energy [r]evolution

A SUSTAINABLE AUSTRALIA ENERGY OUTLOOK

report australia regional energy scenario

Greenpeace International, European Renewable Energy Council (EREC)

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institute DLR, Institute of Technical Thermodynamics, Department of Systems Analysis and Technology Assessment, Stuttgart, Germany: Dr.Wolfram Krewitt, Dr. Sonja Simon, Dr. Thomas Pregger, Ecofys BV,(Demand Projection), P.O. Box 8408, NL-3503 RK Utrecht, Kanaalweg 16-G, NL-3526 KL Utrecht, The Netherlands: Wina Graus, Eliane Blomen

australia scientific reserach Dr Hugh Saddler, Anne Sjostrom; Energy Strategies Pty Ltd., P.O. Box 4170, Level 1, Manuka Arcade, 20 Franklin Street, A.C.T. 2603 Canberra / Australia

European Renewable Energy Council (EREC) Arthouros Zervos, Oliver Schäfer

employment calculations Jay Rutovitz

Greenpeace International Sven Teske

Greenpeace Australia Pacific Julien Vincent

global project manager Sven Teske, Greenpeace International

author Sven Teske, Julien Vincent

editor Julien Vincent

design & layout Tania Dunster, Jens Christiansen, onehemisphere, Sweden, www.onehemisphere.se

contact Greenpeace Australia Pacific: Julien Vincent; julien.vincent@greenpeace.org
Greenpeace International: sven.teske@greenpeace.org
EREC: schaefer@erec.org

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

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cover image WIND FARM LOOKING OVER THE OCEAN AT CAPE JERVIS, SOUTH AUSTRALIA.
image HIGH WINDS IN THE PACIFIC.

foreword

We have far less time to minimise dangerous anthropogenic climate change than previously thought. Observations of the climate system indicate that the impacts of atmospheric warming are at the upper end of the range projected by the IPCC. This puts us in an extremely precarious and urgent situation that compels immediate action.

Australia is one of the world's highest per-capita greenhouse polluters, in large part due to its heavy use of fossil fuels. However, Australia is also recognised as the developed country most vulnerable to climate change and therefore has a major stake in reducing emissions.

A radical transformation is required in the way we produce, as well as use energy. Australia is well placed to lead this transformation with zero emission electricity technologies such as solar PV, solar concentrating thermal, wind, wave and geothermal energy ready to deploy. Aggressive efficiency measures can reduce our overall energy consumption. The only missing ingredient is the political will to drive this transformation.

Forward-thinking governments can act now to maximise employment and investment opportunities as we move to a renewable energy future. If we decouple our economy from fossil fuels, we will have the added benefit of protecting Australia from instabilities caused by ever diminishing supplies.

This report provides a compelling vision for a future energy scenario that should be the basis for future decisions and directions in Australia's energy policy.

Professor David Karoly

ARC FEDERATION FELLOW, SCHOOL OF EARTH SCIENCES, UNIVERSITY OF MELBOURNE

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE LEAD AUTHOR

JUNE 2008

introduction

"IN PRESENTING THE GREATEST THREAT THE PLANET FACES, CLIMATE CHANGE ALSO PRESENTS AN OPPORTUNITY. WE CAN AVERT RUNAWAY CLIMATE CHANGE AND AT THE SAME TIME REVOLUTIONISE THE WAY WE HARNESS AND USE THE RESOURCES AVAILABLE TO US."

image THE PS10 SOLAR TOWER PLANT AT SAN LUCAR LA MAYOR OUTSIDE SEVILLE, SPAIN, APRIL 29, 2008. THE SOLAR TOWER PLANT, THE FIRST COMMERCIAL SOLAR TOWER IN THE WORLD, BY THE SPANISH COMPANY SOLUCAR (ABENGOA), CAN PROVIDE ELECTRICITY FOR UP TO 6,000 HOMES. SOLUCAR (ABENGOA) PLAN TO BUILD A TOTAL OF 9 SOLAR TOWERS OVER THE NEXT 7 YEARS WHICH WILL RAISE THE ELECTRICITY CAPACITY FOR AN ESTIMATED 180,000 HOMES.

Humankind is at a critical crossroads. Since the industrial revolution, the planet has warmed by 0.74°C, a distortion of the climate system caused by human activities such as the burning of carbon-intensive fossil fuels.[1] The impacts we are witnessing are occurring far sooner than had been predicted. Droughts in many parts of the world, the near-total loss of the Arctic ice-cap and an additional 150,000 deaths per year[2] indicate that we are already experiencing dangerous climate change.

The challenge humanity faces now is to avoid "runaway" climate change. Climate scientists warn that if we warm the atmosphere by more than 2°C from pre-industrial levels, we invite catastrophic climate change and trigger processes that result in even more emissions being released, taking global warming beyond our control. The warming we have already experienced, plus an additional degree expected due to the "lag" effect of greenhouse gases already in the atmosphere, takes us to the brink. If we pass this threshold, the economic, social, political, cultural and environmental impacts will be almost indescribable.

In presenting the greatest threat the planet faces, climate change also presents an opportunity. We can avert runaway climate change and at the same time revolutionise the way we harness and use the resources available to us. We can create a sustainable society, using technologies and behaviours that are low-carbon intensive. However, we do not have much time and the transition must begin immediately.

Action is required on all fronts. Internationally, it is critical that parties to the Kyoto Protocol reach an agreement that ensures global emissions fall substantially by the year 2020. Domestically, there is much Australia can do to take a leading role in the climate debate, as well as get ahead of the game as the world moves to a low-carbon future. Currently, Australia is one of the worst greenhouse-polluting countries in the world on a per capita basis. Renewable energy is forced to compete on an uneven playing field, as the lion's share of political and financial support is enjoyed by the powerful fossil fuel industry. However, this can and must be turned around. Australia is fortunate to have some of the best renewable energy resources in the world and, with the political will, could become a renewable energy leader.

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Australia is also well placed to become much more energy efficient and reduce costs of energy as well as emissions. By setting strong targets to reduce greenhouse pollution domestically and taking the lead on climate change, Australia could steer international negotiations towards a binding agreement that ensures global greenhouse gases fall to levels that avoid runaway climate change.

australia's energy [r]evolution scenario

This scenario is based on the global energy scenario produced by The European Renewable Energy Council (EREC) and Greenpeace International, which demonstrates how global CO_2 emissions can be halved by 2050. The Australian scenario provides an exciting, ambitious and necessary blueprint for how emission reductions can be made in the energy and transport sectors and how Australia's energy can be sustainably managed up to the middle of this century.

our renewable energy future

This report demonstrates that renewable energy is mature, ready and can be deployed on a large scale. Decades of technological progress have seen renewable energy technologies such as wind, solar photovoltaic, geothermal power plants and solar thermal collectors move steadily into the mainstream. They will play a vital role in providing secure, reliable and zero-emission energy in the future.

The global market for renewable energy is booming internationally; installed capacity of wind grew by 27% globally[3] in 2007 while solar photovoltaics grew by 50%[4]. As renewable energy is scaled up, we can begin turning off polluting coal-fired power plants, starting with the oldest and dirtiest. Decisions made today by governments and power utilities will determine the energy supply in decades to come and coal-fired power plants are incompatible with an energy mix that helps us avoid runaway climate change. An energy revolution that drives down emissions will be a result of today's political action.

the forgotten solution: energy efficiency

The Australian Energy [R]evolution Scenario takes advantage of the enormous potential for Australia to become more energy efficient. Energy efficiency offers some of the simplest, easiest and most cost effective measures for reducing both greenhouse gas emissions and cost to end-users.

Government interventions such as removal of fossil fuel subsidies, emissions trading and carbon taxes will result in the cost of fossil fuels increasing, perhaps to a level that truly reflects the damage they cause. As fossil fuels are phased out, it will be necessary to protect those most vulnerable to energy price increases. Energy efficiency presents opportunities for people to be protected from the economic impacts of the inevitable shift away from fossil fuels.

keeping it fair

The Energy [R]evolution Scenario: Australia describes a major restructuring of energy and transport markets. An integral part of the inevitable transition from fossil fuels to renewable energy will be ensuring that social and economic impacts are kept to a minimum and the opportunities for new employment, investment and innovation are maximised.

The transition away from fossil fuels opens up new opportunities in skills development and sharing, manufacturing and infrastructure development. Early planning will help ensure that a skilled workforce is ready to deliver the low-carbon future and that the socio-geography of our energy supply is maintained as much as possible. Moving to a renewable energy-based society can be done smoothly and justly.

on the front foot

Avoiding runaway climate change will require the most far-reaching structural reforms carried out by human society. Business as usual is simply not an option. Furthermore, there can be no half measures, or falling short of the required emission reductions. The risk of passing the threshold of runaway climate change is not one that humankind can afford to take. The Energy [R]evolution Scenario demonstrates that making the necessary transformation in how we use energy is achievable, and provides a wealth of opportunities to stimulate economic growth and ensure social stability.

We call on political leaders to turn the Energy [R]evolution Scenario into reality and to begin the inevitable transition from fossil fuels to renewable energy now, delivering immediate reductions in emissions, minimising economic and social disruption and maximising opportunities for Australia to prosper from the transition.

Julien Vincent
CLIMATE & ENERGY UNIT
GREENPEACE
AUSTRALIA PACIFIC

Sven Teske
CLIMATE & ENERGY UNIT
GREENPEACE
INTERNATIONAL

Dr Hugh Saddler
ENERGY STRATEGIES

JUNE 2008

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executive summary

"THE RESERVES OF RENEWABLE ENERGY THAT ARE TECHNICALLY ACCESSIBLE GLOBALLY ARE LARGE ENOUGH TO PROVIDE ABOUT SIX TIMES MORE ENERGY THAN THE WORLD CURRENTLY CONSUMES - FOREVER."

image MAN RUNNING ON THE RIM OF A SOLAR DISH WHICH IS ON TOP OF THE SOLAR KITCHEN AT AUROVILLE, TAMIL NADU, INDIA. THE SOLAR DISH CAPTURES ENOUGH SOLAR ENERGY TO GENERATE HEAT TO COOK FOR 2,000 PEOPLE PER DAY.

the energy [r]evolution

The climate change imperative demands nothing short of an energy revolution. At the core of this revolution will be a change in the way that energy is produced, distributed and consumed. The five key principles behind this shift will be to:

- Implement renewable solutions, especially through decentralised energy systems
- 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

the energy [r]evolution scenario for australia

Two scenarios are outlined in this report. The Reference Scenario is based on the most recent (2007) energy demand projections by the Australian Bureau of Agricultural and Resource Economics, amended to account for the major new policy measures announced by the Government, elected in November 2007. The Energy [R]evolution scenario is characterised by significant efforts to fully exploit the large potential for energy efficiency. At the same time, all cost-effective renewable energy sources are accessed for process heat and electricity generation, as well as the production of sustainable biofuels.

reducing energy related CO_2 emissions

If we are to stand a chance of avoiding runaway climate change, Australia must reduce its greenhouse gas emissions by greater than 40% below 1990 levels by 2020, moving to decarbonisation as quickly as possible thereafter. While energy related CO_2 emissions in Australia will increase under the Reference Scenario by about 20% by 2020 - far removed from a sustainable development pathway - under the Energy [R]evolution Scenario they drop significantly, decreasing from 370 million tonnes (Mt) in 2005 to 232 Mt in 2020, a reduction of 37%.

image ENERGY PLANT NEAR REYKJAVIK, ENERGY IS PRODUCED FROM THE GEOTHERMAL ACTIVITY. NORTH WEST OF ICELAND.

figure 1: australia: development of primary energy consumption under the reference scenario

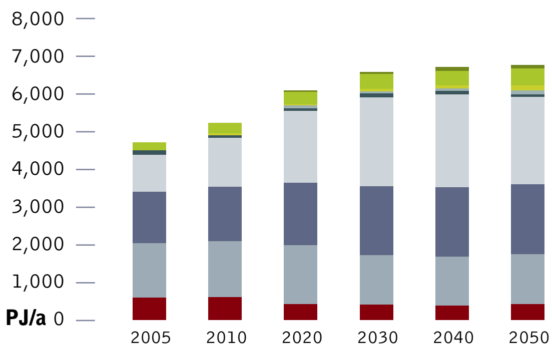
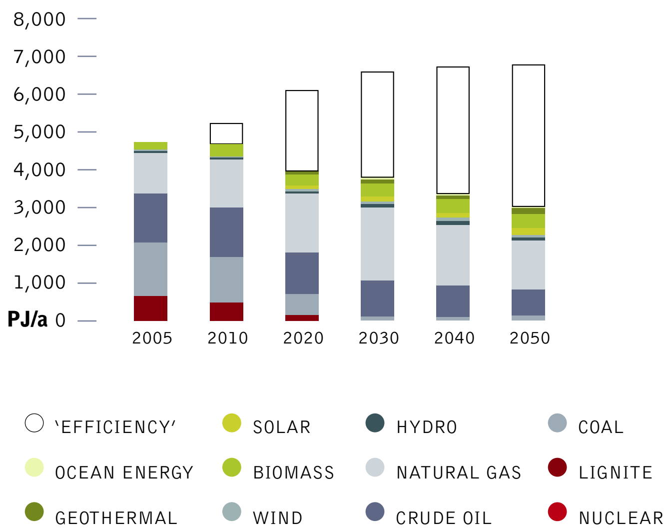


figure 2: australia: development of primary energy consumption under the energy [r]evolution scenario

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

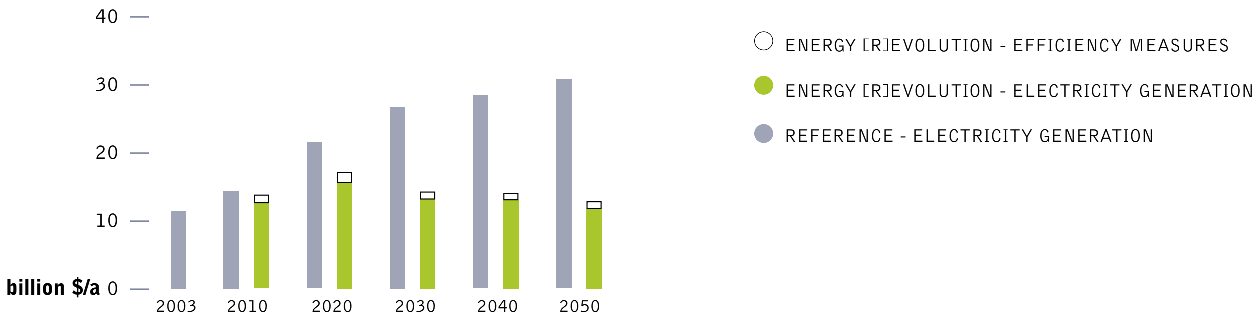


The Energy [R]evolution scenario emission pathway turns the present-day situation into a sustainable energy supply using the following measures:

- **renewable energy: 40% of our electricity provided by renewable sources in 2020**
  The electricity sector will have the strongest growth in renewable energy utilisation. The current share of renewable energy in electricity generation is 9.2%. By 2020, approximately 40% of electricity will be produced from renewable energy sources, increasing to 70% by 2050. A capacity of 23 gigawatts (GW) will produce 82 terrawatt hours per year (TWh/a) of electricity by 2020.
- **energy efficiency: australia can cut its energy consumption by 16% by 2020**
  Exploitation of Australia's existing large energy efficiency potential will reduce primary energy demand from 4,761 PJ/a in 2005 to 3,982 PJ/a in 2020. This compares with a 29% increase in demand to 6127 PJ/a by 2020 in the Reference Scenario. It is vital that we significantly reduce our energy consumption in order to ensure that renewable energy sources meet a significant proportion of our electricity supplies, compensating for reducing the consumption of fossil fuels.
- **coal-fired power will be phased out entirely by 2030**
  The aggressive implementation of energy efficiency measures, efficient use of gas as a transitional fuel and up-scaling of renewable energy technologies allows us to relieve the energy market of the most polluting fossil fuels. By 2010, largely driven by energy efficiency, 5.3 GW of coal-fired capacity will have been removed from the grid. By 2030, coal-fired electricity is phased out entirely and from 2030 to 2050, the installed capacity of gas diminishes from 13 GW to 10 GW, as renewable energy-based electricity continues to take the place of fossil fuel-based electricity.
- **smarter use of resources**
  We will capitalise on the current wastage of heat – a by-product of electricity production – by using it to warm building interior spaces, especially those located close to the source of power generation. This technology – called combined heat and power generation (CHP) – will make power plants more efficient. The use of fossil fuels for CHP will be steadily replaced by biomass and geothermal energy.
- **using electricity for the transport system and cutting consumption of fossil fuels through efficiency**
  Electric vehicles will quickly take the place of petrol/diesel vehicles on Australia's roads. Standards governing fuel efficiency will be introduced more quickly resulting in a decisive shift towards smaller, more fuel-efficient cars.

image 1 and 2. ORIGINAL PHOTOGRAPH TAKEN IN 1928 OF THE UPSALA GLACIER, PATAGONIA, ARGENTINA COMPARED WTIH THE RECEDING GLACIER TODAY.

figure 3: australia: development of total electricity supply costs



ensuring energy remains affordable

Under the Reference Scenario, the continuing growth in energy demand, increases in fossil fuel prices and the costs of CO_2 emissions will result in electricity supply costs nearly tripling from AUD $11.7 billion per year today to AUD $30.9 billion per year in 2020. The Energy [R]evolution scenario, on the other hand, reduces CO_2 emissions and stabilises energy costs, thus avoiding the economic pressure Australians will face under "business as usual". Increasing energy efficiency and shifting energy supply to renewable resources in the long term leads to falls in electricity prices. By 2030, wind will be a cheaper form of electricity than coal.

overall employment increases

The Energy [R]evolution Scenario is a major transformation in the way that electricity is sourced and used. Debates commonly focus on the social and economic impact such a change would have to employment. The Energy [R]evolution is an exercise in job creation, as well as reducing emissions. The vast number of approaches to energy efficiency results in a broad range of potential new jobs created so by 2020, the Energy [R]evolution scenario will generate a net gain of between 33,700 and 57,500 jobs. The expected decrease in the number of jobs in coal-fired electricity generation is more than compensated for by employment stimulated on the renewable energy sector – a net gain of over 10,000 jobs.

the policy framework for the energy [r]evolution scenario

The Energy [R]evolution scenario requires political leadership to become a reality. Large-scale structural reforms will be required to steer Australia away from its current path of increasing emissions and create a political, social and economic framework that reduces emissions.

Below are Greenpeace Australia Pacific's recommendations to the Federal Government:

- Legislate a greenhouse gas reduction target of greater than 40% below 1990 levels by 2020.
- Establish an emissions trading scheme that delivers a decrease of our emissions in line with legislated interim targets.
- Legislate a national target for 40% of electricity to be generated by renewable energy sources by 2020.
- Massively invest in the deployment of renewable energy and strongly regulate for energy efficiency measures.
- Establish an immediate moratorium on new coal-fired power stations and extensions to existing coal-fired power stations, and phase out existing coal-fired power stations in Australia by 2030.
- Set a target of 2% per year to reduce Australia's primary energy demand.
- Ensure transitional arrangements for coal dependent communities that might be affected by the transition to a clean energy economy.
- Redirect all public subsidies that encourage the use and production of fossil fuels towards implementing energy efficiency programs, deploying renewable energy and supporting the upgrading of public transport infrastructure.
- Develop a highly trained "green" workforce through investment in training programs and apprenticeships.

policy

"THE GOAL OF CLIMATE POLICY SHOULD BE TO KEEP THE GLOBAL MEAN TEMPERATURE RISE TO AS FAR BELOW 2°C ABOVE PRE-INDUSTRIAL LEVELS AS POSSIBLE."

image MAJESTIC VIEW OF THE WIND FARM IN ILOCOS NORTE, AROUND 500 KILOMETRES NORTH OF MANILA. THE 25 MEGAWATT WIND FARM, OWNED AND OPERATED BY DANISH FIRM NORTHWIND, IS THE FIRST OF ITS KIND IN SOUTHEAST ASIA.

climate policy

The Intergovernmental Panel on Climate Change (IPCC) projects global temperature increases over the next hundred years of up to 5.8°C, depending on action taken to mitigate greenhouse gas emissions. This is much faster than anything experienced in human history and does not include the very strong likelihood of "positive feedbacks" being triggered, which result in additional greenhouse gases emitted and enhanced warming.

We are already experiencing dangerous climate change. From the Inuit in the far north to residents of low-lying atolls and river delta regions, people are already struggling with climate impacts. Millions of people are threatened with an increased risk of hunger, malaria, flooding and water shortages.

never before has humanity been forced to grapple with such an immense environmental crisis.

impacts of small to moderate warming include:

- Sea level rise due to melting glaciers and the thermal expansion of the oceans as global temperature increases.
- Massive releases of greenhouse gases from melting permafrost and dying forests, which exacerbate global warming.
- A high risk of more extreme weather events such as heat waves, droughts and floods. Already, the global incidence of drought has doubled over the past 30 years and regions such as South-Eastern Australia have been gripped by drought since the turn of the century.
- Natural systems, including glaciers, coral reefs, mangroves, alpine ecosystems, boreal forests, tropical forests, prairie wetlands and native grasslands are severely threatened.
- Increased risk of species extinction and biodiversity loss.

The greatest impacts will be on poorer countries in sub-Saharan Africa, South Asia, Southeast Asia, Andean South America, as well as small islands least able to protect themselves from increasing droughts, rising sea levels, the spread of disease and decline in agricultural production. However, Australia is the most vulnerable of all developed countries to climate change. Australia has a unique environmental sensitivity to climate change and an economy that is largely dependent on a healthy environment.

If immediate political action to stop climate change does not occur and overall temperatures rise to more than 2°C beyond pre-industrial levels, the damage will become catastrophic. Warming from greenhouse gas emissions may trigger the irreversible meltdown of the Greenland ice sheet, adding up to seven metres of sea level rise.

New evidence also shows that the rate of ice discharge from parts of the Antarctic mean it is also at risk of meltdown. Slowing, shifting or shutting down of the Atlantic Gulf Stream current will have dramatic effects in Europe and disrupt the global ocean circulation system. Large releases of methane from melting permafrost and from the oceans will lead to rapid increases of the gas in the atmosphere and consequent warming. There is clearly an imperative to reduce emissions as much and as quickly as possible.

The goal of climate policy should be to keep the global mean temperature rise to as far below 2°C above pre-industrial levels as possible, with an ultimate goal of no more than 0.5°C above pre-industrial levels. Given that we are already committed to 1.8°C increases above pre-industrial levels, the goal of climate policy should be ensuring global emissions peak as soon as possible and are substantially reduced by the year 2020.

the kyoto protocol

The signatories to the 1992 UN Framework Convention on Climate Change agreed the Kyoto Protocol in 1997. The Kyoto Protocol entered into force in early 2005 and its 180 member countries meet regularly each year to negotiate further refinement and development of the agreement. The United States of America is the only industrialised nation not to have ratified the Protocol. The Kyoto Protocol commits thirty seven developed countries and the European Community to reduce their overall greenhouse gas emissions by 5.2% from 1990 levels within the target period of 2008-2012.

This aggregate target in turn resulted in the adoption of a series of legally binding regional and national reduction targets.

The 'Kyoto' countries are currently negotiating the second phase of the agreement, due to begin in 2013. This is widely seen as our last chance to get it right and the outcome of this agreement should be led by the goal of all nations reducing emissions as quickly and substantially as possible to keep the global mean temperature increase as far below 2°C as possible.

However, negotiators are running out of time. Countries agreed a negotiating 'mandate' – known as the Bali Action Plan - in December 2007, but they must end these negotiations with a final agreement on the second commitment period of the Kyoto Protocol by the end of 2009 at the absolute latest. Forward-thinking nations can get ahead of the game by implementing strong domestic targets now and building the industry and skills bases that will deliver the transition to a low-carbon society, and thereby provide a strong platform from which to negotiate the second commitment period.

international energy policy

At present, renewable energy generators have to compete with old nuclear and fossil fuel power stations which produce electricity at marginal costs because consumers and taxpayers have already paid the interest and depreciation on the original investments. Political action is needed to overcome these distortions and create a level playing field for renewable energy technologies to compete.

At a time when governments around the world are in the process of 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 by distortions in the world's electricity markets created by decades of massive financial, political and structural support to conventional technologies. Developing renewables will therefore require strong political and economic efforts, especially through laws that guarantee stable tariffs over a period of up to 20 years.

renewable energy targets

In recent years, in order to reduce greenhouse emissions as well as increase energy security, an increasing number of countries have established targets for renewable energy. These are either expressed in terms of installed capacity or as a percentage of energy consumption. These targets have served as important catalysts for increasing the share of renewable energy throughout the world. A time horizon of just a few years is not long enough in the electricity sector where 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 mechanisms such as feed-in tariffs. In order for the proportion of renewable energy to increase significantly, 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 set amount of renewable energy. In recent years the wind and solar power industries have shown that it is possible to maintain a growth rate of 30 to 35% in the renewables sector. In conjunction with the European Photovoltaic Industry Association[5], the European Solar Thermal Power Industry Association[6] and the Global Wind Energy Council, the European Renewable Energy Council[7] and Greenpeace have documented the development of those industries from 1990 onwards and outlined a prognosis for growth up to 2020 and 2040.

demands for the energy sector

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

- Phase out all subsidies for fossil and nuclear energy and internalise external costs
- Establish legally binding targets for renewable energy
- Provide defined and stable returns for investors
- Guarantee priority access to the grid for renewable power generators
- Mandate strict efficiency standards for all energy consuming appliances, buildings and vehicles

Conventional energy sources receive an estimated $250-300 billion[8] in subsidies per year worldwide, resulting in heavily distorted markets. The Worldwatch Institute estimates that total world coal subsidies are $63 billion, whilst in Germany alone the total is $21 billion, including direct support of more than $85,000 per miner.

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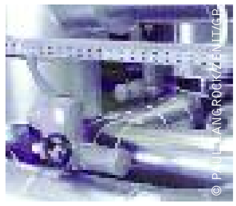
image GEOTHERMAL POWER STATION PRODUCING ELECTRICITY.



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 would not only save taxpayers' money. It would also dramatically reduce the need for renewable energy support.

australia energy policy

Current climate policies in Australia will see our greenhouse emissions increase by 20% from 1990 levels by 2020[9], putting us on a collision course with runaway climate change.[10]

The Government's aspirational emissions reduction target of a 60% reduction from 2000 levels by 2050 does not reflect that developed countries must make larger reductions in order to ensure global carbon equity, nor does it reflect the urgency of the situation. The Government have committed to setting an interim target[11], most likely in mid-late 2008.

emissions trading scheme

The Australian Government have committed to introducing an Emissions Trading Scheme (ETS) "starting no later than 2010 with the detailed design finalised by the end of 2008"[12]. It is anticipated that a policy options "green" paper will be released in July 2008, outlining the structure of the ETS. In the meantime, the Government has outlined key tests for an Emissions Trading Scheme.[13] The ETS is expected to be a cap and trade scheme, to be internationally consistent, include all major emitters, effectively reduce emissions and set Australia on a path to reduce emissions by 60 percent by 2050. The imperative to be "economically responsible" means that the ETS should drive investment in low emission technologies and renewable energy while keeping the total cost as low as possible, as well as ensure that Australian energy-intensive trade-exposed firms are not disadvantaged. Ongoing complementary measures, such as the Mandatory Renewable Energy Target, will aim to encourage the domestic development and use of new technologies. The Government will also endeavour to ensure that costs and benefits and shared across the community.

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subsidies

Each year, approximately $10 billion of State and Federal Government money is used to encourage the use of fossil fuels. A report by the Institute for Sustainable Futures showed that in the 2005-06 financial year, the funding of fossil fuels outweighed Government support for renewable energy and energy efficiency by a ratio of 28:1. The tax-breaks given to polluting industries are keeping the price of fossil fuels artificially low, encouraging the use of fuels that are causing climate change.

mandatory renewable energy target

The Government has committed to a Mandatory Renewable Energy Target of 20 percent of Australia's electricity supply by 2020, effectively increasing the MRET from 9,500 gigawatt-hours to 45,000 gigawatt-hours. The Government is currently planning to phase out the MRET between 2020 and 2030 with the expectation that as the emissions trading scheme matures, the price on carbon will become sufficient to drive the deployment of renewable energy technologies.[14] However, the 20 percent target will include the rolling in of current state-based targets to the national target, diminishing the effect of the policy in terms of extra gigawatt hours as compared to what already existed around the country.

industry development funds

The Rudd ALP Government has committed to a Clean Coal initiative that will deliver $500 million of funding over 7 years to support the development of technologies that aim to burn coal with less emissions. However, many technologies for burning coal "cleanly" either do not reduce emissions to the extent that justify ongoing use of coal[15] or, as in the case of carbon capture and storage (CCS), will not become commercially available for at least two decades.[16]

In addition to the Clean Coal initiative, the Government has committed to a renewable energy fund of $500 million over 7 years. Designed to expand and accelerate the commercialisation and deployment of renewable energy technologies, the programme is not funded until 2009-10.

feed-in tariffs

A number of Australian State Governments have either implemented or proposed solar PV feed-in tariffs. Feed-in rates provide a payment to householders for electricity generated using solar. Tariffs vary in price, and therefore some of the schemes have come under criticism for not driving the uptake of solar PV effectively, usually because the tariff only applies to energy fed back into the grid, rather than the gross amount of energy created by the PV system. As of June 2008, there is no proposal for a national solar feed-in tariff as yet.

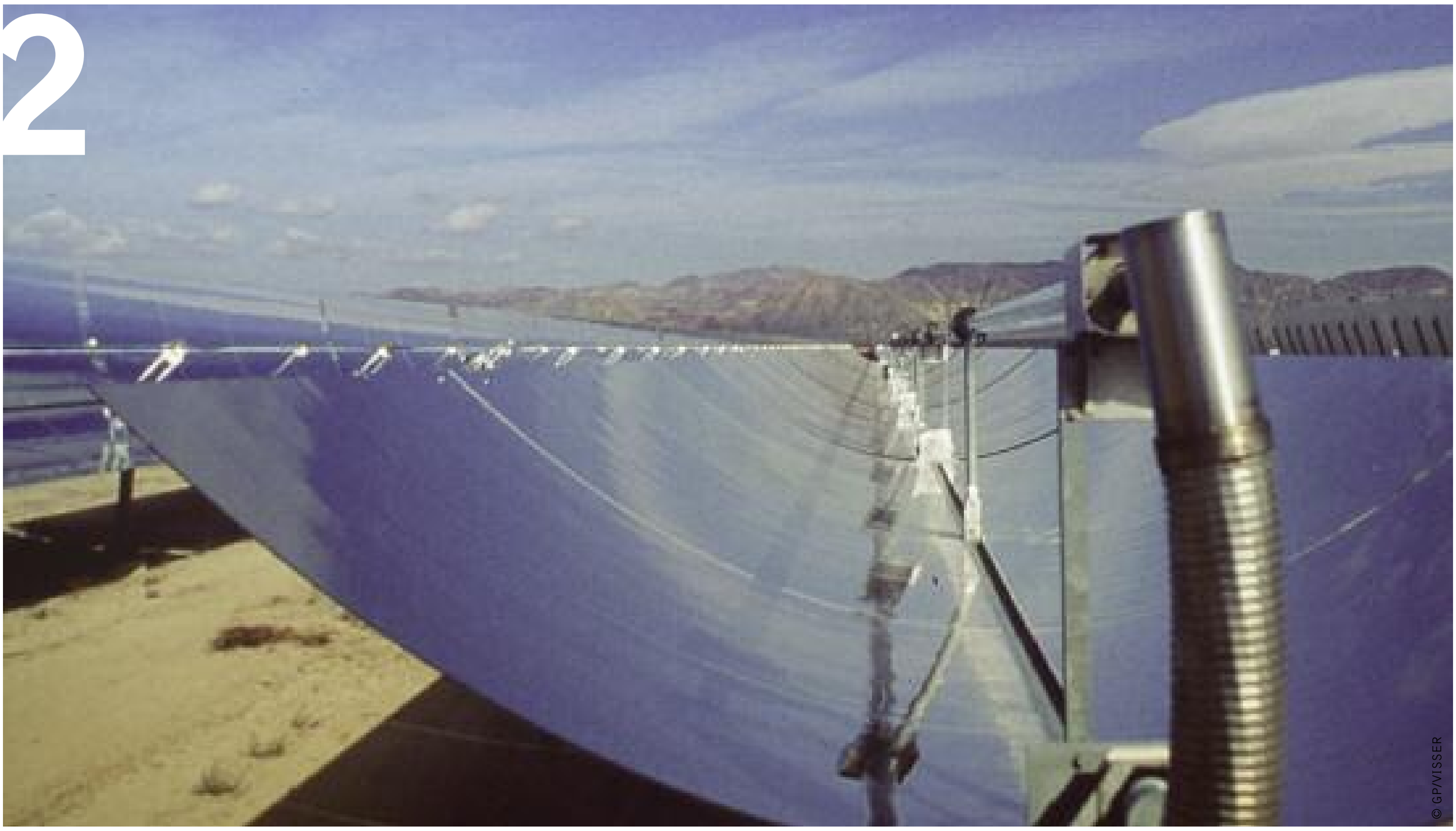
other Government programmes

The Australian Government has allocated approximately $2.3 billion over the next 4 years on climate change programmes[17], though this includes $365 million allocated to clean coal development, which won't deliver emission reductions in the immediate-term. As a proportion of total Government spending, this is a small allocation of resources, less that 0.25% of annual expenditure.[18]

the energy [r]evolution

"THE EXPERT CONSENSUS IS THAT THIS FUNDAMENTAL CHANGE MUST HAPPEN WITHIN THE NEXT TEN YEARS IN ORDER TO AVERT THE WORST IMPACTS."

2



© GP/VISSER

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

The climate change imperative demands nothing short of an energy revolution. Expert consensus is that this fundamental change must begin very soon and be well underway within the next ten years in order to avert the worst impacts. We need a complete transformation in the way we produce, consume and distribute energy. Nothing short of such an energy revolution will enable us to limit global warming to less than 2°C, beyond which we are likely to trigger runaway climate change. Current electricity generation relies mainly on burning fossil fuels, with their associated CO_2 emissions, in very large power stations which waste much of their primary input energy. More energy is lost as the power is moved around the electricity grid network and converted from high transmission voltage down to a supply suitable for domestic or commercial consumers. The system is innately vulnerable to disruption: localised technical, weather-related or even deliberately caused faults can quickly cascade, resulting in widespread blackouts. Whichever technology is used to generate electricity within this old fashioned configuration, it will inevitably be subject to some or all of these problems. Therefore at the core of the Energy [R]evolution is a change in the way that energy is both produced and distributed.

five key principles

the energy [r]evolution can be achieved by adhering to five key principles:

1 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 globally for the past decade.

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

image PLATFORM/OIL RIG DUNLIN IN THE NORTH SEA SHOWING OIL POLLUTION.

2 respect natural limits There is only so much greenhouse pollution that the planet can absorb. Each year we emit about 23 billion tonnes of carbon equivalent; we are literally filling up the sky with greenhouse pollution. Geological resources of coal could provide several hundred years of fuel but committing to continue to use fossil fuels is a commitment to take the planet into runaway climate change, a situation for which no amount of subsidised fuel will provide comfort. 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.

3 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. The idea that the coal industry can somehow clean up its act is a furphy; if CCS ever becomes a commercial reality it is unlikely that this would happen before 2030. Our timeframe to act on climate change is far shorter than this and we will avert runaway climate change using existing and emergent renewable energy technologies or not at all. Similarly, we cannot continue to fuel the myriad of 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.

4 equity and fairness 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 impacts 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.

Equity and fairness must also apply to locally specific transitions from fossil fuel energy to renewables. Although preventing runaway climate change is the goal that we all unquestioningly gain from, there will be winners and losers in the short term, as economies are restructured. Governments can ensure the Energy [R]evolution is carried out justly, by providing supporting measures for affected individuals and communities whilst maximising opportunities for new employment and investment.

5 decouple growth from fossil fuel use Starting in the developed countries, economic growth must fully decouple from fossil fuels; 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 – away from fossil fuels – quickly in order to enable clean and sustainable growth.

from principles to practice

Today, renewable energy sources account for 13% of the world's primary energy demand. Biomass, which is mainly used for heating, is the main renewable energy source. The share of renewable energy in electricity generation is 18%. The contribution of renewables to primary energy demand for heat supply is around 26%. About 80% of primary energy supply today still comes from fossil fuels, and the remaining 7% from nuclear power[19]. The time is right 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 and Brazil, are looking to satisfy the growing energy demand created by expanding economies. Within the next ten years, the power sector will determine how this new demand will be met, either by fossil and nuclear fuels or by the efficient use of renewable energy. This will be driven by directions and decisions made at a political level. The Energy [R]evolution Scenario is based on a new political framework in favour of renewable energy and cogeneration combined with energy efficiency.

To make this happen both renewable energy and co-generation – on a large scale and through decentralised, smaller units – have to grow faster than overall global energy demand. Both approaches must replace old generation and deliver the additional energy required in the developing world.

As it is not possible to switch directly from the current large scale fossil and nuclear fuel based energy system to a full renewable energy supply, a transition phase is required to build up the necessary infrastructure. Whilst remaining firmly committed to the promotion of renewable sources of energy, we appreciate that gas, used in appropriately scaled cogeneration plant, is valuable as a transition fuel, able to 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 particularly valuable means to achieve emission reductions. The transition period must also be used to develop a workforce and manufacturing and transport capacities that can meet the required scale of deployment of renewable energy.

a development pathway

The Energy [R]evolution envisages a development pathway which turns the present energy supply structure into a sustainable system. There are two main stages to this.

step 1: energy efficiency

The Energy [R]evolution is aimed at the ambitious exploitation of the potential for energy efficiency. It focuses on current best practice and available technologies for 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 for future energy conservation.

reference
19 IEA; WORLD ENERGY OUTLOOK 2004

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, which currently use energy in the least efficient way, can reduce their consumption drastically without the loss of either housing comfort or information and entertainment electronics. The Global Energy [R]evolution Scenario uses energy saved in OECD countries as a compensation for 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" – transforming the current one-sided waste of energy in the industrialised countries towards a fairer worldwide distribution of efficiently used supply.

A dramatic reduction in primary energy demand compared to the International Energy Agency's "reference scenario" (see Chapter 4) – 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 coal-fired electricity and reducing the consumption of fossil fuels.

step 2: structural changes

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 is energy generated at or near the point of use.

DE is connected to a local distribution network system, supplying homes and offices, rather than the high voltage transmission system. The proximity of electricity generating plant to consumers allows any waste heat from combustion processes to be piped to buildings nearby, a system known as cogeneration or combined heat and power. This means that nearly all the input energy is put to use, not just a fraction as with traditional centralised fossil fuel plant. DE also includes stand-alone systems entirely separate from the public networks.

DE technologies also include dedicated systems such as ground source and air source heat pumps, solar thermal and biomass heating. These can all be commercialised at a domestic level to provide sustainable low emission heating. Although DE technologies can be considered 'disruptive' because they do not fit the existing electricity market and system, with appropriate changes they have the potential for exponential growth, promising 'creative destruction' of the existing 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 in order to achieve a fast transition to a renewables dominated system. Large offshore wind farms, geothermal energy and concentrating solar power (CSP) plants in the sunbelt regions of the world will therefore have an important role to play.

cogeneration

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, decreasing demand for heat and the large potential for producing heat directly from renewable energy sources will limit the further expansion of CHP.

renewable electricity

The electricity sector will be the pioneer of renewable energy utilisation. All renewable electricity technologies have been experiencing steady growth over the past few decades of up to 35% per year and are expected to consolidate at a high level between 2030 and 2050. By 2050, the majority of electricity worldwide will be produced from renewable energy sources.

renewable heating

In the heat supply sector, the contribution of renewables 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 biofuels can play a substantial role in the transport sector, the existing large efficiency potentials have to be exploited. 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.

Overall, to achieve an economically attractive growth in renewable energy sources, a balanced and timely mobilisation of all technologies is of great importance. Such a mobilisation depends on the resource availability, cost reduction potential and technological maturity.

scenario principles in a nutshell

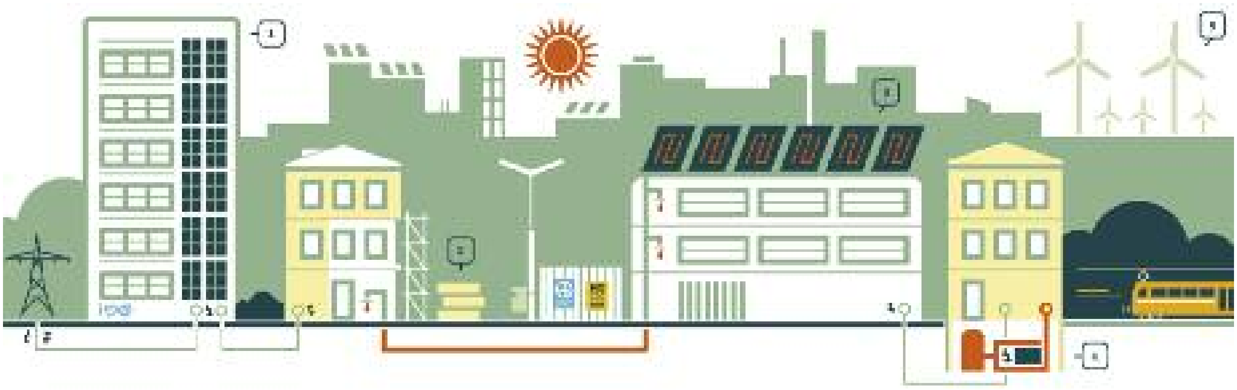
- Smart consumption, generation and distribution
- Energy production moves closer to the consumer
- Maximum use of locally available, environmentally friendly fuels

image SOLON AG PHOTOVOLTAICS FACILITY IN ARNSTEIN, GERMANY OPERATING 1500 HORIZONTAL AND VERTICAL SOLAR 'MOVERS'.

figure 4: a decentralised energy future

THE CITY CENTRES OF TOMORROW'S NETWORKED WORLD WILL PRODUCE POWER AND HEAT AS WELL AS CONSUME IT. THE ROOFS AND FACADES OF PUBLIC BUILDINGS ARE IDEAL FOR HARVESTING SOLAR ENERGY. 'LOW ENERGY' WILL BECOME THE STANDARD FOR ALL BUILDINGS. GOVERNMENTS COMMITTED TO TIGHT CLIMATE-PROTECTION TARGETS WILL HAVE TO IMPOSE STRICT CONDITIONS AND OFFER INCENTIVES FOR RENOVATING THESE BUILDINGS. THIS WILL HELP TO CREATE JOBS.

city



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

suburbs

1. PHOTOVOLTAIC
2. MINI-COGENERATION POWER PLANT = COMBINED HEAT AND POWER [CHP]
3. SOLAR COLLECTORS (HEATING)
4. LOW-ENERGY BUILDINGS
5. GEOTHERMAL HEAT- AND POWER PLANT[CHP]

energy resources and security of supply

"AT PRESENT AROUND 80% OF GLOBAL ENERGY DEMAND IS MET BY FOSSIL FUELS.
THE UNRELENTING INCREASE IN ENERGY DEMAND IS MATCHED BY THE FINITE NATURE OF THESE SOURCES."

3

image GEOTHERMAL ACTIVITY.

the reserves chaos

Public data about oil and gas reserves is strikingly inconsistent, and potentially unreliable for legal, commercial, historical and sometimes political reasons. The most widely available and quoted figures, those from the industry journals Oil & Gas Journal and World Oil, have limited value as they report the reserve figures provided by companies and governments without analysis or verification. Moreover, as there is no agreed definition of reserves or standard reporting practice, these figures usually stand for different physical and conceptual magnitudes. Confusing terminology ('proved', 'probable', 'possible', 'recoverable', 'reasonable certainty') only adds to the problem.

Historically, private oil companies consistently underestimated their reserves to comply with conservative stock exchange rules and through natural commercial caution. Whenever a discovery was made, only a portion of the geologist's estimate of recoverable resources was reported; subsequent revisions would then increase the reserves from that same oil field over time. National oil companies, almost fully represented by OPEC (Organisation of Petroleum Exporting Countries), are not subject to any sort of accountability so their reporting practices are even less clear. In the late 1980s, OPEC countries blatantly overstated their reserves while competing for production quotas, which were allocated as a proportion of the reserves. Although some revision was needed after the companies were nationalised, between 1985 and 1990, OPEC countries increased their joint reserves by 82%. Not only were these dubious revisions never corrected, but many of these countries have reported untouched reserves for years, even if no sizeable discoveries were made and production continued at the same pace. Additionally, the Former Soviet Union's oil and gas reserves have been overestimated by about 30% because the original assessments were later misinterpreted.

Whilst private companies are now becoming more realistic about the extent of their resources, the OPEC countries hold by far the majority of the reported reserves, and information on their resources is as unsatisfactory as ever. In brief, these information sources should be treated with considerable caution. To fairly estimate the world's oil resources a regional assessment of the mean backdated (i.e. 'technical') discoveries would need to be performed.

image OIL FIELDS NEAR BIBI-HEYDAT IN AZERBAIJAN. OIL-WELL DERRICKS.

gas

Natural gas has been the fastest growing fossil energy source in the last two decades, boosted by its increasing share in the electricity generation mix. Gas is generally regarded as a largely abundant resource and public concerns about depletion are limited to oil, even though few in-depth studies address the subject. Gas resources are more concentrated than oil so they were discovered faster because a few massive fields make up for most of the reserves: the largest gas field in the world holds 15% of the "Ultimate Recoverable Resources" (URR), compared to 6% for oil. Unfortunately, information about gas resources suffers from the same bad practices as oil data because gas mostly comes from the same geological formations, and the same stakeholders are involved.

Most reserves are initially understated and then gradually revised upwards, giving an optimistic impression of growth. By contrast, Russia's reserves, the largest in the world, are considered to have been overestimated by about 30%. Owing to geological similarities, gas follows the same depletion dynamic as oil, and thus the same discovery and production cycles. In fact, existing data for gas is of worse quality than for oil and some ambiguities arise as to the amount of gas already produced because flared and vented gas is not always accounted for. As opposed to published reserves, the technical accounts have been almost constant since 1980 because discoveries have roughly matched production.

coal

Coal was the world's largest source of primary energy until it was overtaken by oil in the 1960s. Today, coal supplies almost one quarter of the world's energy. Despite being the most abundant of fossil fuels, coal's development is currently threatened by environmental concerns; hence its future will unfold as much in the context of global warming as it does in energy security.

Coal is abundant and more equally distributed throughout the world than oil and gas. Global recoverable reserves are the largest of all fossil fuels, and most countries have at least some. Moreover, existing and prospective big energy consumers like the US, China and India are self-sufficient in coal and will be for the foreseeable future. Coal has been exploited on a large scale for two centuries so both the product and the available resources are well known; no substantial new deposits are expected to be discovered. Extrapolating the demand forecast, the world will consume 20% of its current reserves by 2030 and 40% by 2050[20]. Hence, if current trends are maintained, coal would still last several 100 years.

reference
20 "PLUGGING THE GAP -A SURVEY OF WORLD FUEL RESOURCES AND THEIR IMPACT ON THE DEVELOPMENT OF WIND ENERGY"; GWEC, RES SEPTEMBER 2006

table 1: overview of fossil fuel reserves and resources

RESERVES, RESOURCES AND ADDITIONAL OCCURRENCES OF FOSSIL ENERGY CARRIERS ACCORDING TO DIFFERENT AUTHORS. **C** CONVENTIONAL (PETROLEUM WITH A CERTAIN DENSITY, FREE NATURAL GAS, PETROLEUM GAS), **NC** NON-CONVENTIONAL (HEAVY FUEL OIL, VERY HEAVY OILS, TAR SANDS AND OIL SHALE, GAS IN COAL SEAMS, AQUIFER GAS, NATURAL GAS IN TIGHT FORMATIONS, GAS HYDRATES). THE PRESENCE OF ADDITIONAL OCCURRENCES IS ASSUMED BASED ON GEOLOGICAL CONDITIONS, BUT THEIR POTENTIAL FOR ECONOMIC RECOVERY IS CURRENTLY VERY UNCERTAIN. IN COMPARISON: IN 1998, THE GLOBAL PRIMARY ENERGY DEMAND WAS 402EJ (UNDP ET AL., 2000).

ENERGY CARRIER		BROWN, 2002 EJ	IEA, 2002c EJ		IPCC, 2001a EJ		NAKICENOVIC ET AL., 2000 EJ		UNDP ET AL., 2000 EJ		BGR, 1998 EJ
Gas	reserves	6,600	6,200	c	5,400	c	5,900	c	5,500	c	5,300
				nc	8,000	nc	8,000	nc	9,400	nc	100
	resources	9,400	11,100	c	11,700	c	11,700	c	11,100	c	7,800
				nc	10,800	nc	10,800	nc	23,800	nc[a)]	111,900
	additional occurrences				796,000		799,700		930,000		
Oil	reserves	5,800	5,700	c	5,900	c	6,300	c	6,000	c	6,700
				nc	6,600	nc	8,100	nc	5,100	nc	5,900
	resources	10,200	13,400	c	7,500	c	6,100	c	6,100	c	3,300
				nc	15,500	nc	13,900	nc	15,200	nc	25,200
	additional occurrences				61,000		79,500		45,000		
Coal	reserves	23,600	22,500		42,000		25,400		20,700		16,300
	resources	26,000	165,000		100,000		117,000		179,000		179,000
	additional occurrences				121,000		125,600				
Total	resource (reserves + resources)	**180,600**	**223,900**		**212,200**		**213,200**		**281,900**		**361,500**
Total	occurrence				**1,204,200**		**1,218,000**		**1,256,000**		

source SEE TABLE **a)** INCLUDING GAS HYDRATES

nuclear

Uranium, the fuel used in nuclear power plants, is a finite resource whose economically available resource is limited. Its distribution is almost as concentrated as oil and does not match regional consumption. Five countries - Canada, Australia, Kazakhstan, Russia and Niger - control three quarters of the world's supply. As a significant user of uranium, however, Russia's reserves will be exhausted within ten years.

Secondary sources, such as old deposits, currently make up nearly half of worldwide uranium reserves. However, those sources will soon be used up. Mining capacities will have to be nearly doubled in the next few years to meet current needs.

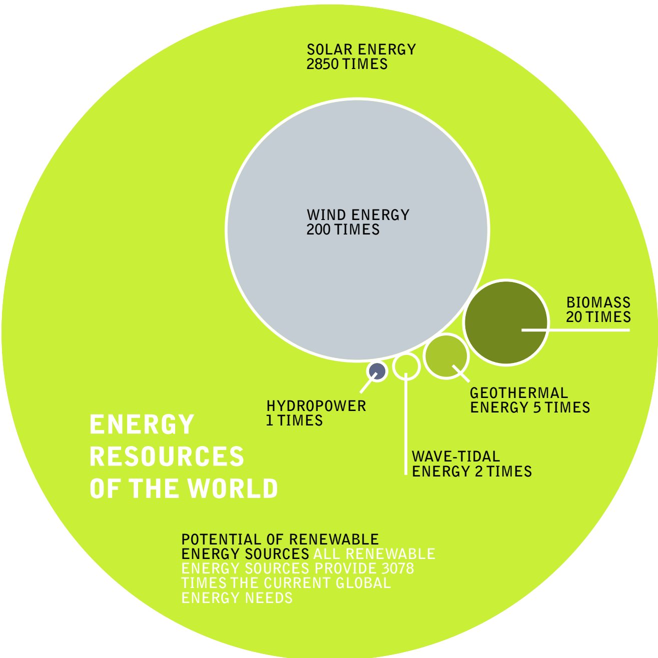
A joint report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency, (Uranium 2003: Resources, Production and Demand) estimates that all existing nuclear power plants will have used up their nuclear fuel, employing current technology, within less than 70 years. In the light of various scenarios for the worldwide development of nuclear power, it is likely that uranium supplies will be exhausted sometime between 2026 and 2070. Assuming a downward trend in the use of nuclear power, realistic estimates indicate that supplies will be enough for only a few countries by 2050. This forecast includes uranium deposits as well as the use of mixed oxide fuel (MOX), a mixture of uranium and plutonium.

renewable energy potential

Nature offers a variety of freely available options for producing energy. It is mainly a question of how to convert sunlight, wind, biomass or water into electricity, heat or power as efficiently, sustainably and cost-effectively as possible.

On average, the energy in the sunshine that reaches the earth is about one kilowatt per square metre worldwide. According to the Research Association for Solar Power, power is gushing from renewable energy sources at a rate of 2,850 times more energy than is needed in the world today. In one day, the sunlight which reaches the earth produces enough energy to satisfy the world's current power requirements for eight years. Even though only a percentage of that potential is technically accessible, this is still enough to provide just under six times more power than the world currently requires.

figure 5: energy resources of the world



source WBGU

table 2: technically accessible today

THE AMOUNT OF ENERGY THAT CAN BE ACCESSED WITH CURRENT TECHNOLOGIES SUPPLIES A TOTAL OF 5.9 TIMES THE GLOBAL DEMAND FOR ENERGY.

Sun	3.8 times
Geothermal heat	1 time
Wind	0.5 times
Biomass	0.4 times
Hydrodynamic power	0.15 times
Ocean power	0.05 times

source DR. JOACHIM NITSCH

definition of types of energy resource potential[21]

theoretical potential

The theoretical potential identifies the physical upper limit of the energy available from a certain source. For solar energy, for example, this would be the total solar radiation falling on a particular surface.

conversion potential

This is derived from the annual efficiency of the respective conversion technology. It is therefore not a strictly defined value, since the efficiency of a particular technology depends on technological progress.

technical potential

This takes into account additional restrictions regarding the area that is realistically available for energy generation. Technological, structural and ecological restrictions, as well as legislative requirements, are accounted for.

economic potential

The proportion of the technical potential that can be utilised economically. For biomass, for example, those quantities are included that can be exploited economically in competition with other products and land uses.

sustainable potential

This limits the potential of an energy source based on evaluation of ecological and socio-economic factors.

renewable energy potential by region and technology

Based on a recently published report "Renewable Energies Potentials" from REN 21, a global policy network, we can provide a more detailed overview of renewable energy potentials by regions and technology. The table below focuses on large economies, which consume 80 percent of the world's primary energy and produce a similar share of the world's greenhouse gas emissions.

Solar photovoltaic (PV) technology can be harnessed almost everywhere, and its technical potential is estimated at over 1500 EJ/year, closely followed by concentrating solar thermal power (CSP). These two potentials cannot simply be added up, because they would require much of the same land resources.

The onshore wind potentials are vast, with almost 400 EJ/year beyond the order of magnitude of future electricity consumption. The estimate for offshore wind potentials (22 EJ/year) is cautious as only wind intensive areas on ocean shelf areas and outside shipping lines and protected areas are included.

The various ocean or marine energy potentials also add up to a similar magnitude, most of it from ocean waves. More cautious estimates arrive at around 50 EJ/year. The estimates of hydro and geothermal power resources are rather well established and identify the technical potentials at around 50 EJ/year for each.

Those figures should be seen in a context of the current global energy demand of around 500 EJ.

With respect to heating and cooling (apart from biomass), there is the option of using direct geothermal energy. The potential is extremely large and could cover 20 times the current world energy demand for heat. The potential for solar heating, including passive solar building design, is virtually endless. However, heat is costly to transport and therefore one should only consider geothermal heat and solar water heating potentials which are sufficiently close to consumption areas. Passive solar technology, which contributes massively to provide heating services, is not considered as a (renewable energy) supply source in this analysis but as an efficiency factor that is implicitly accounted for in the demand.

reference
21 WBGU

table 3: technical renewable energy by region
EXCLUDING BIO ENERGY

sector	SOLAR CSP	SOLAR PV	HYDRO POWER	WIND ONSHORE	WIND OFFSHORE	OCEAN POWER	GEO THERMAL ELECTRIC	GEO THERMAL DIRECT USES	SOLAR WATER HEATING	TOTAL
North America	21	72	4	156	2	68	5	626	23	976
Latin America	59	131	13	40	5	32	11	836	12	1,139
OECD Europe	1	13	2	16	5	20	2	203	23	284
Non-OECD Europe + Transition Economies	58	120	5	67	4	27	6	667	6	926
Africa and Middle East	679	863	9	33	1	19	5	1,217	12	2,838
East and South Asia	22	254	14	10	3	103	12	1,080	45	1.543
Oceania	187	239	1	57	3	51	4	328	2	872
World	992	1,693	47	379	22	321	45	4,955	123	8,578

source REN21

cost projections

"THE MAIN DRIVERS ARE THE PRICES OF FUELS, THE INVESTMENT COSTS OF FUTURE POWER PLANT TECHNOLOGIES AND THE POTENTIAL COSTS OF CO_2 EMISSIONS."

4

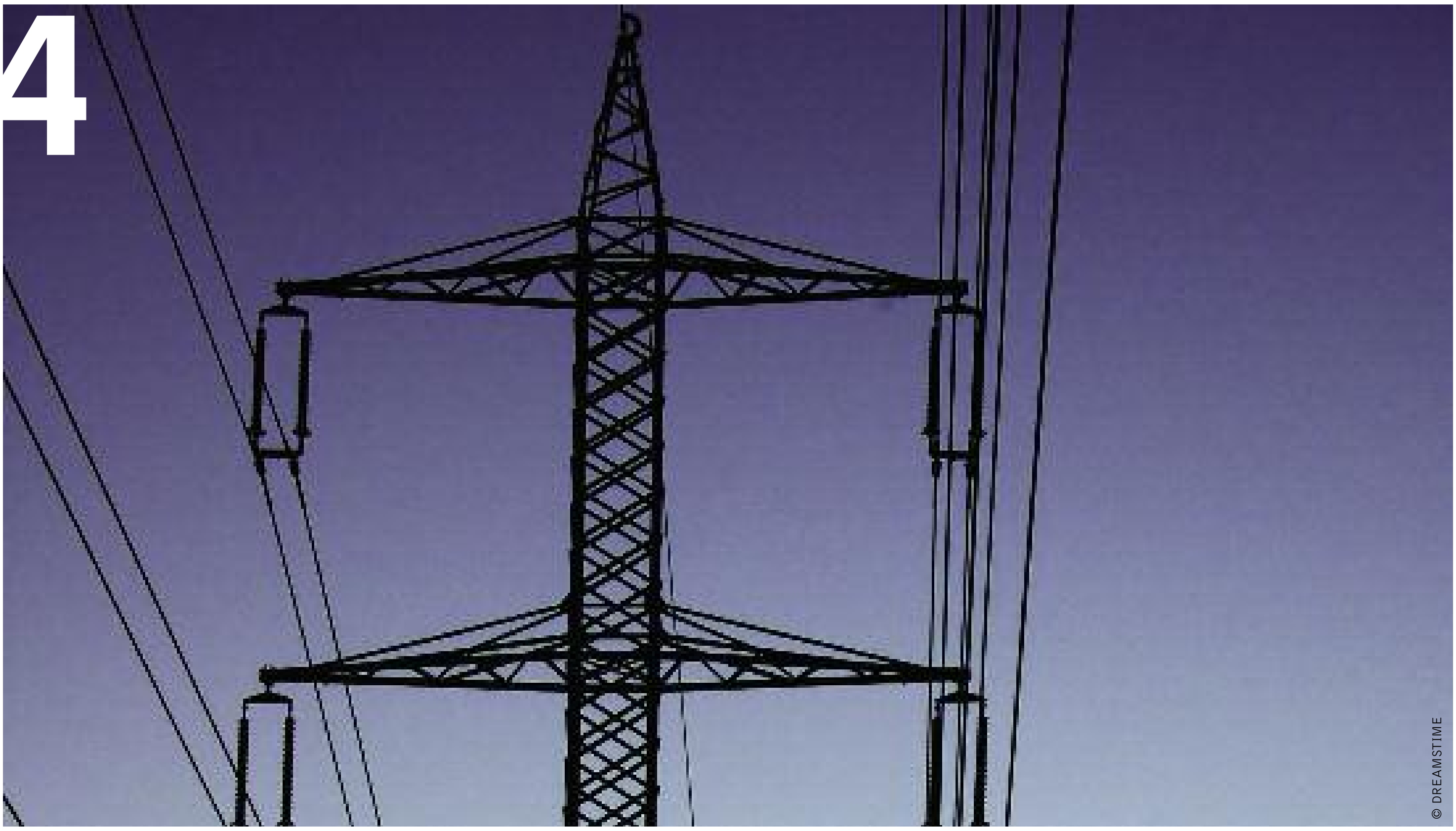


image ELECTRICITY LINES.

future development of costs

The cost of electricity supply is a key parameter for the evaluation of future energy scenarios. The main drivers are the prices of fuels, the investment costs of future power plant technologies and the potential costs of CO_2 emissions.

Future energy prices have been based on projections by the IEA, the US Department of Energy and the European Commission. Future investment costs for power plants have been estimated using a learning curve approach. Technology specific learning factors (progress ratios) are derived from a literature review. The development of cumulative capacity for each technology is taken from the results of the Energy [R]evolution Scenario. All prices are given in US$2000.

The oil price in May 2008 was already higher than the quoted oil price projections for 2050. Cost benefits for the energy [r]evolution scenario will therefore be even higher.

fossil fuel price projections

The recent dramatic increase in global oil prices has resulted in much higher forward price projections. Under the 2004 'high oil and gas price' scenario by the European Commission, for example, an oil price of just $34/bbl was assumed in 2030. Ongoing modelling funded by the Commission (CASCADE-MINTS 2006), on the other hand, assumes an oil price of $94/bbl in 2050, a gas price of $15/GJ and an international coal price of $95/t. Current projections of oil prices in 2030 range from the IEA's $52/bbl (55 $2005/bbl) up to over $100.

As the supply of natural gas is limited by the availability of pipeline infrastructure, there is no world market price for natural gas, though a global spot market for liquefied natural gas (LNG) is beginning to emerge. In most regions of the world the gas price is directly tied to the price of oil. Current projections of gas prices in 2030 range from the US Department of Energy's $4.5/GJ up to its highest figure of $6.9/GJ.

Taking into account the recent development of energy prices, these projections might be considered too conservative. Considering the growing global demand for oil and gas we have assumed a price development path for fossil fuels in which the price of oil reaches $85/bbl by 2030 and $100/bbl in 2050. Gas prices are assumed to increase to $9-$10/GJ by 2050.

image TRANSPORT POLLUTION.

biomass price projections

Compared to fossil fuels, biomass prices are highly variable, ranging from no or low costs for residues or traditional biomass in Africa or Asia to comparatively high costs for biofuels from cultivated energy crops. Despite this variability a biomass price was aggregated for Europe[22] up to 2030 and supplemented with our own assumptions up to 2050. The increasing biomass prices reflect the continuing link between biofuel and fossil fuel prices and a rising share of energy crops. For other regions prices were assumed to be lower, considering the large amount of traditional biomass use in developing countries and the high potential of yet unused residues in North America and the Transition Economies.

cost of CO_2 emissions

Assuming that a CO_2 emissions trading system will be established in all world regions in the long term, the cost of CO_2 allowances needs to be included in the calculation of electricity generation costs. Projections of emission costs are even more uncertain than energy prices, however. The IEA assumes a 'CO_2 reduction incentive' of \$25/tCO_2 in 2050. The European CASCADE-MINTS project, on the other hand, assumes CO_2 costs of \$50/tCO_2 in 2020 and \$100/tCO_2 beyond 2030. For this scenario we have assumed CO_2 costs of \$50/tCO_2 in 2050, which is twice as high as the IEA's projection, but still conservative compared with other studies and certainly below the \$85 per tonne found by the Stern Review to be the cost of climate damage caused by greenhouse gas emissions. We assume that CO_2 emission costs will be accounted for in Non-Annex B countries only after 2020.

table 4: assumptions on fossil fuel, biomass and CO_2 price development

	2003	2010	2020	2030	2040	**2050**
FOSSIL FUELS						
Crude oil in \$2000/bbl	28.0	62.0	75.0	85.0	93.0	**100.0**
Natural gas in \$2000/GJ						
- America	3.1	4.4	5.6	6.7	8.0	**9.2**
- Europe	3.5	4.9	6.2	7.5	8.8	**10.1**
- Asia	5.3	7.4	7.8	8.0	9.2	**10.5**
Hard coal \$2000/t	42.3	59.4	66.2	72.9	79.7	**86.4**
BIOMASS \$2000/GJ						
- Europe	4.8	5.8	6.4	7.0	7.3	**7.6**
- other Regions	1.4	1.8	2.3	2.7	3.0	**3.2**
COUNTRIES(\$/TCO_2)						
Kyoto Annex B countries		10	20	30	40	**50**
Non-Annex B countries			20	30	40	**50**

reference

22 NITSCH ET AL. (2004) AND THE GEMIS-DATABASE (ÖKO-INSTITUT, 2005)

summary of conventional energy cost development

Table 6 gives a summary of expected investment costs for different fossil fuel technologies with varying levels of efficiency.

table 5: development of efficiency and investment costs for selected power plant technologies

		2010	2030	2050
Coal-fired condensing power plant	Efficiency (%)	41	45	**48**
	Investment costs (AUD$/kW)	980	930	**880**
	Electricity generation costs including CO_2 emission costs (AUD$ cents/kWh)	6.6	8.3	**9.6**
	CO_2 emissions a) (g/kWh)	921	801	**767**
Oil-fired condensing power plant	Efficiency (%)	39	41	**41**
	Investment costs (AUD$/kW)	670	620	**570**
	Electricity generation costs including CO_2 emission costs (AUD$ cents/kWh)	24.8	34.1	**50.7**
	CO_2 emissions a) (g/kWh)	1,126	1,022	**977**
Natural gas combined cycle	Efficiency (%)	55	60	**62**
	Investment costs (AUD$/kW)	530	490	**440**
	Electricity generation costs including CO_2 emission costs (AUD$ cents/kWh)	7.4	9.5	**11.7**
	CO_2 emissions a) (g/kWh)	383	370	**358**

source DLR, 2006 a) REFERS TO DIRECT EMISSIONS ONLY, LIFE-CYCLE EMISSIONS ARE NOT CONSIDERED HERE.

renewable energy price projections

The range of renewable energy technologies available today display marked differences in terms of their technical maturity, costs and development potential. Whereas hydro power has been widely used for decades, other technologies, such as the gasification of biomass, have yet to find their way to market maturity. Some renewable sources by their very nature, including wind and solar power, provide a variable supply, requiring a revised coordination with the grid network. But although in many cases these are 'distributed' technologies - their output generated and used locally to the consumer - the future will also see large-scale applications in the form of offshore wind parks, geothermal energy or concentrating solar power (CSP) stations.

By using the individual advantages of the different technologies and linking them with each other, a wide spectrum of available options can be developed to market maturity and integrated step by step into the existing supply structures. This will eventually provide a complementary portfolio of environmentally friendly technologies for heat and power supply and the provision of fuels.

Most of the renewable technologies employed today are at an early stage of market development. Accordingly, their costs are generally higher than for competing conventional systems. Costs can also depend on local conditions such as the wind regime, the availability of cheap biomass supplies or the need for nature conservation requirements when building a new hydro power plant. There is a large potential for cost reduction, however, through technical and manufacturing improvements and large-scale production, especially over the long timescale of this study.

To identify long-term cost developments, learning curves have been applied which reflect the correlation between cumulative capacity and the development of costs. For many technologies, the learning factor (or progress ratio) falls in the range 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. Technology specific progress ratios are derived from a literature review[23]. This 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.

reference
23 DLR 2006, DR. WOLFRAM KREWITT ET. AL.

image CLOSE-UP OF A SOLAR PANEL.

summary of renewable energy cost development

Reduced investment costs for renewable energy technologies lead directly to reduced heat and electricity generation costs, as shown in Table 7. Generation costs today are around 8 to 20 cents per kilowatt hour (kWh) for the most important technologies, with the exception of photovoltaic. In the long term, costs are expected to converge at around 4 to 10 cents/kWh. These estimates depend on site-specific conditions such as the local wind regime or solar irradiation, the availability of biomass at reasonable prices or the credit granted for heat supply in the case of combined heat and power generation.

table 6: investment cost projections for renewable energy technologies

			2010	2030	2050
Photovoltaic	investment costs	AUD$/kW	4,565	1,802	1,950
	generation costs (min/max)	AUD$/kWh	0.34	0.11-0.22	0.08-0.16
Concentrating solar thermal	investment costs	AUD$/kW	2,282	1,181	1,082
	generation costs (min/max)	AUD$/kWh	0.13-0.21	0.10-0.14	0.08-0.16
Wind	investment costs	AUD$/kW	1826	1,517	1,418
	generation costs (min/max)	AUD$/kWh	0.11-0.14	0.08-0.10	0.08-0.10
Biomass (no CHP applications)	investment costs	AUD$/kW	4,629	3,411	3,062
	generation costs (min/max)	AUD$/kWh	0.10-0.18	0.10-0.19	0.11-0.19
Geothermal	investment costs	AUD$/kW	10,158	7,370	6,539
	generation costs (min/max)	AUD$/kWh	0.18-0.32	0.13-0.21	0.11-0.16
Hydro	investment costs	AUD$/kW	3,730	4,114	4,374
	generation costs (min/max)	AUD$/kWh	0.06-0.16	0.08-0.16	0.10-0.18
Ocean energy	investment costs	AUD$/kW	5,126	2,928	2,438
	generation costs (min/max)	AUD$/kWh	0.18-0.58	0.10-0.27	0.06-0.16

references for the cost assumptions section INTERNATIONAL ENERGY AGENCY: "ENERGY TECHNOLOGY PERSPECTIVES – SCENARIOS AND STRATEGIES TO 2050" (IEA 2006); "WORLD ENERGY OUTLOOK 2005" (IEA 2005); "WORLD ENERGY OUTLOOK 2004" (IEA 2004). ENERGY INFORMATION ADMINISTRATION, US DEPARTMENT OF ENERGY: "ANNUAL ENERGY OUTLOOK 2006 WITH PROJECTIONS TO 2030" (EIA 2006). EUROPEAN COMMISSION: "EUROPEAN ENERGY AND TRANSPORT – SCENARIOS ON KEY DRIVERS" (EUROPEAN COMMISSION, 2004). CASCADE (2006): HTTP://WWW.E3MLAB.NTUA.GR/CASCADE.HTML. NITSCH, J.; KREWITT, W.; NAST, M.; VIEBAHN, P.; GÄRTNER, S.; PEHNT, M.; REINHARDT, G.; SCHMIDT, R.; UIHLEIN, A.; BARTHEL, C.; FISCHEDICK, M.; MERTEN, F.; SCHEURLEN, K. (2004): ÖKOLOGISCH OPTIMIERTER AUSBAU DER NUTZUNG ERNEUERBARER ENERGIEN IN DEUTSCHLAND. IN: BUNDESMINISTERIUM FÜR UMWELT, NATURSCHUTZ UND REAKTORSICHERHEIT [ED.]: UMWELTPOLITIK, KÖLLEN DRUCK. ÖKO-INSTITUT (2005): GLOBAL EMISSION MODEL FOR INTEGRATED SYSTEMS (GEMIS), VERSION 4.3; INSTITUTE FOR APPLIED ECOLOGY E.V.; HTTP://WWW.GEMIS.DE. WBGU (2003): ÜBER KIOTO HINAUS DENKEN – KLIMASCHUTZSTRATEGIEN FÜR DAS 21. JAHRHUNDERT. SONDERGUTACHTEN DES WISSENSCHAFTLICHEN BEIRATS DER BUNDESREGIERUNG FÜR GLOBALE UMWELTVERÄNDERUNG, BERLIN, 2003. HTTP://WWW.WBGU.DE/WBGU_SN2003.HTML

global scenario for a future energy supply

"ANY ANALYSIS THAT SEEKS TO TACKLE ENERGY AND ENVIRONMENTAL ISSUES THEREFORE NEEDS TO LOOK DECADES IN ADVANCE."

image SOLAR AND WIND-FACILITY NEAR ROSTOCK, GERMANY.

the global energy [r]evolution scenario

Moving from principles to action on energy supply and climate change mitigation requires perspectives of various time frames. Energy infrastructure takes time to build up; new energy technologies take time to develop, workforces take time to train. Policy shifts often also need many years to realise their goals. Any analysis that seeks to tackle energy and environmental issues therefore needs to look decades in advance. Scenarios are important in describing possible development paths, to give decision-makers an overview of future perspectives and to indicate how far they can shape the future energy system. Two different scenarios are used here to characterise the wide range of possible paths for the future energy supply system: a Reference Scenario, reflecting a continuation of current trends and policies, and the Energy [R]evolution Scenario, which is designed to demonstrate the capacity of existing technological and behavioural solutions to transform the way energy is sourced and used.

the global reference scenario is based on the reference scenario published by the International Energy Agency in World Energy Outlook 2004 (WEO 2004)[24]. This only takes existing policies into account. The 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 scenario only covers a time horizon up to 2030, it has been extended by extrapolating its key macroeconomic indicators. This provides a baseline for comparison with the Energy [R]evolution Scenario.

reference
24 INTERNATIONAL ENERGY AGENCY, WORLD ENERGY OUTLOOK 2004, PARIS 2004 – A NEW WORLD ENERGY OUTLOOK HAS BEEN PUBLISHED IN NOVEMBER 2006 – BASIC PARAMETERS SUCH AS GDP DEVELOPMENT AND POPULATION REMAIN IN THE SAME RANGE (SEE BOX "SENSITIVITY ANALYSIS IEA WEO 2004 -> 2006)

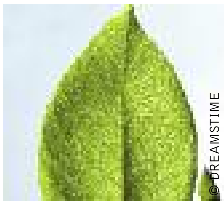


image THE TECHNOLOGY FOR SOLAR PANELS WAS ORIGINAL INSPIRED BY NATURE.

the energy [r]evolution scenario has a key target for the reduction of worldwide carbon dioxide emissions down to a level of around 10 to 12 Giga tonnes per year by 2050 in order for the increase in global temperature to remain under +2°C. A second objective is the global phasing out of nuclear energy. To achieve these targets, the scenario is characterised by significant efforts to fully exploit the large potential for energy efficiency. At the same time, all cost-effective renewable energy sources are accessed 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.

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

scenario background

The scenarios in this report were jointly commissioned by Greenpeace and the European Renewable Energy Council from DLR, the German Aerospace Centre. The supply scenarios were calculated using the MESAP/PlaNet simulation model used for the previous version of Energy [R]evolution scenarios published in January 2007. Energy demand projections were developed by Ecofys based on the analysis of future potential for energy efficiency measures.

energy efficiency study

The aim of the Ecofys study was to develop low energy demand scenarios for the period 2003 to 2050 on a sector level for the IEA regions as defined in the World Energy Outlook report series. Calculations were made for each decade from 2010 onwards. Energy demand was split up into electricity and fuels. The sectors which were taken into account were industry, transport and other consumers, including households and services. Two low energy demand scenarios were developed, a reference version and a more ambitious energy efficiency version. This more advanced scenario focuses on current best practice and available technologies in the future, assuming continuous innovation in the field of energy efficiency. Worldwide final energy demand is reduced by 47% in 2050 in comparison to the Reference Scenario, resulting in a final energy demand of 350 EJ in 2050. The energy savings are fairly equally distributed over the three sectors of industry, transport and other uses. The most important energy saving options are efficient passenger and freight transport and improved heat insulation and building design, together accounting for 46 % of the worldwide energy savings.

global population growth

One driving factor of energy scenario building is future population development. Population growth affects the size and composition of energy demand, directly and through its impact on economic growth and development. The IEA World Energy Outlook 2007 refers to the most recent United Nation projections for population development up to 2030. For the Energy [R]evolution study 2008 the same population projections are applied, also for the expanded time frame until 2050.

The world population is expected to grow by 0.77% per year on average over the period 2005 to 2050, from 6.5 billion in 2005 to more than 9.1 billion in 2050. Population growth will slow over the projection period, from 1.2% in 2005-2010 to 0.41% in 2040-2050. However the updated projections show an increase in population of almost 300 million compared to the previous version. This will further incite the demand for energy. The population of the developing regions will continue to grow most rapidly. The transition economies will face a continuous decline, followed by the OECD Pacific countries with a short time lag. OECD Europe and OECD North America are expected to maintain their population, with a peak around 2020/2030 and a slight decline in population afterwards. The share of the population living in the today's non-OECD countries will increase from today 82% to 86% in 2050. China's contribution to world population will drop from 20% today to 15% in 2050. Africa will remain to be the region with the highest population growth, leading to a share of 21% of world population in 2050.

Satisfying the energy needs of a growing population in the developing regions of the world in an environmentally friendly manner is a key challenge for achieving a global sustainable energy supply.

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 reducing demand in the future. Most global energy-economic-environment models constructed in the past have relied on market exchange rates to put countries in a common currency for estimation and calibration. This approach has been the subject of considerable discussion in recent years, and the alternative of purchasing power parity (PPP) exchange rates has been proposed. Purchasing power parities compare costs in different currencies of a fixed basket of traded and non-traded goods and services and yield a widely-based measure of standard living. This is important in analysing the main drivers of energy demand or comparing energy intensities among countries.

Although PPP accounts today are still conceptually unsettled and empirically imprecise relative to the construction of national income and product accounts and national price indexes, they are considered to provide a better basis for global scenario development (Nordhaus, 2005). Thus all data on economic development in the IEA-WEO 2007 refer to purchasing power adjusted GDP. We follow this approach, and all GDP data in this report are expressed in year-2006 US dollars using purchasing power parities (PPP) rather than market exchange rates. Following the IEA-WEO 2007, we use PPPs constant over time. As the IEA-WEO 2007 only covers the time period until 2030, the projections for the period 2030-2050 are based on own estimates.

Prospects for GDP growth have increased considerably compared to the previous study, while underlying growth trends prevail. GDP growth in all regions is expected to slow gradually over the next decades. World GDP is assumed to grow on average by 3.6% per year over the period 2005-2030 compared to 3.3% from 1971 to 2002, and also on average by 3.6 % per year over the entire modelling period. China and India are expected to grow faster than other regions, followed by the Rest of developing Asia, Africa and the Transition economies. The Chinese economy will slow as it becomes more mature, but will nonetheless become the largest in the world in PPP terms early in the 2020s. GDP in OECD Europe and OECD Pacific is assumed to grow by around 2% per year over the projection period, while the economic growth in OECD North America is expected to be slightly higher. The OECD share in global PPP adjusted GDP will decrease from 55% in 2005 to 29% in 2050.

the global energy [r]evolution scenario

Today, renewable energy sources account for 13% of the world's primary energy demand. Biomass, which is mainly used for heating, is the largest renewable source. The share of renewable energy in electricity generation is 18%, whilst the contribution of renewables to heat supply is around 26%. About 80% of primary energy supply still comes from fossil fuels, and the remaining 7% from nuclear power.

The Energy [R]evolution Scenario describes a development pathway which transforms the present situation into a sustainable energy supply.

- Exploitation of the large energy efficiency potential will reduce primary energy demand from the current 435,000 PJ/a (Peta Joules per year) to 422,000 PJ/a by 2050. Under the reference scenario there would be an increase to 810,000 PJ/a.This dramatic reduction is a crucial prerequisite for achieving a significant share of renewable energy sources, compensating for the phasing out of nuclear energy and reducing the consumption of fossil fuels.
- The increased use of combined heat and power generation (CHP) also improves the supply system's energy conversion efficiency, increasingly using natural gas and biomass. In the long term, decreasing demand for heat and the large potential for producing heat directly from renewable energy sources limits the further expansion of CHP.
- The electricity sector will be the pioneer of renewable energy utilisation. By 2050, around 70% of electricity will be produced from renewable energy sources, including large hydro. An installed capacity of 7,100 GW will produce 21,400 Terawatt hours per year (TWh/a) of electricity in 2050.
- In the heat supply sector, the contribution of renewables will increase to 65% by 2050. Fossil fuels will be increasingly replaced by more efficient modern technologies, in particular biomass, solar collectors and geothermal.
- Before biofuels can play a substantial role in the transport sector, the existing large efficiency potentials have to be exploited. 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.
- By 2050, half of primary energy demand will be covered by renewable energy sources.

To achieve an economically attractive growth of renewable energy sources, a balanced and timely mobilisation of all renewable technologies is of great importance. This depends on technical potentials, actual costs, cost reduction potentials and technological maturity.

development of CO_2 emissions

Whilst worldwide CO_2 emissions will almost double under the reference scenario by 2050 - far removed from a sustainable development path – under the Energy [R]evolution Scenario emissions will decrease from 23,000 million tonnes in 2003 to 11,500 million tonnes in 2050. Annual per capita emissions will drop from 4.0 t to 1.3 t. In the long run, efficiency gains and the increased use of biofuels will even reduce CO_2 emissions in the transport sector. With a share of 36% of total CO_2 emissions in 2050, the power sector will be overtaken by the transport sector as the largest source of emissions.

image SOLAR PANELS ON REFRIGERATION PLANT (FOR KEEPING FISH FRESH). LIKIEP ATOLL, MARSHALL ISLANDS.

costs

Due to the growing demand for power, we are facing a significant increase in society's expenditure on electricity supply. Under the reference scenario, the undiminished growth in demand, the increase in fossil fuel prices and the costs of CO_2 emissions all result in electricity supply costs rising from today's $1,130 billion per year to more than $4,300 bn per year in 2050.

The Energy [R]evolution Scenario not only complies with IPCC prescribed global CO_2 reduction targets but also helps to stabilise energy costs and thus relieve the economic pressure on society. Increasing energy efficiency and shifting energy supply to renewable energy resources leads to long term costs for electricity supply that are one third lower than in the reference scenario. It becomes obvious that following stringent environmental targets in the energy sector also pays off in economic terms.

to make the energy [r]evolution real and to avoid dangerous climate change, the following assumptions need to be implemented:

- The phasing out of all subsidies for fossil fuels and nuclear energy and the internalisation of external costs
- The setting out of legally binding targets for renewable energy
- The provision of defined and stable returns for investors
- Guaranteed priority access to the grid for renewable generators
- Strict efficiency standards for all energy consuming appliances, buildings and vehicles

figure 6: development of global primary energy consumption under the energy [r]evolution scenario

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

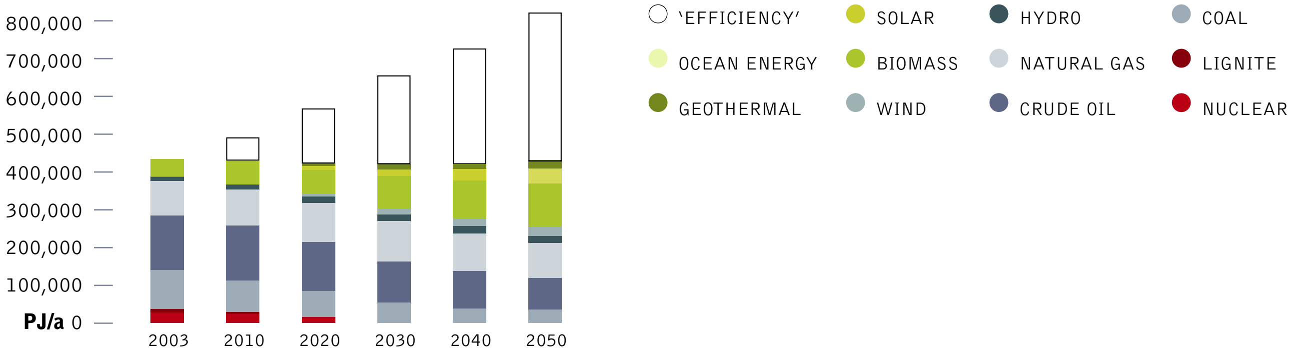
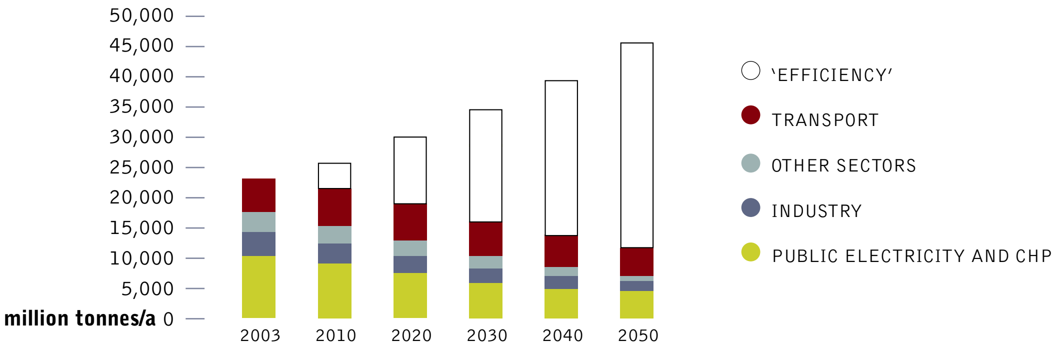


figure 7: development of global co_2 emissions by sector under the energy [r]evolution scenario

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



the australia energy [r]evolution scenario

"BY 2030, COAL-FIRED ELECTRICITY IS PHASED OUT ENTIRELY"

6

image WIND GENERATORS OF A WIND FARM LINE THE HILLTOPS IN THE DISTANCE, AUSTRALIA.

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

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

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

projection of population development

According to projections by the Australian Bureau of Statistics, Australia´s population will increase from 21 million to approx 28 million in 2050. This continuing growth will put additional pressure on energy resources and the environment.

projection of energy intensity

An increase in economic activity does not necessarily result in an equivalent increase in energy demand. There is still a large potential for exploiting energy efficiency measures. Even under the Reference Scenario, we assume that energy intensity will be reduced by about 1.0% per year, leading to a reduction in final energy demand per unit of GDP of about 40% between current levels and 2050. Under the Energy [R]evolution Scenario, it is assumed that active policy and technical support for efficiency measures will lead to a further significant reduction in energy intensity of almost 75%.

figure 8: australia: population development projection

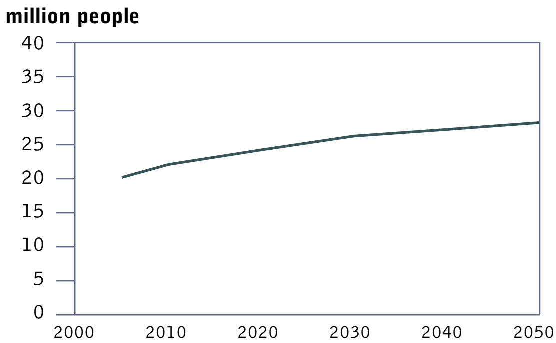


image SOLAR PANES IN A FIELD NEAR SINGLETON, NSW, AUSTRALIA.

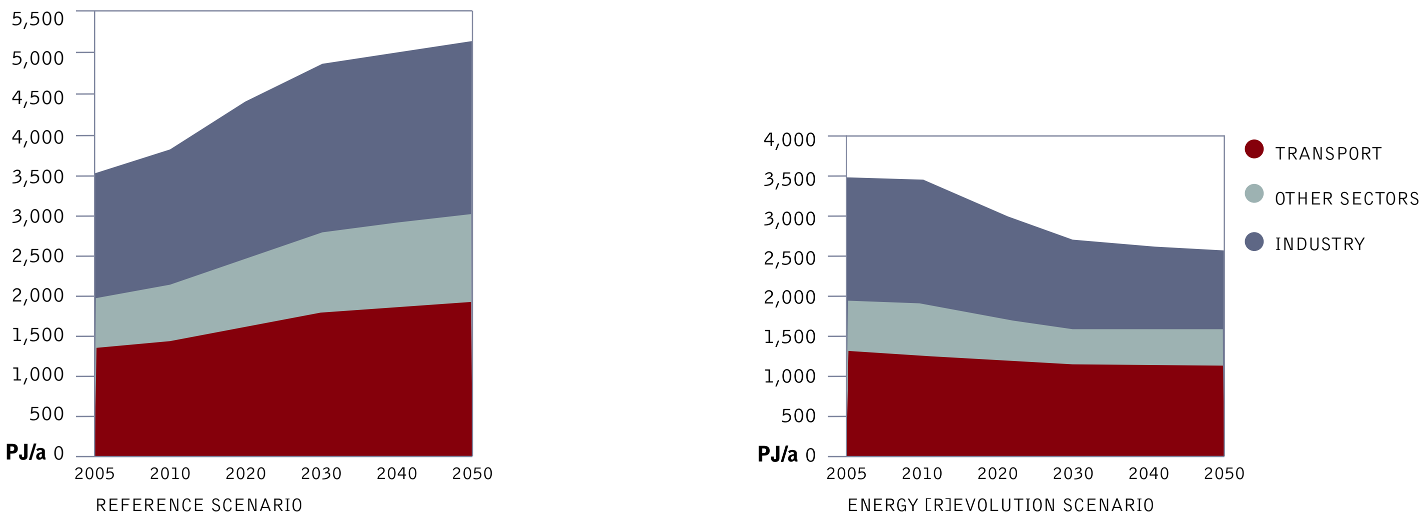
development of energy demand by sector

Combining the projections on population development, GDP growth and energy intensity results in future development pathways for the world's energy demand. These are shown in Figure 9 for both the Reference and the Energy [R]evolution Scenarios. Under the Reference Scenario, total energy demand increases from the current 4,761 PJ/a to 6,127 PJ/a in 2020, an increase of 29%. In the Energy [R]evolution Scenario, a decrease to 3982 PJ/a, or 16% below current consumption is achieved by 2020.

An accelerated increase in energy efficiency, which is a crucial prerequisite for achieving a sufficiently large share of renewable sources in energy supply, will be beneficial from an environmental and economic point of view. Taking into account the full life cycle, in most cases the implementation of energy efficiency measures saves money compared to increasing energy supply. A dedicated energy efficiency strategy therefore helps to compensate in part for the additional costs required during the market introduction phase of renewable energy sources.

figure 9: australia: projection of final energy demand by sector in the reference and energy [r]evolution scenarios

(EXCLUDING NON-ENERGY USE, OWN USE AND LOSSES)

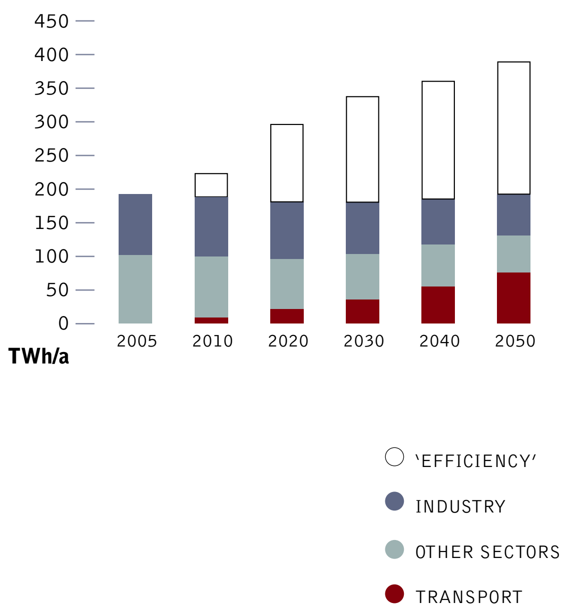


electricity demand by sector

Under the Reference Scenario, electricity demand is expected to increase substantially, with households and services the main source of growing consumption (see figure 10). With the exploitation of efficiency measures, however, final energy consumption can be reduced to 40% below the reference scenario by 2020, a saving of 105 TWh/a. This reduction in energy demand can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors. Employment of solar architecture in both residential and commercial buildings will help to curb the growing demand for active air-conditioning.

figure 10: australia: development of electricity demand by sectors in the energy [r]evolution scenario

('EFFICIENCY' = REDUCTION COMPARED TO THE REFERENCE SCENARIO; OTHER SECTORS = SERVICES, HOUSEHOLDS)



electricity generation

The development of the electricity supply sector is characterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. This will allow for the reduction of coal and a reduction in fossil fuel-fired condensing power plants to the minimum required for grid stabilisation.

By 2020, 40% of the electricity produced in Australia will come from renewable energy sources, rising to 70% by 2050. The following strategy paves the way for a future renewable energy supply:

- The reduction of coal power plants and increasing electricity demand will be compensated for initially by bringing into operation new highly efficient gas-fired combined-cycle power plants, plus an increasing capacity of wind and concentrated solar power. In the long term, wind, geothermal, concentrated solar power and solar photovoltaic will be the most important sources of electricity generation.
- PV, biomass, ocean energy and hydro energy will make substantial contributions to electricity production. In particular, as non-fluctuating renewable energy sources, geothermal, concentrating solar thermal and biomass will be important elements in the overall generation mix.
- Because of nature conservation concerns and anticipated climate change impacts, the use of hydro power will diminish from the current 7,000 MW to 6,300 MW in 2020 and 3,900 MW in 2050.
- Again due to nature conservation concerns, the use of biomass will be largely limited to agricultural waste and grow up to 2,000 MW in 2050, although the technical potential is significantly higher.
- The installed capacity of renewable energy technologies will increase from the current 8.4 GW to 23 GW in 2020.

To achieve economically attractive growth in renewable energy, a balanced and timely mobilisation of all technologies is of great importance. This mobilisation depends on technical potentials, actual costs, cost reduction potentials and technological maturity. Figure 13 shows the complementary evolution of the different renewable technologies over time. Up to 2010, hydro-power will remain the main contributors. However, the most technically developed technologies – wind and solar PV – increase markedly. By 2020, growth in solar PV and wind soars, assuming progressive policies are implemented to develop the manufacturing capacity of components and training a workforce to deliver these technologies. Technologies such as ocean energy, solar concentrating thermal and geothermal are also providing large-scale electricity by 2020.

By 2050, more sustained growth in solar concentrating thermal and geothermal, combined with smaller but still significant increases in solar PV and wind provide a suite of renewable energy technologies that provide over 70% of Australia's electricity.

A combination of renewable energy being deployed at large-scale, aggressive energy efficiency measures in the short-term and the use of gas as a transitional fuel results in overall fossil fuel use to diminish rapidly. By 2010, over 5.3 GW of coal-fired power can be removed from the grid. By 2020, both black and brown coal capacity are reduced 75% from current levels. By 2030, coal-fired electricity is phased out entirely and from 2030 to 2050, the installed capacity of gas diminishes from 13 GW to 10 GW, as renewable energy continues to take the place of fossil fuel-based electricity.

figure 11: australia: development of electricity generation under the reference scenario

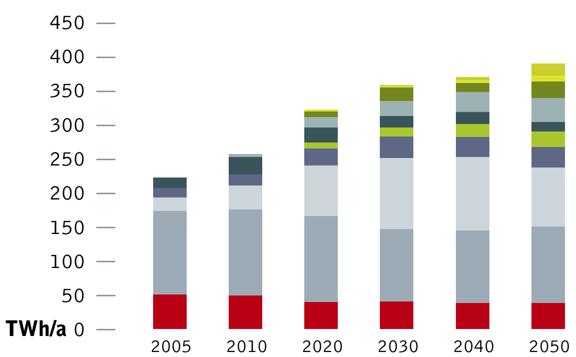


figure 12: australia: development of electricity generation under the energy [r]evolution scenario

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

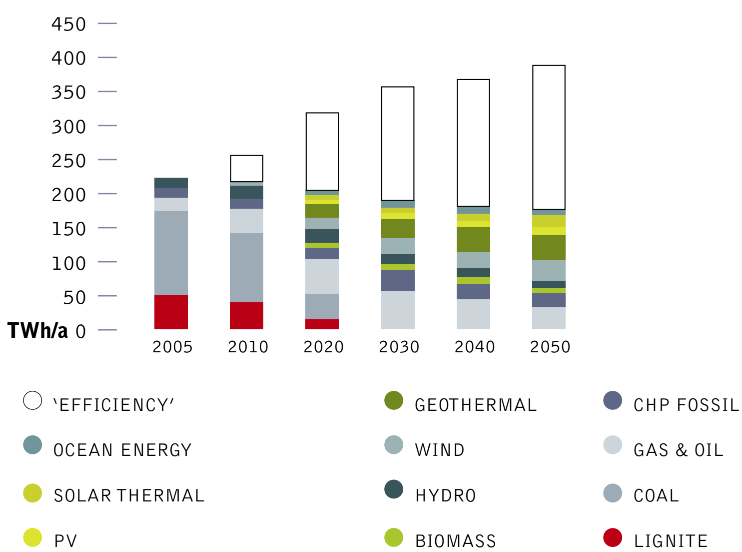


image BLUE MOUNTAINS WIND FARM, NSW, AUSTRALIA.

figure 13: australia: growth of renewable electricity supply under the energy [r]evolution scenario, by source

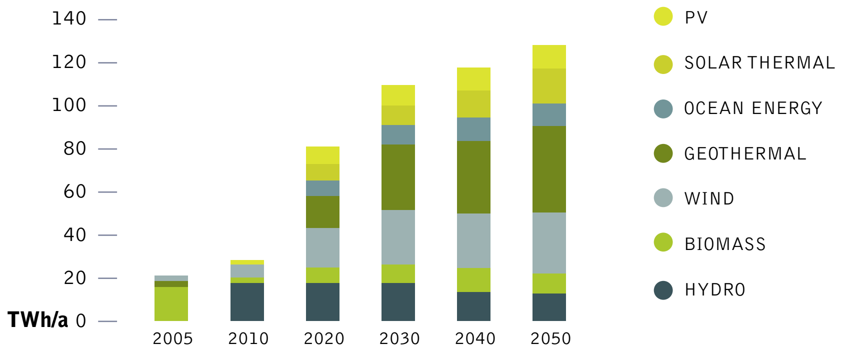


table 7: australia: projection of renewable electricity generation capacity under the energy [r]evolution scenario

IN MW

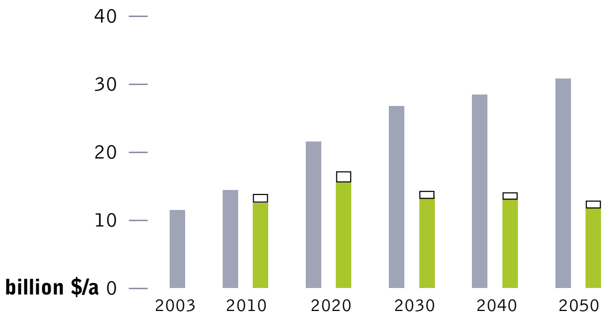
	2005	2010	2020	2030	2040	2050
Hydro	7,000	6,863	6,326	5,392	4,466	3,882
Wind	800	1,634	5,422	6,602	6,805	7,487
PV	85	572	4,000	4,621	4,838	5,096
Biomass	580	687	1,758	2,268	2,179	2,056
Geothermal	0	1	1,804	3,275	3,654	4,356
Solar thermal	0	0	2,000	2,201	3,403	4,160
Ocean energy	0	0	2,000	2,311	2,345	2,293
Total	**8,465**	**9,757**	**23,310**	**26,669**	**27,689**	**29,330**

future costs of electricity generation

The introduction of renewable energy technologies under the Energy [R]evolution Scenario decreases the costs of electricity generation of new power plants compared to the Reference Scenario from 2010 onwards. Taking into account the costs of CO_2 emissions from 2020 onwards, the difference will be about about AUD 2 cents/kWh in 2050 in favour of the Energy [R]evolution scenario. Note that any increase in fossil fuel prices beyond the price projection given in Table 4 is a further direct burden on fossil electricity generation, and thus increases the cost gap between the two scenarios.

Under the Reference Scenario, Australia faces a significant increase in expenditure on electricity. The continuing growth in demand, increases in fossil fuel prices and the costs of CO_2 emissions will result in electricity supply costs nearly doubling from AUD $11.7 billion per year today to AUD $30.9 billion per year in 2020. The Energy [R]evolution Scenario, on the other hand, not only complies with global CO_2 reduction needs but also stabilises energy costs, thus relieving economic pressure on consumers. Increasing energy efficiency and shifting energy supply to renewable energy resources in the long term leads to falls in electricity prices. The Energy [R]evolution Scenario therefore makes both environmental and economic sense.

figure 14: australia: development of total electricity supply costs

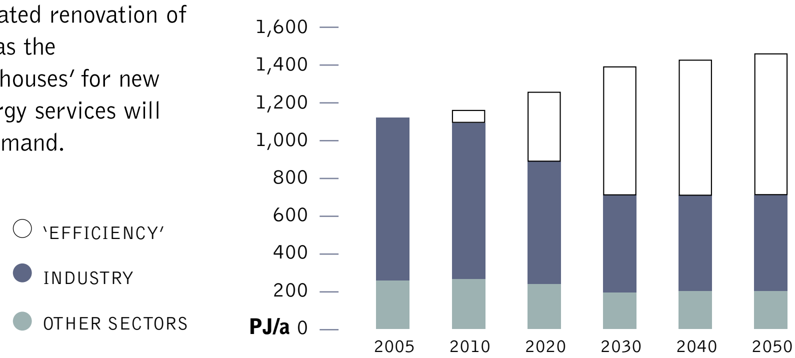


heat demand

Efficiency gains in the heat supply sector are even larger. Under the Energy [R]evolution Scenario, final demand for heat supply can even be reduced (see Figure15). Compared to the Reference Scenario, consumption equivalent to 328 PJ/a is avoided through efficiency gains by 2020. As a result of energy-related renovation of the existing stock of residential buildings, as well as the introduction of low energy standards and 'passive houses' for new buildings, enjoyment of the same comfort and energy services will be accompanied by a much lower future energy demand.

figure 15: australia: development of heat supply demand in the energy [r]evolution scenario

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



heat and cooling supply

Development of renewables in the heating and cooling supply sector raises different issues. Today in Australia, renewables provide over 17% of primary energy demand for heat supply, the main contribution being the traditional use of biomass for heating. The lack of availability of more efficient but cheap appliances is a severe structural barrier to efficiency gains. Large-scale utilisation of geothermal and solar thermal energy for heat supply is restricted to the industrial sector.

Experience shows that it is easier to implement effective support instruments in the grid-connected electricity sector than in the heat market, with its multitude of different actors. Dedicated support instruments are required to ensure a dynamic development of renewables in the heat market.

- Energy efficiency measures can reduce the current demand for heat supply by about 30%, while maintaining living standards.
- In the industrial sector, solar collectors and biomass/biogas will increasingly replace conventional fossil-fuel heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications will lead to a further reduction of CO_2 emissions.

figure 16: australia: development of heat supply under the reference scenario

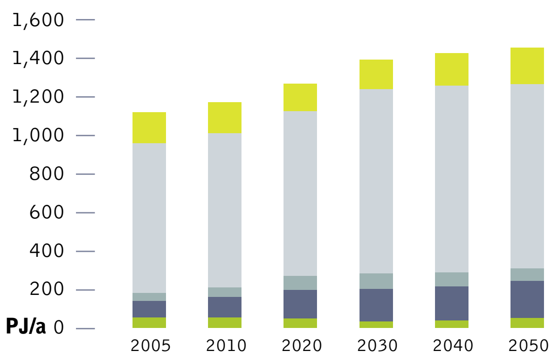


figure 17: australia: development of heat supply under the energy [r]evolution scenario

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

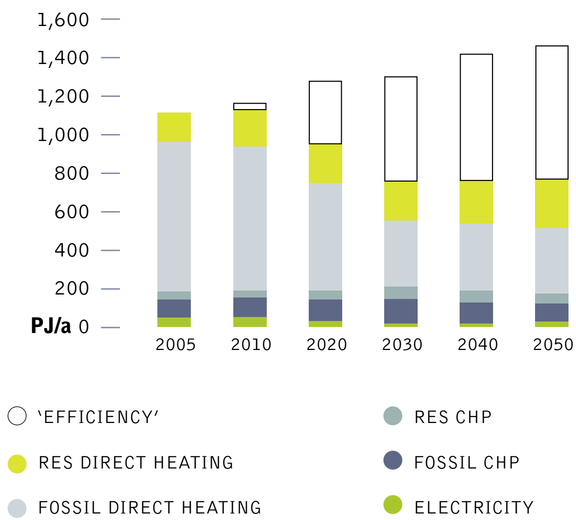


image WEST AUSTRALIAN WIND FARM.

primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption in Australia under the Energy [R]evolution Scenario is shown in Figure 18. Compared to the Reference Scenario, primary energy demand will be reduced by 55% in 2050. Over 27% of the remaining demand is covered by renewable energy sources. Note that because of the 'efficiency method' used for the calculation of primary energy consumption, which postulates that the amount of electricity generation from hydro, wind, solar and geothermal energy equals the primary energy consumption, the share of renewables seems to be lower than their actual importance as energy carriers.

figure 18: australia: development of primary energy consumption under the reference scenario

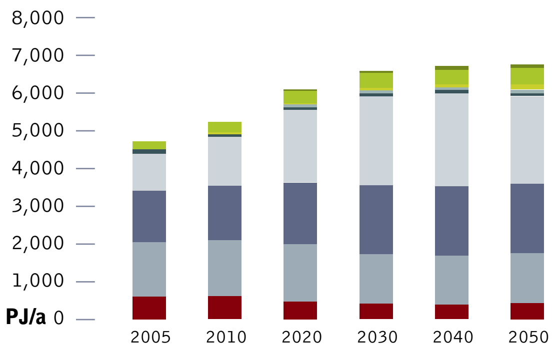
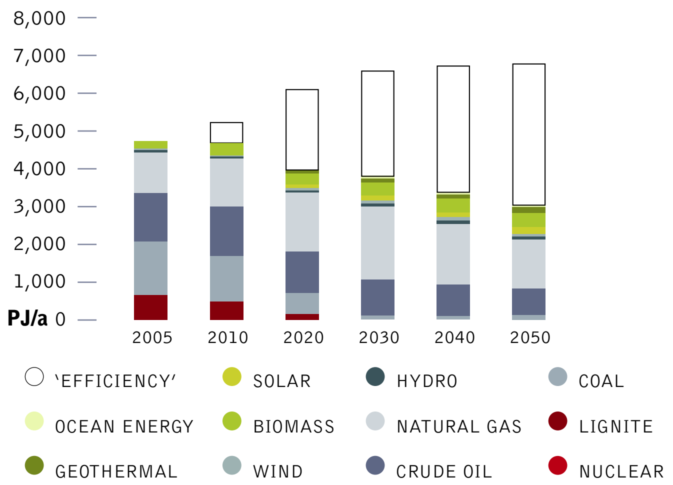


figure 19: australia: development of primary energy consumption under the energy [r]evolution scenario

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

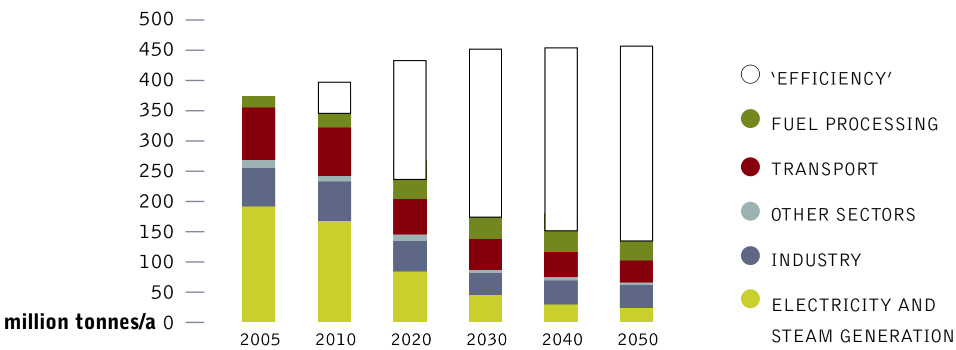


development of CO_2 emissions

development of energy related CO_2 emissions While energy related CO_2 emissions in Australia will increase under the Reference Scenario by 20% by 2020 - far removed from a sustainable development pathway - under the Energy [R]evolution Scenario they drop significantly, decreasing from 370 million tonnes in 2005 to 232 Mt in 2020 and 135 Mt by 2050. Annual per capita CO_2 emissions will drop from 18.5 tonnes to 4.8 tonnes/capita. Whilst the stationary energy sector today is the largest source of energy related CO_2 emissions in Australia, it will contribute about 16% of the total in 2050.

figure 20: australia: development of CO_2 emissions by sector under the energy [r]evolution scenario

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



effect of the energy [r]evolution on employment

Whilst the Energy [R]evolution scenario is an achievable and necessary blueprint for Australia's future energy supply, it is still a major transformation in the way that electricity is generated and used. As policies are instituted that drive down emissions, there will be large-scale structural changes that make debates about economic and social stability all the more necessary.

The Energy [R]evolution is an exercise in job creation, as well as reducing CO_2 emissions. As a result of transforming the stationary electricity sector and implementing energy efficiency measures, overall employment would increase by between 33,700 and 57,500 by 2020 in the Energy [R]evolution Scenario, compared to the Reference Scenario. Employment in electricity supply overall would increase by approximately 10,000 jobs, with 24,800 jobs created in renewable energy more than making up for the decrease of 14,400 jobs in coal-fired power to 2020. Between 23,300 and 47,100 additional jobs would be created in energy efficiency. These estimates are indicative only, particularly in energy efficiency.

table 8: australia: direct employment effects of the energy [r]evolution by 2020

NOTE: ASSUMING 20% OF PV AND 36% OF WIND MANUFACTURING OCCURS ONSHORE

	JOB LOSSES IN FOSSIL FUELS	RENEWABLE ENERGY JOBS	ENERGY EFFICIENCY JOBS	TOTAL
Employment effects	-14,400	24,800	23,300 - 47,100	**33,700 - 57,500**

The range of employment potential in energy efficiency derives from the two different factors used for job creation. Annual capital investment is used to determine employment levels in both cases, assuming that the investment occurs over the next 11 years. The factors range from 3.3 jobs per AUD$ million investment[25] to 6.7 jobs per AUD$ million[26]. An Australian industry survey[27] gave a factor very similar to that found the European study. The investment totals needed to achieve the savings called for in the Energy [R]evolution were derived from work for the National Framework for Energy Efficiency[28].

In electricity supply, jobs would be created in renewable technologies and cogeneration, replacing those lost in coal generation and coal mining. These calculations have assumed that one third of manufacturing for wind power, and one fifth of the manufacturing for PV occurs on-shore. If this could be increased to one half and four fifths respectively, net job creation would rise to approximately 11,700.

Employment creation per unit of energy supply technologies has been taken from global studies, adjusted for the lower proportion of manufacturing in PV and wind likely to occur in Australia.

table 9: australia: employment effects in energy supply in 2020 under the energy [r]evolution

	CAPACITY CHANGE 2005 – 2020 MW	CONSTRUCTION, MANUFACTURING & INSTALLATION	OPERATION AND MAINTENANCE	FUEL SUPPLY	TOTAL JOBS	TOTAL WITH ON-SHORE MANUFACTURING INCREASED TO 80% OF PV AND 50% OF WIND
PV	4,000	3,150	7,000	0	10,100	11,300
Wind	4,600	1,000	410	0	1,400	1,600
Bioenergy	1,200	250	820	590	1,700	1,700
Geothermal	1,800	290	3,060	0	3,300	3,300
Solar thermal	2,000	660	1,400	0	2,100	2,100
Ocean	2,000	150	1,600	0	1,800	1,800
Gas CCGT	4,300	810	380	1,980	3,200	3,200
Gas OCGT	1,400	20	10	60	100	100
Gas Cogeneration	1,400	280	180	700	1,200	1,200
Black coal	-16,500	-2,990	-2,530	-5,100	-10,600	-10,600
Brown coal	-5,700	-1,060	-900	-1,810	-3,800	-3,800
Net change		2,570	11,440	-3,580	10,400	11,700

notes 1) COLUMNS MAY NOT ADD UP TO THE TOTAL, BECAUSE OF ROUNDING TO THE NEAREST 100. 2) FIGURES IN RED SHOW JOB LOSSES. 3) THE CALCULATIONS ASSUME THAT 36% OF MANUFACTURING ASSOCIATED WITH WIND POWER AND 20% OF MANUFACTURING ASSOCIATED WITH PV OCCURS ONSHORE. ALL MANUFACTURING ASSOCIATED WITH OTHER TECHNOLOGIES IS ASSUMED TO OCCUR ONSHORE. 4) THE EMPLOYMENT FACTOR FOR GEOTHERMAL HAS BEEN USED FOR OCEAN POWER, AS THE TECHNOLOGY IS NOT SUFFICIENTLY MATURE FOR THERE TO BE DATA ON EMPLOYMENT UNDER COMMERCIAL SCALE DEPLOYMENT. CURRENT EMPLOYMENT IN OCEAN ENERGY EXCEEDS THIS FACTOR BY AT LEAST 8 TIMES.

image OCEAN WAVES CRASH OVER ROCKS ON WESTERN AUSTRALIA'S SOUTHERN COAST.

The employment factors which have been used for calculation of jobs are shown in Table 10. The last column shows the numbers of jobs normalised per GWh for each technology. These factors are only for direct employment impacts, and do not include indirect jobs created in other industries.

table 10: australia: energy supply employment factors

ENERGY TECHNOLOGY	SOURCE FOR DERIVATION OF EMPLOYMENT FACTOR	C M & I PERSON YEARS / MWP	O & M JOBS PER MWP	FUEL PERSON YEARS/ GWH	TOTAL NORMALISED TO LIFETIME OF FACILITY PERSON YEARS PER GWH
PV[29]	REN21 (2005)	28.9	1.75	0	1.66
Wind[30]	EWEA 2003	9.4	0.09	0	0.15
Bioenergy[29]	REN21 (2005)	5.3	0.26	0.18	0.27
Geothermal[29]	REN21 (2005)	4.0	1.7	0	0.25
Solar thermal[29]	REN21 (2005)	8.3	0.7	0	0.34
Gas[31]	Kamen et al (2004)	8.5	0.10	0.07	0.11
Cogeneration[32]	ACIL (2000)	5.8	0.13	0.07	0.12
Coal generation[31]	Kamen et al (2004) (adjusted)	8.5	0.18	0.05	0.11

notes 1) THE EMPLOYMENT FACTOR FOR FUEL SUPPLY FOR COAL GENERATION HAS BEEN ADJUSTED FROM THE ORIGINAL FIGURE OF 0.06 PER GWH USING DATA FOR COAL MINING EMPLOYMENT FROM THE 2006 CENSUS. 2) PV, BIOENERGY, GEOTHERMAL AND SOLAR THERMAL DERIVED FROM REN21 (2005) RENEWABLES 2005 GLOBAL STATUS REPORT . WIND IS DERIVED FROM EWEA 2003. COGENERATION FROM ACIL (2000). COAL AND GAS EMPLOYMENT FACATORS ARE FROM KAMEN ET AL 2004. 3) REN21 (2005) GIVES A COMBINED FACTOR OF O&M AND FUEL SUPPLY FOR BIOENERGY. THIS HAS BEEN ALLOCATED 78% TO FUEL PROCESSING, AFTER KAMEN ET AL, 2004.

derivation of jobs in energy efficiency

The Energy [R]evolution scenario includes total GWh savings in electricity consumption of 116 TWh, compared to the Reference scenario. These have been allocated to each end use sector according to the proportion of electricity consumption projected by ABARE.

The necessary investment per GWh savings have been calculated from:

- Residential savings from NFFE (2003), the high energy efficiency potential.
- Commercial capital investment is the weighted average of the commercial sectors presented in EMET (2004).
- Industrial investment is from Energetix (2004), with the costs for savings projected from 1-4 year payback measures to 9 year payback measures.

table 11: australia: direct jobs in energy efficiency under the energy [r]evolution

	GWH SAVINGS COMPARED TO BAU	CAPITAL INVESTMENT $ PER GWH	TOTAL INVESTMENT $ MILLION	ANNUAL SPENDING $ MILLION	DIRECT JOBS LOW ESTIMATE	DIRECT JOBS HIGH ESTIMATE
Residential	35,600	$0.62	$21,900	$2,000	6,600	13,400
Commercial	32,500	$0.39	$12,700	1,150	3,800	7,700
Industrial	47,900	$0.89	$42,700	3,880	12,900	26,000
Total	**116,000**		**$77,300**	**$7,000**	**23,300**	**47,100**

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Annual capital investment is used to determine employment levels, assuming that the investment occurs over the next 11 years. Details of the studies considered are given in the table below. The lower factor used comes from Bedzek (2007), while the higher factor comes from Wade et al, (2000). The Australian industry survey in 2002 (MEA 2003) gave a factor very similar to that found in Wade et al.

table 12: australia: direct employment factors in the energy efficiency industry

STUDY	COMMENT	ANNUAL INVESTMENT/ SALES AU$	NUMBER OF EMPLOYEES	JOBS PER $MILLION INVESTMENT
Bezdek (2007)	Gives total employment and sales in the energy efficiency industry in the USA for 2006.	$1,024,086 million	3,500,000	3.3
Wade J et al (2000)	Reviews nine programs across Europe, including all sectors. The weighted average job creation per $million is shown here.	$255 million	1,712 (calculated)	6.7
MEA (2003)	Survey of Australian employment 2002, gives total jobs and sales per employee.	$570 million	5,800	6.6

note EXCHANGE RATES OF 1.6 AU$ PER EURO AND AU$1.11 PER US$ HAVE BEEN USED TO CONVERT FROM ORIGINAL CURRENCIES.

sources ABARE (2007) AUSTRALIAN ENERGY NATIONAL AND STATE PROJECTIONS TO 2029-30.
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image THE STARFISH HILL WIND FARM PROJECT NEAR CAPE JERVIS ON FLEURIEU PENINSULA, SOUTH AUSTRALIA.

overview - scenario assumptions

reference case projections of australia's energy sector greenhouse gas emissions The Reference case is derived from the most recent projections prepared by the Australian Bureau of Agricultural and Resource Economics (ABARE), the Australian Government agency responsible for compiling national energy statistics. These were published in December 2007 (Syed et al., 2007). The ABARE projections extend to 2030.

These projections were prepared prior to the election of November 2007, at which a new Government was elected in Australia. Consequently, the projections do not include the effect of a number of policy changes introduced by the new Government. The most important of these, so far as projected demand for energy is concerned, are:

- the introduction of a national emissions trading scheme, to cover all consumption of energy, starting in July 2010,
- a mandatory renewable energy target for the electricity industry of 20% by 2020,
- the phase out of medium and large size residential electric water heaters.

These policy changes have been allowed for by modifying the ABARE projections as follows.

- The annual rate of energy efficiency increase by 0.2% p.a. above the levels assumed by ABARE, for every year from 2010 onward, to represent the likely demand response to higher fossil fuel energy prices resulting from introduction of the emissions trading scheme. A further allowance for effect on the change in the relative costs of coal and natural gas was made by increasing the rate of uptake of gas fired CHP in both Industry and Other Sectors.
- The effect of the increased Mandatory Renewable Energy Target and its interaction with the emissions trading scheme was allowed for by replacing ABARE's generation fuel mix projections with those estimated in a complex modeling study by McLennan Magasanik Associates (2007), using the study's 20% target and medium emissions price scenario.
- The effect of the electric water heater phase out was allowed for by greatly reducing the share of electricity used for water heating in Other Sectors, and increasing the share of gas and solar energy, over the period up to 2020. The residual electricity consumption for water heating by that date, which is not trivial, represents the combination of electricity used in small electric water heaters (in small apartments and the like) and electric boost energy in solar water heaters.

One further change was made to the ABARE projections, affecting estimates for energy use in the Mining industry. Excluding the very considerable quantity of energy used for processing natural gas and producing liquefied natural gas, which is often included under the definition of Mining, the Mining industry currently accounts for nearly 7% of Australia's total final energy consumption and over 4% of total primary energy consumption. Most energy used by the sector is supplied in the form of diesel fuel. The physical output of the industry, in the form of the tonnage of metal ores and coal mined, has been growing rapidly in recent years, in response to the worldwide boom in demand for mineral commodities. The very high prices currently being realised for most mineral commodities mean that it is profitable to mine lower grade or less accessible ore bodies, with a consequent increase in the volume of overburden removed and of ore extracted, transported and subjected to primary processing at the mine site. As a consequence, energy consumption by the industry has been growing at a rate of around 5% p.a. ABARE projects that energy consumption by the industry will continue to grow at a similar rate up to 2020, and only a little slower for a further ten years to 2030. We do not consider that such high rates of growth in the physical output of the industry are sustainable in the long term, in terms of either commodity prices or volumes extracted. Consequently, we have adopted lower rates of growth in demand for energy by the mining industry, of 3% p.a. up to 2020 and 2% p.a. thereafter.

For the period beyond 2030 there are no ABARE figures. The following assumptions were used to extrapolate from the 2030 Reference Case values.

- The underlying demand for energy services was assumed to grow at a rate at 0.5% p.a. for Industry and Transport and 1.0% p.a. for Other Sectors. The different growth rates imply a structural shift in economic activity away from manufacturing and mining, and towards services and transport, plus a saturating demand for passenger transport services.
- The annual rate of energy efficiency increase was assumed to be 0.4% p.a. above the base level implicit in the calculation of the underlying rate of energy demand. This reflects an expectation of higher carbon prices in the emissions trading scheme during the 2030 to 2050 period.
- For electricity generation, existing coal-fired power stations are retired as they reach the end of their economic lives

assumptions for the energy [r]evolution scenario

general increase in energy efficiency For Transport and most of Industry, it is assumed that energy efficiency will increase by an additional 1% p.a. from 2008. For high temperature heat processes in Industry, Gas Processing and Petroleum Refining, the additional increase in energy efficiency is 0.5% p.a. These efficiency increases are additional to those in the Reference Case.

accelerated energy efficiency improvement in residential and commercial buildings (Other Sectors) For Other Sectors it was assumed that energy efficiency in all categories of energy use, including both heat energy and electricity, would improve by 20% relative to current levels by 2020. Thereafter, energy efficiency would continue to increase by 1% p.a. above the rate of efficiency improvement in the Base Case.

eliminate coal-fired electricity generation coal-fired power stations are reduced in capacity and retired as reductions in demand and installation of sufficient renewable energy and gas capacity become able to replace their contribution to the electricity grid. The sequence for removal of coal-fired power stations is determined by their age, efficiency and levels of CO_2 emissions.

elimination of coal use for heat except in metallurgical industries Use of coal for high temperature thermal (kiln) processes was reduced to the level represented by its consumption, in the form of coke, by the integrated steel industry and its use as boiler fuel was entirely eliminated by 2030, with the exception of a small quantity representing steam raising with coke oven/and blast furnace gas in the integrated steel industry. The replacement fuel for kiln and boiler processes is assumed to be natural gas.

more gas based CHP A large increase in natural gas fuelled CHP plants is assumed in both Industry and Other Sectors (commercial buildings). There is a corresponding decrease in direct use of natural gas and other (minor) fuels used as a boiler fuel. Some of the additional process heat from CHP plants also goes to water heating in Other Sectors. More CHP means that a greater share of electricity is supplied from CHP plants and a lesser share from stand-alone power generators.

more use of solar heat Some use of solar heat is introduced into space heating in Other Sectors and Steam raising in Industry. The Reference Case contains no use of solar heat in either of these sectors. The increased use of solar heat is assumed to mainly displace natural gas, but also other fuels, including biomass.

introduce electric vehicles A significant share of electric vehicles is introduced into road passenger transport, with a corresponding reduction in petrol/diesel share. Electric vehicles are assumed to have an efficiency of conversion of the fuel (electricity) to motive power on the road three times higher than that of internal combustion engine vehicles.

increased road passenger vehicle (car) efficiency Progressively increase the efficiency of all types of cars at a faster rate than the general efficiency increase, representing a decisive shift towards smaller, more fuel efficient cars.

reduced absolute level of demand for air travel Progressively reduce the absolute level of demand for aviation services from that estimated by ABARE, without substituting an alternative transport mode. The reduction means that demand for aviation services grows at an average rate of 2.8% p.a. up to 2030, rather than 3.4% p.a. as in the Reference Case, and at 0.4% p.a. rather than 0.6% p.a. from 2030 to 2050.

increase fuel switching from air and road transport to rail and increase the share of electric rail traction A relatively modest proportion of demand for air and road transport is switched to rail. It is assumed that rail transport is four times as fuel efficient as air transport and twice as fuel efficient as road transport. Most of the increase in rail transport, which is substantial, given the initially low modal share of rail, is met by electric traction, with consequent significant increase in the proportion of electric rail transport, compared with diesel.

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policy recommendations

"URGENT ACTION, DRIVEN BY GOVERNMENT LEADERSHIP, BOLD TARGETS, EFFECTIVE INCENTIVES, AND MAJOR INVESTMENT IN ENERGY EFFICIENCY AND RENEWABLE ENERGY IS NEEDED TO CHANGE THE TRAJECTORY OF AUSTRALIA'S EMISSIONS"

7

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policy recommendations to drive the energy [r]evolution

1. Legislate a greenhouse gas reduction target to cut emissions by greater than 40% below 1990 levels by 2020. This will require that Australia's emissions peak by 2010, and that annual incremental targets are set to ensure that Australia remains on track to meet interim and long-term targets.

The IPCC has identified that to keep warming between 2°C and 2.4°C developed countries' emissions must peak by 2010, and then fall 25-40% below 1990 levels by 2020. This was recognised by the Australian Government at the UNFCCC meeting in Bali in December 2007.

Australia has a high vulnerability to climate impacts. It is therefore in our interests to restrict anthropogenic warming of the atmosphere as much as possible. However, as one of the highest per capita polluting nations in the world, we have a disproportionately high responsibility for producing greenhouse gas emissions for a country our size. In spite of this, Australia managed to negotiate a target under the Kyoto Protocol that allowed us to increase our CO_2 emissions by 8% from 1990 levels. Australia now has an even stronger political and moral obligation to show leadership by setting a strong emission reduction target. This leadership will be essential in driving future international negotiations to reduce emissions globally, as Australia's commitment to addressing domestic emission levels will directly impact on our effectiveness to advocate for global action.

The need to set a strong national 2020 target is underscored by the brief window of opportunity to turn around the rising trend in emissions. Urgent action, driven by Government leadership, bold targets, effective incentives, and major investment in energy efficiency and renewable energy is needed to change the trajectory of Australia's emissions and set us on a pathway that will deliver the long term, deep emission reductions that are required.

2. Legislate a mantatory renewable energy (electricity) target of 40% electricity by 2020, supported by complementary measures that ensure all renewable energy technologies reach their potential.

Australia is blessed with abundant renewable energy resources with wind, solar and geothermal resources among the best worldwide. Unfortunately because we have failed to adequately support the renewable energy industry, it lags behind the rest of the world. However potential development opportunities are significant. A major scaling up of renewable energy technologies, combined with investment in and regulation of energy efficiency to turn around the projected growth in Australia's energy consumption, means that within a few years we could begin to start turning off the most polluting coal-fired power stations.

Specific technologies that do not benefit from the MRET could be brought online through the implementation of a feed-in tariff that rewards generators for the gross amount of energy they feed into the grid. Feed-in tariffs are most suitable for decentralised technologies such as solar PV, which also require a high up-front investment. A feed-in tariff should ensure a minimum tariff rate, specificity over gross metering and a household payback time of no more than 7 years.

Government should expand, extend and legislate the renewable energy target, and it should operate in parallel to any emissions trading scheme. The Energy [R]evolution Scenario has demonstrated how these technologies can be brought online such that renewable energy can deliver 40% of Australia's electricity needs by 2020.

3. Establish an immediate moratorium on new coal-fired power stations and extensions to existing coal-fired power stations, and phase out existing coal-fired power stations in Australia by 2030.

85% of Australia's electricity generation requirements come from coal-fired power[33]. New coal-fired power plants are being planned or proposed in a number of Australia states. A typical large coal-fired power station emits about 15 million tonnes of CO_2 each year[34]. Australia is already one of the world's largest per capita greenhouse gas emitters and adding new coal-fired electricity generation capacity in Australia will make the task of reducing CO_2 emissions to safe levels virtually impossible.

In keeping with the urgency and scale of reductions in greenhouse gas emissions required by 2020, and with the abundance of renewable energy resources in Australia, it is entirely untenable to build new coal-fired power stations or extensions to existing power stations. This imperative is even stronger as Carbon Capture and Storage (CCS) technologies are not yet commercially available, nor are expected be commercially available until at least 2030[35], if at all. By this time, a phase out of coal-fired power will have likely rendered CCS technology irrelevant in Australia.

The Greenpeace Energy [R]evolution Scenario demonstrates how 201 Mt of greenhouse emissions can be saved from a business as usual scenario in energy and transport through a combination of energy efficiency measures and expanding renewable energy capacity to take the place of coal-fired power. Reductions in greenhouse gas emissions must occur in all sectors but given the rapid growth in emissions from energy it is important to place significant effort in making major reductions in electricity generation and prioritise a phase out of coal-fired electricity when planning to reduce Australia's greenhouse gas emissions.

By developing a broad range of renewable energy technologies, including a mix of solar thermal with storage, geographically distributed wind turbines, and biofuels, both base-load and peak energy requirements can be met. Phasing out existing coal-fired power stations is necessary and inevitable if we are to meet targets to reduce greenhouse gas emissions to safe levels.

4. An Emissions Trading Scheme must reduce emissions in line with legislated interim targets and should be reviewed periodically to ensure appropriate response to scientific and technological changes.

An Emissions Trading Scheme (ETS) must meet a number of key design tests to ensure that it effectively, efficiently and equitably delivers significant emission reductions. However, an ETS will not on its own, achieve the necessary short-term reductions required, and must be complemented by a suite of policies, such as a strong renewable energy target, and energy efficiency regulation and programmes, that will drive rapid and deep emission cuts.

All technologies and participants in an emissions trading scheme should be treated equally. There should be no free allocations of carbon credits or 'grandfathering' within the system and 100% of permits should be auctioned from the outset of the scheme. Any adjustment assistance to trade exposed industries should sit outside the ETS. The ETS should cover at least 70% of Australia's emissions, omitting only agriculture, land use and forestry unless robust measurement of these sectors can be achieved in the future. Revenue from the ETS should be used to support the deployment of climate change solutions and minimize the impact of climate change on those most affected.

5. Set a target of 2% per year to reduce Australia's primary energy demand.

There are massive gains to be made in energy efficiency in commercial industrial sites and households. The Government should regulate and invest heavily in energy efficiency measures, set a national energy efficiency target of 2% per year to reduce Australia's primary energy, and commit to strong research, development and investment in energy efficiency. The Government should mandate international best practice energy efficiency standards for all new commercial and residential buildings, and major refits, and set a mandatory target for electricity retailers to reduce average residential electricity consumption by 1% per year. Water heaters should have a mandatory greenhouse standard, and a national programme to retrofitting solar hot water systems to houses, offices and workplaces should be implemented. An energy performance standard for residential lighting for new build and retrofit of 5-10 watts per square metre should be set. The Minimum Energy Performance Standards (MEPS) program should be extended and accelerated. These, and other measures, will deliver the energy efficiency reductions required to deliver the Energy [R]evolution.

references
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image PHOTOVOLTAICS FACILITY AT 'WISSENSCHAFTS UND TECHNOLOGIEZENTRUM ADLERSHOF' NEAR BERLIN, GERMANY. SHEEP BETWEEN THE 'MOVERS' KEEPING THE GRASS SHORT.

6. Redirect Government funding and strategic direction towards environmentally sustainable transport planning that reduces Australia's emissions.

Major public investment and planning is required to shift the focus of Government towards a sustainable transport system that reduces greenhouse emissions. Funding for roads should be reallocated to include all transport, with at least half going towards public transport. This should support the installation of high quality, high-speed passenger rail links between the major centres (Brisbane, Sydney, Newcastle, Canberra, Melbourne) to displace air and road travel. In order to provide the capacity to shift all long-distance freight from road and air to rail, a renewal and electrification of national and regional train networks will be required, including upgrading of rolling stock.

Subsidies that encourage the use of private vehicles should be removed, and instead incentives should be offered to increase public transport use. A combination of industry development and phased-in fuel emissions targets would support the conversion and expansion of Australia's car industry to manufacture zero-emission vehicles for public and private transport.

7. By 2010, redirect all public subsidies that encourage the use and production of fossil fuels towards implementing energy efficiency programs, deploying renewable energy and supporting the upgrading of public transport infrastructure.

Research commissioned by Greenpeace has revealed more than $9 billion of State and Federal Government subsidies annually that encourage fossil fuel use[36]. Most of these subsidies result in an increase in greenhouse gas emissions, thereby resulting in poor public policy outcomes. Also, many fossil fuel subsidies are economically perverse, artificially reducing the price of fossil fuels.

Greenpeace supports the removal of public subsidies that lead to increased greenhouse gas emissions. Public funding should be prioritised for the development and deployment of technologies that can be relied upon to deliver emission-free energy within the 2020 timeframe. As such, the funding of CCS is not a valuable way to spend taxpayers' dollars. A comprehensive review of the taxation system, and energy and transport subsidies is required to ensure that climate protection is integrated into public spending, so that we can invest in technologies and infrastructure that will reduce our greenhouse emissions.

8. Support workers and communities affected by the move away from coal towards a clean energy economy to minimising social and economic impacts and maximise opportunities in investment and employment – a Just Transition.

Greenpeace, with many other environmental organisations and labour unions, refers to the need for support to affected workers and communities in the economic restructuring required for a shift to a low-carbon economy as a 'Just Transition'.

Particular industries will suffer the most in a carbon restrained global economy, including trade-exposed energy intensive industries, coal mining and export industries as well as coal-fired power generation. A Just Transition accepts that workers in these sectors face eventual displacement in a low carbon economy and recognises the needs of current and future generations for secure and low-carbon intensity jobs and lifestyles. A Just Transition builds collaborations rather than conflict and avoids false 'jobs vs. the environment' dichotomies. Failure to plan for and create a Just Transition means that the inevitable cost of moving away from a carbon-based economy will devolve unfairly onto workers in targeted industries and their communities.

A Just Transition involves assistance for displaced workers, contractors and local communities through re-skilling, education and training programs, and income support. It may also include relocation assistance, support for displaced workers, compensation and equipment buy-outs for contractors, and cheap loans for business development. A Just Transition can be funded through the revenue raised in the Emissions Trading Scheme.

9. Develop a highly trained "green" workforce through investment in training programs and apprenticeships, and deliver direct investment to new industries and infrastructure in coal communities to create new, secure, well-paid jobs which are, wherever possible, close to existing coal communities.

The transition to a clean energy economy offers opportunities for the creation of tens of thousands of new jobs in energy efficiency and the renewable energy industry, and a potential revitalisation of the Australian manufacturing sector[37]. Support for innovation and partnerships for new industries, research and development, tax relief and infrastructure investments will be essential.

Investment in renewable energy generates more jobs per unit of energy than the fossil fuel sector. Wind energy, for example, provides 1.4 times the employment of coal. For technologies such as solar concentrating thermal and geothermal, the employment levels are closer to 3 times that of coal.

In order to ensure a skilled workforce, the Government should implement a long-term comprehensive national education strategy that supports the development and deployment of renewable energy technologies. This could specifically include "green apprenticeships", TAFE courses and further education and retraining programmes for those who require upskilling.

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appendix: reference scenario

table 13: electricity generation

TWh/a

	2005	2010	2020	2030	2040	2050
Power plants	**213**	**241**	**298**	**328**	**340**	**354**
Gas	17	32	71	105	109	85
Coal-fired	122	128	129	105	105	110
Diesel	2	2	3	2	2	2
Lignite fired	52	50	40	42	41	42
Hydro	17	18	20	17	16	16
Wind	2	7	18	26	31	36
PV	0	0	2	3	4	5
Geothermal	0	0	6	14	15	28
Solar thermal power plants	0	0	1	2	3	13
Ocean energy	0	0	0	0	0	0
Biomass	1	3	9	14	17	18
Combined heat & power production	**13**	**17**	**27**	**30**	**32**	**34**
Coal	1	2	2	1	1	1
Lignite	1	0	0	0	0	0
Fuel Oil	2	2	2	2	2	1
Gas	9	12	22	25	27	30
Biomass	1	1	2	2	2	2
Total generation	**226**	**258**	**325**	**358**	**372**	**388**
Fossil	205	228	268	281	287	271
Coal	124	129	130	106	107	111
Lignite	52	50	40	42	41	42
Gas	26	45	93	129	136	114
Oil	2	2	2	2	2	1
Diesel	2	2	3	2	2	2
Nuclear	0	0	0	0	0	0
Renewables	**21**	**30**	**57**	**77**	**85**	**117**
Hydro	17	18	20	17	16	16
Wind	2	7	18	26	31	36
PV	0	0	2	3	4	5
Biomass	2	4	11	15	16	19
Geothermal	0	0	6	14	15	28
Solar thermal	0	0	1	2	3	13
Ocean energy	0	0	0	0	0	0
Distribution losses	19	21	27	29	31	32
Final energy consumption (electricity)	**207**	**237**	**298**	**329**	**341**	**356**
Fluctuating RES (PV, Wind, Ocean)	2	7	20	29	35	41
Share of fluctuating RES	0.9%	2.8%	6.2%	8.2%	9.3%	10.5%
RES share	**9.2%**	**11.5%**	**17.6%**	**21.5%**	**22.8%**	**30.0%**

table 14: installed capacity

GW

	2005	2010	2020	2030	2040	2050
Power plants	**44**	**49**	**62**	**80**	**84**	**85**
Coal	21.3	21.3	19.6	17.5	17.7	18.4
Lignite	7.3	7.3	5.8	6.9	6.7	6.9
Gas	6	10	18	31	33	25
Oil & diesel	1.0	0.8	0.5	0.3	0.3	0.3
Nuclear	0	0	0	0	0	0
Biomass	0.2	0.7	1.7	2.6	2.7	3.4
Hydro	7.0	7.0	7.2	6.5	6.2	5.9
Wind	0.8	1.8	5.5	8.5	10.0	11.7
PV	0	0.3	1.0	1.9	2.3	2.8
Geothermal	0	0	0.7	1.9	2.0	3.8
Solar thermal power plants	0	0	0	0.6	0.9	4.2
Ocean energy	0	0	2.0	2.3	2.3	2.3
Combined heat & power production	**2.5**	**2.8**	**3.9**	**4.9**	**5.4**	**5.9**
Coal	0.2	0.2	0.2	0.2	0.2	0.2
Lignite	0.2	0.2	0	0	0	0
Gas	1.4	1.7	2.6	3.4	4.0	4.5
Oil	0.3	0.3	0.3	0.3	0.2	0.2
Biomass	0.4	0.4	0.7	0.9	0.9	0.9
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	2.5	2.8	3.9	4.9	5.4	5.9
Total generation	**46**	**51**	**66**	**85**	**89**	**91**
Fossil	38	41	47	60	62	56
Coal	22	22	20	18	18	19
Lignite	8	8	6	7	7	7
Gas	8	11	21	35	37	30
Oil & diesel	1	1	1	0	0	0
Nuclear	0	0	0	0	0	0
Renewables	**8**	**10**	**19**	**25**	**28**	**35**
Hydro	7	7	7	6	6	6
Wind	1	2	6	9	10	12
PV	0	0	1	2	2	3
Biomass	0.6	1	2	4	4	4
Geothermal	0	0	1	2	2	4
Solar thermal	0	0	0	1	1	4
Ocean energy	0	0	2	2	2	2
Fluctuating RES (PV, Wind, Ocean)	0.8	2.1	8.6	12.7	14.7	16.8
Share of fluctuating RES	1.7%	4.0%	12.9%	14.9%	16.4%	18.4%
RES share	**18.1%**	**19.8%**	**28.6%**	**29.3%**	**30.9%**	**38.4%**

table 15: primary energy demand

PJ/A

	2005	2010	2020	2030	2040	2050
Total	**4,760**	**5,244**	**6,127**	**6,610**	**6,728**	**6,813**
Fossil	**4,443**	**4,867**	**5,581**	**5,959**	**6,028**	**5,958**
Hard coal	1,422	1,485	1,507	1,248	1,252	1,285
Lignite	665	632	471	473	454	472
Natural gas	1,012	1,310	1,958	2,429	2,497	2,364
Crude oil	1,344	1,443	1,644	1,809	1,824	1,837
Nuclear	**0**	**0**	**0**	**0**	**0**	**0**
Renewables	**316**	**377**	**546**	**651**	**700**	**855**
Hydro	61	65	71	59	61	56
Wind	8	24	66	94	110	129
Solar	3	12	38	57	74	125
Biomass	246	276	350	391	403	443
Geothermal	0	0	20	51	53	102
Ocean Energy	0	0	0	0	0	0
RES share	**6.6%**	**7.2%**	**8.9%**	**9.8%**	**10.4%**	**12.5%**

image UPPER HUNTER VALLEY COAL MINES, NSW, AUSTRALIA.

reference scenario

table 16: heat supply

PJ/A

	2005	2010	2020	2030	2040	2050
Heat from CHP	**131**	**162**	**232**	**246**	**254**	**263**
Fossil fuels	94	115	161	167	179	191
Coal	22	24	24	17	17	17
Petroleum Products	21	24	26	23	20	17
Natural Gas	51	68	111	127	141	156
Biomass	36	47	71	78	75	72
Direct heating[1)]	**988**	**1,007**	**1,036**	**1,147**	**1,173**	**1,198**
Fossil fuels	777	801	844	953	956	958
Coal	218	241	284	276	274	270
Petroleum Products	144	119	98	88	80	72
Natural Gas	415	441	492	589	603	616
Biomass	154	144	121	119	127	135
Solar collectors	3	9	28	38	49	61
Geothermal	0	0	0	0	0	0
Electricity	54	53	43	37	40	44
Total heat supply[1)]	**1,118**	**1,168**	**1,268**	**1,393**	**1,427**	**1,461**
Fossil fuels	871	916	1,005	1,120	1,135	1,149
Biomass	190	190	193	198	202	207
Solar collectors	3	9	28	38	49	61
Geothermal	0	0	0	0	0	0
Electricity	54	53	43	37	40	44
RES share (including RES electricity)	**17.7%**	**17.6%**	**18.0%**	**17.5%**	**18.3%**	**19.2%**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 17: CO_2 emissions

MILL t/a

	2005	2010	2020	2030	2040	2050
Power plants	**178**	**185**	**183**	**171**	**170**	**166**
Coal	106	109	107	85	85	89
Lignite	61	58	44	44	43	44
Gas	9	16	30	41	41	32
Diesel	1.6	1.8	2.0	1.1	1.1	1.2
Combined heat & power production	**10**	**13**	**18**	**18**	**19**	**21**
Coal	2	3	3	2	2	2
Lignite	1	1	1	0	0	0
Gas	5	7	12	14	15	17
Oil	2	2	3	2	2	2
CO_2 emissions electricity & steam generation	**188**	**197**	**200**	**189**	**189**	**187**
Coal	108	111	110	87	88	91
Lignite	62	59	44	44	43	44
Gas	14	22	42	54	56	48
Oil & diesel	4	4	5	3	3	3
CO_2 emissions by sector	**370**	**396**	**433**	**453**	**457**	**458**
% of 2000 emissions	100%	107%	117%	122%	124%	124%
Industry	66	70	78	84	84	84
Other sectors	11	12	15	17	17	17
Transport	89	95	107	120	123	126
Electricity & steam generation	188	197	200	189	189	187
District heating	16	22	33	43	44	44
Population (Mill.)	20	22	24	26	27	28
CO_2 emissions per capita (t/capita)	**18.5**	**18.0**	**18.1**	**17.4**	**16.9**	**16.4**

The numbers provided in the table are the data from the model. The estimation for the 2003 CO_2 emissions is 2.7% below the Government's figure for the same year (31.17 Mill t/a). For consistency, we have corrected the figures accordingly and used these to estimate the CO_2 emission reductions.

table 18: transport fuel demand

MILL t/a

	2005	2010	2020	2030	2040	2050
Aviation	**202**	**242**	**331**	**433**	**457**	**481**
Fossil	202	242	331	433	457	481
Petroleum products	202	242	331	433	457	481
Navigation	**58**	**60**	**62**	**62**	**70**	**78**
Fossil	58	60	62	62	70	78
Coal	5	5	5	5	3	0
Petroleum products	53	55	57	58	67	78
Rail	**34**	**36**	**38**	**39**	**53**	**68**
Fossil	26	27	28	28	35	41
Petroleum products	26	27	28	28	35	41
Electricity	8	9	10	11	18	27
Road	**1,026**	**1,076**	**1,167**	**1,247**	**1,261**	**1,273**
Truck	360	377	409	437	435	433
Fossil	360	377	409	437	435	433
Petroleum products	360	377	409	437	429	420
Natural gas	0	0	0	0	7	13
Bus	**19**	**25**	**37**	**50**	**60**	**70**
Fossil	19	25	37	50	60	70
Petroleum products	18	23	34	45	52	60
Natural gas	1	2	3	5	7	11
Passenger Car and Motorcycles	**646**	**673**	**721**	**761**	**766**	**770**
Fossil	641	668	715	753	757	759
Petroleum products	641	668	715	753	756	757
Natural gas	0	0	0	0	1	2
Renewables	5	6	7	8	10	12
Biomass	5	6	7	8	10	12
Hydrogen	0	0	0	0	0	0
Electricity	0	0	0	0	0	0
Total transport fuel demand	**1,320**	**1,412**	**1,597**	**1,782**	**1,841**	**1,900**
Fossil	1,307	1,398	1,581	1,763	1,813	1,861
Coal	5	5	5	5	3	0
Petroleum products	1,301	1,392	1,573	1,754	1,796	1,836
Natural gas	1	2	3	5	15	25
Renewables	5	6	7	8	10	12
Biomass	5	6	7	8	10	12
Hydrogen	0	0	0	0	0	0
Electricity	8	9	10	11	18	27
Total RES	**5**	**6**	**7**	**8**	**10**	**12**
RES share	**0.4%**	**0.4%**	**0.4%**	**0.4%**	**0.5%**	**0.6%**

alternative scenario

table 19: electricity generation

TWh/a

	2005	2010	2020	2030	2040	2050
Power plants	**213**	**206**	**187**	**163**	**157**	**153**
Gas	17	32	52	56	44	31
Coal-fired	122	104	40	0	0	0
Diesel	2	4	0	0	0	0
Lignite fired	52	40	13	0	0	0
Hydro	17	18	19	17	14	12
Wind	2	5	19	24	25	27
PV	0	1	8	10	10	11
Geothermal	0	0	15	29	33	38
Solar thermal power plants	0	0	7	8	13	15
Ocean energy	0	0	8	10	10	10
Biomass	1	1	6	8	8	8
Combined heat & power production	**13**	**15**	**18**	**29**	**27**	**23**
Coal	1	1	1	1	1	0
Lignite	1	0	0	0	0	0
Fuel Oil	2	2	2	1	1	0
Gas	9	11	14	26	24	21
Biomass	1	1	1	1	1	1
Total generation	**226**	**221**	**204**	**192**	**184**	**176**
Fossil	205	194	122	84	69	53
Coal	124	105	41	1	1	0
Lignite	52	40	14	0	0	0
Gas	26	42	66	82	68	52
Oil	2	2	2	1	1	0
Diesel	2	4	0	0	0	0
Nuclear	0	0	0	0	0	0
Renewables	**21**	**27**	**82**	**109**	**114**	**123**
Hydro	17	18	19	17	14	12
Wind	2	5	19	24	25	27
PV	0	1	8	10	10	11
Biomass	2	2	7	10	10	9
Geothermal	0	0	15	29	33	38
Solar thermal	0	0	7	8	13	15
Ocean energy	0	0	8	10	10	10
Distribution losses	19	20	22	23	21	20
Final energy consumption (electricity)	**207**	**201**	**183**	**170**	**163**	**156**
Fluctuating RES (PV, Wind, Ocean)	2	6	34	44	45	48
Share of fluctuating RES	0.9%	2.8%	16.8%	22.9%	24.6%	27.2%
RES share	**9.2%**	**12.2%**	**40.2%**	**56.4%**	**62.2%**	**70.0%**
'Efficiency' savings (compared to Ref.)	**0**	**36**	**116**	**159**	**178**	**200**

table 20: installed capacity

GW

	2005	2010	2020	2030	2040	2050
Power plants	**44**	**42**	**41**	**39**	**38**	**38**
Coal	21.3	17	5	0	0	0
Lignite	7.3	6.3	1.6	0	0	0
Gas	6	9	12	13	11	10
Oil & diesel	1.0	0.7	0	0	0	0
Nuclear	0	0	0	0	0	0
Biomass	0.2	0.3	1.0	1.3	1.3	1.3
Hydro	7.0	7	6	5	4	4
Wind	0.8	2	5	7	7	7
PV	0	0.6	4.0	4.6	5	5
Geothermal	0	0	1.8	3.3	4	4
Solar thermal power plants	0	0	2.0	2.2	3	4
Ocean energy	0	0	2.0	2.3	2	2
Combined heat & power production	**2.5**	**2.8**	**3.9**	**7.2**	**6.6**	**6.1**
Coal	0.2	0.2	0.2	0.2	0.2	0.2
Lignite	0.2	0.2	0	0	0	0
Gas	1.4	1.7	2.6	5.8	5.4	5
Oil	0.3	0.3	0.3	0.3	0.2	0.1
Biomass	0.4	0.4	0.7	0.9	0.8	0.7
Geothermal	0	0	0	0	0	0
CHP by producer						
Main acitivity producers	0	0	0	0	0	0
Autoproducers	2.5	2.8	3.9	7.2	6.6	6.1
Total Generation	**46**	**45**	**45**	**46**	**45**	**44**
Fossil	38	35	21	19	17	15
Coal	22	17	5	0	0	0
Lignite	8	7	2	0	0	0
Gas	8	10	15	19	17	15
Oil & diesel	1	1	0	0	0	0
Nuclear	0	0	0	0	0	0
Renewables	**8**	**10**	**23**	**27**	**28**	**29**
Hydro	7	7	6	5	4	4
Wind	1	2	5	7	7	7
PV	0	1	4	5	5	5
Biomass	0.6	1	2	2	2	2
Geothermal	0	0	2	3	4	4
Solar thermal	0	0	2	2	3	4
Ocean energy	0	0	2	2	2	2
Fluctuating RES (PV, Wind, Ocean)	0.8	2.2	11.4	13.5	14	14.9
Share of fluctuating RES	1.7%	4.9%	25.5%	29.4%	31.2%	33.7%
RES share	**18.1%**	**21.8%**	**52%**	**58.0%**	**61.8%**	**66.4%**

table 22: primary energy demand

PJ/A

	2005	2010	2020	2030	2040	2050
Total	**4,761**	**4,676**	**3,982**	**3,751**	**3,343**	**2,979**
Fossil	**4,443**	**4,286**	**3,374**	**3,030**	**2,576**	**2,159**
Hard coal	1,422	1,226	550	111	112	113
Lignite	665	506	161	0	0	0
Natural gas	1,012	1,265	1,590	1,945	1,636	1,336
Crude oil	1,344	1,289	1,072	974	828	710
Nuclear	**0**	**0**	**0**	**0**	**0**	**0**
Renewables	**317**	**390**	**608**	**721**	**766**	**821**
Hydro	61	67	67	62	51	44
Wind	8	18	67	88	91	99
Solar	3	16	81	110	139	160
Biomass	246	289	339	355	3669	379
Geothermal	0	0	54	106	117	138
Ocean Energy	0	0	28	35	36	35
RES share	**6.7%**	**8.3%**	**15.3%**	**19.2%**	**22.9%**	**27.5%**
'Efficiency' savings (compared to Ref.)	**0**	**568**	**2,144**	**2,860**	**3,386**	**3,833**

image AN AERIAL VIEW SHOWS A WIND TURBINE WITH COAL PILES IN THE BACKGROUND AT THE NEWCASTLE COAL LOADER, NSW, AUSTRALIA.

alternative scenario

table 23: heat supply

PJ/A

	2005	2010	2020	2030	2040	2050
Heat from CHP	**131**	**150**	**156**	**202**	**189**	**173**
Fossil fuels	84	106	107	143	130	115
Coal	22	23	17	9	7	5
Petroleum Products	21	23	18	12	8	5
Natural Gas	51	61	72	122	114	104
Biomass	36	44	49	59	59	59
Direct heating[1]	**988**	**979**	**784**	**563**	**590**	**616**
Fossil fuels	777	744	556	339	339	339
Coal	218	211	159	94	99	104
Petroleum Products	144	110	40	44	41	38
Natural Gas	415	423	357	201	200	197
Biomass	154	175	172	161	173	186
Solar collectors	3	12	28	46	57	67
Geothermal	0	0	0	0	0	0
Electricity	54	48	28	17	21	24
Total heat supply[1]	**1,118**	**1,130**	**940**	**765**	**778**	**789**
Fossil fuels	871	849	663	482	469	454
Biomass	190	220	222	220	232	244
Solar collectors	3	12	28	46	57	67
Geothermal	0	0	0	0	0	0
Electricity	54	48	28	17	21	24
RES share (including RES electricity)	**17.7%**	**21.0%**	**27.0%**	**35.3%**	**37.7%**	**40.4%**
'Efficiency' savings (compared to Ref.)	**0**	**39**	**328**	**628**	**649**	**672**

1) heat from electricity (direct and from electric heat pumps) not included; covered in the model under 'electric appliances'

table 24: CO_2 emissions

MILL t/a

	2005	2010	2020	2030	2040	2050
Condensation power plants	**178**	**154**	**70**	**22**	**17**	**11**
Coal	106	89	33	0	0	0
Lignite	61	47	15	0	0	0
Gas	9	15	22	22	17	11
Oil	1.6	3.0	0	0	0	0
Combined heat & power production	**10**	**11**	**12**	**16**	**14**	**13**
Coal	2	2	2	1	1	1
Lignite	1	1	0	0	0	0
Gas	5	6	8	13	12	11
Oil	2	2	2	1	1	1
CO_2 emissions electricity & steam generation	**188**	**165**	**82**	**38**	**31**	**24**
Coal	108	91	35	1	1	1
Lignite	62	47	15	0	0	0
Gas	14	21	30	35	29	23
Oil & diesel	4	5	2	1	1	1
CO_2 emissions by sector	**370**	**340**	**232**	**168**	**151**	**135**
% of 2000 emissions	100%	92%	63%	45%	41%	36%
Industry	66	65	52	38	38	38
Other sectors	11	11	9	6	5	4
Transport	89	79	61	50	42	36
Electricity & steam generation	188	165	82	38	31	24
District heating	16	21	28	36	34	33
Population (Mill.)	20	22	24	26	27	28
CO_2 emissions per capita (t/capita)	**18.5**	**15.5**	**9.7**	**6.5**	**5.6**	**4.8**
'Efficiency' savings (compared to Ref.)	**0**	**55.4**	**201.7**	**284.6**	**306.9**	**323.4**

The numbers provided in the table are the data from the model. The estimation for the 2003 CO_2 emissions is 2.7% below the Government's figure for the same year (31.17 Mill t/a). For consistency, we have corrected the figures accordingly and used these to estimate the CO_2 emission reductions.

table 25: transport fuel demand

MILL t/a

	2005	2010	2020	2030	2040	2050
Aviation	**202**	**202**	**201**	**183**	**155**	**131**
Fossil	202	202	201	183	155	131
Petroleum products	202	202	201	183	155	131
Navigation	**58**	**52**	**41**	**32**	**31**	**31**
Fossil	58	52	41	32	31	31
Coal	5	4	3	2	1	0
Petroleum products	53	47	38	30	30	31
Rail	**34**	**48**	**68**	**82**	**95**	**106**
Fossil	26	33	35	29	30	30
Petroleum products	26	33	35	29	30	30
Electricity	8	15	33	54	65	76
Road	**1,026**	**887**	**648**	**520**	**442**	**379**
Truck	360	313	233	192	164	140
Fossil	360	313	233	192	164	140
Petroleum products	360	313	233	192	161	136
Natural gas	0	0	0	0	2	4
Bus	**19**	**21**	**21**	**22**	**23**	**23**
Fossil	19	21	21	22	23	23
Petroleum products	18	19	19	20	20	19
Natural gas	1	2	2	2	3	3
Passenger Car and Motorcycles	**646**	**554**	**394**	**306**	**256**	**216**
Fossil	641	536	371	282	220	171
Petroleum products	641	536	371	282	219	171
Natural gas	0	0	0	0	0	0
Renewables	5	5	4	3	4	4
Biomass	5	5	4	3	4	4
Hydrogen	0	0	0	0	0	0
Electricity	0	13	19	21	33	41
Total transport fuel demand	**1,320**	**1,189**	**958**	**818**	**724**	**647**
Fossil	1,307	1,157	902	740	622	526
Coal	5	4	3	2	1	0
Petroleum products	1,301	1,151	897	735	615	518
Natural gas	1	2	2	2	6	8
Renewables	5	5	4	3	4	4
Biomass	5	5	4	3	4	4
Hydrogen	0	0	0	0	0	0
Electricity	8	27	52	74	98	118
Total RES	**5**	**5**	**4**	**3**	**4**	**4**
'Efficiency' savings (compared to Ref.)	**0**	**224**	**640**	**964**	**1,117**	**1,253**

image SOLAR PANELS ON CONISTON STATION, NORTH WEST OF ALICE SPRINGS, NORTHERN TERRITORY.

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greenpeace australia pacific
Level 4, 39 Liverpool Street, Sydney 2000 Australia
t +61 2 9261 4666 f +61 2 9261 4588
greenpeace@au.greenpeace.org
www.greenpeace.org/australia

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EREC european renewable energy council
Renewable Energy House, 63-65 rue d'Arlon,
B-1040 Brussels, Belgium
t +32 2 546 1933 f+32 2 546 1934
erec@erec.org
www.erec.org

image ICE FLOES ON THE SNOW COVERED LAKE BAIKAL, RUSSIA, IN THE SUN.