therefore there are changes both to the way that energy is produced and distributed.

2.1 key principles

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

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

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

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

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

   The global 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.[10]

   Just as climate change is real, so is the renewable energy sector. Sustainable, decentralised energy systems produce fewer carbon emissions, are cheaper and are less dependent 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
9 IPCC – SPECIAL REPORT RENEWABLES, CHAPTER 1, MAY 2011.
10 REN 21, RENEWABLE ENERGY STATUS REPORT 2012, JUNE 2012.

2.2 the "3 step implementation"

In 2009, renewable energy sources accounted for 13% of the world's primary energy demand. Biomass, which is mostly used for heating, was the main renewable energy source. The share of renewable energy in electricity generation was 18%. About 81% of primary energy supply today still comes from fossil fuels.[11]

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 forward a policy and technical model for renewable energy and cogeneration combined with energy efficiency to meet the world's needs.

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

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

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

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

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

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

61.5 units
LOST THROUGH INEFFICIENT GENERATION AND HEAT WASTAGE

3.5 units
LOST THROUGH TRANSMISSION AND DISTRIBUTION

13 units
WASTED THROUGH INEFFICIENT END USE

100 units >>
ENERGY WITHIN FOSSIL FUEL

38.5 units >>
OF ENERGY FED TO NATIONAL GRID

35 units >>
OF ENERGY SUPPLIED

22 units
OF ENERGY ACTUALLY UTILISED

reference
11 'IEA WORLD ENERGY OUTLOOK 2011, PARIS NOVEMBER 2011.

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.

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 term refers to energy generated at or near the point of use.

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

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

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

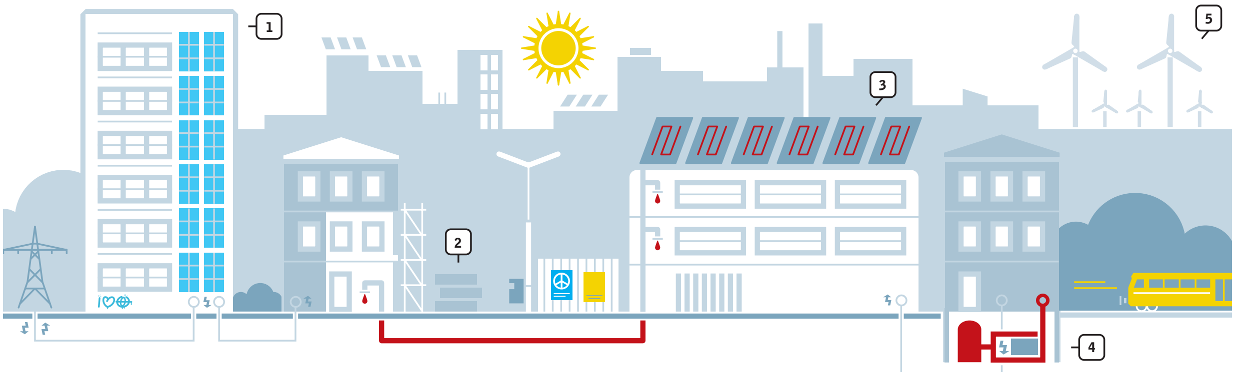
Cogeneration (CHP) The increased use of combined heat and power generation (CHP) will improve the supply system's energy conversion efficiency, whether using natural gas or biomass. In the longer term, a decreasing demand for heat and the large potential for producing heat directly from renewable energy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

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

figure 2.2: a decentralised energy future

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

city



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

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

Transport Before new technologies including hybrid and electric cars can seriously enter the transport sector, 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 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. When combined with 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. Table 2.1 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.

table 2.1: power plant value chain

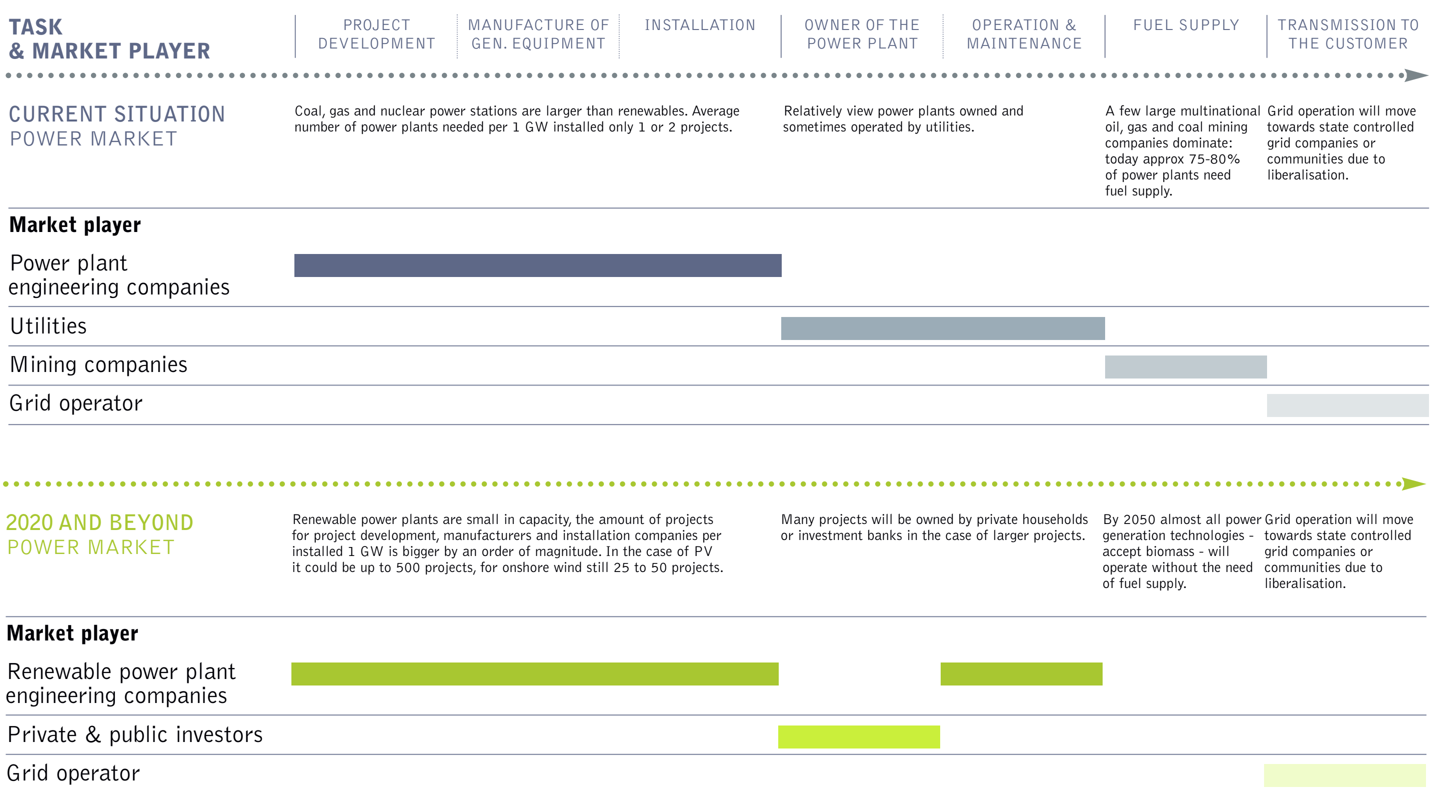
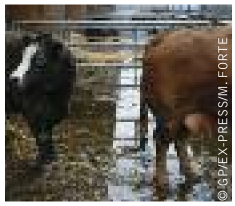


image COWS FROM A FARM WITH A BIOGAS PLANT IN ITTIGEN BERN, SWITZERLAND. THE FARMER PETER WYSS PRODUCES ON HIS FARM WITH A BIOGAS PLANT, GREEN ELECTRICITY WITH DUNG FROM COWS, LIQUID MANURE AND WASTE FROM FOOD PRODUCTION.



Simply selling electricity to customers will play a smaller role, as the power companies of the future will deliver a total power plant and the required IT services to the customer, not just electricity. They will therefore move towards becoming service suppliers for the customer. Moreover, the majority of power plants will 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 the dramatic emissions cuts needed to avoid climate change, around 80% in OECD countries by 2050, will require a massive uptake of renewable energy. The targets for renewable energy must be greatly expanded in industrialised countries both to substitute for fossil fuel and nuclear generation and to create the necessary economies of scale necessary for global expansion. Within the Energy [R]evolution scenario we assume that modern renewable energy sources, such as solar collectors, solar cookers and modern forms of bio energy, will replace inefficient, traditional biomass use.

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

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

Smart 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'.[12] 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 collection and analysis of a lot of data. Smart grids require software, hardware and data networks capable of delivering data quickly, and 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

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

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, page 28).

reference

12 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 of a 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 turn 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.

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 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, e.g. 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 supplies 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 use is low and there are long distances to existing grid.

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

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

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

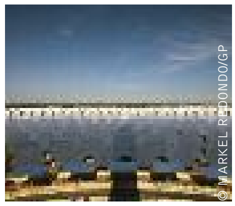


image GEMASOLAR IS A 15 MWE SOLAR-ONLY POWER TOWER PLANT, EMPLOYING MOLTEN SALT TECHNOLOGIES FOR RECEIVING AND STORING ENERGY. IT'S 16 HOUR MOLTEN SALT STORAGE SYSTEM CAN DELIVER POWER AROUND THE CLOCK. IT RUNS AN EQUIVALENT OF 6,570 FULL HOURS OUT OF 8,769 TOTAL. FUENTES DE ANDALUCÍA SEVILLE, SPAIN.

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 dispatchable 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 within 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.[13] 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, a 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.[14] 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.[15] Together, the combination ensures sufficient electricity supply to cover demand.

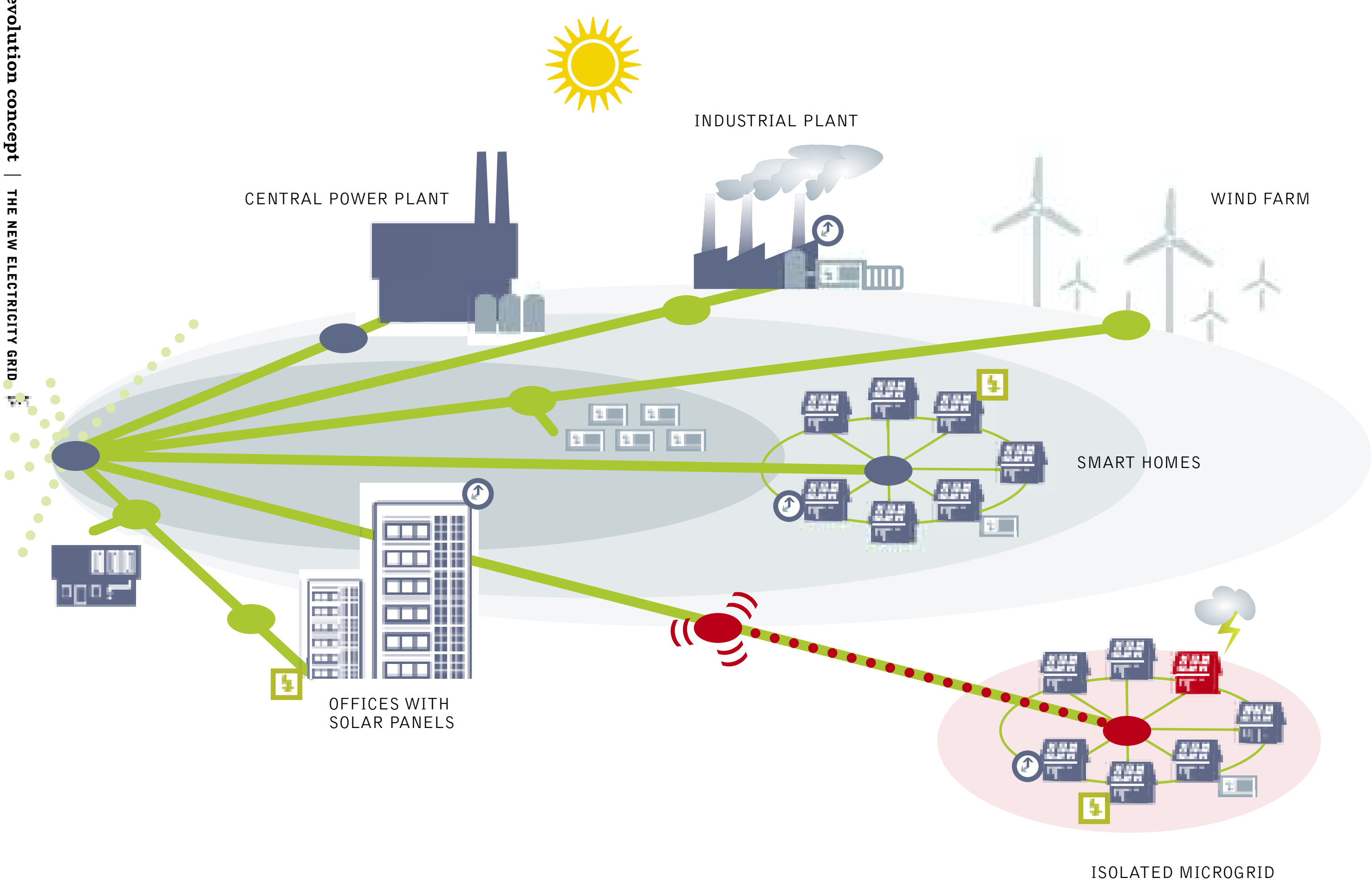
Electricity storage options. Pumped storage is the most established technology for storing energy from a type of hydroelectric power station. Water is pumped from a lower elevation reservoir to a higher elevation during times of low cost, off-peak electricity. During periods of high electrical demand, 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. In 2007, the European Union had 38 GW of pumped storage capacity, representing 5% of total electrical capacity.

references

13 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.
14 SEE ALSO HTTP://WWW.KOMBIKRAFTWERK.DE/INDEX.PHP?ID=27.
15 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 AERIAL VIEW OF THE WORLD'S LARGEST OFFSHORE WINDPARK IN THE NORTH SEA HORNS REV IN ESBJERG, DENMARK.

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

2.3.3 the super grid

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

The Energy [R]evolution scenario assumes that about 70% of all generation is distributed and located close to load centres. The remaining 30% will be large scale renewable generation such as large offshore wind farms or large arrays of concentrating solar power plants. A North Sea offshore super grid, for example, would enable the efficient integration of renewable energy into the power system across the whole North Sea region, linking the UK, France, Germany, Belgium, the Netherlands, Denmark and Norway. By aggregating power generation from wind farms spread across the whole area, periods of very low or very high power flows would be reduced to a negligible amount. A dip in wind power generation in one area would be balanced by higher production in another area, even hundreds of kilometres away. Over a year, an installed offshore wind power capacity of 68.4 GW in the North Sea would be able to generate an estimated 247 TWh of electricity.[16]

2.3.4 baseload blocks progress

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

However, coal and nuclear cannot be turned down on windy days so wind turbines will get switched off to prevent overloading the system. The recent global economic crisis triggered a 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 prices 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, section 2.4 for more). The gas plants and pipelines would then progressively be converted for transporting biogas.

references
16 GREENPEACE REPORT, 'NORTH SEA ELECTRICITY GRID [R]EVOLUTION', SEPTEMBER 2008.
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

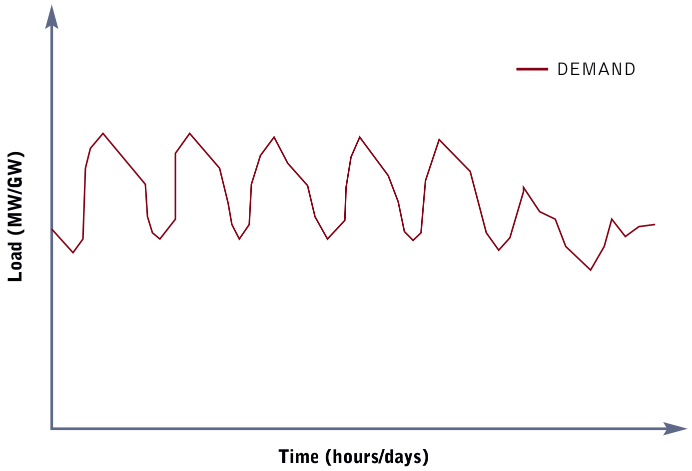
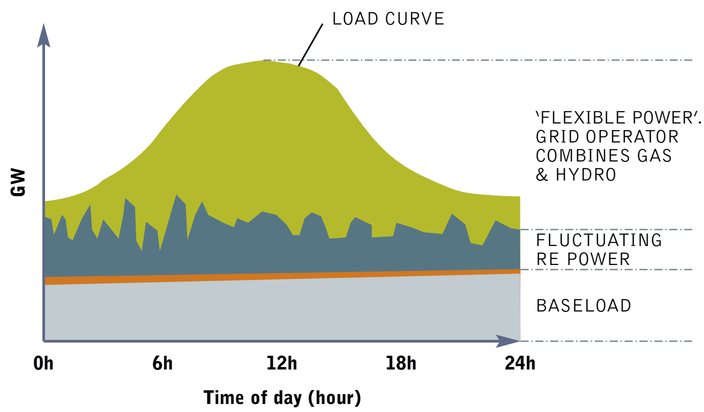


figure 2.5: the evolving approach to grids

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.

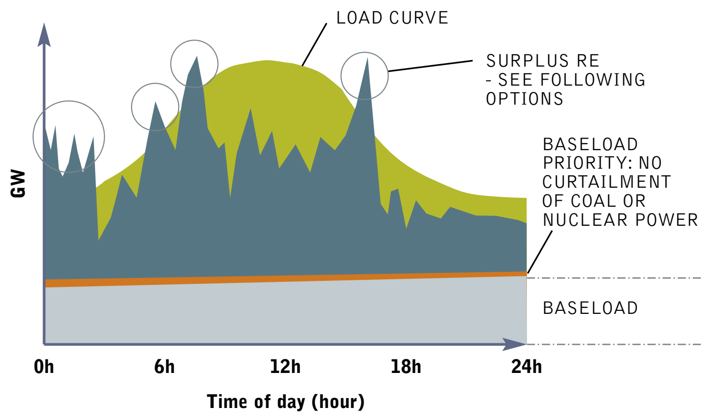


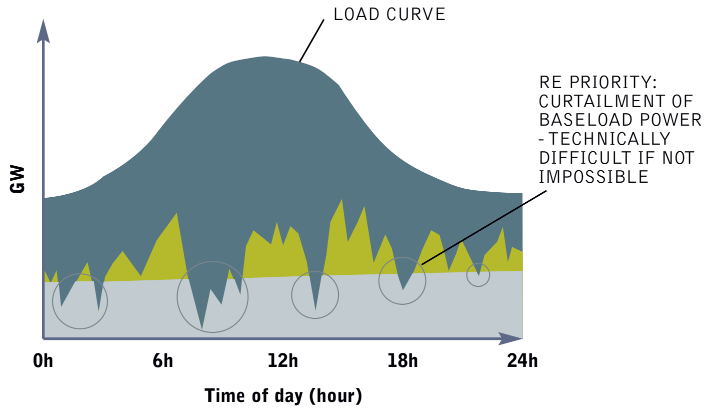
image GREENPEACE OPENS A SOLAR ENERGY WORKSHOP IN BOMA. A MOBILE PHONE GETS CHARGED BY A SOLAR ENERGY POWERED CHARGER.

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.

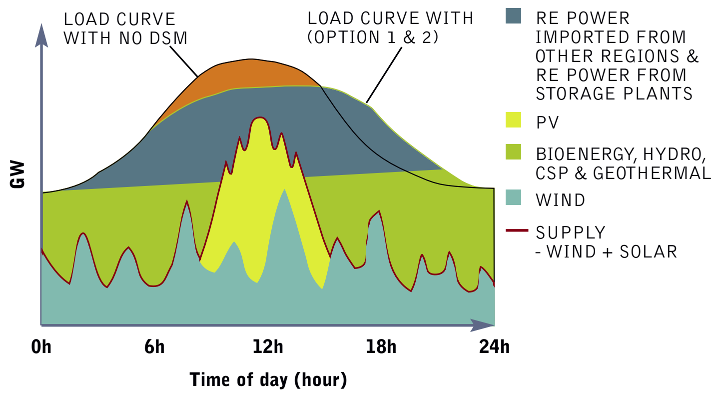
Technically difficult, not a solution.



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-side management (DSM) 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.

implementing the energy [r]evolution

3

“investments in renewables are investments in the future.”

© NASA IMAGE CREATED BY JESSE ALLEN

image GÖREME NATIONAL PARK AND ITS SURROUNDINGS IN CAPPADOCIA, TURKEY.)

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 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 configuration or sites for the technology, 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 provided 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 periods 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 ten years to build large conventional power plants.
- The Renewable Energy Directive granted priority of dispatch to renewable energy producers. Under this principle, 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. 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.

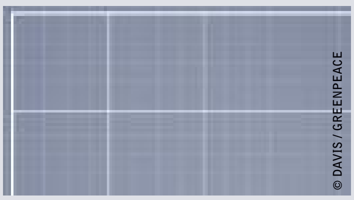
figure 3.3: investment stages of renewable energy projects

RISKS

Higher → **Lower**

Stage

DEVELOPMENT



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

CONSTRUCTION

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

OPERATIONS

- 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. insufficient 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	Renewable energy targets Feed-in tariffs Framework law stability Local content rules
	System integration and infrastructure	Access to grid Energy infrastructure Overall national infrastructure quality Energy market Contracts between generators and users
	Lock-in of existing technologies	Subsidies to other technologies Grid lock-in Skills lock-in Lobbying power
	Permitting and planning regulation	Favourability Transparency Public support
	Government economic position and policy	Monetary policy e.g. interest rates Fiscal policy e.g. stimulus and austerity Currency risks Tariffs in international trade
	Skilled human resources	Lack of training courses
	National governance and legal system	Political stability Corruption Robustness of legal system Litigation risks Intellectual property rights Institutional awareness

Despite the relatively strong growth in renewable energies in some countries, there are still many barriers which hinder the rapid uptake of renewable energy needed to achieve the scale of development required. The key barriers to renewable energy investment identified by Greenpeace through a literature review[18] and interviews with renewable energy sector financiers and developers are shown in Figure 3.4.

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

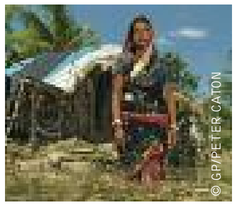


image SOVARANI KOYAL LIVES IN SATJELLIA ISLAND AND IS ONE OF THE MANY PEOPLE AFFECTED BY SEA LEVEL RISE: "NOWADAYS, HEAVY FLOODS ARE GOING ON HERE. THE WATER LEVEL IS INCREASING AND THE TEMPERATURE TOO. WE CANNOT LIVE HERE, THE HEAT IS BECOMING UNBEARABLE. WE HAVE RECEIVED A PLASTIC SHEET AND HAVE COVERED 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."

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 are also 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.

Both state 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[19] 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).

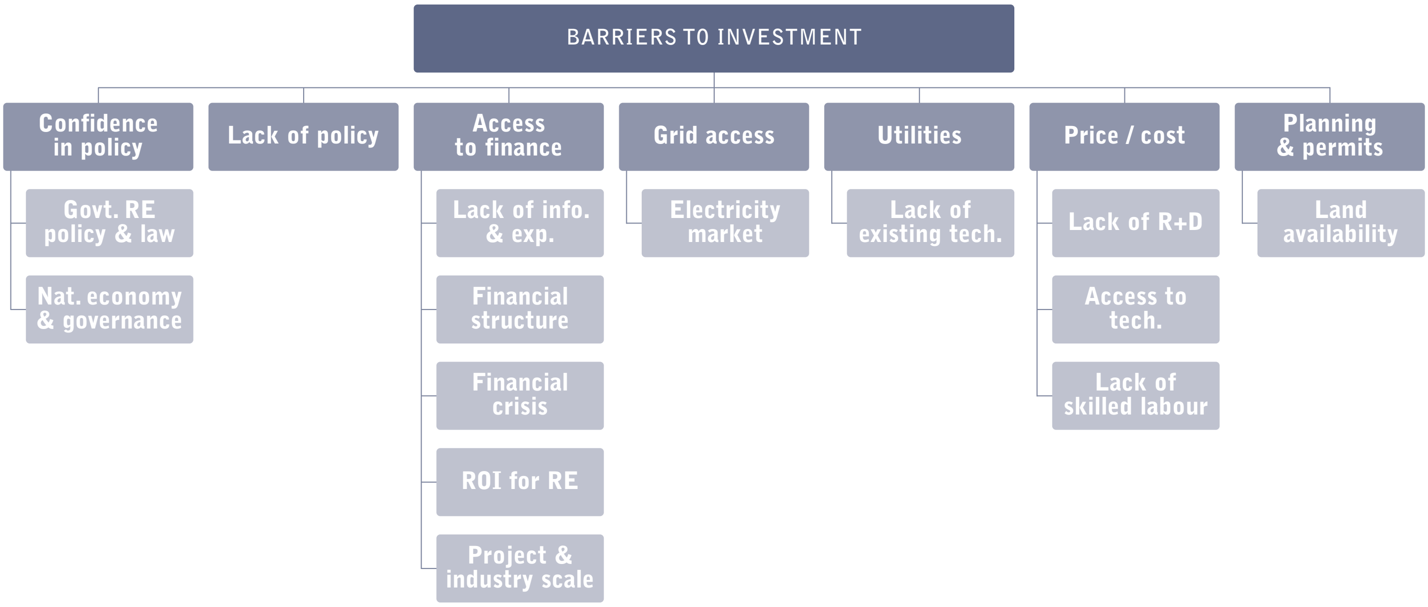
Concerns over planning and permit issues are significant, though vary significantly in their strength and nature depending on the jurisdiction.

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.[20]
- Access to finance can be increased by greater involvement of governments and development banks in programs like loan guarantees and green bonds as well as more active private investors.
- Grid access and infrastructure needs to be improved through investment in smart, decentralised grids.
- Lowering the cost of renewable energy technologies directly will require industry development and boosted research and development.
- A smoother pathway for renewable energy needs to be established through planning and permit issues at the local level.

figure 3.4: key barriers to renewable energy investment



references

18 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.

19 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.

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

scenario for a future energy supply

SCENARIO BACKGROUND
POPULATION DEVELOPMENT
ECONOMIC GROWTH
OIL AND GAS PRICE PROJECTIONS
COST OF CO_2 EMISSIONS
COST PROJECTIONS FOR EFFICIENT FOSSIL FUEL GENERATION AND CCS
COST PROJECTIONS FOR RENEWABLE HEATING TECHNOLOGIES
ASSUMPTIONS FOR FOSSIL FUEL PHASE OUT
REVIEW: GREENPEACE SCENARIO PROJECTS OF THE PAST
HOW DOES THE E[R] SCENARIO COMPARE TO OTHER SCENARIOS

4

"towards a sustainable energy supply system."

image THE METROPOLIS OF ISTANBUL, OCCUPIES BOTH SIDES OF THE ENTRANCE TO THE NARROW, 20-MILE LONG BOSPORUS STRAIT CONNECTING THE MEDITERRANEAN AND SEA OF MARMARA (SOUTH) TO THE BLACK SEA (NORTH).

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

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

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

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

The Reference scenario for Turkey is based on government projections, current new power plant projects and formal announcements of planned or proposed power plant development projects. This reference case has been developed in cooperation with Dr. Ali K. Saysel from the Bogazici University, Institute of Environmental Sciences and has been implemented in the energy modeling software (MESAP/PlaNet) by DLR. For the Reference scenario it is assumed that there will be on change of energy policy in Turkey and therefore renewable energy sources will remain disadvantaged while centralized coal power generation will remain the dominating technology.

This provides a baseline for comparison with the Energy [R]evolution scenario.

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

This global carbon dioxide emission reduction target translates into a carbon budget for Turkey which forms one of the key assumption for the Energy [R]evolution for Turkey. To achieve the target, the scenario includes significant efforts to fully exploit the large potential for energy efficiency, using currently available best practice technology. At the same time, all cost-effective renewable energy sources are used for heat and electricity generation as well as the production of biofuels. The general framework parameters for population and GDP growth remain unchanged from the Reference scenario.

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

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

In all sectors, the latest market development projections of the renewable energy industry[21] have been taken into account. The fast introduction of electric vehicles, combined with the implementation of smart grids and fast expansion of super grids allows a high share of fluctuating renewable power generation (photovoltaic and wind) to be employed. In the global scenario, renewable energy would pass 30% of the global energy supply just after 2020. The Turkey Energy [R]evolution scenario shows that renewable energy would pass 25% of Turkey's energy supply before 2020.

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

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

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

4.1 scenario background

The scenarios in this report were jointly commissioned by Greenpeace and the European Renewable Energy Council from the Systems Analysis group of the Institute of Technical Thermodynamics, part of the German Aerospace Center (DLR). The supply scenarios were calculated using the Mesap/PlaNet simulation model adopted in the previous Energy [R]evolution studies.[22] The new energy demand projections were developed from the University of Utrecht, Netherlands, based on an analysis of the future potential for energy efficiency measures in 2012. The biomass potential calculated for previous editions, judged according to Greenpeace sustainability criteria, has been developed by the German Biomass Research Centre in 2009 and has been further reduced for precautionary principles. The future development pathway for car technologies is based on a special report produced in 2012 by the Institute of Vehicle Concepts, DLR for Greenpeace International. Finally the Institute for Sustainable Futures (ISF) analysed the employment effects of the Energy [R]evolution and Reference scenarios.

4.1.1 status and future projections for renewable heating technologies

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

4.2 population development

Future population development is an important factor in energy scenario building because population size affects the size and composition of energy demand, directly and through its impact on economic growth and development. The Energy [R]evolution scenario uses the Turkish projection for population development.

table 4.1: population development projections
(IN MILLIONS)

	2010	2015	2020	2025	2030	2040	**2050**
Turkey	73	77	81	84	87	90	**92**

source TURKSTAT (2011).

4.3 economic growth

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

Although PPP assessments are still relatively imprecise compared to statistics based on national income and product trade and national price indexes, they are considered to provide a better basis for a scenario development.[23] Thus all data on economic development in WEO 2011 refers to purchasing power adjusted GDP. However, as WEO 2011 only covers the time period up to 2035, the projections for 2035-2050 for the Energy [R]evolution scenario are based on our own estimates.

Prospects for GDP growth have decreased considerably since the previous study, due to the financial crisis at the beginning of 2009, although underlying growth trends continue much the same. GDP growth in all regions is expected to slow gradually over the coming decades. World GDP is assumed to grow on average by 3.8% per year over the period 2009-2030, compared to 3.1% from 1971 to 2007, and on average by 3.1% per year over the entire modelling period (2009-2050). China and India are expected to grow faster than other regions, followed by the Middle East, Africa, remaining Non-OECD Asia, and Eastern Europe/Eurasia. The Chinese economy will slow as it becomes more mature, but will nonetheless become the largest in the world in PPP terms early in the 2020s. GDP in Europe (EU 27) is assumed to grow by around 1.6% per year over the projection period till 2050. For Turkey both scenarios assume an average GDP growth rate of 5.1% per annum from 2010 till 2020 and 2.9% per annum over the entire time frame.

references
22 ENERGY [R]EVOLUTION: A SUSTAINABLE WORLD ENERGY OUTLOOK', GREENPEACE INTERNATIONAL, 2007, 2008 AND 2010.
23 NORDHAUS, W, 'ALTERNATIVE MEASURES OF OUTPUT IN GLOBAL ECONOMIC-ENVIRONMENTAL MODELS: PURCHASING POWER PARITY OR MARKET EXCHANGE RATES?', REPORT PREPARED FOR IPCC EXPERT MEETING ON EMISSION SCENARIOS, US-EPA WASHINGTON DC, JANUARY 12-14, 2005.

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

4.3.1 turkey gdp projections

For Turkey there are several GDP projections by several prominent economic institutions in the world such as the OECD, IMF and the World Bank. Assessing the available particularities and observations, our partner BETAM deduced some insights regarding the potential growth of the Turkish economy in the future assessing:

- Capital intensification and liquidity
- The investment volume and domestic savings / current account deficits
- Labor force
- Total Factor Productivity

BETAM produced its GDP forecasts for three different periods under two different scenarios. The two different scenarios are used for the TFP growth which varies exogenously. The first scenario assumes stable macroeconomic environment and reformist governments for all periods and the second one assumes vice versa, i.e., neither exists in any of the periods. Given the fact that any combination is possible over time and growth path needs not to follow only one of the scenarios; an average of these two GDP forecasts were used for the Energy [R]evolution scenario.

table 4.2: gdp development projections

(AVERAGE ANNUAL GROWTH RATES)

REGION	2009-2020	2020-2035	2035-2050	**2009-2050**
World	4.2%	3.2%	2.2%	3.1%
OECD Americas	2.7%	2.3%	1.2%	2.0%
OECD Asia Oceania	2.4%	1.4%	0.5%	1.3%
Europe (EU 27)	2.1%	1.8%	1.0%	1.6%
Turkey	5.1%	2.8%	1.8%	2.9%
Eastern Europe/ Eurasia	4.2%	3.2%	1.9%	3.0%
India	7.6%	5.8%	3.1%	5.3%
China	8.2%	4.2%	2.7%	4.7%
Non OECD Asia	5.2%	3.2%	2.6%	3.5%
Latin America	4.0%	2.8%	2.2%	2.9%
Middle East	4.3%	3.7%	2.8%	3.5%
Africa	4.5%	4.4%	4.2%	4.4%

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

table 4.3: development projections for fossil fuel and biomass prices in € 2010

FOSSIL FUEL	UNIT	2000	2005	2007	2008	2010	2015	2020	2025	2030	2035	2040	2050
Crude oil imports													
Historic prices (from WEO)	barrel	29	42	63	98	65							
WEO "450 ppm scenario"	barrel					65	80	80	80	80	80		
WEO Current policies	barrel					65	88	88	88	112	116		
Energy [R]evolution 2012	barrel					65	93	93	93	126	126	126	126
Natural gas imports													
Historic prices (from WEO)													
United States	GJ	4.20	1.94	2.71		3.84							
Europe	GJ	3.10	3.77	5.27		6.55							
Japan LNG	GJ	5.11	3.79	5.30		9.61							
WEO 2011 "450 ppm scenario"													
United States	GJ					3.84	5.15	5.68	6.98	7.32	6.81		
Europe	GJ					6.55	8.21	8.56	8.56	8.47	8.21		
Japan LNG	GJ					9.61	10.39	10.48	10.48	10.57	10.57		
WEO 2011 Current policies													
United States	GJ					3.84	5.33	6.12	6.72	7.32	7.86		
Europe	GJ					6.55	8.56	9.61	10.39	11.00	11.35		
Japan LNG	GJ					9.61	11.09	11.78	12.40	12.92	13.27		
Energy [R]evolution 2012													
United States	GJ					3.84	7.03	8.97	10.39	12.06	13.61	15.18	19.89
Europe	GJ					6.55	11.77	13.89	15.08	16.17	17.30	18.45	21.82
Japan LNG	GJ					9.61	13.42	15.79	17.07	18.31	19.55	20.79	24.64
OECD steam coal imports													
Historic prices (from WEO)	tonne	34.76	41.38	57.93	100.96	81.93							
WEO 2011 "450 ppm scenario"	tonne					81.93	82.76	76.96	68.69	61.24	56.27		
WEO 2011 Current policies	tonne					81.93	86.89	90.20	93.51	96.00	97.65		
Energy [R]evolution 2012	tonne						104.85	115.03	134.31	141.51	150.04	164.69	170.73
Biomass (solid)													
Energy [R]evolution 2012													
OECD Europe	GJ			6.21		6.46	6.88	7.71	8.04	8.38	8.51	8.63	8.81
OECD Asia Oceania & North America	GJ			2.76		2.85	2.94	3.19	3.39	3.61	3.77	3.94	4.36
Other regions	GJ			2.27		2.35	2.68	2.94	3.14	3.35	3.61	3.86	4.10

source IEA WEO 2009 & 2011 own assumptions and 2035-2050: DLR, Extrapolation (2012).

4.4 oil and gas price projections

The recent dramatic fluctuations in global oil prices have resulted in slightly higher forward price projections for fossil fuels. Under the 2004 'high oil and gas price' scenario from the European Commission, for example, an oil price of just € 28 per barrel (/bbl) was assumed in 2030. More recent projections of oil prices by 2035 in the IEA's WEO 2011 range from € 80/bbl in the 450 ppm scenario up to € 116/bbl in current policies scenario.

Since the first Energy [R]evolution study was published in 2007, however, the actual price of oil has reached over € 83/bbl for the first time, and in July 2008 reached a record high of more than € 116/bbl. Although oil prices fell back to € 83/bbl in September 2008 and around € 66/bbl in April 2010, prices have increased to more than € 91/bbl in early 2012. Thus, the projections in the IEA Current Policies scenario might still be considered too conservative. Taking into account the growing global demand for oil we have assumed a price development path for fossil fuels slightly higher than the IEA WEO 2011 "Current Policies" case extrapolated forward to 2050 (see Table 4.3).

As the supply of natural gas is limited by the availability of pipeline infrastructure, there is no world market price for gas. In most regions of the world the gas price is directly tied to the price of oil. Gas prices are therefore assumed to increase to €20-25/GJ by 2050.

4.5 cost of CO_2 emissions

The costs of CO_2 allowances needs to be included in the calculation of electricity generation costs. Projections of emissions costs are even more uncertain than energy prices, and a broad range of future estimates has been made in studies. Other projections have assumed higher CO_2 costs than than those included in this Energy [R]evolution study (57 €$_{2010}$/tCO_2)[24], reflecting estimates of the total external costs of CO_2 emissions. The CO_2 cost estimates in the 2010 version of the global Energy [R]evolution were rather conservative (42 €$_{2008}$/t). CO_2 costs are applied in Kyoto Protocol Non-Annex B countries only from 2030 on.

table 4.4: assumptions on CO_2 emissions cost development for Annex-B and Non-Annex-B countries of the UNFCCC.

(€2010/tCO_2)

COUNTRIES	2010	2015	2020	2030	2040	2050
Annex-B countries	0	11	19	30	42	57
Non-Annex-B countries	0	0	0	30	42	57

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

Further cost reduction potentials are assumed for fuel power technologies in use today for coal, gas, lignite and oil. Because they are at an advanced stage of market development the potential for cost reductions is limited, and will be achieved mainly through an increase in efficiency.[25]

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

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

Cost estimates for CCS vary considerably, depending on factors such as power station configuration, technology, fuel costs, size of project and location. One thing is certain, however: CCS is expensive. It requires significant funds to construct the power stations and the necessary infrastructure to transport and store carbon. The IPCC special report on CCS assesses costs at €12-62 per ton of captured CO_2[26], while a 2007 US Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs.[27] These costs are estimated to increase the price of electricity in a range from 21-91%.[28]

Pipeline networks will also need to be constructed to move CO_2 to storage sites. This is likely to require a considerable outlay of capital.[29] Costs will vary depending on a number of factors, including pipeline length, diameter and manufacture from corrosion-resistant steel, as well as the volume of CO_2 to be transported. Pipelines built near population centres or on difficult terrain, such as marshy or rocky ground, are more expensive.[30]

The Intergovernmental Panel on Climate Change (IPCC) estimates a cost range for pipelines of € 0.8 – 6.6/tonne of CO_2 transported. A United States Congressional Research Services report calculated capital costs for an 11 mile pipeline in the Midwestern region of the US at approximately € 5 million. The same report estimates that a dedicated interstate pipeline network in North Carolina would cost upwards of € 4 billion due to the limited geological sequestration potential in that part of the country.[31] Storage and subsequent monitoring and verification costs are estimated by the IPCC to range from € 0.4-6.6/tCO_2 (for storage) and € 0.1-0.25/tCO_2. The overall cost of CCS could therefore be a major barrier to its deployment.[32]

references
24 KREWITT, W., SCHLOMANN, B., EXTERNAL COSTS OF ELECTRICITY GENERATION FROM RENEWABLE ENERGIES COMPARED TO ELECTRICITY GENERATION FROM FOSSIL ENERGY SOURCES, GERMAN FEDERAL MINISTRY FOR THE ENVIRONMENT, NATURE CONSERVATION AND NUCLEAR SAFETY, BERLIN 2006.
25 GREENPEACE INTERNATIONAL BRIEFING: CARBON CAPTURE AND STORAGE', GOERNE, 2007.
26 ABANADES, J C ET AL., 2005, PG 10.
27 NATIONAL ENERGY TECHNOLOGY LABORATORIES, 2007.
28 RUBIN ET AL., 2005A, PG 40.
29 RAGDEN, P ET AL., 2006, PG 18.
30 HEDDLE, G ET AL., 2003, PG 17.
31 PARFOMAK, P & FOLGER, P, 2008, PG 5 AND 12.
32 RUBIN ET AL., 2005B, PG 4444.

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

table 4.5: development of efficiency and investment costs for selected new power plant technologies

POWER PLANT		2009	2015	2020	2030	2040	2050
Coal-fired condensing power plant	Max. efficiency (%)	45	46	48	50	52	53
	Investment costs (€2010/kW)	1,085	1,046	1,029	1,004	987	953
	CO_2 emissions [a)] (g/kWh)	744	728	697	670	644	632
Lignite-fired condensing power plant	Max. efficiency (%)	41	43	44	44.5	45	45
	Investment costs (€2010/kW)	1,278	1,219	1,192	1,167	1,141	1,116
	CO_2 emissions [a)] (g/kWh)	975	929	908	898	888	888
Natural gas combined cycle	Max. efficiency (%)	57	59	61	62	63	64
	Investment costs (€2010/kW)	587	569	556	530	503	477
	CO_2 emissions [a)] (g/kWh)	354	342	330	325	320	315

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

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

Table 4.5 summarises our assumptions on the technical and economic parameters of future fossil-fuelled power plant technologies. Based on estimates from WEO 2010, we assume that further technical innovation will not prevent an increase of future investment costs because raw material costs and technical complexity will continue to increase. Also, improvements in power plant efficiency are outweighed by the expected increase in fossil fuel prices, which would increase electricity generation costs significantly.

4.7 cost projections for renewable energy technologies

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

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

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

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

Assumptions on future costs for renewable electricity technologies in the Energy [R]evolution scenario are derived from a review of learning curve studies, for example by Lena Neij and others[33], from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS project (New Energy Externalities Developments for Sustainability)[34] or the IEA Energy Technology Perspectives 2008, projections by the European Renewable Energy Council published in April 2010 ("Re-Thinking 2050") and discussions with experts from different sectors of the renewable energy industry.

references
33 NEIJ, L, 'COST DEVELOPMENT OF FUTURE TECHNOLOGIES FOR POWER GENERATION - A STUDY BASED ON EXPERIENCE CURVES AND COMPLEMENTARY BOTTOM-UP ASSESSMENTS', ENERGY POLICY 36 (2008), 2200-2211.
34 WWW.NEEDS-PROJECT.ORG.

4.7.1 photovoltaics (PV)

The worldwide photovoltaics (PV) market has been growing at over 40% per annum in recent years and the contribution is starting to make a significant contribution to electricity generation. Photovoltaics are important because of its decentralised / centralised character, its flexibility for use in an urban environment and huge potential for cost reduction. The PV industry has been increasingly exploiting this potential during the last few years, with installation prices more than halving in the last few years. Current development is focused on improving existing modules and system components by increasing their energy efficiency and reducing material usage. Technologies like PV thin film (using alternative semiconductor materials) or dye sensitive solar cells are developing quickly and present a huge potential for cost reduction. The mature technology crystalline silicon, with a proven lifetime of 30 years, is continually increasing its cell and module efficiency (by 0.5% annually), whereas the cell thickness is rapidly decreasing (from 230 to 180 microns over the last five years). Commercial module efficiency varies from 14 to 21%, depending on silicon quality and fabrication process.

The learning factor for PV modules has been fairly constant over the last 30 years with costs reducing by 20% each time the installed capacity doubles, indicating a high rate of technical learning. Assuming a globally installed capacity of 1,500 GW by between 2030 and 2040 in the Energy [R]evolution scenario, and with an electricity output of 2,600 TWh/a, we can expect that generation costs of around 4-8 €cents/kWh (depending on the region) will be achieved. During the following five to ten years, PV will become competitive with retail electricity prices in many parts of the world, and competitive with fossil fuel costs by 2030.

4.7.2 concentrating solar power (CSP)

Solar thermal 'concentrating' power stations (CSP) can only use direct sunlight and are therefore dependent on very sunny locations. Southern Europe has a technical potential for this technology which far exceeds local demand. The various solar thermal technologies have good prospects for further development and cost reductions. Because of their more simple design, 'Fresnel' collectors are considered as an option for additional cost trimming. The efficiency of central receiver systems can be increased by producing compressed air at a temperature of up to 10,000C°, which is then used to run a combined gas and steam turbine.

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

Depending on the level of irradiation and mode of operation, it is expected that long term future electricity generation costs of 5-8 €cents/kWh can be achieved. This presupposes rapid market introduction in the next few years.

table 4.6: photovoltaics (PV) cost assumptions

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

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Investment costs (€/kWp)	2,817	1,200	950	850	780	750
O & M costs €/(kW/a)	40	29	16	11	11	11

O & M = Operation and maintenance.

table 4.7: concentrating solar power (CSP) cost assumptions

INCLUDING COSTS FOR HEAT STORAGE AND ADDITIONAL SOLAR FIELDS

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Investment costs (€/kWp)	8,667	6,501	5,000	4,334	3,982	3,630
O & M costs €/(kW/a)	335	260	200	173	159	145

O & M = Operation and maintenance.

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

4.7.3 wind power

Within a short period of time, the dynamic development of wind power has resulted in the establishment of a flourishing global market. In Europe, favorable policy incentives were the early drivers for the global wind market. The boom in demand for wind power technology has nonetheless led to supply constraints. As a consequence, the cost of new systems has increased. The industry is continuously expanding production capacity, however, so it is already resolving the bottlenecks in the supply chain. Taking into account market development projections, learning curve analysis and industry expectations, we assume that investment costs for wind turbines will reduce by 25% for onshore and 50% for offshore installations up to 2050.

4.7.4 biomass

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

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

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

table 4.8: wind power cost assumptions

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

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Wind turbine offshore						
Investment costs (€/kWp)	4,875	3,500	2,200	1,800	1,600	1,500
O & M costs €/(kW/a)	173	155	122	99	94	81
Wind turbine onshore						
Investment costs (€/kWp)	1,422	1,125	975	967	972	1,016
O & M costs €/(kW/a)	51	42	41	42	44	46

O & M = Operation and maintenance.

table 4.9: biomass cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Biomass power plant						
Investment costs (€/kWp)	2,653	2,329	2,199	2,124	2,037	1,994
O & M costs €/(kW/a)	160	140	132	127	123	120
Biomass CHP						
Investment costs (€/kWp)	4,500	3,815	3,337	2,914	2,686	2,551
O & M costs €/(kW/a)	315	268	234	204	189	179

O & M = Operation and maintenance.

4.7.5 geothermal

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

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

- for conventional geothermal power, from 12 €cents/kWh to about 7 €cents/kWh;
- for EGS, despite the presently high figures (about 17 – 25 €cents/kWh), electricity production costs - depending on the payments for heat supply - are expected to come down to around 6 €cents/kWh in the long term.

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

4.7.6 ocean energy

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

The cost of energy from initial tidal and wave energy farms has been estimated to be in the range of 20-80 €cents/kWh[35], and for initial tidal stream farms in the range of 11-22 €cents/kWh. Generation costs of 7-8 €cents/kWh are expected by 2030. Key areas for development will include concept design, optimisation of the device configuration, reduction of capital costs by exploring the use of alternative structural materials, economies of scale and learning from operation. According to the latest research findings, the learning factor is estimated to be 10-15% for offshore wave and 5-10% for tidal stream. In the long term, ocean energy has the potential to become one of the most competitive and cost effective forms of generation. In the next few years a dynamic market penetration is expected, following a similar curve to wind energy.

Because of the early development stage any future cost estimates for ocean energy systems are uncertain. Present cost estimates are based on analysis from the European NEEDS project.[36]

table 4.10: geothermal cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Geothermal power plant						
Investment costs (€/kWp)	11,159	9,318	7,042	4,821	4,007	3,446
O & M costs €/(kW/ a)	504	406	316	240	224	212

O & M = Operation and maintenance.

table 4.11: ocean energy cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Ocean energy power plant						
Investment costs (€/kWp)	5,466	3,489	2,492	1,733	1,439	1,281
O & M costs €/(kW/a)	219	140	100	69	58	51

O & M = Operation and maintenance.

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

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

4.7.7 hydro power

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

However, in Turkey, this has not been the practice. As Energy ministry has adopted to use all the hydro potential, for big and small hydro projects, local people's right to access to water has been violated with many projects and protecting the river ecosystems has been disregarded. In a few years, the rapid expansion of hydro became an example of how renewable energy policies can go wrong if a balanced approach on using different renewable energy sources together with energy efficiency is not adopted.

4.7.8 summary of renewable energy cost development

Figure 4.1 summarises the cost trends for renewable power technologies derived from the respective learning curves. It is important to note that the expected cost reduction is not a function of time, but of cumulative capacity (production of units), so dynamic market development is required. Most of the technologies will be able to reduce their specific investment costs to between 30% and 60% of current once they have achieved full maturity (after 2040).

Reduced investment costs for renewable energy technologies lead directly to reduced heat and electricity generation costs, as shown in Figure 4.2. Generation costs today are around 7 to 29 €cents/kWh for the most important technologies, including photovoltaic. In the long term, costs are expected to converge at around 5 to 10 €cents/kWh. These estimates depend on site-specific conditions such as the local wind regime or solar irradiation, the availability of biomass at reasonable prices or the credit granted for heat supply in the case of combined heat and power generation.

table 4.12: hydro power cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Investment costs (€/kWp)	2,457	2,568	2,647	2,766	2,866	2,953
O & M costs €/(kW/a)	98	103	106	111	115	118

O & M = Operation and maintenance.

figure 4.1: future development of investment costs for renewable energy technologies (NORMALISED TO 2010 COST LEVELS)

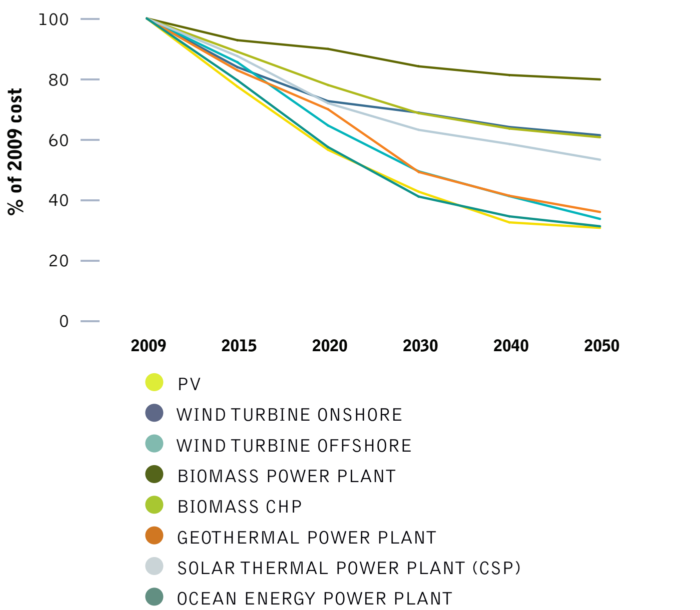
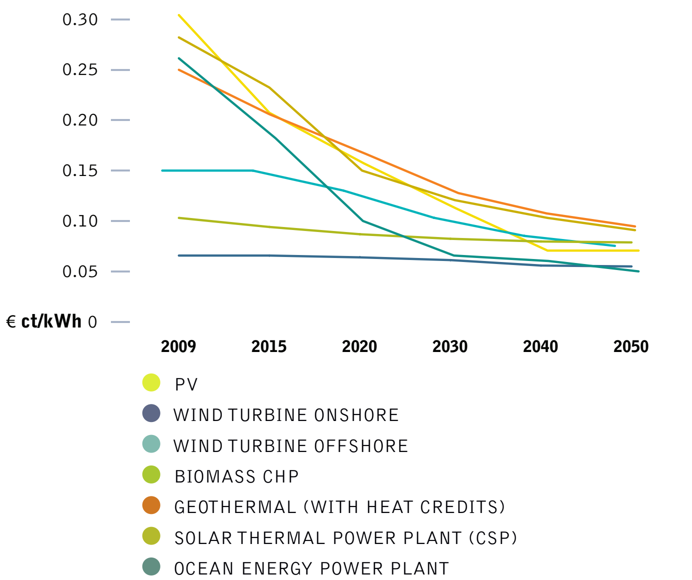


figure 4.2: expected development of electricity generation costs from fossil fuel and renewable options

EXAMPLE FOR OECD EUROPE



4.8 cost projections for renewable heating technologies

Renewable heating has the longest tradition of all renewable technologies. EREC and DLR carried out a survey on costs of renewable heating technologies in Europe, which analyses installation costs of renewable heating technologies, ranging from direct solar collector systems to geothermal and ambient heat applications and biomass technologies. The report shows that some technologies are already mature and compete on the market – especially simple heating systems in the domestic sector. However, more sophisticated technologies, which can provide higher shares of heat demand from renewable sources, are still under development and rather expensive. Market barriers slow down the further implementation and cost reduction of renewable heating systems, especially for heating networks. Nevertheless, significant learning rates can be expected if renewable heating is increasingly implemented as projected in the Energy [R]evolution scenario.

4.8.1 solar thermal technologies

Solar collectors depend on direct solar irradiation, so the yield strongly depends on the location. In very sunny regions, simple thermosiphon systems can provide total hot water demand in households at around 400 €/m^2 installation costs. In parts of Europe with less sun, where additional space heating is needed, installation cost for pumped systems are twice as high. In these areas, economies of scales can decrease solar heating costs significantly. Large scale solar collector systems are known from 250-600 €/m^2, depending on the share of solar energy in the whole heating system and the level of storage required.

4.8.2 deep geothermal applications

Deep geothermal heat from aquifers or reservoirs can be used directly in hydrothermal heating plants to supply heat demand close to the plant or in a district heating network for several different types of heat. Due to the high drilling costs deep geothermal energy is mostly feasible for large applications in combination with heat networks. It is already economic feasible and has been in use for a long time, where aquifers can be found near the surface. In Europe deep geothermal applications are being developed for heating purposes at investment costs from 500€/kWth (shallow) to 3000 €/kWth (deep), with the costs strongly dependent on the drilling depth.

4.8.3 heat pumps

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

4.8.4 biomass applications

There is broad portfolio of modern technologies for heat production from biomass, ranging from small scale single room stoves to heating or CHP-plants in MW scale. Investments costs show a similar variety: simple log wood stoves can be obtained from 100 €/kW, more sophisticated automated heating systems that cover the whole heat demand of a building are significantly more expensive. Log wood or pellet boilers range from 400-1200 €/kW, with large applications being cheaper than small systems.

Economy of scales apply to heating plants above 500kW, with investment cost between 400 and 700 €/kW. Heating plants can deliver process heat or provide whole neighbourhoods with heat. Even if heat networks demand additional investment, there is great potential to use solid biomass for heat generation in both small and large heating centers linked to local heating networks.

Heat from cogeneration (CHP) is another option with a broad range of technologies at hand. It is a very varied energy technology – applying to co-firing in large coal-fired cogeneration plants; biomass gasification combined with CHP or biogas from wet residues. But the costs for heat are often mainly dependent on the power production.

Main biomass input into renewable heating today is solid biomass – wood in various specifications from waste wood and residues to pellets from short rotation forestry. Biomass costs are as versatile: In Europe biomass costs ranged from 1-6 €/GJ for sawmill products, over 2-7 €/GJ for log wood to 6-18 €/GJ for wood pellets.[37]

Cost reductions expected vary strongly within each technology sector, depending on the maturity of a specific technology. E.g. Small wood stoves will not see significant cost reductions, while there is still learning potential for automated pellet heating systems. Cost for simple solar collectors for swimming pools might be already optimised, whereas integration in large systems is neither technological nor economical mature. Table 4.13 shows average development pathways for a variety of heat technology options.

table 4.13: overview over expected investment costs pathways for heating technologies (IN €2010/KWTH

	2015	2020	2030	2040	2050
Geothermal distict heating*	2,000	1,900	1,700	1,508	1,328
Heat pumps	1,500	1,455	1,369	1,288	1,212
Small solar collector systems	886	849	759	670	570
Large solar collector systems	714	684	612	540	460
Solar district heating*	814	814	814	814	814
Small biomass heating systems	700	679	639	601	566
Large biomass heating systems	500	485	456	429	404
Biomass district heating*	500	485	456	429	404

* WITHOUT NETWORK

references
37 OLSON, O. ET AL. (2010): WP3-WOOD FUEL PRICE STATISTICS IN EUROPE - D.31. SOLUTIONS FOR BIOMASS FUEL MARKET BARRIERS AND RAW MATERIAL AVAILABILITY. EUBIONET3. UPPSALA, SWEDEN, SWEDISH UNIVERSITY OF AGRICULTURAL SCIENCES.

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

4.9 assumptions for fossil fuel phase out

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

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

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

4.9.1 oil – production decline assumptions

Figure 4.3 shows the remaining production capacities with an annual production decline between 2.5% and 5% and the additional production capacities assuming all new projects planned for 2012 to 2020 will go ahead. Even with new projects, the amount of remaining conventional oil is very limited and therefore a transition towards a low oil demand pattern is essential.

4.9.2 coal – production decline assumptions

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

figure 4.3: global oil production 1950 to 2011 and projection till 2050

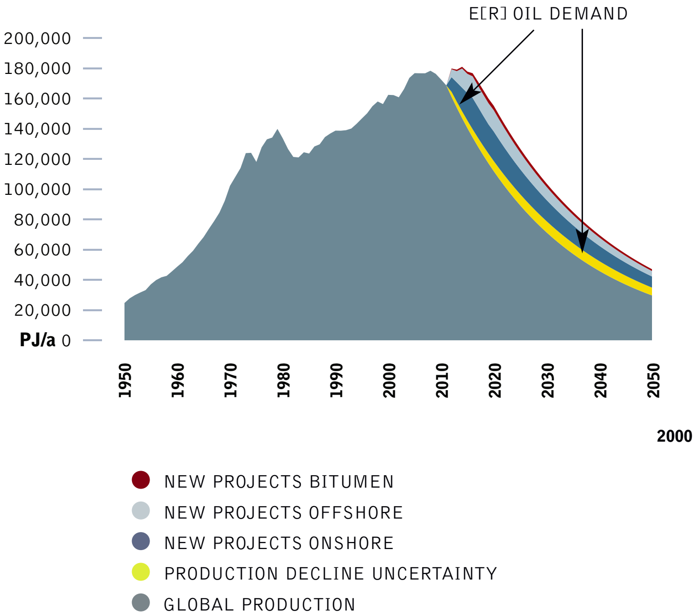
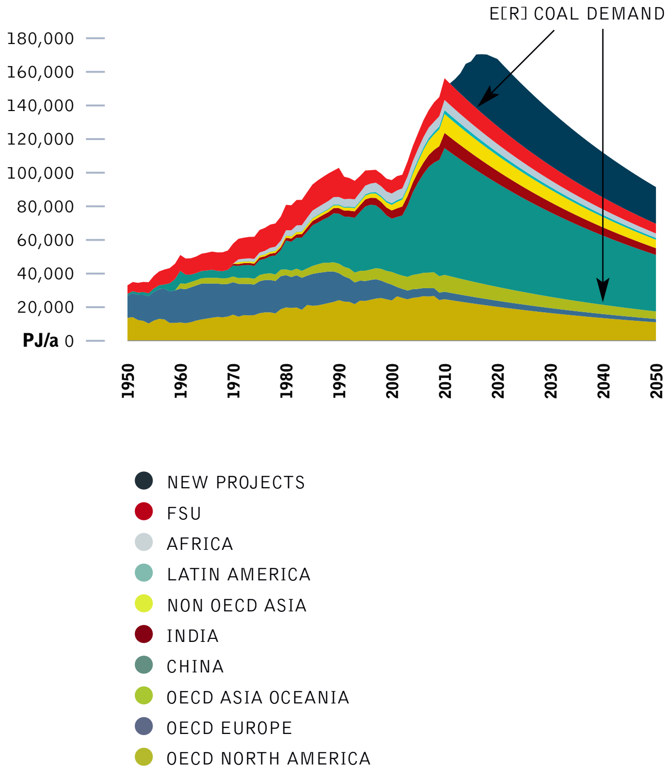


figure 4.4: coal scenario: base decline of 2% per year and new projects



4.10 review: greenpeace scenario projections of the past

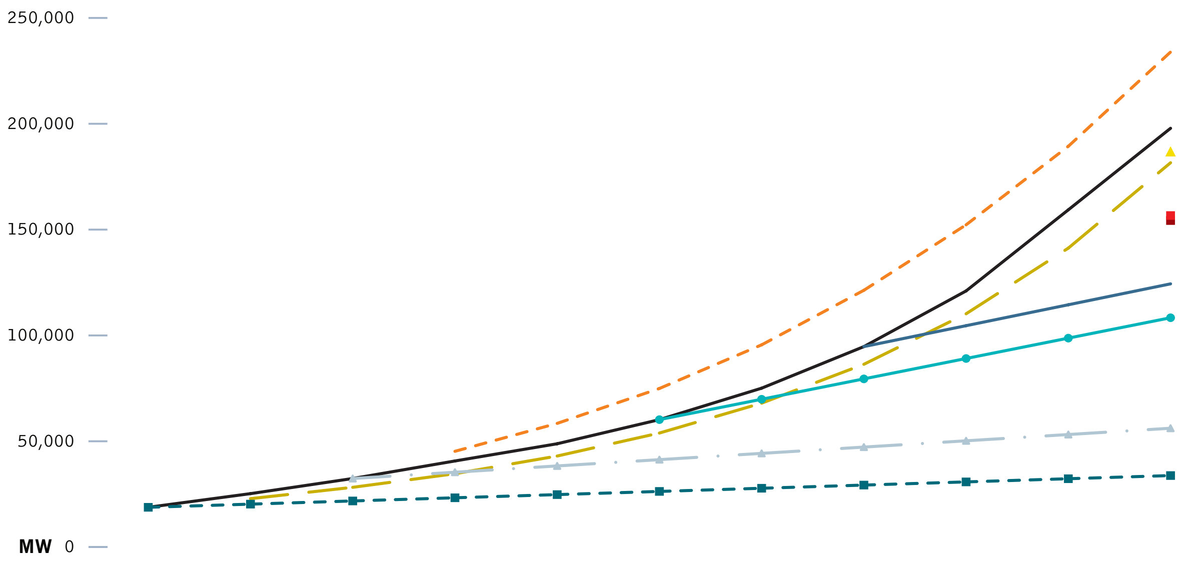
Greenpeace has published numerous projections in cooperation with renewable industry associations and scientific institutions in the past decade. This section provides an overview of the projections between 2000 and 2011 and compares them with real market developments and projections of the IEA World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

4.10.1 the development of the global wind industry

Greenpeace and the European Wind Energy Association published "Windforce 10" for the first time in 1999– a global market projection for wind turbines until 2030. Since then, an updated prognosis has been published every second year. Since 2006 the report has been renamed to "Global Wind Energy Outlook" with a new partner – the Global Wind Energy Council (GWEC) – a new umbrella organisation of all regional wind industry associations. Figure 4.5 shows the projections made each year between 2000 and 2010 compared to the real market data. The graph also includes the first two Energy [R]evolution (ER) editions (published in 2007 and 2008) against the IEA's wind projections published in World Energy Outlook (WEO) 2000, 2002, 2005 and 2007.

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

figure 4.5: wind power: short term prognosis vs real market development - global cummulative capacity



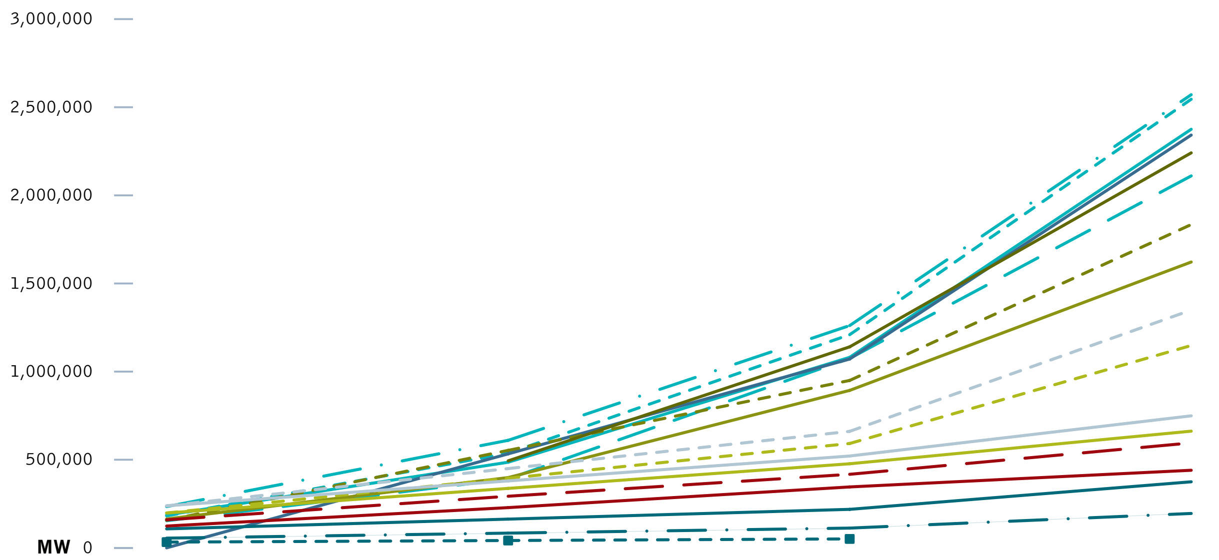
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
REAL	17,400	23,900	31,100	39,431	47,620	59,091	74,052	93,820	120,291	158,864	197,637
WF 10 (1999)		21,510	26,901	33,371	41,781	52,715	66,929	85,407	109,428	140,656	181,252
WF 12 (2002)				44,025	57,306	73,908	94,660	120,600	151,728	189,081	233,905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

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

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

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

figure 4.6: wind power: long term market projects until 2030



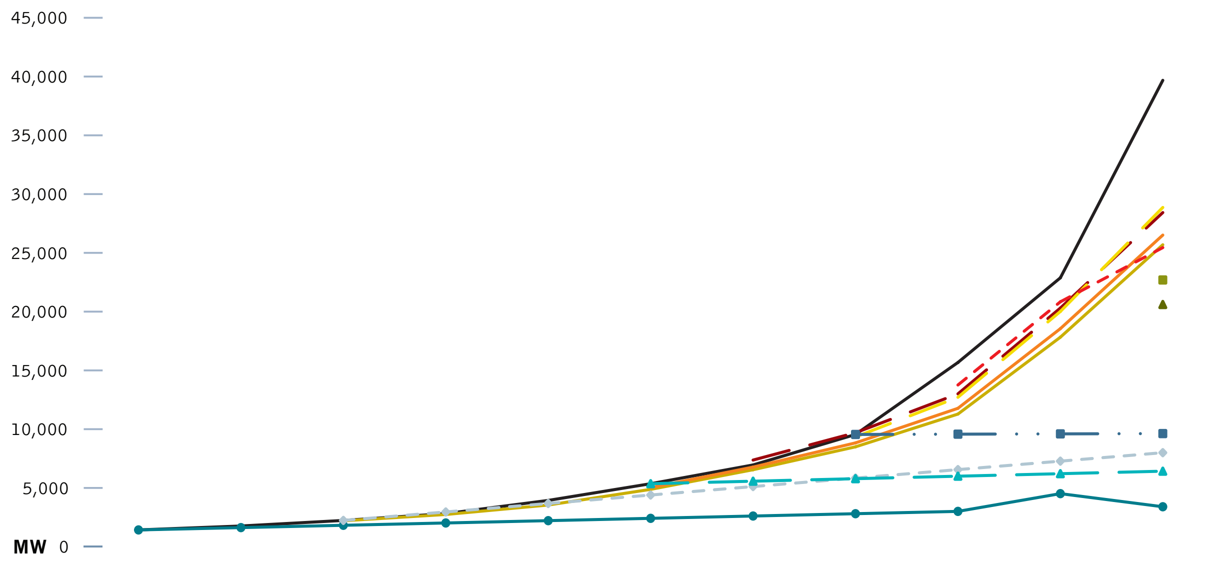
	2010	2015	2020	2030
WF 10 (1999)	181,252	537,059	1,209,466	2,545,232
WF 12 (2002)	233,905	610,000	1,261,157	2,571,000
GWEO 2006 (Advanced)	153,759	391,077	1,074,835	2,110,401
GWEO 2008 (Advanced)	186,309	485,834	1,080,886	2,375,000
GWEO 2008 (Advanced)	0	533,233	1,071,415	2,341,984
E[R] 2007	156,149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

4.10.2 the development of the global solar photovoltaic industry

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

Figure 4.7 shows the actual projections for each year between 2001 and 2010 compared to the real market data, against the first two Energy [R]evolution editions (published in 2007 and 2008) and the IEA's solar projections published in World Energy Outlook (WEO) 2000, 2002, 2005 and 2007. The IEA did not make specific projections for solar photovoltaic in the first editions analysed in the research, instead the category "Solar/Tidal/Other" are presented in Figure 4.7 and 4.8.

figure 4.7: photovoltaics: short term prognosis vs real market development - global cummulative capacity



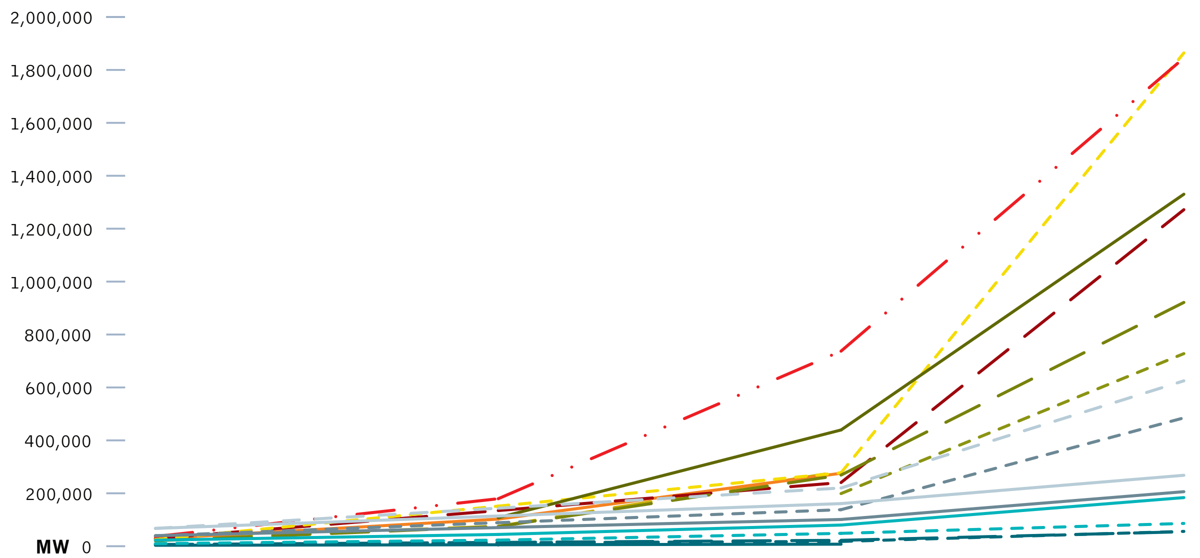
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
REAL	1,428	1,762	2,236	2,818	3,939	5,361	6,956	9,550	15,675	22,878	39,678
SG I 2001			2,205	2,742	3,546	4,879	6,549	8,498	11,285	17,825	25,688
SG II 2004						5,026	6,772	8,833	11,775	18,552	26,512
SG III 2006							7,372	9,698	13,005	20,305	28,428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

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.

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

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

figure 4.8: photovoltaic: long term market projects until 2030



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

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

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

Four future pathways, the following models were assessed intensively:

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

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

The IPCC notes that scenario results are determined partly by assumptions, but also might depend on the underlying modelling architecture and model specific restrictions. The scenarios analysed use different modelling architectures, demand projections and technology portfolios for the supply side. The full results are provided in Table 4.14, but in summary:

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

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

table 4.14: overview of key parameter of the illustrative scenarios based on assumptions that are exogenous to the models respective endogenous model results

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

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

key results of the turkey energy [r]evolution scenario

> “renewable energy should become the central pillar of our future energy supply”
>
> **ANGELA MERKEL**
> CHANCELLOR OF GERMANY

image LOCATED IN THE WESTERN ANATOLIA REGION OF TURKEY, İZMIR IS THE COUNTRY'S THIRD MOST POPULOUS CITY AND ITS SECOND LARGEST PORT (AFTER ISTANBUL).

5.1 energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for Turkey's final energy demand. These are shown in Figure 5.1 for the Reference and the Energy [R]evolution scenario. Under the Reference scenario, total final energy demand increases by 92% from the current 3,359 PJ/a (2012) to 6,438 PJ/a in 2050. In the Energy [R]evolution scenario, final energy demand increases at a much lower rate by 25% compared to current consumption and it is expected to reach 4,184 PJ/a by 2050.

Under the Energy [R]evolution scenario, due to economic growth, increasing living standards and electrification of the transport sector, electricity demand is exptected to increase in the industry sector, in the residential and service sectors as well as in the transport sector (see Figure 5.2). Total electricity demand will rise from 193 TWh/a to 397 TWh/a by the year 2050. Compared to the Reference scenario, efficiency measures in the industry, residential and service sectors avoid the generation of about 132 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors.

Efficiency gains in the heating and cooling sector are even larger. Under the Energy [R]evolution scenario, demand for heating and cooling is expected to increase until 2040 and remains rather constant afterwards (see Figure 5.4). Compared to the Reference scenario, consumption equivalent to 783 PJ/a is avoided through efficiency gains by 2050. As a result of energy-related renovation of the existing stock of residential buildings, the introduction of low energy standards and 'passive climatisation' for new buildings, as well as highly efficient air conditioning systems, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

figure 5.1: total final energy demand by sector under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

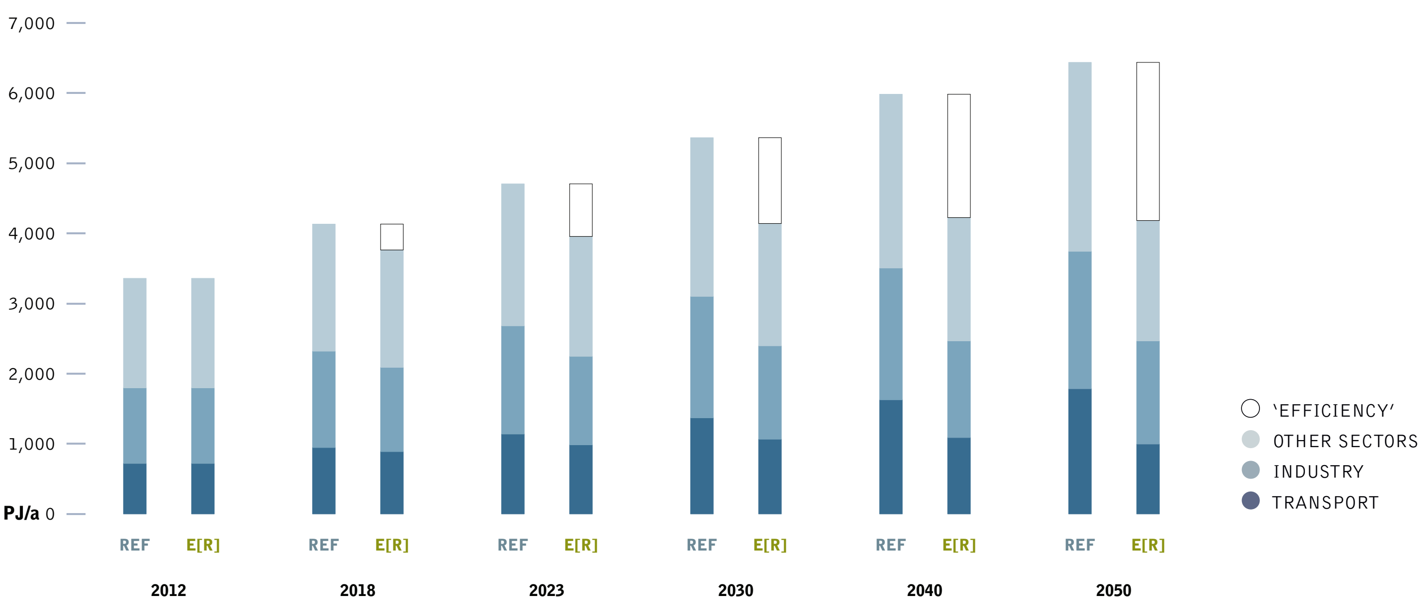


image WINDMILLS AT SUNSET IN BOZCAADA, TURKEY.

image SOLAR WATER HEATERS AND PHOTOVOLTAIC CELLS ON ROOFTOPS IN TURKEY.

figure 5.2: development of electricity demand by sector in the energy [r]evolution scenario

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

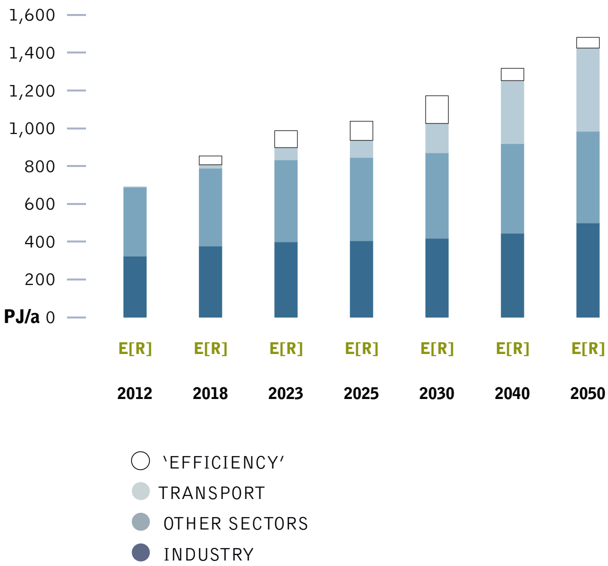


figure 5.4: development of heat demand by sector in the energy [r]evolution scenario

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

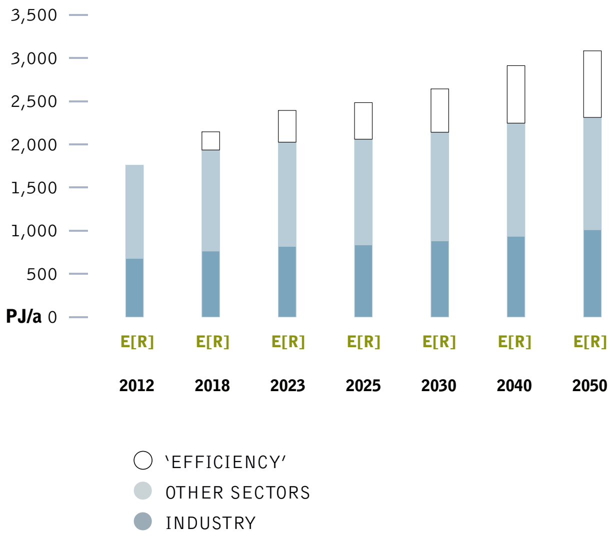
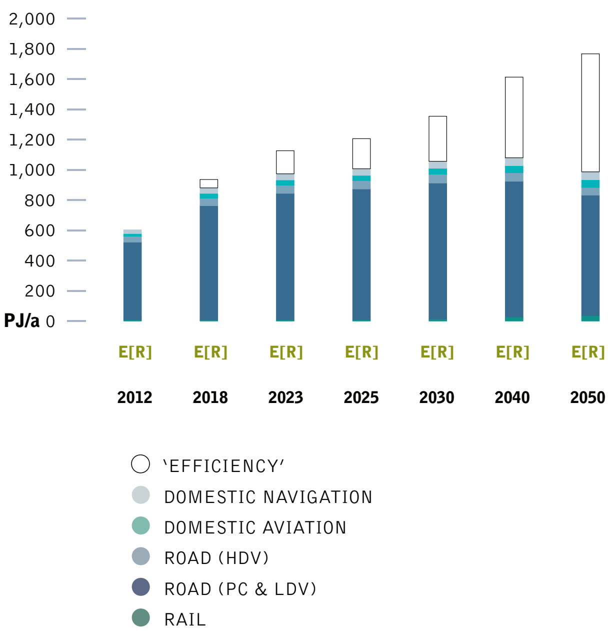


figure 5.3: development of the final energy demand for transport by sector in the energy [r]evolution scenario



5.2 electricity generation

The development of the electricity supply sector is charaterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the abstinence of nuclear power production in the Energy [R]evolution scenario and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 90% of the electricity produced in Turkey will come from renewable energy sources. 'New' renewables – mainly wind, solar energy and geothermal energy – will contribute 68% to the total electricity generation. Already by 2023 the share of renewable electricity production will be 47% and 65% by 2030. The installed capacity of renewables will reach 83 GW in 2030 and 156 GW by 2050.

Table 5.1 shows the comparative evolution of the different renewable technologies in Turkey over time. Up to 2023 wind and PV will become the main contributors of the growing market share. After 2023, the continuing growth of wind and PV will be complemented by electricity from biomass, solar thermal and geothermal energy. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 26% by 2030 and 42% by 2050, therefore the expansion of smart grids, demand side management (DSM) and storage capacity from the increased share of electric vehicles will be used for a better grid integration and power generation management.

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

IN GW

		2012	2018	2023	2030	2040	2050
Hydro[a]	REF	18	20	22	24	26	27
	E[R]	18	18	18	19	19	19
Biomass[b]	REF	0	1	1	2	3	4
	E[R]	0	2	4	9	14	15
Wind	REF	3	6	8	12	16	20
	E[R]	3	8	13	20	33	42
Geothermal	REF	0	0	0	0	1	1
	E[R]	0	1	1	2	4	4
PV	REF	0	2	3	5	7	7
	E[R]	0	6	13	26	44	55
CSP[c]	REF	0	0	0	0	0	1
	E[R]	0	1	3	7	15	19
Ocean energy	REF	0	0	0	0	0	0
	E[R]	0	0	0	0	1	1
Total	**REF**	**21**	**29**	**35**	**44**	**53**	**60**
	E[R]	**21**	**35**	**53**	**83**	**129**	**156**

notes
A - GIVEN THE LOCAL RESISTANCES AGAINST HYDRO PROJECTS AND THE RIGHT FOR ACCESS TO WATER, ONLY EFFICIENCY IMPROVEMENTS IN CURRENT HYDRO PLANTS ARE TAKEN INTO ACCOUNT.
B - BIOMASS PROJECTIONS HAS BEEN LIMITED IN ALLOWANCE OF FOOD SECURITY.
C - ON CSP, THE PRINCIPLE OF NOT USING THE AGRICULTURAL LANDS HAS BEEN IMPLEMENTED TO E(R) SCENARIO.

figure 5.5: electricity generation structure under the reference scenario and the energy [r]evolution scenario (INCLUDING ELECTRICITY FOR ELECTROMOBILITY, HEAT PUMPS AND HYDROGEN GENERATION)

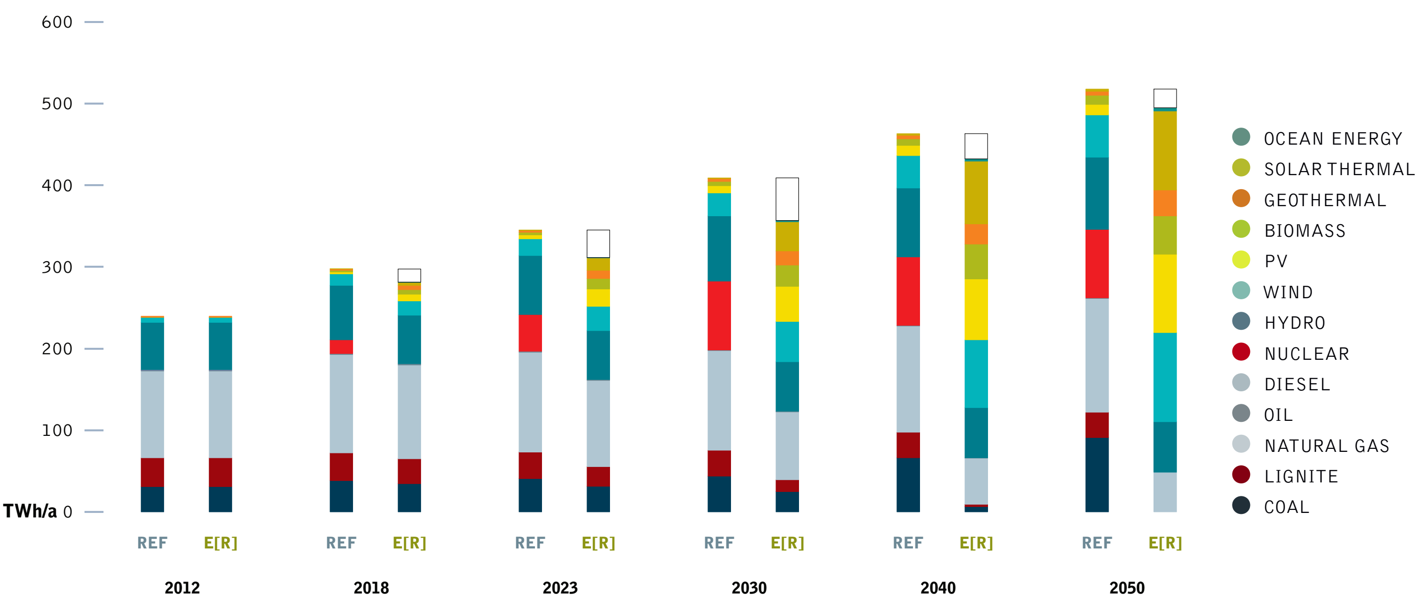


image PHOTOVOLTAIC CELLS ON A ROOFTOP, TURKEY.

image OIL REFINERY, KIRIKKALE, TURKEY.

5.3 future costs of electricity generation

Figure 5.6 shows that the introduction of renewable technologies under the Energy [R]evolution scenario increases the future costs of electricity generation compared to the Reference scenario until 2018. This difference will be less than 1 €ct/kWh up to 2018, however. Because of high prices for conventional fuels and the lower CO_2 intensity of electricity generation, from 2023 on electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be 4.3 €ct/kWh below those in the Reference version.

Under the Reference scenario, on the other hand, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's € 22 billion per year to more than € 63 billion in 2050, compared to € 46 billion in the Energy [R]evolution scenario. Figure 5.6 shows that the Energy [R]evolution scenario not only complies with Turkey's CO_2 reduction targets, but also helps to stabilise energy costs and relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are more than 27% lower than in the Reference scenario.

5.4 future investments in the power sector

It would require € 397 billion in investment for the Energy [R]evolution scenario to become reality within four decades until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately € 9.9 billion per year or € 157 billion more than in the Reference scenario (€ 240 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 47% while approximately 53% would be invested in renewable energy until 2050.

Under the Energy [R]evolution scenario, however, Turkey would shift more than 90% of the entire investment towards renewables. Until 2030, the fossil fuel share of power sector investment would be focused mainly on gas power plants.

Because renewable energy has no fuel costs, the fuel cost savings in the Energy [R]evolution scenario reach a total of € 280 billion within four decades up to 2050, or € 7 billion per year. The total fuel cost savings therefore would cover about 180% of the total additional investments compared to the Reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.

figure 5.6: total electricity supply costs and specific electricity generation costs under two scenarios

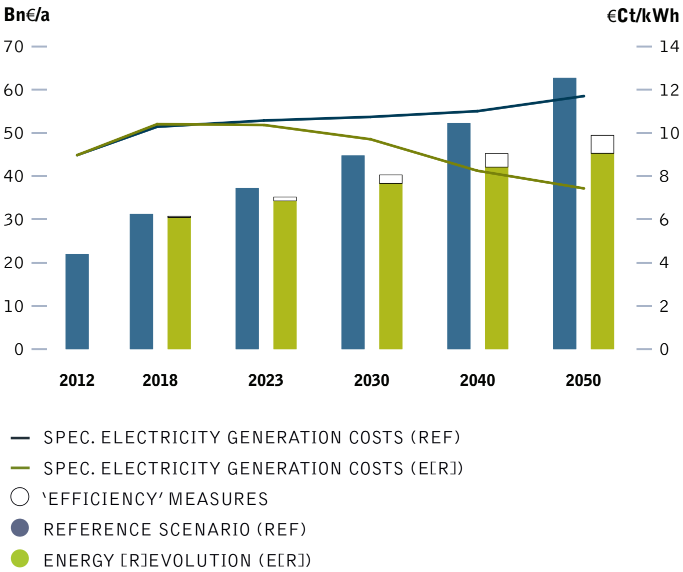
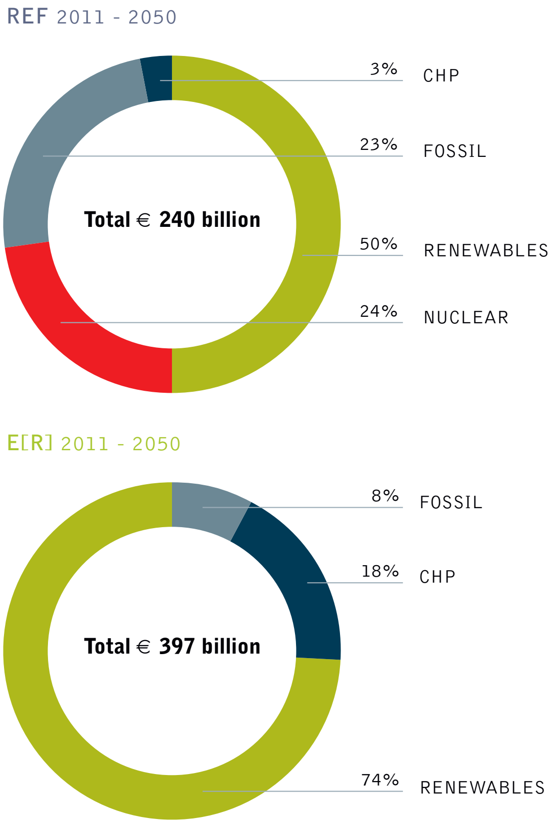


figure 5.7: investment shares - reference scenario versus energy [r]evolution scenario



5 key results | TURKEY - ELECTRICITY GENERATION

5.5 heating supply

Today, renewables meet 15% of Turkey's energy demand for heating and cooling, the main contribution coming from the use of biomass. Dedicated support instruments are required to ensure a dynamic development in particular for renewable cooling technologies (e.g. solar cooling) and renewable process heat production. In the Energy [R]evolution scenario, renewables provide 52% of Turkey's total heat demand in 2030 and 87% in 2050.

- Energy efficiency measures help to reduce the currently growing energy demand for heating and cooling by 25% in 2050 (relative to the Reference scenario), in spite of improving living standards and economic growth.
- In the industry sector solar collectors, geothermal energy (incl. heat pumps) as well as electricity and hydrogen from renewable sources are increasingly substituting for fossil fuel-fired systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of CO_2 emissions.

Table 5.2 shows the development of the different renewable technologies for heating and cooling in Turkey over time. All technologies (biomass, solar thermal heating and cooling as well as geothermal heating and heat pumps) will grow over the whole time and thus will reduce the dependence on fossil fuels.

table 5.2: renewable heating capacities under the reference scenario and the energy [r]evolution scenario

IN GW

		2012	2018	2023	2030	2040	2050
Biomass	REF	109	121	133	153	196	232
	E[R]	109	177	260	393	562	664
Solar (heating & cooling)	REF	32	52	66	86	113	126
	E[R]	32	151	243	371	527	685
Geothermal heat and heat pumps	REF	90	101	111	123	138	161
	E[R]	90	159	218	299	409	524
Total	**REF**	**231**	**274**	**310**	**361**	**447**	**519**
	E[R]	**231**	**488**	**720**	**1,063**	**1,497**	**1,873**

figure 5.8: heat supply structure under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

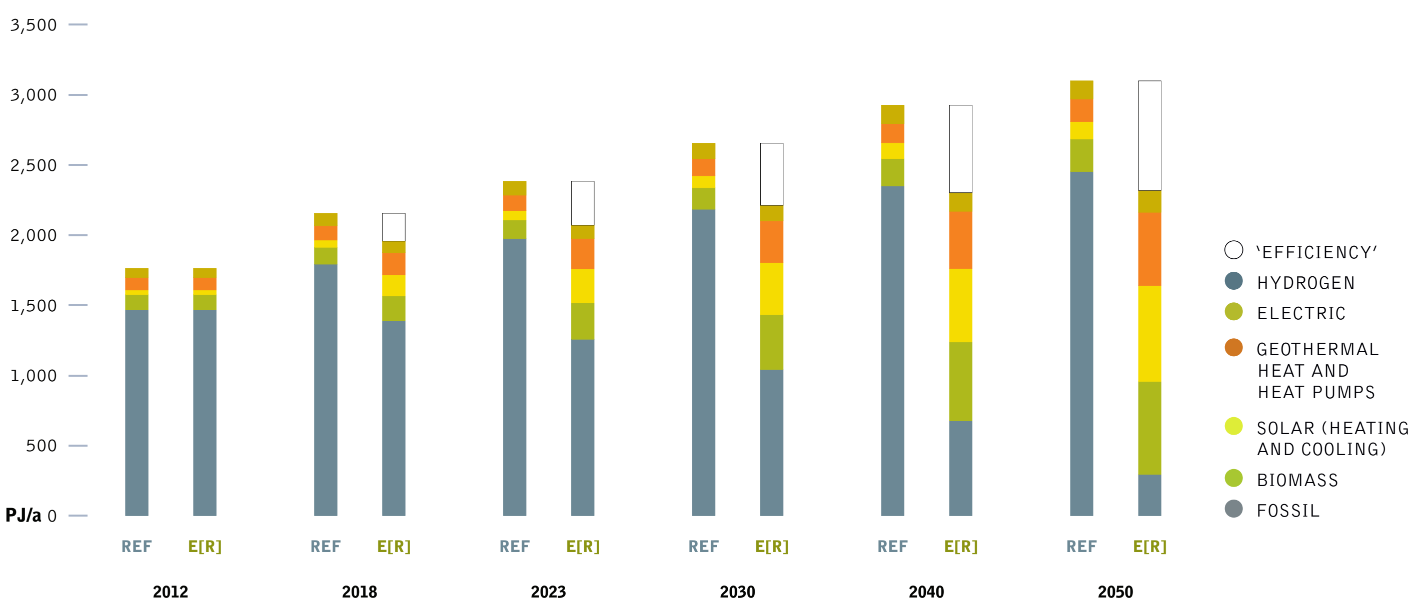


image A SOLAR POWERED LIGHT BUOY NEAR BODRUM HARBOUR ENTRANCE, TURKEY

image ATATURK DAM IN TURKEY AND SANLIURFA.

5.6 future investments in the heat sector

Also in the heating and cooling sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially solar thermal, solar cooling and geothermal and heat pump technologies need enourmous increase in installations, if these potentials are to be tapped for the heat sector. The use of biomass for heating purposes - mostly traditional biomass today - will be substantially reduced in the Energy [R]evolution scenario and be replaced by more efficient and sustainable renewable heating technologies.

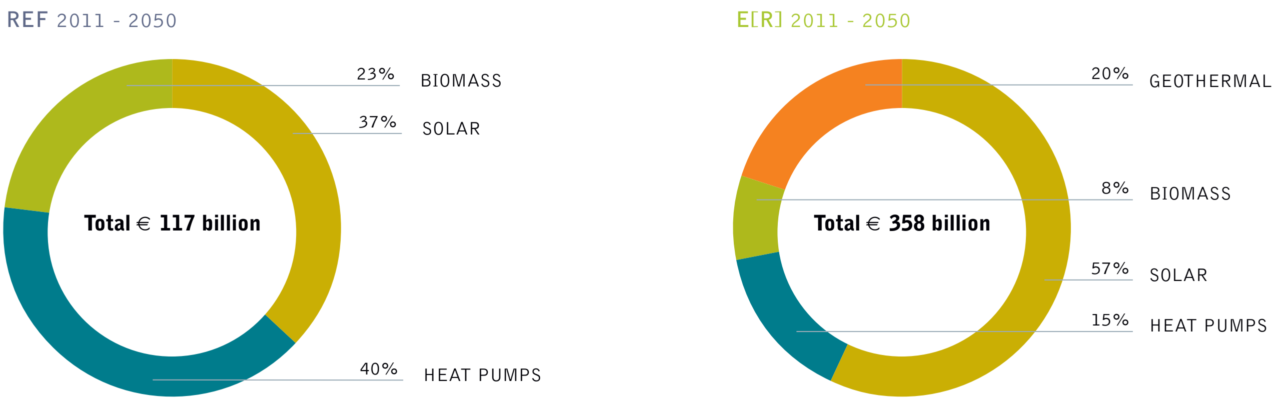
Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar cooling systems. Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around € 358 billion to be invested in renewable heating technologies within four decades until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately € 9 billion per year.

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

		2012	2018	2023	2030	2040	2050
Biomass	REF	32	29	32	35	40	43
	E[R]	32	34	38	43	44	45
Deep geothermal	REF	0	0	0	0	0	0
	E[R]	0	7	12	19	24	28
Solar thermal (heating and cooling)	REF	7	16	20	26	34	38
	E[R]	7	43	70	108	158	211
Heat pumps	REF	17	19	20	22	25	28
	E[R]	17	20	22	24	28	31
Total[1]	**REF**	**56**	**64**	**72**	**84**	**99**	**109**
	E[R]	**56**	**104**	**142**	**194**	**254**	**315**

1) excluding direct electric heating

figure 5.9: investments for renewable heat generation technologies under the reference scenario and the energy [r]evolution scenario



5.7 transport

A key target in Turkey is to introduce incentives for people to drive smaller cars. In addition, it is vital to shift transport use to efficient modes like rail, light rail and buses, especially in the expanding large metropolitan areas. Together with rising prices for fossil fuels, these changes reduce the huge growth in car sales projected under the Reference scenario. Due to population increase, GDP growth and higher living standards, energy demand from the transport sector is expected to increase in the Energy [R]evolution scenario by 39% to about 1,000 PJ/a in 2050, 279 PJ/a higher than today's levels (721 PJ/a). However, in 2050 efficiency measures and mode shifts will save 44% compared to the Reference scenario (1,785 PJ/a).

Highly efficient propulsion technology with hybrid, plug-in hybrid and batteryelectric power trains will bring large efficiency gains. By 2030, electricity will provide 15% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 44%.

table 5.4: transport energy demand by mode under the reference scenario and the energy [r]evolution scenario

(WITHOUT ENERGY FOR PIPELINE TRANSPORT) IN PJ/A

		2012	2018	2023	2030	2040	2050
Rail	REF	9	11	12	13	15	16
	E[R]	9	10	10	13	28	35
Road	REF	669	857	1,023	1,252	1,495	1,639
	E[R]	669	808	882	962	958	854
Domestic aviation	REF	16	36	40	47	55	60
	E[R]	16	33	35	39	47	50
Domestic navigation	REF	20	37	43	50	56	60
	E[R]	20	36	41	47	52	54
Total	**REF**	**715**	**941**	**1,117**	**1,362**	**1,621**	**1,775**
	E[R]	**715**	**887**	**968**	**1,062**	**1,085**	**992**

figure 5.10: final energy consumption for transport under the reference scenario and the energy [r]evolution scenario

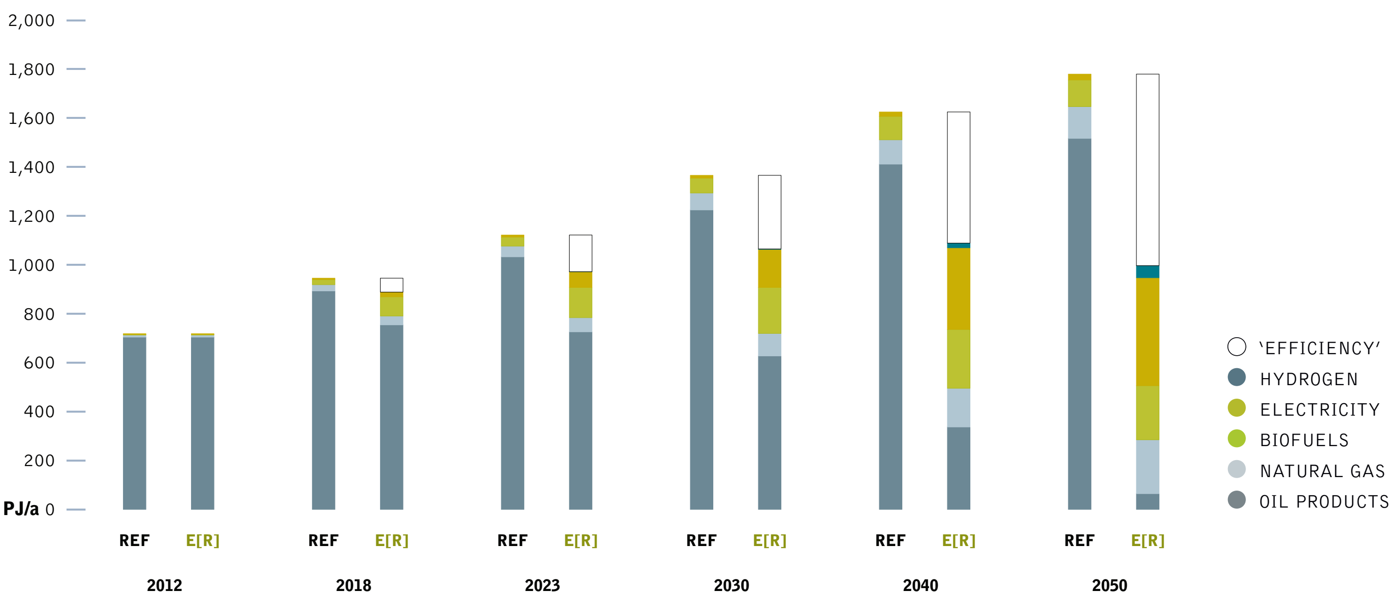


image SOLAR WATER HEATING SYSTEM ON THE ROOF, TURKEY.

image COAL MINE SHAFT IN ZONGULDAK, TURKEY.

5.8 development of CO_2 emissions

While Turkey's emissions of CO_2 will increase by 76% between 2012 and 2050 under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 278 million tonnes in 2012 to 59 million tonnes in 2050. Annual per capita emissions will drop from 3.7 tonnes to 0.6 tonnes. In spite of the abstinence of nuclear power production and increasing energy demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable in vehicles will reduce emissions also in the transport sector. With a share of 37% of CO_2, the industry sector will be the largest source of emissions in 2050. By 2050, Turkey's CO_2 emissions are 54% below 1990 levels.

5.9 primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the Energy [R]evolution scenario is shown in Figure 5.11. Under the Energy [R]evolution scenario, primary energy demand will increase by 15% from today's 4,956 PJ/a to 5,682 PJ/a. Compared to the Reference scenario, overall primary energy demand will be reduced by 38% in 2050 under the Energy [R]evolution scenario (Reference scenario: 9,095 PJ in 2050).

The Energy [R]evolution version aims to phase out coal and oil as fast as technically and economically possible. This is made possible mainly by replacement of coal power plants with renewables and a fast introduction of very efficient electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 45% in 2030 and 79% in 2050. In contrast to the Reference scenario, no nuclear power plants will be built in Turkey in the Energy [R]evolution scenario.

figure 5.12: development of CO_2 emissions by sector under the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

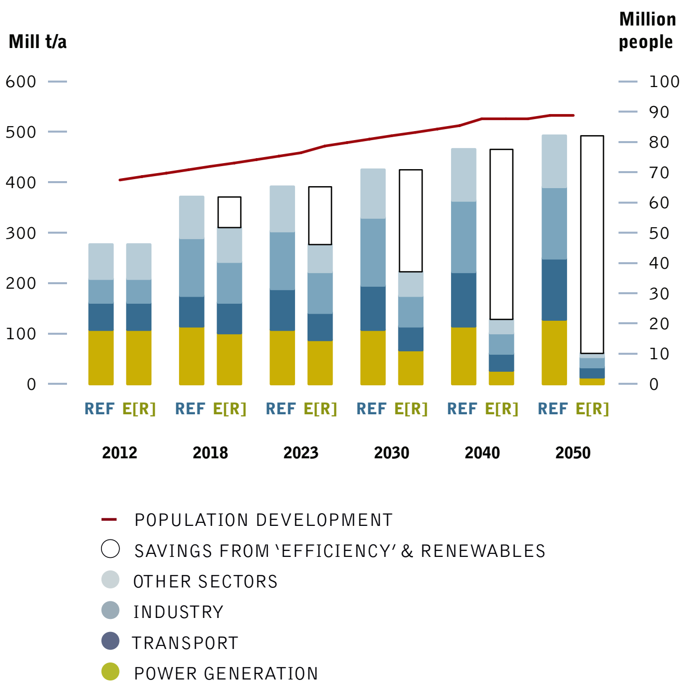


figure 5.11: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

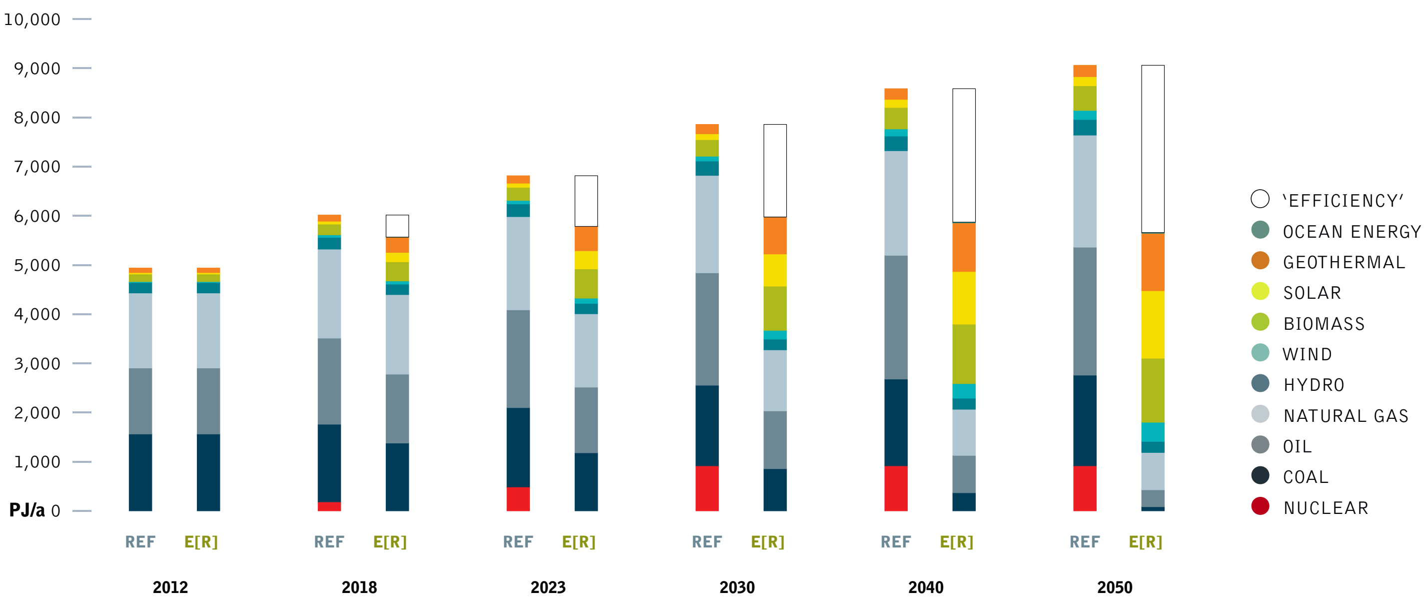


table 5.5: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

ACCUMULATED INVESTMENT COSTS		2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE REF MINUS E[R]							
Conventional (fossil + nuclear)	billion €	20.1	42.7	9.4	9.5	81.7	81.7
Renewables (incl. CHP)	billion €	-19.2	-59.4	-80.7	-79.8	-239.0	-239.0
Total	billion €	0.9	-16.7	-71.3	-70.3	-157.4	-157.4

ACCUMULATED FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion €	-0.2	0.2	1.3	2.0	3.2	3.2
Gas	billion €	1.3	16.6	58.3	103.2	179.4	179.4
Hard coal	billion €	0.8	5.2	17.3	36.8	60.2	60.2
Lignite	billion €	0.2	1.5	3.0	4.0	8.7	8.7
Nuclear energy	billion €	0.7	5.9	10.0	12.2	28.8	28.8
Total	billion €	2.9	29.4	89.9	158.1	280.4	280.4

employment projections

image THE ARAS RIVER SEPARATES THE ARMENIA TO THE NORTH-NORTHEAST AND TURKEY TO THE SOUTH-SOUTHWEST. EXTENSIVE GREEN AGRICULTURAL FIELDS ARE COMMON ON BOTH SIDES OF THE RIVER (IMAGE TOP), AS WELL AS A NUMBER OF GRAY TO TAN URBAN AREAS INCLUDING ARTASHAT AND ARMAVIR IN ARMENIA, AND IGDIR IN TURKEY. THE DOMINANT GEOGRAPHIC FEATURE IN THE REGION IS MT. ARARAT, ALSO KNOWN AS AGRI DAGI. THE WHITE, GLACIER-CLAD PEAK OF MT. ARARAT IS EVIDENT AT IMAGE CENTER.

6.1 methodology to calculate jobs

Greenpeace International and the European Renewable Energy Council have published four global Energy [R]evolution scenarios. These compare a low-carbon Energy [R]evolution scenario to a Reference scenario based on the International Energy Agency (IEA) "business as usual" projections (from the World Energy Outlook series, for example International Energy Agency, 2007, 2011a). The Institute for Sustainable Futures (ISF) analysed the employment effects of the 2008 and 2012 Energy [R]evolution global scenarios. The methodology used in the 2012 global analysis is used to calculate energy sector employment for Turkey's Energy [R]evolution and Reference scenario.

Employment is projected for Turkey for both scenarios at 2015, 2020 and 2030 by using a series of employment multipliers and the projected electrical generation, electrical capacity, heat collector capacity, and primary consumption of coal, gas and biomass (excluding gas used for transport). The results of the energy scenarios are used as inputs to the employment modelling.

Only direct employment is included, namely jobs in construction, manufacturing, operations and maintenance (O&M), and fuel supply associated with electricity generation and direct heat provision. Indirect jobs and induced jobs are not included in the calculations. Indirect jobs generally include jobs in secondary industries that supply the primary industry sector, for example, catering and accommodation. Induced jobs are those resulting from spending wages earned in the primary industries. Energy efficiency jobs are also excluded, despite the fact that the Energy [R]evolution includes significant development of efficiency, as the uncertainties in estimation are too great.

A detailed description of the methodology is given in Rutovitz & Harris, 2012a.

6.1.1 overview

Inputs for energy generation and demand for each scenario include:

- 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; and
- The amount of electricity generated per year from nuclear, oil and diesel.

Inputs for each technology include:

- "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 that reduces the employment factors by a certain percentage per year to reflect the employment per unit reduction as technology efficiencies improve;
- The percentage of local manufacturing and domestic fuel production in each region, in order to calculate the number of manufacturing and fuel production jobs in the region; and
- The percentage of world trade which originates in the region for coal and gas fuels, and for renewable traded components.

The electrical capacity increase and energy use figures from each scenario are multiplied by the employment factors for each of the technologies, as well as the proportion of fuel or manufacturing occurring locally. The calculation is summarised in Table 6.1.

image THROUGH BURNING OF WOOD CHIPS THE POWER PLANT GENERATES ELECTRICITY, ENERGY OR HEAT. HERE WE SEE THE STOCK OF WOOD CHIPS WITH A CAPACITY OF 1000 M³ ON WHICH THE PLANT CAN RUN, UNMANNED, FOR ABOUT FOUR DAYS. LELYSTAD, THE NETHERLANDS.

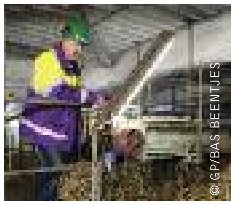


table 6.1: methodology overview

MANUFACTURING (FOR LOCAL USE)	=	MW INSTALLED PER YEAR IN REGION	×	MANUFACTURING EMPLOYMENT FACTOR	×	% OF LOCAL MANUFACTURING
MANUFACTURING (FOR EXPORT)	=	MW EXPORTED PER YEAR	×	MANUFACTURING EMPLOYMENT FACTOR		
CONSTRUCTION	=	MW INSTALLED PER YEAR	×	CONSTRUCTION EMPLOYMENT FACTOR		
OPERATION & MAINTENANCE	=	CUMULATIVE CAPACITY	×	O&M EMPLOYMENT FACTOR		
FUEL SUPPLY (COAL, GAS & BIOMASS)	=	PRIMARY ENERGY DEMAND PLUS EXPORTS	×	FUEL EMPLOYMENT FACTOR (ALWAYS REGIONAL FOR COAL)	×	% OF LOCAL PRODUCTION
HEAT SUPPLY	=	MW INSTALLED PER YEAR	×	EMPLOYMENT FACTOR FOR HEAT		

JOBS	=	**MANUFACTURING** + **CONSTRUCTION** + **OPERATION & MAINTENANCE (O&M)** + **FUEL** + **HEAT**
EMPLOYMENT FACTOR AT 2020 OR 2030	=	**2010 EMPLOYMENT FACTOR** × TECHNOLOGY DECLINE FACTOR$^{\text{(NUMBER OF YEARS AFTER 2010)}}$

6.1.2 limitations

Employment numbers are indicative only, as a large number of assumptions are required to make calculations. Quantitative data on present employment based on actual surveys is difficult to obtain, so it is not possible to calibrate the methodology against time series data, or even against current data in many regions. There are also some significant areas of employment that are not included, including replacement of generating plant, and energy efficiency jobs. However, within the limits of data availability, the figures presented are indicative of employment levels in the electricity and heat sectors under the two scenarios.

Insufficient data means it was not possible to include a comprehensive assessment for the heat supply sector. Only a partial estimate of the jobs in heat supply is included, as biomass, gas and coal jobs in this sector include only fuel supply jobs where heat is supplied directly (that is, not via a combined heat and power plant), while jobs in heat from geothermal and solar collectors primarily include manufacturing and installation.

6.1.3 employment factors

The employment factors used in the 2013 Turkey analysis are shown in Table 6.2, with the main source given in the notes. Most factors are from the 2012 global analysis (Rutovitz & Harris 2012a), and are OECD factors. Other than coal mining, local data was unfortunately not available, so coal mining is the only local factor for Turkey.

The employment factor for coal mining is considerably higher than the OECD factor, by 15 times in the case of hard coal mining, and by 2.7 times in the case of lignite. It is possible that job creation in other areas would also be higher per MW.

Turkish labour productivity, or the ratio of GDP per worker, is approximately 42% and 34% lower than OECD and EU labour productivity respectively. This would imply that job creation per MW could be 1.5 times higher than the OECD averages. Clearly, coal production jobs per PJ are a great deal higher than this.

ISF has taken a conservative approach and used the OECD job multipliers unchanged where there is no local data. As the main fossil fuel employer is coal mining, which uses local data with a factor 3 – 15 times higher than the OECD, this has the effect of reducing the projected numbers of renewable energy jobs relative to fossil fuel jobs in this projection.

table 6.2: employment factors used in the 2013 analysis for turkey

FUEL	CONSTRUCTION TIMES *Years*	CONSTRUCTION /INSTALLATION *Job years/MW*	MANUFACTURING *Jobs years/MW*	OPERATION & MAINTENANCE *Jobs/MW*	FUEL – PRIMARY ENERGY DEMAND *Jobs/PJ*	
Coal	5	7.7	3.5	0.1	350.7	Note 1
Lignite	5	7.7	3.5	0.1	61.0	Note 1
Gas	2	1.7	1.0	0.1	21.9	Note 2
Nuclear	8	13.7	1.3	0.3		Note 3
Biomass	2	14.0	2.9	1.5	32.2	Note 4
Hydro	2	6.0	1.5	0.3		Note 5
Wind onshore	2	2.5	6.1	0.2		Note 6
Wind offshore	4	7.1	10.7	0.2		Note 7
PV	1	10.9	6.9	0.3		Note 8
Geothermal	2	6.8	3.9	0.4		Note 9
Solar thermal	2	8.9	4.0	0.5		Note 10
Ocean	2	9.0	1.0	0.3		Note 11
Geothermal - heat	6.92 jobs/ MW (construction and manufacturing)					Note 12
Solar - heat	7.4 jobs/ MW (construction and manufacturing)					Note 13
Combined Heat and Power (CHP)	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.					
Oil and diesel	Use the employment factors for gas					Note 2

sources for employment factors

1. **Hard coal and lignite:** Construction, manufacturing and O&M factors are from the JEDI model (National Renewable Energy Laboratory 2011a). The hard coal and lignite mining employment factors are calculated from Eurocoal data (Euracoal 2011). Coal mining employment per PJ is extremely high compared to other European coal mining, particularly for hard coal.

2. **Gas, oil and diesel:** Installation and manufacturing factors are from the Jobs and Economic Development Impact (JEDI) model (National Renewable Energy Laboratory 2011b). O&M factor is an average figure from the 2010 report (Rutovitz & Usher 2010) , the JEDI model (National Renewable Energy Laboratory 2011b), a US study (National Commission on Energy Policy 2009) and ISF research (Rutovitz & Harris 2012b). Fuel factor per PJ is the weighted average of US, Canadian, and Russian employment in gas production, derived from US and Canadian information (America's Natural Gas Alliance 2008; IHS Global Insight (Canada) Ltd 2009; Zubov 2012).

3. **Nuclear:** The construction factor is the average of two studies from the UK and one from the US (Cogent Sector Skills Council 2010; Cogent Sector Skills Council 2011; National Commission on Energy Policy 2009). The manufacturing factor is the average of the two UK reports, while the O&M factor is the average of values from all three studies and ISF research (Rutovitz & Harris 2012b).The fuel factor was derived by ISF in 2009 (Rutovitz & Atherton 2009).

4. **Bioenergy:** Employment factors for construction, manufacturing and O&M use the average value of studies from Greece, the UK, Spain, USA and Europe (Kjaer 2006; Thornley 2006; Thornley et al. 2008; Tourkolias & Mirasgedis 2011; Moreno & López 2008; EPRI 2001). Fuel employment per PJ primary energy is derived from six studies, all in Europe (Domac et al. 2005; Hillring 2002; Thornley 2006; Upham & Speakman 2007; Kjaer 2006; Valente et al. 2011)

5. **Hydro:** Construction and manufacturing factors are from a US study (Navigant Consulting 2009). O&M factor is an average of data from the US study (Navigant Consulting 2009) and ISF research (Rutovitz 2010; Rutovitz & Ison 2011; Rutovitz & Harris 2012b).

6. **Wind – onshore:** The installation factor used is from the European Wind Energy Association (European Wind Energy Association 2009). The manufacturing and O&M factors were derived in the Institute's 2012 global study (Rutovitz & Harris 2012a).

7. **Wind - offshore:** All factors are from a German report (Price Waterhouse Coopers 2012).

8. **Solar PV:** The installation factor is the average of five estimates in Germany and the US, while manufacturing is taken from the JEDI model (National Renewable Energy Laboratory, 2010), a Greek study (Tourkolias & Mirasgedis 2011), a Korean national report (Korea Energy Management Corporation (KEMCO) & New and Renewable Energy Center (NREC) 2012), and ISF research for Japan (Rutovitz & Ison 2011).

9. **Geothermal:** Construction and O&M jobs are from the ISF global study, and are a weighted average of 19 reported power plants (3223 MW) in the US, Spain, and Australia (Rutovitz & Harris 2012a). The manufacturing factor is derived from a US study (Geothermal Energy Association 2010).

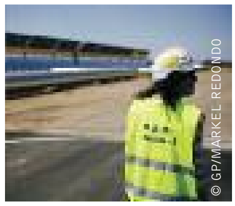
10. **Solar thermal power:** Construction and O&M jobs were derived from a weighted average of 10 reported power plants (951 MW) in Europe (Rutovitz & Harris, 2012a). The manufacturing factor came from the European Renewable Energy Council, 2008, page 16.

11. **Ocean:** The construction factor used in this study is a combined projection for wave and tidal power derived from data for offshore wind power (Batten & Bahaj 2007). A study of a particular wave power technology, Wave Dragon, provided jobs creation potential for that technology, and the O&M factor used here is based on that report (Soerensen 2008).

12. **Geothermal and heat pumps:** One overall factor has been used for jobs per MW installed. This is derived from analysis of a US industry survey in 2012, which reported 9,088 total jobs in 2012, including 2,611 manufacturing jobs (Battocletti & Glassley 2012). Shipments of heat pumps during that year came to 1,314 MW.

13. **Solar thermal heating:** One overall factor has been used for jobs per MW installed, as this is the only data available on any large scale. This may underestimate jobs, as it may not include O&M. The global figure was derived from the IEA heating and cooling program report (Weiss & Mauthner 2011).

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



6.1.4 coal, gas and renewable technology trade

It is assumed that all manufacturing for energy technologies, other than wind and PV, occurs within Turkey, but that only 30% of manufacturing for these two technologies occurs domestically. This allows for such items as support frames and wind turbine towers, which are generally locally manufactured.

Turkey produces a small amount of hard coal, approximately 7% of their consumption. However, hard coal and lignite mining employ a significant amount of people. Euroacoal reports 18,500 persons employed in hard coal mining, and 37,000 in lignite mining (Euracoal 2011). The data from Euracoal has been used to calculate the local employment factors for coal.

It is assumed that the coal production stays steady, and the proportion of local coal consumption in Table 6.3 is calculated on this basis. All lignite is produced domestically, and accounts for 90% of local coal consumption. There is no gas production in Turkey.

6.1.5 adjustment for learning rates – decline factors

Employment factors are adjusted to take into account the reduction in employment per unit of electrical capacity as technologies and production techniques mature. The learning rates assumed have a significant effect on the outcome of the analysis, and are given in Table 6.4. These declines rates are calculated directly from the cost data used in the Energy [R]evolution modelling for Turkey.

table 6.4: technology cost decline factors

	ANNUAL DECLINE IN JOB FACTORS		
	2010-2015	2015-2020	2020-30
Coal	0.3%	0.5%	0.3%
Lignite	0.4%	0.4%	0.4%
Gas	0.5%	1.0%	0.5%
Oil	0.4%	0.8%	0.4%
Diesel	0.0%	0.0%	0.0%
Nuclear	0.0%	0.0%	0.0%
Biomass	1.1%	0.7%	1.6%
Hydro	-0.6%	-0.9%	-0.6%
Wind onshore	2.2%	0.2%	1.6%
Wind offshore	8.9%	3.9%	6.4%
Solar PV	4.6%	2.2%	12.0%
Geothermal power	5.4%	7.3%	3.5%
Solar thermal power	5.1%	2.8%	5.6%
Ocean	6.5%	7.0%	4.8%
Coal CHP	0.3%	0.5%	0.3%
Lignite CHP	0.3%	0.5%	0.3%
Gas CHP	1.0%	1.0%	0.9%
Oil CHP	0.4%	0.8%	0.4%
Biomass CHP	2.2%	2.2%	2.0%
Geothermal CHP	3.2%	4.5%	2.6%
Geothermal - heat	0.0%	0.2%	0.9%
Solar thermal heat	0.0%	0.9%	1.8%

table 6.3: proportion of coal consumption produced within turkey

	REFERENCE				ENERGY [R]EVOLUTION			
	2010	2015	2020	2030	2010	2015	2020	2030
Hard coal	7%	7%	6%	6%	6%	8%	9%	12%
Lignite	100%	100%	100%	100%	100%	100%	100%	100%

6.2 future employment in the energy sector

Energy sector jobs in Turkey are higher in the Energy [R]evolution scenario at every stage of the projection. Jobs increase in both scenarios to 2015. Exceptionally strong growth in renewable energy in the Energy [R]evolution scenario takes jobs at 2020 to 42,000, 49% above 2010 levels. Energy sector jobs continue to grow in the Energy [R]evolution scenario, and at 2030 are 49,000 above 2010 levels. Jobs in the Reference scenario drop slightly after 2020, but are still 13,200 above 2010 levels by 2030.

- Jobs increase in both scenarios to 2015, with jobs in the Energy [R]evolution scenario up 16,100 (19%) and jobs in the Reference scenario up 11,400 (13%) relative to 2010.
- In 2020, there are more than 126,000 jobs in the Energy [R]evolution scenario and just under 102,000 in the Reference scenario.
- In 2030, there are approximately 133,000 jobs in the Energy [R]evolution scenario and 98,000 jobs in the Reference scenario.

Figure 6.1 shows the change in job numbers under both scenarios for each technology between 2010 and 2030. Jobs in the Reference scenario increase to 2020 and then drop slightly to 2030. In the Energy [R]evolution scenario, jobs rise sharply to 2020, and then rise slightly until 2030. Renewable energy accounts for 74% of energy jobs in 2030, with biomass having the greatest share (29%), followed by solar heating (22%).

Coal mining is the only sector where the analysis uses local employment data, and employment per unit of generation is high compared to OECD and European averages. Employment in other sectors is calculated using OECD data, so may have been underestimated. It is thus likely that renewable energy employment is higher than shown here.

figure 6.1: employment in the energy sector under the reference and energy [r]evolution scenarios

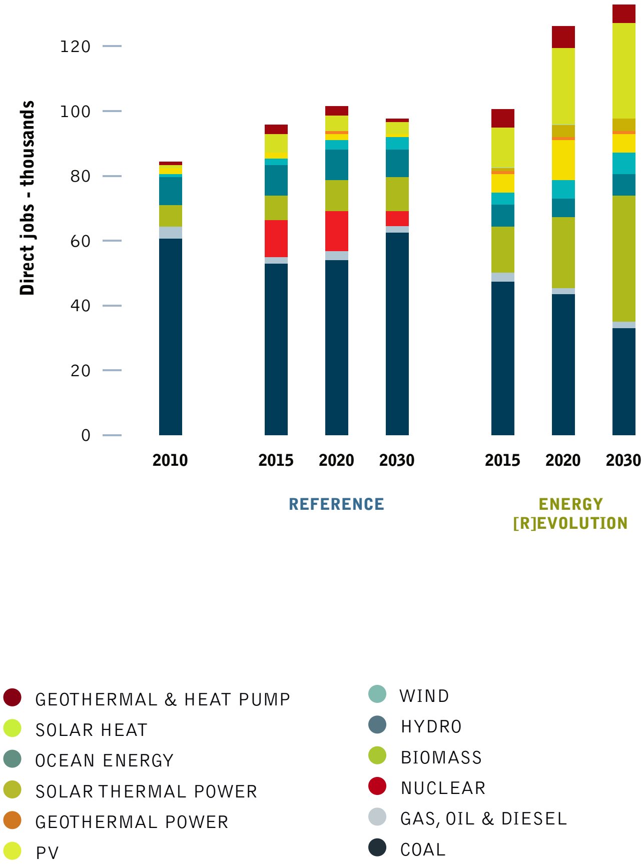


table 6.5: total employment in the energy sector

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	60,500	52,800	54,300	62,600	47,500	43,500	32,900
Gas, oil & diesel	3,900	2,200	2,100	2,100	2,400	2,200	1,900
Nuclear	-	11,400	13,000	4,200	-	-	-
Renewable	20,000	29,500	32,500	28,800	50,700	80,500	98,400
Total Jobs	**84,500**	**95,900**	**101,900**	**97,700**	**100,600**	**126,200**	**133,200**
Construction and installation	10,300	24,200	23,200	12,000	23,200	41,000	39,000
Manufacturing	4,000	6,400	6,100	5,100	9,000	14,400	14,400
Operations and maintenance	8,500	10,400	14,200	20,300	12,500	16,800	27,400
Fuel supply (domestic)	61,700	54,900	58,500	60,300	55,800	54,000	52,400
Coal and gas export	-	-	-	-	-	-	-
Total Jobs	**84,500**	**95,900**	**101,900**	**97,700**	**100,600**	**126,200**	**133,200**

image SOLAR PANEL INSTALLATION IN THE GARDEN,DIYARBAKIR,TURKEY.

figure 6.2: employment in the energy sector by technology in 2010 and 2030

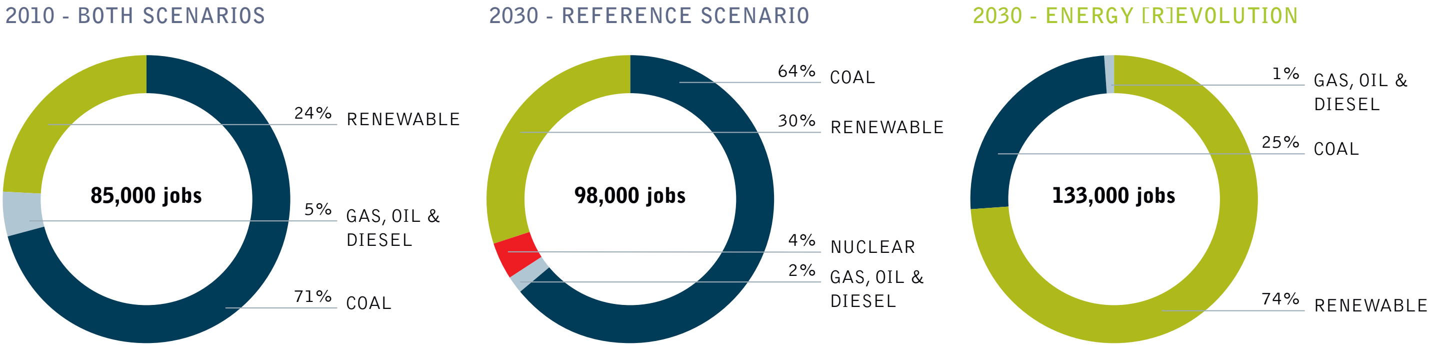


table 6.6: employment in the energy sector by technology, under the reference and energy [r]evolution scenarios

		REFERENCE			ENERGY [R]EVOLUTION		
By sector	2010	2015	2020	2030	2015	2020	2030
Construction and installation	8,800	18,300	17,300	8,600	10,500	19,500	13,700
Manufacturing	3,300	3,600	3,500	3,700	3,400	5,700	4,500
Operations and maintenance	8,500	10,400	14,200	20,300	12,500	16,800	27,400
Fuel supply (domestic)	61,700	54,900	58,500	60,300	55,800	54,000	52,400
Coal and gas export	0	0	0	0	0	0	0
Solar and geothermal heat	2,200	8,600	8,400	4,800	18,200	30,300	35,200
Total jobs	**84,500**	**95,800**	**101,900**	**97,700**	**100,400**	**126,300**	**133,200**
By technology							
Coal	60,500	52,800	54,300	62,600	47,500	43,500	32,900
Gas, oil & diesel	3,900	2,200	2,100	2,100	2,400	2,200	1,900
Nuclear	0	11,400	13,000	4,200	0	0	0
Renewable	**20,100**	**29,500**	**32,600**	**28,700**	**50,700**	**80,500**	**98,300**
Biomass	*6,600*	*7,600*	*8,900*	*10,300*	*14,900*	*21,600*	*39,200*
Hydro	*8,200*	*9,100*	*9,800*	*9,100*	*5,900*	*5,900*	*6,500*
Wind	*1,200*	*2,100*	*2,400*	*3,400*	*4,100*	*5,300*	*6,800*
PV	*1,700*	*1,800*	*2,700*	*900*	*6,000*	*13,000*	*5,400*
Geothermal power	*200*	*200*	*200*	*100*	*800*	*900*	*800*
Solar thermal power	-	-	*100*	*100*	*700*	*3,500*	*4,300*
Ocean	-	-	-	-	*100*	*100*	*100*
Solar - heat	*1,300*	*5,400*	*5,600*	*3,600*	*12,500*	*23,800*	*28,900*
Geothermal & heat pump	*900*	*3,300*	*2,900*	*1,200*	*5,700*	*6,400*	*6,300*
Total jobs	**84,500**	**95,900**	**101,900**	**97,700**	**100,600**	**126,200**	**133,200**

Note: numbers may not add up due to rounding.

6.3 employment in the renewable heating sector

6.3.1 employment in solar heating

In the Energy [R]evolution scenario, solar heating grows extremely strongly. It provides 10% of total heat supply by 2030. The solar heat sector is projected to employ approximately 28,900 people by 2030, more than twenty times the number in 2010. Capacity in the Energy Revolution scenario increases by 62 MW between 2010 and 2030. Capacity in the Reference scenario increases by 16 MW between 2010 and 2030, and employment only reaches 3,600, just double the number in 2010.

6.3.2 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, compared to 6% in 2010. Jobs remain constant, at around 6,000. Growth is slower in the Reference scenario, with geothermal and heat pump heating providing 5% of heat supply in 2030, and employing about 1,200 people.

6.3.3 employment in biomass heat supply

Biomass heat grows strongly in the Energy [R]evolution scenario, and provides 22% of heat supply by 2030. Employment grows from 4,500 people in 2010 to 11,800 people in 2030. In the Reference scenario the biomass heat sector remains almost constant, providing between 6% and 8% of heat supply, and employing close to 4,000 people.

table 6.7: solar heating: capacity, heat supplied and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	4.6	9.5	19.5	8	19	66
Heat supplied	PJ	16	32	66	28	66	219
Share of total heat supply	%	0.9%	1.5%	2.5%	1.6%	4%	10%
Annual increase in capacity	MW	181	967	957	1,921	2,255	4,747
Employment							
Direct jobs in installation and manufacture	jobs	5,400	5,600	3,600	12,500	23,800	28,900

table 6.8: geothermal and heat pump heating: capacity, heat supplied and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	16.6	18.9	23.2	18.7	22.9	33.7
Heat supplied	PJ	89	102	126	102	129	223
Share of total heat supply	%	5%	5%	5%	6%	7%	10%
Annual increase in capacity	MW	128	471	444	1,204	828	1,233
Employment							
Direct jobs in installation and manufacture	jobs	3,300	2,900	1,200	5,700	6,400	6,300

table 6.9: biomass heat: direct jobs in fuel supply

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Heat supplied	PJ	138	139	160	208	246	472
Share of total heat supply	%	8%	7%	6%	12%	13%	22%
Employment							
Direct jobs in fuel supply	jobs	4,200	4,100	4,000	6,300	7,200	11,800

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

6.4 renewable electricity: employment, generation and capacities

6.4.1 employment in hydro

Hydro supplies 25% of Turkey's electricity, and there are a number of schemes under construction. In the Energy [R]evolution scenario, hydro generation and employment are relatively stable. Employment falls from 8,000 in 2010 to 6,000 by 2015, and remains almost constant after that. In the Reference scenario, hydro capactiy continues growing steadily, and employment rises to 10,000 and then falls back to 9,000 by 2030.

6.4.2 employment in solar thermal power

Solar thermal power is yet to be developed in Turkey. In the Energy [R]evolution scenario, this technology is developed over the period, and by 2030 employs 4,300 people and provides 10% of total electricity generation. In contrast, in the Reference scenario, solar thermal power starts much more slowly, and by 2030 would employ only around 140 people.

table 6.10: hydro: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	18	21	24	17	17	18
Total generation	TWh	60	68	80	55	57	59
Share of total supply	%	24%	22%	20%	23%	21%	17%
Annual increase in capacity	GW	1.5	1.3	0.4	0.1	0.1	0.1
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	9,100	9,800	9,100	5,900	5,900	6,500

table 6.11: solar thermal power: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	-	0.02	0.14	0.06	1.2	6.9
Total generation	TWh	-	0.1	0.7	0.3	6.0	36.0
Share of total supply	%	-	0.0%	0.2%	0.1%	2.2%	10.3%
Annual increase in capacity	GW	0.005	0.01	0.02	0.05	0.31	0.58
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	-	80	140	700	3,500	4,300

6.4.3 employment in biomass

In the Energy [R]evolution scenario, electricity generation from biomass increases from almost nothing in 2010 to 7% of supply in 2030. Employment increases 13 fold, to reach 27,000 in 2030, compared to only 2,000 in 2010.

In the Reference scenario, biomass generation increases much more slowly, and provides 1.3% of electricity in 2030. Jobs increase by 63% to 3,000 in 2015, and to 6,000 by 2030, three times greater than 2010 levels. Jobs in biomass fuels for heating are not included here.

6.4.4 employment in solar photovoltaics

In the Energy [R]evolution scenario, solar photovoltaics grows from a small base in 2010, to provide 12% of electricity by 2030. Employment is highest in 2020, with 13,000 jobs. Employment then falls to 5,400 jobs 1in 2030. In the Reference scenario, growth is much more modest. Solar photovoltaics provides 2% of generation in 2030. Employment peaks at 2015, with 1,800, and 900 jobs remain in 2030.

6.4.5 employment in wind energy

In the Energy [R]evolution scenario, wind energy grows strongly and would provide 14% of total electricity generation by 2030, employing approximately 7,000 people. Growth is much more modest in the Reference scenario, with wind energy providing 7% of generation, and employing approximately 3,000 people.

table 6.12: biomass: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	0.2	0.7	1.7	1.4	2.3	8.5
Total generation	TWh	0.7	2.2	5.2	4.1	7.1	26.3
Share of total supply	%	0.3%	0.7%	1.3%	1.7%	2.6%	7.5%
Annual increase in capacity	GW	0.07	0.09	0.09	0.16	0.43	0.58
Employment							
Direct jobs in construction, manufacture, operation and maintenance, and fuel supply for power generation	jobs	3,400	4,800	6,300	8,600	14,400	27,400

table 6.13: solar photovoltaics: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	0.7	2.0	5.5	1.3	7.6	26.4
Total generation	TWh	1.0	3.2	8.9	2.0	12.0	43.0
Share of total supply	%	0.4%	1.0%	2.2%	0.8%	4.4%	12.3%
Annual increase in capacity	GW	0.2	0.2	0.2	0.6	1.2	1.5
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	1,800	2,700	900	6,000	13,000	5,400

table 6.14: wind energy: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	2.7	5.2	11.0	3.8	9.3	20.2
Total generation	TWh	6.0	12.0	26.4	8.5	21.5	49.0
Share of total supply	%	2%	4%	7%	3%	8%	14%
Annual increase in capacity	GW	0.8	0.4	0.5	0.9	1.0	1.2
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	2,100	2,400	3,400	4,100	5,300	6,800


© GP/VINAI DITHAJOHN

image WORKERS BUILD A WIND TURBINE IN A FACTORY IN PATHUM THANI, THAILAND. THE IMPACTS OF SEA-LEVEL RISE DUE TO CLIMATE CHANGE ARE PREDICTED TO HIT HARD ON COASTAL COUNTRIES IN ASIA, AND CLEAN RENEWABLE ENERGY IS A SOLUTION.

6.5 fossil fuels and nuclear energy - employment, generation and capacities

6.5.1 employment in coal

Coal generation currently supplies around 25% of Turkey's electricity. In the Energy [R]evolution scenario, this falls to 7% by 2030. Employment falls as well, from 61,000 to 33,000 by 2030. In the Reference scenario, coal generation remains at 18% of total electricity supply in 2030, and employment increases somewhat from 2010 levels, to reach 63,000 in 2030.

Coal mining is the only area where the analysis uses local employment data, and the employment per unit of generation is high compared to OECD and European averages. Employment in other sectors has been calculated using OECD data, and some may have been underestimated. It is thus likely that coal employment is not quite as high relative to other energy sectors as it appears here. Coal jobs in both scenarios include coal used for heat supply.

6.5.2 employment in gas, oil & diesel

Gas generation and employment is very similar in the Energy [R]evolution and the Reference scenarios. Generation from gas falls from 48% of electricity supply in 2010 to 27% in the Energy [R]evoltion scenario in 2030, and to 31% in the Reference scenario. Employment falls from 3,900 in 2010 and then remains close to 2,200 in both scenarios.

6.5.3 employment in nuclear energy

There are currently no nuclear power stations in Turkey. In the Reference scenario, nuclear power is projected to provide 21% of Turkey's electricity by 2030. The sector would employ approximately 4,200 people. In the Energy [R]evolution scenario, nuclear power is not developed.

table 6.15: fossil fuels and nuclear energy: capacity, generation and direct jobs

Employment in the energy sector - fossil fuels and nuclear	UNIT	REFERENCE 2015	REFERENCE 2020	REFERENCE 2030	ENERGY [R]EVOLUTION 2015	ENERGY [R]EVOLUTION 2020	ENERGY [R]EVOLUTION 2030
coal	jobs	52,800	54,300	62,600	47,500	43,500	32,900
gas, oil & diesel	jobs	2,200	2,100	2,100	2,400	2,200	1,900
nuclear energy	jobs	11,400	13,000	4,200	-	-	-
COAL							
Installed capacity	GW	14	15	16	12	12	5
Total generation	TWh	60	64	71	52	42	23
Share of total supply	%	24%	21%	18%	21%	15%	7%
Annual increase in capacity	GW	0.2	0.1	0.6	-0.1	-0.7	-1.4
GAS, OIL & DIESEL							
Installed capacity	GW	24	23	23	22	23	23
Total generation	TWh	124	124	123	119	118	96
Share of total supply	%	49%	41%	31%	49%	44%	27%
Annual increase in capacity	GW	-	-	0.1	0.1	0.0	-0.1
NUCLEAR ENERGY							
Installed capacity	GW	-	4.0	12.0	-	-	-
Total generation	TWh	-	28.0	84	-	-	-
Share of total supply	%	-	9.2%	21%	-	-	-
Annual increase in capacity	GW	-	0.6	-	-	-	-

references for this chapter:

America's Natural Gas Alliance, 2008. *Natural gas: Working for Amercia.*

Batten, W.M.J. & Bahaj, A.S., 2007. An assessment of growth scenarios and implications for ocean energy industries in Europe. In *Seventh European Wave and Tidal Energy Conference*. Porto, Portugal.

Battocletti, E.C. & Glassley, W.E., 2012. Measuring the costs & benefits of nationwide geothermal heat pump (GHP) deployment. In *Presentation at the International Ground Source Heat Pump Association Conference.* Indianapolis, Indiana, USA.

Cogent Sector Skills Council, 2011. *Future skills for the nuclear industry in North Wales (Wylfa and Trawsfynydd).*

Cogent Sector Skills Council, 2010. *The South West nuclear workforce.*

Domac, J., Richards, K. & Risovic, S., 2005. Socio-economic drivers in implementing bioenergy projects. *Biomass and Bioenergy*, 28(2), pp.97–106.

EPRI, 2001. *California renewable technology market and benefits assessment*.

Euracoal, 2011. *Turkey coal statistics*.

European Renewable Energy Council, 2008. *Renewable energy technology roadmap. 20% 2020*.

European Wind Energy Association, 2009. *Wind at work*.

Geothermal Energy Association, 2010. *Green jobs through geothermal energy.*

Hillring, B., 2002. Rural development and bioenergy — experiences from 20 years of development in Sweden. *Biomass and Bioenergy*, 23, pp.443–451.

IHS Global Insight (Canada) Ltd, 2009. *The contributions of the natural gas industry to the Canadian national and provincial economies*.

International Energy Agency, 2007. *World energy outlook 2007*, Paris: OECD/IEA.

International Energy Agency, 2011. *World energy outlook 2011*, Paris: OECD/IEA.

Kjaer, T., 2006. *Socio-economic and regional benefits. Employment assessment*. EU project: Regenergy, Denmark.

Korea Energy Management Corporation (KEMCO) & New and Renewable Energy Center (NREC), 2012. *Overview of new and renewable energy in Korea 2012.*

Moreno, B. & López, A.J., 2008. The effect of renewable energy on employment. The case of Asturias (Spain). *Renewable and Sustainable Energy Reviews*, 12(3), pp.732–751.

National Commission on Energy Policy, 2009. *Task force on America's future energy jobs.*

National Renewable Energy Laboratory, 2011a. Jobs and Economic Development Model (JEDI) - Coal model: Release Number: C1.11.1.

National Renewable Energy Laboratory, 2011b. Jobs and Economic Development Model (JEDI) - Gas model: Release Number: NG1.11.01.

National Renewable Energy Laboratory, 2010. Jobs and Economic Development Model (JEDI) - Photovoltaics model: Release Number: PV10.17.11.

Navigant Consulting, 2009. *Job creation opportunities in hydropower: Final report.*

Price Waterhouse Coopers, 2012. *Volle Kraft aus Hochseewind.*

Rutovitz, J., 2010. *South African energy sector jobs to 2030*, Prepared for Greenpeace Africa by the Institute for Sustainable Futures, University of Technology, Sydney.

Rutovitz, J. & Atherton, A., 2009. *Energy sector jobs to 2030: A global analysis*, Prepared for Greenpeace International by the Institute for Sustainable Futures, University of Technology, Sydney.

Rutovitz, J. & Harris, S., 2012a. *Calculating global energy sector jobs: 2012 methodology*, Prepared for Greenpeace International by the Institute for Sustainable Futures, University of Technology, Sydney.

Rutovitz, J. & Harris, S., 2012b. Chapter 7 in "*The advanced energy [R]evolution. A sustainable energy outlook for South Korea,*" Prepared for Greenpeace International and European Renewable Energy Council by the Institute for Sustainable Futures, University of Technology, Sydney.

Rutovitz, J. & Ison, N., 2011. Chapter 2 in "*The advanced energy [R]evolution. A sustainable energy outlook for Japan*" 2nd ed., Prepared for Greenpeace International and European Renewable Energy Council by the Institute for Sustainable Futures, University of Technology, Sydney.

Rutovitz, J. & Usher, J., 2010. *Methodology for calculating energy sector jobs*, Prepared for Greenpeace International by the Institute for Sustainable Futures, University of Technology, Sydney.

Soerensen, H.C., 2008. *Co-ordination action on ocean energy: Work Session 5 Environmental, Economics, Development Policy and Promotion of Opportunities report*, Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006).

Thornley, P. et al., 2009. Integrated assessment of bioelectricity technology options. *Energy Policy*, 37(3), pp.890–903.

Thornley, P., 2006. *Life cycle assessment of bioenergy systems*.

Thornley, P., Rogers, J. & Huang, Y., 2008. Quantification of employment from biomass power plants. *Renewable Energy,* 33(8), pp.1922–1927.

Tourkolias, C. & Mirasgedis, S., 2011. Quantification and monetization of employment benefits associated with renewable energy technologies in Greece. *Renewable and Sustainable Energy Reviews*, 15(6), pp.2876–2886.

Upham, P. & Speakman, D., 2007. Stakeholder opinion on constrained 2030 bioenergy scenarios for North West England. *Energy Policy*, 35(11), pp.5549–5561.

Valente, C., Spinelli, R. & Hillring, B.G., 2011. LCA of environmental and socio-economic impacts related to wood energy production in alpine conditions: Valle di Fiemme (Italy). *Journal of Cleaner Production*, 19(17-18), pp.1931–1938.

Weiss, W. & Mauthner, F., 2011. *Solar heat worldwide: Markets and contribution to energy supply 2009*, Gleisdorf, Austria: Prepared within the framework of the International Energy Agency's (IAE) Solar Heating and Cooling Program.

Zubov, A.N., 2012. Personal communication, 29th May 2012.

abbreviations

CHP Combined Heat and Power
EIA Energy Information Administration (USA)
FTE Full Time Equivalent
GDP Gross Domestic Product
GWh Gigawatt hour
IEA International Energy Agency
ISF Institute for Sustainable Futures
JEDI Jobs and Economic Development Impact
MW Megawatt
NREL National Renewable Energy Laboratories (USA)
O&M Operations and Maintenance
OECD Organisation for Economic Co-operation and Development
PJ Petajoules
PV Photovoltaic
TWh Terawatt hour

the energy [r]evolution protects turkey's water resources

BENEFITS OF THE ENERGY [R]EVOLUTION FOR WATER

WATER IMPACT ASSESSMENT: METHODOLOGY AND ASSUMPTIONS

technology NUMEROUS PEAKS IN THE RUGGED MOUNTAINS OF EASTERN TURKEY ARE HIGH ENOUGH AND COLD ENOUGH TO SUSTAIN YEAR-ROUND ICE. ABOUT TWO-THIRDS OF TURKEY'S GLACIERS LIE WITHIN THE TAURUS MOUNTAINS, A CHAIN OF PEAKS THAT STRETCH FROM THE MEDITERRANEAN COAST TOWARD THE BORDERS OF IRAN AND IRAQ. THE SOUTHEASTERN PORTION OF THE RANGE SUPPORTS TURKEY'S LARGEST GLACIERS.

Turkey and the Mediterranean region are facing the risk of intensifying water shortages due to climate change and growing demands from different sectors. From hydropower dams to the massive cooling needs of coal-fired power stations and to the farming of food crops for biofuels, energy production has enormous impacts on water – yet water impacts are rarely considered when making energy choices.

Turkey's climate is mainly semi-arid with a mean precipitation of 643 mm/year. The country went through severe drought periods since 1950s with growing frequency. The current drought started in 2012 and continues to affect the country. A recent study on dams and drought in Turkey shows that water levels in dams are significantly low.[38]

Water available to human use in Turkey is 112 billion m^3/year. Available water per capita is 1519 m^3/year; meaning Turkey is already water stressed, and considered to be "approaching physical water scarcity".[39] Turkey's population is expected to be 100 million[40] by 2030 according to the Turkish Statistical Institute (TUIK) and this means that water per capita will fall down to 1,120 m^3/year. Therefore, Turkey will be very close to water scarcity threshold; 1000 m3/year per capita.[41] In 2010 thermal power plants in Turkey drew 4.29 billion m^3 water, 99% of which was used for cooling and only 0.4% of it was treated.[42]

Global water consumption for power generation and fuel production has almost doubled in the past two decades, and the trend is projected to continue. According to a report published by European Wind Energy Association (EWEA) power sector is the largest consumer of freshwater in the EU (44%) and the water used by thermal electricity generation and nuclear is equivalent to the average annual household water use the population of Germany.[43] Moreover, OECD predicts that in a business-as-usual scenario, the power sector would consume 25% of the world's water in 2050 and be responsible for more than half of demand growth.[44]

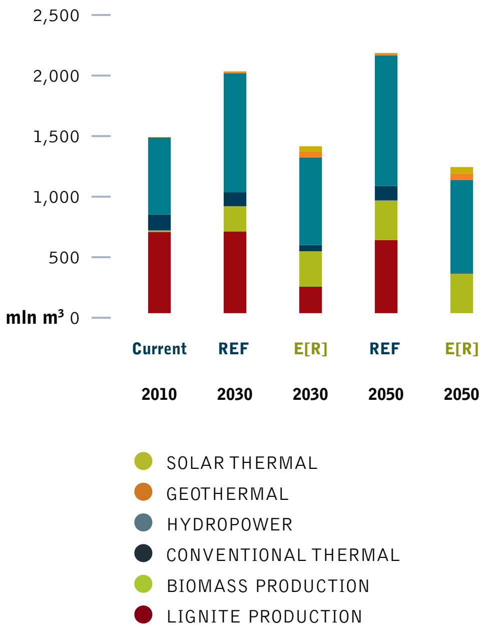
7.1 benefits of the energy r]evolution for water

The climate-friendly energy pathway proposed in this Energy [R]evolution report would have multiple, significant benefits for the water impacts of Turkey's energy system:

- Electric technologies with low to no water requirements – energy efficiency, wind and solar PV – are substituted for thermal power generation and hydropower dams with high water impacts.
- Reduced water use and contamination from fossil fuel production: no need for unconventional fossil fuels with massive water impacts such as shale gas; lowered consumption of conventional coal and oil.
- Bioenergy is based on waste-derived biomass and cellulosic biomass requiring no irrigation (no food for fuel). As a result, water intensity of biomass use is a fraction of that in energy pathways that require lots of liquid biofuels for transport.
- Energy efficiency programmes reduce water consumption in buildings and industry.
- Rapid CO_2 emission reductions protect water resources from catastrophic climate change.

It is estimated that in a business-as-usual pathway relying on lignite, hydropower and conventional fossil fuels, the water consumption for energy in Turkey would increase by a third by 2050. Turkey's "external water footprint" would increase even more due to reliance on imported coal, oil, gas more than doubling and imports of biofuels increasing even more

figure 7.1: energy use for water PROJECTED WATER CONSUMPTION OF THE TURKISH ENERGY SYSTEM IN THE BUSINESS-AS-USUAL (REFERENCE, REF) SCENARIO AND IN THE ENERGY [R]EVOLUTION (ER) SCENARIO. WATER CONSUMPTION INCREASES BY A THIRD IN THE BUSINESS-AS-USUAL SCENARIO. THE ENERGY [R]EVOLUTION SCENARIO SUPPLIES THE SAME, GROWING ENERGY NEEDS WHILE REDUCING THE IMPACTS ON WATER.



references

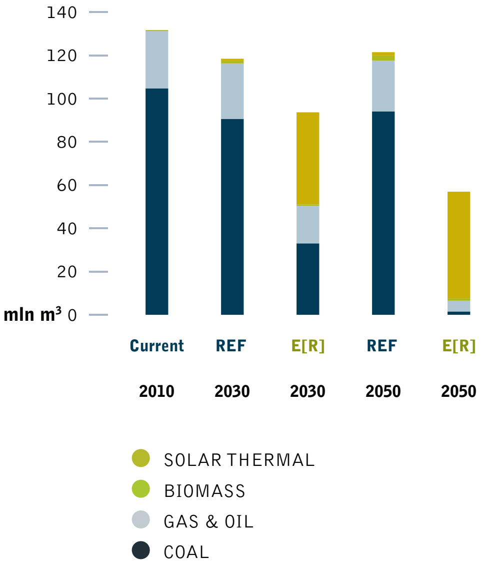
38 MURAT TÜRKEŞ & DURSUN YILDIZ, 2014. "TÜRKIYE'DE HIDROELEKTRIK SANTRALLERIN GELECEĞI".
39 HTTP://WWW.DSI.GOV.TR/TOPRAK-VE-SU-KAYNAKLARI
40 IBID.
41 THE FALKENMARK INDICATOR IS ONE OF THE MOST WIDELY USED MEASURE OF WATER STRESS. BASED ON THE PER CAPITA USAGE, THE WATER CONDITIONS IN AN AREA CAN BE CATEGORIZED AS "NO STRESS", "STRESS", "SCARCITY", AND "ABSOLUTE SCARCITY". THE INDEX THRESHOLDS 1,700M3, 1000M3 AND 500M3 PER CAPITA PER YEAR ARE THE THRESHOLDS BETWEEN WATER STRESSED, WATER SCARCE AND ABSOLUTE WATER SCARCE AREAS, RESPECTIVELY.
42 TÜİK (2012) " TERMIK SANTRAL SU, ATIK SU VE ATIK İSTATISTIKLERI 2010" BASIN BÜLTENI, HTTP://WWW.TUIK.GOV.TR/PREHABERBULTENLERI.DO?ID=10732
43 EWEA (2014) SAVING WATER WITH WIND ENERGY. HTTP://WWW.EWEA.ORG/FILEADMIN/FILES/LIBRARY/PUBLICATIONS/REPORTS/SAVING_WATER_WITH_WIND_ENERGY.PDF
44 OECD ENVIRONMENTAL OUTLOOK TO 2050: THE CONSEQUENCES OF INACTION. HTTP://WWW.OECD.ORG/DOCUMENT/11/0,3746,EN_2649_37465_49036555_1_1_1_37465,00.HTML

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.

dramatically. The Energy [R]evolution pathway would halt the rise in water demand for energy, mitigating the pressures on the Turkey's already stressed water resources. Approximately 600 million cubic meters of water would be saved in fuel production and power generation by 2030, enough to satisfy the water needs of 8 million urban dwellers, or to irrigate enough fields to produce 300,000 tonnes of wheat, equal to the average direct consumption of 1.3 million Turkish people.[45]

In the business-as-usual scenario, it is assumed that the currently planned massive lignite-fired power generation projects are not implemented and the growth in coal-fired power generation is based on coastal generating units firing hard coal. The water benefits of the Energy [R]evolution scenario would be even larger when compared to an energy future where these projects with extremely high water impacts (and CO_2 emissions) are implemented.

figure 7.2: energy use for thermal power PROJECTED WATER CONSUMPTION BY THERMAL POWER GENERATION IN TURKEY IN THE BUSINESS-AS-USUAL (REFERENCE, REF) SCENARIO AND IN THE ENERGY [R]EVOLUTION (ER) SCENARIO. WATER CONSUMPTION DECREASES RAPIDLY IN THE ENERGY [R]EVOLUTION SCENARIO AS WATER-THIRSTY CONVENTIONAL GENERATION TECHNOLOGIES ARE REPLACED BY WIND, SOLAR AND OTHER TECHNOLOGIES WITH VERY LITTLE WATER NEEDS.



7.2 water impact assessment: methodology and assumptions

The water footprint of power generation and fuel production is estimated by taking the production levels in each scenario and multiplying by technology-specific water consumption factors. Water consumption factors for power generation technologies are taken from U.S. Department of Energy and University of Texas and adjusted for projected region-specific thermal efficiencies of different operating power plant types.[46] Water footprints of coal, oil and gas extraction are based on data from Wuppertal Institute, complemented by estimates of water footprint of unconventional fossil fuels as well as first and second generation transport biofuels.[47]

The cooling water sources of different generation technologies were estimated by mapping a total of 3,200 operating, under construction and planned generating units in Turkey[48] on the map and assuming that power plants within 5 kilometers of coast will use seawater for their cooling. For example, 5% of currently operating and 25% of planned hard coal-fired capacity was estimated to use fresh water for cooling. 50% of solar thermal power plants were assumed to use freshwater. From 2020 onwards, 50% of new solar thermal capacity is projected to be solar towers which have a higher thermal efficiency and lower cooling needs than solar thermal power stations based on parabolic throughs, and from 2030 onwards, 50% of new capacity is expected to install hybrid cooling.

While the business-as-usual energy pathway relies on imports of water-intensive biofuels from edible feedstocks, the Energy [R]evolution pathway emphasizes reliance on local resources. 75% of the biomass and biofuels used in the Energy [R]evolution scenario were estimated to be obtainable from agricultural waste.

references

45 USING TYPICAL URBAN RESIDENTIAL WATER CONSUMPTION OF 200 LITERS/PERSON/DAY. AVERAGE WHEAT WATER REQUIREMENT OF 1830 M3/TONNE (MEKONNEN & HOEKSTRA 2010: A GLOBAL AND HIGH-RESOLUTION ASSESSMENT OF THE GREEN, BLUE AND GREY WATER FOOTPRINT OF WHEAT; HTTP://WWW.HYDROL-EARTH-SYST-SCI-DISCUSS.NET/7/2499/2010/HESSD-7-2499-2010.PDF) AND WHEAT CONSUMPTION OF 254 KG/PERSON/YEAR (USDA ECONOMICS, STATISTICS AND MARKET INFORMATION SYSTEM).

46 NATIONAL ENERGY TECHNOLOGY LABORATORY 2009: WATER REQUIREMENTS FOR EXISTING AND EMERGING THERMOELECTRIC PLANT TECHNOLOGIES. US DEPARTMENT OF ENERGY. AUGUST 2008 (APRIL 2009 REVISION); U.S. DEPARTMENT OF ENERGY 2006: ENERGY DEMANDS ON WATER RESOURCES. REPORT TO CONGRESS ON THE INTERDEPENDENCY OF ENERGY AND WATER. UNIVERSITY OF TEXAS & ENVIRONMENTAL DEFENSE FUND 2009: ENERGY?WATER NEXUS IN TEXAS. U.S. DOE 2008: REDUCING WATER CONSUMPTION OF CONCENTRATING SOLAR POWER ELECTRICITY GENERATION.

47 WUPPERTAL INSTITUT: MATERIAL INTENSITY OF MATERIALS, FUELS, TRANSPORT SERVICES, FOOD. HTTP://WWW.WUPPERINST.ORG/UPLOADS/TX_WIBEITRAG/MIT_2011.PDF; WORLD ECONOMIC FORUM 2009: ENERGY VISION UPDATE 2009. THIRSTY ENERGY; HARTO ET AL: LIFE CYCLE WATER CONSUMPTION OF ALTERNATIVE, LOW-CARBON TRANSPORTATION ENERGY SOURCES. FUNDED BY ARIZONA WATER INSTITUTE.

48 GENERATION TECHNOLOGY, STATUS AND LOCATION DATA FROM THE PLATTS WEPP DATABASE, DEC 2013.

transport

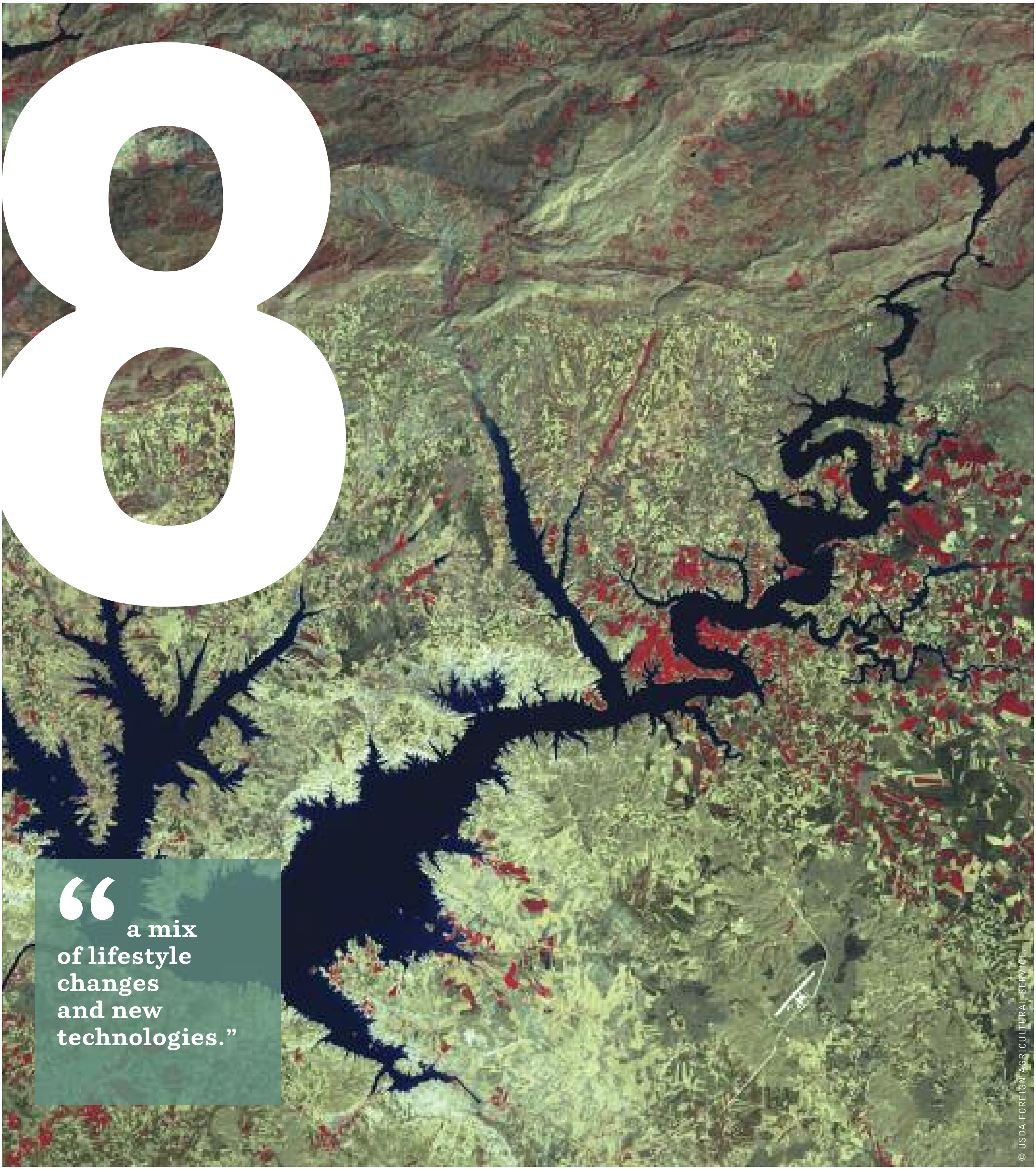


image TURKEY'S ATATURK DAM WAS COMPLETED IN 1990. IT IS THE LARGEST OF A SERIES OF DAMS ALONG THE TWO MAJOR RIVERS OF THE REGION, THE TIGRIS AND EUPHRATES, WHICH BOTH HAVE THEIR HEADWATERS IN SOUTHEASTERN TURKEY. BUILT BOTH TO GENERATE ELECTRICITY FOR THE REGION AND TO IRRIGATE THE PLAINS BETWEEN THE EUPHRATES AND THE TIGRIS, ATATURK DAM IS THE CENTERPIECE OF A HUGE PUBLIC WORKS PROGRAM WITHIN TURKEY KNOWN AS THE SOUTHEASTERN ANATOLIA PROJECT.

image DEUTSCHE BAHN AG IN GERMANY, USING RENEWABLE ENERGY. WIND PARK MAERKISCH LINDEN (BRANDENBURG) RUN BY THE DEUTSCHE BAHN AG.

image CYCLING THROUGH FRANKFURT.

8.1 the future of the transport sector in the energy [r]evolution scenario

Sustainable transport is needed to reduce the level of greenhouse gases in the atmosphere, just as much as a shift to renewable electricity and heat production. Today, about one fifth (21%) of current energy use comes from the transport sector, mainly road transport (91%) but also from trains (1.4%) and domestic aviation (2.8%). However the most efficient form of transport, railways, currently only has a market share of less than 2% (1.4%).This chapter provides an overview of the selected measures required to develop a more energy efficient and sustainable transport system in the future, with a focus on:

- reducing transport demand,
- shifting transport 'modes' (from high to low energy intensity), and
- energy efficiency improvements from technology development.

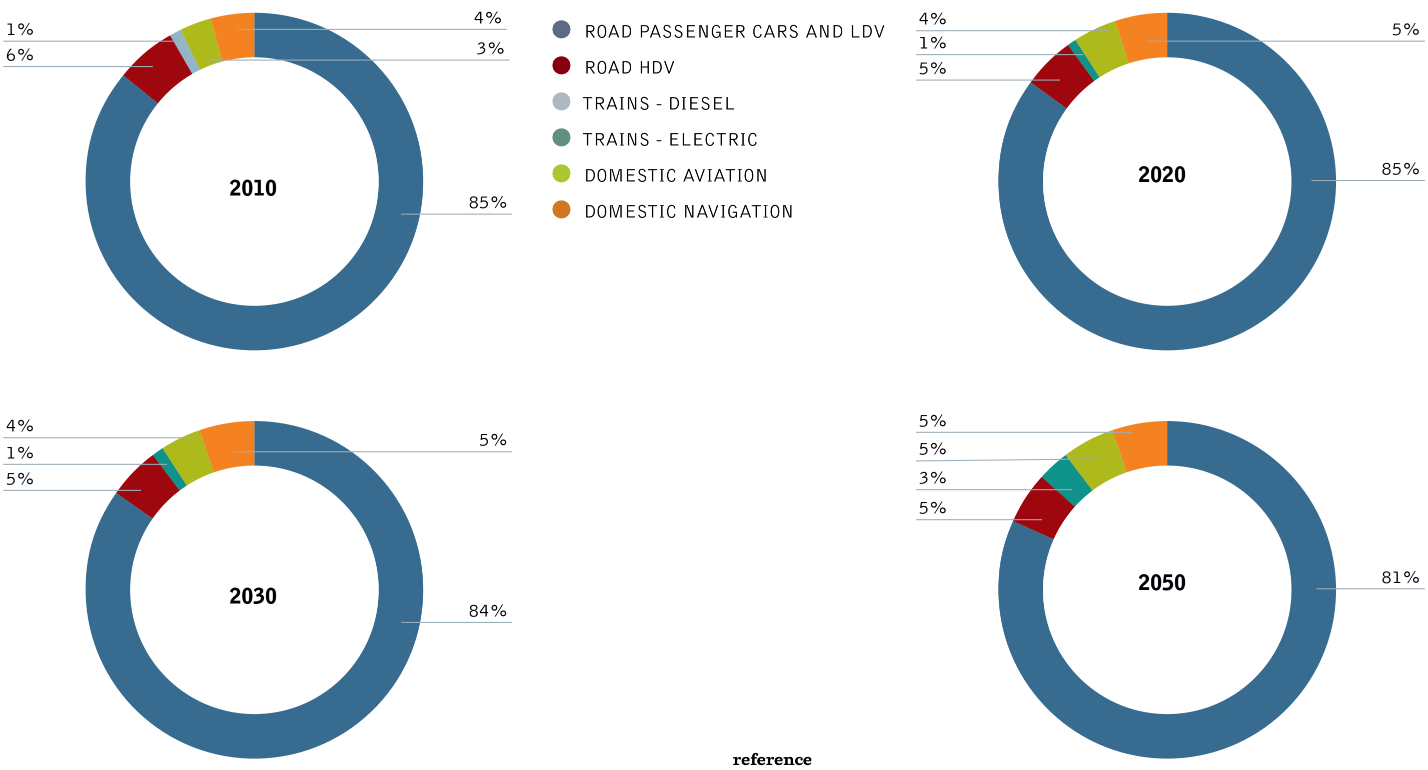
The section provides the assumptions for Turkey's transport sector energy demand calculations used in the Reference and the Energy [R]evolution scenarios including projections for the passenger vehicle market (light duty vehicles). Overall, some technologies will have to be adapted for greater energy efficiency. In other situations, a simple modification will not be enough. The transport of people in megacities and urban areas will have to be almost entirely re-organized and individual transport must be complemented or even substituted by public transport systems. Car sharing and public transport on demand are only the beginning of the transition needed for a system that carries more people more quickly and conveniently to their destination while using less energy. The 2013 Energy [R]evolution scenario is based on an analysis by the German DLR Institute of Vehicle Concepts of the entire global transport sector, broken down to the ten IEA regions. This report outlines the key findings of the analysis' calculations for Turkey.

The definitions of the transport modes for the scenarios[41] are:

- Light duty vehicles (LDV) are four-wheel vehicles used primarily for personal passenger road travel. These are typically cars, Sports Utility Vehicles (SUVs), small passenger vans (up to eight seats) and personal pickup trucks. Light duty vehicles are also simply called 'cars' within this chapter.
- Heavy duty vehicles (HDV) are as long haul trucks operating almost exclusively on diesel fuel. These trucks carry large loads with lower energy intensity (energy use per tonne-kilometre of haulage) than medium duty trucks such as delivery trucks.
- Medium duty vehicles (MDV) include medium haul trucks and delivery vehicles.
- Aviation in each region denotes domestic air travel (intraregional and international air travel is provided as one figure).
- Inland navigation denotes freight shipping with vessels operating on rivers and canals or in coastal areas for domestic transport purposes.

Figure 8.1 shows the breakdown of final energy demand for all transport modes in 2010 and 2050 in the Reference scenario.

figure 8.1: turkey's final energy use per transport mode 2010/2050 – energy [r]evolution scenario



reference
41 FULTON & EADS (2004).

As can be seen from Figure 8.1, the largest share of energy demand comes from road transport (mainly transport by cars and trucks), although the share decreases while the share of rail transport increases in the Energy [R]evolution scenario between 2010 and 2050.

In the Reference scenario, overall energy demand in the transport sector adds up to 1,789 PJ/by 2050 compared to 613 PJ/a in 2010, an overal increase of 192%. In the Energy [R]evolution scenario, implying the implementation of more efficiency and behavioral measures. We calculated a possible increase to 1,000 PJ/a by 2050, which is an increase of 64%, nearly 130% less than the increase of the Reference case.

8.2 technical and behavioural measures to reduce transport energy consumption

The following section describes how the transport modes contribute to total and relative energy demand. Then, a selection of measures to reduce total and specific energy transport consumption are put forward for each mode. Measures are grouped as either behavioural or technical.

There are three ways to decrease energy demand in the transport sector:

- reduction of transport demand of high-energy intensity modes
- modal shift from high-energy intensive transport to low-energy intensity modes
- energy efficiency improvements.

Table 8.1 summarises these options and the indicators used to quantify them.

8.2.1 step 1: reduction of transport demand

To use less transport overall means reducing the amount of 'passenger-kilometres' travelled per capita and reducing freight transport demand. The amount of freight transport is to a large extent linked to GDP development and therefore difficult to influence. However, by improved logistics, for example optimal load profiles for trucks or a shift to regionally- produced and shipped goods demand can be limited.

Passenger transport The study focussed on the change in passenger-km per capita of high-energy intensity air transport and personal vehicles modes. Passenger transport by Light duty vehicles (LDV), for example, is energy demanding both in absolute and relative terms. Policy measures that enforce a reduction of passenger-km travelled by individual transport modes are an effective means to reduce transport energy demand.

Policy measures for reducing passenger transport demand in general could include:

- charge and tax policies that increase transport costs for individual transport
- price incentives for using public transport modes
- installation or upgrading of public transport systems
- incentives for working from home
- stimulating the use of video conferencing in business
- improved cycle paths in cities.

In the Reference scenario, there is a forecast of a sharp increase in passenger-km up to 2050, whereas in the 2050 Energy [R]evolution scenario the increase is moderate in individual transport on a per capita basis. The reduction in passenger-km per capita in the Energy [R]evolution scenario compared to the Reference scenario comes with a general reduction in car use due to behavioural and traffic policy changes and partly with a shift of transport to public modes. A shift from energy-intensive individual transport to low-energy demand public transport of course aligns with an increase in low-energy public transport p-km.

table 8.1: selection of measures and indicators

MEASURE	REDUCTION OPTION	INDICATOR
Reduction of transport demand	Reduction in volume of passenger transport in comparison to the Reference scenario	Passenger-km/capita
	Reduction in volume of freight transport in comparison to Reference scenario	Tonne-km/unit of GDP
Modal shift	Modal shift from trucks to rail	MJ/tonne-km
	Modal shift from cars to public transport	MJ/Passenger-km
Energy efficiency improvements	Shift to energy efficient passenger car drive trains (battery electric vehicles, hybrid and fuel cell hydrogen cars) and trucks (fuel cell hydrogen, battery electric, catenary or inductive supplied)	MJ/Passenger-km, MJ/tonne-km
	Shift to powertrain modes that may be fuelled by renewable energy (electric, fuel cell hydrogen)	MJ/Passenger-km, MJ/tonne-km
	Autonomous efficiency improvements of LDV, HDV, Trains, Airplanes over time	MJ/Passenger-km, MJ/tonne-km

image A SIGN PROMOTES A HYDROGEN REFUELING STATION IN REYKJAVIK. THESE STATIONS ARE PART OF A PLAN TO TRY AND MAKE ICELAND A 'HYDROGEN ECONOMY.'

image PARKING SPACE FOR HYBRIDS ONLY.

8.2.2 step 2: changes in transport mode

In order to figure out which vehicles or transport modes are the most efficient for each purpose requires an analysis of the transport modes' technologies. Then, the energy use and intensity for each type of transport is used to calculate energy savings resulting from a transport mode shift. The following information is required:

- Passenger transport: Energy demand per passenger-kilometre, measured in MJ/p-km.
- Freight transport: Energy demand per kilometre of transported tonne of goods, measured in MJ/tonne-km.

For this study passenger transport includes light duty vehicles, passenger rail and air transport. Freight transport includes medium duty vehicles, heavy duty vehicles, inland navigation, marine transport and freight rail. WBCSD 2004 data was used as baseline data and updated where more recent information was available.

Passenger transport Travelling by rail is the most efficient – but car transport improves strongly. Figure 8.2 shows the average specific energy consumption (energy intensity) by transport mode in 2010 and in the Energy [R]evolution scenario in 2050. Passenger transport by rail will consume on a per p-km basis 28% less energy in 2050 than car transport and 85% less than aviation which shows that shifting from road to rail can make large energy savings.

From Figure 8.2 we can conclude that in order to reduce transport energy demand, passengers will need to shift from cars and especially air transport to the lower intensity passenger rail transport.

In the Energy [R]evolution scenario it is assumed that a certain portion of passenger kilometer of domestic air traffic growth is suitable to be substituted by better railway services . However Turkey's overal domestic aviation is assumed to grow over the coming decade. While all transport modes increase due to population growth and economical growth, the relative growth rates are lower compared to the Reference case. For international aviation there is obviously no substitution potential to other modes whatsoever.

Freight transport Similar to Figure 8.2 which showed average specific energy consumption for passenger transport modes, Figure 8.3 shows the respective energy consumption for various freight transport modes in 2009 and in the Energy [R]evolution scenario 2050, the values are weighted according to stock-and-traffic performance. Energy intensity for all modes of transport is expected to decrease by 2050. In absolute terms, road transport has the largest efficiency gains whereas transport on rail and on water remain the modes with the lowest relative energy demand per tonne-km. Rail freight transport will consume approx 80% less energy per tonne-km in 2050 than long haul HDV. Therefore large energy savings are achievable by a modal shift from road to rail.

figure 8.2: stock-weighted passenger transport energy intensity for 2009 and 2050

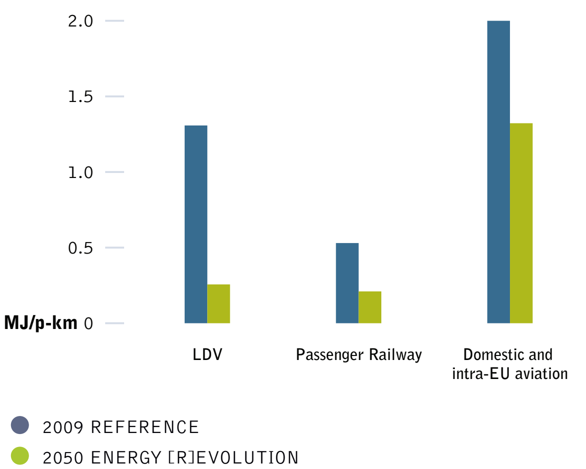
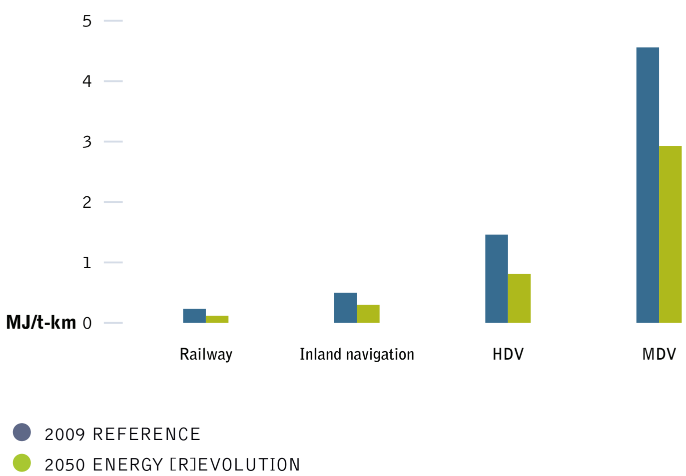


figure 8.3: world average (stock-weighted) freight transport energy intensities in 2009 and 2050



Modal shifts for transporting goods in the Energy [R]evolution scenario The figures above indicate that as much road freight as possible should be shifted from road freight transport to less energy intensive freight rail, to gain the most energy savings from modal shifts. Since the use of ships largely depends on the geography of the country, a modal shift is not proposed for national ships but instead a shift towards freight rail. For long-haul heavy duty vehicles transport, however, especially low value density, heavy goods that are transported on a long range are suitable for a modal shift to railways.[49]

8.2.3 step 3: efficiency improvements

Energy efficiency improvements are the third important way of reducing transport energy demand. This section explains ways for improving energy efficiency up to 2050 for each type of transport:

- air transport
- passenger and freight trains
- trucks
- inland navigation and marine transport
- cars.

In general, an integral part of an energy reduction scheme is an increase in the load factor – this applies both for freight and passenger transport. As the load factor increases, less transport vehicles need to be employed and thus the energy intensity decreases when measured per passenger-km or tonne-km.

In aviation there are already sophisticated efforts to optimise the load factor, however for other modes such as road and rail freight transport there is still room for improvement. Lifting the load factor may be done through improved logistics and supply chain planning for freight transport and in enhanced capacity utilisation in passenger transport.

Air transport A study conducted by NASA (2011) shows that energy use of new subsonic aicrafts can be reduced by up to 58% up to 2035. Akerman (2005) reports that a 65% reduction in fuel use is technically feasible by 2050. Technologies to reduce fuel consumption of aircrafts mainly comprise:

- Aerodynamic adaptations to reduce the drag of the aircraft, for example by improved control of laminar flow, the use of riblets and multi-functional structures, the reduction in fasteners, flap fairings and the tail size as well as by advanced supercritical airfoil technologies.
- Structural technologies to reduce the weight of the aircraft while at the same time increasing the stiffness. Examples include the use of new lightweight materials like advanced metals, composites and ceramics, the use of improved coatings as well as the optimised design of multi-functional, integrated structures.
- Subsystem technologies including, for example, advanced power management and generation as well as optimised flight avionics and wiring.
- Propulsion technologies like advanced gas turbines for powering the aircraft more efficiently; this could also include:
  - improved combustion emission measures, improvements in cold and hot section materials, and the use of turbine blade/vane technology;
  - investigation of all-electric, fuel-cell gas turbine and electric gas turbine hybrid propulsion devices;
  - the usage of electric propulsion technologies comprise advanced lightweight motors, motor controllers and power conditioning equipment.[50]

Passenger and freight trains Transport of passengers and freight by rail is currently one of the most energy efficient means of transport. However, there is still potential to reduce the specific energy consumption of trains. Apart from operational and policy measures to reduce energy consumption like raising the load factor of trains, technological measures to reduce energy consumption of future trains are necessary, too. Key technologies are:

- reducing the total weight of a train is seen as the most significant measure to reduce traction energy consumption. By using lightweight structures and lightweight materials, the energy needed to overcome inertial and grade resistances as well as friction from tractive resistances can be reduced.
- aerodynamic improvements to reduce aerodynamic drag, especially important when running on high velocity. A reduction of aerodynamic drag is typically achieved by streamlining the profile of the train.
- switch from diesel-fuelled to more energy efficient electrically driven trains.
- improvements in the traction system to further reduce frictional losses. Technical options include improvements of the major components as well as improvements in the energy management software of the system.
- regenerative braking to recover waste energy. The energy can either be transferred back into the grid or stored on-board in an energy storage device. Regenerative braking is especially effective in regional traffic with frequent stops.
- improved space utilisation to achieve a more efficient energy consumption per passenger kilometre. The simplest way to achieve this is to transport more passengers per train. This can either be achieved by a higher average load factor, more flexible and shorter trainsets or by the use of double-decker trains on highly frequented routes.
- improved accessory functions, e.g. for passenger comfort. The highest amount of energy in a train is used is to ensure the comfort of the train's passengers by heating and cooling. Some strategies for efficiency include adjustments to the cabin design, changes to air intakes and using waste heat from traction.

By research on developing an advanced high-speed train, DLR's 'Next Generation Train' project aims to reduce the specific energy consumption per passenger kilometre by 50% relative to today's existing state-of-the-art high speed trains in the future.

reference
49 TAVASSZY AND VAN MEIJEREN 2011.
50 IBIDEM.

image ITALIAN EUROSTAR TRAIN.

image TRAFFIC IN AUCKLAND.

Electric trains as of today are about 2 to 3.5 times less energy intensive (from a tank-to-wheel-perspective) than diesel trains depending on the specific type of rail transport, so the projections to 2050 maintain the dominance of electric trains in the Energy [R]evolution 2050 scenario.

Marine Transport Several technological measures can be applied to new vessels in order to reduce overall fuel consumption in national and international marine transport. These technologies comprise for example:

- weather routing to optimise the vessel's route
- autopilot adjustments to minimise steering
- improved hull coatings to reduce friction losses
- improved hull openings to optimise water flow
- air lubrication systems to reduce water resistances
- improvements in the design and shape of the hull and rudder
- waste heat recovery systems to increase overall efficiency
- improvement of the diesel engine (e.g. common-rail technology)
- installing towing kites and wind engines to use wind energy for propulsion
- using solar energy for on-board power demand.

Adding each technology effectiveness figure stated by ICCT (2011), these technologies have a potential to improve energy efficiency of new vessels between 18.4% and about 57%. Another option to reduce energy demand of ships is simply to reduce operating speeds. Up to 36% of fuel consumption can be saved by reducing the vessel's speed by 20%.[51] Eyring et al. (2005) report that a 25% reduction of fuel consumption for an international marine diesel fleet is achievable by using more efficient alternative propulsion devices only.[52] Up to 30% reduction in energy demand is reported by Marintek (2000) only by optimising the hull shape and propulsion devices of new vessels.[53]

The methodology is described as more elaborated than it actually is. The model assumes a total of 50% energy efficiency improvement potential for the whole transport sector, in terms of energy demand per unit of GDP. There is no energy efficiency for certain transport modes used in the model. But the overall efficiency improvement of 50% could be reached by technological improvements of about 40%, in addition to modal shifts to technologies that are less energy intensive.

8.3 light-duty vehicles

8.3.1 projection of the CO_2 emission development

This section draws on the future vehicle technologies study conducted by the DLR's Institute of Vehicle Concepts. The approach shows the potential of different technologies influencing the energy efficiency of future cars and gives detailed analysis of possible cost developments.[54]

Many technologies can be used to improve the fuel efficiency of passenger cars. Examples include improvements in engines, weight reduction as well as friction and drag reduction.[55] The impact of the various measures on fuel efficiency can be substantial. Hybrid vehicles, combining a conventional combustion engine with an electric engine, have relatively low fuel consumption. Applying new lightweight materials, in combination with new propulsion technologies, can bring fuel consumption levels down to 1 litre ge/100 km.

8.3.2 projection of the future vehicle segment split

For future vehicle segment split the scenario is constructed to disaggregate the light-duty vehicle sales into three segments: small, medium and large vehicles. In this way, the model shows the effect of 'driving small urban cars', to see if they are suitable for megacities of the future. The size and CO_2 emissions of the vehicles are particularly interesting in the light of the enormous growth predicted in the LDV stock. For our purposes we could divide up the numerous car types as follows:

- The very small car bracket includes city, supermini, minicompact cars as well as one and two seaters.
- The small sized bracket includes compact and subcompact cars, micro and subcompact vans and small SUVs.
- The medium sized bracket includes car derived vans and small station wagons, upper medium class, midsize cars and station wagons, executive class, compact passenger vans, car derived pickups, medium SUVs, 2WD and 4WD.
- The large car bracket includes all kinds of luxury class, luxury multi purpose vehicles, medium and heavy vans, compact and full-size pickup trucks (2WD, 4WD), standard and luxury SUVs.

8.2.3 projection of the future technology mix

To achieve the substantial CO_2-reduction targets in the Energy [R]evolution scenario requires a radical implementation of efficiency measures and a shift in fuels for cars and other light duty vehicles. For viable electrification based on renewable energy sources, the model assumes that petrol and diesel fuelled autonomous hybrids and plug-in hybrids that we have today are substituted to a large extent already by 2050. That is, two generations of hybrid technologies will pave the way for a significant market share of light duty vehicles with full battery electric or hydrogen fuel cell powertrains. In the far future it may not be possible to power LDVs for all purposes by rechargeable batteries only. Therefore, hydrogen is required as an additional renewable fuel especially for larger LDVs incl. light commercial vehicles. Biofuels and remaining oil will be used especially in other sectors where a substitution is even harder than for LDVs.

references
51 ICCT, 2011.
52 EYRING ET AL., 2005.
53 MARINTEK, 2000.
54 DLR, 2011.
55 DECICCO ET AL., 2001.

figure 8.4: shows the development of vehicle stock over time for small, medium and large trucks up to 2050 under the energy [r]evolution by technologies.

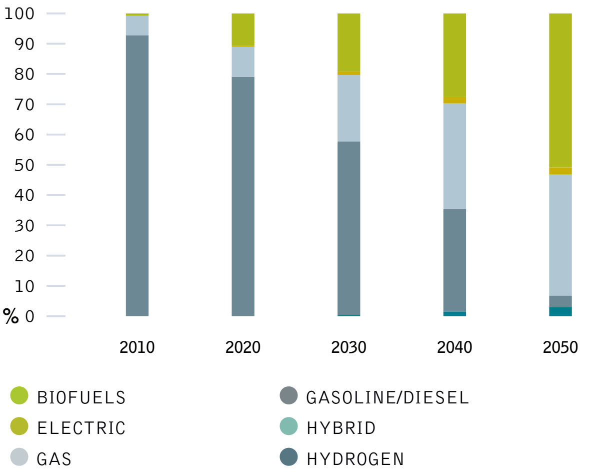
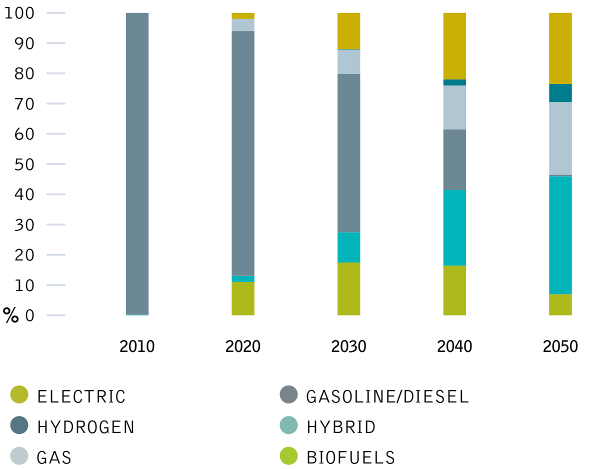


figure 8.5: shows the development of vehicle stock over time for cars up to 2050 under the energy [r]evolution by fuels.



8.2.4 renewable energy in the transport sector

While in the Energy [R]evolution scenario, 44% of the CO_2 reduction in the transport sector is achieved through a reduction in transport energy demand by 2050, through both behavioural measures and vehicle efficiency improvements, the remaining energy demand needs to be covered by renewable sources, to achieve the CO_2 reductions needed. By 2050, 65% of transport energy comes from renewable sources, compared to 0.1% in 2010.

The Energy [R]evolution assumes that the potential for sustainable biomass is limited. For Turkeys's transport sector, therefore the focus for renewable energy use in the transport sector is on electricity, given that other sectors such as power and heat production also partly rely on biomass energy.

8.3 conclusion

The aim of this chapter was to show ways on how to significantly reduce energy demand in general and the dependency on climate-damaging fossil fuels in particular in the transport sector, especially since transport energy demand will increase in Turkey.

The findings of our scenario calculations show that in order to reach the ambitious energy reduction goals of the Energy [R]evolution scenario a combination of behavioral changes and tremendous technical efforts is needed:

- a decrease of passenger and freight kilometers on a per capita base,
- a massive shift to electrically and hydrogen powered vehicles whose energy sources may be produced by renewables,
- a gradual decrease of all modes' energy intensities,
- a modal shift from aviation to high speed rail and from road freight to rail freight.

These measures must of course be accompanied by major efforts in the installation and extension of the necessary infrastructures (e. g. railway networks, hydrogen infrastructure, charging infrastructure for electric vehicles).

The government which plays a particular role in regulating the vehicle and fuel market, should support these efforts by tightening existing vehicle efficiency legislation and introducing new standards for trucks and other vehicle categories. In parallel, it should adopt regulations to control both fossil and renewable fuel production such that the decreasing energy demand is met by truly sustainable, low carbon energy. It should also promote the roll-out of refuelling infrastructure across all the whole country.

Literature

Eyring, V., Köhler, H., Lauer, A., Lemper, B. (2005): Emissions from International Shipping: 2. Impact of Future Technologies on Scenarios Until 2050, Journal of Geophysical Research, 110, D17305.

Fulton, L. and Eads, G. (2004): IEA/SMP Model Documentation and Reference Case Projection, published by WBSCD.

Geerts, S., Verwerft, B., Vantorre, M. and Van Rompuy, F. (2010):

Improving the efficiency of small inland vessels, Proceedings of the European Inland Waterway Navigation Conference.

ICCT (2011): Reducing Greenhouse Gas Emissions from Ships – Cost Effectiveness of Available Options.

Marintek (2000): Study of Greenhouse Emissions from Ships, Final Report to the International Maritime Organziation.

Tavasszy, L. and Van Meijeren, J. (2011): Modal Shift Target for Freight Transport Above 300 km: An Assessment, Discussion Paper, 17th ACEA SAG Meeting.

TOSCA (2011): Technology Opportunities and Strategies toward Climate-friendly transport (Reports).

glossary & appendix

GLOSSARY OF COMMONLY USED TERMS AND ABBREVIATIONS

DEFINITION OF SECTORS

TURKEY: SCENARIO RESULTS DATA

image AT 10 A.M. ON FEBRUARY 10, 2011, DISASTER STRUCK THE ÇÖLLOLAR COALFIELD IN CENTRAL TURKEY, NEAR THE CITY OF ELBISTAN. THE NORTHEASTERN WALL OF AN OPEN-PIT MINE COLLAPSED, SENDING ABOUT 50 MILLION TONS OF MATERIAL INTO THE MINE. THE DEBRIS BURIED AND KILLED TEN WORKERS. THE MATERIAL MINED AT THE ÇÖLLOLAR COALFIELD IS LIGNITE, A BROWN TYPE OF COAL THAT IS GENERALLY YOUNGER AND SOFTER THAN BITUMINOUS OR ANTHRACITE. TURKEY RELIES ON LIGNATE FOR 21 PERCENT OF ITS ELECTRIC POWER PRODUCTION, AND THE AFSIN-ELBISTAN LIGNITE BASIN CONTAINS ABOUT HALF OF TURKEY’S LIGNATE RESERVES.

9.1 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 9.1: 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 9.2: 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

9.2 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")

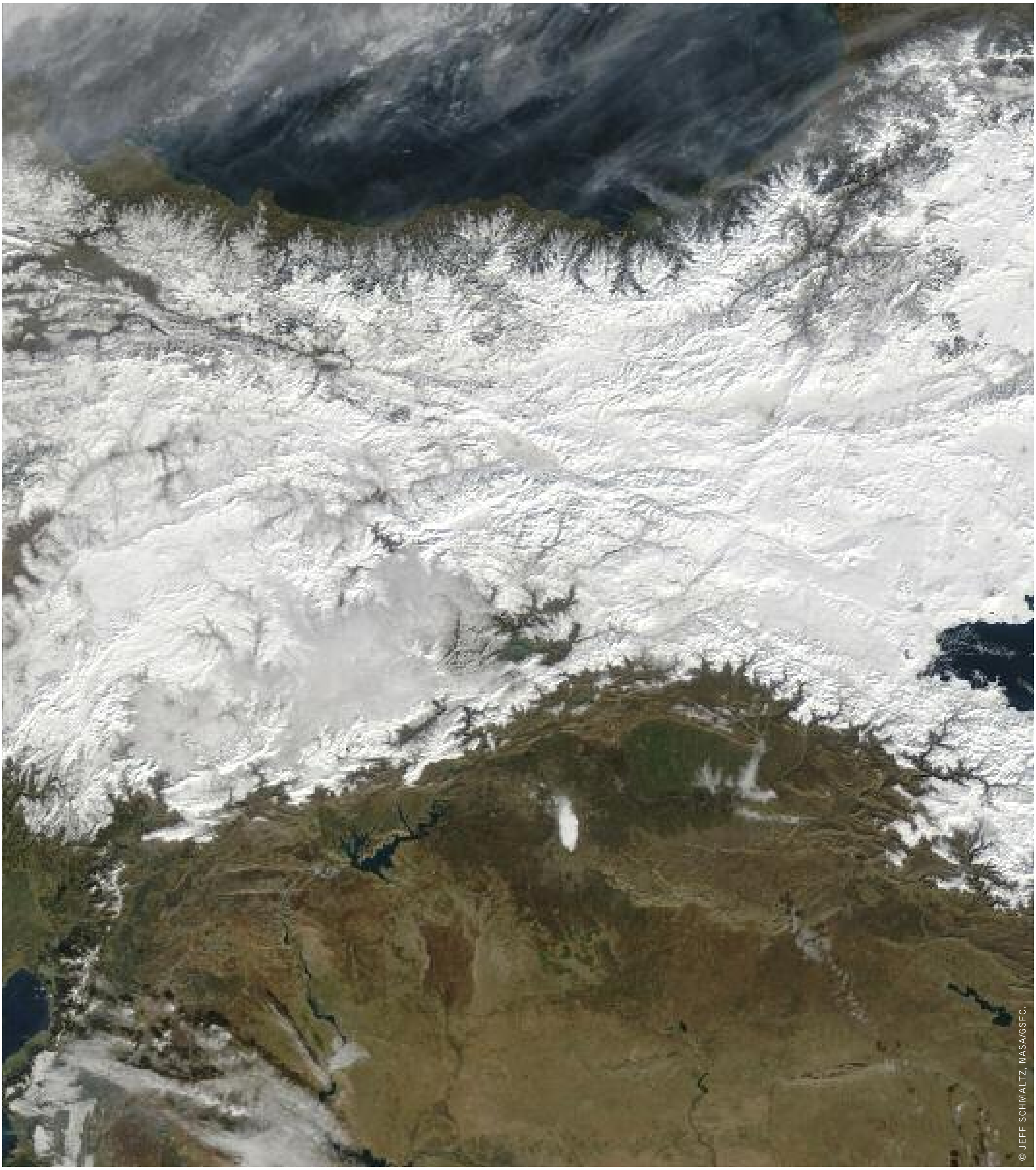
- Iron and steel industry
- Chemical industry
- Non-metallic mineral products e.g. glass, ceramic, cement etc.
- Transport equipment
- Machinery
- Mining
- Food and tobacco
- Paper, pulp and print
- Wood and wood products (other than pulp and paper)
- Construction
- Textile and Leather

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.

turkey: scenario results data



© JEFF SCHMALTZ, NASA/GSFC.

image TURKEY'S EASTERN ANATOLIA REGION COATED WITH SNOW. THE KUZEY ANADOLU DAGLARI, A LONG MOUNTAIN RANGE, SEPARATES THE SHORES OF THE BLACK SEA, IMAGE TOP, FROM THE ANATOLIA PLATEAU. OTHER MOUNTAIN RANGES AND INDIVIDUAL MOUNTAINS ALSO APPEAR AS WRINKLES IN THE LANDSCAPE. THE FLATTER REGION IN THE SOUTH IS THE ANATOLIA PLATEAU. THE HEADWATERS OF THE EUPHRATES RIVER GATHER IN THIS REGION. UNLIKE THE REST OF TURKEY, WHICH ENJOYS A TEMPERATE CLIMATE, EASTERN ANATOLIA EXPERIENCES HOT SUMMERS AND COLD WINTERS.

turkey: reference scenario

table 9.3: turkey: electricity generation

TWh/a	2012	2018	2023	2025	2030	2040	2050
Power plants	**232**	**288**	**334**	**352**	**397**	**449**	**500**
Hard coal (& non-renewable waste)	31	38	40	41	43	66	91
Lignite	35	33	32	31	31	30	30
Gas	100	113	114	113	112	118	124
of which from H_2	0	0	0	0	0	0	0
Oil	1	1	1	1	1	0	0
Diesel	1	0	0	0	0	0	0
Nuclear	0	17	45	56	84	84	84
Biomass (& renewable waste)	0	2	3	3	5	7	10
Hydro	58	67	73	75	80	84	88
Wind	6	14	21	23	28	40	52
of which wind offshore	0	5	5	6	2	0	0
PV	0	2	5	6	9	12	13
Geothermal	1	2	2	3	4	4	5
Solar thermal power plants	0	0	0	0	1	2	3
Ocean energy	0	0	0	0	0	0	0
Combined heat & power plants	**8**	**9**	**10**	**11**	**12**	**14**	**18**
Hard coal (& non-renewable waste)	0	0	0	0	0	0	0
Lignite	0	0	1	1	1	1	1
Gas	7	8	8	9	10	12	15
of which from H_2	0	0	0	0	0	0	0
Oil	0	0	0	0	1	1	1
Biomass (& renewable waste)	0	0	0	1	1	1	1
Geothermal	0	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0	0
CHP by producer							
Main activity producers	4	4	5	5	5	6	7
Autoproducers	4	5	6	6	7	8	10
Total generation	**240**	**298**	**345**	**363**	**409**	**463**	**518**
Fossil	174	194	196	196	199	229	262
Hard coal (& non-renewable waste)	31	39	40	41	44	66	91
Lignite	36	34	32	32	32	31	31
Gas	106	120	122	122	122	130	139
Oil	1	1	1	1	1	1	1
Diesel	1	0	0	0	0	0	0
Nuclear	0	17	45	56	84	84	84
Hydrogen	0	0	0	0	0	0	0
Renewables	**65**	**87**	**104**	**111**	**126**	**151**	**172**
Hydro	58	67	73	75	80	84	88
Wind	6	14	21	23	28	40	52
PV	0	2	5	6	9	12	13
Biomass (& renewable waste)	1	2	3	4	5	8	11
Geothermal	1	2	2	3	4	4	5
Solar thermal	0	0	0	0	1	2	3
Ocean energy	0	0	0	0	0	0	0
Distribution losses	36	44	50	53	59	70	77
Own consumption electricity	14	18	20	21	23	26	28
Electricity for hydrogen production	0	0	0	0	0	0	0
Final energy consumption (electricity)	**193**	**238**	**275**	**289**	**327**	**368**	**413**
Fluctuating RES (PV, Wind, Ocean)	6	17	25	29	37	52	65
Share of fluctuating RES	2.4%	5.5%	7.3%	7.9%	9.0%	11.3%	12.5%
RES share (domestic generation)	**27.2%**	**29.1%**	**30.1%**	**30.5%**	**30.9%**	**32.5%**	**33.2%**

table 9.4: turkey: heat supply

PJ/a	2012	2018	2023	2025	2030	2040	2050
District heating	**0**	**10**	**14**	**15**	**16**	**12**	**3**
Fossil fuels	0	8	11	12	13	9	2
Biomass	0	2	3	3	3	3	1
Solar collectors	0	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0	0
Heat from CHP	**51**	**56**	**62**	**65**	**73**	**91**	**115**
Fossil fuels	50	54	60	62	68	83	103
Biomass	1	2	3	3	4	8	12
Geothermal	0	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0	0
Direct heating & air conditioning	**1,717**	**2,096**	**2,335**	**2,422**	**2,575**	**2,832**	**2,992**
Fossil fuels	1,422	1,737	1,929	1,998	2,110	2,265	2,356
Biomass	108	117	127	132	145	185	219
Solar collectors	32	52	66	72	86	113	126
Geothermal	0	0	0	0	0	0	0
Heat pumps[1)]	90	101	112	116	122	138	161
Electric direct heating[2)]	65	89	100	104	111	130	130
Hydrogen	0	0	0	0	0	0	0
Total heat supply[1)]	**1,768**	**2,162**	**2,411**	**2,502**	**2,664**	**2,935**	**3,109**
Fossil fuels	1,472	1,799	2,000	2,072	2,191	2,358	2,461
Biomass	109	121	133	138	153	196	232
Solar collectors	32	52	66	72	86	113	126
Geothermal	0	0	0	0	1	0	0
Heat pumps[1)]	90	101	112	116	122	138	161
Electric direct heating[2)]	65	89	100	104	111	130	130
Hydrogen	0	0	0	0	0	0	0
RES share (including RES electricity)	**15.3%**	**14.9%**	**15.1%**	**15.2%**	**15.8%**	**17.5%**	**18.9%**
Electricity consumption heat pumps (TWh/a)	7.9	8.6	9.2	9.4	9.6	10.2	11.2

1) heat from ambient energy and electricity use; 2) heat from electric direct heating.

table 9.5: turkey: CO_2 emissions

MILL t/a	2012	2018	2023	2025	2030	2040	2050
Condensation power plants	**104**	**108**	**105**	**104**	**102**	**113**	**126**
Hard coal (incl. non-renewable waste)	26	31	31	31	32	47	61
Lignite	41	36	33	32	31	28	25
Gas	37	41	40	39	38	39	39
Oil	0	1	1	1	0	0	0
Diesel	0	0	0	0	0	0	0
Combined heat & power production	**6**	**6**	**7**	**7**	**8**	**9**	**11**
Hard coal (incl. non-renewable waste)	0	0	0	0	0	0	0
Lignite	1	1	1	1	1	1	1
Gas	5	5	6	6	6	7	9
Oil	0	0	0	0	0	0	1
CO_2 emissions power generation (incl. CHP public)	**110**	**115**	**112**	**111**	**110**	**122**	**136**
Hard coal (incl. non-renewable waste)	26	31	32	32	33	47	61
Lignite	41	37	34	33	31	29	27
Gas	42	46	46	45	45	46	48
Oil & diesel	1	1	1	1	1	1	1
CO_2 emissions by sector	**278**	**368**	**396**	**406**	**424**	**462**	**489**
% of 1990 emissions (126.7 Mill t)	220%	290%	312%	320%	334%	365%	386%
Industry[1)]	53	68	76	78	83	87	89
Other sectors[1)]	71	82	89	91	94	98	99
Transport	51	65	78	83	92	107	116
Power generation[2)]	107	111	108	107	105	117	130
Other conversion[3)]	0	41	45	47	49	53	55
Population (Mill.)	75.4	79.3	82.7	84.0	86.7	90.3	91.6
CO_2 emissions per capita (t/capita)	**3.7**	**4.6**	**4.8**	**4.8**	**4.9**	**5.1**	**5.3**

1) incl. CHP autoproducers. 2) incl. CHP public. 3) district heating, refineries, coal transformation, gas transport.

table 9.6: turkey: installed capacity

GW	2012	2018	2023	2025	2030	2040	2050
Power plants	**55**	**68**	**79**	**83**	**93**	**108**	**122**
Hard coal	7	9	9	9	10	15	21
Lignite	8	8	7	7	7	7	7
Gas (incl. H_2)	18	20	20	20	20	21	22
Oil	1	1	1	1	1	0	0
Diesel	1	0	0	0	0	0	0
Nuclear	0	2	6	8	12	12	12
Biomass	0	1	1	1	1	2	3
Hydro	18	20	22	23	24	26	27
Wind	3	6	9	10	12	16	20
of which wind offshore	0	0	0	0	1	1	2
PV	0	1	3	4	5	7	7
Geothermal	0	0	0	0	0	1	1
Solar thermal power plants	0	0	0	0	0	0	1
Ocean energy	0	0	0	0	0	0	0
Combined heat & power production	**2**	**2.1**	**2.3**	**2.4**	**2.6**	**3.2**	**4.0**
Hard coal	0	0	0	0	0	0	0
Lignite	0	0	0	0	0	0	0
Gas (incl. H_2)	1	1	1	2	2	2	3
Oil	0	0	0	0	0	1	1
Biomass	0	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0	0
CHP by producer							
Main activity producers	1	1	1	1	1	1	1
Autoproducers	1	1	1	1	2	2	3
Total generation	**56**	**70**	**81**	**85**	**96**	**111**	**126**
Fossil	36	39	40	40	40	47	54
Hard coal	7	9	9	10	10	15	21
Lignite	8	8	7	7	7	7	7
Gas (w/o H_2)	19	21	22	22	22	23	25
Oil	1	1	1	1	1	1	1
Diesel	1	0	0	0	0	0	0
Nuclear	0	2	6	8	12	12	12
Hydrogen (fuel cells, gas power plants & CHP)	0	0	0	0	0	0	0
Renewables	**21**	**29**	**35**	**38**	**44**	**53**	**60**
Hydro	18	20	22	23	24	26	27
Wind	3	6	9	10	12	16	20
PV	0	1	3	4	5	7	7
Biomass	0	1	1	1	2	3	4
Geothermal	0	0	0	0	0	1	1
Solar thermal	0	0	0	0	0	0	1
Ocean energy	0	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	3	7	12	13	17	23	28
Share of fluctuating RES	4.7%	10.6%	14.2%	15.3%	17.8%	20.9%	22.2%
RES share (domestic generation)	**36.6%**	**40.7%**	**43.3%**	**44.2%**	**45.7%**	**47.3%**	**47.5%**

table 9.7: turkey: primary energy demand

PJ/a	2012	2018	2023	2025	2030	2040	2050
Total	**4,956**	**6,036**	**6,875**	**7,194**	**7,886**	**8,616**	**9,095**
Fossil	**4,447**	**5,158**	**5,545**	**5,684**	**5,931**	**6,432**	**6,751**
Hard coal (& non-renewable waste)	940	907	928	929	968	1,121	1,257
Lignite	627	674	680	681	681	652	598
Natural gas	1,532	1,819	1,915	1,947	1,991	2,135	2,287
Crude oil	1,348	1,758	2,022	2,127	2,291	2,524	2,610
Nuclear	**0**	**183**	**489**	**611**	**916**	**916**	**916**
Renewables	**509**	**694**	**841**	**900**	**1,038**	**1,267**	**1,427**
Hydro	208	240	261	270	288	302	317
Wind	21	51	74	83	101	144	187
Solar	32	60	84	94	120	164	183
Biomass (& renewable waste)	153	219	266	285	337	438	506
Geothermal/ambient heat	94	125	155	168	192	219	234
Ocean energy	0	0	0	0	0	0	0
RES share	**10.3%**	**11.5%**	**12.2%**	**12.5%**	**13.2%**	**14.7%**	**15.7%**

table 9.8: turkey: final energy demand

PJ/a	2012	2018	2023	2025	2030	2040	2050
Total (incl. non-energy use)	**3,656**	**4,473**	**5,078**	**5,312**	**5,783**	**6,442**	**6,904**
Total (energy use)	**3,359**	**4,135**	**4,706**	**4,926**	**5,364**	**5,983**	**6,438**
Transport	**721**	**948**	**1,140**	**1,220**	**1,370**	**1,630**	**1,785**
Oil products	707	896	1,051	1,116	1,228	1416	1,521
Natural gas	8	25	44	52	70	100	130
Biofuels	3	21	37	43	61	96	110
Electricity	3	6	8	9	12	18	24
RES electricity	1	2	2	3	4	6	8
Hydrogen	0	0	0	0	0	0	0
RES share Transport (in %)	**0.5%**	**2.4%**	**3.5%**	**3.8%**	**4.7%**	**6.3%**	**6.6%**
Industry	**1,079**	**1,373**	**1,544**	**1,600**	**1,731**	**1,877**	**1,960**
Electricity	325	412	464	481	526	585	601
RES electricity	88	120	140	147	162	190	199
District heat	51	60	69	73	80	92	104
RES district heat	2	5	7	8	10	13	17
Hard coal + lignite	268	325	356	367	386	384	379
Oil products	70	125	148	155	168	176	179
Gas	353	429	475	489	524	572	600
Solar	11	13	15	16	18	19	20
Biomass and waste	0	9	17	20	29	45	60
Geothermal/ambient heat	0	0	0	0	1	4	15
Hydrogen	0	0	0	0	0	0	0
RES share Industry (in %)	**9.4%**	**10.8%**	**11.6%**	**12.0%**	**12.7%**	**14.5%**	**16.0%**
Other Sectors	**1,559**	**1,814**	**2,022**	**2,105**	**2,262**	**2,476**	**2,694**
Electricity	366	440	519	552	640	720	863
RES electricity	100	128	156	168	198	234	286
District heat	0	0	0	0	0	1	3
RES district heat	0	0	0	0	0	0	0
Hard coal + lignite	376	415	432	437	447	447	405
Oil products	185	266	310	325	333	340	327
Gas	404	431	471	489	513	585	684
Solar	21	38	51	56	68	93	105
Biomass and waste	145	153	160	163	173	192	201
Geothermal	61	70	78	82	87	98	105
Hydrogen	0	0	0	0	0	0	0
RES share Other Sectors (in %)	**20.9%**	**21.5%**	**22.1%**	**22.3%**	**23.2%**	**24.9%**	**25.9%**
Total RES	**432**	**561**	**665**	**707**	**810**	**991**	**1,128**
RES share (in %)	**12.9%**	**13.6%**	**14.1%**	**14.3%**	**15.1%**	**16.6%**	**17.5%**
Non energy use	**297**	**338**	**372**	**386**	**419**	**459**	**466**
Oil	286	325	356	370	400	436	443
Gas	11	13	15	16	19	23	24
Coal	0	0	0	0	0	0	0

turkey: energy [r]evolution scenario

table 9.9: turkey: electricity generation

TWh/a	2012	2018	2023	2025	2030	2040	2050
Power plants	**232**	**265**	**286**	**295**	**313**	**369**	**421**
Hard coal (& non-renewable waste)	31	35	31	29	25	6	0
Lignite	35	30	24	21	14	3	0
Gas	100	104	94	88	66	38	29
of which from H_2	0	0	0	0	0	0	0
Oil	1	1	1	1	1	0	0
Diesel	1	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0	0
Biomass (& renewable waste)	0	1	2	2	3	5	5
Hydro	58	59	60	60	61	61	62
Wind	6	18	29	35	49	83	109
of which wind offshore	0	1	2	3	4	8	12
PV	0	8	20	26	43	75	96
Geothermal	1	5	9	11	15	18	20
Solar thermal power plants	0	4	14	20	36	76	97
Ocean energy	0	0	1	1	1	3	4
Combined heat & power plants	**8**	**17**	**26**	**30**	**43**	**63**	**73**
Hard coal (& non-renewable waste)	0	0	0	0	0	0	0
Lignite	0	0	0	0	0	0	0
Gas	7	11	15	16	17	19	20
of which from H_2	0	0	0	0	0	0	0
Oil	0	0	0	0	0	0	0
Biomass (& renewable waste)	0	4	10	13	23	38	42
Geothermal	0	0	1	1	2	7	12
Hydrogen	0	0	0	0	0	0	0
CHP by producer							
Main activity producers	4	7	10	12	17	25	29
Autoproducers	4	10	16	18	26	38	44
Total generation	**240**	**281**	**312**	**325**	**357**	**432**	**495**
Fossil	174	182	165	156	124	66	49
Hard coal (& non-renewable waste)	31	35	31	29	25	6	0
Lignite	36	30	24	21	14	3	0
Gas	106	115	109	104	83	57	49
Oil	1	2	1	1	1	0	0
Diesel	1	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0	0
Renewables	**65**	**100**	**146**	**168**	**233**	**366**	**446**
Hydro	58	59	60	60	61	61	62
Wind	6	18	29	35	49	83	109
PV	0	8	20	26	43	75	96
Biomass (& renewable waste)	1	6	12	15	26	42	47
Geothermal	1	5	10	12	17	25	32
Solar thermal	0	4	14	20	36	76	97
Ocean energy	0	0	1	1	1	3	4
Distribution losses	36	41	44	45	50	54	57
Own consumption electricity	14	17	18	19	20	21	22
Electricity for hydrogen production	0	0	0	0	1	7	18
Final energy consumption (electricity)	**193**	**225**	**250**	**261**	**286**	**350**	**397**
Fluctuating RES (PV, Wind, Ocean)	6	26	50	61	93	161	209
Share of fluctuating RES	2.4%	9.2%	16.1%	18.9%	26.2%	37.2%	42.2%
RES share (domestic generation)	**27.2%**	**35.5%**	**47.0%**	**51.9%**	**65.4%**	**84.7%**	**90.2%**
'Efficiency' savings (compared to Ref.)	**0**	**17**	**41**	**51**	**81**	**106**	**132**

table 9.10: turkey: heat supply

PJ/a	2012	2018	2023	2025	2030	2040	2050
District heating	**0**	**48**	**85**	**99**	**103**	**72**	**12**
Fossil fuels	0	0	0	0	0	0	0
Biomass	0	10	18	20	24	19	3
Solar collectors	0	21	34	40	39	25	5
Geothermal	0	18	34	40	41	27	5
Heat from CHP	**51**	**110**	**183**	**215**	**327**	**507**	**616**
Fossil fuels	50	79	105	113	128	138	133
Biomass	1	29	72	94	177	304	368
Geothermal	0	2	5	7	22	65	115
Hydrogen	0	0	0	0	0	0	0
Direct heating & air conditioning	**1,717**	**1,805**	**1,813**	**1,811**	**1,789**	**1,732**	**1,699**
Fossil fuels	1,422	1,314	1,163	1,097	918	542	163
Biomass	108	138	161	170	192	238	293
Solar collectors	32	130	215	248	333	502	680
Geothermal	0	33	62	74	105	167	238
Heat pumps[1]	90	107	118	123	131	150	166
Electric direct heating[2]	65	82	95	100	111	133	158
Hydrogen	0	0	0	0	0	0	0
Total heat supply[1]	**1,768**	**1,963**	**2,081**	**2,125**	**2,220**	**2,310**	**2,327**
Fossil fuels	1,472	1,393	1,268	1,211	1,045	680	296
Biomass	109	177	251	283	393	562	664
Solar collectors	32	151	248	288	371	527	685
Geothermal	0	52	101	120	168	259	358
Heat pumps[1]	90	107	118	123	131	150	166
Electric direct heating[2]	65	82	95	100	111	133	158
Hydrogen	0	0	0	0	0	0	0
RES share (including RES electricity)	**15.3%**	**27.4%**	**37.5%**	**41.6%**	**51.8%**	**70.0%**	**86.8%**
Electricity consumption heat pumps (TWh/a)	7.9	9.1	9.8	10.0	10.3	11.1	11.6
'Efficiency' savings (compared to Ref.)	**0**	**198**	**329**	**377**	**444**	**625**	**783**

1) heat from ambient energy and electricity use; 2) heat from electric direct heating.

table 9.11: turkey: CO_2 emissions

MILL t/a	2012	2018	2023	2025	2030	2040	2050
Condensation power plants	**104**	**99**	**83**	**76**	**56**	**20**	**9**
Hard coal (incl. non-renewable waste)	26	28	24	22	19	5	0
Lignite	41	33	25	22	14	3	0
Gas	37	37	33	31	22	12	9
Oil	0	1	1	1	1	0	0
Diesel	0	0	0	0	0	0	0
Combined heat & power production	**6**	**8**	**11**	**11**	**12**	**12**	**12**
Hard coal (incl. non-renewable waste)	0	0	0	0	0	0	0
Lignite	1	0	0	0	0	0	0
Gas	5	8	10	11	12	12	12
Oil	0	0	0	0	0	0	0
CO_2 emissions power generation (incl. CHP public)	**110**	**107**	**94**	**87**	**68**	**32**	**21**
Hard coal (incl. non-renewable waste)	26	28	24	22	19	5	0
Lignite	41	33	25	22	14	3	0
Gas	42	45	43	42	34	25	21
Oil & diesel	1	1	1	1	1	0	0
CO_2 emissions by sector	**278**	**308**	**279**	**264**	**219**	**125**	**59**
% of 1990 emissions (351.9 Mill t)	220%	243%	220%	208%	173%	99%	46.2%
Industry[1]	53	50	46	43	37	23	10
Other sectors[1]	71	65	56	52	42	23	6
Transport	51	56	56	55	50	32	16
Power generation[2]	107	103	89	82	64	29	15
Other conversion[3]	0	35	33	31	27	18	11
Population (Mill.)	75.4	79	83	84	87	90	92
CO_2 emissions per capita (t/capita)	**3.7**	**3.9**	**3.4**	**3.1**	**2.5**	**1.4**	**0.6**
'Efficiency' savings (compared to Ref.)	**0**	**59**	**117**	**142**	**204**	**337**	**430**

1) incl. CHP autoproducers. 2) incl. CHP public. 3) district heating, refineries, coal transformation, gas transport.

table 9.12: turkey: installed capacity

GW	2012	2018	2023	2025	2030	2040	2050
Power plants	**55**	**69**	**82**	**88**	**104**	**136**	**159**
Hard coal	7	9	8	8	6	1	0
Lignite	8	8	6	5	3	1	0
Gas (incl. H_2)	18	18	18	18	18	18	18
Oil	1	1	1	1	1	0	0
Diesel	1	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0	0
Biomass	0	0	1	1	1	1	2
Hydro	18	18	18	18	19	19	19
Wind	3	8	12	15	20	33	42
of which wind offshore	0	1	1	1	1	3	4
PV	0	5	13	16	26	44	55
Geothermal	0	1	1	2	2	3	3
Solar thermal power plants	0	1	3	4	7	15	19
Ocean energy	0	0	0	0	0	1	1
Combined heat & power production	**2**	**4**	**6**	**7**	**11**	**17**	**19**
Hard coal	0	0	0	0	0	0	0
Lignite	0	0	0	0	0	0	0
Gas (incl. H_2)	1	2	3	3	3	3	3
Oil	0	0	0	0	0	0	0
Biomass	0	1	3	4	8	12	14
Geothermal	0	0	0	0	0	1	2
Hydrogen	0	0	0	0	0	0	0
CHP by producer							
Main activity producers	1	1	2	2	3	5	6
Autoproducers	1	3	4	5	8	11	13
Total generation	**56**	**73**	**89**	**95**	**115**	**153**	**177**
Fossil	36	39	37	35	32	24	22
Hard coal	7	9	8	8	6	1	0
Lignite	8	8	6	6	3	1	0
Gas (w/o H_2)	19	20	21	21	22	22	22
Oil	1	1	1	1	1	0	0
Diesel	1	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0	0
Hydrogen (fuel cells, gas power plants & CHP)	0	0	0	0	0	0	0
Renewables	**21**	**34**	**52**	**60**	**83**	**129**	**156**
Hydro	18	18	18	18	19	19	19
Wind	3	8	12	15	20	33	42
PV	0	5	13	16	26	44	55
Biomass	0	2	4	5	9	14	15
Geothermal	0	1	1	2	2	4	4
Solar thermal	0	1	3	4	7	15	19
Ocean energy	0	0	0	0	0	1	1
Fluctuating RES (PV, Wind, Ocean)	3	13	25	31	47	78	98
Share of fluctuating RES	4.7%	17.5%	28.7%	32.5%	40.9%	51.0%	55.4%
RES share (domestic generation)	**36.6%**	**46.9%**	**58.4%**	**62.8%**	**72.5%**	**84.2%**	**87.7%**

table 9.13: turkey: primary energy demand

PJ/a	2012	2018	2023	2025	2030	2040	2050
Total	**4,956**	**5,586**	**5,833**	**5,908**	**6,000**	**5,890**	**5,682**
Fossil	**4,447**	**4,412**	**4,051**	**3,863**	**3,286**	**2,075**	**1,194**
Hard coal	940	853	752	703	581	271	81
Lignite	627	533	430	386	278	100	0
Natural gas	1,532	1 624	1 519	1 461	1 246	943	765
Crude oil	1,348	1 403	1 350	1 313	1 181	761	347
Nuclear	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Renewables	**509**	**1,174**	**1,782**	**2,045**	**2,714**	**3,815**	**4,488**
Hydro	208	213	216	216	218	221	223
Wind	21	64	105	124	176	299	392
Solar	32	193	373	454	656	1 072	1 378
Biomass	153	394	582	664	903	1 217	1 305
Geothermal/ambient heat	94	309	503	584	755	996	1 175
Ocean energy	0	1	2	3	5	10	14
RES share	**10.3%**	**21.0%**	**30.6%**	**34.6%**	**45.2%**	**64.8%**	**79.0%**
'Efficiency' savings (compared to Ref.)	**0**	**450**	**1,042**	**1,287**	**1,886**	**2,726**	**3,413**

table 9.14: turkey: final energy demand

PJ/a	2012	2018	2023	2025	2030	2040	2050
Total (incl. non-energy use)	**3,656**	**4,077**	**4,281**	**4,350**	**4,476**	**4,548**	**4,464**
Total (energy use)	**3,359**	**3,766**	**3,958**	**4,021**	**4,140**	**4,226**	**4,184**
Transport	**721**	**891**	**985**	**1,019**	**1,069**	**1,092**	**1,000**
Oil products	707	757	737	715	629	339	65
Natural gas	8	36	58	67	92	158	221
Biofuels	3	79	125	145	189	241	221
Electricity	3	20	65	92	156	336	443
RES electricity	1	7	31	48	102	284	399
Hydrogen	0	0	0	0	2	19	50
RES share Transport (in %)	**0.5%**	**9.6%**	**15.8%**	**18.9%**	**27.4%**	**49.5%**	**66.6%**
Industry	**1,079**	**1,200**	**1,265**	**1,283**	**1,331**	**1,375**	**1,470**
Electricity	325	379	401	407	420	447	502
RES electricity	88	134	188	211	274	378	452
District heat	51	67	82	88	105	132	151
RES district heat	2	36	49	53	64	88	118
Hard coal + lignite	268	250	223	210	175	91	0
Oil products	70	65	59	57	49	30	10
Gas	353	335	310	298	265	187	116
Solar	11	48	81	95	131	204	292
Biomass and waste	0	33	63	75	108	159	217
Geothermal/ambient heat	0	24	45	54	78	125	182
Hydrogen	0	0	0	0	0	0	0
RES share Industry (in %)	**9.4%**	**22.9%**	**33.7%**	**38.1%**	**49.3%**	**69.4%**	**85.8%**
Other Sectors	**1,559**	**1,675**	**1,708**	**1,720**	**1,741**	**1,759**	**1,715**
Electricity	366	413	435	442	454	476	486
RES electricity	100	146	205	229	297	403	439
District heat	0	72	141	170	255	392	474
RES district heat	0	39	84	103	155	260	370
Hard coal + lignite	376	336	285	264	209	103	0
Oil products	185	167	143	133	107	54	2
Gas	404	361	311	290	236	140	52
Solar	21	82	133	153	201	298	388
Biomass and waste	145	159	160	161	159	145	132
Geothermal	61	84	100	106	121	152	180
Hydrogen	0	0	0	0	0	0	0
RES share Other Sectors (in %)	**20.9%**	**30.5%**	**39.9%**	**43.8%**	**53.6%**	**71.5%**	**88.0%**
Total RES	**432**	**871**	**1,264**	**1,434**	**1,881**	**2,752**	**3,436**
RES share (in %)	**12.9%**	**23.1%**	**31.9%**	**35.7%**	**45.4%**	**65.1%**	**82.1%**
Non energy use	**297**	**311**	**323**	**328**	**335**	**321**	**280**
Oil	286	296	307	312	319	305	266
Gas	11	14	16	16	17	16	14
Coal	0	0	0	0	0	0	0

turkey: investment & employment

table 9.15: turkey: 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)	**33,583**	**45,470**	**15,957**	**18,799**	**113,809**	**2,845**
Renewables	**35,261**	**28,289**	**27,051**	**28,853**	**119,455**	**2,986**
Biomass	1,241	1,880	2,965	3,513	9,599	240
Hydro	18,577	14,575	9,133	9,434	51,719	1,293
Wind	11,358	7,192	10,001	11,517	40,068	1,002
PV	2,451	3,098	3,027	2,780	11,355	284
Geothermal	1,633	1,340	848	946	4,768	119
Solar thermal power plants	0	205	1,078	663	1,945	49
Ocean energy	0	0	0	0	0	0
Energy [R]evolution						
Conventional (fossil & nuclear)	**13,509**	**2,789**	**6,564**	**9,276**	**32,139**	**803**
Renewables	**48,355**	**70,861**	**88,056**	**87,790**	**295,062**	**7,377**
Biomass	850	1,225	1,714	1,470	5,258	131
Hydro	11,078	6,377	6,374	6,405	30,234	756
Wind	14,049	12,711	23,055	22,942	72,756	1,819
PV	8,686	16,732	20,508	22,228	68,154	1,704
Geothermal	7,554	6,665	3,596	5,066	22,881	572
Solar thermal power plants	6,138	26,667	32,188	29,141	94,134	2,353
Ocean energy	0	485	622	539	1,646	41

table 9.16: turkey: 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						
Heat pumps	15,944	15,534	8,200	7,282	46,960	1,174
Deep geothermal	182	73	0	56	311	8
Solar thermal	13,032	7,463	14,783	7,246	42,525	1,063
Biomass	7,461	13,255	2,232	4,124	27,072	677
Total	**36,619**	**36,326**	**25,215**	**18,708**	**116,868**	**2,922**
Energy [R]evolution scenario						
Heat pumps	17,810	16,274	10,976	8,279	53,339	1,333
Deep geothermal	18,534	13,512	19,536	20,947	72,528	1,813
Solar thermal	41,667	39,640	63,509	60,099	204,915	5,123
Biomass	9,459	9,192	4,168	4,667	27,487	687
Total	**87,470**	**78,618**	**98,189**	**93,991**	**358,269**	**8,957**

table 9.17: turkey: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	8,760	18,313	17,348	8,648	10,535	19,483	13,706
Manufacturing	3,287	3,639	3,454	3,726	3,448	5,654	4,507
Operations and maintenance	8,506	10,384	14,191	20,324	12,535	16,783	27,401
Fuel supply (domestic)	61,681	54,898	58,505	60,255	55,799	53,980	52,429
Coal and gas export	-	-	-	-	-	-	-
Solar and geothermal heat	2,229	8,622	8,442	4,785	18,236	30,253	35,180
Total jobs	**84,463**	**95,856**	**101,940**	**97,738**	**100,554**	**126,152**	**133,223**
By technology							
Coal	60,509	52,773	54,294	62,607	47,508	43,501	32,913
Gas, oil & diesel	3,942	2,228	2,097	2,111	2,353	2,163	1,935
Nuclear	-	11,358	13,029	4,223	-	-	-
Total renewables	**20,012**	**29,497**	**32,520**	**28,797**	**50,694**	**80,489**	**98,375**
Biomass	*6,567*	*7,628*	*8,900*	*10,327*	*14,940*	*21,607*	*39,218*
Hydro	*8,160*	*9,089*	*9,810*	*9,128*	*5,931*	*5,902*	*6,485*
Wind	*1,196*	*2,074*	*2,446*	*3,424*	*4,068*	*5,282*	*6,801*
PV	*1,697*	*1,848*	*2,680*	*877*	*5,971*	*13,025*	*5,435*
Geothermal power	*163*	*189*	*165*	*117*	*803*	*855*	*824*
Solar thermal power	*-*	*46*	*77*	*140*	*687*	*3,471*	*4,289*
Ocean	*-*	*-*	*-*	*-*	*58*	*92*	*143*
Solar - heat	*1,343*	*5,367*	*5,569*	*3,615*	*12,510*	*23,848*	*28,861*
Geothermal & heat pump	*886*	*3,255*	*2,873*	*1,169*	*5,726*	*6,405*	*6,319*
Total jobs	**84,463**	**95,856**	**101,940**	**97,738**	**100,554**	**126,152**	**133,223**

turkey: transport

table 9.18: turkey: final energy consumption transport

PJ/a	2012	2018	2023	2025	2030	2040	2050
Reference scenario							
Road	**669**	**857**	**1,037**	**1,112**	**1,252**	**1,495**	**1,639**
Fossil fuels	664	816	960	1,020	1,123	1,298	1,396
Biofuels	3	21	36	43	59	93	105
Natural gas	2	18	37	44	62	91	120
Hydrogen	0	0	0	0	0	0	0
Electricity	0	3	4	5	8	13	18
Rail	**9**	**11**	**12**	**12**	**13**	**15**	**16**
Fossil fuels	6	7	8	8	9	9	9
Biofuels	0	0	0	0	0	0	1
Electricity	3	3	4	4	4	5	6
Navigation	**20**	**37**	**44**	**46**	**50**	**56**	**60**
Fossil fuels	20	37	43	45	49	53	56
Biofuels	0	0	1	1	1	3	4
Aviation	**16**	**36**	**40**	**42**	**47**	**55**	**60**
Fossil fuels	16	36	40	42	47	55	60
Biofuels	0	0	0	0	0	0	0
Total (incl. pipeline)	**721**	**948**	**1,140**	**1,220**	**1,370**	**1,630**	**1,785**
Fossil fuels	707	896	1,051	1,116	1,228	1,416	1,521
Biofuels (incl. biogas)	3	21	37	43	61	96	110
Natural gas	8	25	44	52	70	100	130
Hydrogen	0	0	0	0	0	0	0
Electricity	3	6	8	9	12	18	24
Total (incl. pipeline)	**4**	**23**	**41**	**48**	**68**	**111**	**131**
RES share	**0.5%**	**2.4%**	**3.5%**	**3.8%**	**4.7%**	**6.3%**	**6.6%**
Energy [R]evolution							
Road	**669**	**808**	**893**	**923**	**962**	**958**	**854**
Fossil fuels	664	684	659	634	547	263	13
Biofuels	3	79	124	144	182	215	169
Natural gas	2	29	51	60	85	151	213
Hydrogen	0	0	0	0	2	19	50
Electricity	0	16	59	85	145	310	409
Rail	**9**	**10**	**10**	**10**	**13**	**28**	**35**
Fossil fuels	6	6	4	2	2	1	1
Biofuels	0	0	0	0	0	0	0
Electricity	3	4	6	7	11	26	34
Navigation	**20**	**36**	**41**	**43**	**47**	**52**	**54**
Fossil fuels	20	35	40	42	43	39	27
Biofuels	0	0	1	1	4	13	27
Aviation	**16**	**33**	**35**	**36**	**39**	**47**	**50**
Fossil fuels	16	33	35	36	36	35	25
Biofuels	0	0	0	0	3	12	25
Total	**721**	**891**	**985**	**1,019**	**1,069**	**1,092**	**1,000**
Fossil fuels	707	757	737	715	629	339	65
Biofuels (incl. biogas)	3	79	125	145	189	241	221
Natural gas	8	36	58	67	92	158	221
Hydrogen	0	0	0	0	2	19	50
Electricity	3	20	65	92	156	336	443
Total (incl. pipeline)	**4**	**86**	**156**	**193**	**292**	**541**	**666**
RES share	**0.5%**	**9.6%**	**15.8%**	**18.9%**	**27.4%**	**49.5%**	**66.6%**

GREENPEACE

Greenpeace is a global organisation that uses non-violent direct action to tackle the most crucial threats to our planet's biodiversity and environment. Greenpeace is a non-profit organisation, present in 40 countries across Europe, the Americas, Africa, Asia and the Pacific. It speaks for 2.8 million supporters worldwide, and inspires many millions more to take action every day. To maintain its independence, Greenpeace does not accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants. Greenpeace has been campaigning against environmental degradation since 1971 when a small boat of volunteers and journalists sailed into Amchitka, an area west of Alaska, where the US Government was conducting underground nuclear tests. This tradition of 'bearing witness' in a non-violent manner continues today, and ships are an important part of all its campaign work.

Istiklal Caddesi Kallavi Sok. No:1 Kat:2
Beyoglu / Istanbul
t +212 292 76 19 f+212 292 76 22
http://www.greenpeace.org/turkey/tr/
bilgi.tr@greenpeace.org

image THE CITY OF DEMRE AND SURROUNDING AREAS, TURKEY © NASA EARTH OBSERVATORY IMAGE BY JESSE ALLEN AND ROBERT SIMMON. **front cover images** ANATOLIAN PENINSULA OF TURKEY © JEFF SCHMALTZ/NASA. WIND TURBINE BY THE SMOKING PIPE OF THE FACTORY, TURKEY © AHMET IHSAN ARITURK. PHOTOVOLTAIC CELLS, TURKEY © JAHMAICAN/DREAMSTIME.