energy

[r]evolution

A SUSTAINABLE MEXICO ENERGY OUTLOOK

GWEC
GLOBAL WIND ENERGY COUNCIL

EREC
EUROPEAN RENEWABLE ENERGY COUNCIL

GREENPEACE

report 2012 mexico energy scenario

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

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

partners

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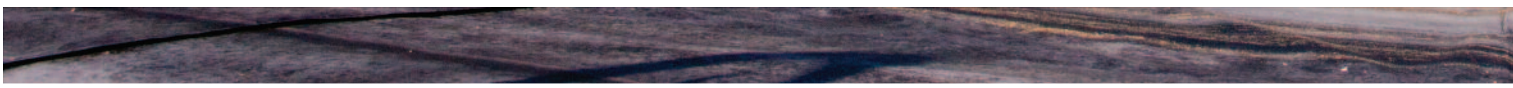

image LA DEHESA, 50 MW PARABOLIC THROUGH SOLAR THERMAL POWER PLANT WITH MOLTEN SALTS STORAGE IN SPAIN. COMPLETED IN FEBRUARY 2011, IT IS LOCATED IN LA GAROVILLA AND IT IS OWNED BY RENOVABLES SAMCA. WITH AN ANNUAL PRODUCTION OF 160 MILLION KWH, LA DEHESA WILL BE ABLE TO COVER THE ELECTRICITY NEEDS OF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

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

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contents

introduction **6**

executive summary **8**

1
climate and energy policy **11**

1.1 the UNFCCC and the kyoto protocol **12**
1.2 international energy policy **12**
1.3 renewable energy targets **12**
1.4 policy changes in the energy sector **13**
1.4.1 the most effective way to implement the energy [r]evolution: feed in laws 13
1.4.2 bankable renewable energy support schemes 15
1.5 mexico energy policy **16**
1.5.1 deep-water drilling 16
1.5.2 current regulations 16
1.5.3 wind power in the isthmus of tehuantepec 17

2
the energy [r]evolution concept **18**

2.1 key principles **19**
2.2 the "3 step implementation" **20**
2.3 the new electricity grid **23**
2.3.1 hybrid systems 24
2.3.2 smart grids 25
2.3.3 the super grid 27
2.3.4 baseload blocks progress 27

3
implementing the energy [r]evolution **30**

3.1 renewable energy project planning basics **31**
3.2 renewable energy financing basics **32**
3.2.1 overcoming barriers to finance and investment for renewable energy 34
3.2.2 how to overcome investment barriers for renewable energy 35

4
scenarios for a future energy supply **36**

4.1 scenario background **38**
4.1.1 status and future projections for renewable heating technologies 38
4.2 population development **38**
4.3 economic growth **38**
4.4 oil and gas price projections **39**
4.5 cost of CO_2 emissions **40**
4.6 cost projections for efficient fossil fuel generation and carbon capture and storage (CCS) **40**
4.7 cost projections for renewable energy technologies **41**
4.7.1 photovoltaics (pv) 42
4.7.2 concentrating solar power (csp) 42
4.7.3 wind power 43
4.7.4 biomass 43
4.7.5 geothermal 44
4.7.6 ocean energy 44
4.7.7 hydro power 45
4.7.8 summary of renewable energy cost development 45
4.8 cost projections for renewable heating technologies **46**
4.8.1 solar thermal technologies 46
4.8.2 deep geothermal applications 46
4.8.3 heat pumps 46
4.8.4 biomass applications 46
4.9 assumptions for fossil fuel phase out **47**
4.9.1 oil - production decline assumptions 47
4.9.2 coal - production decline assumptions 47
4.10 review: greenpeace scenario projections of the past **48**
4.10.1 the development of the global wind industry 48
4.10.2 the development of the global solar photovoltaic industry 50
4.11 how does the energy [r]evolution scenario compare to other scenarios **52**

5
key results of the mexico energy [r]evolution scenario **53**

5.1 energy demand by sector **54**
5.2 electricity generation **56**
5.3 future costs of electricity generation **57**
5.4 future investments in the power sector **57**
5.5 heating supply **58**
5.6 future investments in the heat sector **59**
5.7 transport **60**
5.8 development of CO_2 emissions **61**
5.9 primary energy consumption **61**

6
glossary & appendix **63**

6.1 glossary of commonly used terms and abbreviations **64**
6.2 definition of sectors **64**
scenario results data **65**

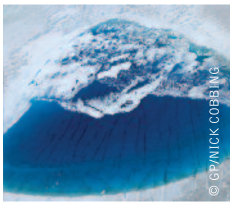

image GREENPEACE AND AN INDEPENDENT NASA-FUNDED SCIENTIST COMPLETED MEASUREMENTS OF MELT LAKES ON THE GREENLAND ICE SHEET THAT SHOW ITS VULNERABILITY TO WARMING TEMPERATURES.

list of figures

2

figure 2.1	centralised generation systems waste more than two thirds of their original energy input	20
figure 2.2	a decentralised energy future	21
figure 2.3	the smart-grid vision for the energy [r]evolution	26
figure 2.4	a typical load curve throughout europe, shows electricity use peaking and falling on a daily basis	28
figure 2.5	the evolving approach to grids	28

3

figure 3.1	return characteristics of renewable energies	32
figure 3.2	overview risk factors for renewable energy projects	33
figure 3.3	investment stages of renewable energy projects	33
figure 3.4	key barriers to renewable energy investment	35

4

figure 4.1	future development of investment costs for renewable energy technologies	45
figure 4.2	expected development of electricity generation costs from fossil fuel and renewable options	45
figure 4.3	global oil production 1950 to 2011 and projection till 2050	47
figure 4.4	coal scenario: base decline of 2% per year and new projects	47
figure 4.5	wind power: short term prognosis vs real market development - global cummulative capacity	48
figure 4.6	wind power: long term market projects until 2030	49
figure 4.7	photovoltaic: short term prognosis vs real market development - global cummulative capacity	50
figure 4.8	photovoltaic: long term market projects until 2030	51

5

figure 5.1	total final energy demand under the reference scenario and the energy energy [r]evolution scenario	54
figure 5.2	development of electricity demand by sector in the energy [r]evolution scenario	55
figure 5.3	development of the transport demand by sector in the energy [r]evolution scenario	55
figure 5.4	development of heat demand by sector in the energy [r]evolution scenario	55
figure 5.5	electricity generation structure under the reference scenario and the energy [r]evolution scenario	56
figure 5.6	total electricity supply costs & specific electricity generation costs under two scenarios	57
figure 5.7	investment shares - reference scenario versus energy [r]evolution scenario	57
figure 5.8	heat supply structure under the reference scenario and the energy [r]evolution scenario	58
figure 5.9	investments for renewable heat generation technologies under the reference scenario and the energy [r]evolution scenario	59
figure 5.10	final energy consumption for transport under the reference scenario and the energy [r]evolution scenario	60
figure 5.11	global: primary energy consumption under the reference scenario and the energy [r]evolution scenario	61
figure 5.12	development of CO_2 emissions by sector under the energy [r]evolution scenarios	61

list of tables

2

table 2.1	power plant value chain	22

3

table 3.1	how does the current renewable energy market work in practice?	31
table 3.2	categorisation of barriers to renewable energy investment	34

4

table 4.1	population development projections	38
table 4.2	gdp development projections	39
table 4.3	development projections for fossil fuel and biomass prices in € 2010	39
table 4.4	assumptions on CO_2 emissions cost development for Annex-B and Non-Annex-B countries of the UNFCCC	40
table 4.5	development of efficiency and investment costs for selected new power plant technologies	41
table 4.6	photovoltaics (pv) cost assumptions	42
table 4.7	concentrating solar power (csp) cost assumptions	42
table 4.8	wind power cost assumptions	43
table 4.9	biomass cost assumptions	43
table 4.10	geothermal cost assumptions	44
table 4.11	ocean energy cost assumptions	44
table 4.12	hydro power cost assumptions	45
table 4.13	overview over expected investment costs for pathways for heating technologies	46
table 4.14	overview of key parameter of the illustrative scenarios based on assumptions that are exogenous to the models respective endogenous model results	52

5

table 5.1	renewable electricity generation capacity under the reference scenario and the energy [r]evolution scenario	56
table 5.2	renewable heating capacities under the reference scenario and the energy [r]evolution scenario	58
table 5.3	renewable heat generation capacities under the reference scenario and the energy [r]evolution scenario	59
table 5.4	transport energy demand by mode under the reference scenario and the energy [r]evolution scenario	60
table 5.5	investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario	62

6

table 6.1	conversion factors – fossil fuels	64
table 6.2	conversion factors – different energy units	64
table 6.3-6.17	mexico scenario results	64

introduction

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

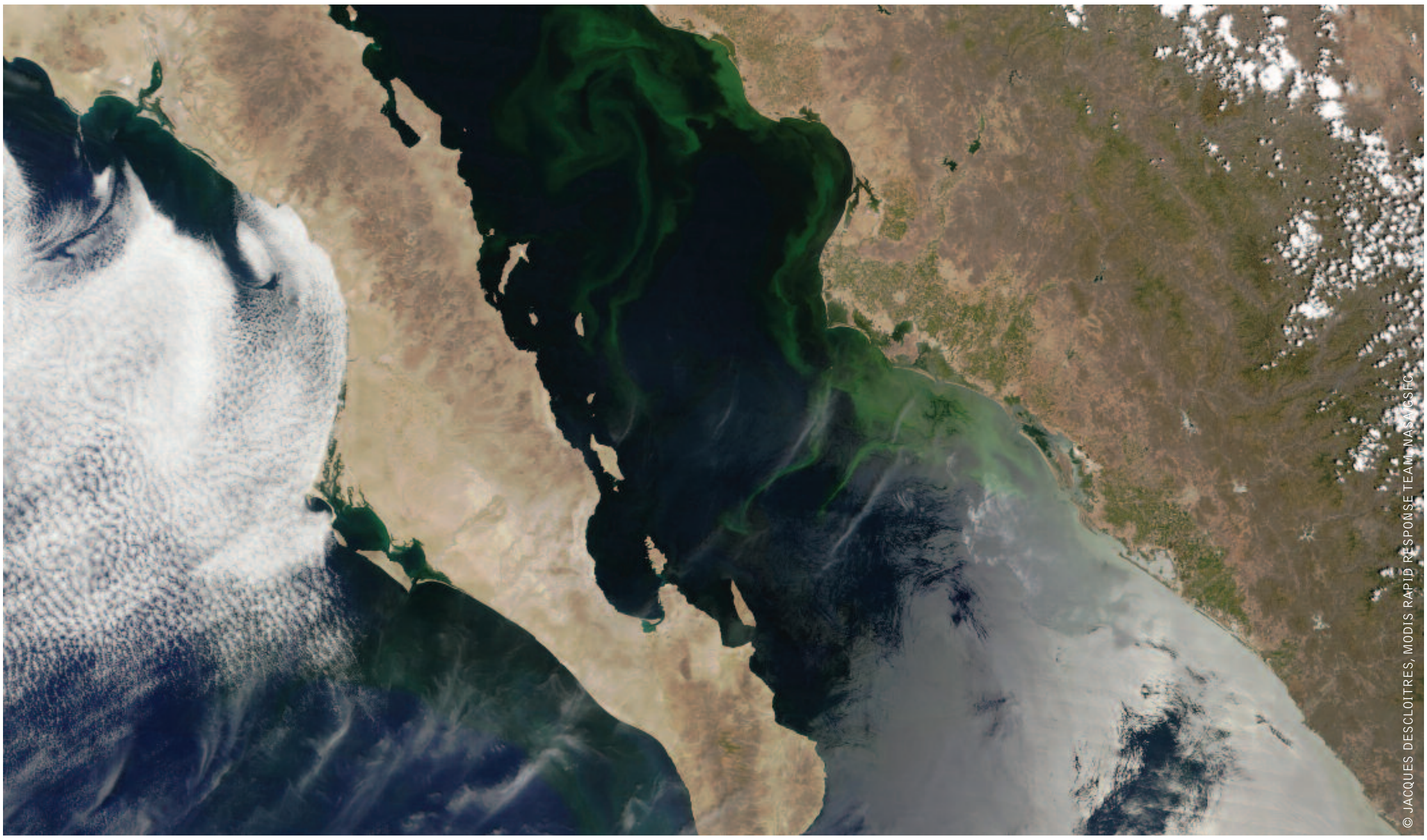

image BETWEEN THE ARID TERRAIN OF THE BAJA CALIFORNIA PENINSULA (LEFT) AND WESTERN MEXICO (RIGHT) A BLOOM OF MICROSCOPIC MARINE ORGANISMS CALLED PHYTOPLANKTON COLORS THE WATERS OF THE GULF OF CALIFORNIA VARIOUS SHADES OF GREEN.

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

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

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

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

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

Japan's major nuclear accident at Fukushima in March 2011 following a tsunami came 25 years after the disastrous explosion in the Chernobyl nuclear power plant in former Soviet Union, showing that nuclear energy is an inherently unsafe source of power. The Fukushima disaster triggered a surge in global renewable energy

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.

© GP/FLAVIO CANNALONGA

and energy efficiency deals. At the same time, the poor state of the global economy has resulted in decreasing carbon prices, some governments reducing support for renewables, and a stagnation of overall investment, particularly in the OECD.

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

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

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

the new energy [r]evolution for mexico

Mexico faces a new political era as the Institutional Revolutionary Party (PRI), which ruled the country for more than 70 years, returned to power in the last elections of 2012. With this new situation, plans, programs and strategies have begun to develop in the field of taxation and energy. In this crucial political moment, the current government should make a shift to renewable energy. Never before has it been so critical for the planet and for the country to start implementing this type of energy in ambitious, objective, serious and forceful way.

Mexico, characterised by having a large amount of natural resources, has the potential to make the most of renewable energy sources such as solar, wind, geothermal and small hydroelectric dams, to reduce their GHG emissions and thereby avoiding worst consequences of climate change.

Diversifying energy sources is a strategic need, and the fact that the Mexican energy system depends mainly on oil, makes our economy more vulnerable, as it is subject to the volatility of international prices and the availability of these resources.

The current model of energy production generates severe environmental damage, in addition to the well known impact on global warming. In the country, an average of 1.3 oil spills and environmental emergencies occur a day, involving serious damages to the environment and biodiversity, as well as social impacts generated by the country's main oil states: Veracruz, Tabasco and Campeche.

In Greenpeace, we believe in the feasibility of reducing current energy demand in the world by 50 percent by 2050, if we maximize the potential of renewable energy and energy efficiency. Therefore, this report sets out the way for both the energy sector and transport, to reach their peak by 2015 and then drastically reduce. Only in then, can a massive increase in global temperature of the planet be avoided and enable the preservation of our ecosystems as well as life of those who live on them

The Energy [R]evolution scenario proposes a model that promotes renewable energy and energy efficiency. There is an urgent task of combating climate change through a real transformation of the energy sector and not only a limited energy reform in the oil sector. A real energy reform must give a prominent role to the production of electricity by renewable resources, as well as energy saving and efficiency in all sectors: government, production, domestic and transport. The upcoming years will be key in defining the country's energy policy. If there is a will to implement changes in Mexico, the Energy Department must increase the participation of renewable sources in the national energy matrix, as a safe, reliable and abundant alternative to generate electricity for both public and private use. At the same time plans to increase the use of coal, oil and shale gas, which would exacerbate climate change, must be left out.

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JANUARY 2013

executive summary

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

image EOLIAN ENERGY POWER STATION LOCATED NEAR THE CITY OF TECATE, LOCATED IN THE MEXICAN STATE OF BAJA CALIFORNIA.

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, white maintaining economic growth. At the core of this Energy [R]evolution will be a change in the way that energy is produced, distributed and consumed. The five key principles behind this shift 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 super 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.

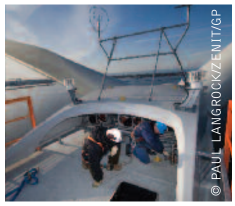
the energy [r]evolution for mexico – key results

Renewable energy sources account for 10% of Mexico's primary energy demand in 2009. The main source is biomass, which is mostly used in the heat sector.

For electricity generation renewables contribute about 14% and for heat supply 21%. In the heat sector, the main pillar is biomass, but solar thermal collectors and geothermal heat pumps will play an increasingly important role. About 89% of the primary energy supply today still comes from fossil fuels and 1.6% from nuclear energy.

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

- **Curbing energy demand:** Combining the projections on population development, GDP growth and energy intensity results in future development pathways for Mexico's final energy demand. Under the Reference scenario, total primary energy demand increases by 103% from the current 7,346 PJ/a to 14,924 PJ/a in 2050. In the Energy [R]evolution scenario, primary energy demand decreases by 5% compared to current consumption and it is expected to reach 6,986 PJ/a by 2050.
- **Controlling power demand:** Under the Energy [R]evolution scenario, electricity demand is exptected to increase in all sectors (industry, transport, residential and service sectors, see Figure 5.2) due to increasing GDP, population and wealth. Total electricity demand will rise from 201 TWh/a to 514 TWh/a by the year 2050. However, compared to the Reference scenario, efficiency measures in the industry, residential and service sectors avoid the generation of about 200 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors.
- **Reducing heating demand**: Efficiency gains in the heat supply sector are large. Under the Energy [R]evolution scenario, demand for heat supply is expected to increase. However, compared to the Reference scenario, consumption equivalent to 163 PJ/a is avoided through efficiency gains by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.
- **Electricity generation:** The development of the electricity supply sector is characterized by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 93% of the electricity produced in Mexico will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 81% of electricity generation. Already by 2020 the share of renewable electricity production will be 44% and 74% by 2030. The installed capacity of renewables will reach 144 GW in 2030 and 319 GW by 2050.
- **Future costs of electricity generation:** The introduction of renewable technologies under the Energy [R]evolution scenario significantly decreases the future costs of electricity generation compared to the Reference scenario. Already in 2020, power generation costs in the Energy [R]evolution scenario are 1.1 $cent/kWh lower than in the Reference case. Because of high prices for conventional fuels and the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favorable under the Energy [R]evolution scenario and by 2050 costs will be 13.7 $cents/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 CO_2 emissions result in total electricity supply costs rising from today's $ 37 billion per year to more than $ 200 billion in 2050. The Energy [R]evolution scenario not only complies with Mexico's CO_2 reduction targets but also helps to stabilize 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 $ 61 billion lower than in the Reference scenario.
- **Future investment in power generation:** The Energy [R]evolution scenario would require $ 1,105 billion in investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately $ 867 billion in total (or $ 22 billion annually) more than in the Reference case ($ 238 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 55% while approx 45% would be invested in renewable energy and cogeneration (CHP) until 2050. Under the Energy [R]evolution scenario, however, Mexico would shift almost 98% of the entire investment towards renewables and cogeneration. Until 2030, the fossil fuel share of power sector investments would be focused mainly on CHP plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately $ 28 billion.
- **Fuel costs savings:** Because renewable energy has no fuel costs, however, the fuel cost savings in the Energy [R]evolution scenario reach a total of $ 1,671 billion up to 2050, or $ 42 billion per year. The total fuel cost savings therefore would cover nearly twice 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 21% of Mexico's primary energy demand for heat supply, the main contribution coming from the use of biomass and increasing contributions from geothermal and solar thermal energy. Dedicated support instruments are required to ensure a dynamic development. In the Energy [R]evolution scenario, renewables provide 52% of Mexico's total heat demand in 2030 and 89% in 2050. Energy efficiency measures help to reduce the currently growing energy demand for heating by 6 % in 2050 (relative to the reference scenario), in spite of improving living standards. 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. Up to 2020 biomass will remain the main contributors of the growing market share. After 2020, the continuing growth of solar collectors and a growing share of geothermal heat pumps will reduce the dependence on fossil fuels.
- **Future investments in the heat sector:** Also in the heat sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially the not yet so common solar and geothermal and heat pump technologies need enormous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacities need to increase drastically for solar thermal heating systems. Other technologies as geothermal heat pumps and hydrogen from renewable sources (for high temperature process heat) are not yet or only rarely used in Mexico today. However, they will play an important role for Mexico's heat supply in 2050. Capacity of biomass technologies, which are already rather wide spread today will increase only slightly, but will remain a main pillar of heat supply. Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar thermal district heating plants with seasonal storage. Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around $ 456 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately $ 11 billion per year.
- **Transport:** A key target in Mexico is to introduce incentives for people to drive smaller cars, something almost completely absent today. In addition, it is vital to shift transport use to efficient modes like rail, light rail and buses, especially in the expanding large metropolitan areas. Together with rising prices for fossil fuels, these changes reduce the huge growth in car sales projected under the Reference scenario. Energy demand from the transport sector is reduced by 2,609 PJ/a 2050, saving 68% compared to the Reference scenario. Energy demand in the transport sector will therefore decrease between 2009 and 2050 by 42% to 1,221 PJ/a. Highly efficient propulsion technology with hybrid, plug-in hybrid and battery-electric power trains will bring large efficiency gains. By 2030, electricity will provide 5% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 32%.
- **Primary energy consumption:** Taking into account the assumptions discussed above, the resulting primary energy demand will be reduced by 53% in 2050 compared to the Reference case. Around 78% of the remaining demand will be covered by renewable energy sources. 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 42% in 2030 and 78% in 2050. Nuclear energy is phased out just after 2030.
- **Development of CO_2 emissions:** While Mexico's emissions of CO_2 will more than double between 2009 and 2050 under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 429 million tonnes in 2009 to 62 million tonnes in 2050 Annual per capita emissions will drop from 3.8 tonnes to 0.4 tonnes. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable in vehicles will reduce emissions in the transport sector. With a share of 42% of CO_2, the transport sector will be the largest sources of emissions in 2050. By 2050, Mexico's CO_2 emissions are 86% 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 energy.
2. Internalise the external (social and environmental) costs of energy production through 'cap and trade' emissions trading.
3. Mandate strict efficiency standards for all energy consuming appliances, buildings and vehicles.
4. Establish legally binding targets for renewable energy and combined heat and power generation.
5. Reform the electricity markets by guaranteeing priority access to the grid for renewable power generators.
6. Provide defined and stable returns for investors, for example by feed-in tariff programmes.
7. Implement better labelling and disclosure mechanisms to provide more environmental product information.
8. Increase research and development budgets for renewable energy and energy efficiency.

climate and energy policy

THE UNFCCC AND THE KYOTO PROTOCOL

INTERNATIONAL ENERGY POLICY

RENEWABLE ENERGY TARGETS

POLICY CHANGES IN THE ENERGY SECTOR

ENERGY POLICY IN MEXICO

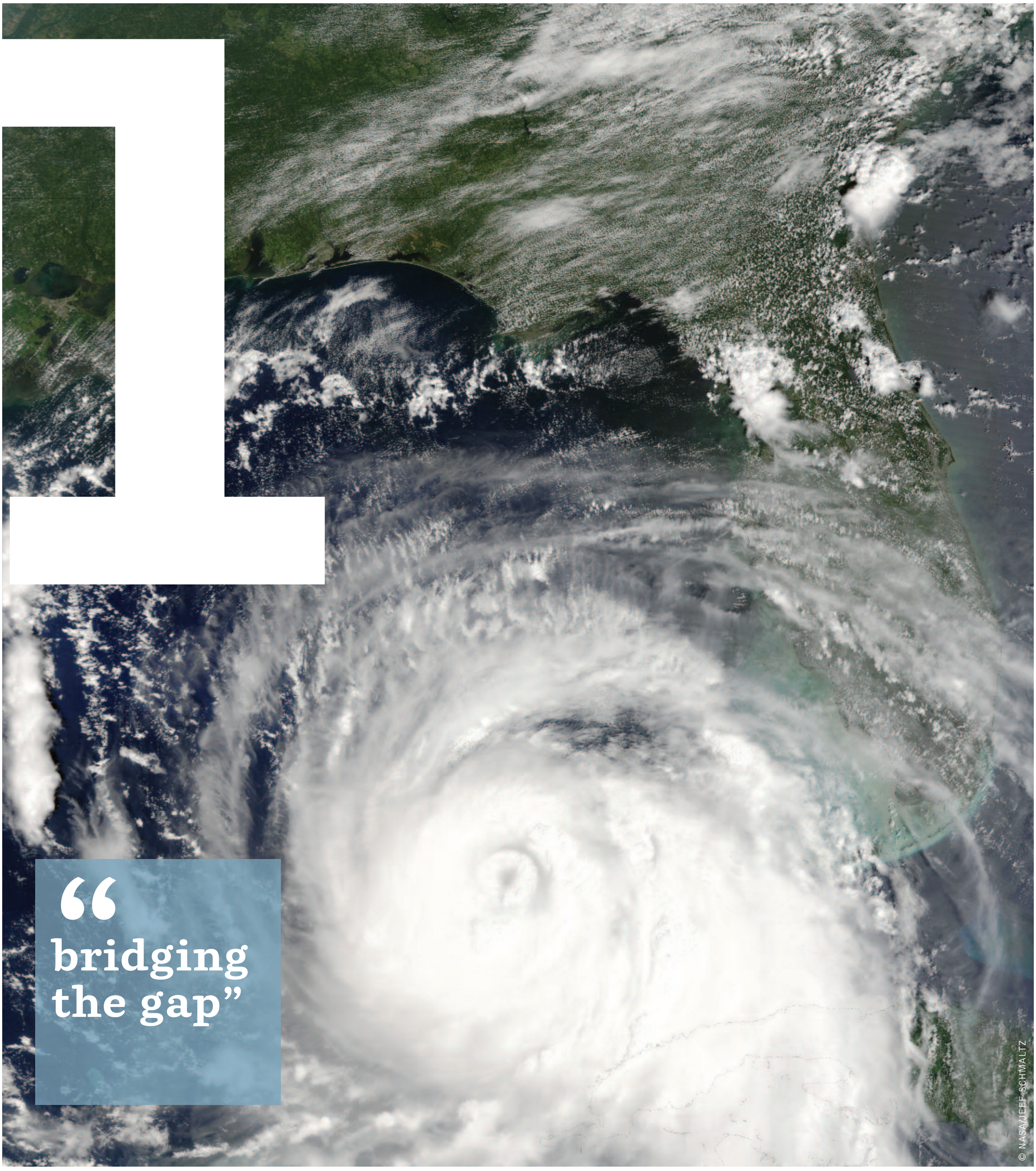


image HURRICANE KATRINA.

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

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

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

1.1 the UNFCCC and the kyoto protocol

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

box 1.1: what does the kyoto protocol do?

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

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

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

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

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

1.2 international energy policy

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

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

1.3 renewable energy targets

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

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

reference
5 UNEP EMISSIONS GAP REPORT.

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.

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,[2] the European Solar Thermal Power Industry Association[3] and the Global Wind Energy Council,[4] the European Renewable Energy Council, Greenpeace has documented the development of these clean energy industries in a series of Global Outlook documents from 1990 onwards and predicted growth up to 2020 and 2040.

1.4 policy changes in the energy sector

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

The main demands are:

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

Conventional energy sources receive an estimated $409 billion[5] in subsidies in 2010, resulting in heavily distorted markets. Subsidies artificially reduce the price of power, keep renewable energy out of the market place and prop up non-competitive technologies and fuels. Eliminating direct and indirect subsidies to fossil fuels and nuclear power would help move us towards a level playing field across the energy sector. Renewable energy would not need special provisions if markets factored in the cost of climate damage from greenhouse gas pollution. Subsidies to polluting technologies are perverse in that they are economically as well as environmentally detrimental. Removing subsidies from conventional electricity supply would not only save taxpayers' money, it would also dramatically reduce the need for renewable energy support.

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

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

The key requirements are:

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

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

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

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

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4 'GLOBAL WIND ENERGY OUTLOOK 2008', OCTOBER 2008.
5 'IEA WORLD ENERGY OUTLOOK 2011', PARIS NOVEMBER 2011, CHAPTER 14, PAGE 507.

box 1.2: example of a sustainable feed-in tariff

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

Structure of the German renewable energy Act:

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

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

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

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

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

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

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

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

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

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

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

1.4.2 bankable renewable energy support schemes

Since the early development of renewable energies within the power sector, there has been an ongoing debate about the best and most effective type of support scheme. The European Commission published a survey in December 2005 which concluded that feed-in tariffs are by far the most efficient and successful mechanism. A more recent update of this report, presented in March 2010 at the IEA Renewable Energy Workshop by the Fraunhofer Institute[6] underscores the same conclusion. The Stern Review on the Economics of Climate Change also concluded that feed-in tariffs "achieve larger deployment at lower costs". Globally more than 40 countries have adopted some version of the system.

Although the organisational form of these tariffs differs from country to country some criteria have emerged as essential for successful renewable energy policy. At the heart of these is a reliable, bankable support scheme for renewable projects which provides long term stability and certainty.[7] Bankable support schemes result in lower-cost projects because they lower the risk for both investors and equipment suppliers. The cost of wind-powered electricity in Germany is up to 40% cheaper than in the United Kingdom,[8] for example, because the support system is more secure and reliable.

box 1.3: experience of feed-in tariffs

- Feed-in tariffs are seen as the best way forward, especially in developing countries. By 2009 this system has created an incentive for 75% of PV capacity worldwide and 45% of wind capacity.
- Based on experience, feed-in tariffs are the most effective mechanism to create a stable framework to build a domestic market for renewable energy. They have the lowest investment risk, highest technology diversity, lowest windfall profits for mature technologies and attract a broad spectrum of investors.[9]
- The main argument against them is the increase in electricity prices for households and industry, because the extra costs are shared across all customers. This is particularly difficult for developing countries, where many people can't afford to spend more money for electricity services.

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

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

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

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

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

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7 'THE SUPPORT OF ELECTRICITY FROM RENEWABLE ENERGY SOURCES', EUROPEAN COMMISSION, 2005.
8 SEE ABOVE REPORT, P. 27, FIGURE 4.
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1.5 energy policy in mexico

With the start of a new presidential term, 2013 will be a year of many reforms including labor, taxation, energy, politics and education matters. This is a good opportunity for the Mexican government to design, develop and implement a new energy policy. It is bound to be a topic of great importance if the government is serious about boosting the country's economic development and sustainable energy security.

The previous administration was characterized by talking about renewable energy plans and initiatives, while any concrete action was minimal. While renewable energy output has increased and begun developing within the national energy matrix, its enormous potential remains untapped. For now the existing energy policy continues to pursue expensive and dangerous energy resources such as oil drilling in deep water of the Gulf of Mexico, the extraction of shale gas in the north of the country and nuclear energy.

1.5.1 deep-water drilling

Projects for oil drilling in the Gulf of Mexico have become very important in recent years. Pemex, the national petroleum company has estimated that 52% of Mexico's total oil reserves are in the deep water region of the Gulf of Mexico Basin and the Southeastern Basins. The director of Pemex Exploration and Production, Carlos Morales Gil said that "to be profitable, a deep water well should have a potential of between US$ 200 and 300 million barrels."[10] Currently, five drilling platforms have already been contracted in the deep of the Gulf of Mexico; With teams working simultaneously it will take about 20 years to finish building. Contracts signed only by the income of these platforms for a period of 1,825 days show that the daily cost of their rent is US$ 495,000, with the total cost of the contract being US$ 942 million. The deep water oil drilling will cost the country US$ 2.19 billion in the next three years. These resources are 3.19 times higher than those aimed at boosting energy transition. So far $ 4 billion (50 billion pesos) has been spent on the deep-water drilling, and not a single barrel of oil has been sold"[11], despite the "major" findings announced.

In Mexico, Pemex is in the process of carrying out deep-water dives in the search for oil, using the argument that it is to generate income to sustain public finances. The Mexican government's insistence on exploring and extracting oil from deep water has convinced many Mexicans that this is the only way to replenish the reserves of hydrocarbons, to increase oil production and to fund much of the government budget. This is despite the fallout of the Deep Water Horizon spill. In fact Pemex signed agreements to receive technical advice from British Petroleum on spills.

1.5.2 current regulations

The current regulatory framework on energy transition in Mexico consists of two laws: the Law on Sustainable Energy and the Law on the Use of Renewable Energy and Energy Transition Financing. After almost four years of been published in the Official Journal of the Federation, both regulations of the energy reform from 2008, remain evidence of an energy transition that has not been ambitiously implemented with a real vision for the country.

Enrique Peña Nieto, the new Mexican President stated in his book 'Mexico: The Great Hope', his commitment to combat climate change: "it is a global challenge that society and government must face together. We need a new culture and environmental commitment to change our lifestyle, the way we produce, consume and even throw away... ". One of his proposals is to use oil to finance a new sustainable energy model, as part of a comprehensive tax reform: "(...) That the oil itself is the source to fund the energies of the future."[12]

So although renewable energies are gaining greater importance it is dependent on the hydrocarbon market. Mexico is an oil producing country whose public finances depend on more than 35% of the exploitation of these resources. In addition, 12% of the federal budget is executed by Pemex. In a global analysis of the resources allocated to Pemex in 2012 for Programs and Investment Projects (IPPs), the 83.62% went to Pemex Exploration and Production (PEP). This subsidiary devoted part of that budget to finance two major projects with low profitability, high environmental impact and high uncertainty of success, according to the National Hydrocarbons Commission. These projects are the Tertiary Gulf Oil, which received 7% of the total investment of PEP, and the draft Comprehensive Deepwater Lakach, which was assigned US$ 120 million.[13] With 2% of the resources that Pemex allocated to these two projects, six renewable energy projects that ran out of budget in 2012 could be funded.

US$ 225 million (3 billion pesos) which must be allocated to the Renewable Energy and Energy Transition Financing as established in the Law on the "Use of Renewable Energy and Energy Transition Financing" published in the Official Journal of the Federation on November 28, 2008 have not been assigned to the Energy Transition Fund. In addition, this fund has been used to finance projects to replace appliances and effective policies to promote renewable energy, as established in the report of the Directorate General for Research, Technological Development and Environment of the Ministry of Energy on the fate of the resources allocated to the "Trust 2145: Fund for Energy Transition and Sustainable Use of Energy".

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13 GABRIELA NIÑO, BEATRIZ OLIVERA Y AROA DE LA FUENTE. THE FIGHT AGAINST CLIMATE CHANGE REQUIRES A PUBLIC BUDGET ORIENTED ENERGY TRANSITION. ONE PAGER. FINANCING GROUP FOR CLIMATE CHANGE.

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

An analysis[14] of the expenditure budget of the federation in 2012, shows that within the energy policy of the country, the development of nuclear energy has been boosted even when other safer and more cost effective solutions, such as boosting energy efficiency and renewable energy. The budget for the National Nuclear Research Institute in 2012 was 5.5 times higher than the one of the National Commission for the Efficient Use of Energy.

Investment in the efficient use of energy and in the generation of renewable resources, play an important role to ensure the country's energy sovereignty. It is therefore necessary to increase expenses for energy efficiency, using the budget that the Federal Commission of Electricity allocates to large hydroelectric such as Parota, even though it is not operating yet funded. It is also relevant a transparent use of resources allocated to the Fund for Energy Transition and Sustainable Energy, and the Energy Sustainability Sector Fund CONACYT-SENER.

1.5.3 wind power in the isthmus of tehuantepec[15]

The wind farms developed in the Isthmus of Tehuantepec (Oaxaca, Mexico) are having negative social and environmental impacts that outweigh the potential benefits they generate. The human rights of rural and indigenous communities living in the area (Zapotec and Jijots) are being ignored. The Mexican state has authorized the development at least 14 wind projects in Oaxaca; one of the poorest states and where 34% of the population is indigenous. However no clear development guidelines have been created by the Mexican state, leaving private companies to negotiate directly with the local communities.

Most people close to the project have expressed their dissatisfaction with the lack of appropriate and comprehensive information. They have denounced threats and violence against communities who oppose these projects. For over two years, the communities have reported serious cases of violence against the main leaders of Zapotec and Jijots indigenous peoples by paramilitary groups and state authorities that are responding to the demands of the private sector. They are about to set up projects even against the will of the communities. No prior orfree and informed consultation processes have existed. The administrative concessions and licenses required to construct and operate the wind farms were awarded without due process or the consent of indigenous peoples living in the area, as established under international law: convention No. 169 International Labour Organization to which Mexico is obligated.

The developer companies have signed contracts with communities offering minimum payments (as members of communities, in the order of 0.1 dollar per hectare). In addition, the conditions of the contracts vary from one company to another, without a process to negotiate under the same standards.

The development of wind power is a key to the energy transition. For the wind projects to be truly sustainable, the social conflicts generated by the installation of the first wind farms in the La Ventosa, Oaxaca must be settled. It is essential to create a protocol for the development of projects with a gender perspective, which ensures respect for human rights enshrined in Mexican and international standards and must integrate criteria and indicators to verify compliance of the necessary environmental and social conditions. The economic benefits need to remain within the region so that the wind farms benefit those who have no land, and promote collaboration between private developers, thestate government and local communities.

Before approving the funding for these projects, the State should ensure that affected communities have information in their language that is timely, complete, and clear. It must be ensured that the decisions made by the communities are respected, even if they are negative about a project, respecting the free, prior and informed consent. Similarly, the creation of opportunities for communities, such as the supply of jobs and even support for the development of community projects should be ensured.

Developing, publishing and implementing a methodology for measuring the externalities of the projects needs to happen, in which, the Regulatory Energy Commission of Mexico assess their sustainability, based on independent assessments. Depending on the results, the Commission may grant or deny access to the priority network, giving preference to projects that benefit more local communities.

Policy demands:

- New projects from independent power producers (IPPs), which are directed towards renewable technologies, such as wind farms, essential for energy transition necessary to tackle climate change should be brought prioritised.
- Funds allocated for renewable projects should be allocated quickly.
- The creation of a protocol for the development of clean energy projects with a gender perspective, which ensures respect for human rights enshrined in Mexican and international standards and must integrate criteria and indicators to verify compliance of the necessary environmental and social conditions.

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14 IBIDEM FINANCING GROUP FOR CLIMATE CHANGE.

15 CHALLENGES IN IMPLEMENTATION OF WIND ENERGY PROJECTS IN MEXICO. THE CASE OF THE ISTHMUS OF TEHUANTEPEC. LETTER DEVELOPED BY ASOCIACIÓN INTERAMERICANA PARA LA DEFENSA DEL AMBIENTE (AIDA), EL CENTRO MEXICANO DE DERECHO AMBIENTAL (CEMDA), HEINRICH BÖLL STIFTUNG, COMUNICACIÓN Y EDUCACIÓN AMBIENTAL S.C., FUNDAR, CENTRO DE ANÁLISIS E INVESTIGACIÓN, INICIATIVAS PARA LA IDENTIDAD Y LA INCLUSIÓN, A.C., RED NACIONAL DE ORGANISMOS CIVILES DE DERECHOS HUMANOS "TODOS LOS DERECHOS PARA TODOS Y TODAS", (INTEGRATED BY 73 NGO'S IN THE COUNTRY).

the energy [r]evolution concept

KEY PRINCIPLES

THE "3 STEP IMPLEMENTATION"

THE NEW ELECTRICITY GRID

CASE STUDY GERMANY

image CENTRAL MEXICO.

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.

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.[16] 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 wellbeing.

   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.[17]

   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.

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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.[18]

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.

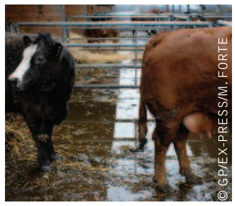
The most important energy saving options are improved heat insulation and building design, super efficient electrical machines and drives, replacement of old-style electrical heating systems by renewable heat production (such as solar collectors) and a reduction in energy consumption by vehicles used 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

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

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.



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.

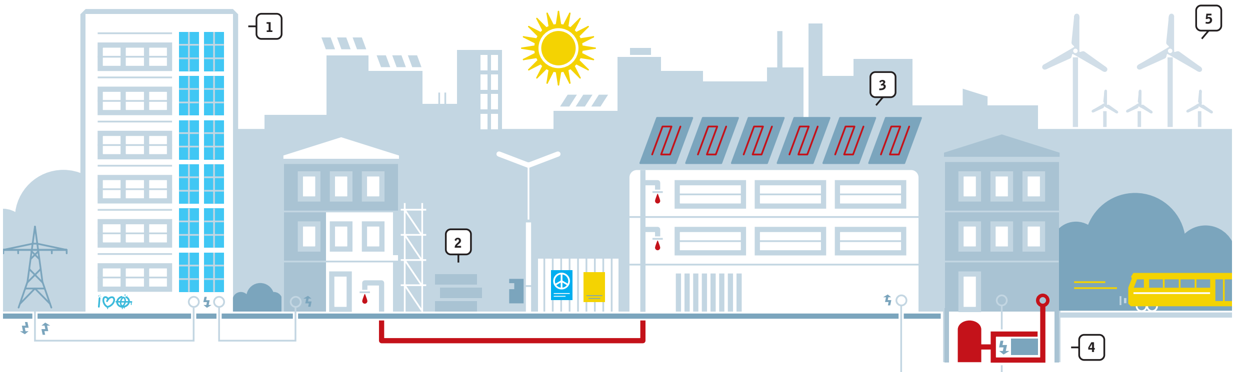
Cogeneration (CHP) The increased use of combined heat and power generation (CHP) will improve the supply system's energy conversion efficiency, whether using natural gas or biomass. In the longer term, a decreasing demand for heat and the large potential for producing heat directly from renewable energy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

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

image 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.

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.

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

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

Clever technologies can track and manage energy use patterns, provide flexible power that follows demand through the day, use better storage options and group customers together to form 'virtual batteries'. With current and emerging solutions, we can secure the renewable energy future needed to avert catastrophic climate change. Renewable energy 24/7 is technically and economically possible, it just needs the right policy and the commercial investment to get things moving and 'keep the lights on'.[19] 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 26).

reference

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

2.3.2 smart grids

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

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

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

Integrating renewable energy by using a smart grid means moving away from the concept of baseload power towards a mix of flexible and 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.[20] 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.[21] 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.[22] Together, the combination ensures sufficient electricity supply to cover demand.

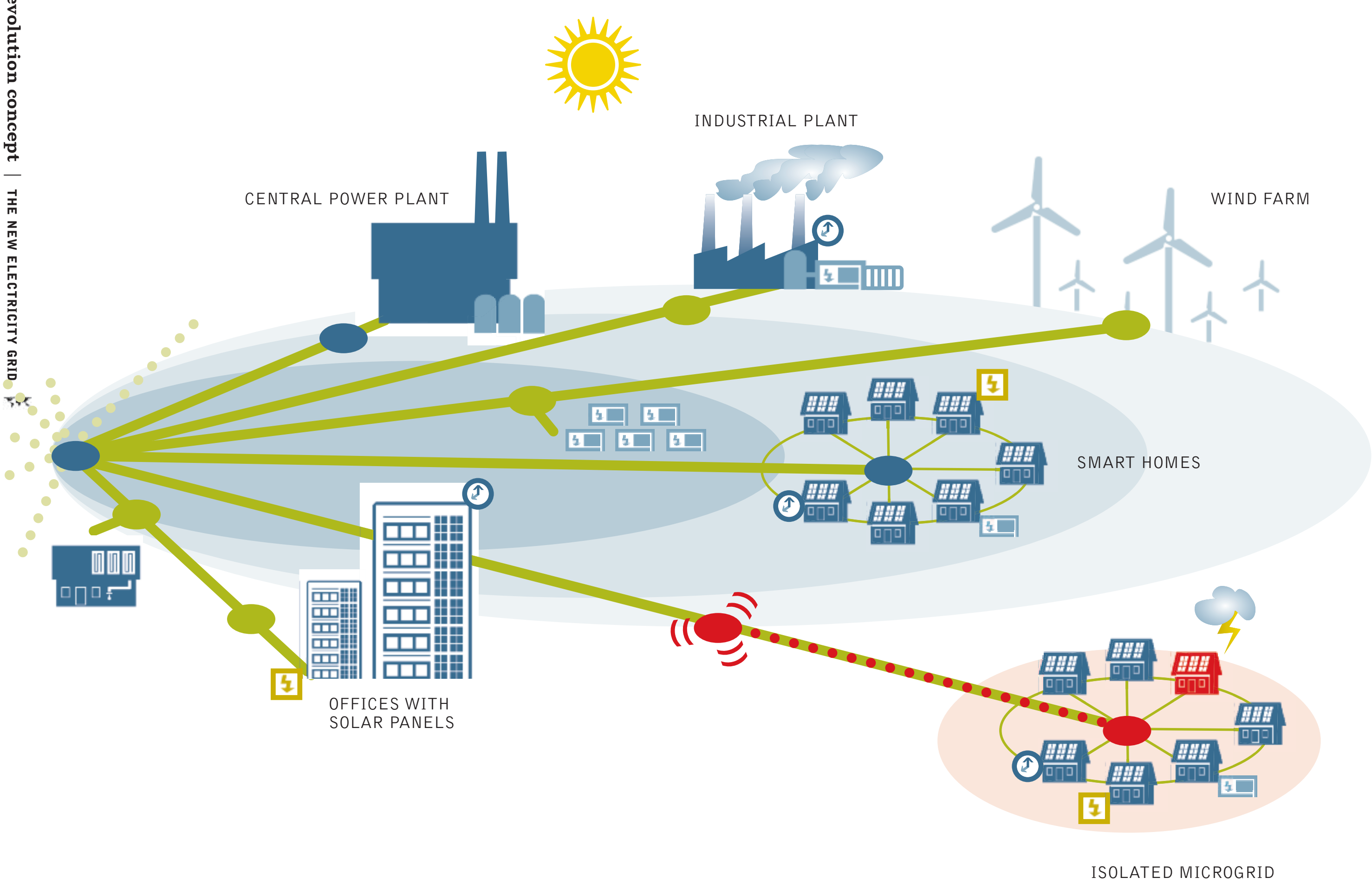
Electricity storage options. Pumped storage is the most established technology for storing energy from a type of hydroelectric power station. Water is pumped from a lower elevation reservoir to a higher elevation during times of low cost, off-peak electricity. During periods of high electrical demand,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

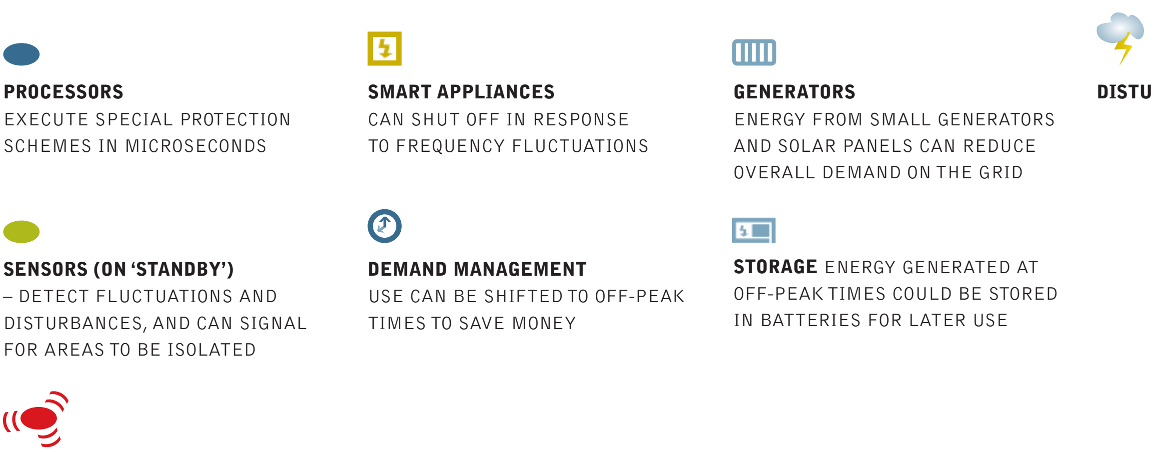
references

20 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.
21 SEE ALSO HTTP://WWW.KOMBIKRAFTWERK.DE/INDEX.PHP?ID=27.
22 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 GREENPEACE OPENS A SOLAR ENERGY WORKSHOP IN BOMA. A MOBILE PHONE GETS CHARGED BY A SOLAR ENERGY POWERED CHARGER.

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.[23]

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?[24]

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
23 GREENPEACE REPORT, 'NORTH SEA ELECTRICITY GRID [R]EVOLUTION', SEPTEMBER 2008.
24 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

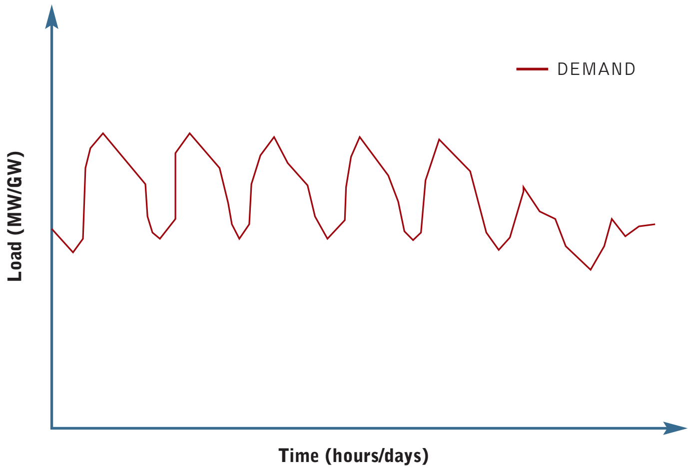
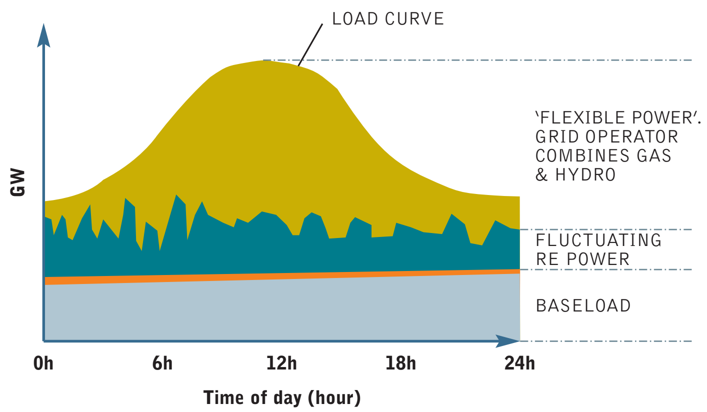


figure 2.5: the evolving approach to grids

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.

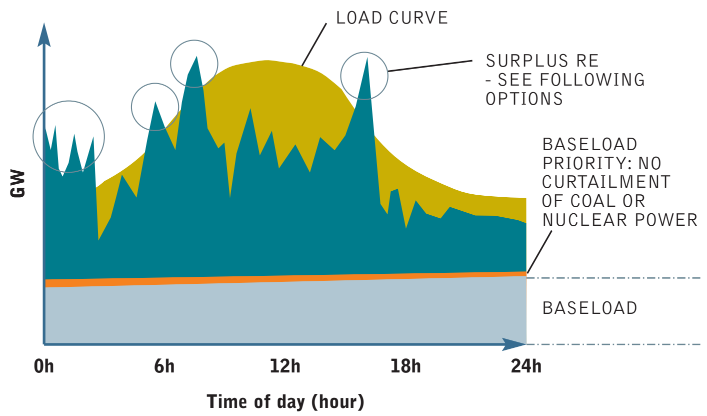


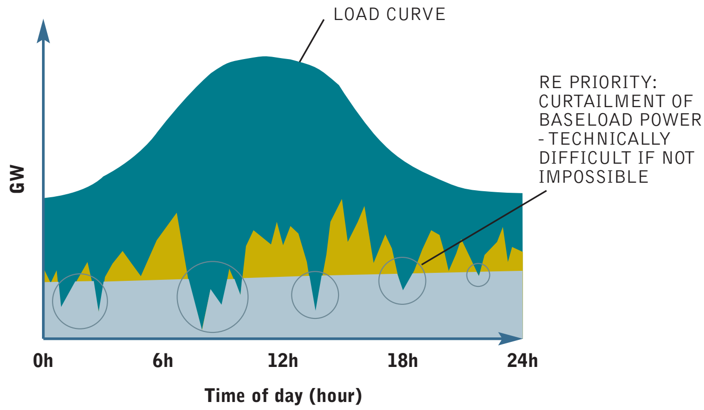
image LE NORDAIS WINDMILL PARK, ONE OF THE MOST IMPORTANT IN AMERICA, LOCATED ON THE GASPÈ PENINSULA IN CAP-CHAT, QUEBEC, CANADA.

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.

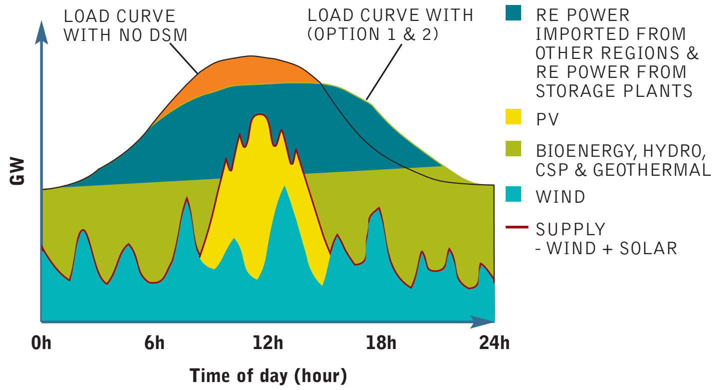
Technically difficult, not a solution.



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

RENEWABLE ENERGY PROJECT PLANNING BASICS

RENEWABLE ENERGY FINANCING BASICS

3

image IN SEPTEMBER 2010, TENS OF THOUSANDS OF RESIDENTS OF SOUTHERN MEXICO HAD FLED THEIR HOMES WHILE TENS OF THOUSANDS MORE SLEPT ON THEIR ROOFTOPS REFUSING TO LEAVE. TORRENTIAL RAINS HIT THE STATES OF VERACRUZ, OAXACA, AND TABASCO THE HARDEST, AFFECTING SOME 900,000 PEOPLE IN VARIOUS WAYSAGENCE FRANCE-PRESSE DESCRIBED THE HEAVY RAINS STRIKING SOUTHERN MEXICO AND GUATEMALA IN THE SUMMER OF 2010 AS THE WORST IN LIVING MEMORY, AND REPORTED THAT THE DEATH TOLL HAD RISEN TO 50 AS OF SEPTEMBER 8.

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).

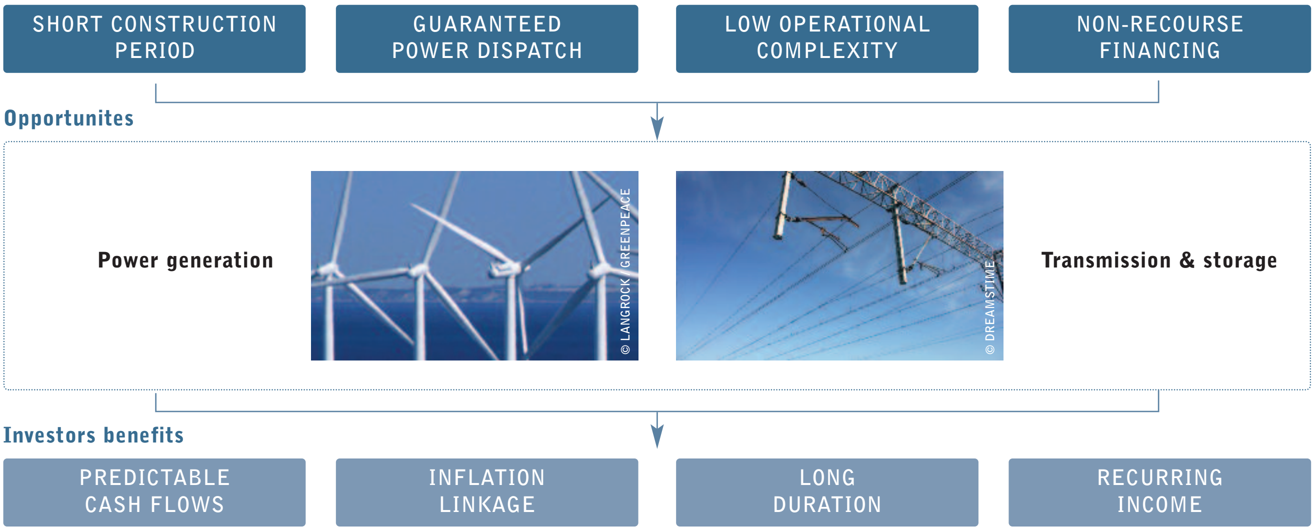
P = Project developer, **M** = Meteorological Experts, **I** = Investor, **U** = utility.

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

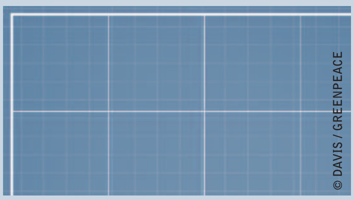
source
SWISS RE PRIVATE EQUITY PARTNERS.

figure 3.3: investment stages of renewable energy projects

RISKS

Higher — Lower

Stage

DEVELOPMENT	CONSTRUCTION	OPERATIONS
		
© DAVIS / GREENPEACE	© DAVIS / GREENPEACE	© LANGROCK / GREENPEACE
• Site identification • Approval & permitting process • Land procurement • Technical planning	• Financing close • Equipment procurement • Engineering • Construction • Commissioning	• Operations • Maintenance • Refinancing • Refurbishment/Repowering

Strategy

EARLY-STAGE GREENFIELD	LATE-STAGE GREENFIELD	BROWNFIELD

source
SWISS RE PRIVATE EQUITY PARTNERS.

3.2.1 overcoming barriers to finance and investment for renewable energy

table 3.2: categorisation of barriers to renewable energy investment

CATEGORY	SUB-CATEGORY	EXAMPLE BARRIERS
Barriers to finance	Cost barriers	Costs of renewable energy to generate Market failures (e.g. 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[25] and interviews with renewable energy sector financiers and developers are shown in Figure 3.4.

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

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[26] and while it exists, renewable energy will rely on policy intervention by governments in order to be competitive, which creates additional risks for investors. It is important to note though, that in some regions of the world specific renewable technologies are broadly competitive with current market energy prices (e.g. onshore wind in Europe).

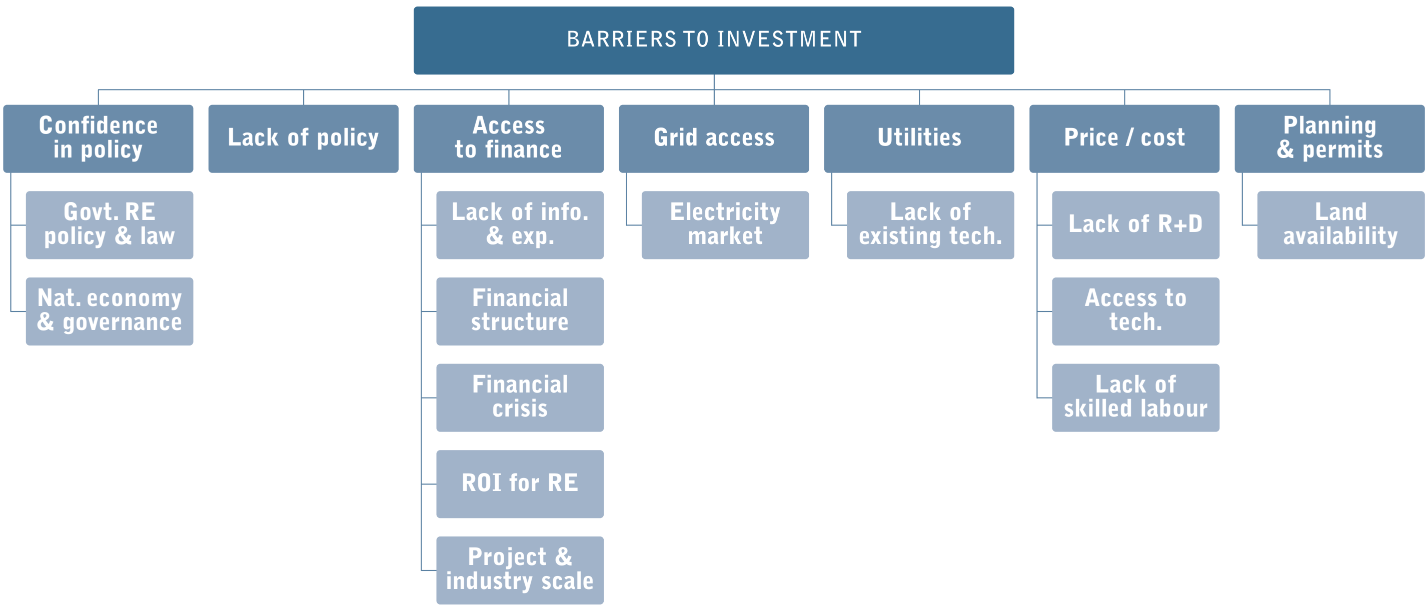
Concerns over planning and permit issues are significant, though vary significantly in their strength and nature depending on the jurisdiction.

3.2.2 how to overcome investment barriers for renewable energy

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

- Additional and improved policy support mechanisms for renewable energy are needed in all countries and regions.
- Building confidence in the existing policy mechanisms may be just as important as making them stronger, particularly in the short term.
- Improved policy mechanisms can also lower the cost of finance, particularly by providing longer durations of revenue support and increasing revenue certainty.[27]
- Access to finance can be increased by greater involvement of governments and development banks in programs like loan guarantees and green bonds as well as more active private investors.
- Grid access and infrastructure needs to be improved through investment in smart, decentralised grids.
- Lowering the cost of renewable energy technologies directly will require industry development and boosted research and development.
- A smoother pathway for renewable energy needs to be established through planning and permit issues at the local level.

figure 3.4: key barriers to renewable energy investment



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

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

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

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

image FIRES IN MEXICO AND NORTHERN GUATAMALA.

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 is based on the Current Policies scenarios published by the International Energy Agency (IEA) in World Energy Outlook 2011 (WEO 2011).[28] It only takes existing international energy and environmental policies into account. Its assumptions include, for example, continuing progress in electricity and gas market reforms, the liberalisation of cross-border energy trade and recent policies designed to combat environmental pollution. The Reference scenario does not include additional policies to reduce greenhouse gas emissions. As the IEA's projections only extend to 2035, they have been extended by extrapolating their key macroeconomic and energy indicators forward to 2050. This provides a baseline for comparison with the Energy [R]evolution 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 Mexico: the basis of this Energy [R]evolution for Mexico. 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. Current EU sustainability standards for biofuels are insufficient 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[29] 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 secenario, renewable energy would pass 30% of the global energy supply just after 2020. The Energy [R]evolution scenario for Mexico shows that renewable energy would pass 20% of Mexico'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
28 INTERNATIONAL ENERGY AGENCY (IEA), 'WORLD ENERGY OUTLOOK 2011', OECD/IEA 2011.
29 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.[30] 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 UNEP World Population Prospect 2010 projection for population development.

table 4.1: population development projections
(IN MILLIONS)

	2009	2015	2020	2030	2040	2050
Mexico	112	120	126	135	142	**144**

source UNEP WORLD POPULATION PROSPECT 2010.

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 global scenario development.[31] Thus all data on economic development in WEO 2011 refers to purchasing power adjusted GDP. However, as WEO 2011 only covers the time period up to 2035, the projections for 2035-2050 for the Energy [R]evolution scenario are based on our own estimates. Furthermore, estimates of Africa's GDP development have been adjusted upward compared to WEO 2011.

Prospects for GDP growth have decreased considerably since the previous study, due to the financial crisis at the beginning of 2009, although underlying growth trends continue much the same. GDP growth in all regions is expected to slow gradually over the coming decades. World GDP is assumed to grow on average by 3.8% per year over the period 2009-2030, compared to 3.1% from 1971 to 2007, and on average by 3.1% per year over the entire modelling period (2009-2011). China and India are expected to grow faster than other regions, followed by the Middle East, Africa, remaining Non OECD Asia, and Eastern Europe/Eurasia. The Chinese economy will slow as it becomes more mature, but will nonetheless become the largest in the world in PPP terms early in the 2020s. GDP in OECD Europe and OECD Asia Oceania is assumed to grow by around 1.6 and 1.3% per year over the projection period, while economic growth in OECD North America is expected to be slightly higher. The OECD share of global PPP-adjusted GDP will decrease from 56% in 2009 to 33% in 2050. GDP in Mexico is assumed to grow by on average 1.5% per year over the projection period.

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

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	2.2%	1.7%	1.0%	1.5%
Mexico	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%
Eastern Europe/ Eurasia	4.2%	3.2%	1.9%	3.0%
India	7.6%	5.8%	3.1%	5.3%
China	8.2%	4.2%	2.7%	4.7%
Non OECD Asia	5.2%	3.2%	2.6%	3.5%
Latin America	4.0%	2.8%	2.2%	2.9%
Middle East	4.3%	3.7%	2.8%	3.5%
Africa	4.5%	4.4%	4.2%	4.4%

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

4.4 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 $ 34 per barrel was assumed in 2030. More recent projections of oil prices by 2035 in the IEA's WEO 2011 range from $2010 97/bbl in the 450 ppm scenario up to $2010 140/bbl in current policies scenario.

Since the first Energy [R]evolution study was published in 2007, however, the actual price of oil has moved over $ 100/bbl for the first time, and in July 2008 reached a record high of more than $ 140/bbl. Although oil prices fell back to $ 100/bbl in September 2008 and around $ 80/bbl in April 2010, prices have increased to more than $ 110/bbl in early 2012. Thus, the projections in the IEA Current Policies scenario might still be considered too conservative. Taking into account the growing global demand for oil we have assumed a price development path for fossil fuels slightly higher than the IEA WEO 2011 "Current Policies" case extrapolated forward to 2050 (see Table 4.3).

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 $24-30/GJ by 2050.

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

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

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 (75 $\$_{2010}/tCO_2$)[32], 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 (50 $\$_{2008}/t$). 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.

($\$2000/tCO_2$)

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

4.6 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.[33]

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

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

Cost estimates for CCS vary considerably, depending on factors such as power station configuration, technology, fuel costs, size of project and location. One thing is certain, however: CCS is expensive. It requires significant funds to construct the power stations and the necessary infrastructure to transport and store carbon. The IPCC special report on CCS assesses costs at $15-75 per ton of captured CO_2[34], while a 2007 US Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs.[35] These costs are estimated to increase the price of electricity in a range from 21-91%.[36]

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.[37] 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.[38]

The Intergovernmental Panel on Climate Change (IPCC) estimates a cost range for pipelines of $1-8/tonne of CO_2 transported. A United States Congressional Research Services report calculated capital costs for an 11 mile pipeline in the Midwestern region of the US at approximately $6 million. The same report estimates that a dedicated interstate pipeline network in North Carolina would cost upwards of $5 billion due to the limited geological sequestration potential in that part of the country.[39] Storage and subsequent monitoring and verification costs are estimated by the IPCC to range from $\$0.5\text{-}8/tCO_2$ (for storage) and $\$0.1\text{-}0.3/tCO_2$. The overall cost of CCS could therefore be a major barrier to its deployment.[40]

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.

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

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

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[41], from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS project (New Energy Externalities Developments for Sustainability)[42] or the IEA Energy Technology Perspectives 2008, projections by the European Renewable Energy Council published in April 2010 ("Re-Thinking 2050") and discussions with experts from different sectors of the renewable energy industry.

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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 $ 5-10 cents/kWh (depending on the region) will be achieved. During the following five to ten years, PV will become competitive with retail electricity prices in many parts of the world, and competitive with fossil fuel costs 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 $ 6-10 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)	3,000	2,300	1,650	1,280	1,040	1,060
O & M costs $/(kW · a)	43	38	21	15	14	15

O & M = Operation and maintenance.

table 4.7: 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)	9,300	8,100	6,600	5,750	5,300	4,800
O & M costs $/(kW · a)	420	330	265	229	211	193

O & M = Operation and maintenance.

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

© GP/BAS BEENTJES

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)	6,000	5,100	3,800	3,000	2,700	2,350
O & M costs $/(kW · a)	230	205	161	131	124	107
Wind turbine onshore						
Investment costs ($/kWp)	1,800	1,500	1,290	1,280	1,300	1,350
O & M costs $/(kW · a)	64	55	55	56	59	61

O & M = Operation and maintenance.

table 4.9: biomass cost assumptions

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

O & M = Operation and maintenance.

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 $ 15 cents/kWh to about $ 9 cents/kWh;
- for EGS, despite the presently high figures (about $ 20-30 cents/kWh), electricity production costs - depending on the payments for heat supply - are expected to come down to around $ 8 cents/kWh in the long term.

Because of its non-fluctuating supply and a grid load operating almost 100% of the time, geothermal energy is considered to be a key element in a future supply structure based on renewable sources. Up to now we have only used a marginal part of the potential. Shallow geothermal drilling, for example, can deliver 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 $ 25-95 cents/kWh[41], and for initial tidal stream farms in the range of $ 14-28 cents/kWh. Generation costs of $ 8-10 cents/kWh are expected by 2030. Key areas for development will include concept design, optimisation of the device configuration, reduction of capital costs by exploring the use of alternative structural materials, economies of scale and learning from operation. According to the latest research findings, the learning factor is estimated to be 10-15% for offshore wave and 5-10% for tidal stream. In the long term, ocean energy has the potential to become one of the most competitive and cost effective forms of generation. In the next few years a dynamic market penetration is expected, following a similar curve to wind energy.

Because of the early development stage any future cost estimates for ocean energy systems are uncertain. Present cost estimates are based on analysis from the European NEEDS project.[42]

table 4.10: geothermal cost assumptions

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

O & M = Operation and maintenance.

table 4.11: ocean energy cost assumptions

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

O & M = Operation and maintenance.

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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.

table 4.12: hydro power cost assumptions

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

O & M = Operation and maintenance.

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 $ 8 to 35 cents/kWh for the most important technologies, including photovoltaic. In the long term, costs are expected to converge at around $ 6 to 12 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.

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

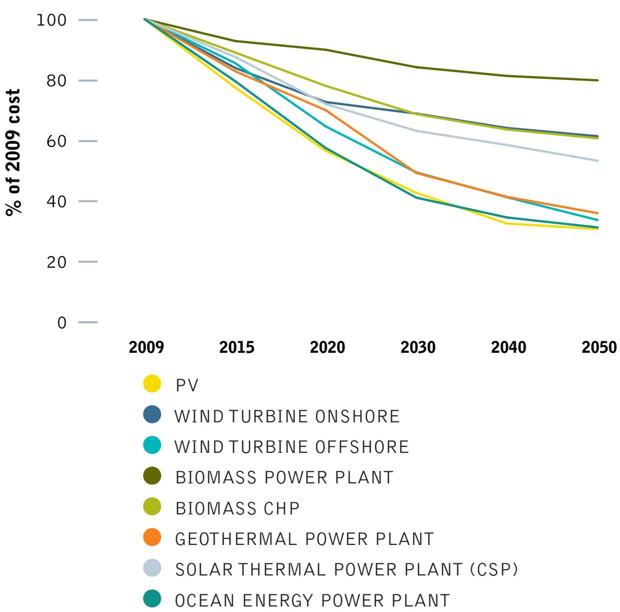
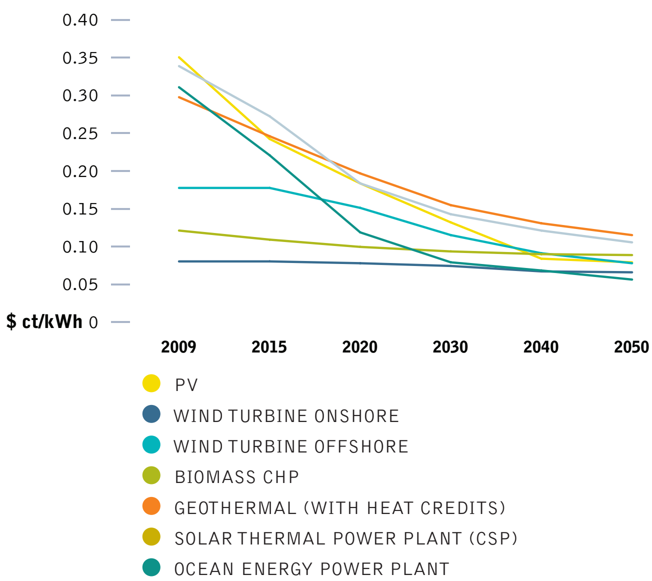


figure 4.2: expected development of electricity generation costs from fossil fuel and renewable options
EXAMPLE FOR OECD EUROPE



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 €/m² 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 system are known from 250-600 €/m², depending on the share of solar energy in the whole heating system and the level of storage required.

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.[45]

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 $/KW

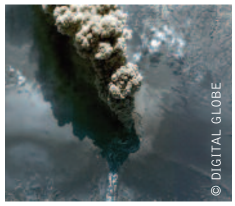
	2015	2020	2030	2040	2050
Geothermal distict heating*	2,650	2,520	2,250	2,000	1,760
Heat pumps	1,990	1,930	1,810	1,710	1,600
Low tech solar collectors	140	140	140	140	140
Small solar collector systems	1,170	1,120	1,010	890	750
Large solar collector systems	950	910	810	720	610
Solar district heating*	1,080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

* WITHOUT NETWORK

references

45 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

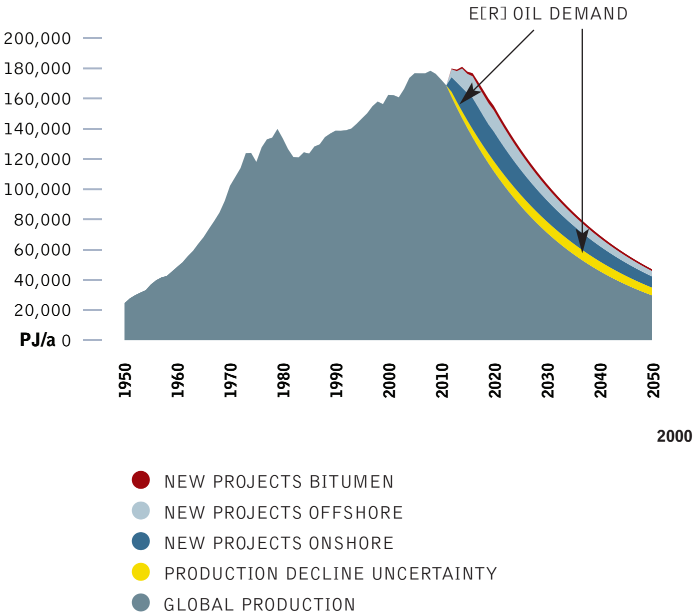
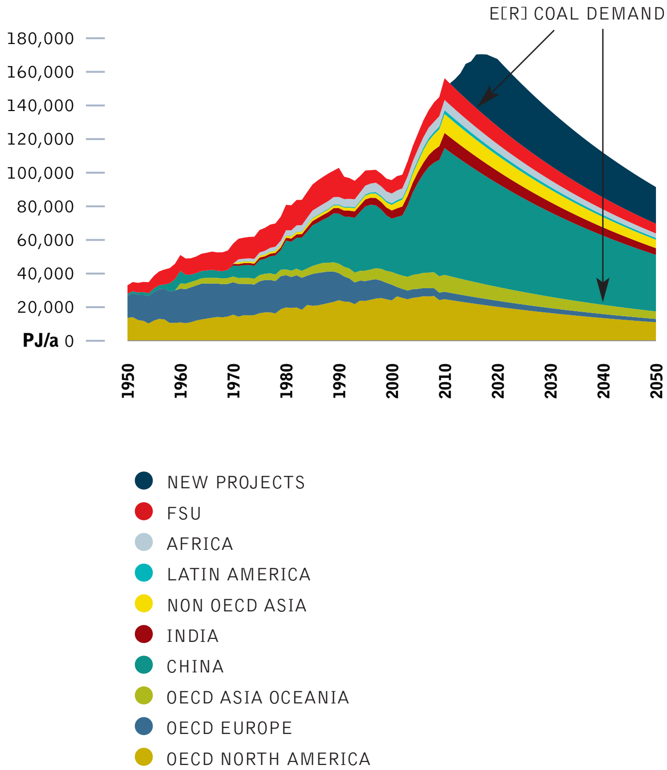


figure 4.4: coal scenario: base decline of 2% per year and new projects



4.10 review: greenpeace scenario projections of the past

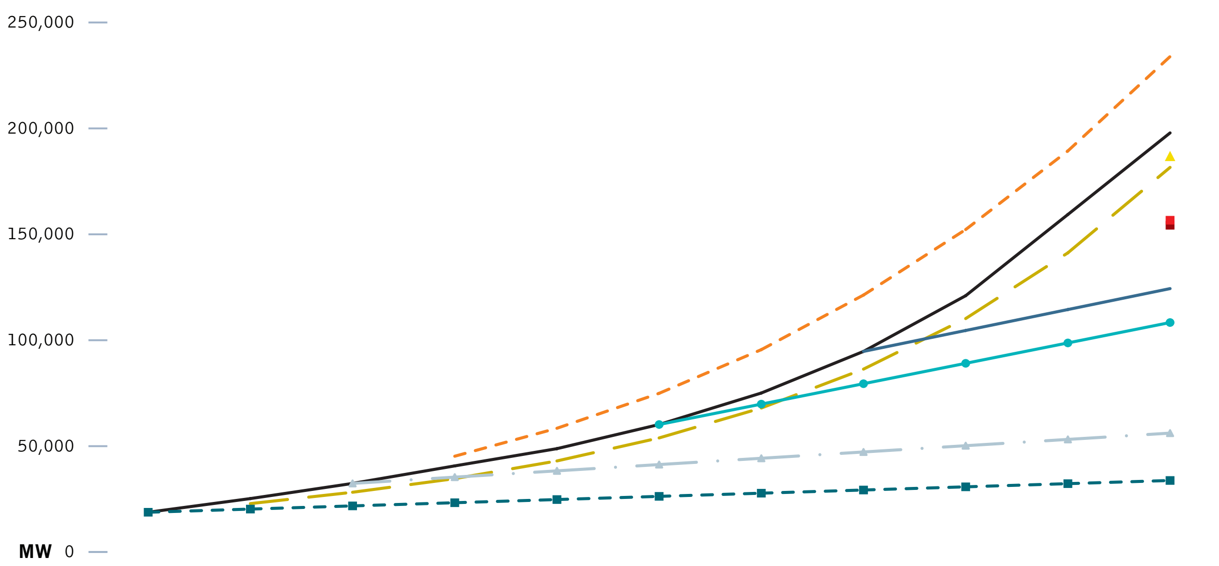
Greenpeace has published numerous projections in cooperation with renewable industry associations and scientific institutions in the past decade. This section provides an overview of the projections between 2000 and 2011 and compares them with real market developments and projections of the IEA World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



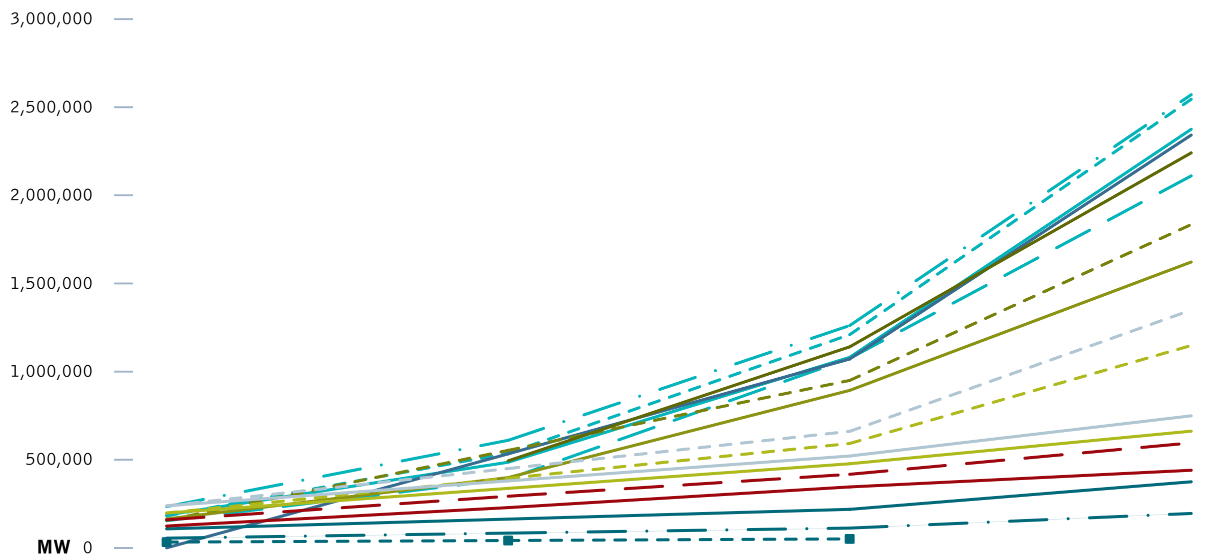
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
REAL	17,400	23,900	31,100	39,431	47,620	59,091	74,052	93,820	120,291	158,864	197,637
WF 10 (1999)		21,510	26,901	33,371	41,781	52,715	66,929	85,407	109,428	140,656	181,252
WF 12 (2002)				44,025	57,306	73,908	94,660	120,600	151,728	189,081	233,905
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



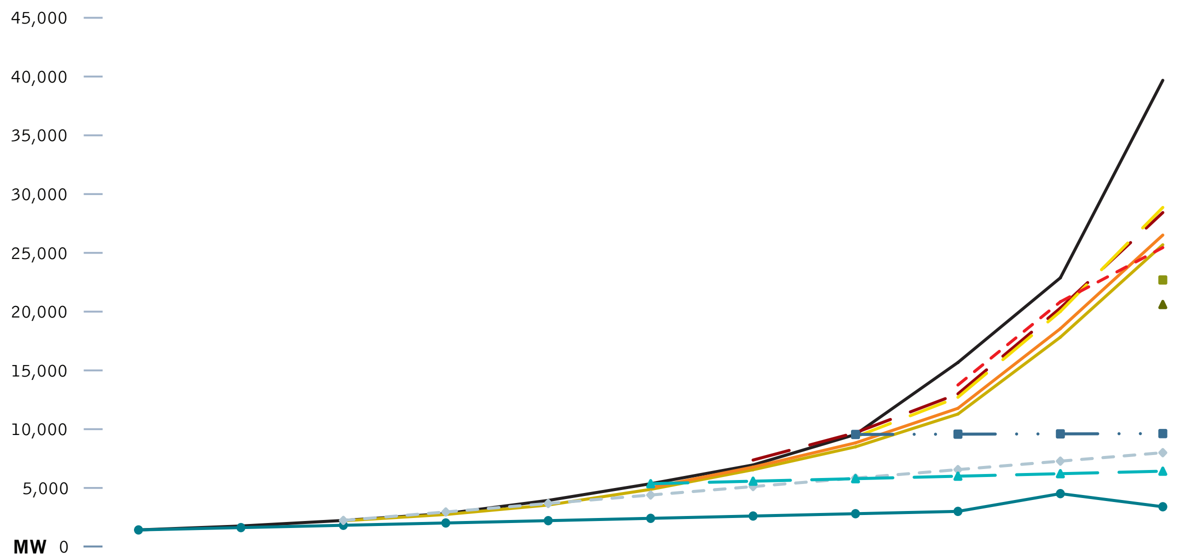
	2010	2015	2020	2030
WF 10 (1999)	181,252	537,059	1,209,466	2,545,232
WF 12 (2002)	233,905	610,000	1,261,157	2,571,000
GWEO 2006 (Advanced)	153,759	391,077	1,074,835	2,110,401
GWEO 2008 (Advanced)	186,309	485,834	1,080,886	2,375,000
GWEO 2008 (Advanced)	0	533,233	1,071,415	2,341,984
E[R] 2007	156,149	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



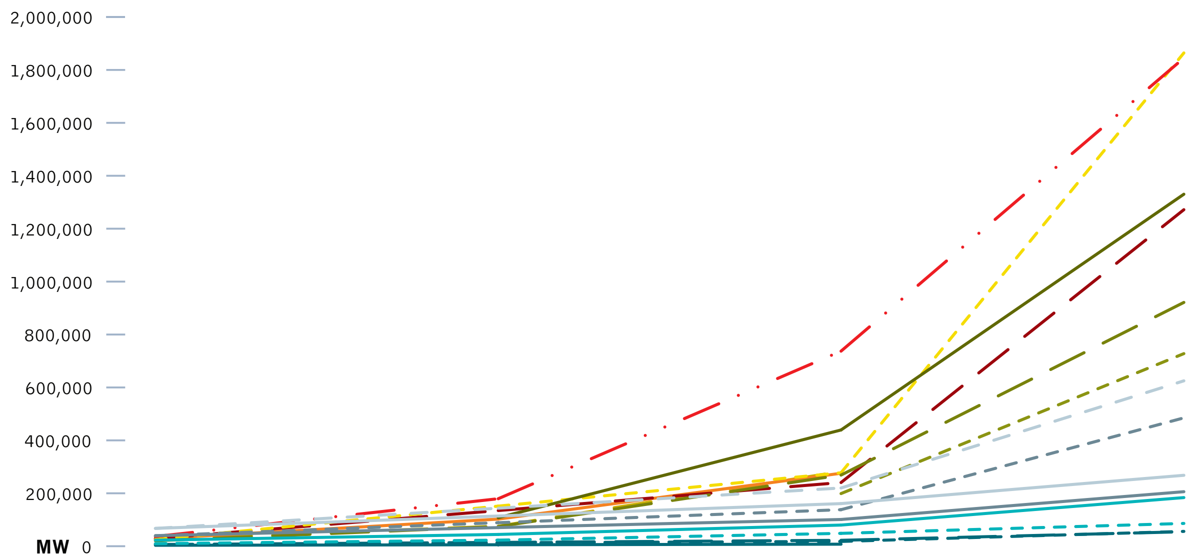
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
REAL	1,428	1,762	2,236	2,818	3,939	5,361	6,956	9,550	15,675	22,878	39,678
SG I 2001			2,205	2,742	3,546	4,879	6,549	8,498	11,285	17,825	25,688
SG II 2004						5,026	6,772	8,833	11,775	18,552	26,512
SG III 2006							7,372	9,698	13,005	20,305	28,428
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 ER 2010 relies on and low demand (due to a significant increase of energy efficiency) combined with high renewable energy deployment, no CCS employment and a global nuclear phase-out by 2045.

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

table 4.14: 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 Agency (DLR) by extrapolating the key macroeconomic and energy indicators of the WEO 2009 forward to 2050 (Publication filed in June 2010 to Energy Policy).

key results of the mexico energy [r]evolution scenario

ENERGY DEMAND BY SECTOR
ELECTRICITY GENERATION
FUTURE COSTS OF ELECTRICITY GENERATION
FUTURE INVESTMENTS IN THE POWER SECTOR
HEATING SUPPLY
FUTURE INVESTMENTS IN THE HEAT SECTOR
FUTURE EMPLOYMENT IN THE ENERGY SECTOR
TRANSPORT
DEVELOPMENT OF CO_2 EMISSIONS
PRIMARY ENERGY CONSUMPTION

5

“renewable energy should become the central pillar of our future energy supply”

ANGELA MERKEL
CHANCELLOR
OF GERMANY

image FIRES CAUSED BY LIGHTNING ARE BURNING IN NORTHERN MEXICO’S COAHUILA STATE. LACK OF WINTER RAIN AND FROST LEFT THE PLANTS DRY AND PRONE TO FIRE. ON TOP OF THAT, THE AREA HAS NOT BURNED FOR MORE THAN 20 YEARS, DURING WHICH TIME FUEL BUILT UP. THUNDERSTORMS AND STEADY STRONG WINDS WITH GUSTS UP TO 70 MILES PER HOUR COMPLETED THE FORMULA FOR A DANGEROUS, FAST-MOVING WILDFIRE.

5.1 energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for Mexico'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 114% from the current 4,279 PJ/a to 9,152 PJ/a (without non-energy use). In the Energy [R]Evolution scenario, final energy demand increases by only 20% compared to the current consumption and is expected to reach 5,136 PJ/a by 2050."

Under the Energy [R]evolution scenario, electricity demand is exptected to increase in all sectors (industry, transport, residential and service sectors, see Figure 5.2) due to increasing GDP, population and wealth. Total electricity demand will rise from 201 TWh/a to 514 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 200 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors.

Efficiency gains in the heat supply sector are large. Under the Energy [R]evolution scenario, demand for heat supply is expected to increase (see Figure 5.4). However, compared to the Reference scenario, consumption equivalent to 163 PJ/a is avoided through efficiency gains by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

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

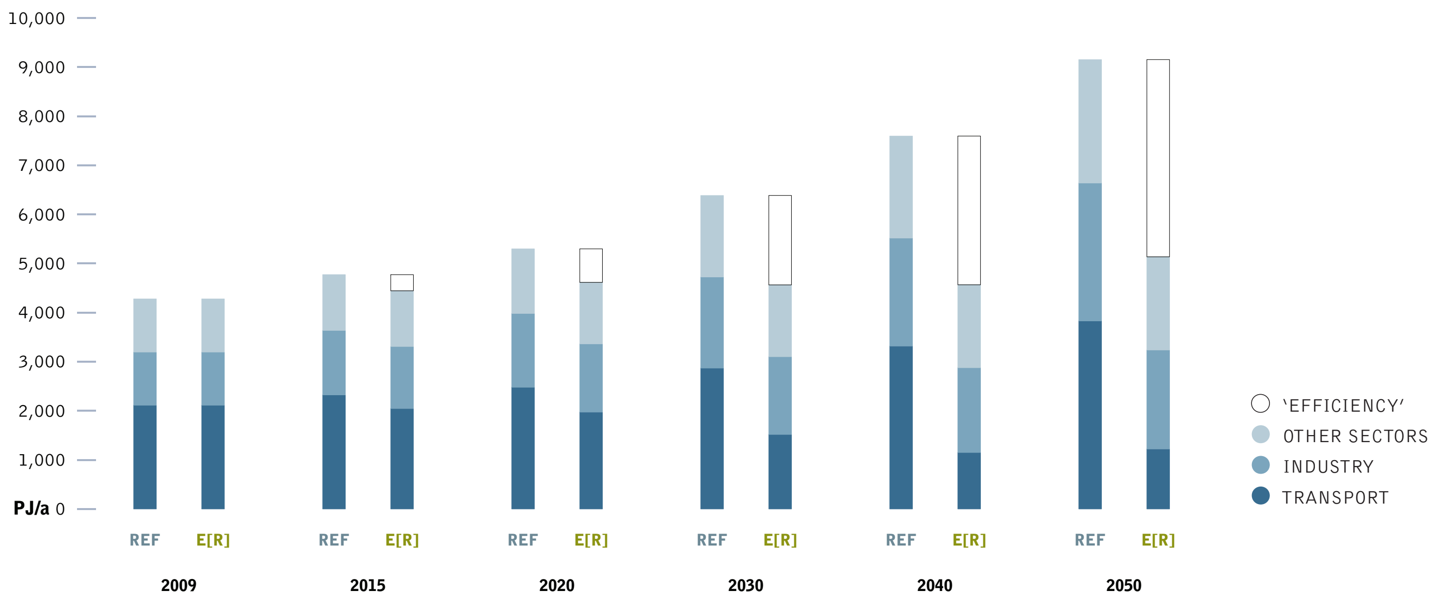


image SUN SETTING OFF THE GULF OF MEXICO.

image GEOTHERMIC WELL IN THE AZUFRES NATURAL PARK, MICHOACAN, MEXICO.

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

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

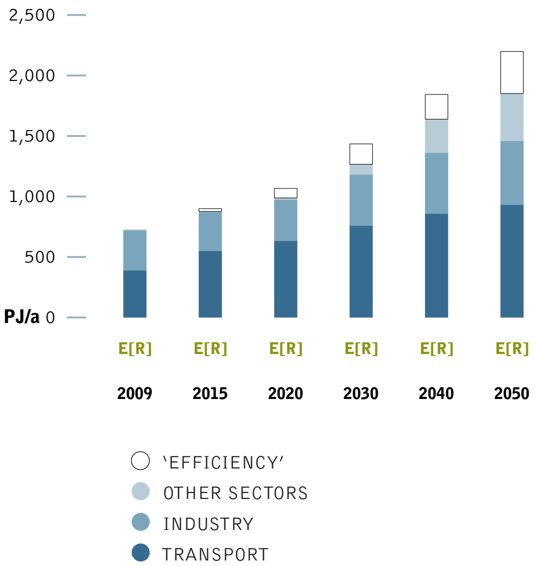


figure 5.4: development of heat demand by sector in the energy [r]evolution scenario

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

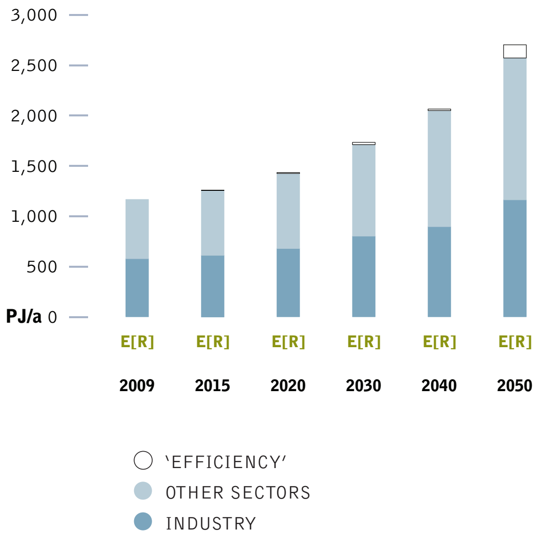
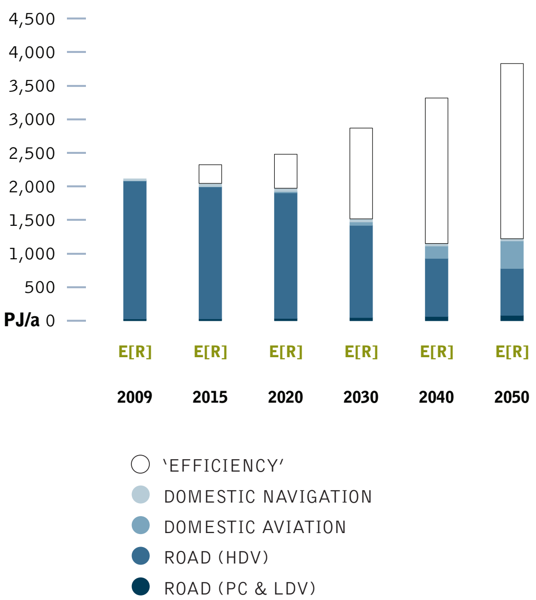


figure 5.3: development of the transport demand by sector in the energy [r]evolution scenario



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 phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2050, 93% of the electricity produced in Mexico will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 81% of electricity generation. Already by 2020 the share of renewable electricity production will be 44% and 74% by 2030. The installed capacity of renewables will reach 144 GW in 2030 and 319 GW by 2050.

Table 5.1 shows the comparative evolution of the different renewable technologies in Mexico over time. Today, renewable power generation is mainly from hydro power. Up to 2020, wind and PV will become the main drivers of the growing renewable power market. After 2020, the continuing growth of wind and PV will be complemented mainly by electricity from solar thermal power plants (CSP), but also from ocean energy, biomass and geothermal energy. The Energy [R]evolution scenario will lead to a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 36% by 2030, therefore the expansion of smart grids, demand side management (DSM) and storage capacity from the increased share of electric vehicles will be used for a better grid integration and power generation management.

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

IN MW

		2009	2020	2030	2040	2050
Hydro	REF	6	6	7	7	7
	E[R]	6	6	7	7	7
Biomass	REF	1	1	1	2	2
	E[R]	1	2	3	5	6
Wind	REF	0	7	11	16	23
	E[R]	0	24	51	78	96
Geothermal	REF	1	1	2	2	2
	E[R]	1	3	4	6	8
PV	REF	0	1	2	2	4
	E[R]	0	18	36	57	74
CSP	REF	0	0	1	1	1
	E[R]	0	7	37	85	120
Ocean energy	REF	0	0	0	0	0
	E[R]	0	3	5	7	10
Total	**REF**	**8**	**17**	**24**	**30**	**39**
	E[R]	**8**	**63**	**144**	**246**	**319**

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)

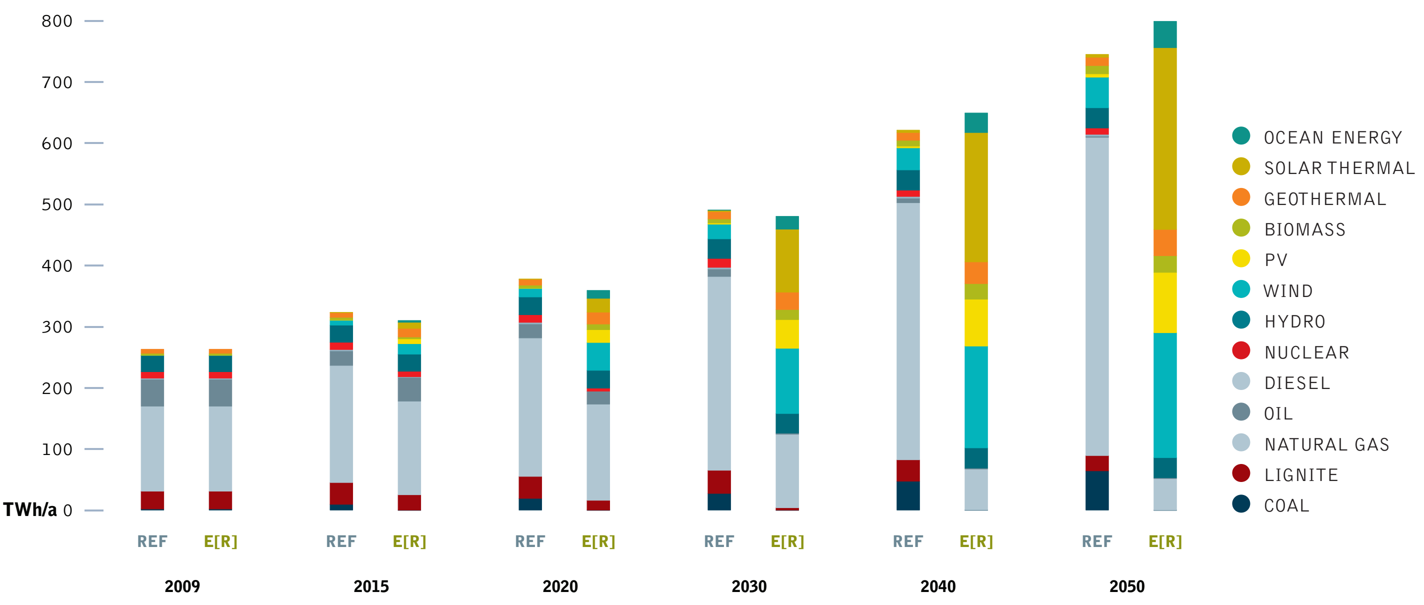
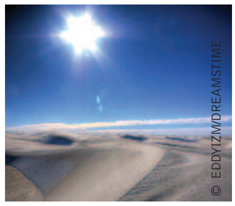


image THE SUN IN THE DESERT, MEXICO. MEXICO HAS IMMENSE POTENTIAL FOR SOLAR ENERGY.

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



5.3 future costs of electricity generation

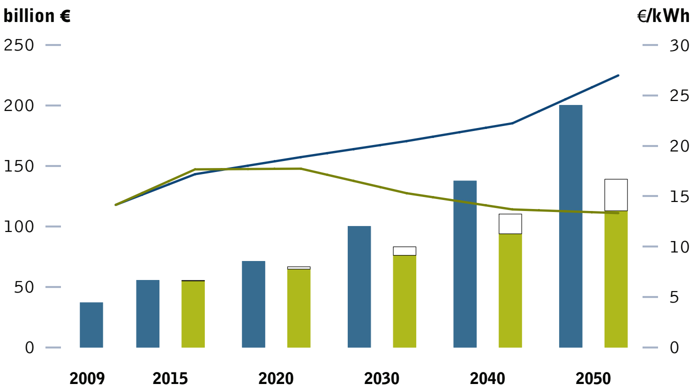
Figure 5.6 shows that the introduction of renewable technologies under the Energy [R]evolution scenario significantly decreases the future costs of electricity generation compared to the Reference scenario. Already in 2020, power generation costs in the Energy [R]Evolution scenario are 1.1 $ct/kWh lower than in the Reference case. Because of high prices for conventional fuels and the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be 13.7 $cents/kWh below those in the Reference version.

Under the Reference scenario,on the other hand, unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $ 37 billion per year to more than $ 200 billion in 2050. Figure 5.6 shows that the Energy [R]evolution scenario not only complies with Mexico'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 $61 billion lower than in the Reference scenario.

Under the Energy [R]evolution scenario, however, Mexico would shift almost 98% of the entire investment towards renewables and cogeneration. Until 2030, the fossil fuel share of power sector investment would be focused mainly on CHP plants. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately $ 28 billion.

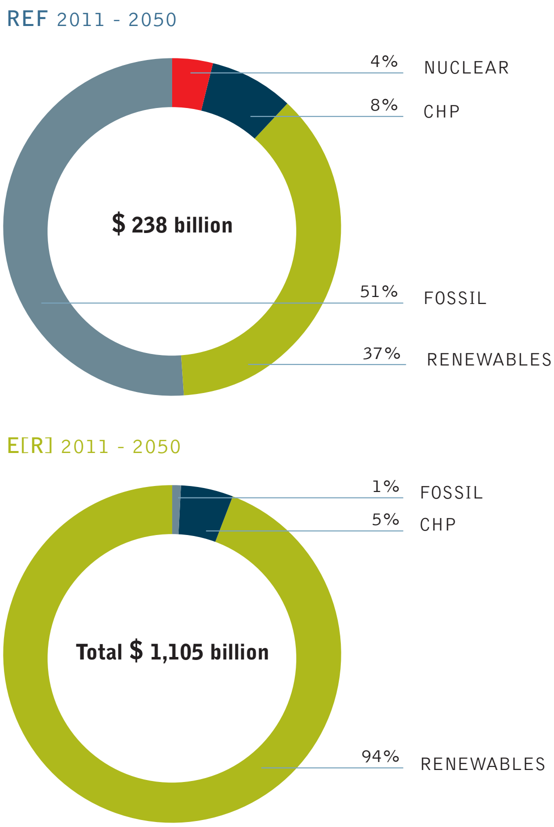
Because renewable energy has no fuel costs, however, the fuel cost savings in the Energy [R]evolution scenario reach a total of $ 1,671 billion up to 2050, or $ 42 billion per year. The total fuel cost savings therefore would cover more than twice the total additional investments compared to the Reference 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



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

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



5.4 future investments in the power sector

It would require $ 1,105 billion in investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately $ 867 billion in total (or $ 22 billion annually) more than in the Reference case ($ 238 billion). Under the Reference version, the levels of investment in conventional power plants add up to almost 55% while approx 45% would be invested in renewable energy and cogeneration (CHP) until 2050.

5.5 heating supply

Today, renewables meet 21% of Mexico's energy demand for heat supply, the main contribution coming from the use of biomass and increasing contributions from geothermal and solar thermal energy. Dedicated support instruments are required toensure a dynamic development. In the Energy [R]evolution scenario, renewables provide 52% of Mexico's total heat demand in 2030 and 89% in 2050.

- Energy efficiency measures help to reduce the currently growing energy demand for heating by 6% in 2050 (relative to the reference scenario), in spite of improving living standards.
- 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 5.8 shows the development of the different renewable technologies for heating in Mexico over time. Up to 2020 biomass will remain the main contributors of the growing market share. After 2020, the continuing growth of solar collectors and a growing share of geothermal heat pumps and renewable hydrogen will reduce the dependence on fossil fuels.

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

IN PJ/A

		2009	2020	2030	2040	2050
Biomass	REF	243	283	311	350	400
	E[R]	243	290	319	345	258
Solar collectors	REF	7	10	17	31	75
	E[R]	7	138	353	607	887
Geothermal (incl. heat pumps)	REF	0	0	0	0	0
	E[R]	0	38	159	405	794
Hydrogen	REF	0	0	0	0	0
	E[R]	0	16	62	159	339
Total	**REF**	**250**	**293**	**328**	**381**	**475**
	E[R]	**250**	**482**	**893**	**1,516**	**2,278**

figure 5.8: heat supply structure under the reference scenario and the energy [r]evolution scenario

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

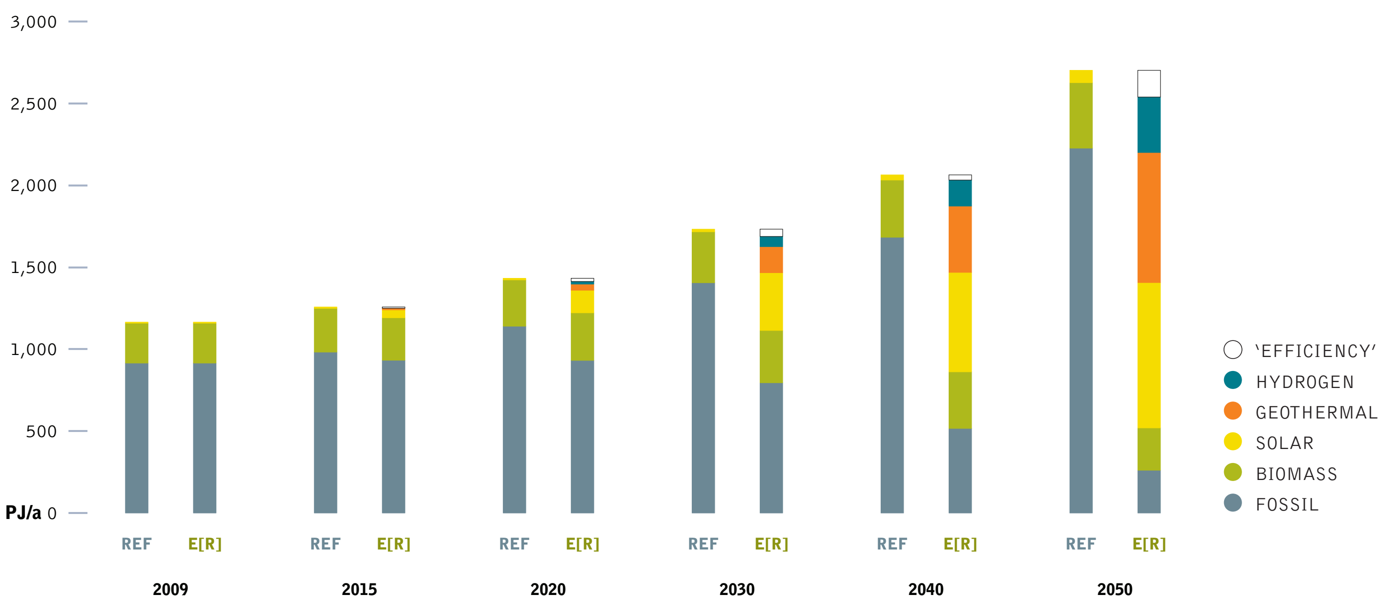


image BUILDING WITH A SOLAR PANEL ON THE ISLA CONTOY, MEXICO.

image FIRE BOAT RESPONSE CREWS BATTLE THE BLAZING REMNANTS OF THE OFF SHORE OIL RIG DEEPWATER HORIZON. ELEVEN WORKERS DIED AND MILLIONS OF BARRELS OF CRUDE OIL GUSHED INTO THE GULF IN WORST OIL SPILL IN UNITED STATES HISTORY.

5.6 future investments in the heat sector

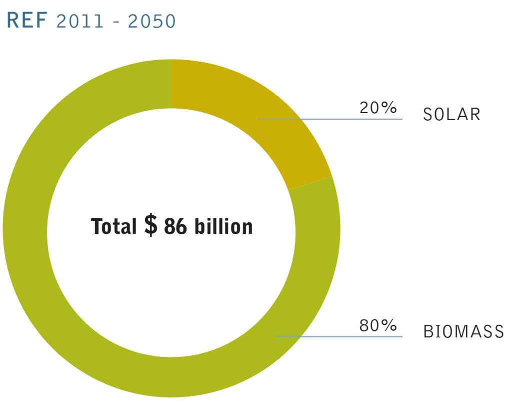
Also in the heat sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Installed capacities need to increase drastically for solar thermal heating systems, if their potential is to be tapped for the heat sector. Other technologies as geothermal heat pumps and hydrogen from renewable sources (for high temperature process heat) are not yet or only rarely used in Mexico today. However, they will play an important role for Mexico's heat supply in 2050. Capacity of biomass technologies, which are already rather wide spread today will increase only slightly, but will remain a main pillar of heat supply.

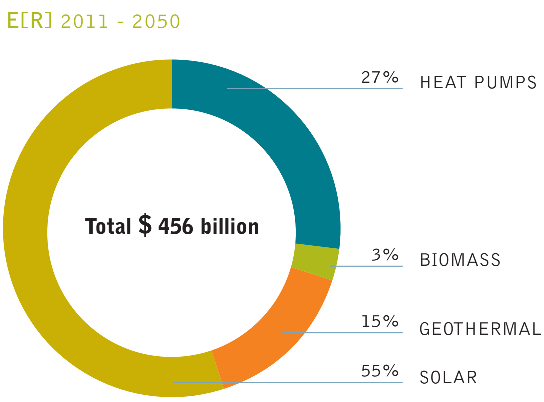
Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated enhanced geothermal systems and solar themal district heating plants with seasonal storage.Thus it can only roughly be calculated, that the Energy [R]evolution scenario in total requires around $ 456 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately $ 11 billion per year.

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

		2009	2020	2030	2040	2050
Biomass	REF	52	59	64	72	81
	E[R]	52	53	48	39	16
Geothermal	REF	0	0	0	0	0
	E[R]	0	2	5	12	33
Solar thermal	REF	2	3	4	8	19
	E[R]	2	35	91	154	223
Heat pumps	REF	0	0	0	0	0
	E[R]	0	2	15	37	64
Total	**REF**	**54**	**61**	**68**	**79**	**100**
	E[R]	**54**	**93**	**158**	**243**	**336**

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 Mexico is to introduce incentives for people to drive smaller cars, something almost completely absent today. In addition, it is vital to shift transport use to efficient modes like rail, light rail and buses, especially in the expanding large metropolitan areas. Together with rising prices for fossil fuels, these changes reduce the huge growth in car sales projected under the Reference scenario. Energy demand from the transport sector is reduced by 2,609 PJ/a 2050, saving 68% compared to the Reference scenario. Energy demand in the transport sector will therefore decrease between 2009 and 2050 by 42% to 1,221 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 5% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 32%.

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

		2009	2020	2030	2040	2050
Rail	REF	27	43	57	75	96
	E[R]	27	34	47	63	80
Road	REF	2,058	2,370	2,701	2,948	3,088
	E[R]	2,058	1,871	1,373	866	698
Domestic aviation	REF	1	20	57	232	574
	E[R]	1	20	51	183	410
Domestic navigation	REF	27	46	54	62	71
	E[R]	27	48	46	38	33
Total	**REF**	**2,113**	**2,479**	**2,869**	**3,317**	**3,830**
	E[R]	**2,113**	**1,973**	**1,517**	**1,150**	**1,221**

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

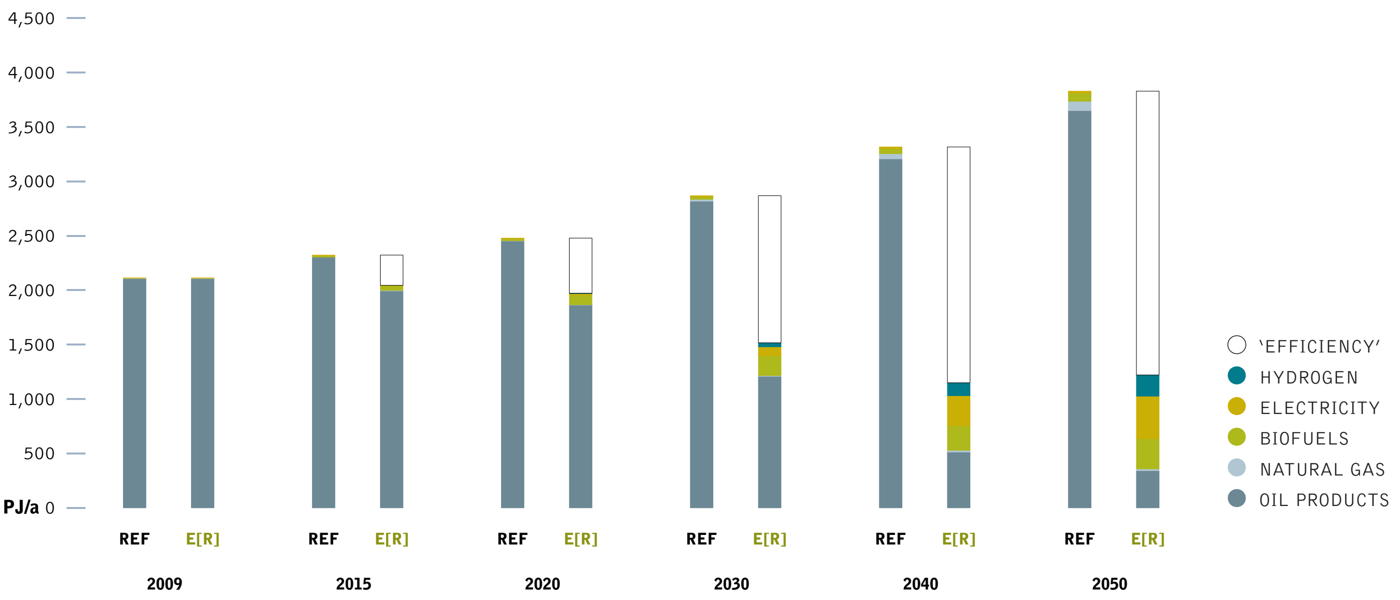
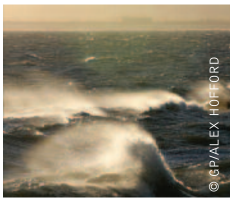


image THE POTENTIAL OF OCEAN ENERGY, GULF OF MEXICO.

image THOUSANDS OF HOMES WERE FLOODED AFTER SEVERAL RIVERS BURST THEIR BANKS IN THE SOUTHERN MEXICAN STATE OF TABASCO AND HEAVY RAINS LEAVE 70 PERCENT OF THE SWAMPY REGION UNDER WATER. AN ESTIMATED 700,000 PEOPLE LOST THEIR HOMES AND BELONGINGS.



5.8 development of CO_2 emissions

Whilst Mexico's emissions of CO_2 will more than double between 2009 and 2050 under the Reference scenario, under the Energy [R]evolution scenario they will decrease from 429 million tonnes in 2009 to 62 million tonnes in 2050 Annual per capita emissions will drop from 3.8 tonnes to 0.4 tonnes. In spite of the phasing out of nuclear energy and increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable in vehicles will reduce emissions in the transport sector. With a share of 42% of CO_2, the transport sector will be the largest sources of emissions in 2050. By 2050, Mexico's CO_2 emissions are 86% 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. Compared to the Reference scenario, overall primary energy demand will be reduced by 53% in 2050 compared to the Reference case. Around 78% of the remaining demand will be covered by renewable energy sources.

The Energy [R]evolution version aims to phases out coal and oil as fast as technically and economically possible. This is made possible mainly by replacement of coal power plants with renewables and a fast introduction of very efficient electric vehicles in the transport sector to replace oil combustion engines. This leads to an overall renewable primary energy share of 42% in 2030 and 78% in 2050. Nuclear energy is phased out just after 2030.

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

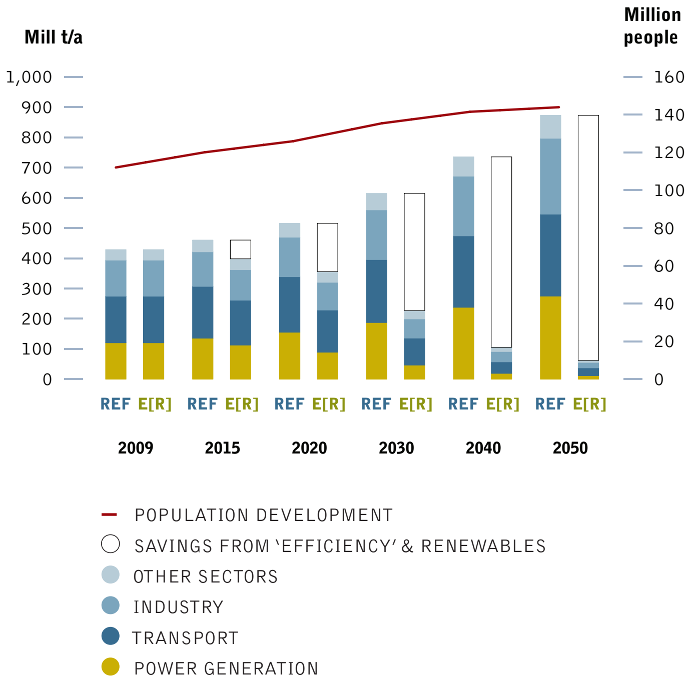


figure 5.11: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

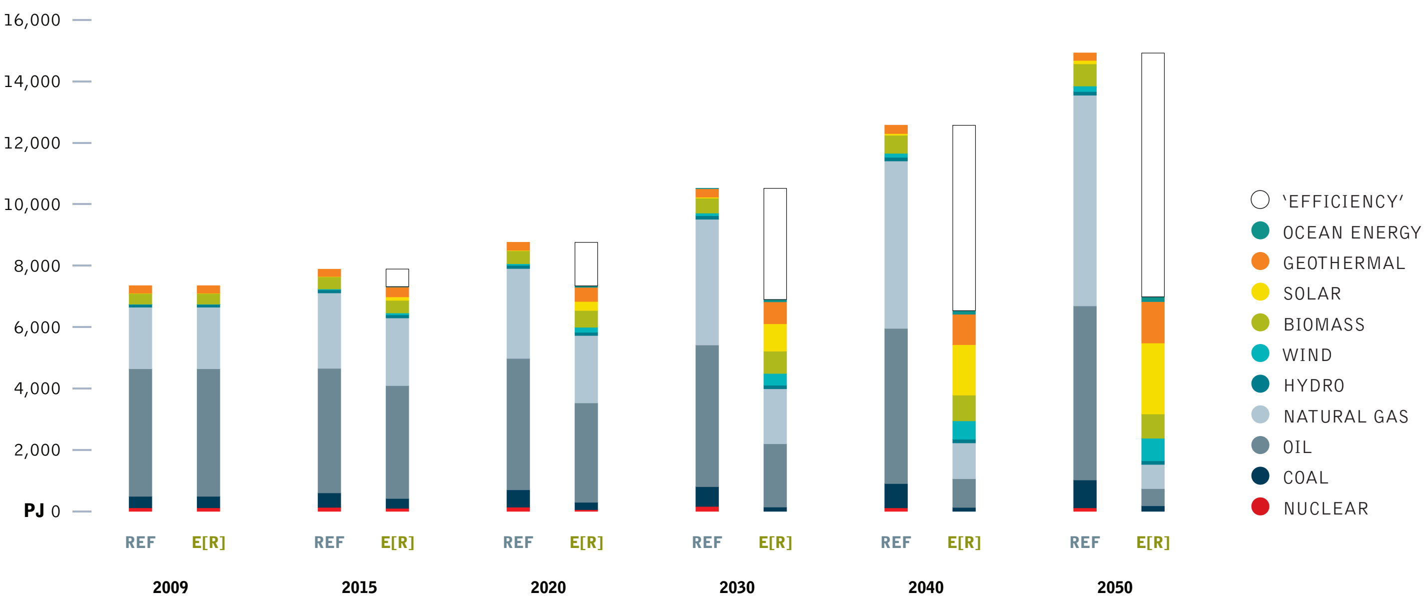


table 5.5: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

INVESTMENT COSTS	EURO	2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE E[R] VERSUS REF							
Conventional (fossil & nuclear)	billion €	-21.8	-25.7	-30.2	-28.2	-106.5	-2.7
Renewables	billion €	118.2	207.8	335.7	312.2	973.9	24.3
Total	billion €	**96.4**	**182.1**	**305.5**	**283.4**	**867.4**	**21.7**

CUMULATED FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion €/a	-12.1	14.1	17.1	7.0	26.1	0.7
Gas	billion €/a	49.6	199.2	474.0	834.4	1,557.3	38.9
Hard coal	billion €/a	4.3	12.2	22.4	32.9	71.7	1.8
Lignite	billion €/a	1.5	4.0	5.4	5.0	15.9	0.4
Total	billion €/a	**43.3**	**229.4**	**518.9**	**879.3**	**1,671.0**	**41.8**

glossary & appendix

GLOSSARY OF COMMONLY USED TERMS AND ABBREVIATIONS

DEFINITION OF SECTORS

MEXICO: SCENARIO RESULTS DATA

image HALFWAY BETWEEN THE U.S-MEXICO BORDER AND THE SOUTHERN TIP OF BAJA CALIFORNIA, FACING THE PACIFIC OCEAN, LIES LAGUNA OJO DE LIEBRE. A WORLD HERITAGE SITE, AND A MAJOR SALT WORKS, THE LAGOON SPANS DIVERSE WORLDS OF NATURE AND INDUSTRIALIZATION. IT IS A NESTING AND WINTERING SITE FOR HARBOR SEALS, CALIFORNIA SEA LIONS, NORTHERN ELEPHANT SEALS, BLUE WHALES AND GRAY WHALES. THE AREA ALSO SERVES AS A SANCTUARY FOR A VARIETY OF SEA BIRDS, AND FOUR ENDANGERED SPECIES OF MARINE TURTLE.

6.1 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 6.1: 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 6.2: 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

6.2 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.

mexico: scenario results data

image FISHING BOATS DRAG LARGE NETS ACROSS THE SEA FLOOR, SCOOPING UP SEAFOOD FROM SHRIMP TO SQUID. BUT IN ADDITION TO THEIR HARVESTING OF INTENDED SPECIES, MANY TRAWLS INDISCRIMINATELY CAPTURE NON-TARGET SPECIES, LIKE SEA TURTLES. THE PERVASIVENESS OF THE INFLUENCE OF BOTTOM TRAWLERS ON THE GULF OF MEXICO IS EVIDENT IN THESE IMAGES FROM NASA'S LANDSAT SATELLITE. THE IMAGES REVEAL DOZENS OF MUDTRAILS STREAKING THE GULF IN THE WAKE OF NUMEROUS TRAWLERS, WHICH APPEAR AS WHITE DOTS.

mexico: reference scenario

table 6.3: mexico: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**263**	**318**	**369**	**469**	**581**	**692**
Coal	2	9	19	26	46	63
Lignite	29.1	35.6	36.0	37.9	35.0	25.0
Gas	139	188	220	301	392	484
Oil	44	23	22	11	6	0
Diesel	2	2	3	3	3	3
Nuclear	11	12	13	15	10	10
Biomass	2.7	3.4	3.2	2.4	0.4	0
Hydro	26.7	28.0	29.0	32.0	33.0	33.0
Wind	0.6	8.0	14	24	36	50
of which wind offshore	0	0	0.3	3.0	8.5	15.0
PV	0	0.5	1	2	3	6
Geothermal	7	8	9.4	12.0	12.8	13.5
Solar thermal power plants	0	0	1	2	4	5
Ocean energy	0	0	0	0.3	0	0
Combined heat & power plants	**0**	**5**	**8**	**22**	**40**	**53**
Coal	0	0.1	0.2	0.8	1.4	1.6
Lignite	0	0	0	0	0	0
Gas	0	3	6	15	28	36
Oil	0	0.3	0.5	1.2	1.9	1.6
Biomass	0	0.8	1.5	4.2	8.9	13.5
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	3	5	13	24	31
Autoproducers	0	2	4	9	16	22
Total generation	**263**	**323**	**378**	**490**	**621**	**745**
Fossil	216	262	307	397	512	614
Coal	2	9	19	27	47	64
Lignite	29.1	35.7	36.0	37.9	35.0	25.0
Gas	139	191	226	317	420	520
Oil	44	24	23	12	8	2
Diesel	2	2	3	3	3	3
Nuclear	11	12	13	15	10	10
Hydrogen	0	0	0	0	0	0
Renewables	**36.8**	**49**	**58**	**79**	**98**	**120**
Hydro	26.7	28.0	29.0	32.0	33.0	33.0
Wind	0.6	8.0	14	24	36	50
PV	0	0.5	1	2	3	6
Biomass	2.7	4.1	4.7	6.6	9.3	13.5
Geothermal	7	8	9.4	12.0	12.8	13.5
Solar thermal	0	0	1	2	4	5
Ocean energy	0	0	0	0.3	0	0
Distribution losses	42	52	58	65	77	95
Own consumption electricity	18	22	25	28	33	40
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	201	249	**296**	**398**	**512**	**610**
Fluctuating RES (PV, Wind, Ocean)	1	9	15	26	39	56
Share of fluctuating RES	0.2%	2.6%	3.9%	5.4%	6.3%	7.5%
RES share (domestic generation)	**14.0%**	**15.1%**	**15.5%**	**16.2%**	**15.8%**	**16.2%**

table 6.4: mexico: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**0**	**0**	**0**	**0**	**0**	**0**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Solar collectors	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Heat from CHP	**0**	**0**	**0**	**0**	**0**	**0**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
Direct heating[1]	**1,165**	**1,258**	**1,433**	**1,733**	**2,064**	**2,702**
Fossil fuels	915	982	1,140	1,405	1,683	2,227
Biomass	243	266	283	311	350	400
Solar collectors	7	9	10	17	31	75
Geothermal[2]	0	0	0	0	0	0
Total heat supply[1]	**1,165**	**1,258**	**1,433**	**1,733**	**2,064**	**2,702**
Fossil fuels	915	982	1,140	1,405	1,683	2,227
Biomass	243	266	283	311	350	400
Solar collectors	7	9	10	17	31	75
Geothermal[2]	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	**21.5%**	**21.9%**	**20.4%**	**18.9%**	**18.5%**	**17.6%**

1) including cooling 2) including heat pumps.

table 6.5: mexico: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**120**	**135**	**154**	**183**	**229**	**264**
Coal	2	8	16	22	37	47
Lignite	28	30	30	31	28	20
Gas	56	77	89	120	158	195
Oil	34	18	17	8	4	0
Diesel	1	2	2	2	2	2
Combined heat & power production	**0**	**2**	**3**	**8**	**14**	**17**
Coal	0	0	0	1	1	1
Lignite	0	0	0	0	0	0
Gas	0	1	2	6	11	15
Oil	0	0	0	1	1	1
CO_2 emissions power generation (incl. CHP public)	**120**	**136**	**157**	**190**	**243**	**281**
Coal	2	8	16	22	38	48
Lignite	28	30	30	31	28	20
Gas	56	78	91	126	169	210
Oil & diesel	35	20	19	11	7	3
CO_2 emissions by sector	**429**	**460**	**516**	**615**	**735**	**873**
% of 1990 emissions	8%	9%	10%	12%	15%	17%
Industry[1]	43	48	53	63	73	102
Other sectors[1]	35	39	46	55	64	76
Transport	154	171	184	208	236	271
Power generation[2]	120	136	155	187	238	275
District heating & other conversion	77	66	78	102	124	148
Population (Mill.)	112.0	120.1	125.9	135.4	141.5	143.9
CO_2 emissions per capita (t/capita)	**3.8**	**3.8**	**4.1**	**4.5**	**5.2**	**6.1**

1) including CHP autoproducers. 2) including CHP public

table 6.6: mexico: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**66**	**86**	**92**	**111**	**136**	**164**
Coal	0	1	3	4	7	9
Lignite	4.5	5.3	5.3	5.4	5.0	3.6
Gas	35	49	52	69	90	111
Oil	16.1	14.6	13.1	6.0	3.1	0.3
Diesel	1	1	1	1	2	2
Nuclear	2	2	2	2	1	1
Biomass	0.8	0.9	0.8	0.5	0.1	0
Hydro	5.9	5.9	6.1	6.8	7.0	7.0
Wind	0.4	4.4	7.2	11	16	23
of which wind offshore	0	0	0.1	1.2	3.3	5.8
PV	0	0.5	1	2	2	4
Geothermal	1	1	1.36	1.7	1.8	1.9
Solar thermal power plants	0	0	0	1	1	1
Ocean energy	0	0	0	0.1	0	0
Combined heat & power production	**0**	**1.1**	**1.8**	**4.7**	**8.7**	**11.4**
Coal	0	0	0	0.1	0.2	0.2
Lignite	0	0	0	0	0	0
Gas	0	0.7	1.2	3.3	6	8
Oil	0	0.2	0.3	0.6	0.9	0.9
Biomass	0	0.2	0.3	0.8	1.6	2.4
Geothermal	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0.7	1.2	3.2	5.7	7.2
Autoproducers	0	0.4	0.6	1.6	3.0	4.1
Total generation	**66**	**87**	**94**	**116**	**145**	**175**
Fossil	56	72	76	90	113	134
Coal	0	1	3	4	7	9
Lignite	4.5	5.3	5.3	5.4	5.0	3.6
Gas	35	49	53	73	96	119
Oil	16.1	14.8	13.4	6.5	4.0	1.1
Diesel	1	1	1	1	2	2
Nuclear	2	2	2	2	1	1
Hydrogen	0	0	0	0	0	0
Renewables	**8.2**	**13**	**17**	**24**	**30**	**39**
Hydro	5.9	5.9	6.1	6.8	7.0	7.0
Wind	0.4	4.4	7.2	11	16	22.5
PV	0	0.5	1	2	2	4.1
Biomass	0.8	1.0	1.1	1.3	1.7	2.4
Geothermal	1	1	1.36	1.7	1.8	1.9
Solar thermal	0	0	0	1	1	1.4
Ocean energy	0	0	0	0.1	0	0
Fluctuating RES (PV, Wind, Ocean)	0.5	4.9	7.9	13	19	27
Share of fluctuating RES	0.7%	5.6%	8.3%	11.3%	12.9%	15.2%
RES share (domestic generation)	**12.4%**	**15.0%**	**17.6%**	**20.4%**	**20.9%**	**22.5%**

table 6.7: mexico: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**7,354**	**7,875**	**8,751**	**10,510**	**12,563**	**14,915**
Fossil	**6,541**	**6,973**	**7,761**	**9,342**	**11,285**	**13,426**
Hard coal	82	139	229	298	478	680
Lignite	299	323	327	337	304	217
Natural gas	2,006	2,456	2,928	4,095	5,452	6,861
Crude oil	4,154	4,055	4,277	4,611	5,052	5,668
Nuclear	**115**	**130**	**137**	**159**	**114**	**114**
Renewables	**699**	**772**	**852**	**1,009**	**1,164**	**1,375**
Hydro	96	101	104	115	119	119
Wind	2	29	50	86	130	180
Solar	7	12	15	32	57	112
Biomass	351	394	422	486	588	721
Geothermal/ambient heat	243	237	260	288	271	243
Ocean energy	0	0	0	1	0	0
RES share	**9.5%**	**9.8%**	**9.7%**	**9.6%**	**9.3%**	**9.2%**

table 6.8: mexico: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**4,610**	**5,164**	**5,708**	**6,819**	**8,044**	**9,615**
Total (energy use)	**4,279**	**4,772**	**5,298**	**6,385**	**7,595**	**9,152**
Transport	**2,113**	**2,323**	**2,479**	**2,869**	**3,317**	**3,830**
Oil products	2,109	2,304	2,453	2,818	3,207	3,651
Natural gas	1	0	2	17	48	85
Biofuels	0	13	17	25	48	75
Electricity	4	6	7	9	14	18
RES electricity	1	1	1	1	2	3
Hydrogen	0	0	0	0	0	0
RES share Transport	**0.0%**	**0.6%**	**0.7%**	**0.9%**	**1.5%**	**2.0%**
Industry	**1,082**	**1,314**	**1,503**	**1,856**	**2,200**	**2,810**
Electricity	389	570	680	878	1,071	1,257
RES electricity	54	86	105	142	169	203
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	45	49	52	54	64	157
Oil products	259	356	381	410	458	590
Gas	345	283	332	455	544	729
Solar	0	0	1	1	2	13
Biomass and waste	43	54	58	59	61	64
Geothermal/ambient heat	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
RES share Industry	**9.0%**	**10.7%**	**10.9%**	**10.9%**	**10.6%**	**10.0%**
Other Sectors	**1,084**	**1,135**	**1,316**	**1,660**	**2,078**	**2,513**
Electricity	331	322	379	547	757	923
RES electricity	46	49	59	88	120	149
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	0	0	0	0	0	0
Oil products	448	500	542	588	638	728
Gas	37	30	98	193	297	394
Solar	6	8	10	16	29	63
Biomass and waste	261	275	288	316	356	406
Geothermal/ambient heat	0	0	0	0	0	0
RES share Other Sectors	**28.9%**	**29.3%**	**27.1%**	**25.3%**	**24.3%**	**24.6%**
Total RES	**412**	**487**	**538**	**649**	**788**	**976**
RES share	**9.6%**	**10.2%**	**10.2%**	**10.2%**	**10.4%**	**10.7%**
Non energy use	**331**	**392**	**410**	**434**	**449**	**463**
Oil	220	285	298	316	326	337
Gas	111	107	112	118	123	126
Coal	0	0	0	0	0	0

mexico: energy [r]evolution scenario

table 6.9: mexico: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**263**	**303**	**320**	**418**	**564**	**705**
Coal	2	0	0	0	0	0
Lignite	29.1	25	16	4	0	0
Gas	139	148	128	78	18	4
Oil	44	38	20	2	1	1
Diesel	2	1	0	0	0	0
Nuclear	11	9	5	0	0	0
Biomass	2.7	1.7	1.0	0.4	0	0
Hydro	26.7	28	29	32	33	33
Wind	0.6	17	46	107	166	204
of which wind offshore	0	0	1	7	13	19
PV	0	8	21	47	77	99
Geothermal	7	14	19	25	25	24
Solar thermal power plants	0	10	23	103	211	297
Ocean energy	0	3	13	21	32	43
Combined heat & power plants	**0**	**7**	**39**	**62**	**85**	**94**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	5	29	42	49	48
Oil	0	0	1	0	0	0
Biomass	0	1	8	16	25	27
Geothermal	0	0	1	4	11	19
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	3	27	39	44	45
Autoproducers	0	4	12	23	41	49
Total generation	**263**	**310**	**359**	**480**	**649**	**799**
Fossil	216	218	194	126	69	53
Coal	2	0	0	0	0	0
Lignite	29.1	25.0	15.9	4	0	0
Gas	139	153	157	120	67	52
Oil	44	39	21	1.9	1.5	1
Diesel	2	1	0	0	0	0
Nuclear	11	9	5	0	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**36.8**	**83**	**160**	**354**	**580**	**746**
Hydro	26.7	28	29	32	33	33
Wind	0.6	17	46	107	166	204
PV	0	8	21	47	77	99
Biomass	2.7	3	9	16	25	27
Geothermal	7	14	19	28	36	43
Solar thermal	0	10	23	103	211	297
Ocean energy	0	3	13	21	32	43
Distribution losses	42	47	54	62	59	58
Own consumption electricity	18	20	23	26	25	25
Electricity for hydrogen production	0	0	9	41	110	203
Final energy consumption (electricity)	**201**	**243**	**274**	**351**	**455**	**514**
Fluctuating RES (PV, Wind, Ocean)	1	28	80	175	275	346
Share of fluctuating RES	0.2%	9.0%	22.1%	36.4%	42.4%	43.3%
RES share (domestic generation)	**14.0%**	**26.8%**	**44.5%**	**73.8%**	**89.4%**	**93.4%**
'Efficiency' savings (compared to Ref.)	**0**	**6**	**24**	**67**	**130**	**200**

table 6.10: mexico: heat supply

PJ/a	2009	2015	2020	2030	2040	2050
District heating	**0**	**5**	**6**	**15**	**47**	**116**
Fossil fuels	0	0	0	0	0	0
Biomass	0	4	4	7	18	23
Solar collectors	0	0	1	4	17	58
Geothermal	0	0	1	3	12	35
Heat from CHP	**0**	**24**	**112**	**232**	**384**	**467**
Fossil fuels	0	18	73	120	150	147
Biomass	0	7	34	81	137	148
Geothermal	0	0	5	31	96	172
Hydrogen	0	0	0	0	0	0
Direct heating[1)]	**1,165**	**1,221**	**1,296**	**1,442**	**1,602**	**1,957**
Fossil fuels	915	915	859	675	366	114
Biomass	243	248	253	232	190	87
Solar collectors	7	48	137	348	590	829
Geothermal[2)]	0	9	31	125	297	587
Hydrogen	0	0	16	62	159	339
Total heat supply[1)]	**1,165**	**1,250**	**1,413**	**1,688**	**2,033**	**2,539**
Fossil fuels	915	933	932	795	516	261
Biomass	243	259	290	319	345	258
Solar collectors	7	48	138	353	607	887
Geothermal[2)]	0	10	38	159	405	794
Hydrogen	0	0	16	62	159	339
RES share (including RES electricity)	**21.5%**	**25.4%**	**33.5%**	**51.9%**	**73.8%**	**88.8%**
'Efficiency' savings (compared to Ref.)	**0**	**8**	**20**	**45**	**32**	**163**

1) including cooling 2) including heat pumps.

table 6.11: mexico: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**120**	**112**	**81**	**36**	**8**	**2**
Coal	2	0	0	0	0	0
Lignite	28	21	13	3	0	0
Gas	56	61	52	31	7	2
Oil	34	29	15	1	1	1
Diesel	1	1	0	0	0	0
Combined heat & power production	**0**	**2**	**12**	**17**	**20**	**19**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	2	12	17	20	19
Oil	0	0	1	0	0	0
CO_2 emissions power generation (incl. CHP public)	**120**	**114**	**93**	**52**	**28**	**22**
Coal	2	0	0	0	0	0
Lignite	28	21	13	3	0	0
Gas	56	63	63	48	27	21
Oil & diesel	35	30	16	1	1	1
CO_2 emissions by sector	**429**	**398**	**356**	**227**	**106**	**62.0**
% of 1990 emissions	8%	87%	78%	50%	23%	14%
Industry[1)]	43	44	42	35	23	14
Other sectors[1)]	35	36	36	28	14	7
Transport	154	148	140	89	38	26
Power generation[2)]	120	113	89	47	19	12
District heating & other conversion	77	57	50	29	11	4
Population (Mill.)	112.0	120	126	135	142	144
CO_2 emissions per capita (t/capita)	**3.8**	**3.3**	**2.8**	**1.7**	**0.7**	**0.4**
'Efficiency' savings (compared to Ref.)	**0**	**62**	**160**	**387**	**630**	**811**

1) including CHP autoproducers. 2) including CHP public

table 6.12: mexico: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**66**	**90**	**110**	**165**	**245**	**311**
Coal	0	0	0	0	0	0
Lignite	4.5	4	2	1	0	0
Gas	35	38	33	24	6	1
Oil	16.1	16	12	1	1	1
Diesel	1	1	0	0	0	0
Nuclear	2	1	1	0	0	0
Biomass	0.8	0	0	0	0	0
Hydro	5.9	6	6	7	7	7
Wind	0.4	9	24	51	78	96
of which wind offshore	0	0	0	3	5	7
PV	0	8	18	36	57	74
Geothermal	1	2	3	4	4	4
Solar thermal power plants	0	3	7	37	85	120
Ocean energy	0	1	3	5	7	10
Combined heat & power production	**0**	**1**	**9**	**14**	**20**	**23**
Coal	0	0	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0	1	6	10	13	13
Oil	0	0	0	0	0	0
Biomass	0	0	2	3	5	6
Geothermal	0	0	0	1	2	4
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	1	7	9	10	11
Autoproducers	0	1	2	5	10	12
Total generation	**66**	**91**	**118**	**179**	**265**	**334**
Fossil	56	60	54	35	19	15
Coal	0	0	0	0	0	0
Lignite	4.5	3.7	2.3	1	0	0
Gas	35	39	40	34	18	14
Oil	16.1	16.2	12.3	1.0	0.8	1
Diesel	1	1	0	0	0	0
Nuclear	2	1	1	0	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**8.2**	**30**	**63**	**144**	**246**	**319**
Hydro	5.9	5.9	6.1	6.8	7.0	7.0
Wind	0.4	9.3	24	51	78	96
PV	0	8	18	36	57	74
Biomass	0.8	0.7	2.0	3.3	5.3	6
Geothermal	1	2.04	2.87	4.4	6.1	8.0
Solar thermal	0	3	7	37	85	120
Ocean energy	0	0.7	2.9	4.7	7.2	9.6
Fluctuating RES (PV, Wind, Ocean)	0.5	18	45	92	142	179
Share of fluctuating RES	0.7%	20.2%	37.8%	51.4%	53.8%	53.5%
RES share (domestic generation)	**12.4%**	**32.8%**	**53.4%**	**80.2%**	**92.8%**	**95.5%**

table 6.13: mexico: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**7,354**	**7,293**	**7,338**	**6,895**	**6,531**	**6,983**
Fossil	**6,541**	**6,176**	**5,669**	**3,990**	**2,228**	**1,527**
Hard coal	82	73	94	105	127	180
Lignite	299	224	143	33	0	0
Natural gas	2,006	2,202	2,196	1,792	1,167	788
Crude oil	4,154	3,677	3,236	2,060	934	559
Nuclear	**115**	**98**	**55**	**0**	**0**	**0**
Renewables	**699**	**1,019**	**1,615**	**2,905**	**4,304**	**5,456**
Hydro	96	101	104	115	119	119
Wind	2	61	164	383	599	735
Solar	7	113	295	892	1,644	2,312
Biomass	351	410	545	725	838	788
Geothermal/ambient heat	243	323	460	713	989	1,348
Ocean energy	0	11	47	76	115	155
RES share	**9.5%**	**13.9%**	**22.0%**	**42.2%**	**65.9%**	**78.1%**
'Efficiency' savings (compared to Ref.)	**0**	**573**	**1,417**	**3,620**	**6,037**	**7,938**

table 6.14: mexico: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**4,610**	**4,852**	**5,019**	**4,959**	**4,954**	**5,515**
Total (energy use)	**4,279**	**4,444**	**4,615**	**4,564**	**4,566**	**5,136**
Transport	**2,113**	**2,045**	**1,973**	**1,517**	**1,150**	**1,221**
Oil products	2,109	1,994	1,866	1,208	513	341
Natural gas	1	4	1	7	16	16
Biofuels	0	43	88	181	226	276
Electricity	4	4	13	83	276	392
RES electricity	1	1	6	62	247	366
Hydrogen	0	0	4	37	119	195
RES share Transport	**0.0%**	**2.2%**	**4.9%**	**17.8%**	**50.4%**	**67.5%**
Industry	**1,082**	**1,264**	**1,390**	**1,584**	**1,728**	**2,016**
Electricity	389	550	633	759	858	931
RES electricity	54	147	281	560	768	870
District heat	0	19	60	114	196	239
RES district heat	0	8	23	59	128	178
Coal	45	43	44	17	0	0
Oil products	259	250	207	143	50	36
Gas	345	349	344	318	216	55
Solar	0	6	26	79	118	185
Biomass and waste	43	45	48	52	53	55
Geothermal/ambient heat	0	2	11	33	66	163
Hydrogen	0	0	18	69	171	353
RES share Industry	**9.0%**	**16.5%**	**28.6%**	**52.7%**	**74.4%**	**88.3%**
Other Sectors	**1,084**	**1,135**	**1,252**	**1,463**	**1,689**	**1,899**
Electricity	331	322	341	423	504	527
RES electricity	46	86	152	312	450	493
District heat	0	6	43	100	180	269
RES district heat	0	3	17	50	120	214
Coal	0	0	0	0	0	0
Oil products	448	448	437	334	138	39
Gas	37	49	43	44	49	42
Solar	6	42	111	269	473	645
Biomass and waste	261	262	262	227	174	48
Geothermal	0	6	16	65	172	329
RES share Other Sectors	**28.9%**	**35.2%**	**44.5%**	**63.2%**	**82.3%**	**91.0%**
Total RES	**412**	**652**	**1,050**	**2,028**	**3,254**	**4,333**
RES share	**9.6%**	**14.7%**	**22.8%**	**44.4%**	**71.3%**	**84.4%**
Non energy use	**331**	**408**	**404**	**396**	**387**	**379**
Oil	220	276	253	209	165	105
Gas	111	111	110	108	106	104
Coal	0	20	40	79	116	171

mexico: investment

table 6.15: mexico: 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)	**37,923**	**31,954**	**40,769**	**32,042**	**142,688**	**3,567**
Renewables	**19,296**	**20,550**	**29,015**	**26,434**	**95,294**	**2,382**
Biomass	2,131	1,931	2,717	3,268	10,046	251
Hydro	3,814	5,567	6,072	1,857	17,310	433
Wind	9,798	8,272	16,077	15,981	50,129	1,253
PV	984	1,194	1,125	2,350	5,652	141
Geothermal	1,322	988	166	368	2,844	71
Solar thermal power plants	1,247	2,428	2,727	2,557	8,959	224
Ocean energy	0	170	132	54	355	9
Energy [R]evolution						
Conventional (fossil & nuclear)	**16,141**	**6,225**	**10,614**	**3,257**	**36,237**	**906**
Renewables	**137,506**	**228,393**	**364,674**	**338,603**	**1,069,176**	**26,729**
Biomass	6,285	5,198	11,019	5,550	28,052	701
Hydro	3,814	5,567	4,244	1,783	15,407	385
Wind	35,495	41,840	69,028	66,048	212,412	5,310
PV	31,538	20,434	36,020	28,758	116,749	2,919
Geothermal	4,275	2,839	3,448	4,214	14,775	369
Solar thermal power plants	45,044	147,990	235,109	223,008	651,152	16,279
Ocean energy	11,054	4,525	5,806	9,243	30,628	766

table 6.16: mexico: total investment in renewable heating only

(EXCLUDING INVESTMENTS IN FOSSIL FUELS)

MILLION €	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Renewables	**27,945**	**25,008**	**13,586**	**19,522**	**86,061**	**2,152**
Heat pumps	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Solar	1,679	2,259	3,726	9,121	16,785	420
Biomass	26,266	22,749	9,861	10,401	69,276	1,732
Energy [R]evolution scenario						
Renewables	**55,794**	**77,188**	**137,771**	**185,674**	**456,428**	**11,411**
Heat pumps	4,248	21,940	38,586	60,134	124,907	3,123
Geothermal	5,659	4,212	19,381	38,428	67,680	1,692
Solar	34,592	49,494	79,101	86,387	249,575	6,239
Biomass	11,296	1,542	704	725	14,266	357

GREENPEACE

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

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GWEC
GLOBAL WIND ENERGY COUNCIL

The Global Wind Energy Council (GWEC) is the voice of the global wind energy sector. GWEC works at highest international political level to create better policy environment for wind power. GWEC's mission is to ensure that wind power established itself as the answer to today's energy challenges, producing substantial environmental and economic benefits. GWEC is a member based organisation that represents the entire wind energy sector. The members of GWEC represent over 1,500 companies, organisations and institutions in more than 70 countries, including manufacturers, developers, component suppliers, research institutes, national wind and renewables associations, electricity providers, finance and insurance companies.

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EREC

European Renewable Energy Council (EREC) Created in April 2000, the European Renewable Energy Council (EREC) is the umbrella organisation of the European renewable energy industry, trade and research associations active in the sectors of bioenergy, geothermal, ocean, small hydro power, solar electricity, solar thermal and wind energy. EREC thus represents the European renewable energy industry with an annual turnover of €70 billion and employing 550,000 people.

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image NORTHEAST OF MEXICO IS TEXAS. THE SOUTHERN PORTION OF MEXICO IS SHOWN, EMPHASIZING THE FERTILE COASTAL PLAIN ALONG THE CAMPECHE BAY IN THE GULF OF MEXICO (CENTER). RIGHT OF CENTER IS THE YUCATAN PENINSULA. AT BOTTOM RIGHT, THE CHIAPAS REGION OF MEXICO MEETS THE BORDER OF NORTHWEST GUATEMALA.
front cover images RUGGED MOUNTAINS THAT TAPER OFF AS THEY RUN SOUTHWARD DOMINATE THE TERRAIN OF MEXICO'S BAJA CALIFORNIA PENINSULA. © JEFF SCHMALTZ, NASA/GSFC © JERL71/DREAMSTIME, © NATALIYA HORA/DREAMSTIME.