energy [r]evolution

A SUSTAINABLE NEW ZEALAND ENERGY OUTLOOK

GWEC
GLOBAL WIND ENERGY COUNCIL

GREENPEACE

report 2nd edition 2013 new zealand energy scenario

partners

Greenpeace International, European Renewable Energy Council (EREC)

date February 2013

project manager & lead author Sven Teske, Greenpeace International

Greenpeace New Zealand Simon Boxer

Greenpeace International Sven Teske

Global Wind Energy Council (GWEC): Steve Sawyer

research & co-authors
Overall modelling: DLR, Institute of Technical Thermodynamics, Department of Systems Analysis and Technology Assessment, Stuttgart, Germany: Dr. Thomas Pregger, Dr. Sonja Simon, Dr. Tobias Naegler, Marlene O'Sullivan

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.

© MARKEL REDONDO/GREENPEACE

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

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

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

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

contacts
sven.teske@greenpeace.org
simon.boxer@greenpeace.org

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

Published by Greenpeace International and EREC. (GPI reference number JN 439). Printed on 100% recycled chlorine-free paper.

contents

introduction 8

executive summary 10

1 climate and energy policy 13

1.1 the UNFCCC and the kyoto protocol 14
1.2 international energy policy 14
1.3 new zealand government's energy strategy 15
1.3.1 policies 15
1.4 renewable energy targets 17
1.5 policy changes in the energy sector 17
1.5.1 the most effective way to implement the energy [r]evolution: feed-in laws 18

2 the energy [r]evolution concept 19

2.1 key principles 20
2.2 the "3 step implementation" 21
2.3 the new electricity grid 24
2.3.1 hybrid systems 25
2.3.2 smart grids 26
2.3.3 the super grid 28
2.3.4 baseload blocks progress 28
2.4 case study: a year after the german nuclear phase out 31
2.4.1 target and method 31
2.4.2 carbon dioxide emissions trends 31
2.4.3 shortfall from first round of closures 31
2.4.4 the renewable energy sector in germany 31
2.4.5 energy and climate targets 32
2.4.6 details of the german nuclear phase-out plan 32
2.4.7 no 'blackouts' 32

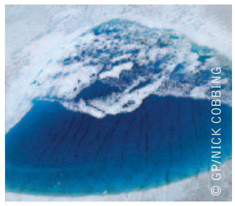
3 implementing the energy [r]evolution 34

3.1 renewable energy project planning basics 35
3.2 renewable energy financing basics 36
3.2.1 overcoming barriers to finance and investment for renewable energy 38
3.2.2 how to overcome investment barriers for renewable energy 39

4 scenarios for a future energy supply 40

4.1 scenario background 42
4.1.1 status and future projections for renewable heating technologies 42
4.2 population development 42
4.3 economic growth 42
4.4 oil and gas price projections 43
4.5 cost of CO_2 emissions 44
4.6 cost projections for efficient fossil fuel generation and carbon capture and storage (CCS) 44
4.7 cost projections for renewable energy technologies 45
4.7.1 photovoltaics (pv) 46
4.7.2 concentrating solar power (csp) 46
4.7.3 wind power 47
4.7.4 biomass 47
4.7.5 geothermal 48
4.7.6 ocean energy 48
4.7.7 hydro power 49
4.7.8 summary of renewable energy cost development 49
4.8 cost projections for renewable heating technologies 50
4.8.1 solar thermal technologies 50
4.8.2 deep geothermal applications 50
4.8.3 heat pumps 50
4.8.4 biomass applications 50
4.9 assumptions for fossil fuel phase out 51
4.9.1 oil - production decline assumptions 51
4.9.2 coal - production decline assumptions 51
4.10 review: greenpeace scenario projections of the past 52
4.10.1 the development of the global wind industry 52
4.10.2 the development of the global solar photovoltaic industry 54
4.11 how does the energy [r]evolution scenario compare to other scenarios 56

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.



5 key results of the New Zealand energy [r]evolution scenario 57

5.1 energy demand by sector 58
5.2 electricity generation 60
5.3 future costs of electricity generation 61
5.4 future investments in the power sector 61
5.5 heating supply 62
5.6 future investments in the heat sector 63
5.7 future employment in the energy sector
5.8 transport 64
5.9 development of CO_2 emissions 65
5.10 primary energy consumption 65

6 employment projections 67

6.1 methodology to calculate jobs 68
6.2 overview 68
6.3 limitations 69
6.4 employment factors 69
6.5 coal, gas and renewable technology trade 70
6.6 adjustment for learning rates - decline factors 70
6.7 future employment in the energy sector 71
6.8 employment in the renewable heating sector 73
6.8.1 employment in solar heating 73
6.8.2 employment in geothermal and heat pump heating 73
6.8.3 employment in biomass heat 73
6.8.4 employment in hydro 74
6.8.5 employment in biomass 74
6.8.6 employment in geothermal power 75
6.8.7 employment in wind energy 75
6.8.8 employment in solar photovoltaics 75
6.8.9 employment in coal 76
6.8.10 employment in gas, oil & diesel 76

7 the silent revolution – past and current market developments 78

7.1 the global market shares in the power plant market: renewables gaining ground 81
7.2 development of the installed power plant capacity in europe 82

8 transport 83

8.1 technical and behavioural measures to reduce transport energy consumption 85
8.1.1 step 1: reduction of transport demand 85
8.1.2 step 2: changes in transport mode 86
8.1.3 step 3: efficiency improvements 87
8.2 light-duty vehicles 88
8.2.1 projection of the CO_2 emission development 88
8.2.2 projection of the future vehicl segment split 89
8.2.3 projection of the future technology mix 89
8.2.4 renewable energy in the transport sector 89
8.3 conclusion 89

9 glossary & appendix 91

9.1 glossary of commonly used terms and abbreviations 92
9.2 definition of sectors 92
scenario results data 93

list of figures

2

figure 2.1 centralised generation systems waste more than two thirds of their original energy input 21
figure 2.2 a decentralised energy future 22
figure 2.3 the smart-grid vision for the energy [r]evolution 27
figure 2.4 a typical load curve throughout europe, shows electricity use peaking and falling on a daily basis 29
figure 2.5 the evolving approach to grids 29
figure 2.6 renewable energy sources as a share of energy supply in germany 32
figure 2.7 renewable energy sources in total final energy consumption in germany 2011/2010 32
figure 2.8 phase out of nuclear energy 33
figure 2.9 electricity imports/exports germany 33

3

figure 3.1 return characteristics of renewable energies 36
figure 3.2 overview risk factors for renewable energy projects 37
figure 3.3 investment stages of renewable energy projects 37
figure 3.4 key barriers to renewable energy investment 39

4

figure 4.1 future development of investment costs for renewable energy technologies 49
figure 4.2 expected development of electricity generation costs from fossil fuel and renewable options 49
figure 4.3 global oil production 1950 to 2011 and projection till 2050 51
figure 4.4 coal scenario: base decline of 2% per year and new projects 51
figure 4.5 wind power: short term prognosis vs real market development - global cummulative capacity 52
figure 4.6 wind power: long term market projects until 2030 53
figure 4.7 photovoltaic: short term prognosis vs real market development - global cummulative capacity 54
figure 4.8 photovoltaic: long term market projects until 2030 55

5

figure 5.1 total final energy demand under the reference scenario and the energy energy [r]evolution scenario 58
figure 5.2 development of electricity demand by sector in the energy [r]evolution scenario 59
figure 5.3 development of the transport demand by sector in the energy [r]evolution scenario 59
figure 5.4 development of heat demand by sector in the energy [r]evolution scenario 59
figure 5.5 electricity generation structure under the reference scenario and the energy [r]evolution scenario 60
figure 5.6 total electricity supply costs & specific electricity generation costs under two scenarios 61
figure 5.7 investment shares - reference scenario versus energy [r]evolution scenario 61
figure 5.8 heat supply structure under the reference scenario and the energy [r]evolution scenario 62
figure 5.9 investments for renewable heat generation technologies under the reference scenario and the energy [r]evolution scenario 63
figure 5.10 final energy consumption for transport under the reference scenario and the energy [r]evolution scenario 64
figure 5.11 primary energy consumption under the reference scenario and the energy [r]evolution scenario 65
figure 5.12 development of CO_2 emissions by sector under the energy [r]evolution scenarios 65

6

figure 6.1 employment in the energy sector under the reference scenario and the energy [r]evolution scenarios 71
figure 6.2 employment in the energy sector by technology in 2010 and 2030 72

7

figure 7.1 global power plant market 1970-2010 79
figure 7.2 global power plant market 1970-2010, excl china 80
figure 7.3 europe (eu 27): annual power plant market 1970-2010 80
figure 7.4 power plant market shares 1970-2010 81
figure 7.5 new installed capacity and decommissioned capacity in mw. total 35,468 mw. 82

8

figure 8.1 development of final energy use per transport mode from 2010 to 2050 in the reference scenario 84
figure 8.2 world (stock-weighted) passenger transport energy intensity for 2009 and 2050 86
figure 8.3 world average (stock-weighted) freight transport energy intensity in the energy [r]evolution scenario 86
figure 8.4 fuel share of electric and diesel rail traction for passenger and freight transport 88
figure 8.5 sales share of vehicle technologies up to 2050 in the energy [r]evolution scenario for new zealand 89

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

list of tables

2

table 2.1	power plant value chain	23
table 2.2	german government short, medium and long term binding targets	33

3

table 3.1	how does the current renewable energy market work in practice?	35
table 3.2	categorisation of barriers to renewable energy investment	38

4

table 4.1	population development projections	42
table 4.2	gdp development projections	43
table 4.3	development projections for fossil fuel and biomass prices in $NZ	43
table 4.4	assumptions on CO_2 emissions cost development for Annex-B and Non-Annex-B countries of the UNFCCC	44
table 4.5	development of efficiency and investment costs for selected new power plant technologies	45
table 4.6	photovoltaics (pv) cost assumptions	46
table 4.7	concentrating solar power (csp) cost assumptions	46
table 4.8	wind power cost assumptions	47
table 4.9	biomass cost assumptions	47
table 4.10	geothermal cost assumptions	48
table 4.11	ocean energy cost assumptions	48
table 4.12	hydro power cost assumptions	49
table 4.13	overview over expected investment costs for pathways for heating technologies	50
table 4.14	overview of key parameter of the illustrative scenarios based on assumptions that are exogenous to the models respective endogenous model results	56

5

table 5.1	renewable electricity generation capacity under the reference scenario and the energy [r]evolution scenario	60
table 5.2	renewable heating capacities under the reference scenario and the energy [r]evolution scenario	62
table 5.3	renewable heat generation capacities under the reference scenario and the energy [r]evolution scenario	63
table 5.4	transport energy demand by mode under the reference scenario and the energy [r]evolution scenario	64
table 5.5	investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario	66

6

table 6.1	methodology overview	68
table 6.2	employment factors used in the 2012 analysis for new zealand	69
table 6.3	technology cost decline factors	70
table 6.4	total employment in the energy sector	71
table 6.5	employment in the energy sector by technology, two technologies	72
table 6.6	solar heating: capacity, heat supplied and direct jobs	73
table 6.7	geothermal and heat pump heating: capacity, heat supplied and direct jobs	73
table 6.8	biomass heat: direct jobs in fuel supply	73
able 6.9	hydro: capacity, generation and direct jobs	74
table 6.10	biomass: capacity, generation and direct jobs	74
table 6.11	geothermal power: capacity, generation and direct jobs	75
table 6.12	wind energy: capacity, generation and direct jobs	75
table 6.13	solar photovoltaics: capacity, generation and direct jobs	75
table 6.15	fossil fuels: capacity, generation and direct jobs	76

8

table 8.1	selection of measure and indicators	85

9

table 9.1	conversion factors – fossil fuels	92
table 9.2	conversion factors – different energy units	92
table 9.3-9.17	new zealand scenario results	94

introduction

"NOT LEAST IN TIMES OF TIGHT PUBLIC BUDGETS, CREDIBLE LONG-TERM COMMITMENTS ARE NEEDED. TARGETS HAVE PROVEN TO BE A KEY ELEMENT FOR TRIGGERING THE VITAL INVESTMENTS WHICH ARE NEEDED FOR A TRANSITION TO A SUSTAINABLE ENERGY SYSTEM."

image SUNLIGHT RAYS POUR THROUGH FERN LEAVES IN A NEW ZEALAND FOREST.

This 2nd edition of the New Zealand Energy [R]evolution comes at a critical juncture in our energy history. The energy policy choices being made by the New Zealand Government in the next few years will determine whether the country can become less dependent on economically and environmentally costly fossil fuels.

Despite having an electricity sector that in 2011 supplied over 70% electricity from renewable resources, mainly from hydro, the overall energy picture is looking bleak. The Government's Energy Strategy is clearly focused on achieving a major escalation of petroleum and coal extraction whilst undermining our renewables industry by further weakening the Emissions Trading Scheme. And in its strongest signal yet to the rest of the world about where the Government stands on climate change, New Zealand withdrew from the second commitment term of the legally binding Kyoto Protocol.

The Government has renewed its commitment to the target of 90% of our electricity coming from renewable energy by 2025. However, there is no strategy for getting there and it has overlooked the necessary electricity market policy measures that will enable this target to be met. This is clearly evident in the Government's latest forecast that we will only achieve 80% renewable electricity supply in 2030, with both coal and gas still supplying almost 20% of electricity demand.

With its support for the massive development of the country's lignite coal reserves for liquid fuels and its preferred focus on a major road building scheme over public transport investment, New Zealand is on the verge of being locked into a high carbon energy pathway. This will prove both costly and damaging to consumers and the economy in the decades ahead.

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.

However, New Zealand is endowed with a wealth of renewable energy resources with world class expertise in renewable energy technologies, especially in geothermal energy, that could be the foundation of a major export industry. With the right Government support and market framework, New Zealand businesses could rightly claim a lucrative share of the rapidly expanding global clean energy market.

This publication shows that the New Zealand Energy [R]evolution scenario creates 5,000 more jobs by 2030 than the business as usual reference case, where little is done to support a shift to renewable energy. Renewable energy and increased energy efficiency are the effective means of both reducing emissions and improving security of energy supply.

The New Zealand Energy [R]evolution 2013 presents a blueprint for how to achieve a more sustainable energy system now and for generations to come. Such a profound change will deliver a variety of skilled home-grown green jobs at a time when manufacturing jobs are being lost and unemployment is on the rise. Investment in renewable energy, which is now becoming competitive with fossil fuels, can also help cut household bills and improve well-being.

Under this Energy [R]evolution scenario, New Zealand will become the role-model for the rest of the world in achieving in low carbon, prosperous economy. It will boost the national wealth, reduce costs to consumers and create new industries and jobs that can compete on the world stage. New Zealanders will once again pioneer the energy solutions to the world's greatest challenge, climate change.

Sven Teske
CLIMATE & ENERGY UNIT
GREENPEACE INTERNATIONAL

Simon Boxer
CLIMATE TEAM LEADER
GREENPEACE NEW ZEALAND

Steve Sawyer
SECRETARY GENERAL
GLOBAL WIND ENERGY
COUNCIL (GWEC)

FEBRUARY 2013

executive summary

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

© BRIAN SCANTLEBURY/DREAMSTIME

image WIND TURBINES ON HILLS OF MANAWATU FARMLAND, NEW ZEALAND.

The expert consensus is that a fundamental shift in the way we consume and generate energy must begin immediately and be well underway within the next ten years in order to avert the worst impacts of climate change.[1] The scale of the challenge requires a complete transformation of the way we produce, consume and distribute energy, while maintaining economic growth. The five key principles behind this Energy [R]evolution will be to:

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

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

the energy [r]evolution – key results

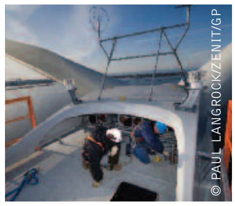
Renewable energy sources accounted for 36.2% New Zealand's primary energy demand in 2009. The main sources are geothermal, hydro and biomass, which are mostly used in the power and the heat sector.

Renewables contributed about 72% for electricity generation and for heat supply around 41%, thereof mostly biomass and geothermal heat but increasingly from heat pumps and - although to a much lower extend - solar thermal collectors as well. About 74% of the primary energy supply today still comes from fossil fuels.

The Energy [R]evolution scenario describes development pathways to a sustainable energy supply, achieving the urgently needed CO_2 reduction target and a fossil fuel phase-out. The results of the Energy [R]evolution scenario which will be achieved through the following measures:

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.



- **Curbing energy demand:** The New Zealand energy demand is projected by combining population development, GDP growth and energy intensity. Under the Reference scenario, total primary energy demand in New Zealand increases by 17% from the current 737 PJ/a to 860 PJ/a in 2050. The energy demand in 2050 in the Energy [R]evolution scenario increases only by 0.4% compared to current consumption and it is expected by 2050 to reach 740 PJ/a.
- **Controlling power demand:** Under the Energy [R]evolution scenario, electricity demand in the industry as well as in the residential and service sectors is expected to decrease after 2015. Because of the growing shares of electric vehicles, heat pumps and hydrogen generation, however, electricity demand increases to 54 TWh/a in 2050, still 2% below the Reference case.
- **Reducing heating demand:** Efficiency gains in the heat supply sector are larger than in the electricity sector. Under the Energy [R]evolution scenario, final demand for heat supply can even be reduced significantly. Compared to the Reference scenario, consumption equivalent to 50 PJ/a is avoided through efficiency measures by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a lower future energy demand.
- **Electricity generation:** The development of the electricity supply market is characterised by a dynamically growing renewable energy market. By 2025, 100% of the electricity produced in New Zealand will come from renewable energy sources. 'New' renewables – wind, geothermal, PV and ocean energy – will contribute 52% of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 94% already by 2020. The installed capacity of renewables will reach 13 GW in 2030 and 17 GW by 2050.
- **Future costs of electricity generation:** The introduction of renewable technologies under the Energy [R]evolution scenario does not increase the costs of electricity generation in New Zealand compared to the Reference scenario. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be NZ$ 1.9 cents/kWh below those in the Reference version.
- **The future electricity bill:** Under the Reference scenario, the unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's NZ$ 5.5 billion per year to NZ$ 6.9 billion in 2050. The Energy [R]evolution scenario not only complies with New Zealand´s CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are still 1% lower than in the Reference scenario, although costs for efficiency measures of up to NZ$ 5 ct/kWh are taken into account.
- **Future investment in power generation:** It would require about NZ$ 62 billion in investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately NZ$ 9 billion or NZ$ 0.23 billion annually more than in the Reference scenario (NZ$ 53 billion). Under the Reference scenario, the levels of investment in conventional power plants add up to almost 8% while around 92% would be invested in renewable energy and cogeneration (CHP) until 2050. Under the Energy [R]evolution scenario, however, New Zealand would shift almost 100% of its entire energy investment towards renewables and cogeneration. The average annual investment in the power sector under the Energy [R]evolution scenario between today and 2050 would be approximately NZ$ 1.55 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 NZ$ 35 billion up to 2050, or NZ$ 0.88 billion per year. The total fuel cost savings based on the assumed energy price path therefore would cover 300% of the total additional investments compared to the Reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on the economy.
- **Heating supply:** The lack of district heating networks is a severe structural barrier to the large scale utilisation of geothermal and solar thermal energy. In the Energy [R]evolution scenario, renewables provide 67% of New Zealand's total heat demand in 2030 and 94% in 2050. Energy efficiency measures can decrease the current total demand for heat supply by at least 10%, in spite of growing population and economic activities and improving living standards. For direct heating, solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for fossil fuel-fired systems. The introduction of strict efficiency measures e.g. via strict building standards and ambitious support programs for renewable heating systems are needed to achieve economies of scale within the next 5 to 10 years.

- **Future investments in the heat sector:** The heat sector in the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially the solar, geothermal and heat pump technologies need enormous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity need to be increased by the factor of 50 for solar thermal and by the factor of 10 for geothermal and heat pumps. Capacity of biomass technologies, which are already rather wide spread still need to remain a pillar of heat supply. Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated geothermal systems and solar thermal district heating plants. Thus it can only roughly be calculated that the Energy [R]evolution scenario in total requires around NZ$ 42 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately NZ$ 1 billion per year. Due to a lack of information on costs for conventional heating systems and fuel prices, total investments and fuel cost savings for the heat supply in the scenarios have not been estimated.

- **Future employment in the energy sector:** The Energy [R]evolution scenario results in more energy sector jobs in New Zealand at every stage of the projection. There are about 8,400 energy sector jobs in the Energy [R]evolution in 2015, and just over 7,000 in the Reference scenario. By 2020, there are nearly 8,600 jobs In the Energy [R]evolution scenario, about 2,700 more than in the Reference case. By 2030, strong growth in the [R]evolution scenario boosts employment figures up to about 11,000 persons, significantly greater than the 6,100 jobs estimated for the Reference scenario at that same time.

- **Transport:** In the transport sector, it is assumed under the Energy [R]evolution scenario that an energy demand reduction of about 87 PJ/a can be achieved by 2050, saving 42% compared to the Reference scenario. Energy demand will therefore decrease between 2009 and 2050 by 39% to 118 PJ/a. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns. Implementing a mix of increased public transport as attractive alternatives to individual cars, the car stock is growing slower and annual person kilometres are lower than in the Reference scenario. A shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains and the reduction of vehicle kilometres travelled lead to significant energy savings. In 2030, electricity will provide 8% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 33%. Sustainable biofuels are expected to play an important role in the future road transport sector, achieving a final energy share of 53% in 2050.

- **Primary energy consumption:** Under the Energy [R]evolution scenario the overall primary energy demand will be reduced by 14% in 2050. Most of the remaining demand will be covered by renewable energy sources. The Energy [R]evolution scenario leads to an overall renewable primary energy share of 72% in 2030 and 92% in 2050.

- **Development of CO_2 emissions:** While CO_2 emissions in New Zealand will decrease by 16% in the Reference scenario, under the Energy [R]evolution scenario they will decrease from around 30 million tonnes in 2009 to 2 million tonnes in 2050. Annual per capita emissions will drop from 6.8 tonnes to 2.3 tonnes in 2030 and 0.3 tonne in 2050. In the long run efficiency gains and the increased use of renewable electricity and biofuels in vehicles will reduce emissions in the transport sector. The transport sector remains as the largest source of emissions. By 2050, New Zealand's CO_2 emissions are 8% of 1990 levels.

policy changes

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

1. Phase out all subsidies for fossil fuels.
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

THE NEW ZEALAND GOVERNMENT'S ENERGY STRATEGY

RENEWABLE ENERGY TARGETS

POLICY CHANGES IN THE ENERGY SECTOR

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

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

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

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

1.1 the UNFCCC and the kyoto protocol

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

box 1.1: what does the kyoto protocol do?

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

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

At the 2012 Conference of the Parties in Durban, there was agreement to reach a new agreement by 2015. There is also agreement to adopt a second commitment period at the end of 2012. However, the United Nations Environment Program's examination of the climate action pledges for 2020 shows that there is still a major gap between what the science demands to curb climate change and what the countries plan to do. The proposed mitigation pledges put forward by governments are likely to allow global warming to at least 2.5 to 5 degrees temperature increase above pre-industrial levels.[2]

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

- 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.

reference
2 UNEP EMISSIONS GAP REPORT.

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

1.3 the new zealand government's energy strategy

The key aspects of the New Zealand Government's Energy Strategy were published in August 2011 and are broken down into four priority areas as follows:

Priority: Develop resources

Areas of focus:

1. Develop petroleum and mineral fuel resources.
2. Develop renewable energy resources.
3. Embrace new energy technologies.

Priority: Secure and affordable energy

Areas of focus:

1. Competitive energy markets deliver value for money.
2. Oil security and transport.
3. Reliable electricity supply.

Priority: Efficient use of energy

Areas of focus:

1. Better consumer information to inform energy choices.
2. Enhance business competitiveness through energy efficiency.
3. An energy efficient transport system.
4. Warm, dry, energy efficient homes.

Priority: Environmental responsibility

Areas of focus:

1. Best practice in environmental management for energy projects.
2. Reduce energy-related greenhouse gas emissions.

Fundamentally the New Zealand Government's strategic approach to economic and energy policy is based on a neo-liberal doctrine. Therefore in principal the Government does not intervene in the regulation of markets and is continuing with the privatization of State Owned Enterprises (SOE), especially in the energy sector, and continues to lower trade barriers across the economy. In practice, however the Government has been more selective across the various parts of the energy sector about its level of prioritization and level of involvement.

Within the four priority areas, key policies identified by the Government are outlined that it asserts are delivering changes to the energy sector. However, the impacts of these policies have been detrimental to the development of renewable energy and energy efficiency.

1.3.1 policies

"The Government wants New Zealand to be a highly attractive global destination for petroleum exploration and production investment so we can develop the full potential of our petroleum resources. Significant discoveries of oil and gas resources will help boost New Zealand's foreign earnings and domestic gas supplies."

In practice;

- This is the main priority within the Energy Strategy and is the area of policy that the Government has spent the most time and money on achieving. The Government has pinned its hopes for economic recovery on revenues from oil and gas extraction, along with coal mining. To that end, it has created an industry-friendly policy and operational environment, offering inducements and tax breaks designed to lure international oil companies to New Zealand.
- The New Zealand Petroleum and Minerals department was formed on 2 May 2011 from the old Crown Minerals Business Unit of the Ministry of Economic Development. In the 2011 fiscal year the department has increased its full time equivalent staff numbers by 35%[3], while most other Ministries are required to cut staff and reduce expenditure.
- Since 2004, the Government has also been acquiring and making available scientific data about New Zealand's oil reserves to oil companies for free, including a recent $ 25 million programme[4] paid for by taxpayers to complete seismic surveys over new frontier basins and to rework old seismic data.
- The Government has extended until the end of 2014 an exemption from tax on the profits of non-resident operators of offshore rigs and seismic vessels.[5]
- The Government has also prioritised creating a pathway to develop potential offshore gas hydrates, despite major climate change concerns over this potential fuel.

"The Government retains the target that 90 percent of electricity generation be from renewable sources by 2025 (in an average hydrological year) providing this does not affect security of supply."

In practice;

- The Government has kept this inherited target, although it has not put in place any specific market policy measures to enable this target to be met.
- In fact the weakening of Emissions Trading Scheme (ETS) and thereby reducing the price of carbon in New Zealand has impacted on further renewable energy development.
- The Government's latest modeling forecast of electricity supply is projecting less than 80% renewable energy by 2025 with both coal and gas still supplying 20% of electricity demand by 2025.[6]

references

3 HTTP://WWW.MED.GOVT.NZ/ABOUT-US/PUBLICATIONS/CORPORATE-PUBLICATIONS/ANNUAL-REPORT-CURRENT/ANNUAL-REPORT-2012.PDF

4 SEE P2 AND P8 HTTP://WWW.NZPAM.GOVT.NZ/CMS/PDF-LIBRARY/ABOUT/ANNUAL%20REPORT%20WEB%20VERSION.PDF

5 HTTP://WWW.IRD.GOVT.NZ/TECHNICAL-TAX/LEGISLATION/2010/2010-109/2010-109-FIVE-YEAR-EXTENSION

6 HTTP://WWW.MED.GOVT.NZ/SECTORS-INDUSTRIES/ENERGY/ENERGY-MODELLING/MODELLING/NEW-ZEALANDS-ENERGY-OUTLOOK.

"The electricity market governance changes and Resource Management Act reforms have adjusted the regulatory framework to facilitate appropriate investment."[7]

In practice;

- The five State Owned Enterprises (SOE) in energy have had their assets shuffled ostensibly to make them more competitive but practically to prepare them for privatisation.
- The market operator rules were changed to allow energy companies to legally maximise returns from the market whenever there is a grid constraint. This is central step to prepare the sector for privatization which has resulted in higher prices and examples of 'price gouging' by energy companies.

"The New Zealand Emissions Trading Scheme (ETS) provides a price incentive for reducing carbon emissions."[8]

In practice;

- The Government 'reformed' the ETS in a way that forces the price of carbon to the lowest available global price, regardless of the quality of the carbon credit, by repealing restrictions on the type of units that could be surrendered under our obligation. Those restrictions were similar to the European Union's restrictions. Now there are no restrictions.
- The Government's policy is to "Maintain the ETS settings to ensure businesses and households do not face additional costs"[9] This defeats the price signal purpose of having an ETS, and has therefore weakened the ETS to the extent that it is now merely window dressing.
- The Government repealed the 'thermal ban' clause of the ETS legislation[10], which had originally severely restricted any new thermal electricity generation from being built.

"The Resource Management Act 1991 (RMA) provides New Zealand with a resource management framework that gives due consideration to the benefits and adverse effects of developments. The Government's aim is to ensure this framework is administered effectively while minimising delays and costs for all parties." [11]

In practice;

- The Resource Management Act (RMA), which stipulates how consents for development are given was weakened 'to facilitate appropriate investment'. Public consultation has been curbed and the Minister has been granted powers to 'call in' key projects.
- This means that developments of all kinds, including high carbon energy projects, can be fast tracked without due consideration of environmental impacts. A number of tests have been replaced with purely economic ones. The Minister of Energy now has authority to directly input into consents on Conservation Land based on economic criteria.

"The Government has injected new funds into upgrading transport infrastructure to create an efficient mix of integrated modes and travel options."[12]

In practice;

- The Government has a mixed record of simultaneously weakening some and strengthening other vehicle emission standards for new and used import vehicles. The Government halted the introduction of a vehicle fuel economy standard that would have significantly lowered the gm/km of CO_2 of our very old, dirty fleet.[13]
- The Government repealed a very modest biofuel sales obligation[14], which has impacted on the emerging New Zealand biofuels sector. Consumption of biodiesel and bio-ethanol in New Zealand in 2011 was still 0.3% of diesel and 1.2% of petrol consumption. Therefore instead of achieving the original target of 2.5%, consumption is only at 1.2% biofuels.[15]
- The Government maintains an 8:1 ratio of road to public transport funding[16], and together with the roll-back of vehicle efficiency noted above, means that New Zealand is becoming even more dependent on oil.
- The Government has simultaneously weakened and delayed the introduction of Clean Air Standards.[17]

"Making improvements in energy efficiency, energy conservation and renewable energy is an important priority for the Government. As such, the New Zealand Energy Efficiency and Conservation Strategy (NZEECS) contributes to the delivery of the Government's energy priorities set out in the New Zealand Energy Strategy."[18]

In practice;

- This statutory document in theory provides the strategy by which the aspirations outlined in the Energy Strategy will be achieved. It outlines a number of targets across a number of sectors, which are identical in most respects to the targets put in place for the 2007 version of the strategy. The key difference is that there are no programmes or funding outlined to achieve the targets as there were in 2007.

references

7 NEW ZEALAND ENERGY STRATEGY 2011-2021, DEVELOPING OUR ENERGY POTENTIAL, MINISTRY OF ECONOMIC DEVELOPMENT, AUGUST 2011.
8 IBID.
9 HTTP://WWW.MBIE.GOVT.NZ/WHAT-WE-DO/BUSINESS-GROWTH-AGENDA/PDF-FOLDER/BGA-NATURAL-RESOURCES-REPORT-DECEMBER-2012.PDF (PAGE 29).
10 HTTP://WWW.BEEHIVE.GOVT.NZ/RELEASE/THERMAL-BAN-REPEAL
11 IBID 7.
12 IBID 7.
13 HTTP://WWW.SCOOP.CO.NZ/STORIES/PA0908/S00433.HTM.
14 HTTP://WWW.BEEHIVE.GOVT.NZ/RELEASE/BIOFUEL-OBLIGATION-LAW-REPEALED
15 HTTP://WWW.MED.GOVT.NZ/SECTORS-INDUSTRIES/ENERGY/ENERGY-MODELLING/PUBLICATIONS/ENERGY-DATA-FILE
16 HTTP://WWW.TRANSPORT.GOVT.NZ/OURWORK/KEYSTRATEGIESANDPLANS/DOCUMENTS/GPS%202012%20FOR%20PUBLICATION%20-%20OCT%20REVISION_1.1_V2.PDF
17 HTTP://WWW.MFE.GOVT.NZ/LAWS/STANDARDS/AIR-QUALITY/REVIEW/INDEX.HTML
18 IBID 7.

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

- Almost the entire energy efficiency programme of the previous Government's energy strategy has been halted or turned into 'information only campaigns'. The only efficiency programme to survive intact is the Home Insulation Scheme which was too popular with voters to cut despite the new government's promise to do so during the election. The Government has committed $340 million over four years to the programme with the aim of improving at least 188,500 homes.[19] However, the Government shelved the high efficiency light bulb and shower head schemes.[20]

1.4 renewable energy targets

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

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

Data from the wind and solar power industries show that it is possible to maintain a growth rate of 30 to 35% in the renewable energy sector. In conjunction with the European Photovoltaic Industry Association,[21] the European Solar Thermal Power Industry Association[22] and the Global Wind Energy Council,[23] 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.

1.5 policy changes in the energy sector

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

1. Phase out all subsidies for fossil fuels and nuclear energy.
2. Internalise 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.

Conventional energy sources globally receive an estimated $409 billion[24] 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.

references
19 IBID 7.
20 HTTP://BEEHIVE.GOVT.NZ/RELEASE/LIGHT-BULB-BAN-ENDED
21 SOLARGENERATION IV', SEPTEMBER 2009.
22 GLOBAL CONCENTRATED SOLAR POWER OUTLOOK – WHY RENEWABLES ARE HOT!' MAY, 2009.
23 GLOBAL WIND ENERGY OUTLOOK 2008', OCTOBER 2010.
24 IEA WORLD ENERGY OUTLOOK 2011', PARIS NOVEMBER 2011, CHAPTER 14, PAGE 507.

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

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

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

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

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

the energy [r]evolution concept

KEY PRINCIPLES | THE "3 STEP IMPLEMENTATION" | THE NEW ELECTRICITY GRID | CASE STUDY GERMANY

image MOUNT RUAPEHU ON THE NORTH ISLAND OF NEW ZEALAND AND ITS SUMMIT LAKE.

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.[25] 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.[26]

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

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

Sheikh Zaki Yamani, former Saudi Arabian oil minister

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

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

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

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

references

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

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.

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.[27]

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.

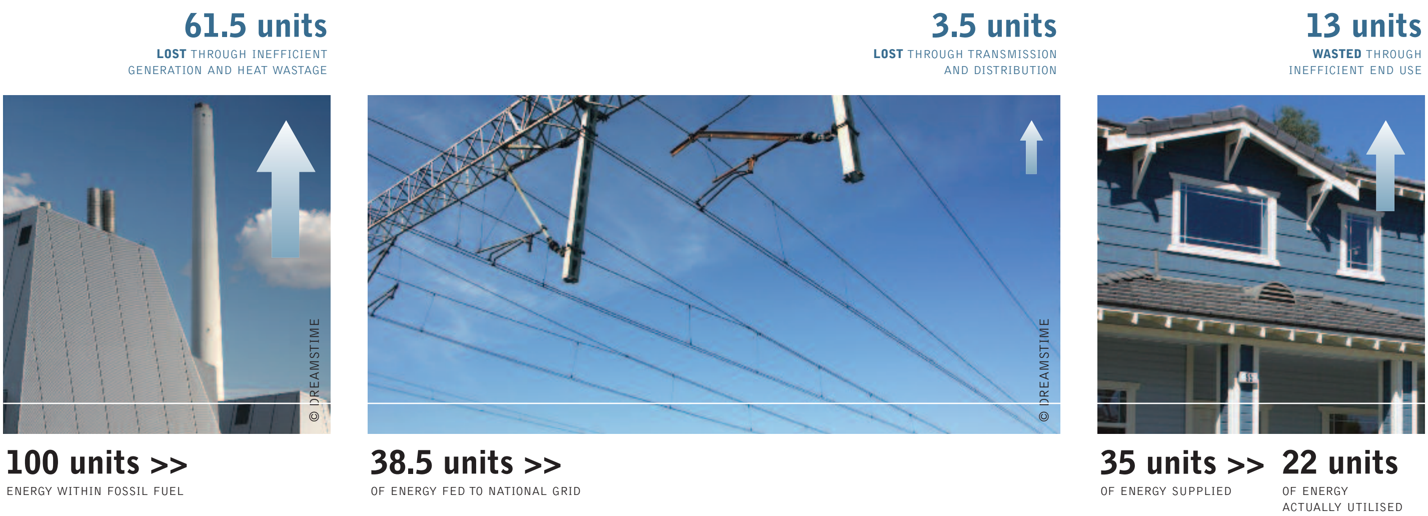
A transition phase is required to build up the necessary infrastructure because it is not possible to switch directly from a large scale fossil and nuclear fuel based energy system to a full renewable energy supply. Whilst remaining firmly committed to the promotion of renewable sources of energy, we 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
27 'IEA WORLD ENERGY OUTLOOK 2011, PARIS NOVEMBER 2011.

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.

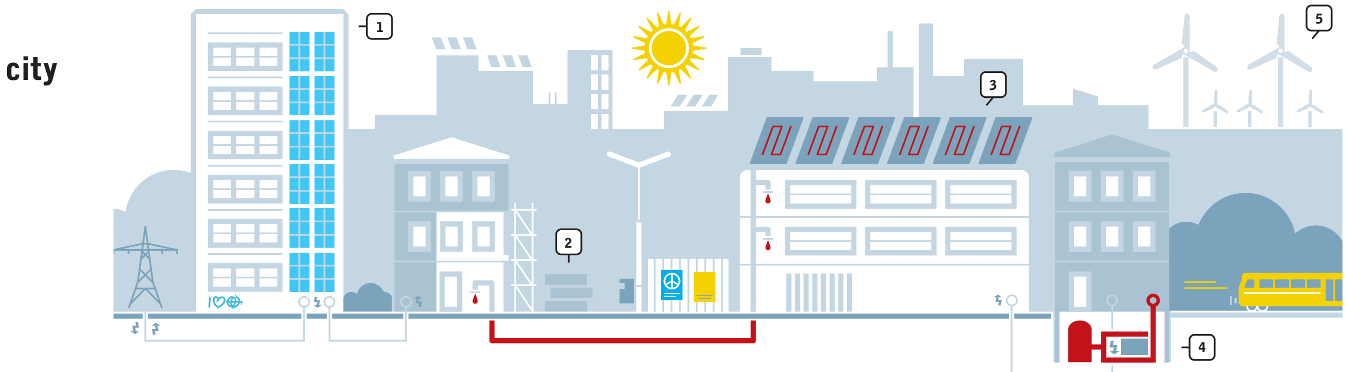
A huge proportion of global energy in 2050 will be produced by decentralised energy sources, although large scale renewable energy supply will still be needed for an energy revolution. Large offshore wind farms and concentrating solar power (CSP) plants in the sunbelt regions of the world will therefore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



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.

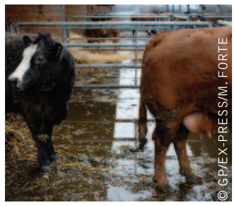


image COWS FROM A FARM WITH A BIOGAS PLANT IN ITTIGEN BERN, SWITZERLAND. THE FARMER PETER WYSS PRODUCES ON HIS FARM WITH A BIOGAS PLANT, GREEN ELECTRICITY WITH DUNG FROM COWS, LIQUID MANURE AND WASTE FROM FOOD PRODUCTION.

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, first generation biofuels are entirely banned now for use in private cars.[28] 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 few 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 - except biomass - will operate without the need of fuel supply.	Grid operation will move towards state controlled grid companies or communities due to liberalisation.
Market player							
Renewable power plant engineering companies							
Private & public investors							
Grid operator							

reference
28 SEE CHAPTER 8.

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'.[29] 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 27).

reference

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

image 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.

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.

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.[30] 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.[31] 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.[32] 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.

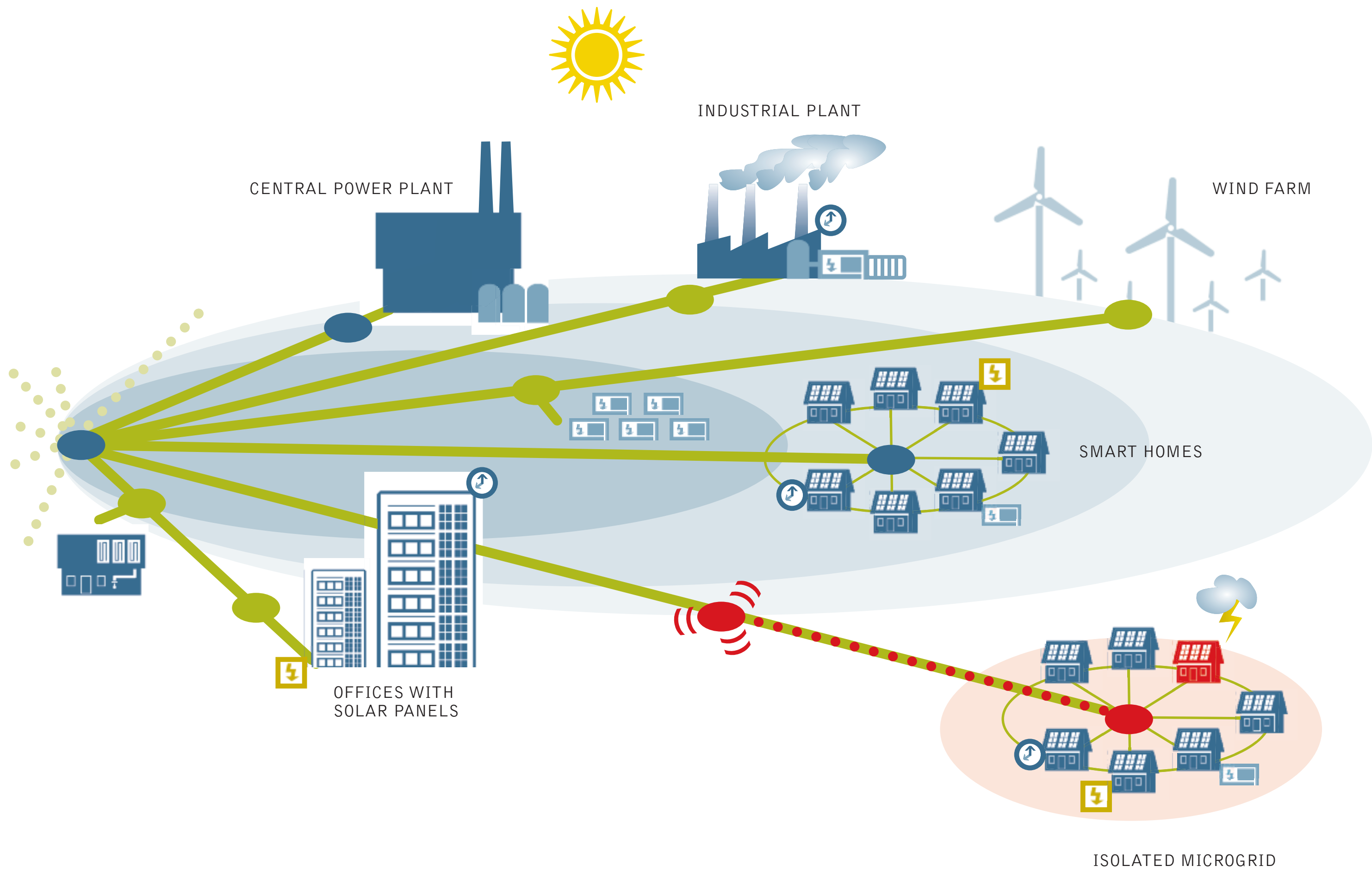
references

30 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.
31 SEE ALSO HTTP://WWW.KOMBIKRAFTWERK.DE/INDEX.PHP?ID=27.
32 SEE ALSO HTTP://WWW.SOLARSERVER.DE/SOLARMAGAZIN/ANLAGEJANUAR2008_E.HTML.

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

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

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.[33]

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?[34]

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

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

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

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

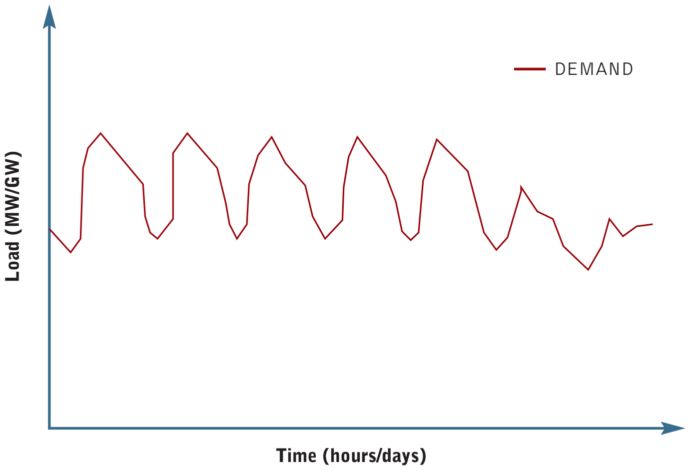
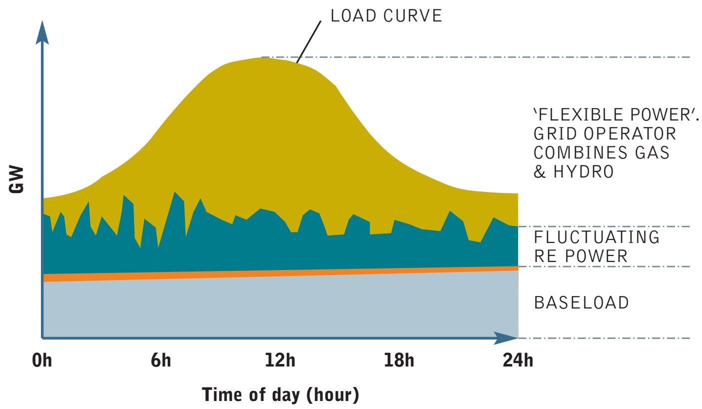


figure 2.5: the evolving approach to grids

Current supply system

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

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



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

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

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

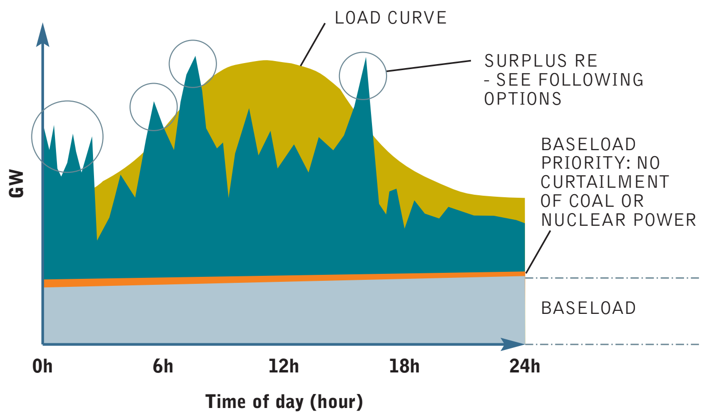
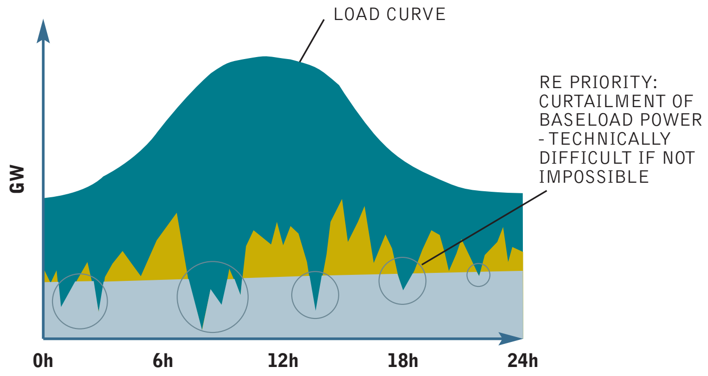


figure 2.5: the evolving approach to grids *continued*

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

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

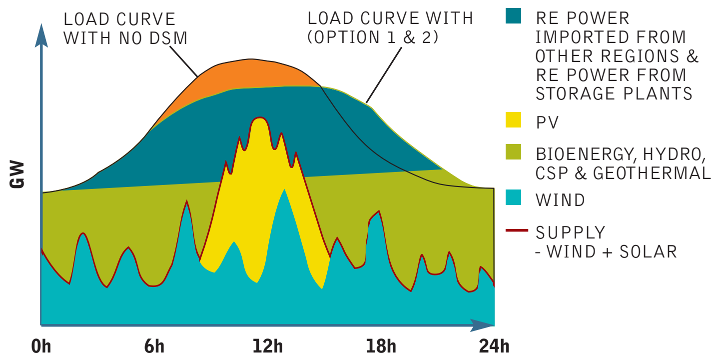
Technically difficult, not a solution.



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

- A fully optimised grid, where 100 percent renewables operate with storage, transmission of electricity to other regions, demand management and curtailment only when required.
- Demand-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.

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

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

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

2.4.1 target and method

The German government expects renewables to generate 35% of German electricity by 2020.[35] The German Federal Environment Agency believes that the phase out would be technically feasible from 2017, requiring only 5 GW of additional combined heat-and-power or combined cycle gas plant (other than those already under construction) to meet peak time demand.[36]

2.4.2 carbon dioxide emissions trends

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

However, the decision to phase out nuclear energy has renewed the political pressure to deliver a secure climate-friendly energy policy and ensure Germany still meets its greenhouse targets. The Energiewende ('energy transition') measures include €200 billion investment in renewable energy over the next decade, a major push on energy efficiency and an accelerated roll out of infrastructure to support the transition.[37] Germany has also become an advocate for renewables at the European level.[38] In the longer-term, by deploying a large amount of renewable capability Germany should be able to continue reducing its emissions at this accelerated rate and its improved industrial production should make it more viable for other countries to deliver greater and faster emissions reductions.

2.4.3 shortfall from first round of closures

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

In 2011 only 18% of the country's energy generation came from nuclear.[39] In the previous year, nuclear energy's contribution had already fallen from 22% to 18%, a shortfall covered mostly by renewable electricity which increased from 16% to 20% in the same period, while use of lignite (a greenhouse-intensive fossil fuel) increased from 23% to 25%.

In the first half of 2011, Germany was a net exporter of electricity (Figure 2.9), exporting 29 billion kWh and importing 24 kWh.[40] Complete figures for electricity imports and exports in the second half of 2011 are not yet available, once nuclear reactors were decommissioned, however it is known that Germany exported electricity to France during a cold spell in February 2012.[41]

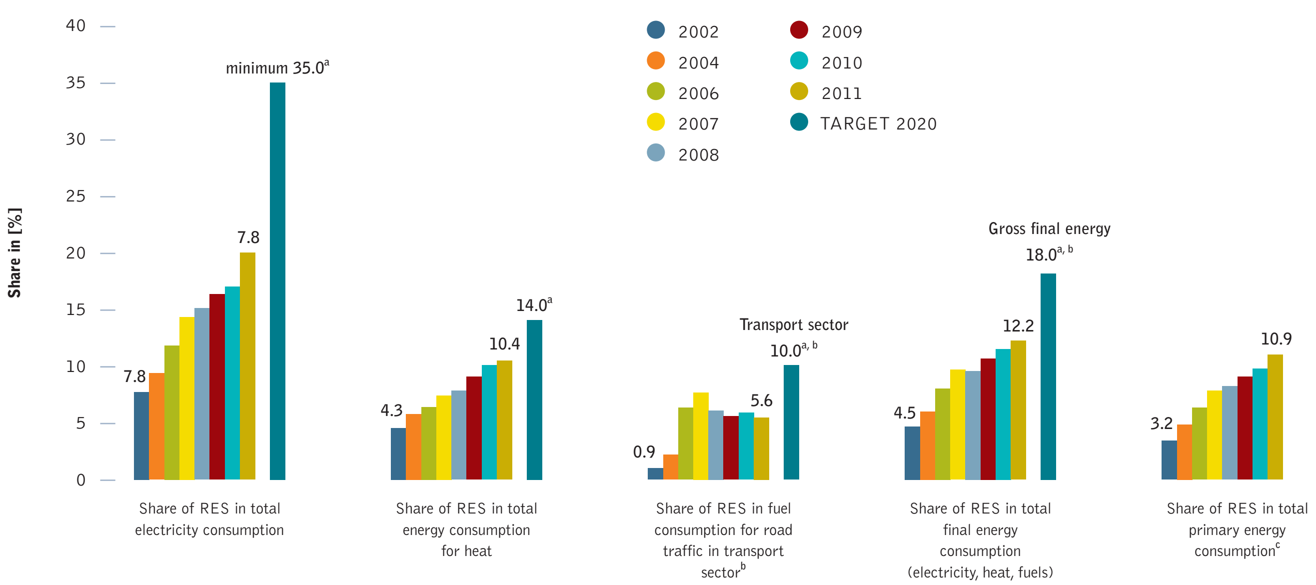
Inside Germany, the demand for energy is falling.[42] Between 2010 and 2011 energy demand dropped by 5%, because the mild weather reduced demand for gas heating. While the British government is planning for electricity demand in the UK to double by 2050, the German government expects a cut of 25% from 2008 levels.[43] Total energy demand is expected to halve over the same time period.

2.4.4 the renewable energy sector in germany

Germany has successfully increased the share of renewable energy constantly over the last twenty years (see Figures 2.6 and 2.7), and the sector was employing over 350,000 employees by the end of 2011. The back bone of this development has been the Renewable Energy Act (Erneuerbare Energien Gesetz – EEG); a feed-in law which guarantees a fixed tariff per kWh for 20 years. The tariffs are different for each technology and between smaller and larger, to reflect their market penetration rates.

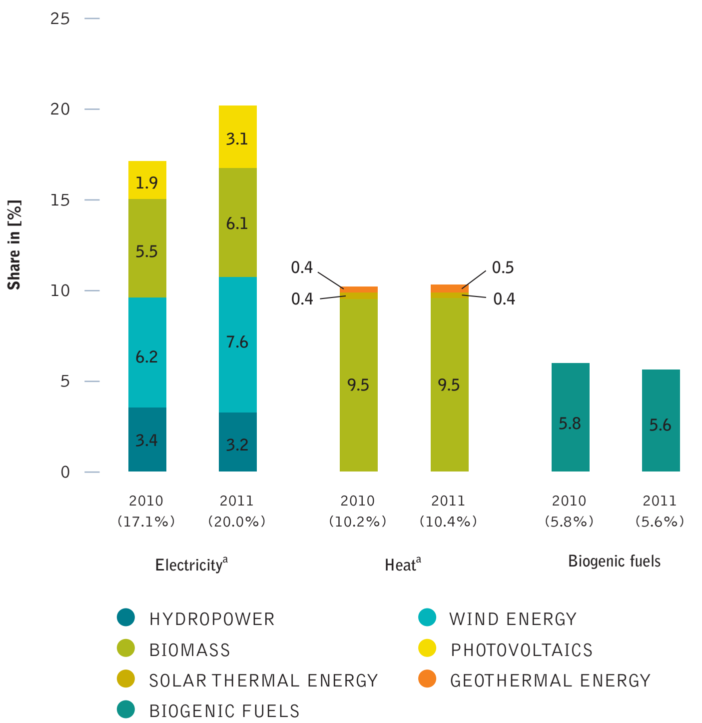
references
35 HTTP://WWW.UMWELTDATEN.DE/PUBLIKATIONEN/FPDF-L/4147.PDF
36 HTTP://WWW.UMWELTDATEN.DE/PUBLIKATIONEN/FPDF-L/4147.PDF
37 HTTP://WWW.ERNEUERBARE-ENERGIEN.DE/INHALT/47872/3860/
38 HTTP://WWW.ERNEUERBARE-ENERGIEN.DE/INHALT/48192/3860/
39 THE GERMAN ASSOCIATION OF ENERGY AND WATER INDUSTRIES (BDEW), 16 DECEMBER 2011. HTTP://WWW.BDEW.DE/INTERNET.NSF/ID/EN_?OPEN&CCM=900010020010
40 HTTP://WWW.BDEW.DE/INTERNET.NSF/ID/8EF9E5927BDAAE28C12579260029ED3B/$FILE/110912%20RICHTIGSTELLUNG%20IMPORT-EXPORT-ZAHLEN_ENGLISCH.PDF
41 HTTP://WWW.REUTERS.COM/ARTICLE/2012/02/14/EUROPE-POWER-SUPPLY-IDUSL5E8DD87020120214
42 HTTP://WWW.AG-ENERGIEBILANZEN.DE/COMPONENTEN/DOWNLOAD.PHP?FILEDATA=1329148695.PDF&FILENAME=AGEB_PRESSEDIENST_09_2011EN.PDF&MIMETYPE=APPLICATION/PDF
43 HTTP://WWW.BMU.DE/FILES/ENGLISH/PDF/APPLICATION/PDF/ENERGIEKONZEPT_BUNDESREGIERUNG_EN.PDF (PAGE 5)

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



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

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



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

2.4.5 energy and climate targets

The German government agreed on short, medium and long term – binding - targets for renewable, energy efficiency and greenhouse gas reduction (Table 2.2).

2.4.6 details of the german nuclear phase-out plan

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

2.4.7 no 'blackouts'

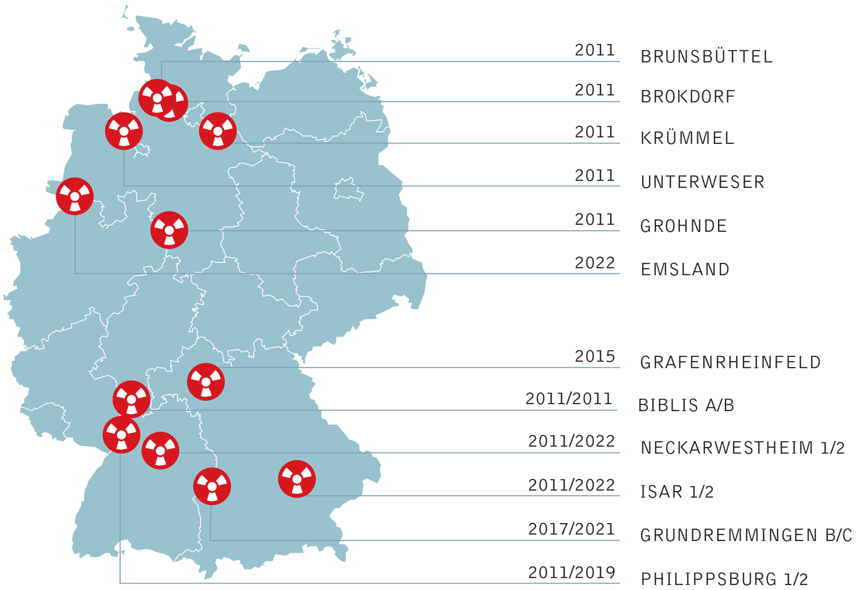
The nuclear industry has implied there would be a "black-out" in winter 2011 - 2012, or that Germany would need to import electricity from neighbouring countries, when the first set of reactors were closed. Neither event happened, and Germany actually remained a net- export of electricity during the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

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

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

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

figure 2.8: phase out of nuclear energy

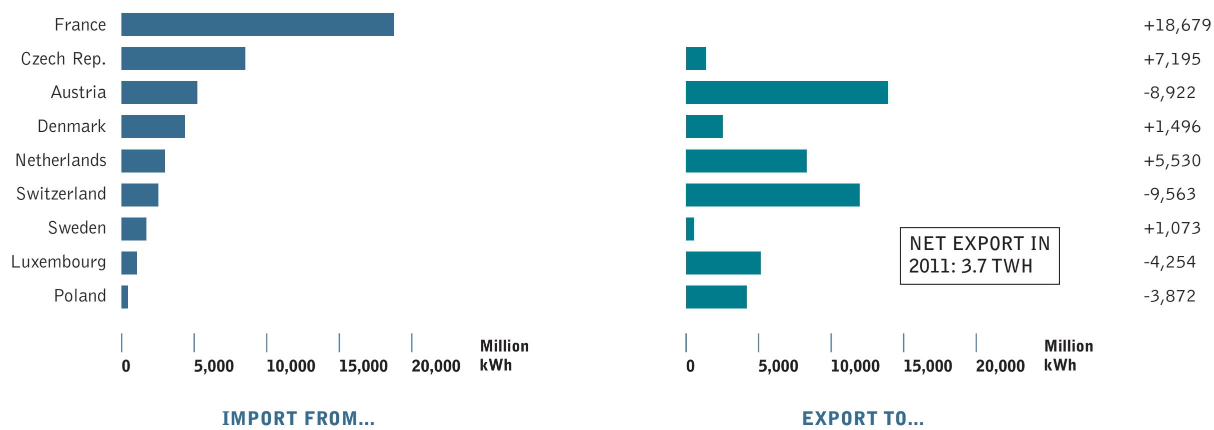


- Seven oldest plants plus Krümmel: immediate decommissioning
- Gradual phasing out of nuclear power by 2022
- Shutdown years: 2015, 2017, 2019, 2021, 2022

source UMWELTBUNDESAMT (UBA) 2012, GERMAN MINISTRY FOR ENVIRONMENT

figure 2.9: electricity imports/exports germany

JANUARY TO NOVEMBER 2011. (VOLUME MEASURE IN MILLION KWH)



implementing the energy [r]evolution

RENEWABLE ENERGY PROJECT PLANNING BASICS

RENEWABLE ENERGY FINANCING BASICS

> investments in renewables are investments in the future."

image THE SWIRLS OF TURQUOISE AND GREEN MAP OUT A LARGE PHYTOPLANKTON BLOOM ALONG THE SHORES OF NEW ZEALAND'S SOUTH ISLAND.

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).

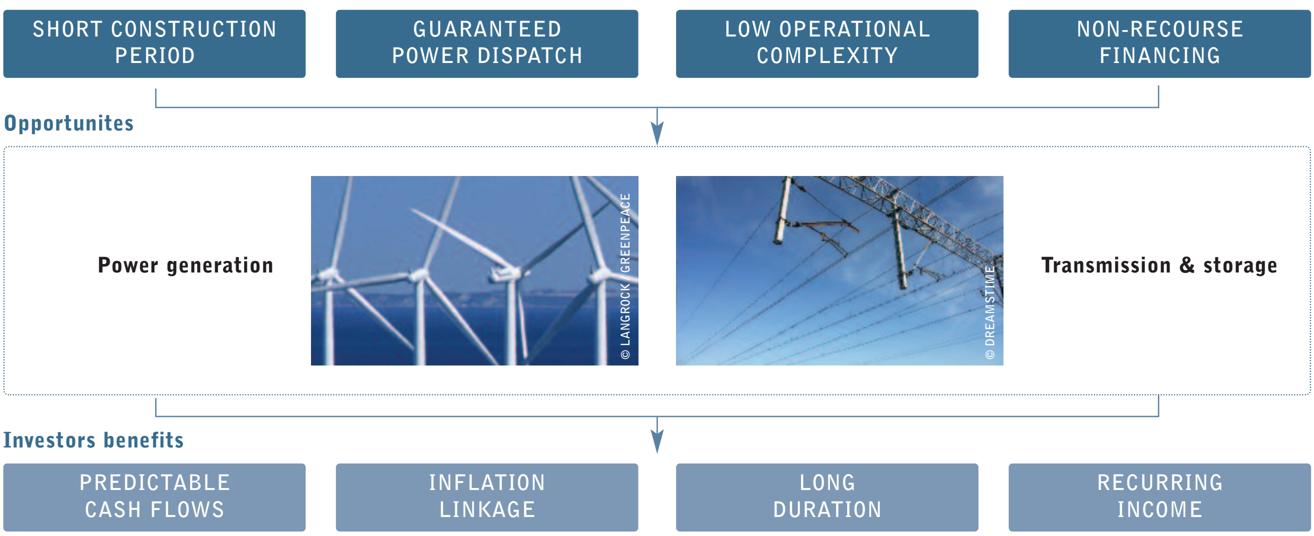
P = Project developer, **M** = Meteorological Experts, **I** = Investor, **U** = utility.

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

figure 3.1: return characteristics of renewable energies



source
SWISS RE PRIVATE EQUITY PARTNERS.

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

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

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

figure 3.2: overview risk factors for renewable energy projects

REGULATORY RISKS	CONSTRUCTION RISKS
FINANCING RISKS	OPERATIONAL RISKS

source
SWISS RE PRIVATE EQUITY PARTNERS.

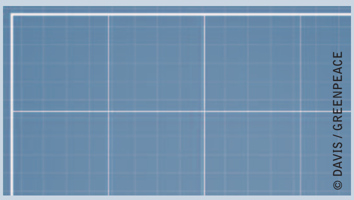
figure 3.3: investment stages of renewable energy projects

RISKS

Higher → **Lower**

Stage

DEVELOPMENT	CONSTRUCTION	OPERATIONS



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

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

- Operations
- Maintenance
- Refinancing
- Refurbishment/Repowering

Strategy

EARLY-STAGE GREENFIELD	LATE-STAGE GREENFIELD	BROWNFIELD

source
SWISS RE PRIVATE EQUITY PARTNERS.

3.2.1 overcoming barriers to finance and investment for renewable energy

table 3.2: categorisation of barriers to renewable energy investment

CATEGORY	SUB-CATEGORY	EXAMPLE BARRIERS
Barriers to finance	Cost barriers	Costs of renewable energy to generate Market failures (e.g. 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[44] 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[45] 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).

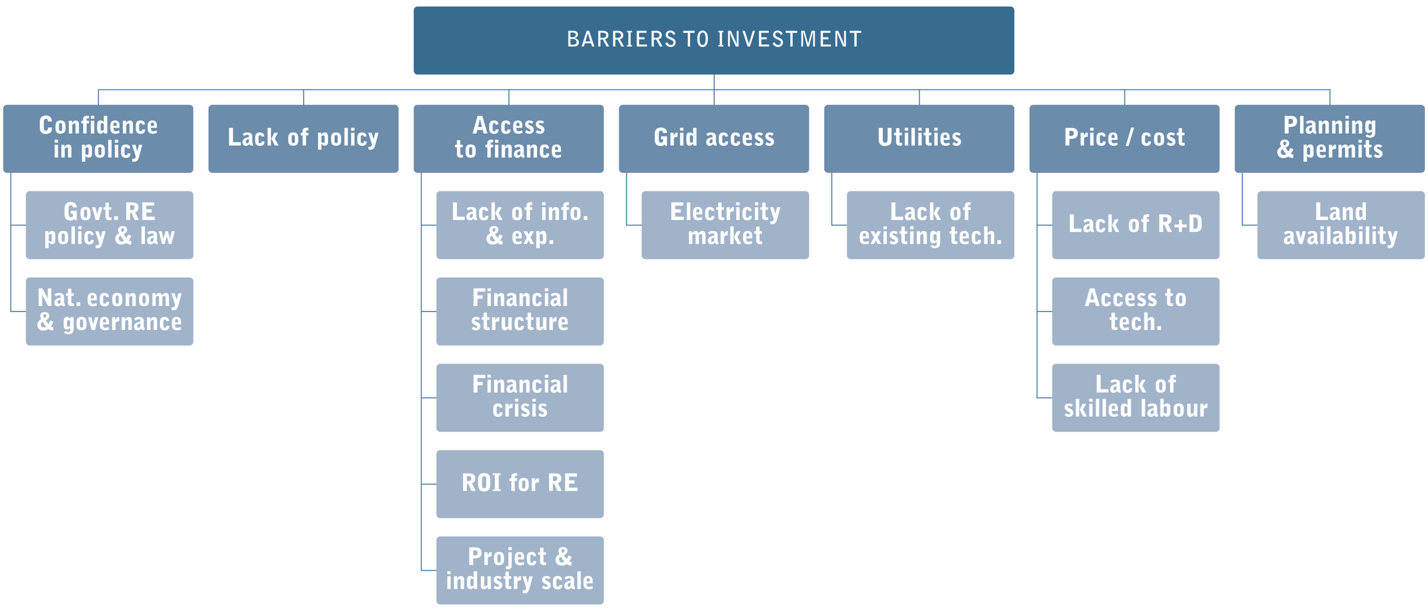
Concerns over planning and permit issues are significant, though vary significantly in their strength and nature depending on the jurisdiction.

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.[46]
- Access to finance can be increased by greater involvement of governments and development banks in programs like loan guarantees and green bonds as well as more active private investors.
- Grid access and infrastructure needs to be improved through investment in smart, decentralised grids.
- Lowering the cost of renewable energy technologies directly will require industry development and boosted research and development.
- A smoother pathway for renewable energy needs to be established through planning and permit issues at the local level.

figure 3.4: key barriers to renewable energy investment



references

44 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.

45 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.

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

scenario for a future energy supply

SCENARIO BACKGROUND

POPULATION DEVELOPMENT

ECONOMIC GROWTH

OIL AND GAS PRICE PROJECTIONS

COST OF CO_2 EMISSIONS

COST PROJECTIONS FOR EFFICIENT FOSSIL FUEL GENERATION AND CCS

COST PROJECTIONS FOR RENEWABLE HEATING TECHNOLOGIES

ASSUMPTIONS FOR FOSSIL FUEL PHASE OUT

REVIEW: GREENPEACE SCENARIO PROJECTS OF THE PAST

HOW DOES THE E[R] SCENARIO COMPARE TO OTHER SCENARIOS

4

© NASA/JESSE ALLEN

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

image 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).[47] 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, the 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 New Zealand which forms one of the key assumption for the Energy [R]evolution scenario. 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 compared to earlier versions of the Energy [R]evolution scenarios using a consistent approach based on technical efficiency potentials and energy intensities. One key difference for the new Energy [R]evolution for New Zealand is incorporating stronger efforts to develop better technologies to achieve CO_2 reduction. There is lower oil demand factored into the transport sector (compared to the scenario published in 2007), from a change in driving patterns and a faster uptake of efficient combustion vehicles and a larger share of biofuels, electric and plug-in hybrid vehicles especially after 2025.

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 generation can have high energy losses, however the limited potentials of biofuels and probably also battery electric mobility could make it necessary to have a third renewable option: Sustainable biofuels for the transport sector. The unique situation of New Zealand allows a limited amount of sustainable biofuels which will be grown, harvested and refined within New Zealand. The quantities of biomass power generators and large hydro power remain limited in the new Energy [R]evolution scenarios, for reasons of ecological sustainability.

In all sectors, the latest market development projections of the renewable energy industry[48] have been taken into account. The fast introduction of electric vehicles, combined with the implementation of smart grids and a further expansion of the transmission grid allows a high share of fluctuating renewable power generation (photovoltaic and wind) to be employed. In this scenario, renewable energy would pass 50% of New Zealands energy supply just after 2020.

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.

reference

47 INTERNATIONAL ENERGY AGENCY (IEA), 'WORLD ENERGY OUTLOOK 2011', OECD/IEA 2011.
48 SEE EREC ('RE-THINKING 2050'), GWEC, EPIA ET AL.

4.1 scenario background

The scenarios in this report were jointly commissioned by Greenpeace, the Global Wind Energy Council (GWEC) and the European Renewable Energy Council (EREC) 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.[49] 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 sustainable biomass potential assumed for New Zealand has been judged according to Greenpeace sustainability criteria. 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 projections from Statistics New Zealand[50] for population development

4.3 economic growth

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

Although PPP assessments are still relatively imprecise compared to statistics based on national income and product trade and national price indexes, they are considered to provide a better basis for a scenario development.[51] Thus all data on economic development in WEO 2011 refers to purchasing power adjusted GDP. However, as WEO 2011 only covers the time period up to 2035, the projections for 2035-2050 for the Energy [R]evolution scenario are based on our own estimates.

Prospects for GDP growth have decreased considerably since the previous study, due to the financial crisis at the beginning of 2009, although underlying growth trends continue much the same. GDP growth in all regions is expected to slow gradually over the coming decades. World GDP is assumed to grow on average by 3.8% per year over the period 2009-2030, compared to 3.1% from 1971 to 2007, and on average by 3.1% per year over the entire modelling period (2009-2050). China and India are expected to grow faster than other regions, followed by the Middle East, Africa, remaining Non-OECD Asia, and Eastern Europe/Eurasia. The Chinese economy will slow as it becomes more mature, but will nonetheless become the largest in the world in PPP terms early in the 2020s. GDP in New Zealand is assumed to grow by on average 1.4% per year over the projection period.

table 4.1: population development projection
(IN MILLIONS)

	2009	2015	2020	2025	2030	2040	2050
New Zealand	4.5	4.6	4.8	5.0	5.2	5.5	**5.7**

references
49 ENERGY [R]EVOLUTION: A SUSTAINABLE WORLD ENERGY OUTLOOK', GREENPEACE INTERNATIONAL, 2007, 2008 AND 2010.
50 HTTP://WWW.STATS.GOVT.NZ/BROWSE_FOR_STATS/POPULATION/ESTIMATES_AND_PROJECTIONS.ASPX
51 NORDHAUS, W, 'ALTERNATIVE MEASURES OF OUTPUT IN GLOBAL ECONOMIC-ENVIRONMENTAL MODELS: PURCHASING POWER PARITY OR MARKET EXCHANGE RATES?', REPORT PREPARED FOR IPCC EXPERT MEETING ON EMISSION SCENARIOS, US-EPA WASHINGTON DC, JANUARY 12-14, 2005.

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

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%
New Zealand	3.2%	1.5%	0.6%	1.4%
OECD Americas	2.7%	2.3%	1.2%	2.0%
OECD Asia Oceania	2.4%	1.4%	0.5%	1.3%
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 NZ$ 47 per barrel (/bbl) was assumed in 2030. More recent projections of oil prices by 2035 in the IEA's WEO 2011 range from NZ$135/bbl in the 450 ppm scenario up to NZ$194/bbl in current policies scenario.

Since the first Energy [R]evolution study was published in 2007, however, the actual price of oil has reached over NZ$ 139/bbl for the first time, and in July 2008 reached a record high of more than NZ$ 194/bbl. Although oil prices fell back to NZ$ 139/bbl in September 2008 and around NZ$ 111/bbl in April 2010, prices have increased to more than NZ$ 153/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 NZ$33-42/GJ by 2050.

table 4.3: development projections for fossil fuel and biomass prices in $NZ (BASED ON EXCHANGE RATE OF NZ$ 1.19 TO US$ 1 (FEBRUARY 2013)

FOSSIL FUEL	UNIT	2000	2005	2007	2008	2010	2015	2020	2025	2030	2035	2040	2050
Crude oil imports													
Historic prices (from WEO)	barrel	49	71	105	136	108							
WEO "450 ppm scenario"	barrel					108	135	135	135	135	135		
WEO Current policies	barrel					108	147	147	147	187	194		
Energy [R]evolution 2012	barrel					108	155	155	155	211	211	211	211
Natural gas imports													
Historic prices (from WEO)													
United States	GJ	7.03	3.26	4.55		6.44							
Europe	GJ	5.20	6.31	8.84		10.97							
Japan LNG	GJ	8.57	6.35	8.89		16.11							
WEO 2011 "450 ppm scenario"													
United States	GJ					6.44	8.63	9.52	11.71	12.28	11.42		
Europe	GJ					10.97	13.76	14.35	14.35	14.19	13.76		
Japan LNG	GJ					16.11	17.43	17.56	17.56	17.72	17.72		
WEO 2011 Current policies													
United States	GJ					6.44	8.94	10.25	11.27	12.28	13.18		
Europe	GJ					10.97	14.35	16.11	17.43	18.44	19.04		
Japan LNG	GJ					16.11	18.59	19.76	20.78	21.66	22.25		
Energy [R]evolution 2012													
United States	GJ					6.44	11.78	15.04	17.43	20.21	22.82	25.45	33.35
Europe	GJ					10.97	19.73	23.28	25.28	27.11	29.01	30.93	36.59
Japan LNG	GJ					16.11	22.50	26.47	28.62	30.69	32.77	34.85	41.30
OECD steam coal imports													
Historic prices (from WEO)	tonne	58.27	69.37	97.12	169.27	137.36							
WEO 2011 "450 ppm scenario"	tonne					137.36	138.74	129.03	115.16	102.67	94.35		
WEO 2011 Current policies	tonne					137.36	145.68	151.23	156.78	160.94	163.72		
Energy [R]evolution 2012	tonne						175.79	192.85	225.18	237.25	251.54	276.10	286.23
Biomass (solid)													
Energy [R]evolution 2012													
OECD Europe	GJ			10.41		10.82	11.53	12.93	13.49	14.05	14.26	14.47	14.76
OECD Asia Oceania & North America	GJ			4.63		4.77	4.93	5.34	5.69	6.05	6.33	6.60	7.31
Other regions	GJ			3.80		3.94	4.50	4.93	5.27	5.62	6.05	6.47	6.88

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 (104 NZ$$_{2010}$/t$CO_2$)[52], reflecting estimates of the total external costs of CO_2 emissions. The CO_2 cost estimates in the 2010 version of the global Energy [R]evolution were rather conservative (69 NZ$$_{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.
(NZ$2010/t$CO_2$)

COUNTRIES	2010	2015	2020	2030	2040	2050
Annex-B countries	0	21	35	55	76	104
Non-Annex-B countries	0	0	0	55	76	104

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.[53]

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 NZ$ 21-104 per tonne of captured CO_2[54], while a 2007 US Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs.[55] These costs are estimated to increase the price of electricity in a range from 21-91%.[56]

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.[57] 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.[58]

The Intergovernmental Panel on Climate Change (IPCC) estimates a cost range for pipelines of NZ$ 1.4 – 11.1/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 NZ$ 8.3 million. The same report estimates that a dedicated interstate pipeline network in North Carolina would cost upwards of NZ$ 6.9 billion due to the limited geological sequestration potential in that part of the country.[59] Storage and subsequent monitoring and verification costs are estimated by the IPCC to range from NZ$ 0.7-11.1/tCO_2 (for storage) and NZ$ 0.14-0.42/tCO_2. The overall cost of CCS could therefore be a major barrier to its deployment.[60]

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.

references
52 KREWITT, W., SCHLOMANN, B., EXTERNAL COSTS OF ELECTRICITY GENERATION FROM RENEWABLE ENERGIES COMPARED TO ELECTRICITY GENERATION FROM FOSSIL ENERGY SOURCES, GERMAN FEDERAL MINISTRY FOR THE ENVIRONMENT, NATURE CONSERVATION AND NUCLEAR SAFETY, BERLIN 2006.
53 GREENPEACE INTERNATIONAL BRIEFING: CARBON CAPTURE AND STORAGE', GOERNE, 2007.
54 ABANADES, J C ET AL., 2005, PG 10.
55 NATIONAL ENERGY TECHNOLOGY LABORATORIES, 2007.
56 RUBIN ET AL., 2005A, PG 40.
57 RAGDEN, P ET AL., 2006, PG 18.
58 HEDDLE, G ET AL., 2003, PG 17.
59 PARFOMAK, P & FOLGER, P, 2008, PG 5 AND 12.
60 RUBIN ET AL., 2005B, PG 4444.

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

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

POWER PLANT		2009	2015	2020	2030	2040	2050
Coal-fired condensing power plant	Max. efficiency (%)	45	46	48	50	52	53
	Investment costs (NZ$2010/kW)	1,992	1,920	1,891	1,845	1,797	1,751
	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 (NZ$2010/kW)	2,349	2,239	2,189	2,144	2,096	2,051
	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 (NZ$2010/kW)	1,078	1,046	1,021	973	924	875
	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[61], from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS project (New Energy Externalities Developments for Sustainability)[62] or the IEA Energy Technology Perspectives 2008, projections by the European Renewable Energy Council published in April 2010 ("Re-Thinking 2050") and discussions with experts from different sectors of the renewable energy industry.

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

4.7.1 photovoltaics (PV)

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

The learning factor for PV modules has been fairly constant over the last 30 years with costs reducing by 20% each time the installed capacity doubles, indicating a high rate of technical learning. Assuming a globally installed capacity of 1,500 GW by between 2030 and 2040 in the Energy [R]evolution scenario, and with an electricity output of 2,600 TWh/a, we can expect that generation costs of around NZ$ 7-14 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 NZ$ 8-14 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 (NZ$2010/kWp)	4,162	3,191	2,289	1,776	1,443	1,471
O & M costs NZ$2010/(kW/a)	60	53	29	21	19	21

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 (NZ$2010/kWp)	12,903	11,238	9,157	7,978	7,353	6,660
O & M costs NZ$2010/(kW/a)	583	458	368	318	293	268

O & M = Operation and maintenance.

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

4.7.3 wind power

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

4.7.4 biomass

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

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

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

table 4.8: wind power cost assumptions

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

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Wind turbine offshore						
Investment costs (NZ$2010/kWp)	8,325	7,076	5,272	4,162	3,746	3,260
O & M costs NZ$/(kW · a)	319	284	223	182	172	148
Wind turbine onshore						
Investment costs (NZ$2010/kWp)	2,497	2,081	1,790	1,776	1,804	1,873
O & M costs NZ$2010/(kW/a)	89	76	76	78	82	85

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 (NZ$2010/kWp)	4,648	4,301	4,162	3,885	3,746	3,677
O & M costs NZ$2010/(kW · a)	279	257	243	234	225	230
Biomass CHP						
Investment costs (NZ$2010/kWp)	7,908	7,007	6,105	5,342	4,925	4,690
O & M costs NZ$2010/(kW/a)	551	491	430	375	347	329

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.

New Zealand has a large and very active volcanic zone with thick beds of pumice buried at depths of one to three kms which are saturated with water at 250 to 350 degrees Celsius. At present only the fields with very high natural permeability are developed. Steam is flashed off from the hot water and used to drive turbines. Power and heat generation costs are competitive with conventional generation technologies. Therefore in New Zealand geothermal energy has the potential to make a significant contribution to New Zealand's future energy supply without the need for Enhanced Geothermal Systems (EGS) and deep underground drilling. For hydrothermal geothermal power in New Zealand costs power generation costs are in the range from NZ$ 5 cents/kWh to about NZ$ 8 cents/kWh assuming a technical life time of 50 years.

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 NZ$ 35-132 cents/kWh[63], and for initial tidal stream farms in the range of NZ$ 19-39 cents/kWh. Generation costs of NZ$ 11-14 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.[64]

table 4.10: geothermal cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Geothermal power plant						
Investment costs ($NZ\$_{2010}$/kWp)	3,700	3,700	3,700	3,700	3,700	3,700
O & M costs $NZ\$_{2010}$/(kW/a)	174	174	174	174	174	174

O & M = Operation and maintenance.

table 4.11: ocean energy cost assumptions

SCENARIO	2009	2015	2020	2030	2040	2050
E[R]						
Ocean energy power plant						
Investment costs ($NZ\$_{2010}$/kWp)	8,186	6,452	4,579	3,191	2,636	2,359
O & M costs $NZ\$_{2010}$/(kW/a)	329	257	183	126	107	94

O & M = Operation and maintenance.

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

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

4.7.7 hydro power

Hydro power 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 (NZ$2010/kWp)	4,579	4,717	4,856	5,064	4,856	5,411
O & M costs NZ$2010/(kW/a)	183	189	196	203	211	216

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 NZ$ 11 to 49 cents/kWh for the most important technologies, including photovoltaic. In the long term, costs are expected to converge at around NZ$ 8 to 17 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)

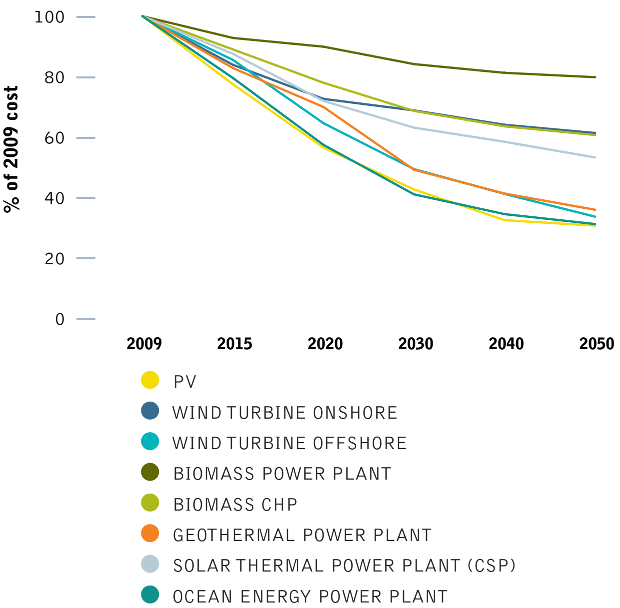
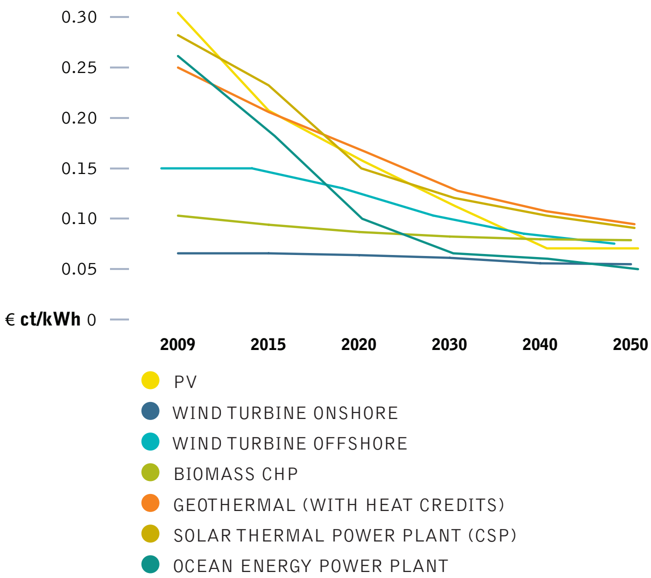


figure 4.2: expected development of electricity generation costs from fossil fuel and renewable options

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 630 NZ$/m^2 installation costs. In parts of New Zealnd with less sun, where additional space heating is needed, installation cost for pumped systems are twice as high. In these areas, economies of scales can decrease solar heating costs significantly. Large scale solar collector system are known from 390-940 NZ$/m^2, depending on the share of solar energy in the whole heating system and the level of storage required.

4.8.2 deep geothermal applications

Deep geothermal heat from aquifers or reservoirs can be used directly in hydrothermal heating plants to supply heat demand close to the plant or in a district heating network for several different types of heat. Due to the high drilling costs deep geothermal energy is mostly feasible for large applications in combination with heat networks. It is already economic feasible and has been in use for a long time, where aquifers can be found near the surface. In New Zealand deep geothermal applications are being developed for heating purposes at investment costs from 780NZ$/kWth (shallow) to 3,100 NZ$/kWth (deep), with the costs strongly dependent on the drilling depth.

4.8.3 heat pumps (aerothermal systems)

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 780-2,500 NZ$/kW for ground water systems and higher costs from 1,900-4,700 NZ$/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 160 NZ$/kW, more sophisticated automated heating systems that cover the whole heat demand of a building are significantly more expensive. Log wood or pellet boilers range from 630-1,900 NZ$/kW, with large applications being cheaper than small systems.

Economy of scales apply to heating plants above 500kW, with investment cost between 360 and 110 NZ$/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 1.6-11 NZ$/GJ for sawmill products, over 3-11 NZ$/GJ for log wood to 9-28 NZ$/GJ for wood pellets.[65]

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

table 4.13: overview over expected investment costs pathways for heating technologies (IN €$_{2010}$/KW$_{TH}$)

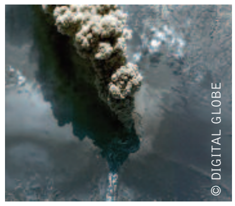
	2015	2020	2030	2040	2050
Geothermal district heating*	3,677	3,496	3,122	2,775	2,442
Heat pumps	2,761	2,678	2,511	2,373	2,220
Small solar collector systems	1,623	1,554	1,401	1,235	1,041
Large solar collector systems	1,318	1,263	1,124	999	846
Solar district heating*	1,498	1,429	1,276	1,138	957
Small biomass heating systems	180	180	180	180	180
Large biomass heating systems	1,290	1,249	1,179	1,110	1,041
Biomass district heating*	916	888	832	791	735

* WITHOUT NETWORK

references

65 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 global 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

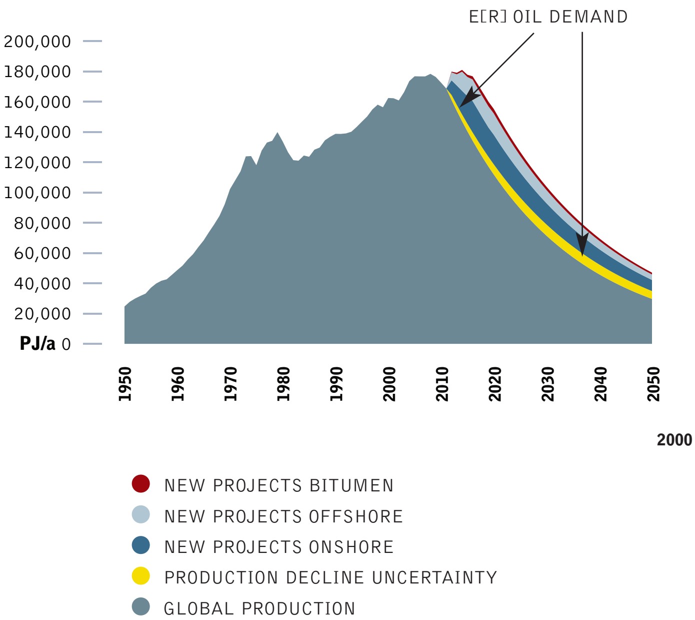
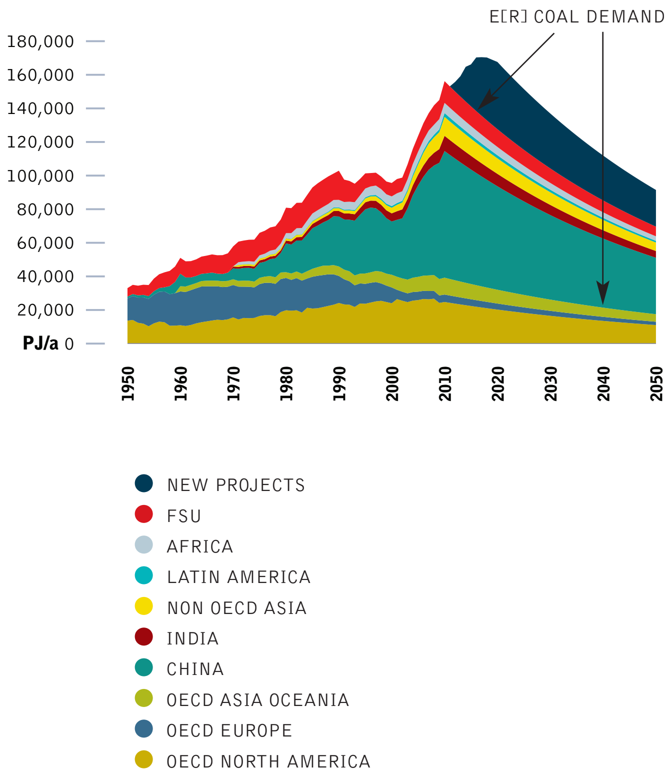


figure 4.4: coal scenario: base decline of 2% per year and new projects



4.10 review: greenpeace scenario projections of the past

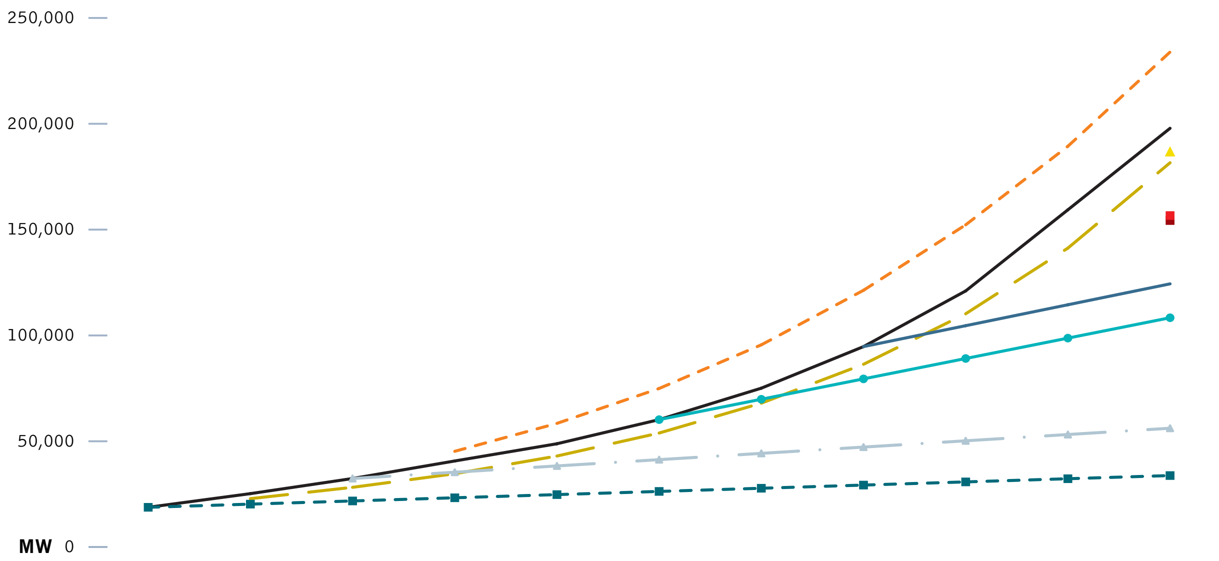
Greenpeace has published numerous projections in cooperation with renewable industry associations and scientific institutions in the past decade. This section provides an overview of the projections between 2000 and 2011 and compares them with real market developments and projections of the IEA World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



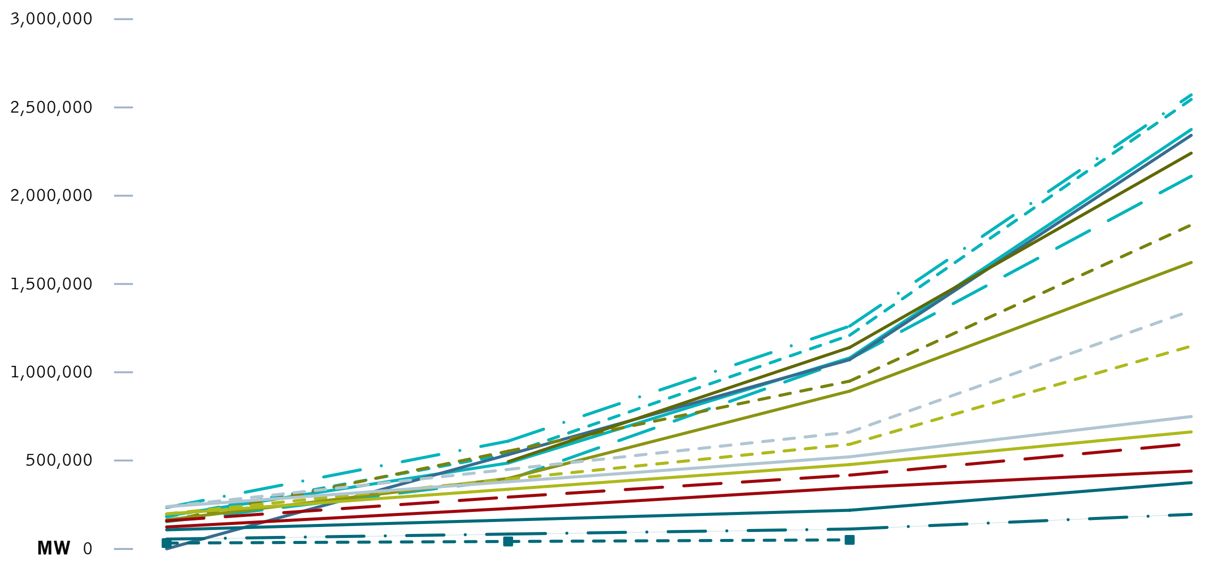
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
REAL	17,400	23,900	31,100	39,431	47,620	59,091	74,052	93,820	120,291	158,864	197,637
WF 10 (1999)		21,510	26,901	33,371	41,781	52,715	66,929	85,407	109,428	140,656	181,252
WF 12 (2002)				44,025	57,306	73,908	94,660	120,600	151,728	189,081	233,905
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 projections until 2030



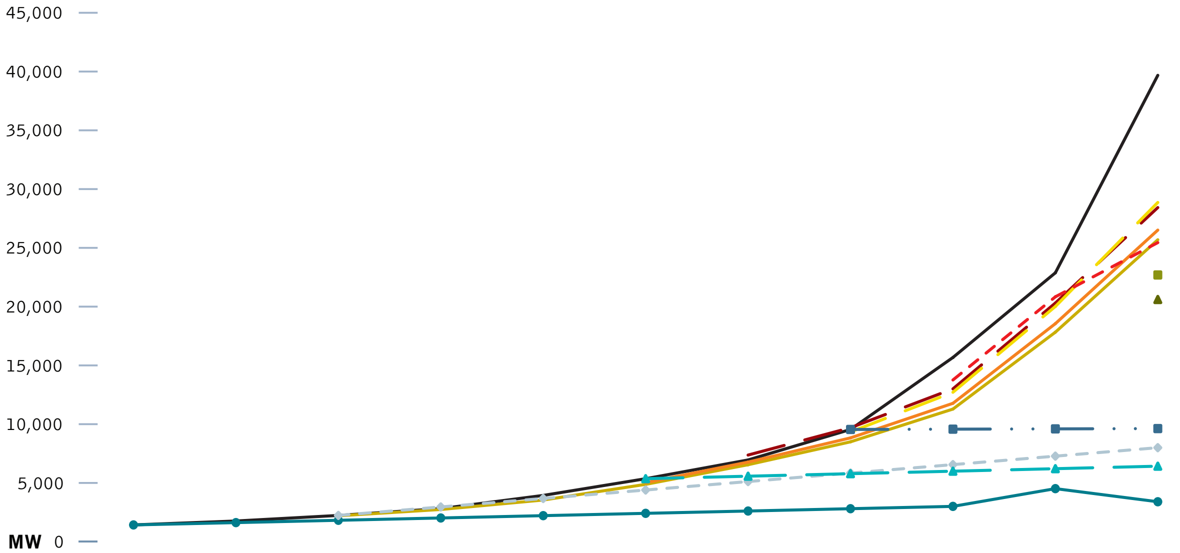
	2010	2015	2020	2030
WF 10 (1999)	181,252	537,059	1,209,466	2,545,232
WF 12 (2002)	233,905	610,000	1,261,157	2,571,000
GWEO 2006 (Advanced)	153,759	391,077	1,074,835	2,110,401
GWEO 2008 (Advanced)	186,309	485,834	1,080,886	2,375,000
GWEO 2008 (Advanced)	0	533,233	1,071,415	2,341,984
E[R] 2007	156,149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



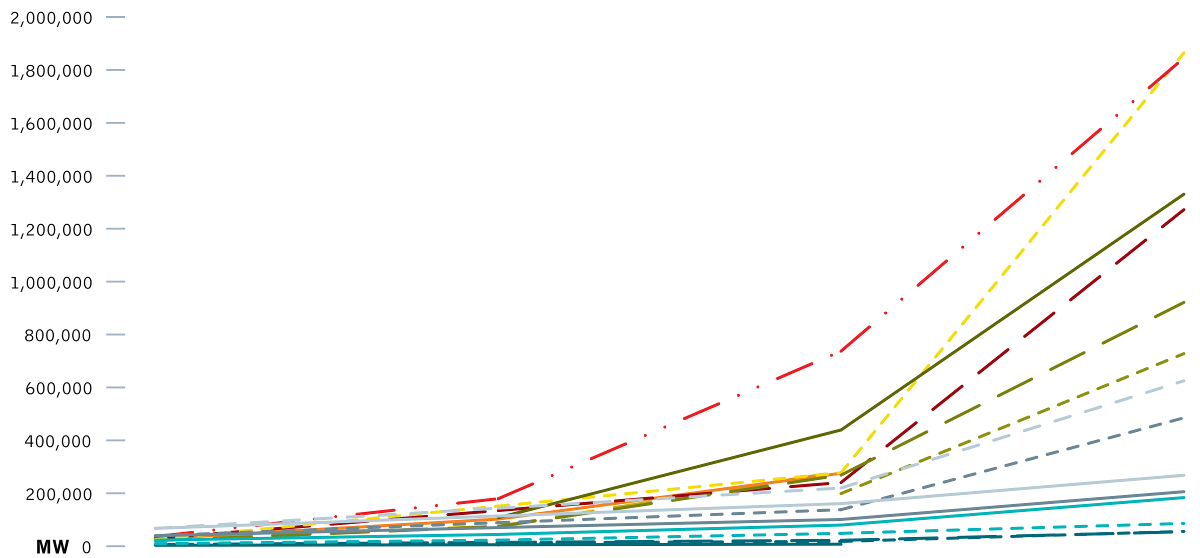
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
REAL	1,428	1,762	2,236	2,818	3,939	5,361	6,956	9,550	15,675	22,878	39,678
SG I 2001			2,205	2,742	3,546	4,879	6,549	8,498	11,285	17,825	25,688
SG II 2004						5,026	6,772	8,833	11,775	18,552	26,512
SG III 2006							7,372	9,698	13,005	20,305	28,428
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 projections 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 Center (DLR) by extrapolating the key macroeconomic and energy indicators of the WEO 2009 forward to 2050 (Publication filed in June 2010 to Energy Policy).

key results of the new zealand 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

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

ANGELA MERKEL
CHANCELLOR OF GERMANY

image ON THE NORTHERN TIP OF NEW ZEALAND'S SOUTH ISLAND, FAREWELL SPIT STRETCHES 30 KILOMETERS EASTWARD INTO THE TASMAN SEA FROM THE CAPE FAREWELL MAINLAND. A SANDY BEACH FACES THE OPEN WATERS OF THE TASMAN SEA, WHILE AN INTRICATE WETLAND ECOSYSTEM FACES SOUTH TOWARD GOLDEN BAY. ON THE SOUTHERN SIDE, THE SPIT IS PROTECTED BY SEVERAL KILOMETERS OF MUDFLATS, WHICH ARE ALTERNATELY EXPOSED AND INUNDATED WITH THE TIDAL RHYTHMS OF THE OCEAN. THE WETLANDS OF FAREWELL SPIT ARE ON THE RAMSAR LIST OF WETLANDS OF INTERNATIONAL SIGNIFICANCE.

5.1 energy demand by sector

The future development pathways for New Zealand's energy demand are shown in Figure 5.1 for the Reference and the Energy [R]evolution scenario. Under the Reference scenario, total final energy demand in New Zealand increases by 17% from the current 527 PJ/a to 626 PJ/a in 2050. The energy demand in 2050 in the Energy [R]evolution scenario is similar to current consumption and it is expected by 2050 to reach 449 PJ/a.

Under the Energy [R]evolution scenario, electricity demand in the industry as well as in the residential and service sectors is expected to decrease after 2015 (see Figure 5.2). Because of the growing shares of electric vehicles, heat pumps and hydrogen generation however, electricity demand increases to 54 TWh/a in 2050, still 2% below the Reference case.

Efficiency gains in the heat supply sector are larger than in the electricity sector. Under the Energy [R]evolution scenario, final demand for heat supply can even be reduced significantly (see Figure 5.4). Compared to the Reference scenario, consumption equivalent to 48 PJ/a is avoided through efficiency measures by 2050. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a 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)

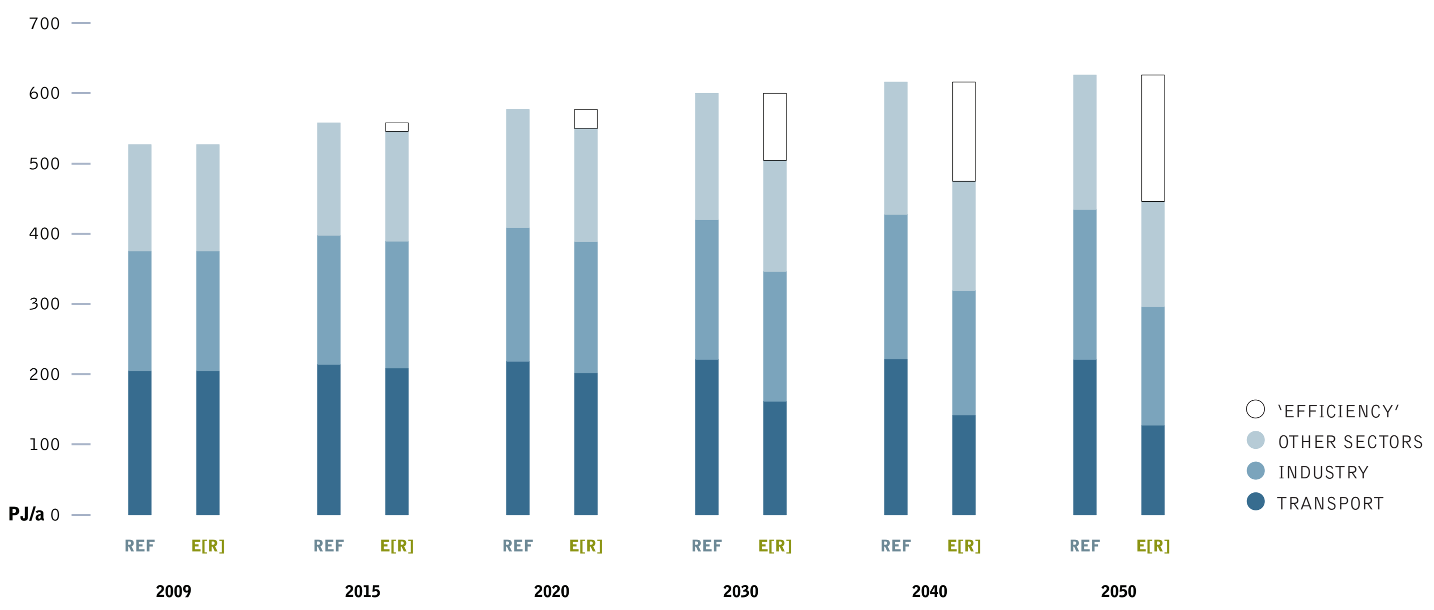


image HOT-RIVETED STEEL PENSTOCKS AT AN OLD HYDRO-ELECTRIC POWER STATION, LAKE COLERIDGE, CANTERBURY, NEW ZEALAND.

image ECO FRIENDLY HOME ON THE WEST COAST OF NEW ZEALAND.

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

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

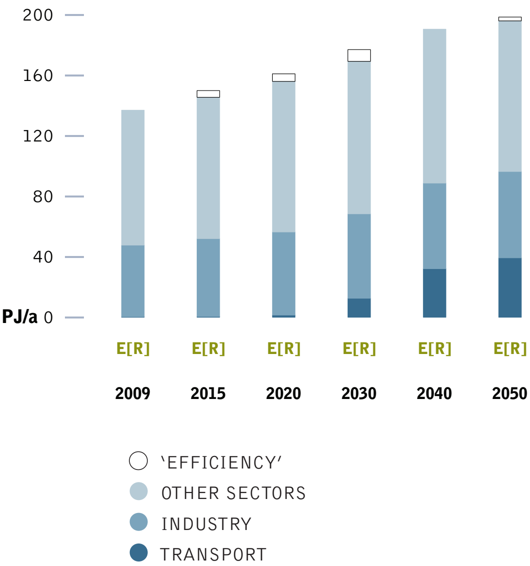


figure 5.4: development of heat demand by sector in the energy [r]evolution scenario

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

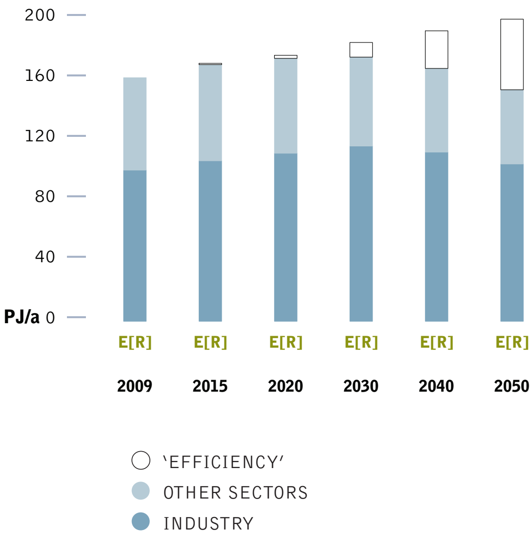
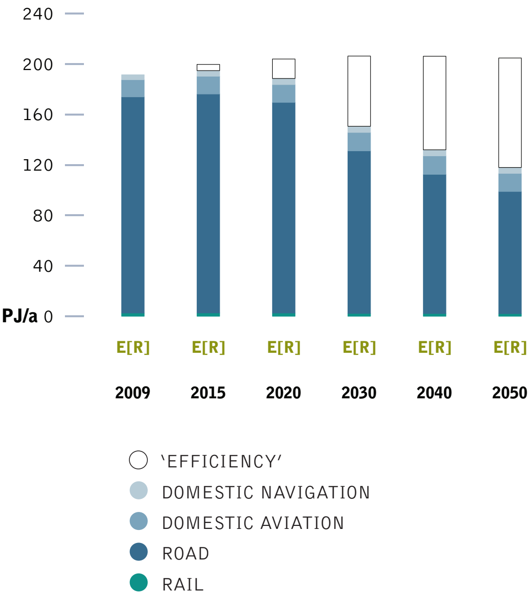


figure 5.3: development of the transport demand by sector in the energy [r]evolution scenario



5.2 electricity generation

The development of the electricity supply market is characterised by a dynamically growing renewable energy market. This will reduce the number of fossil fuel-fired power plants required for grid stabilisation. By 2025, 100% of the electricity produced in New Zealand will come from renewable energy sources. 'New' renewables – mainly wind, geothermal and PV – will contribute 52% of electricity generation in 2025. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 94% already by 2020 and 100% by 2030. The installed capacity of renewables will reach 13 GW in 2030 and 17 GW by 2050.

Table 5.1 shows the comparative evolution of the different renewable technologies in New Zealand over time. Up to 2020 hydro, geothermal power and wind will remain the main contributors of the growing market share. After 2020, the continuing growth of wind and geothermal energy will be complemented by electricity from biomass, photovoltaics and ocean energy. The Energy [R]evolution scenario will lead to a relative high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 23% by 2030, therefore the expansion of smart grids, demand side management (DSM) and storage capacity e.g. from the increased share of electric vehicles will be used for a better grid integration and power generation management.

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

IN GW

		2009	2020	2030	2040	2050
Hydro	REF	5.4	6.0	6.4	6.5	6.5
	E[R]	5.4	6.0	6.1	6.3	6.4
Biomass	REF	0.1	0.1	0.2	0.2	0.2
	E[R]	0.1	0.4	0.8	1.0	1.1
Wind	REF	0.5	3.1	3.5	4.1	4.4
	E[R]	0.5	3.2	3.8	4.4	4.8
Geothermal	REF	0.6	1.2	1.4	1.6	1.8
	E[R]	0.6	1.3	1.7	2.2	2.3
PV	REF	0	0.1	0.1	0.1	0.2
	E[R]	0	0.1	0.4	1.0	1.6
CSP	REF	0	0	0	0	0
	E[R]	0	0	0	0	0
Ocean energy	REF	0	0.02	0.1	0.2	0.2
	E[R]	0	0.02	0.1	0.3	0.4
Total	**REF**	**6.7**	**11**	**12**	**13**	**13**
	E[R]	**6.7**	**11**	**13**	**15**	**17**

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)

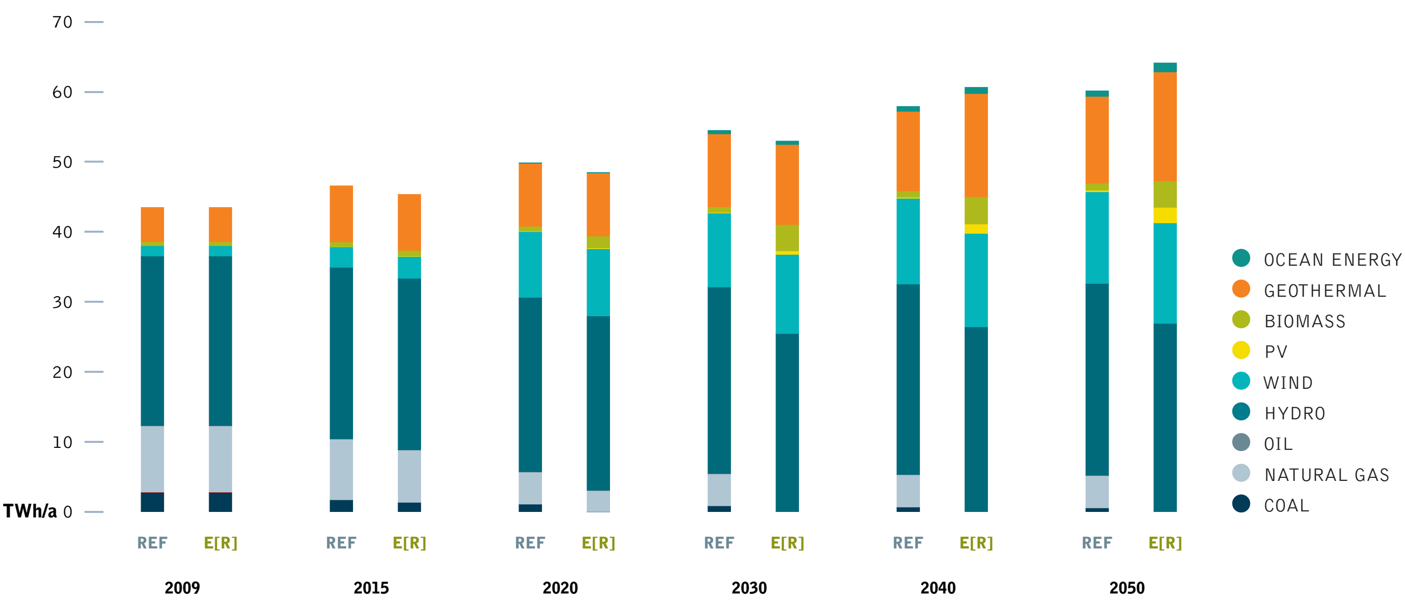


image WIARAKE GEOTHERMAL POWER STATION, NEW ZEALAND.

image WINDFARM IN NEW ZEALAND.

5.3 future costs of electricity generation

Figure 5.6 shows that the introduction of renewable technologies under the Energy [R]evolution scenario does not increase the costs of electricity generation in New Zealand compared to the Reference scenario. Because of the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable under the Energy [R]evolution scenario and by 2050 costs will be NZ$ 1.9 cents/kWh below those in the Reference version.

Under the Reference scenario, the unchecked growth in demand, an increase in fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's NZ$ 5.5 billion per year to NZ$ 6.9 billion in 2050. Figure 5.6 shows that the Energy [R]evolution scenario not only complies with New Zealand's CO_2 reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables lead to long term costs for electricity supply that are still 1% lower than in the Reference scenario, although costs for efficiency measures of up to NZ$ 5 ct/kWh are taken into account.

Under the Energy [R]evolution scenario, however, New Zealand would shift almost 100% of its entire energy investment towards renewables and cogeneration. Until 2025, 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 NZ$ 1.55 billion.

Because renewable energy has no fuel costs, however, the fuel cost savings in the Energy [R]evolution scenario reach a total of NZ$ 35 billion up to 2050, or NZ$ 0.88 billion per year. The total fuel cost savings based on the assumed energy price path therefore would cover 300% of the total additional investments compared to the Reference scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies.

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

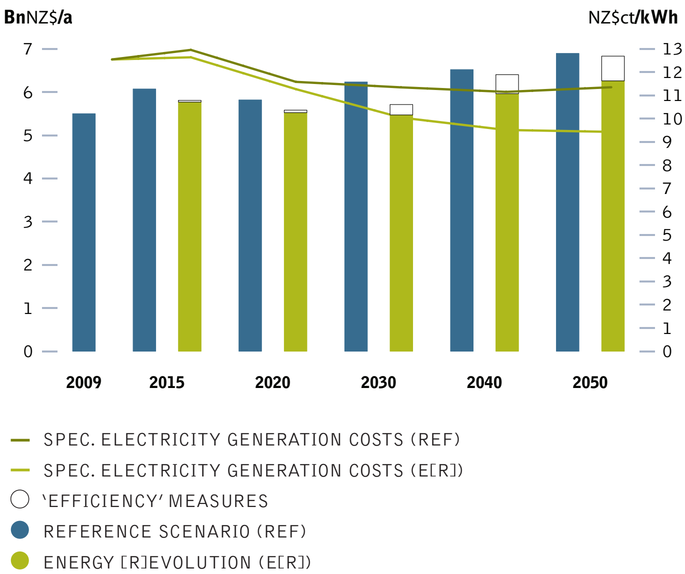
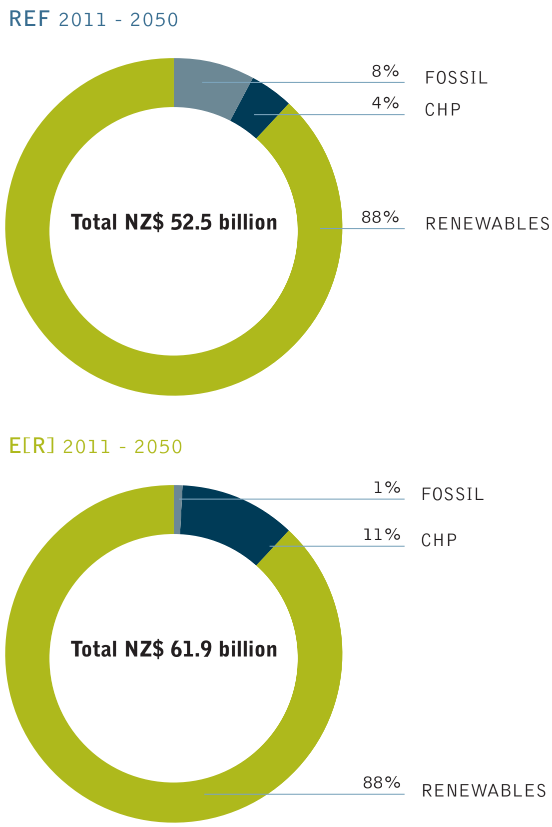


figure 5.7: investment shares - reference scenario versus energy [r]evolution scenario



5.4 future investments in the power sector

It would require about NZ$ 62 billion in investment for the Energy [R]evolution scenario to become reality (including investments for replacement after the economic lifetime of the plants) - approximately NZ$ 9 billion or NZ$ 0.23 billion annually more than in the Reference scenario (NZ$ 53 billion). Under the Reference scenario, the levels of investment in conventional power plants add up to almost 8% while around 92% would be invested in renewable energy and cogeneration (CHP) until 2050.

5.5 heating supply

Renewables currently provide 41% of New Zealand's energy demand for heat supply, the main contribution coming from the use of biomass. The lack of district heating networks is a severe structural barrier to the large scale utilisation of geothermal and solar thermal energy. In the Energy [R]evolution scenario, renewables provide 67% of New Zealands total heat demand in 2030 and 94% in 2050.

- For direct heating, solar collectors, biomass/biogas as well as geothermal energy are increasingly substituting for fossil fuel-fired systems.
- The introduction of strict efficiency measures e.g. via strict building standards and ambitious support programs for renewable heating systems are needed to achieve economies of scale within the next five to ten years.

Table 5.2 shows the development of the different renewable technologies for heating in New Zealand over time. Up to 2020, biomass will remain the main contributor of the growing market share. After 2020, the continuing growth of solar collectors and a growing share of geothermal heat use will further reduce the dependence on fossil fuels. In addition, market share of efficient heat pumps will continuously grow and partly substitute direct electric heating.

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

IN GW

		2009	2020	2030	2040	2050
Biomass	REF	29	30	30	30	30
	E[R]	29	33	36	38	38
Solar collectors	REF	0	1	1	1	1
	E[R]	0	5	12	17	18
Geothermal	REF	10	11	11	11	11
	E[R]	10	12	16	18	18
Hydrogen	REF	0	0	0	0	0
	E[R]	0	0	1	3	5
Total	**REF**	**40**	**42**	**42**	**42**	**42**
	E[R]	**40**	**50**	**67**	**75**	**79**

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

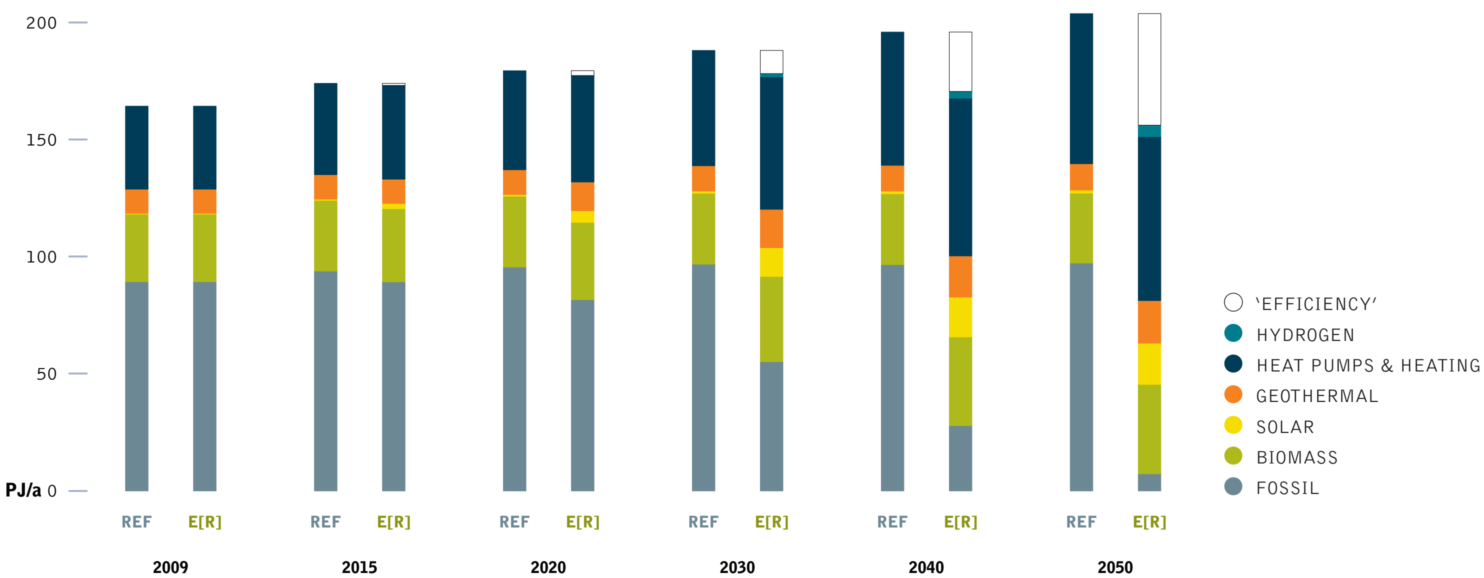


image SUN SHINING THROUGH THE TOE TOE GRASS.

image GEOTHERMAL POWER STATION, NORTH ISLAND, NEW ZEALAND.

5.6 future investments in the heat sector

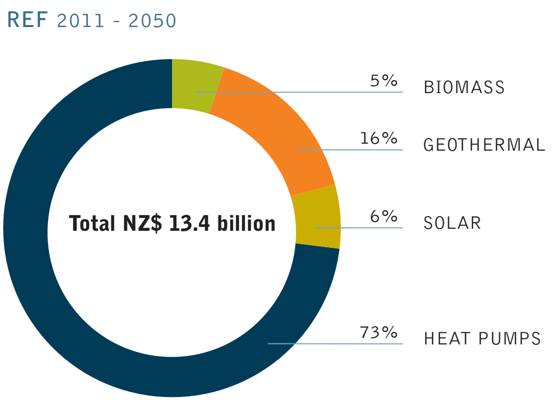
Also in the heat sector the Energy [R]evolution scenario would require a major revision of current investment strategies in heating technologies. Especially the solar, geothermal and heat pump technologies need enormous increase in installations, if these potentials are to be tapped for the heat sector. Installed capacity need to be increased by the factor of 50 for solar thermal and by the factor of 10 for geothermal and heat pumps. Capacity of biomass technologies, which are already rather wide spread still need to remain a pillar of heat supply.

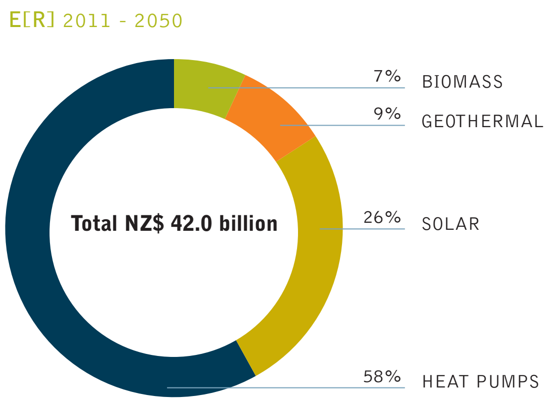
Renewable heating technologies are extremely variable, from low tech biomass stoves and unglazed solar collectors to very sophisticated geothermal systems and solar thermal district heating plants.Thus it can only roughly be calculated that the Energy [R]evolution scenario in total requires around NZ$ 42 billion to be invested in renewable heating technologies until 2050 (including investments for replacement after the economic lifetime of the plants) - approximately NZ$ 1 billion per year. Due to a lack of information on costs for conventional heating systems and fuel prices, total investments and fuel cost savings for the heat supply in the scenarios have not been estimated.

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

		2009	2020	2030	2040	2050
Biomass	REF	4	4	4	4	4
	E[R]	4	4	4	4	4
Geothermal	REF	1	1	1	1	1
	E[R]	1	1	2	2	2
Solar thermal	REF	0	0	0	0	0
	E[R]	0	2	4	5	6
Heat pumps	REF	1	1	2	3	3
	E[R]	1	2	4	6	7
Total	**REF**	**6**	**7**	**8**	**8**	**9**
	E[R]	**6**	**9**	**14**	**17**	**19**

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





5.8 transport

In the transport sector, it is assumed under the Energy [R]evolution scenario that an energy demand reduction of about 87 PJ/a can be achieved by 2050, saving 42% compared to the Reference scenario. Energy demand will therefore decrease between 2009 and 2050 by 39% to 118 PJ/a. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility related behaviour patterns. Implementing a mix of increased public transport as attractive alternatives to individual cars, the car stock is growing slower and annual person kilometres are lower than in the Reference scenario.

A shift towards smaller cars triggered by economic incentives together with a significant shift in propulsion technology towards electrified power trains and the reduction of vehicle kilometres travelled lead to significant energy savings. In 2030, electricity will provide 8% of the transport sector's total energy demand in the Energy [R]evolution, while in 2050 the share will be 33%. Biofuels are expected to play an important role in the future road transport sector, achieving a final energy share of 53% in 2050.

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	3	3	3	3	3
	E[R]	3	3	2	2	2
Road	REF	171	182	183	182	180
	E[R]	171	167	129	110	97
Domestic aviation	REF	14	15	16	16	16
	E[R]	14	14	15	15	14
Domestic navigation	REF	4	5	5	5	5
	E[R]	4	5	5	5	5
Total	**REF**	**192**	**204**	**206**	**206**	**205**
	E[R]	**192**	**189**	**151**	**132**	**118**

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

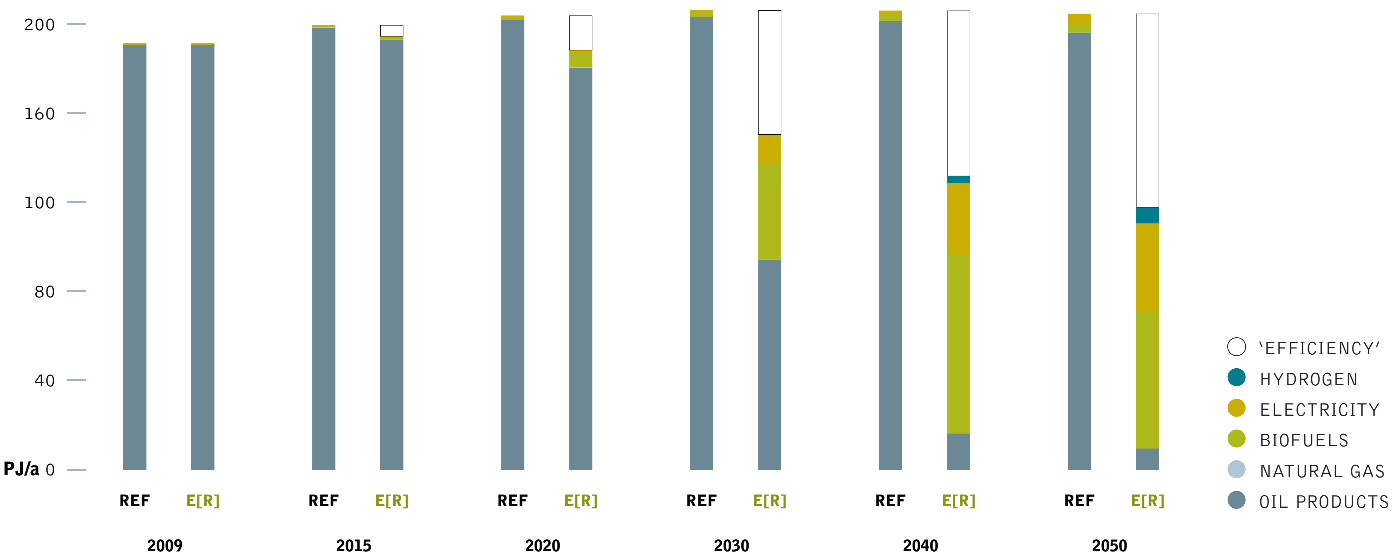


image THE NEW VALE LIGNITE COAL MINE, NEAR INVERCARGILL, USED BY FONTERRA TO HELP FUEL OPERATIONS AT IT'S NEARBY EDENDALE DAIRY FACTORY.

image SOLAR POWER PANELS IN THE LANDSCAPE.

5.9 development of CO_2 emissions

While CO_2 emissions in New Zealand will decrease by 16% in the Reference scenario, under the Energy [R]evolution scenario they will decrease from around 30 million tonnes in 2009 to 2 million tonne in 2050. Annual per capita emissions will drop from 6.8 tonne to 2.3 tonne in 2030 and 0.3 tonne in 2050. In spite of increasing demand, CO_2 emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will reduce emissions in the transport sector. The transport sector remains as the largest source of emissions. By 2050, New Zealand's CO_2 emissions are 8% of 1990 levels.

5.10 primary energy consumption

Taking into account the assumptions discussed above, the resulting energy consumption under the Energy [R]evolution scenario is shown in Figure 5.12. Compared to the Reference scenario, overall primary energy demand will be reduced by 14% in 2050. Most of the remaining demand will be covered by renewable energy sources.

The Energy [R]evolution scenario leads to an overall renewable primary energy share of 72% in 2030 and 92% in 2050.

figure 5.11: development of CO_2 emissions by sector under the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

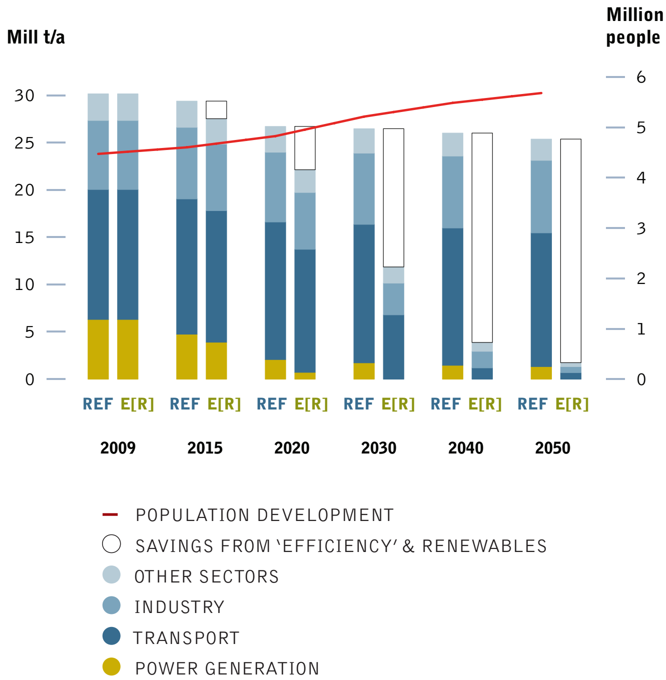


figure 5.12: primary energy consumption under the reference scenario and the energy [r]evolution scenario ('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO)

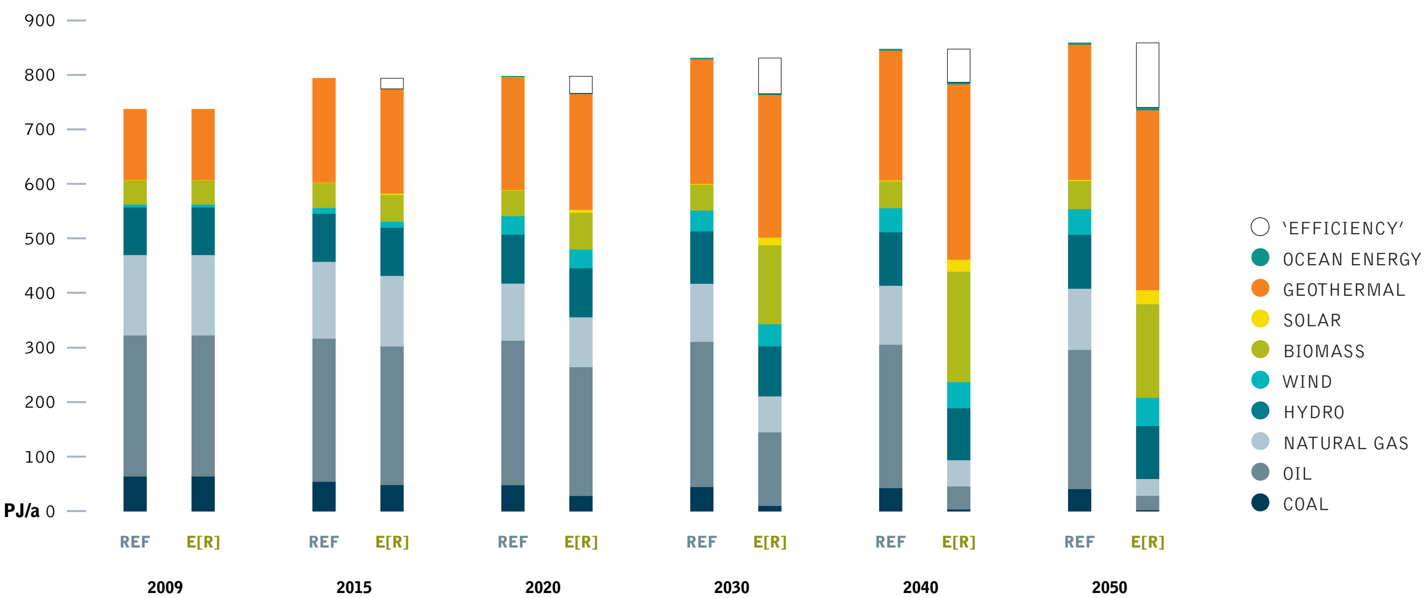


table 5.6: investment costs for electricity generation and fuel cost savings under the energy [r]evolution scenario compared to the reference scenario

INVESTMENT COSTS		2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2011 - 2050	2011 - 2050 AVERAGE PER ANNUM
DIFFERENCE E[R] VERSUS REF							
Conventional (fossil)	billion NZ$	-0.6	-1.8	-1.8	-1.8	-4.7	-0.1
Renewables	billion NZ$	1.7	2.5	5.1	5.1	14.1	0.4
Total	billion NZ$	**1.1**	**0.7**	**3.3**	**3.3**	**9.4**	**0.2**

CUMULATED FUEL COST SAVINGS							
SAVINGS CUMULATIVE E[R] VERSUS REF							
Fuel oil	billion NZ$/a	0.0	0.0	0.0	0.0	0.0	0.0
Gas	billion NZ$/a	2.2	8.4	10.4	11.8	32.8	0.8
Hard coal	billion NZ$/a	0.3	0.8	0.6	0.5	2.2	0.1
Lignite	billion NZ$/a	0.0	0.0	0.0	0.0	0.0	0.0
Total	billion NZ$/a	**2.5**	**9.1**	**11.1**	**12.3**	**35.1**	**0.9**

employment projections

METHODOLOGY TO CALCULATE JOBS
OVERVIEW
LIMITATIONS
EMPLOYMENT FACTORS
COAL, GAS AND RENEWABLE TECHNOLOGY TRANDE
ADJUSTMENT FOR LEARNING RATES - DECLINE FACTORS
FUTURE EMPLOYMENT IN THE ENERGY SECTOR
EMPLOYMENT IN RENEWABLE HEATING SECTOR

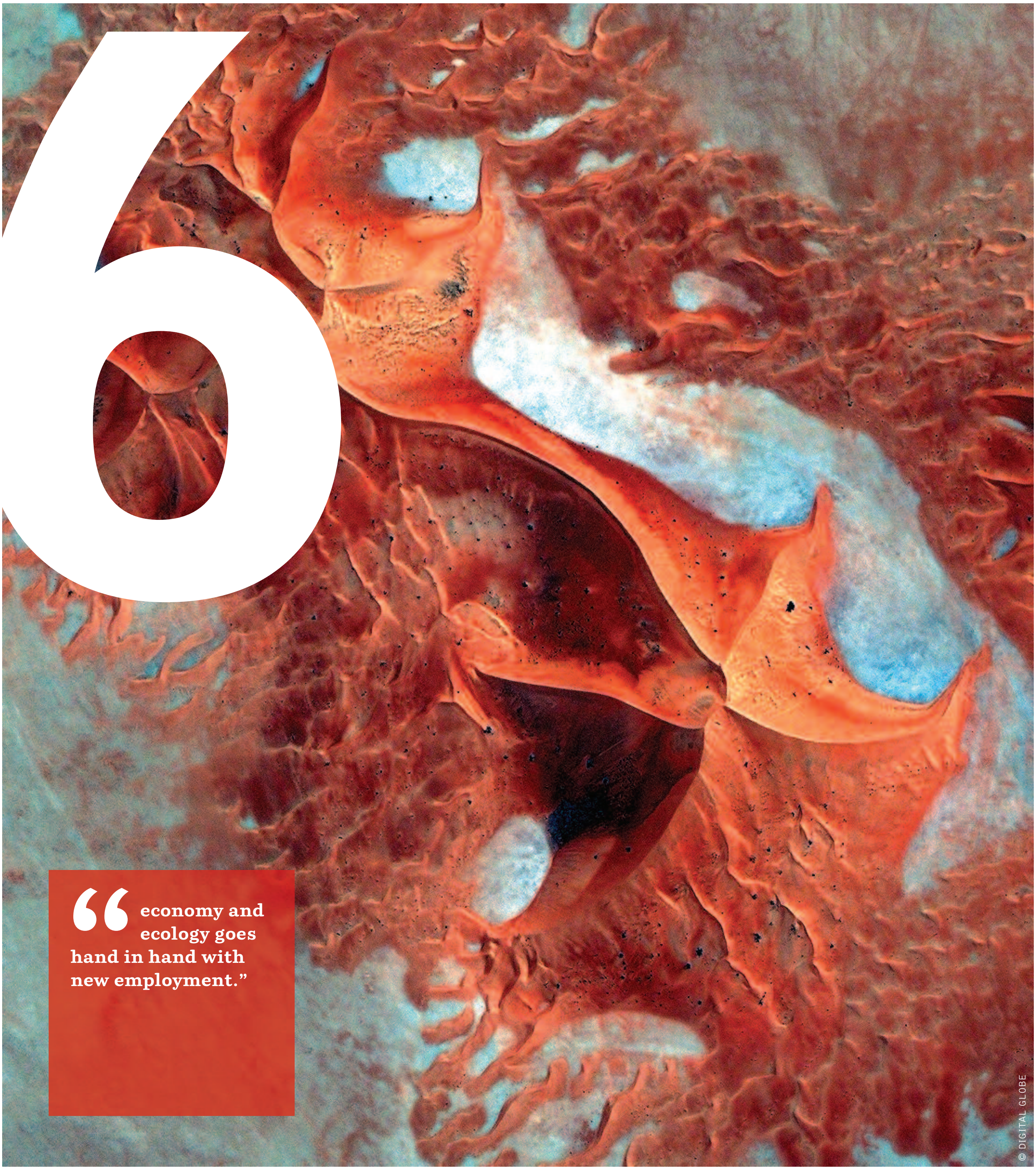


image SAND DUNES NEAR THE TOWN OF SAHMAH, OMAN.

6.1 methodology to calculate jobs

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

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

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

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

6.2 overview

Inputs for energy generation and demand for each scenario include:

- The amount of electrical and heating capacity that will be installed each year for each technology.
- The primary energy demand for coal, gas, and biomass fuels in the electricity and heating sectors.
- The amount of electricity generated per year from nuclear, oil, and diesel.

Inputs for each technology include:

- 'Employment factors', or the number of jobs per unit of capacity, separated into manufacturing, construction, operation and maintenance, and per unit of primary energy for fuel supply.
- For the 2020 and 2030 calculations, a 'decline factor' for each technology which reduces the employment factors by a certain percentage per year to reflect the employment per unit reduction as technology efficiencies improve.
- The percentage of local manufacturing and domestic fuel production in each region, in order to calculate the number of manufacturing and fuel production jobs in the region.
- The percentage of world trade which originates in the region for coal and gas fuels, and renewable traded components.

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

table 6.1: methodology overview

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

JOBS	=	MANUFACTURING + CONSTRUCTION + OPERATION & MAINTENANCE (O&M) + FUEL SUPPLY + FUEL SUPPLY
EMPLOYMENT FACTOR AT 2020 OR 2030	=	2010 EMPLOYMENT FACTOR × TECHNOLOGY DECLINE FACTOR (NUMBER OF YEARS AFTER 2010)

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

© GP/BAS BEENTJES

6.3 limitations

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

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

6.4 employment factors

The employment factors used in the 2013 New Zealand analysis are shown in Table 6.2, with the main source given in the notes. Local factors have been used for coal and gas production, hydro construction; geothermal construction and O&M; and for wind O&M and construction. OECD factors from the 2012 global analysis (Rutovitz & Harris, 2012a) are used in all other cases.

table 6.2: employment factors used in the 2012 analysis for new zealand

FUEL	CONSTRUCTION TIMES *Years*	CONSTRUCTION /INSTALLATION *Job years/MW*	MANUFACTURING *Jobs years/MW*	OPERATION & MAINTENANCE *Jobs/MW*	FUEL – PRIMARY ENERGY DEMAND *Jobs/PJ*	
Coal	5	7.7	3.5	0.1	**8.3**	Note 1
Gas	2	1.7	1.0	0.1	**3.2**	Note 2
Biomass	2	14	2.9	1.5	0.3	Note 3
Hydro-large	2	3.3	1.5	0.3		Note 4
Wind onshore	2	**2.6**	6.1	**0.2**		Note 5
PV	1	10.9	6.9	0.3		Note 6
Geothermal	2	**4.9**	3.9	**0.4**		Note 7
Solar thermal	2	8.9	4.0	0.5		Note 8
Ocean	2	9.0	1.0	0.3		Note 9
Geothermal - heat	3.0 jobs/ MW (construction and manufacturing)					Note 10
Solar - heat	7.4 jobs/ MW (construction and manufacturing)					Note 11
Combined Heat and Power	CHP technologies use the factor for the technology, i.e. coal, gas, biomass, geothermal, etc, increased by a factor of 1.5 for O&M only.					
Oil and diesel	Use the employment factors for gas					

notes on employment factors

1. Coal: Construction, manufacturing and operations and maintenance factors are from the JEDI model (National Renewable Energy Laboratory, 2011a). Jobs per PJ fuel have been derived using production and data from the Ministry of Business Innovation and Employment (2012a) and employment data from the Department of Labour New Zealand Government (2010).
2. Gas, oil and diesel: Installation and manufacturing factors are from the JEDI model (National Renewable Energy Laboratory, 2011b). O&M factor is an average of the figures from the 2010 report, the JEDI model (National Renewable Energy Laboratory, 2011b), a US study (National Commission on Energy Policy, 2009) and ISF research (Rutovitz & Harris, 2012b). The factor for fuel (job years per PJ) is derived from production data from the Ministry of Business Innovation and Employment (2012b) and employment data from the Department of Labour New Zealand Government, 2010.
3. Bioenergy: Employment factors for construction, manufacturing, and O&M use the average values of several European and US studies (Kjaer, 2006; Moreno & López, 2008; Thornley, 2006; Thornley et al., 2009; Thornley, Rogers, & Huang, 2008; Tourkolias & Mirasgedis, 2011) Fuel employment per PJ primary energy is derived from five European studies (Domac, Richards, & Risovic, 2005; EPRI, 2001; Hillring, 2002; Thornley, 2006; Upham & Speakman, 2007; Valente, Spinelli, & Hillring, 2011). A local bioenergy study of the potential employment from wood pellet production produced slightly higher factors for fuel (PA Consulting Group, 2010).
4. Hydro – large: A local factor for construction was derived from employment projected for the Pukaki scheme (Meridian Energy Limited, 2010). Unfortunately local figures for operations and maintenance were not available in time for inclusion. O&M factor is an average of data from the US study (Navigant Consulting, 2009) and ISF research (Rutovitz & Harris, 2012b; Rutovitz & Ison, 2011; Rutovitz, 2010).
5. Wind – onshore: The construction and installation factor, and the O&M factor, are drawn from Leung-Wai & Generosa (2012). The manufacturing factor is derived using the employment per MW in turbine manufacture at Vestas from 2007 – 2011 (Vestas, 2011), adjusted for total manufacturing using the ratio used by the EWEA (European Wind Energy Association, 2009).
6. Solar PV: The Solar PV installation employment factor is the average of five estimates in Germany and the US, while manufacturing is taken from the JEDI model (National Renewable Energy Laboratory, 2010a), a Greek study (Tourkolias & Mirasgedis, 2011), a Korean national report (Korea Energy Management Corporation (KEMCO) & New and Renewable Energy Center (NREC), 2012), and ISF research for Japan (Rutovitz & Ison, 2011).
7. Geothermal: The construction and installation and operations and maintenance factor is derived from a study conducted by Sinclair Knight Merz (SKM) (2005). The O&M factors are the weighted averages from employment data reported for thirteen power stations totalling 1050 MW in the US, Canada, Greece and Australia (some of them hypothetical). The manufacturing factor is derived from a US study (Geothermal Energy Association, 2010).
8. Solar thermal power: The OECD Europe figure is used for the EU27, and is higher than the overall OECD factors of 8.9 job years/MW (construction) and 0,5 jobs/MW (O&M). Overall OECD figures were derived from a weighted average of 19 reported power plants (3223 MW), while the OECD Europe figure includes only European data (951 MW). The manufacturing factor is unchanged from the 2010 analysis (European Renewable Energy Council, 2008, page 16).
9. Ocean: These factors are unchanged from the 2010 analysis. The construction factor used in this study is a combined projection for wave and tidal power derived from data for offshore wind power (Batten & Bahaj, 2007). A study of a particular wave power technology, Wave Dragon, provided the O&M factor (Soerensen, 2008).
10. Geothermal and heat pumps: One overall factor has been used for jobs per MW installed, from the US EIA annual reporting (US Energy Information Administration, 2010), adjusted to include installation using data from WaterFurnace (WaterFurnace, 2009).
11. Solar thermal heating: One overall factor has been used for jobs per MW installed, as this was the only data available on any large scale. This may underestimate jobs, as it may not include O&M. The global figure is derived from the IEA heating and cooling program report (International Energy Agency Solar Heating and Cooling Program, 2011).

6.5 coal, gas and renewable technology trade

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

New Zealand is self-sufficient in natural gas and is assumed to remain so for the study period.

New Zealand is self-sufficient for coal for power generation and direct use, and exports approximately half of its coal production for use in steel making. These exports are not included in this analysis.

6.6 adjustment for learning rates – decline factors

Employment factors are adjusted to take into account the reduction in employment per unit of electrical capacity as technologies and production techniques mature. The learning rates assumed have a significant effect on the outcome of the analysis, and are given in Table 6.3. These declines rates are calculated directly from the cost data used in the Energy [R]evolution modelling for New Zealand.

table 6.3: technology cost decline factors

	ANNUAL DECLINE IN JOB FACTORS		
	2010-2015	2015-2020	2020-30
Coal	0.3%	0.3%	0.5%
Lignite	0.4%	0.4%	0.4%
Gas	0.5%	0.5%	1.0%
Oil	0.4%	0.4%	0.8%
Diesel	0.0%	0.0%	0.0%
Biomass	1.6%	1.1%	0.7%
Hydro-large	-0.6%	-0.6%	-0.9%
Wind onshore	3.6%	2.8%	0.2%
PV	8.0%	4.4%	4.2%
Geothermal power	0.0%	0.0%	0.0%
Solar thermal power	5.6%	5.1%	2.8%
Ocean	4.8%	6.5%	7.0%
Coal CHP	0.3%	0.3%	0.5%
Lignite CHP	0.3%	0.3%	0.5%
Gas CHP	0.9%	1.0%	1.0%
Oil CHP	0.4%	0.4%	0.8%
Biomass CHP	2.0%	2.2%	2.2%
Geothermal CHP	2.6%	3.2%	4.5%
Geothermal - heat	0.0%	0.9%	0.9%
Solar thermal heat	Uses decline factor for solar thermal power		

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

6.7 future employment in the energy sector

Energy sector jobs in New Zealand are higher in the Energy [R]evolution scenario at every stage in the projection. Jobs grow in both scenarios until 2015, by which time the Reference scenario has added 1,000 jobs and the Energy [R]evolution 2,200 jobs. After 2015 jobs in the Reference scenario fall. Jobs in the Energy [R]evolution scenario continue to grow strongly, to just over 11,000 by 2030.

- There are approximately 7,100 energy sector jobs in the Reference scenario and 8,400 in the Energy [R]evolution scenario in 2015, up from 6,200 in 2010.
- In 2020, there are nearly 8,600 jobs in the Energy [R]evolution scenario, and 5,900 in the Reference scenario.
- In 2030, there are approximately 11,000 jobs in the Energy [R]evolution scenarios, and nearly 6,100 jobs in the Reference scenario

Figure 6.1 shows the change in job numbers under both scenarios for each technology between 2010 and 2030. Jobs in the Reference scenario decrease by 2% between 2010 and 2030, with job losses in most technology sectors.

Extremely strong growth in renewable energy leads to an increase of 77% in total energy sector jobs in the Energy [R]evolution Scenario between 2010 and 2030. Renewable energy accounts for 98% of energy jobs by 2030, with biomass having the greatest share (46%), followed by geothermal, wind, solar heat and PV.

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

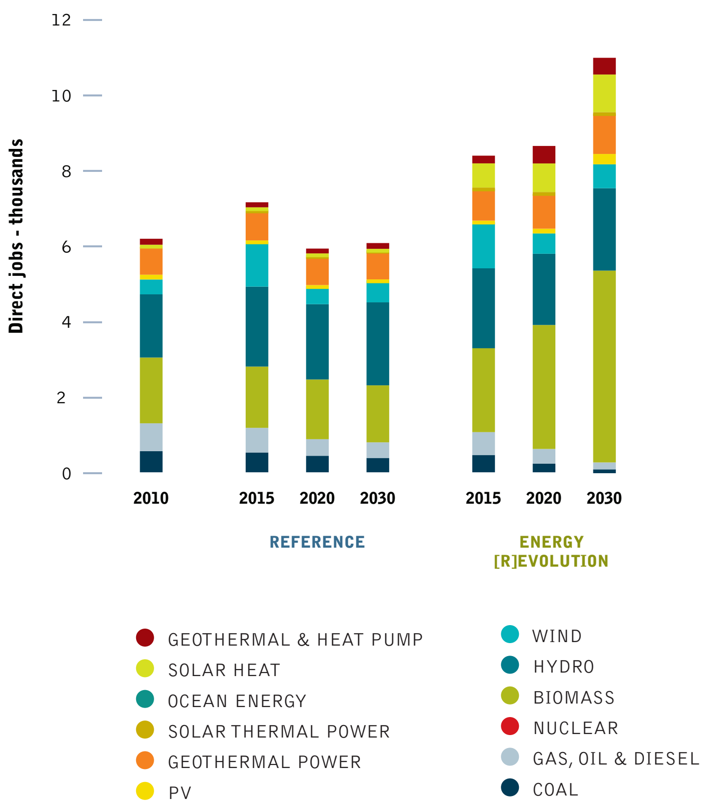


table 6.4: total employment in the energy sector THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
Coal	600	500	400	400	500	200	100
Gas, oil & diesel	700	700	400	400	600	400	200
Nuclear	-	-	-	-	-	-	-
Renewable	4,900	6,000	5,000	5,300	7,300	8,000	10,700
Total Jobs (thousands)	**6,200**	**7,100**	**5,900**	**6,100**	**8,400**	**8,600**	**11,000**
Construction and installation	800	1,300	500	400	2,200	2,000	1,800
Manufacturing	500	800	300	200	1,100	800	800
Operations and maintenance	2,500	2,700	3,100	3,500	2,800	3,500	4,400
Fuel supply (domestic)	2,400	2,200	2,000	1,900	2,300	2,400	4,000
Coal and gas export	-	-	-	-	-	-	-
Total Jobs (thousands)	**6,200**	**7,100**	**5,900**	**6,100**	**8,400**	**8,600**	**11,000**

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

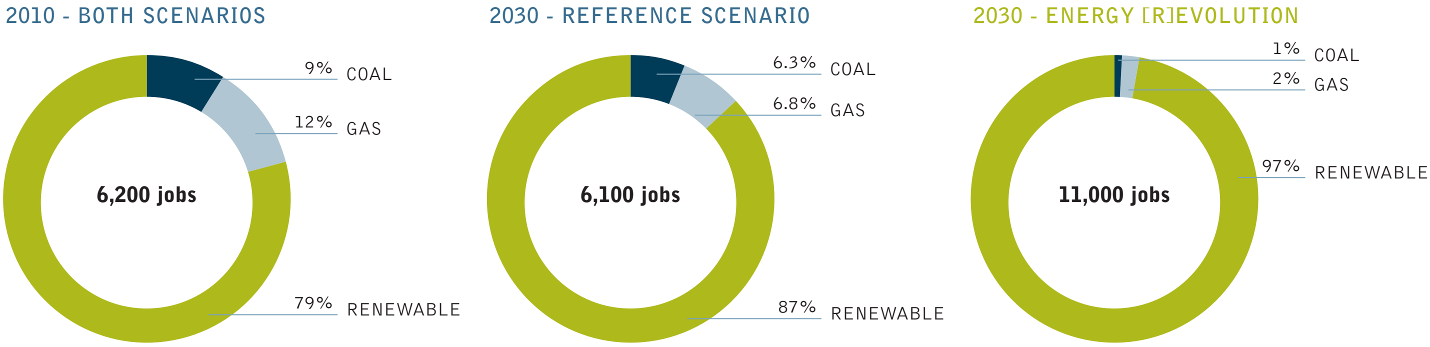


table 6.5: employment in the energy sector by technology, two scenarios THOUSAND JOBS

		REFERENCE			ENERGY [R]EVOLUTION		
By sector	2010	2015	2020	2030	2015	2020	2030
Construction and installation	600	1,200	400	300	1,600	1,100	800
Manufacturing	400	800	200	200	900	400	400
Operations and maintenance	2,500	2,700	3,100	3,500	2,800	3,500	4,400
Fuel supply (domestic)	2,400	2,200	2,000	1,900	2,300	2,400	4,000
Coal and gas export	-	-	-	-	-	-	-
Solar and geothermal heat	200	200	200	200	800	1,200	1,400
Total jobs (thousands)	**6,100**	**7,100**	**5,900**	**6,100**	**8,400**	**8,600**	**11,000**
By technology							
Coal	560	520	440	380	460	230	80
Gas, oil & diesel	740	650	440	410	610	390	180
Nuclear	-	-	-	-	-	-	-
Renewable	**4,890**	**5,980**	**5,030**	**5,270**	**7,330**	**8,030**	**10,710**
Biomass	*1,740*	*1,620*	*1,580*	*1,510*	*2,220*	*3,280*	*5,080*
Hydro	*1,670*	*2,120*	*1,990*	*2,200*	*2,120*	*1,890*	*2,180*
Wind	*390*	*1,190*	*470*	*580*	*1,220*	*540*	*630*
PV	*130*	*40*	*30*	*20*	*50*	*130*	*270*
Geothermal power	*740*	*790*	*740*	*750*	*850*	*920*	*1,070*
Solar thermal power	-	-	-	-	-	-	-
Ocean	-	*30*	*50*	*30*	*30*	*50*	*40*
Solar - heat	*60*	*60*	*40*	*30*	*640*	*760*	*1,000*
Geothermal & heat pump	*160*	*130*	*130*	*150*	*200*	*460*	*440*
Total jobs (thousands)	**6,180**	**7,150**	**5,920**	**6,070**	**8,380**	**8,640**	**10,970**

note
numbers may not add up due to rounding

image WORKERS OUTSIDE GEOTHERMAL POWER PLANT IN KAWERAU, NEW ZEALAND.

6.8 employment in the renewable heating sector

Employment in the renewable heat sector includes jobs in installation, manufacturing, and fuel supply. However, this analysis includes only jobs associated with fuel supply in the biomass sector, and jobs in installation and manucturing for direct heat from solar, geothermal and heat pumps. It will therefore be an underestimate of jobs in this sector.

6.8.1 employment in solar heating

In the Energy [R]evolution scenario, solar heating would provide 8% of total heat supply by 2030, and would employ approximately 1,000 people. Growth is much more modest in the Reference Scenario, with solar heating providing 0.7% of heat supply, and employing less than 100 people.

6.8.2 employment in geothermal and heat pump heating

In the Energy [R]evolution scenario, geothermal and heat pump heating would provide 31% of total heat supply by 2030, and employ approximately 400 people. Growth is much more modest in the Reference Scenario, with geothermal and heat pump heating providing 16% of heat supply, and employing approximately 200 people.

6.8.3 employment in biomass heat

In the Energy [R]evolution scenario, biomass heat would provide 24% of total heat supply by 2030, and would employ approximately 1,000 people. Growth is similar in the Reference Scenario, with biomass heat providing 20% of heat supply, and employing about 800 people.

table 6.6: solar heating: capacity, heat supplied and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	0.2	0.2	0.3	0.7	1.6	3.8
Heat supplied	PJ	0.5	0.7	1.0	2.2	5.0	12.3
Share of total supply	%	0.4%	0.5%	0.7%	1.5%	3%	8%
Annual increase in capacity	MW	10	10	8	115	177	310
Employment							
Direct jobs in installation and manufacture	jobs	60	40	30	640	760	1,000

table 6.7: geothermal and heat pump heating: capacity, heat supplied and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	2	3	3	3	3	5
Heat supplied	PJ	20	21	24	21	29	46
Share of total supply	%	14	14%	16%	14.5%	19%	31%
Annual increase in capacity	MW	44	45	59	68	162	170
Employment							
Direct jobs in installation and manufacture	jobs	130	130	150	200	460	440

table 6.8: biomass heat: direct jobs in fuel supply

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Heat supplied	PJ	30	30	30	31	33	36
Share of total supply	%	21%	20%	20%	22%	22%	24%
Employment							
Direct jobs in fuel supply	jobs	890	850	790	930	930	950

6.8.4 employment in hydro

Hydro currently accounts for more than half of New Zealand's electricity generation, which falls to slightly below half in both scenarios by 2030.

Hydro provides 1,700 jobs in 2010, 27% of all energy sector jobs. Development is very similar in both the Energy [R]evolution and the Reference scenarios. In both scenarios jobs increase to 2,100 by 2015, and then remain relatively stable, with a slight reduction to 2020 followed by an increase to reach 2,200 in 2030.

6.8.5 employment in biomass

In the Energy [R]evolution scenario, biomass provides 7.1% of total electricity generation by 2030. Employment grows very strongly, with approximately 1,300 jobs by 2030, 46% of total energy sector employment.

Growth is much lower in the Reference Scenario, with biomass providing 1.4% of generation by 2030, and employing approximately 270 people.

Jobs in heating from biomass fuels are included here.

table 6.9: hydro: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	5.6	6.0	6.4	5.6	6.0	6.1
Total generation	TWh	24.5	24.9	26.6	24.5	24.9	25.4
Share of total supply	%	53%	50%	49%	54%	51%	48%
Annual increase in capacity	MW	93	28	9	93	7	23
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	2,100	2,000	2,200	2,100	1,900	2,200

table 6.10: biomass: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	0.1	0.1	0.2	0.2	0.4	0.8
Total generation	TWh	0.7	0.7	0.8	0.8	1.7	3.7
Share of total supply	%	1.4%	1.4%	1.4%	1.7%	3.5%	7.1%
Annual increase in capacity	MW	1	2	3	29	53	14
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	260	270	270	770	1,400	1,300
Direct jobs in fuel supply (includes biomass for heat)	jobs	1,360	1,310	1,240	1,450	1,880	3,780
Total biomass jobs	jobs	**1,620**	**1,580**	**1,510**	**2,220**	**3,280**	**5,080**

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

6.8.6 employment in geothermal power

In the Energy [R]evolution scenario, geothermal power would provide 22% of total electricity generation by 2030, and would employ approximately 1,100 people.

Growth is also strong in the Reference Scenario, with geothermal power providing 19% of generation, and employing approximately 700 people.

6.8.7 employment in wind energy

In the Energy [R]evolution scenario, wind energy would provide 21% of total electricity generation by 2030, and would employ approximately 600 people. Growth is only slightly more modest in the Reference Scenario, with wind energy providing 19% of generation, and employing approximately the same number of people.

6.8.8 employment in solar photovoltaics

Modest growth in PV in the Energy [R]evolution scenario results in 270 jobs by 2030, with PV supplying 1.0% of electricity. In the Reference scenario, solar PV provides only 0.2% of electricity generation, and employs only 20 people, a decline from the 2015 figures.

table 6.11: geothermal power: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	1.0	1.2	1.4	1.0	1.3	1.7
Total generation	TWh	8.0	9.0	10.4	8.0	9.0	11.4
Share of total supply	%	17%	18%	19%	18%	19%	22%
Annual increase in capacity	MW	55	44	21	58	53	42
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	790	740	750	850	920	1,070

table 6.12: wind energy: capacity, generation and direct jobs

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	1.0	3.1	3.5	1.0	3.2	3.8
Total generation	TWh	2.9	9.4	10.6	3.1	9.6	11.3
Share of total supply	%	6%	19%	19%	7%	20%	21%
Annual increase in capacity	MW	256	42	66	262	60	73
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	1,200	500	600	1,200	500	600

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

		REFERENCE			ENERGY [R]EVOLUTION		
Energy	UNIT	2015	2020	2030	2015	2020	2030
Installed capacity	GW	0.04	0.05	0.08	0.06	0.09	0.37
Total generation	TWh	0.05	0.07	0.11	0.09	0.12	0.52
Share of total supply	%	0.1%	0.1%	0.2%	0.2%	0.2%	1.0%
Annual increase in capacity	MW	2.5	2.6	2.7	4.2	16.6	53.5
Employment							
Direct jobs in construction, manufacture, operation and maintenance	jobs	40	30	20	50	130	270

6.8.9 employment in coal

Jobs in the coal sector drop in both the Reference Scenario and the Energy [R]evolution scenario, continuing the ongong decline in this sector. In the Reference Scenario coal employment is projected to fall from 520 to 380 jobs between 2015 and 2030.

Coal sector employment in the Energy [R]evolution scenario falls below 100, reflecting a complete phase out of coal generation between 2015 and 2030. Coal jobs in both scenarios include coal used for heat supply.

6.8.10 employment in gas, oil & diesel

Jobs in the gas sector drop in both the Reference Scenario and the Energy [R]evolution scenario. In the Reference Scenario gas employment is projected to fall from 520 to 380 jobs between 2015 and 2030. In the same period electricity generation from gas falls by 47%.

Gas sector employment in the Energy [R]evolution scenario falls from 460 to 80 jobs between 2015 and 2030. In the same period electricity generation from gas falls to almost zero, reflecting a virtual phase out of gas generation between 2015 and 2030. Gas jobs in both scenarios include gas used for heat supply.

table 6.14: fossil fuels: capacity, generation and direct jobs

Employment in the energy sector - fossil fuels and nuclear	UNIT	REFERENCE 2015	REFERENCE 2020	REFERENCE 2030	ENERGY [R]EVOLUTION 2015	ENERGY [R]EVOLUTION 2020	ENERGY [R]EVOLUTION 2030
coal	jobs	520	440	380	460	230	80
gas, oil & diesel	jobs	650	440	410	610	390	180
COAL							
Energy							
Installed capacity	GW	0.6	0.4	0.3	0.4	neg	neg
Total generation	TWh	1.7	1.1	0.8	1.3	neg	neg
Share of total supply	%	4%	2%	2%	3%	neg	neg
Annual increase in capacity	MW	-14	-34	-13	-34	-1.5	neg
GAS, OIL & DIESEL							
Energy							
Installed capacity	GW	2.3	1.2	1.2	2.3	1.3	neg
Total generation	TWh	8.7	4.6	4.6	7.5	3.0	neg
Share of total supply	%	19%	9%	8%	17%	6%	neg
Annual increase in capacity	MW	-5	-146	5	-20	-158	neg

note
"neg" = negligible

references for this chapter:

Batten, W. M. J., & Bahaj, A. S. (2007). An assessment of growth scenarios and implications for ocean energy industries in Europe.

Department of Labour New Zealand Government. (2010). Employment and skills snapshot – mining , gas and oil extraction.

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

EPRI. (2001). California renewable technology market and benefits assessment.

European Renewable Energy Council. (2008). Renewble energy technology roadmap. 20% 2020.

European Wind Energy Association. (2009). Wind at Work.

Geothermal Energy Association. (2010). Green Jobs Through Geothermal Energy (pp. 1–22).

Hillring, B. (2002). Rural development and bioenergy — experiences from 20 years of development in Sweden, 23, 443–451.

International Energy Agency. (2007). World Energy Outlook 2007.

International Energy Agency. (2011). World Energy Outlook 2011 (p. 654). Paris: OECD/IEA.

International Energy Agency Solar Heating and Cooling Program. (2011). Solar Heat Worldwide - Markets and Contricution to Energy Supply 2009.

Kjaer, T. (2006). Socio-economic and regional benefits. Employment assessment. Regenergy.

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

Leung-Wai, J., & Generosa, A. (2012). Economic benefits of wind farms in New Zealand. Report to New Zealand Wind Energy Association.

Meridian Energy Limited. (2010). Pukaki Hydro Scheme (information sheet 01).

Ministry of Business Innovation and Employment. (2012a). Annual Coal Production and Consumption.

Ministry of Business Innovation and Employment. (2012b). Gas Production and Consumption.

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

National Commission on Energy Policy. (2009). Task force on America's future energy jobs.

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

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

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

Navigant Consulting. (2009). Job Creation Opportunities in Hydropower.

PA Consulting Group. (2010). Research project: how many jobs can be created by biomass for energy? Report to the Energy Efficiency and Conservation Authority.

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

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

Rutovitz, J., & Harris, S. (2012b). Chapter 7 in The advanced energy [r]evolution. A sustainable energy outlook for South Korea. Greenpeace International and European Renewable Energy Council. Renewable Energy.

Rutovitz, J., & Ison, N. (2011). Chapter 2 in The advanced energy [r]evolution. A sustainable energy outlook for Japan. (2nd Editio.). Greenpeace International and European Renewable Energy Council.

Sinclair Knight Merz (SKM). (2005). Review of current and future personnel capability requirements of the NZ geothermal industry.

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

Thornley, P. (2006). Life Cycle Assessment of Bioenergy Systems.

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

Thornley, P., Upham, P., Huang, Y., Rezvani, S., Brammer, J., & Rogers, J. (2009). Integrated assessment of bioelectricity technology options. Energy Policy, 37(3), 890–903.

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

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

US Energy Information Administration. (2010). Solar Thermal Collector Manufacturing Activities 2009.

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

Vestas. (2011). Annual report 2011.

WaterFurnace. (2009). Renewable energy is poised to contribute to economic recovery and long-term energy goals (press release).

abbreviations

EIA Energy Information Administration (USA)
CO_2 Carbon Dioxide
IEA International Energy Agency
ISF Institute for Sustainable Futures
MW Megawatt
O&M Operations and Maintenance
OECD Organisation for Economic Co-operation and Development
PV Photovoltaic
REN21 Renewables Global Status Report
TWh Terawatt hour

the silent revolution
– past and current market developments

POWER PLANT MARKETS

GLOBAL MARKET SHARES IN THE POWER PLANT MARKET: RENEWABLE GAINING GROUND

DEVELOPMENT OF THE INSTALLED POWER PLANT CAPACITY IN EUROPE

7

> “the bright future for renewable energy is already underway.”

technology SOLAR PARKS PS10 AND PS20, SEVILLE, SPAIN. THESE ARE PART OF A LARGER PROJECT INTENDED TO MEET THE ENERGY NEEDS OF SOME 180,000 HOMES — ROUGHLY THE ENERGY NEEDS OF SEVILLE BY 2013, WITHOUT GREENHOUSE GAS EMISSIONS.

A new analysis of the global power plant market shows that since the late 1990s, wind and solar installations grew faster than any other power plant technology across the world - about 430,000 MW total installed capacities between 2000 and 2010. However, it is too early to claim the end of the fossil fuel based power generation, because more than 475,000 MW of new coal power plants were built with embedded cumulative emissions of over 55 billion tonnes CO_2 over their technical lifetime.

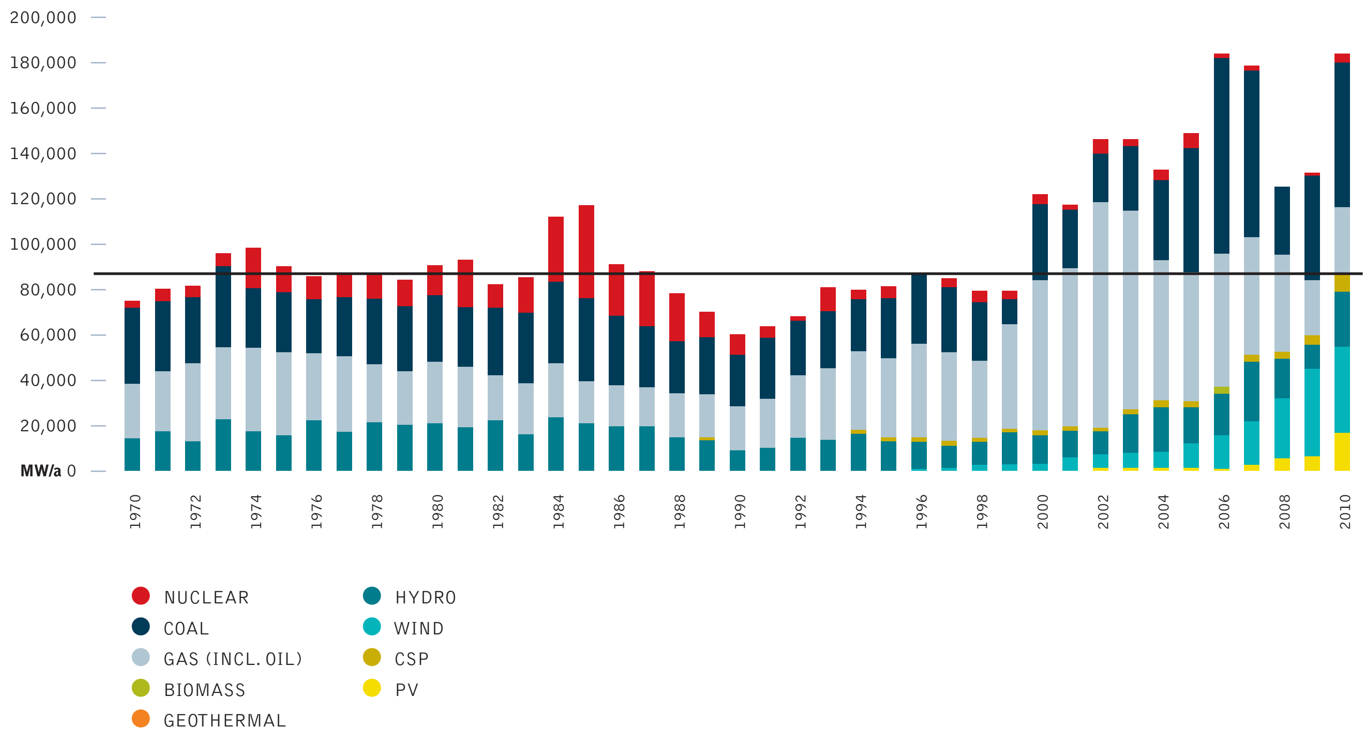
The global market volume of renewable energies constructed in 2010 was on average, equal to the total global energy market volume (all kinds) added each year between 1970 and 2000. There is a window of opportunity for new renewable energy installations to replace old plants in OECD countries and for electrification in developing countries. However, the window will close within the next few years without good renewable energy policies and legally binding CO_2 reduction targets.

Between 1970 and 1990, the OECD[66] global power plant market was dominated by countries that electrified their economies mainly with coal, gas and hydro power plants. The power sector was in the hands of state-owned utilities with regional or nationwide supply monopolies. The nuclear industry had a relatively short period of steady growth between 1970 and the mid 1980s - with a peak in 1985, one year before the Chernobyl accident - and went into decline in following years, with no recent signs of growth.

Between 1990 and 2000, the global power plant industry went through a series of changes. While OECD countries began to liberalise their electricity markets, electricity demand did not match previous growth, so fewer new power plants were built. Capital-intensive projects with long payback times, such as coal and nuclear power plants, were unable to get sufficient financial support. The decade of gas power plants started.

The economies of developing countries, especially in Asia, started growing during the 1990s, triggering a new wave of power plant projects. Similarly to the US and Europe, most of the new markets in the 'tiger states' of Southeast Asia partly deregulated their power sectors. A large number of new power plants in this region were built from Independent Power Producer (IPPs), who sell the electricity mainly to state-owned utilities. The majority of new power plant technology in liberalised power markets is fuelled by gas, except for in China which focused on building new coal power plants. Excluding China, the rest of the global power plant market has seen a phase-out of coal since the late 1990s with growing gas and renewable generation, particularly wind.

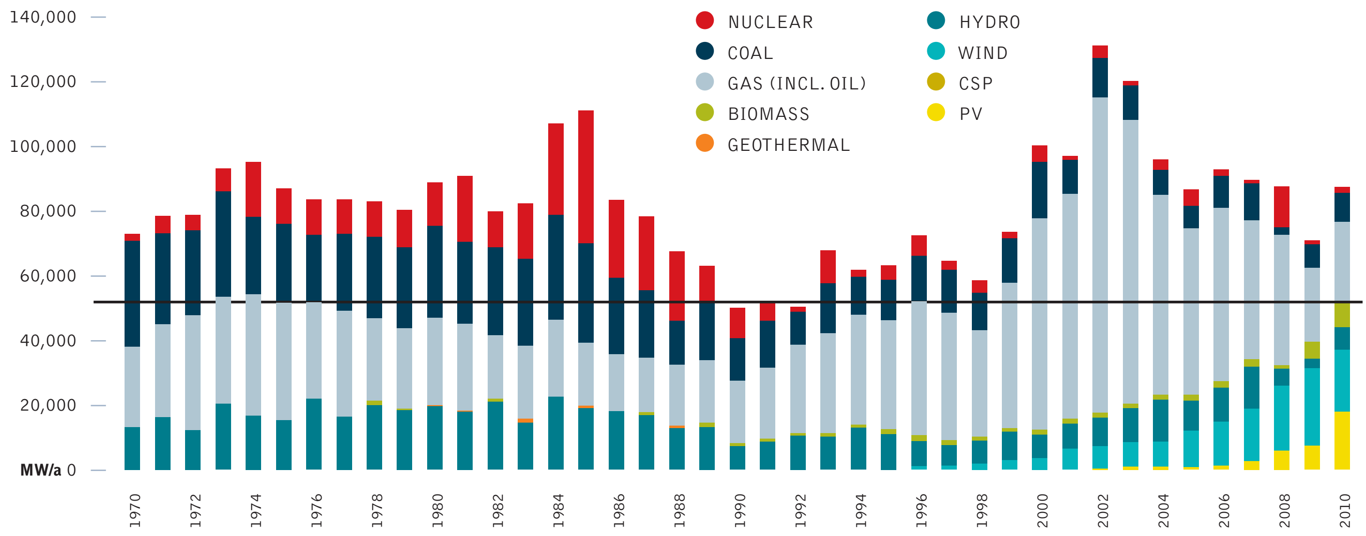
figure 7.1: global power plant market 1970-2010



source
Platts, IEA, Breyer, Teske.

reference
66 ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT.

figure 7.2: global power plant market 1970-2010, excluding china



source
Platts, IEA, Breyer, Teske.

Europe: About five years after the US began deregulating the power sector, the European Community started a similar process with similar effect on the power plant market. Investors backed fewer new power plants and extended the lifetime of the existing ones. New coal and nuclear power plants have seen a market share of well below 10% since then. The growing share of renewables, especially wind and solar photovoltaic, are due to a legally-binding target and the associated feed-in laws which have been in force in several member states of the EU 27 since the late 1990s. Overall, new installed power plant capacity jumped to a record high because the aged power plant fleet in Europe needed re-powering.

figure 7.3: europe (eu 27): power plant market 1970-2010

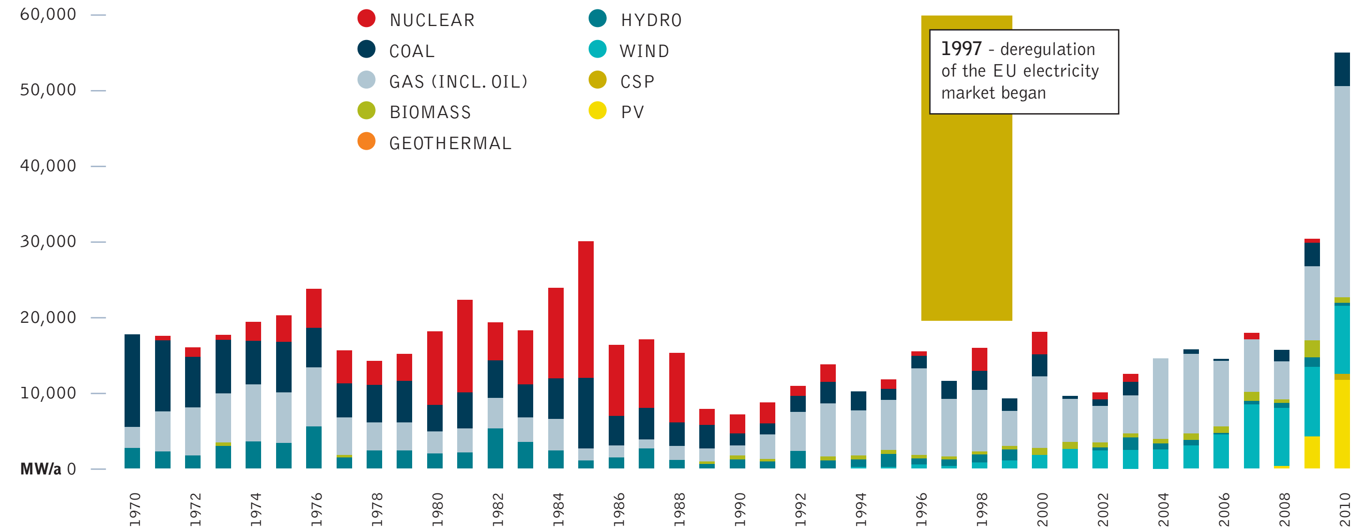
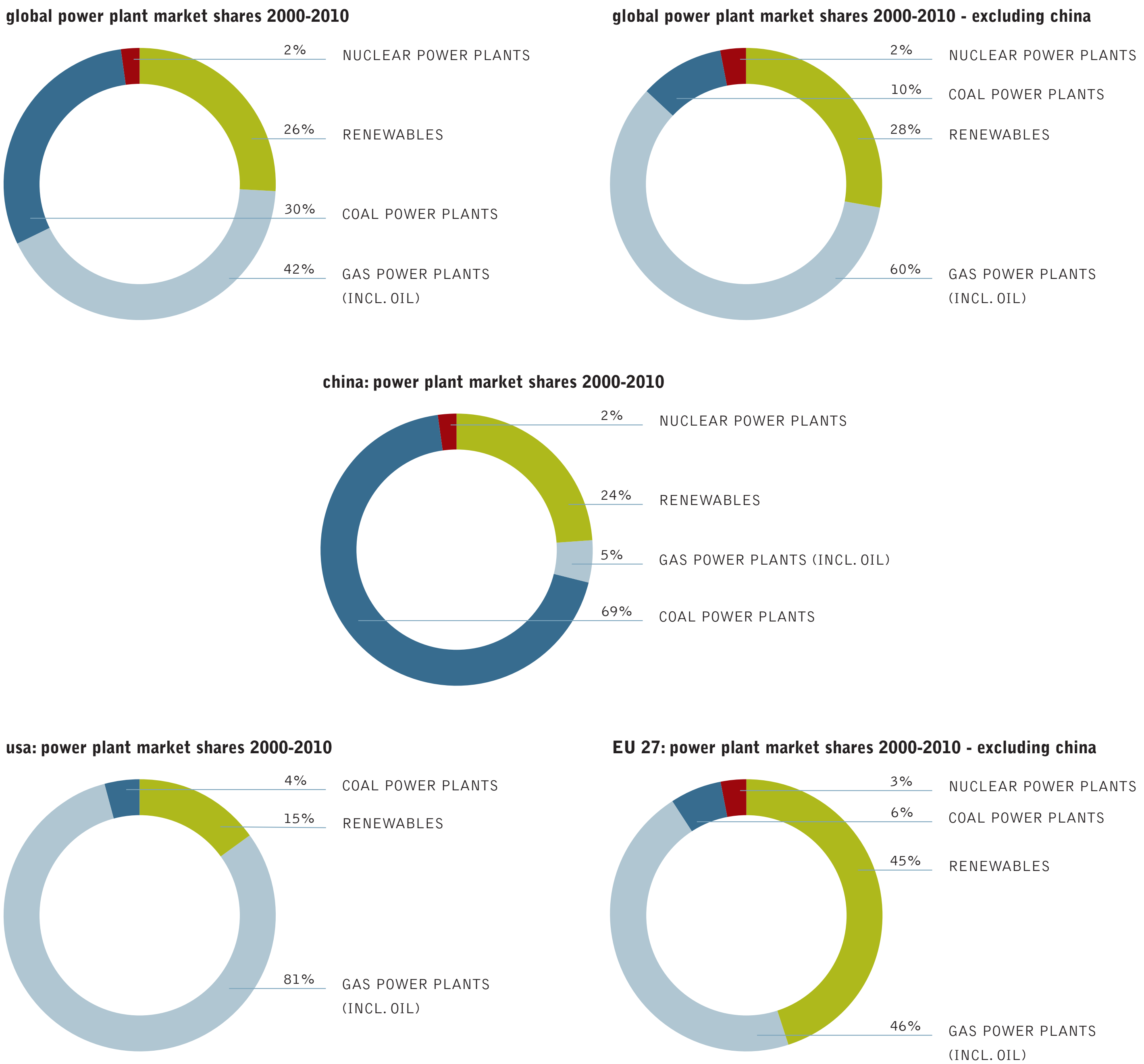


image NESJAVELLIR GEOTHERMAL PLANT GENERATES ELECTRICITY AND HOT WATER BY UTILIZING GEOTHERMAL WATER AND STEAM. IT IS THE SECOND LARGEST GEOTHERMAL POWER STATION IN ICELAND. THE STATION PRODUCES APPROXIMATELY 120MW OF ELECTRICAL POWER, AND DELIVERS AROUND 1,800 LITRES (480 US GAL) OF HOT WATER PER SECOND, SERVICING THE HOT WATER NEEDS OF THE GREATER REYKJAVIK AREA. THE FACILITY IS LOCATED 177 M (581 FT) ABOVE SEA LEVEL IN THE SOUTHWESTERN PART OF THE COUNTRY, NEAR THE HENGILL VOLCANO.

7.1 the global market shares in the power plant market: renewables gaining ground

Since the year 2000, the wind power market gained a growing market share within the global power plant market. Initially only a handful of countries, namely Germany, Denmark and Spain, dominated the wind market, but the wind industry now has projects in over 70 countries around the world. Following the example of the wind industry, the solar photovoltaic industry experienced an equal growth since 2005. Between 2000 and 2010, 26% of all new power plants worldwide were renewable-powered – mainly wind – and 42% run on gas. So, two-thirds of all new power plants installed globally are gas power plants and renewable, with close to one-third as coal. Nuclear remains irrelevant on a global scale with just 2% of the global market share. About 430,000 MW of new renewable energy capacity has been installed over the last decade, while 475,000 MW of new coal, with embedded cumulative emissions of more than 55 billion tonnes CO_2 over their technical lifetime, came online – 78% or 375,000 MW in China.

figure 7.4: power plant market shares



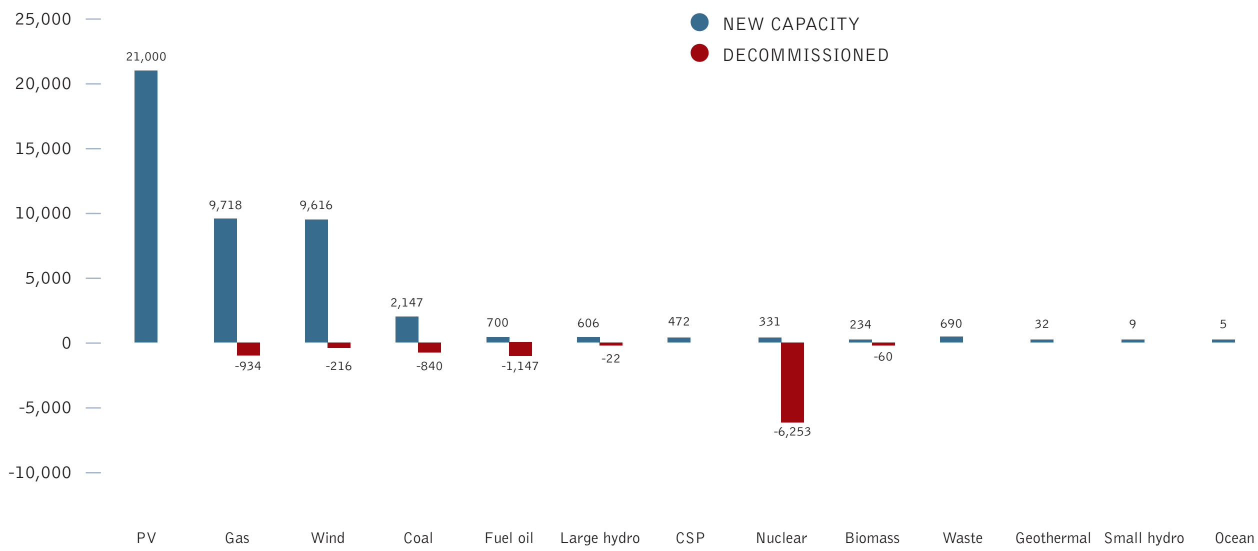
source PLATTS, IEA, BREYER, TESKE, GWAC, EPIA.

The energy revolution has started on a global level already. This picture is even clearer when we look into the global market shares but exclude China, the only country with a massive expansion of coal. About 28% of all new power plants since 2000 have been renewables and 60% have been gas power plants (88% in total). Coal gained a market share of only 10% globally, excluding China. Between 2000 and 2010, China has added over 350,000 MW of new coal capacity: twice as much as the entire coal capacity of the EU. However, China has also recently kick-started its wind market, and solar photovoltaics is expected to follow in the years to come.

7.2 development of the installed power plant capacity in europe

Figure 7.5 provides shows the new installed capacity and decommissioned power plant capacity. The trend away from nuclear towards renewable energy – especially wind and solar pv – and gas has been quite robust over recent years. However, in 2011 more coal power plants have been connected to the grid than decommissioned which will lead to high and long term carbon emissions.

figure 7.5: new installed capacity and decommissioned capacity in mw, 2011. total 35,468 mw.



source
EWEA 2012

transport

TECHNICAL AND BEHAVIOURAL MEASURES TO REDUCE TRANSPORT ENERGY CONSUMPTION

LIGHT DUTY VEHICLES

CONCLUSION

image THE SUNDARBANS OF INDIA AND BANGLADESH IS THE LARGEST REMAINING TRACT OF MANGROVE FOREST IN THE WORLD. A TAPESTRY OF WATERWAYS, MUDFLATS, AND FORESTED ISLANDS AT THE EDGE OF THE BAY OF BENGAL. HOME TO THE ENDANGERED BENGAL TIGER, SHARKS, CROCODILES, AND FRESHWATER DOLPHINS, AS WELL AS NEARLY TWO HUNDRED BIRD SPECIES, THIS LOW-LYING PLAIN IS PART OF THE MOUTHS OF THE GANGES. THE AREA HAS BEEN PROTECTED FOR DECADES BY THE TWO COUNTRIES AS A NATIONAL PARK.

Sustainable transport is needed to reduce the level of greenhouse gases in the atmosphere, just as much as a shift to renewable electricity and heat production. Today, over a third (39%) of current energy use comes from the transport sector, mainly road transport (89%) but also from domestic aviation (7%) and shipping (2%). However the most efficient form of transport, railways, currently only has a market share of 1.4%. This chapter provides an overview of the selected measures required to develop a more energy efficient and sustainable transport system in the future, with a focus on:

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

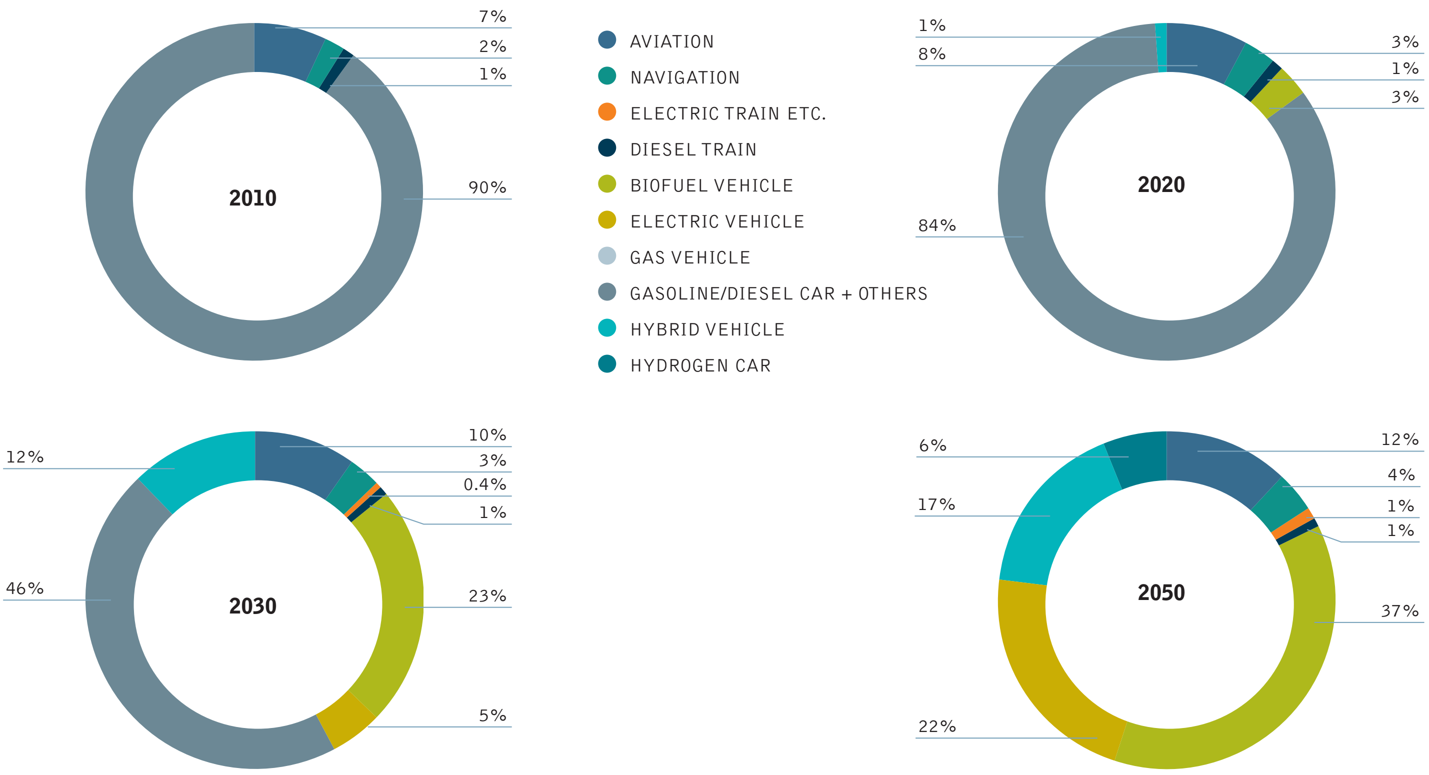
This section provides the assumptions for the New Zealand's transport sector energy demand calculations used in the Reference and the Energy [R]evolution scenarios including projections for the passenger vehicle market (light duty vehicles). Overall, some technologies will have to be adapted for greater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

The definitions of the transport modes for the scenarios[67] are:

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

Figure 8.1 shows the breakdown of final energy demand for the transport modes in 2010 to 2050 in the Energy [R]evolution scenario.

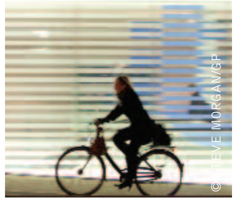
figure 8.1: new zealand final energy use per transport mode from 2010 to 2050 in the energy [r]evolution scenario



reference
67 FULTON & EADS (2004).

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

image CYCLING THROUGH FRANKFURT.



8.1 technical and behavioural measures to reduce transport energy consumption

The following section describes how the transport modes contribute to total and relative energy demand. Then, a selection of measures for reducing total and specific energy transport consumption are put forward for each mode.

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

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

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

8.1.1 step 1: reduction of transport demand

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

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

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

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

In the Reference Scenario, there is a forecast increase in passenger-km up to 2050, whereas in the 2050 Energy [R]evolution scenario there is a decline in individual transport on a per capita basis. The reduction in passenger-km per capita in the Energy [R]evolution scenario compared to the Reference scenario comes with a general reduction in car use due to behavioral and traffic policy changes and partly with a shift of transport to public modes. A shift from energy-intensive individual transport to low-energy intensive demand public transport is limited to the urban areas with higher population density in New Zealand and aligns with an increase in low-energy intensive public transport passenger-km.

table 8.1: selection of measures and indicators

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

8.1.2 step 2: changes in transport mode

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

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

For the purpose of this study, passenger transport includes light-duty vehicles, passenger rail and air transport. Freight transport includes medium-duty vehicles, heavy-duty vehicles, inland navigation, marine transport and freight rail. WBCSD 2004 data was used as baseline data for the global Energy [R]evolution including specific data for OECD Asia Oceania. For the New Zealand analysis those quantitative changes between the Reference and the Energy [R]evolution scenario have been taken into account. However a specific analysis of the energy intensity of New Zealand's entire vehicle fleet has not been done.

Passenger transport Travelling by rail is the most efficient – but car transport improves strongly. Figure 8.2 shows the average specific energy consumption (energy intensity) by transport mode in 2009 and in the Energy [R]evolution scenario in 2050. Passenger transport by rail will consume on a per passenger-km basis 18/28% less energy in 2050 than car transport and 84/85% less than aviation, which shows that shifting from road to rail can make large energy savings.

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

In the [E]nergy [R]evolution Scenario it is assumed that a certain portion of passenger kilometer of domestic air traffic is suitable to be reduced via behaviour changes. For the remaining flights more efficient plans will be used to further reduce energy demand in domestic air traffic beyond 2025. For international aviation there is obviously no substitution potential to other modes whatsoever.

Freight transport Similar to Figure 8.2 which showed average specific energy consumption for passenger transport modes, Figure 8.3 shows the respective energy consumption for various freight transport modes in 2009 and in the Energy [R]evolution scenario 2050. The values are weighted according to stock-and-traffic performance. The energy intensity of all modes of transport is expected to decrease by 2050. In absolute terms, road transport shows the largest efficiency gains whereas transport on rail and water remain the modes with the lowest relative energy demand per tonne-km. Rail freight transport will consume 85% less specific energy per tonne-km in 2050 than long haul HDV.

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

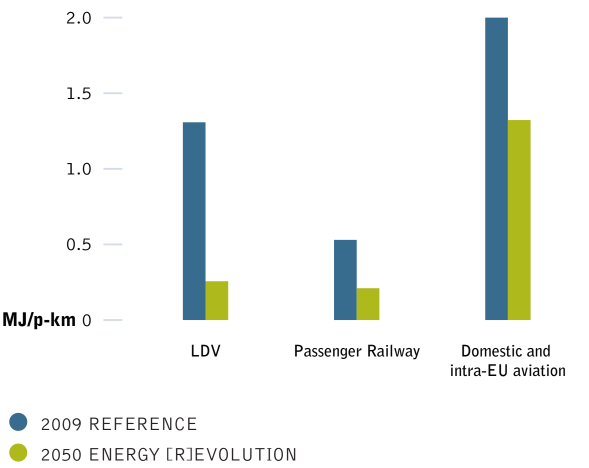


figure 8.3: world average (stock-weighted) freight transport energy intensity in the energy [r]evolution scenario

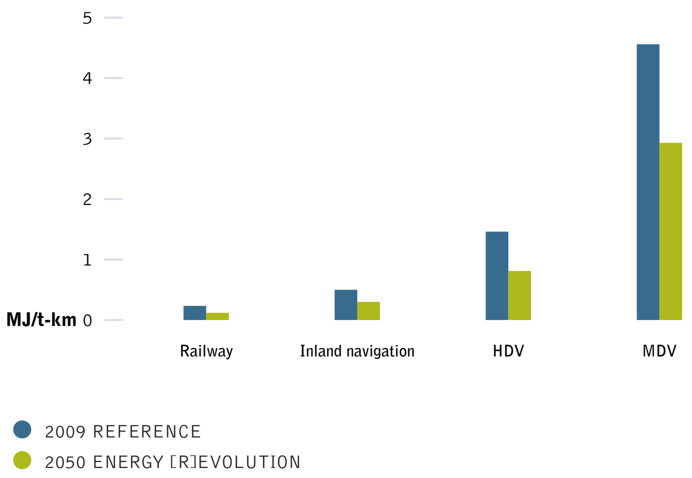


image ITALIAN EUROSTAR TRAIN.

image TRAFFIC IN AUCKLAND.

© ITALIANESTRO/DREAMSTIME

© XXX

Modal shifts for transporting goods in the Energy [R]evolution scenario The figures above indicate that as much road freight as possible should be shifted from road-bound freight transport to less energy intensive freight rail and inland navigation, in order to achieve maximum energy savings from modal shifts. As the goods transported by medium-duty vehicles are mainly going to regional destinations (and are therefore unsuitable for the long distance nature of freight rail transport), no modal shift to rail is assumed for this type of transport. For long-haul heavy-duty vehicle transport, however, especially low value densities, heavy goods that are transported on a long range are suitable for a modal shift to railways and inland navigation.[68]

8.1.3 step 3: efficiency improvements

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

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

In general, an integral part of any energy reduction scheme is an increase in the load factor – this applies both for freight and passenger transport. As the load factor increases, fewer transport vehicles are needed and thus the energy intensity decreases when measured on a passenger-km or tonne-km base.

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

Air transport A study conducted by NASA in 2011 shows that energy use of new subsonic aicrafts can be reduced by up to 58% up to 2035. Akerman (2005) reports that a more than 50/65% reduction in fuel use is technically feasible by 2050. Technologies to reduce fuel consumption of aircrafts mainly comprise:

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

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

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

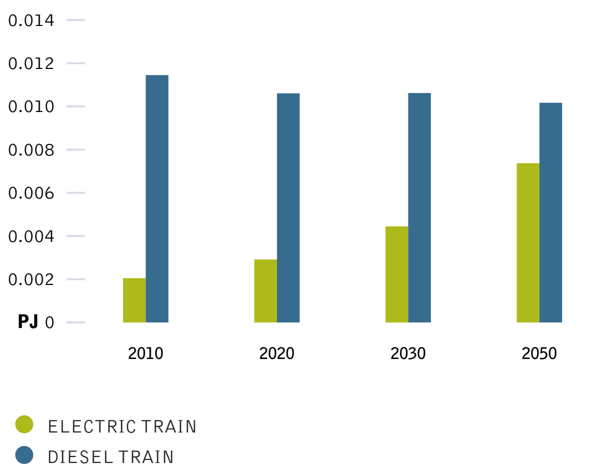
reference

68 TAVASSZY AND VAN MEIJEREN 2011.

- improved accessory functions, e.g. for passenger comfort. A substantial amount of energy in a train needed is to ensure the comfort of the train's passengers by heating and cooling. Strategies to enhance efficiency include adjustments to the cabin design, changes to air intakes and using waste heat from the propulsion system.

Figure 8.4 shows the weighted global average share of electric and diesel traction today and as of 2030 and 2050 in Energy [R]evolution scenarios. However a specific survey for New Zealand has not be done.

figure 8.4: fuel share of electric and diesel rail traction for passenger and freight transport



Electric trains as of today are about 2 to 3.5 times less energy intensive (on a tank-to-wheel-perspective) than diesel trains depending on the specific type of rail transport. As an increasing share of electric energy is to come from renewable sources in the future, the projections to 2050 include a massive shift away from diesel to electric traction in the Energy [R]evolution scenario.

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

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

Adding up each technology's effectiveness as stated by ICCT (2011), these technologies have an overall potential to improve energy efficiency of new vessels between 18.4% and about 57%. Another option to reduce energy demand of ships is simply to reduce operating speeds. Up to 36% of fuel consumption can be saved by reducing the vessel's speed by 20%.[69] Eyring et al. (2005) report that a 25% reduction of fuel consumption for an international marine diesel fleet is achievable by using more efficient alternative propulsion devices only.[70] Up to 30% reduction in energy demand is reported by Marintek (2000) only by optimising the hull shape and propulsion devices of new vessels.[71]

8.2 light-duty vehicles

8.2.1 projection of the CO_2 emission development

This section draws on a study on future vehicle technologies conducted by the DLR's Institute of Vehicle Concepts. The approach shows the potential of different technologies to increase the energy efficiency of future cars (light-duty vehicles) and gives a detailed analysis of possible cost developments.[72]

Many technologies can be used to improve the fuel efficiency of conventional passenger cars. Examples include improvements in engines, weight reduction as well as friction and drag reduction.[73] The impact of the various measures on fuel efficiency can be substantial. The introduction of hybrid vehicles, combining a conventional internal combustion engine with an electric motor and a battery, can further reduce fuel consumption. Applying advanced lightweight materials, in combination with new propulsion technologies, can bring fuel consumption levels down to 1 litre ge/100 km.

references
69 ICCT, 2011.
70 EYRING ET AL., 2005.
71 MARINTEK, 2000.
72 DLR, 2011.
73 DECICCO ET AL., 2001.

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

image PARKING SPACE FOR HYBRIDS ONLY.

8.2.2 projection of the future vehicle segment split

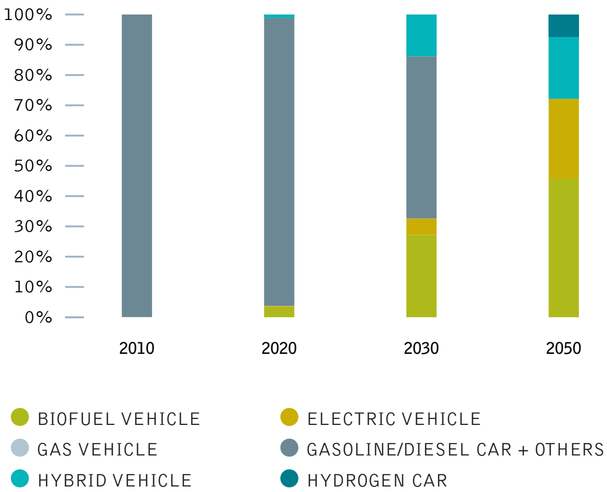
For the future vehicle segment split the scenario deals with the light-duty vehicle sales in three segments: small, medium and large vehicles. For our purposes we divide up the numerous car types as follows:

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

8.2.3 projection of the future technology mix

Further to incremental efficiency improvements, greater occupancy rates and a shift toward smaller vehicle segments, a radical shift is needed in the fuels used in cars to achieve the CO_2 reduction targets in the Energy [R]evolution scenario. This means that conventional fossil fuelled cars are no longer sold in 2050 and that the petrol and diesel fuelled autonomous hybrids and plug-in hybrids (PHEV) that we have today are also phased out by 2050. That is, two generations of hybrid technologies will pave the way for the complete transformation toward light-duty vehicles with full battery electric or hydrogen fuel cell powertrains. Since it may not be possible to power LDVs for all purposes by rechargeable batteries only, hydrogen is introduced as a renewable fuel especially for larger long-range LDVs. Biofuels and remaining oil would be used in other sectors where a substitution is even harder to achieve than for LDVs. Figures 8.5 show the development of powertrain sales shares over time for small, medium and large LDVs up to 2050 in the Energy [R]evolution scenario.

figure 8.5: sales share of vehicle technologies up to 2050 in the energy [r]evolution for new zealand



8.2.4 renewable energy in the transport sector

In the Energy [R]evolution scenario, over half of the CO_2 reduction in the transport sector is achieved through a reduction in transport energy demand by 2050, through both behavioural measures and vehicle efficiency improvements. The remaining energy demand needs to be covered largely by renewable sources, to achieve the required CO_2 reductions in a sustainable manner. As petrol and diesel fuelled vehicles are phased out, alternative vehicle technologies are brought to market which can tap into electricity and hydrogen from renewable energy sources. By 2050, 92% of transport energy comes from renewable sources, compared to 0.2% in 2009.

The Energy [R]evolution assumes that the potential for sustainable biomass is limited. For the New Zealand transport sector, there are no more than around 90 PJ available, given that other sectors such as power and heat production also partly rely on biomass energy.

8.3 conclusion

In a business as usual world we project only a very slight decrease in transport energy demand until 2050 in New Zealand. The aim of this Transport Chapter was therefore to show ways to dramatically reduce transport energy demand in general, and the dependency on climate-damaging fossil fuels in particular, also in view of the ever rising transport energy demand in other world regions.

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

- a decrease of passenger- and freight-kilometres on a per capita base,
- a massive shift to electrically and hydrogen powered vehicles whose energy sources are produced from renewable sources,
- a gradual decrease of all modes' energy intensities,
- a modal shift from aviation to rail and from road freight to rail freight.

These measures should be accompanied by major efforts on the installation and extension of the necessary infrastructures, e. g. improved public transport systems in urban areas, charging and fueling infrastructure for electric vehicles, just to mention a few.

The government of New Zealand should support these efforts by tightening existing vehicle efficiency and fuel regulations and introducing new standards for trucks and other vehicle categories. In parallel, it should adopt regulations to control both fossil and renewable fuel production such that the energy demand in transport is met by truly sustainable, low-carbon energy. It should also promote the roll-out of refuelling infrastructure across all countries.

Literature

Akerman, J. (2005): Sustainable air transport – on track in 2050, Transportation Research Part D: Transport and Environment, Volume 10, Issue 2, 111-126.

European Environmental Agency (2011): Laying the foundations for greener transport, TERM.

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

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

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

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

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

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

Sachverständigenrat für Umweltfragen (2012): Umweltgutachten 2012, Verantwortung in einer begrenzten Welt.

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

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

glossary & appendix

GLOSSARY OF COMMONLY USED TERMS AND ABBREVIATIONS

DEFINITION OF SECTORS

NEW ZEALAND: SCENARIO RESULTS DATA

9

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

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

9.1 glossary of commonly used terms and abbreviations

CHP Combined Heat and Power
CO_2 Carbon dioxide, the main greenhouse gas
GDP Gross Domestic Product (means of assessing a country's wealth)
PPP Purchasing Power Parity (adjustment to GDP assessment to reflect comparable standard of living)
IEA International Energy Agency

J Joule, a measure of energy:
kJ (Kilojoule) = 1,000 Joules
MJ (Megajoule) = 1 million Joules
GJ (Gigajoule) = 1 billion Joules
PJ (Petajoule) = 10^{15} Joules
EJ (Exajoule) = 10^{18} Joules

W Watt, measure of electrical capacity:
kW (Kilowatt) = 1,000 watts
MW (Megawatt) = 1 million watts
GW (Gigawatt) = 1 billion watts
TW (Terawatt) = 1^{12} watts

kWh Kilowatt-hour, measure of electrical output:
kWh (Kilowatt-hour) = 1,000 watt-hours
TWh (Terawatt-hour) = 10^{12} watt-hours

t Tonnes, measure of weight:
t = 1 tonne
Gt = 1 billion tonnes

table 9.1: conversion factors - fossil fuels

FUEL				
Coal	23.03	MJ/kg	1 cubic	0.0283 m^3
Lignite	8.45	MJ/kg	1 barrel	159 liter
Oil	6.12	GJ/barrel	1 US gallon	3.785 liter
Gas	38000.00	kJ/m^3	1 UK gallon	4.546 liter

table 9.2: conversion factors - different energy units

FROM / TO: MULTIPLY BY	TJ	Gcal	Mtoe	Mbtu	GWh
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	$10^{(-7)}$	3.968	1.163×10^{-3}
Mtoe	4.1868×10^{4}	10^{7}	1	3968×10^{7}	11630
Mbtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-5}	3412	1

9.2 definition of sectors

The definition of different sectors follows the sectorial break down of the IEA World Energy Outlook series.

All definitions below are from the IEA Key World Energy Statistics.

Industry sector: Consumption in the industry sector includes the following subsectors (energy used for transport by industry is not included -> see under "Transport")

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

Transport sector: The Transport sector includes all fuels from transport such as road, railway, aviation, domestic navigation. Fuel used for ocean, coastal and inland fishing is included in "Other Sectors".

Other sectors: "Other Sectors" covers agriculture, forestry, fishing, residential, commercial and public services.

Non-energy use: Covers use of other petroleum products such as paraffin waxes, lubricants, bitumen etc.

new zealand: scenario results data

image TASMAN GLACIER, ON NEW ZEALAND'S SOUTH ISLAND, IS THE NATION'S LONGEST GLACIER. IN NOVEMBER 2007, NEW ZEALAND'S NATIONAL INSTITUTE OF WATER AND ATMOSPHERIC RESEARCH (NIWA) ANNOUNCED THAT ICE VOLUME IN THE COUNTRY'S SOUTHERN ALPS HAD SHRUNK NEARLY 11 PERCENT OVER THE PREVIOUS 30 YEARS.

new zealand: reference scenario

table 9.3: new zealand: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**41**	**44**	**47**	**51**	**55**	**57**
Coal	2.6	1.6	1.0	0.8	0.6	0.5
Lignite	0.1	0	0	0	0	0
Gas	7.5	6.6	2.5	2.3	2.2	2.2
Oil	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0
Biomass	0.2	0.2	0.2	0.2	0.3	0.4
Hydro	24	25	25	27	27	27
Wind	1.5	2.9	9.4	11	12	13
including offshore	0	0	0	0	0	0
PV	0	0.1	0.1	0.1	0.2	0.2
Geothermal	4.8	7.9	8.9	10	11	12
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0.1	0.5	0.7	0.8
Combined heat & power plants	**2.6**	**2.7**	**2.8**	**3.0**	**3.2**	**3.2**
Coal	0.1	0.1	0.1	0.1	0.1	0.1
Lignite	0	0	0	0	0	0
Gas	2.0	2.1	2.2	2.3	2.5	2.5
Oil	0	0	0	0	0	0
Biomass	0.4	0.5	0.5	0.6	0.6	0.6
Geothermal	0.1	0.1	0.1	0.1	0.1	0.1
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	3	3	3	3	3	3
Total generation	**43**	**47**	**50**	**54**	**58**	**60**
Fossil	12	10	5.7	5.4	5.3	5.2
Coal	2.7	1.7	1.1	0.8	0.7	0.5
Lignite	0	0	0	0	0	0
Gas	9.5	8.7	4.6	4.6	4.6	4.6
Oil	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
Renewables	31	36	44	49	53	55
Hydro	24	25	25	27	27	27
Wind	1.5	2.9	9.4	11	12	13
including offshore	0	0	0	0	0	0
PV	0	0.1	0.1	0.1	0.2	0.2
Biomass	0.6	0.7	0.7	0.8	0.9	1.0
Geothermal	4.9	8.0	9.0	10	11	12
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0.1	0.5	0.7	0.8
Distribution losses	3	3	3	3	3	3
Own consumption electricity	2	2	2	2	2	2
Electricity for hydrogen production	0	0	0	0	0	0
Final energy consumption (electricity)	**38**	**42**	**45**	**49**	**53**	**55**
Fluctuating RES (PV, Wind, Ocean)	1	3	10	11	13	14
Share of fluctuating RES	3.4%	6.4%	19.1%	20.5%	22.6%	23.5%
RES share (domestic generation)	**71.7%**	**77.7%**	**88.5%**	**90.0%**	**90.8%**	**91.4%**

table 9.4: new zealand: 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	**1.8**	**2.3**	**2.5**	**2.6**	**2.8**	**2.8**
Fossil fuels	1.0	1.4	1.4	1.5	1.6	1.6
Biomass	0.3	0.4	0.5	0.6	0.6	0.6
Geothermal	0.5	0.5	0.5	0.6	0.6	0.6
Hydrogen	0	0	0	0	0	0
Direct heating	**163**	**172**	**177**	**186**	**193**	**201**
Fossil fuels	88	93	94	95	95	96
Biomass	29	30	30	30	30	29
Solar collectors	0.3	0.5	0.7	1.0	1.2	1.3
Heat pumps[1]	7.6	9.3	11	14	17	20
Geothermal	10	10	10	10	10	11
Electricity[2]	28	30	32	36	40	44
Total heat supply	**164**	**174**	**180**	**188**	**196**	**204**
Fossil fuels	89	94	96	97	97	97
Biomass	29	30	30	30	30	30
Solar collectors	0.3	0.5	0.7	1.0	1.2	1.3
Heat pumps[1]	7.6	9.3	11	14	17	20
Geothermal	10	10	11	11	11	11
Hydrogen	0	0	0	0	0	0
Electricity[2]	28	30	32	36	40	44
RES share (including RES electricity)	**40.8%**	**42.2%**	**44.7%**	**46.6%**	**48.8%**	**50.4%**

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

table 9.5: new zealand: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**6.3**	**4.8**	**2.1**	**1.7**	**1.5**	**1.3**
Coal	2.4	1.4	0.9	0.6	0.5	0.4
Lignite	0.1	0	0	0	0	0
Gas	3.8	3.3	1.2	1.1	1.0	1.0
Oil	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Combined heat & power production	**0.6**	**0.5**	**0.5**	**0.5**	**0.6**	**0.6**
Coal	0.04	0.03	0.03	0.03	0.03	0.02
Lignite	0	0	0	0	0	0
Gas	0.5	0.5	0.5	0.5	0.5	0.5
Oil	0	0	0	0	0	0
CO_2 emissions power generation (incl. CHP public)	**6.9**	**5.3**	**2.6**	**2.3**	**2.0**	**1.9**
Coal	2.5	1.5	0.9	0.7	0.5	0.4
Lignite	0.1	0	0	0	0	0
Gas	4.3	3.8	1.7	1.6	1.5	1.5
Oil & diesel	0	0	0	0	0	0
CO_2 emissions by sector	**30**	**29**	**27**	**27**	**26**	**25**
% of 1990 emissions	136%	132%	120%	119%	117%	114%
Industry[1]	5.1	5.4	5.5	5.6	5.7	5.8
Other sectors[1]	2.8	2.8	2.7	2.6	2.4	2.3
Transport	14	14	15	15	15	14
Power generation[2]	6.3	4.8	2.1	1.7	1.5	1.3
District heating & other conversion	2.2	2.2	1.9	1.9	1.9	1.9
Population (Mill.)	4.5	4.6	4.8	5.2	5.5	5.7
CO_2 emissions per capita (t/capita)	**6.8**	**6.4**	**5.5**	**5.1**	**4.8**	**4.5**

1) including CHP autoproducers. 2) including CHP public

table 9.6: new zealand: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**9.6**	**10**	**12**	**13**	**13**	**14**
Coal	0.9	0.5	0.3	0.3	0.2	0.2
Lignite	0.01	0	0	0	0	0
Gas	2.0	1.8	0.7	0.6	0.6	0.6
Oil	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0
Biomass	0.05	0.06	0.06	0.06	0.09	0.1
Hydro	5.4	5.6	6.0	6.4	6.5	6.5
Wind	0.5	1.0	3.1	3.5	4.1	4.4
including offshore	0	0	0	0	0	0
PV	0	0.04	0.05	0.08	0.1	0.2
Geothermal	0.6	1.0	1.2	1.4	1.6	1.8
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0.4**	**0.6**	**0.6**	**0.6**	**0.7**	**0.8**
Coal	0.03	0.03	0.02	0.02	0.02	0.02
Lignite	0	0	0	0	0	0
Gas	0.3	0.4	0.5	0.5	0.6	0.6
Oil	0	0	0	0	0	0
Biomass	0.1	0.1	0.1	0.1	0.1	0.1
Geothermal	0.01	0.01	0.01	0.01	0.01	0.01
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	1	1	1	1	1
Total generation	**10**	**11**	**12**	**13**	**14**	**15**
Fossil	3.3	2.9	1.6	1.5	1.5	1.5
Coal	0.9	0.6	0.4	0.3	0.2	0.2
Lignite	0.01	0	0	0	0	0
Gas	2.3	2.3	1.1	1.1	1.2	1.2
Oil	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**6.7**	**7.7**	**11**	**12**	**13**	**13**
Hydro	5.4	5.6	6.0	6.4	6.5	6.5
Wind	0.5	1.0	3.1	3.5	4.1	4.4
including offshore	0	0	0	0	0	0
PV	0	0.04	0.05	0.08	0.11	0.16
Biomass	0.1	0.1	0.1	0.2	0.2	0.2
Geothermal	0.6	1.0	1.2	1.4	1.6	1.8
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	1	1	3	4	4	5
Share of fluctuating RES	5.2%	9.4%	26.4%	28.3%	30.9%	32.1%
RES share (domestic generation)	**66.9%**	**72.6%**	**87.2%**	**88.8%**	**89.4%**	**89.7%**

table 9.7: new zealand: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**737**	**794**	**797**	**831**	**847**	**858**
Fossil	**470**	**457**	**418**	**417**	**414**	**408**
Hard coal	60	51	44	41	39	38
Lignite	4	4	4	4	4	3
Natural gas	147	141	105	107	108	112
Crude oil	259	262	265	266	263	255
Nuclear	**0**	**0**	**0**	**0**	**0**	**0**
Renewables	**267**	**336**	**380**	**413**	**433**	**450**
Hydro	87	88	90	96	98	99
Wind	5.3	11	34	38	44	47
Solar	0.3	0.7	1.0	1.4	1.7	2.1
Biomass	45	46	47	48	49	51
Geothermal/ambient heat	129	191	208	229	238	248
Ocean energy	0	0	0.3	1.8	2.5	2.9
RES share	**36.2%**	**42.4%**	**47.6%**	**49.8%**	**51.2%**	**52.4%**

table 9.8: new zealand: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**527**	**558**	**577**	**600**	**616**	**626**
Total (energy use)	**492**	**520**	**539**	**560**	**573**	**580**
Transport	**192**	**200**	**204**	**206**	**206**	**205**
Oil products	191	199	202	203	202	196
Natural gas	0.03	0.05	0.05	0.07	0.09	0.1
Biofuels	0.1	0.4	1.3	2.1	2.9	3.8
Electricity	0.4	0.4	0.5	0.7	1.4	4.5
RES electricity	0.3	0.3	0.5	0.6	1.2	4.1
Hydrogen	0	0	0	0	0	0
RES share Transport	**0.2%**	**0.4%**	**0.8%**	**1.3%**	**2.0%**	**3.8%**
Industry	**159**	**171**	**178**	**185**	**192**	**198**
Electricity	47	53	56	61	66	69
RES electricity	34	41	50	55	60	63
District heat	1.8	2.3	2.5	2.6	2.8	2.8
RES district heat	0.4	1.0	1.0	1.1	1.2	1.2
Coal	18	19	20	20	20	20
Oil products	16	17	16	17	16	15
Gas	34	38	40	41	42	45
Solar	0	0	0	0	0	0
Biomass and waste	32	33	33	33	32	32
Geothermal/ambient heat	9.2	10	10	11	12	12
Hydrogen	0	0	0	0	0	0
RES share Industry	**47.4%**	**49.3%**	**52.8%**	**53.9%**	**54.9%**	**55.2%**
Other Sectors	**142**	**149**	**157**	**168**	**175**	**177**
Electricity	89	97	104	115	122	125
RES electricity	64	75	92	104	111	114
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	2.8	3.3	2.8	2.2	2.0	1.7
Oil products	24	22	22	20	18	17
Gas	14	14	15	15	16	15
Solar	0.3	0.5	0.6	0.8	0.9	1.0
Biomass and waste	6.2	6.2	6.1	5.9	5.7	5.3
Geothermal/ambient heat	5.2	5.9	6.6	8.2	10	12
RES share Other Sectors	**53.5%**	**58.8%**	**67.2%**	**70.5%**	**73.0%**	**75.0%**
Total RES	**152**	**173**	**201**	**221**	**237**	**250**
RES share	**30.8%**	**33.2%**	**37.4%**	**39.5%**	**41.4%**	**43.1%**
Non energy use	**35**	**37**	**38**	**41**	**43**	**46**
Oil	12	13	13	14	15	16
Gas	23	24	25	27	28	30
Coal	0	0	0	0	0	0

new zealand: energy [r]evolution scenario

table 9.9: new zealand: electricity generation

TWh/a	2009	2015	2020	2030	2040	2050
Power plants	**41**	**43**	**46**	**50**	**57**	**60**
Coal	2.6	1.3	0	0	0	0
Lignite	0.1	0	0	0	0	0
Gas	7.5	5.5	1.5	0	0	0
Oil	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0
Biomass	0.2	0.2	0.5	0.8	0.8	0.6
Hydro	24	25	25	25	26	27
Wind	1.5	3.1	9.6	11	13	14
of which wind offshore	0	0	0	0	0	0
PV	0	0.1	0.1	0.5	1.4	2.2
Geothermal	4.8	7.9	8.9	11	14	15
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0.1	0.5	0.9	1.3
Combined heat & power plants	**2.6**	**2.7**	**2.9**	**3.4**	**3.7**	**3.7**
Coal	0.1	0.1	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	2.0	2.0	1.6	0	0	0
Oil	0	0	0	0	0	0
Biomass	0.4	0.6	1.2	3.0	3.1	3.1
Geothermal	0.1	0.1	0.1	0.4	0.6	0.6
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	3	3	3	3	4	4
Total generation	**43**	**45**	**48**	**53**	**61**	**64**
Fossil	12	8.8	3.1	0	0	0
Coal	2.7	1.3	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	9.5	7.5	3.0	0	0	0
Oil	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**31**	**36**	**45**	**53**	**61**	**64**
Hydro	24	25	25	25	26	27
Wind	1.5	3.1	9.6	11	13	14
of which wind offshore	0	0	0	0	0	0
PV	0	0.1	0.1	0.5	1.4	2.2
Biomass	0.6	0.8	1.7	3.7	3.9	3.8
Geothermal	4.9	8.0	9.0	11	15	16
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0.1	0.5	0.9	1.3
Distribution losses	3	3	3	4	4	4
Own consumption electricity	2	2	2	2	1	1
Electricity for hydrogen production	0	0	0	1	2	5
Final energy consumption (electricity)	**38**	**40**	**43**	**47**	**53**	**54**
Fluctuating RES (PV, Wind, Ocean)	1	3	10	12	16	18
Share of fluctuating RES	3.4%	7.1%	20.2%	23.3%	25.7%	27.9%
RES share (domestic generation)	**71.7%**	**80.5%**	**93.7%**	**100%**	**100%**	**100%**
'Efficiency' savings (compared to Ref.)	**0**	**1**	**2**	**5**	**8**	**10**

table 9.10: new zealand: 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	**1.8**	**2.4**	**3.4**	**7.3**	**8.3**	**8.4**
Fossil fuels	1.0	1.3	1.1	0	0	0
Biomass	0.3	0.6	1.4	4.3	5.4	5.3
Geothermal	0.5	0.5	1.0	2.9	3.0	3.1
Hydrogen	0	0	0	0	0	0
Direct heating	**163**	**171**	**174**	**171**	**162**	**148**
Fossil fuels	88	88	81	55	28	7.3
Biomass	29	31	32	32	33	33
Solar collectors	0.3	2.2	5.0	12	17	18
Heat pumps[1)]	7.6	10	16	30	45	54
Geothermal	10	10	11	13	15	15
Hydrogen	0	0	0	1.4	2.9	4.9
Electricity[2)]	28	30	29	27	22	16
Total heat supply	**164**	**173**	**178**	**178**	**171**	**156**
Fossil fuels	89	89	82	55	28	7.3
Biomass	29	31	33	36	38	38
Solar collectors	0.3	2.2	5.0	12	17	18
Heat pumps[1)]	7.6	10	16	30	45	54
Geothermal	10	10	12	16	18	18
Hydrogen	0	0	0	1.4	2.9	4.9
Electricity[2)]	28	30	29	27	22	16
RES share (including RES electricity)	**40.8%**	**44.6%**	**52.1%**	**67.5%**	**82.3%**	**94.2%**
'Efficiency' savings (compared to Ref.)	**0**	**1**	**2**	**10**	**25**	**48**

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

table 9.11: new zealand: CO_2 emissions

MILL t/a	2009	2015	2020	2030	2040	2050
Condensation power plants	**6.3**	**3.9**	**0.7**	**0**	**0**	0
Coal	2.4	1.1	0	0	0	0
Lignite	0.1	0	0	0	0	0
Gas	3.8	2.8	0.7	0	0	0
Oil	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Combined heat & power production	**0.6**	**0.5**	**0.4**	**0**	**0**	**0**
Coal	0.04	0.02	0.01	0	0	0
Lignite	0	0	0	0	0	0
Gas	0.5	0.5	0.3	0	0	0
Oil	0	0	0	0	0	0
CO_2 emissions power generation (incl. CHP public)	**6.9**	**4.4**	**1.1**	**0**	**0**	**0**
Coal	2.5	1.1	0.01	0	0	0
Lignite	0.1	0	0	0	0	0
Gas	4.3	3.2	1.1	0	0	0
Oil & diesel	0	0	0	0	0	0
CO_2 emissions by sector	**30**	**28**	**22**	**12**	**3.9**	**1.8**
% of 1990 emissions	136%	124%	100%	53%	17%	8%
Industry[1)]	5.1	5.0	4.3	2.3	1.2	0.3
Other sectors[1)]	2.8	2.7	2.4	1.7	0.9	0.4
Transport	14	14	13	6.8	1.2	0.7
Power generation[2)]	6.3	3.9	0.7	0	0	0
District heating & other conversion	2.2	2.1	1.7	1.0	0.5	0.3
Population (Mill.)	4.5	4.6	4.8	5.2	5.5	5.7
CO_2 emissions per capita (t/capita)	**6.8**	**6.0**	**4.6**	**2.3**	**0.7**	**0.3**
'Efficiency' savings (compared to Ref.)	**0**	**2**	**5**	**15**	**22**	**24**

1) including CHP autoproducers. 2) including CHP public

table 9.12: new zealand: installed capacity

GW	2009	2015	2020	2030	2040	2050
Power plants	**9.6**	**10**	**12**	**12**	**14**	**16**
Coal	0.9	0.4	0	0	0	0
Lignite	0.01	0	0	0	0	0
Gas	2.0	1.8	0.9	0	0	0
Oil	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0
Biomass	0.05	0.05	0.2	0.3	0.4	0.4
Hydro	5.4	5.6	6.0	6.1	6.3	6.4
Wind	0.5	1.0	3.2	3.8	4.4	4.8
of which wind offshore	0	0	0	0	0	0
PV	0	0.1	0.1	0.4	1.0	1.6
Geothermal	0.6	1.0	1.2	1.6	2.1	2.2
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0.02	0.1	0.3	0.4
Combined heat & power production	**0.4**	**0.5**	**0.6**	**0.6**	**0.7**	**0.7**
Coal	0.03	0.02	0	0	0	0
Lignite	0	0	0	0	0	0
Gas	0.3	0.4	0.3	0	0	0
Oil	0	0	0	0	0	0
Biomass	0.1	0.1	0.2	0.5	0.6	0.6
Geothermal	0.01	0.01	0.03	0.1	0.1	0.1
Hydrogen	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	1	1	1	1	1
Total generation	**10**	**11**	**12**	**13**	**15**	**17**
Fossil	3.3	2.8	1.3	0	0	0
Coal	0.9	0.4	0	0	0	0
Lignite	0.01	0	0	0	0	0
Gas	2.3	2.3	1.2	0	0	0
Oil	0	0	0	0	0	0
Diesel	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0
Renewables	**6.7**	**7.8**	**11**	**13**	**15**	**17**
Hydro	5.4	5.6	6.0	6.1	6.3	6.4
Wind	0.5	1.0	3.2	3.8	4.4	4.8
of which wind offshore	0	0	0	0	0	0
PV	0	0.1	0.1	0.4	1.0	1.6
Biomass	0.1	0.2	0.4	0.8	1.0	1.1
Geothermal	0.6	1.0	1.3	1.7	2.2	2.3
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0.02	0.1	0.3	0.4
Fluctuating RES (PV, Wind, Ocean)	1	1	3	4	6	7
Share of fluctuating RES	5.2%	10.2%	27.0%	33.2%	37.4%	40.8%
RES share (domestic generation)	**66.9%**	**73.9%**	**89.7%**	**100%**	**100%**	**100%**

table 9.13: new zealand: primary energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total	**737**	**774**	**766**	**765**	**786**	**740**
Fossil	**470**	**432**	**356**	**211**	**94**	**60**
Hard coal	60	46	28	10	3.7	2.3
Lignite	4	3	0	0	0	0
Natural gas	147	129	92	66	48	31
Crude oil	259	254	236	135	42	26
Nuclear	**0**	**0**	**0**	**0**	**0**	**0**
Renewables	**267**	**342**	**410**	**554**	**692**	**681**
Hydro	87	88	90	92	95	97
Wind	5.3	11	35	41	48	52
Solar	0.3	2.5	5.5	14	22	26
Biomass	45	49	67	145	203	172
Geothermal/ambient heat	129	191	213	261	321	330
Ocean energy	0	0	0.3	1.8	3.2	4.6
RES share	**36.2%**	**44.2%**	**53.5%**	**72.4%**	**88.0%**	**91.9%**
'Efficiency' savings (compared to Ref.)	**0**	**19**	**31**	**66**	**61**	**118**

table 9.14: new zealand: final energy demand

PJ/a	2009	2015	2020	2030	2040	2050
Total (incl. non-energy use)	**527**	**546**	**552**	**509**	**480**	**449**
Total (energy use)	**492**	**509**	**513**	**470**	**442**	**413**
Transport	**192**	**195**	**189**	**151**	**132**	**118**
Oil products	191	193	181	95	17	10
Natural gas	0.03	0	0	0	0	0
Biofuels	0.1	0.9	6.2	44	80	62
Electricity	0.4	0.5	1.5	13	32	39
RES electricity	0.3	0.4	1.4	13	32	39
Hydrogen	0	0	0	0	3.1	7.2
RES share Transport	**0.2%**	**0.7%**	**4.0%**	**37.2%**	**87.4%**	**91.8%**
Industry	**159**	**168**	**174**	**173**	**165**	**156**
Electricity	47	52	55	56	57	57
RES electricity	34	41	51	56	57	57
District heat	1.8	2.4	3.4	7.3	8.3	8.4
RES district heat	0.4	1.1	2.3	7.3	8.3	8.4
Coal	18	17	14	2.0	1.4	0.1
Oil products	16	15	12	8.8	6.2	1.8
Gas	34	37	38	31	14	3.8
Solar	0	0.7	2.4	7.4	11	11
Biomass and waste	32	34	36	36	36	37
Geothermal/ambient heat	9.2	10	14	23	28	31
Hydrogen	0	0	0	1.6	3.3	5.5
RES share Industry	**47.4%**	**52.2%**	**61.0%**	**75.9%**	**87.2%**	**96.4%**
Other Sectors	**142**	**146**	**150**	**147**	**145**	**139**
Electricity	89	93	100	101	102	100
RES electricity	64	75	93	101	102	100
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	2.8	2.6	1.7	0	0	0
Oil products	24	22	20	13	7.0	3.9
Gas	14	14	14	12	7.5	2.4
Solar	0.3	1.5	2.6	4.9	6.3	6.4
Biomass and waste	6.2	6.0	5.8	5.7	5.5	5.3
Geothermal/ambient heat	5.2	6.0	7.0	10	16	21
RES share Other Sectors	**53.5%**	**60.9%**	**72.3%**	**82.4%**	**89.9%**	**95.5%**
Total RES	**152**	**178**	**223**	**308**	**389**	**391**
RES share	**30.8%**	**35.0%**	**43.4%**	**65.6%**	**88.2%**	**94.8%**
Non energy use	**35**	**37**	**38**	**39**	**38**	**36**
Oil	12	13	13	13	11	10
Gas	23	24	25	25	25	23
Coal	0	0	0	1	2	2

new zealand: investment & employment

table 9.15: new zealand: total investment in power sector

MILLION NZ$2010	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Conventional (fossil & nuclear)	**1,229**	**1,764**	**1,796**	**552**	**5,341**	**134**
Renewables	**15,250**	**9,775**	**14,592**	**7,563**	**47,181**	**1,180**
Biomass	423	324	284	274	1,305	33
Hydro	6,954	6,266	5,024	3,488	21,731	543
Wind	5,310	1,357	5,639	1,226	13,532	338
PV	153	55	127	114	450	11
Geothermal	2,303	1,298	3,350	2,170	9,122	228
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	106	474	169	291	1,040	26
Energy [R]evolution						
Conventional (fossil & nuclear)	**656**	**0**	**0**	**0**	**656**	**16**
Renewables	**16,936**	**12,250**	**19,735**	**12,340**	**61,260**	**1,532**
Biomass	1,638	2,534	1,852	2,304	8,328	208
Hydro	6,954	4,820	5,528	3,875	21,177	529
Wind	5,457	1,675	5,962	1,651	14,745	369
PV	261	549	1,095	1,337	3,241	81
Geothermal	2,520	2,198	4,968	2,679	12,365	309
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	106	474	330	494	1,404	35

table 9.16: new zealand: total investment in renewable heating only

(EXCLUDING INVESTMENTS IN FOSSIL FUELS)

MILLION NZ$2010	2011-2020	2021-2030	2031-2040	2041-2050	2011-2050	2011-2050 AVERAGE PER YEAR
Reference scenario						
Renewables	**3,828**	**4,258**	**2,691**	**2,641**	**13,419**	**335**
Biomass	0	595	0	0	595	15
Geothermal	1,084	952	67	83	2,187	55
Solar	245	202	190	152	788	20
Heat pumps	2,499	2,510	2,434	2,406	9,848	246
Energy [R]evolution scenario						
Renewables	**8,822**	**11,139**	**11,956**	**10,037**	**41,954**	**1,049**
Biomass	1,578	1,259	222	73	3,132	78
Geothermal	961	1,544	513	586	3,604	90
Solar	2,195	2,810	3,362	2,364	10,731	268
Heat pumps	4,087	5,527	7,858	7,015	24,486	612

table 9.17: new zealand: total employment

THOUSAND JOBS		REFERENCE			ENERGY [R]EVOLUTION		
	2010	2015	2020	2030	2015	2020	2030
By sector							
Construction and installation	600	1,200	400	300	1,600	1,100	800
Manufacturing	400	800	200	200	900	400	400
Operations and maintenance	2,500	2,700	3,100	3,500	2,800	3,500	4,400
Fuel supply (domestic)	2,400	2,200	2,000	1,900	2,300	2,400	4,000
Coal and gas export	-	-	-	-	-	-	-
Solar and geothermal heat	200	200	200	200	800	1,200	1,400
Total jobs	**6,100**	**7,100**	**5,900**	**6,100**	**8,400**	**8,600**	**11,000**
By technology							
Coal	560	520	440	380	460	230	80
Gas, oil & diesel	740	650	440	410	610	390	180
Nuclear	-	-	-	-	-	-	-
Total renewables	**4,890**	**5,980**	**5,030**	**5,270**	**7,330**	**8,030**	**10,710**
Biomass	*1,740*	*1,620*	*1,580*	*1,510*	*2,220*	*3,280*	*5,080*
Hydro	*1,670*	*2,120*	*1,990*	*2,200*	*2,120*	*1,890*	*2,180*
Wind	*390*	*1,190*	*470*	*580*	*1,220*	*540*	*630*
PV	*130*	*40*	*30*	*20*	*50*	*130*	*270*
Geothermal power	*740*	*790*	*740*	*750*	*850*	*920*	*1,070*
Solar thermal power	-	-	-	-	-	-	-
Ocean	-	*30*	*50*	*30*	*30*	*50*	*40*
Solar - heat	*60*	*60*	*40*	*30*	*640*	*760*	*1,000*
Geothermal & heat pump	*160*	*130*	*130*	*150*	*200*	*460*	*440*
Total jobs	**6,180**	**7,150**	**5,920**	**6,070**	**8,380**	**8,640**	**10,970**

note
numbers may not add up due to rounding

new zealand: transport

table 9.18: new zealand: final energy consumption transport in

PJ/a	2009	2015	2020	2030	2040	2050
Reference scenario						
Road	**171**	**178**	**182**	**183**	**182**	**180**
Fossil fuels	171	178	180	180	178	173
Liquid biofuels	0.1	0.4	1.3	2.1	2.9	3.8
Natural gas	0.03	0.05	0.05	0.07	0.09	0.1
Hydrogen	0	0	0	0	0	0
Electricity	0	0.01	0.01	0.1	0.8	3.9
Rail	**2.6**	**2.7**	**2.8**	**2.9**	**2.9**	**3.0**
Fossil fuels	2.2	2.3	2.3	2.4	2.4	2.3
Biofuels	0	0	0	0	0	0
Electricity	0.4	0.4	0.5	0.5	0.6	0.6
Navigation	**3.9**	**4.5**	**5.0**	**5.0**	**5.0**	**5.0**
Fossil fuels	3.9	4.5	5.0	5.0	5.0	5.0
Biofuels	0	0	0	0	0	0
Aviation	**14**	**14**	**15**	**16**	**16**	**16**
Fossil fuels	14	14	15	16	16	16
Biofuels	0	0	0	0	0	0
Total	**192**	**200**	**204**	**206**	**206**	**205**
Fossil fuels	191	199	202	203	202	196
Biofuels (incl. biogas)	0.1	0.4	1.3	2.1	2.9	3.8
Natural gas	0.03	0.05	0.05	0.07	0.09	0.1
Hydrogen	0	0	0	0	0	0
Electricity	0.4	0.4	0.5	0.7	1.4	4.5
Total RES	**0.4**	**0.7**	**1.7**	**2.7**	**4.2**	**7.9**
RES share	**0.2%**	**0.4%**	**0.8%**	**1.3%**	**2.0%**	**3.8%**
Energy [R]evolution						
Road	**171**	**174**	**167**	**129**	**110**	**97**
Fossil fuels	171	173	160	73	0	0
Liquid biofuels	0.1	0.9	6.2	44	76	51
Natural gas	0.03	0.05	0.05	0.04	0.02	0
Hydrogen	0	0	0	0	3.1	7.2
Electricity	0	0.05	0.9	12	31	38
Rail	**2.6**	**2.6**	**2.5**	**2.3**	**2.2**	**2.1**
Fossil fuels	2.2	2.2	2.0	1.6	1.0	0.1
Biofuels	0	0	0	0	0.4	1.1
Electricity	0.4	0.4	0.5	0.7	0.8	0.9
Navigation	**3.9**	**4.5**	**4.8**	**4.9**	**4.8**	**4.7**
Fossil fuels	3.9	4.5	4.8	4.9	3.8	2.4
Biofuels	0	0	0	0	1.0	2.4
Aviation	**14**	**14**	**14**	**15**	**15**	**14**
Fossil fuels	14	14	14	15	12	7.2
Biofuels	0	0	0	0	2.9	7.2
Total	**192**	**195**	**189**	**151**	**132**	**118**
Fossil fuels	191	193	181	95	17	10
Biofuels (incl. biogas)	0.1	0.9	6.2	44	80	62
Natural gas	0.03	0.05	0.05	0.04	0.02	0
Hydrogen	0	0	0	0	3.1	7.2
Electricity	0.4	0.5	1.5	13	32	39
Total RES	**0.4**	**1.3**	**7.6**	**56**	**115**	**108**
RES share	**0.2%**	**0.7%**	**4.0%**	**37.2%**	**87.4%**	**91.8%**

energy
[r]evolution

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.

Greenpeace New Zealand
11 Akiraho Street, Mt Eden
Auckland, New Zealand
info@greenpeace.org.nz
www.greenpeace.org/new-zealand

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.

Rue d'Arlon 80
1040 Brussels, Belgium
t +32 2 213 1897 f+32 2 213 1890
info@gwec.net **www.gwec.net**

image GEOTHERMAL VENTS, ROTORUA, NEW ZEALAND. **front cover images** THE NEW ZEALAND LAND MASS IS ANCIENT. GEOLOGISTS ESTIMATE THAT IT SEPARATED FROM THE ANCIENT SUPERCONTINENT OF GONDWANA AROUND 80 MILLION YEARS AGO AS A SINGLE LAND MASS, WHICH GEOLOGISTS CALL RANGITATA. © JACQUES DESCLOITRES, MODIS LAND RAPID RESPONSE TEAM AT NASA GSFC © AHUWARI/DREAMSTIME, © GREG0070/ISTOCK.