# the advanced energy [r]evolution

A SUSTAINABLE ENERGY OUTLOOK FOR SOUTH AFRICA

EREC
EUROPEAN RENEWABLE ENERGY COUNCIL

GREENPEACE

**report** 2nd edition 2011 south africa energy scenario

**Greenpeace International, European Renewable Energy Council (EREC)**

**date** May 2011

**project manager & lead author** Sven Teske, Greenpeace International

**EREC** Arthouros Zervos, Christine Lins

**Greenpeace International** Sven Teske

**Greenpeace Africa** Melita Steele, Fiona Musana, Dr. Rianne Teule, Ferrial Adam

# partners

**image** THE INDIGENOUS NENETS PEOPLE IN RUSSIA MOVE EVERY 3 OR 4 DAYS SO THAT THEIR REINDEER DO NOT OVER GRAZE THE GROUND AND THEY DO NOT OVER FISH THE LAKES. THE YAMAL PENINSULA IS UNDER HEAVY THREAT FROM GLOBAL WARMING AS TEMPERATURES INCREASE AND RUSSIA'S ANCIENT PERMAFROST MELTS.

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

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

© GREENPEACE/WILL ROSE

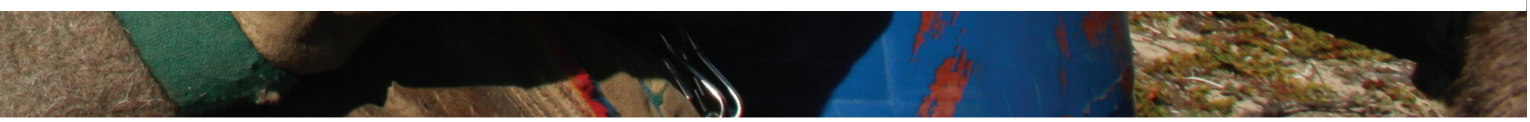
**research & co-authors** DLR, Institute of Technical Thermodynamics, Department of Systems Analysis and Technology Assessment, Stuttgart, Germany: Dr. Wolfram Krewitt (†),Dr. Thomas Pregger, Dr. Sonja Simon, Dr. Tobias Naegler. DLR, Institute of Vehicle Concepts, Stuttgart, Germany: Dr. Stephan Schmid. Ecofys BV, Utrecht, The Netherlands: Wina Graus, Eliane Blomen. Institute for Sustainable Futures, University of Technology, Sydney: Jay Rutovitz (chapter 7, employment).

**editors** Crispin Aubrey, Melita Steele and Dr. Rianne Teule

**printing** Kai Toma Creatives

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

**contact** sven.teske@greenpeace.org, lins@erec.org



for further information about the global, regional and national scenarios please visit the Energy [R]evolution website: **www.energyblueprint.info/**
Published by Greenpeace International and EREC. (GPI reference number JN 330). Printed on 100% post consumer recycled chlorine-free paper.

# foreword

**Over the past three years, the Energy [R]evolution has provided an invaluable contribution to the energy sector and has become a point of reference for many. It is a valuable source of information for the International Renewable Energy Agency (IRENA) which, with 152 affiliated states and 74 ratifications to date, has a clear political mandate to support the global transition to a sustainable energy system based largely on renewable energy.**

IRENA's mandate also confirms the recognition by the international community that our planet is facing severe economic and environmental challenges, that we urgently need to create a clean, more secure energy industry, and that renewable energy is an essential – indeed an inexorable – part of the solution.

The energy system is characterized by capital stock with a long life span and by large infrastructure projects that take many years from conception to completion. Within such timeframes, many parameters can change. Climate change is probably currently the most compelling issue, but supply security and fossil fuel depletion, energy access and economic

ANDASOL 1 SOLAR POWER STATION SUPPLIES UP TO 200,000 PEOPLE WITH CLIMATE-FRIENDLY ELECTRICITY AND SAVES ABOUT 149,000 TONNES OF CARBON DIOXIDE PER YEAR COMPARED WITH A MODERN COAL POWER PLANT.

growth, and local air pollution all must be considered. Scenarios are a tool that help deal with uncertainty and assist in mapping out the complexity of issues that have to be considered in the decision making process. The Energy [R]evolution study on emerging economies, such as South Africa, highlight new and different challenges that such contexts pose. At the same time, it shows that countries like South Africa can be put on a more sustainable development path that is practicable and affordable. As Africa is one the priority areas for IRENA's work in 2011, this study will be an important building block in that context.

IRENA's work programme for 2011 incorporates action on three key fronts: First, the knowledge management and technology sub-programme designated to facilitate an increased role for renewable energy; Second, the policy advisory services and capacity building sub-program that will encourage an enabling environment for renewables. And third, under the innovation and technology sub-programme, IRENA will create a framework for technology support, work of cost reduction potentials and the wider use of standards. All of these will contribute to accelerating the uptake of renewables.

IRENA cannot do this work alone, but only with the cooperation of a plethora of partners and expertise that organizations such as the European Renewable Energy Council and Greenpeace can bring. I hope we will work together with swift, decisive action to harness the full potential of IRENA to support the international community on the path to a sustainable energy future.

***Adnan Amin,***
DIRECTOR GENERAL
INTERNATIONAL RENEWABLE ENERGY AGENCY (IRENA)
MAY 2011

© GREENPEACE/MARKEL REDONDO

# contents

**foreword** 4

**introduction** 8

**executive summary** 10

**1 climate protection & energy policy** 15

**1.1 the kyoto protocol** 18

**2 implementing the energy [r]evolution in south africa** 18

**2.1 international energy policy** 19
**2.2 south africa's energy policy** 19
2.2.1 background 19
2.2.2 key players in the energy sector 19
2.2.3 south africa's primary energy supply 20
2.2.4 the renewable energy feed-in tariff (REFIT) 20
2.2.5 government response plan 20
2.2.6 national policies and trends 21
2.2.7 private sector contribution 23
2.2.8 key issues 24

**3 nuclear power and climate protection** 25

**3.1 a solution to climate protection?** 26
**3.2 nuclear power blocks solutions** 27
**3.3 nuclear power in the energy [r]evolution scenario** 27
**3.4 the dangers of nuclear power** 27
3.4.1 safety risks 27
3.4.2 nuclear waste 28
3.4.3 nuclear proliferation 28

**4 the energy [r]evolution** 30

**4.1 key principles** 31
**4.2 from principles to practice** 31
**4.3 a sustainable development pathway** 32
**4.4 new business model** 34
**4.5 the new electricity grid** 35
**4.6 hybrid systems** 36
**4.7 smart grids** 36

**5 scenarios for a future energy supply** 40

**5.1 price projections for fossil fuels and biomass** 41
**5.2 cost of $CO_2$ emissions** 41
**5.3 cost projections for efficient fossil fuel generation and carbon capture and storage (CCS)** 42
**5.4 cost projections for renewable energy technologies** 43
5.4.1 photovoltaics (pv) 43
5.4.2 concentrating solar power 44
5.4.3 wind power 44
5.4.4 biomass 45
5.4.5 geothermal 45
5.4.6 ocean energy 46
5.4.7 hydro power 46
5.4.8 summary of renewable energy cost development 47

**6 key results of the south africa energy [r]evolution scenario** 52

**6.1 energy demand by sector** 53
**6.2 economic growth** 53
**6.3 development of energy demand to 2050** 53
**6.4 electricity generation** 55
**6.5 future costs of electricity generation** 56
**6.6 future investment** 56
**6.7 heating and cooling supply** 58
**6.8 transport** 58
**6.9 development of $CO_2$ emissions** 59
**6.10 primary energy consumption** 59

**7 employment** 60

**7.1 future employment** 61
**7.2 methodology overview** 62
7.2.1 manufacturing and enhanced manufacturing 63
7.2.2 energy efficiency 63
7.2.3 coal trade 63

**8 energy resources and security of supply** 64

**8.1 oil** 65
8.1.1 the reserves chaos 65
8.1.2 non-conventional oil reserves 65
**8.2 gas** 65
8.2.1 shale gas 66
**8.3 coal** 67
**8.4 nuclear** 67
**8.5 renewable energy** 76
8.5.1 the global potential for sustainable biomass 82
8.5.2 assessment of biomass potential studies 82
8.5.3 potential of energy crops 82

**9 renewable energy technologies** 84

**9.1 renewable energy technologies** 85
9.1.1 solar power (photovoltaics) 85
9.1.2 concentrating solar power (CSP) 86
9.1.3 solar thermal collectors 87
9.1.4 wind power 87
9.1.5 biomass energy 88
9.1.6 biofuels 89
9.1.7 geothermal energy 90
9.1.8 hydro power 90
9.1.9 ocean energy 91

**10 climate and energy policy** 92

**10.1 climate policy** 93
**10.2 energy policy and market regulation** 94
**10.3 targets and incentives for renewables** 95
10.3.1 fixed price systems 95
10.3.2 renewables quota systems 96
**10.4 energy efficiency and innovation** 96
10.4.1 appliances and lighting 97
10.4.2 buildings 97
10.4.3 transport 97

**11 glossary & appendix** 98

**11.1 glossary of commonly used terms and abbreviations** 99
**11.2 definition of sectors** 99
**11.3 methodology to calculate employment** 100
11.3.1 employment factors 100


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

# list of figures


| | | |
|---|---|---|
| figure 0.1 | development of primary energy consumption under the advanced energy [r]evolution scenario | 13 |
| figure 3.1 | the nuclear fuel chain | 29 |
| figure 4.1 | energy loss, by centralised generation systems | 32 |
| figure 4.2 | a decentralised energy future | 33 |
| figure 4.3 | overview of the future power system with high penetration of renewables | 37 |
| figure 4.4 | the smart-grid vision for the enery [r]evolution | 39 |
| figure 5.1 | future development of renewable energy investment costs | 47 |
| figure 5.2 | expected development of electricity generation costs | 47 |
| figure 6.1 | projection of total final energy demand by sector under three scenarios | 54 |
| figure 6.2 | development of electricity demand by sector under both energy [r]evolution scenarios | 54 |
| figure 6.3 | development of heat demand by sector under both energy [r]evolution scenarios | 54 |
| figure 6.4 | development of electricity generation structure under three scenarios | 55 |
| figure 6.5 | development total electricity supply costs & development of specific electricity generation costs under three scenarios | 56 |
| figure 6.6 | investment shares - reference versus energy [r]evolution scenarios | 57 |
| figure 6.7 | change in cumulative power plant investment in both energy [r]evolution scenarios | 57 |
| figure 6.8 | development of heat supply structure under three scenarios | 58 |
| figure 6.9 | transport under three scenarios | 58 |
| figure 6.10 | development of $CO_2$ emissions by sector under the both energy [r]evolution scenarios | 59 |
| figure 6.11 | development of primary energy consumption under three scenarios | 59 |
| figure 7.1 | jobs by technology under three scenarios | 61 |
| figure 8.1 | energy resources of the world | 76 |
| figure 8.2 | ranges of potential for different biomass types | 82 |
| figure 8.3 | bio energy potential analysis from different authors | 82 |
| figure 8.4 | world wide energy crop potentials in different scenarios | 83 |
| figure 9.1 | photovoltaics technology | 85 |
| figure 9.2 | csp technologies: parabolic trough, central receiver/solar tower and parabolic dish | 86 |
| figure 9.3 | flat panel solar technology | 87 |
| figure 9.4 | wind turbine technology | 88 |
| figure 9.5 | biomass technology | 88 |
| figure 9.6 | geothermal technology | 90 |
| figure 9.7 | hydro technology | 90 |


# list of tables


| | | |
|---|---|---|
| table 0.1 | energy [r]evolution: summary for policy makers | 14 |
| table 4.1 | power plant value chain | 34 |
| table 5.1 | development projections for fossil fuel prices, in $2008 | 41 |
| table 5.2 | assumptions on $CO_2$ emissions cost development | 42 |
| table 5.3 | development of efficiency and investment costs for selected power plant technologies | 42 |
| table 5.4 | photovoltaics (pv) cost assumptions | 43 |
| table 5.5 | concentrating solar power (csp) cost assumptions | 44 |
| table 5.6 | wind power cost assumptions | 44 |
| table 5.7 | biomass cost assumptions | 45 |
| table 5.8 | geothermal cost assumptions | 45 |
| table 5.9 | ocean energy cost assumptions | 46 |
| table 5.10 | hydro power cost assumptions | 46 |
| table 6.1 | population development projections in million | 53 |
| table 6.2 | projection of renewable electricity generation capacity under both energy [r]evolution scenarios | 55 |
| table 6.3 | fuel cost savings and invesment costs under three scenarios | 57 |
| table 7.1 | energy sector jobs in the advanced energy [r]evolution | 61 |
| table 7.2 | methodology to calculate employment | 63 |
| table 8.1 | overview of fossil fuel reserves and resources | 66 |
| table 8.2 | assumptions on fossil fuel use in the three scenarios | 67 |
| table 8.3 | technical potential by renewable energy technology for 2020, 2030 and 2050 | 77 |
| table 11.1 | conversion factors - fossil fuels | 99 |
| table 11.2 | conversion factors - different energy units | 99 |
| table 11.3 | employment factors for use in south african analysis | 101 |

# introduction

"SOUTH AFRICA IS FORTUNATE ENOUGH TO HAVE HUGE RENEWABLE ENERGY RESOURCES AND, WITH THE POLITICAL WILL, COULD BECOME A RENEWABLE ENERGY LEADER IN AFRICA."


**image** A WORKER ENTERS A TURBINE TOWER FOR MAINTENANCE AT DABANCHENG WIND FARM. CHINA'S BEST WIND RESOURCES ARE MADE POSSIBLE BY THE NATURAL BREACH IN TIANSHAN (TIAN MOUNTAIN).

South Africa is making crucial energy decisions at a time when 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. And it is the world's poorest and most vulnerable people who will be affected first – that means that the African continent is on the frontline of 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 will 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 catastrophic. South Africa is the largest $CO_2$ emitter on the African continent, and the 12th largest emitter in the world. As such, the country has a moral responsibility to act and implement a coordinated, coherent, efficient and effective response to the global challenge of climate change.

In presenting the greatest threat the planet faces, climate change also provides an opportunity for sustainable development. South Africa has massive renewable energy sources, from wind and marine energy to some of the best solar resources in the world. Harnessing these resources would not only make a huge contribution to averting runaway climate change, but would also create a green economy based on green jobs. We can and must create a much more sustainable society, using existing clean technologies. However, time is not on our side and the transition must begin immediately. Action is required both through the international United Nations climate negotiations (aimed at limiting greenhouse gas emissions), but also through concrete and immediate action domestically.

There is much South Africa can do to become a climate leader. Currently, South Africa's greenhouse-gas emissions are still on a sharp upward trajectory, with more than 90% of South Africa's electricity coming from coal, and two of the biggest coal-fired power stations in the world (Medupi and Kusile) under construction.

**references**
**1** IPCC FOURTH ASSESSMENT SYNTHESIS REPORT HTTP://WWW.IPCC.CH/PDF/ASSESSMENT-REPORT/AR4/SYR/AR4_SYR.PDF
**2** WORLD HEALTH ORGANISATION - HTTP://WWW.WHO.INT/GLOBALCHANGE/NEWS/FSCLIMANDHEALTH/EN/INDEX.HTML

Renewable energy is forced to compete on an uneven playing field, as the majority of political and financial support is still enjoyed by the powerful fossil fuel industry, and Eskom enjoys a monopoly in the electricity sector. However, this can and must be turned around. With the political will and South Africa's abundance of renewable energy resources, the country could become a renewable energy leader in Africa. It is also well placed to become much more energy efficient and reduce the costs of energy as well as emissions.

## the advanced energy [r]evolution scenario: South Africa

This scenario is based on the global energy scenario produced by Greenpeace International, which demonstrates how energy-related global $CO_2$ emissions can be reduced by 80% by 2050 based on 1990 levels. The South African scenario provides an exciting, ambitious and necessary blueprint for how emission reductions can be made in the energy and transport sectors and how South Africa'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; between 2005 and 2010 the installed capacity of wind grew by 333% globally[3] while solar photovoltaics grew by over 700%[4]. As renewable energy is scaled up, we can start phasing out coal. In fact, this report illustrates how if renewable energy is implemented with enough ambition, together with comprehensive energy efficiency measures, South Africa would not have to build one of the biggest coal-fired power stations in the world (Kusile) at all. 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 [R]evolution driven by the creation of green jobs and the creation of a sustainable, clean future must be the result of political action taken today.

## the forgotten solution: energy efficiency

The South African Advanced Energy [R]evolution scenario takes advantage of the enormous potential for the country to become much more energy efficient. Energy efficiency offers some of the simplest, easiest and most cost effective measures for reducing both greenhouse gas emissions and costs to end-users. Removal of government subsidies, emissions trading and carbon taxes will all 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 poorest and most vulnerable to energy price increases – and energy efficiency presents major opportunities for people to be protected from the costs of rising energy prices.

## keeping it fair

The Advanced Energy [R]evolution Scenario describes a major restructuring of energy and transport markets in South Africa. An integral part of the inevitable transition from fossil fuels to renewable energy will be ensuring that the overall negative social and economic impacts are kept to a minimum and the opportunities for new employment, investment and innovation are maximized. The transition away from fossil fuels opens up new opportunities in skills development, manufacturing and infrastructure development. Early planning will help ensure that a skilled workforce is ready to deliver South Africa's low-carbon future, through a just transition towards a renewable energy-based society.

## 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 Advanced Energy [R]evolution scenario demonstrates that making the necessary transformations in how we use energy is achievable, and provides a wealth of opportunities to stimulate economic growth, ensure access to electricity for all and create green, sustainable jobs. We call on South Africa's political leaders to turn the Advanced Energy [R]evolution scenario into a 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 the South African economy to prosper from the transition.

***Sven Teske***
CLIMATE & ENERGY UNIT
GREENPEACE
INTERNATIONAL

***Christine Lins***
SECRETARY GENERAL
EUROPEAN RENEWABLE
ENERGY COUNCIL (EREC)

MAY 2011

***Olivia Langhoff***
CAMPAIGNS DIRECTOR
GREENPEACE AFRICA

**"...Our commitment to tackle climate change does not rest only on the achievement and implementation of international agreements. Our commitment must be borne out by what we do here at home. We have the means indeed, the responsibility to ensure that our policies, programmes and activities contribute to emission reduction and respond to the impact of climate change on our country and region."**

**PRESIDENT JACOB ZUMA**
KEYNOTE ADDRESS, GREEN ECONOMY SUMMIT, 18 MAY 2010

**references**
**3** GWEC, MARCH 2011, GLOBAL WIND REPORT – ANNUAL MARKET UPDATE 2010.
**4** EPIA 2011, SOLARGENERATION 6 - SOLAR PHOTOVOLTAIC ELECTRICITY EMPOWERING THE WORLD.

# executive summary

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

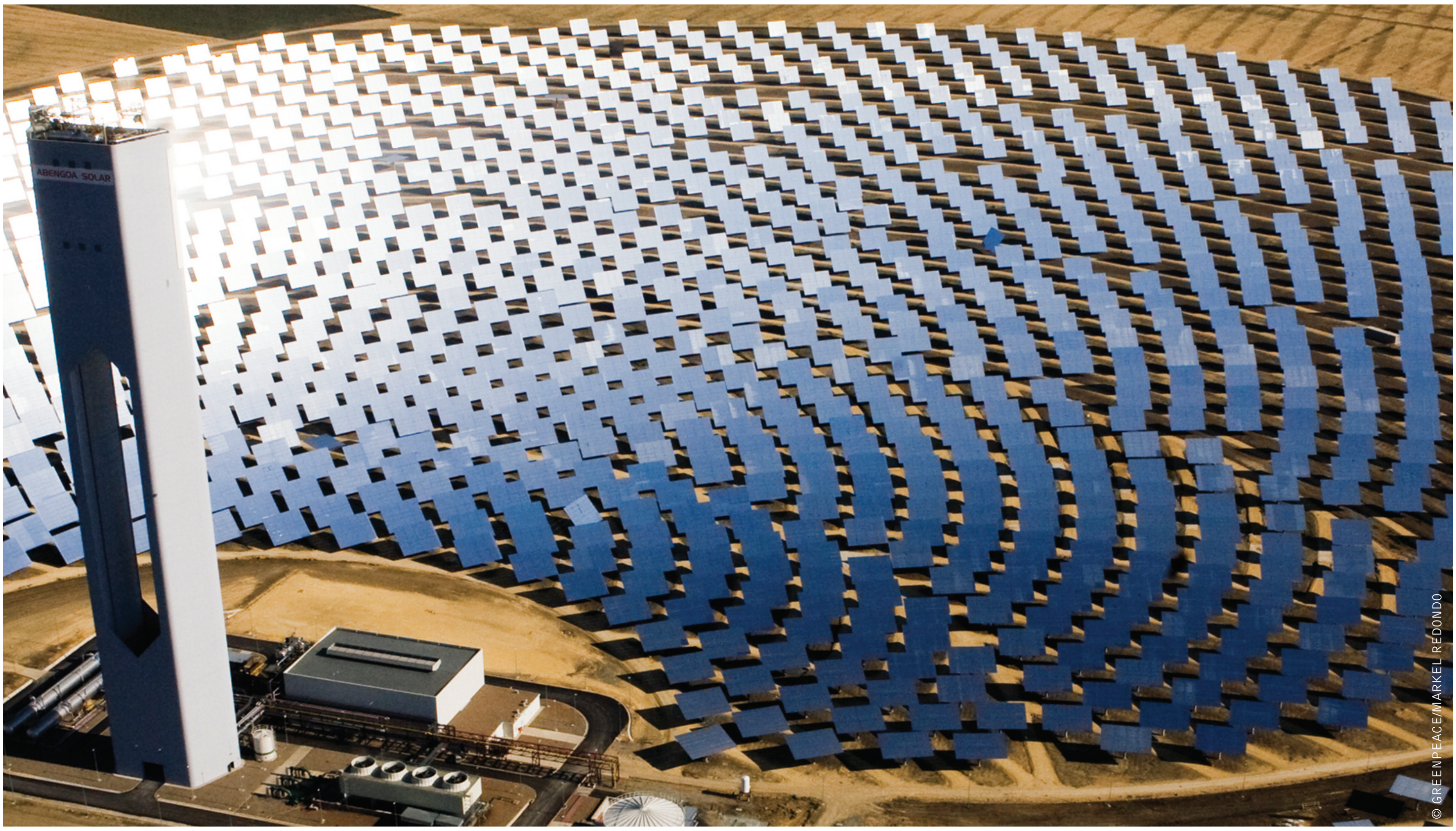




**image** THE PS10 CONCENTRATING SOLAR THERMAL POWER PLANT IN SEVILLA, SPAIN. THE 11 MEGAWATT SOLAR POWER TOWER PRODUCES ELECTRICITY WITH 624 LARGE MOVABLE MIRRORS CALLED HELIOSTATS. THE SOLAR RADIATION, MIRROR DESIGN PLANT IS CAPABLE OF PRODUCING 23 GWH OF ELECTRICITY WHICH IS ENOUGH TO SUPPLY POWER TO A POPULATION OF 10,000.

The threat of climate change, caused by rising global temperatures, is the most significant environmental challenge facing the world at the beginning of the 21st century. It has major implications for the world's social and economic stability, its natural resources and in particular, the way we produce our energy.

The Copenhagen Accord, agreed at the international climate change summit in December 2009, has the stated aim of keeping the increase in global temperatures to below 2°C, and then considering a 1.5°C limit by 2015. However, the national emissions reduction pledges submitted by various countries to the United Nations coordinating body, the UNFCCC, in the first half of 2010 are likely to lead to a world with global emissions of between 47.9 and 53.6 gigatonnes of carbon dioxide equivalent per year by 2020. This is about 10–20% higher than today's levels. In the worst case, the Copenhagen Accord pledges could even permit emission allowances to exceed a 'business as usual' projection[5].

In order to avoid the most catastrophic impacts of climate change, the global temperature increase must be kept as far below 2°C as possible. This is still possible, but time is running out. To stay within this limit, global greenhouse gas emissions will need to peak by 2015 and decline rapidly after that, reaching as close to zero as possible by the middle of the 21st century.

## a safe level of warming?

Keeping the global temperature increase to 2°C is often referred to as a 'safe level' of warming, but this does not reflect the reality of the latest science. This shows that a warming of 2°C above pre-industrial levels would pose unacceptable risks to many of the world's key natural and human systems[6]. Even with a 1.5°C warming, increases in droughts, heatwaves and floods, along with other adverse impacts such as increased water stress for up to 1.7 billion people, and wildfire frequency, are projected in many regions. Neither does staying below 2°C rule out large scale disasters such as melting ice sheets. Partial de-glaciation of the Greenland ice sheet, and possibly the West Antarctic ice sheet, could even occur from additional warming within a range of 0.8 – 3.8°C above current levels[7]. If rising temperatures are

**references**

**5** COPENHAGEN ACCORD PLEDGES ARE PALTRY - JOERI ROGELJ, MALTE MEINSHAUSEN, APRIL 2010.
**6** W. L. HARE. A SAFE LANDING FOR THE CLIMATE. STATE OF THE WORLD. WORLDWATCH INSTITUTE. 2009.
**7** JOEL B. SMITH, STEPHEN H. SCHNEIDER, MICHAEL OPPENHEIMER, GARY W. YOHE, WILLIAM HARE, MICHAEL D. MASTRANDREA, ANAND PATWARDHAN, IAN BURTON, JAN CORFEE-MORLOT, CHRIS H. D. MAGADZA, HANS-MARTIN FÜSSEL, A. BARRIE PITTOCK, ATIQ RAHMAN, AVELINO SUAREZ, AND JEAN-PASCAL VAN YPERSELE: ASSESSING DANGEROUS CLIMATE CHANGE THROUGH AN UPDATE OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) "REASONS FOR CONCERN". PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES. PUBLISHED ONLINE BEFORE PRINT FEBRUARY 26, 2009, DOI: 10.1073/PNAS.0812355106. THE ARTICLE IS FREELY AVAILABLE AT: HTTP://WWW.PNAS.ORG/CONTENT/EARLY/2009/02/25/0812355106.FULL.PDF A COPY OF THE GRAPH CAN BE FOUND ON APPENDIX 1.

**image** WELDER WORKING AT VESTAS WIND TURBINE FACTORY, CAMPBELLTOWN, SCOTLAND.

to be kept within acceptable limits then we need to significantly reduce our greenhouse gas emissions. This makes both environmental and economic sense. The main greenhouse gas is carbon dioxide ($CO_2$) produced by using fossil fuels for energy and transport.

## climate change and security of supply

Spurred by recent rapidly fluctuating oil prices, the issue of security of supply – both in terms of access to supplies and financial stability – is now at the top of the energy policy agenda. One reason for these price fluctuations is the fact that supplies of all proven resources of fossil fuels – oil, gas and coal – are becoming scarcer and more expensive to produce. So-called 'non-conventional' resources such as shale oil have even in some cases become more prevalent, with devastating consequences for the local environment. What is certain is that the days of 'cheap oil and gas' are coming to an end. Uranium, the fuel for nuclear power, is also a finite resource. By contrast, the reserves of renewable energy that are technically accessible globally are large enough to provide about six times more power than the world currently consumes - forever.

Renewable energy technologies vary widely in their technical and economic maturity, but there are a range of sources which offer increasingly attractive options. These include wind, biomass, photovoltaics, solar thermal, geothermal, ocean and hydroelectric power. Their common feature is that they produce little or no greenhouse gases, and rely on virtually inexhaustible natural elements for their 'fuel'. Some of these technologies are already competitive. The wind power industry, for example, continued its explosive growth in the face of a global recession and a financial crisis and is a testament to the inherent attractiveness of renewable technology.

At the same time there is enormous potential for reducing our consumption of energy, and still continuing to provide the same level of energy services. This study details a series of energy efficiency measures which together can substantially reduce demand across industry, homes, business and services.

## the energy [r]evolution

The climate change imperative demands nothing short of an Energy [R]evolution, a transformation that has already started as renewable energy markets continue to grow. In the first global edition of the Energy [R]evolution, published in January 2007, we projected a global installed renewable capacity of 156 GW by 2010. At the end of 2009, 158 GW has been installed. More needs to be done, however. 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

Decentralised energy systems, where power and heat are produced close to the point of final use, will avoid the current waste of energy during conversion and distribution. Investments in 'climate infrastructure' such as smart interactive grids, as well as super grids to transport large quantities of offshore wind and concentrating solar power, are essential. Building up clusters of renewable micro grids, especially for people living in remote areas, will be a central tool in providing sustainable electricity to the almost two billion people around the world for whom access to electricity is presently denied.

The Advanced Energy [R]evolution scenario follows the first series of Energy [R]evolution scenarios published between 2007-2009, increasing the emission reductions as needed according to latest climate science. While the Basic Energy [R]evolution scenario is based on a global $CO_2$ reduction target of minus 50% by 2050 (base year 1990) and a global per capita emission of around 1 ton $CO_2$ per year, the advanced aims for a 80% reduction target and a per capita of around 0.5 ton $CO_2$ per capita and year

## towards a renewable future

The Advanced Energy [R]evolution scenario reduces carbon dioxide emissions from the South African energy sector by 85% below 1990 levels by 2050. This, in concert with additional greenhouse gas savings in other sectors, is necessary to keep the increase in global temperature as much below +2°C as possible. A second objective of the Energy [R]evolution 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 both heat and electricity generation.

Today, renewable energy sources account for 13% of the world's primary energy demand. Biomass, which is mostly used in the heat sector, is the main source. The share of renewable energies for electricity generation is 18%, while their contribution to heat supply is around 24%, to a large extent accounted for by traditional uses such as collected firewood. About 80% of the primary energy supply today still comes from fossil fuels. Both Energy [R]evolution scenarios describe development pathways which turn the present situation into a sustainable energy supply, with the advanced version achieving the urgently needed $CO_2$ reduction target more than a decade earlier than the basic scenario. The Reference scenario used in this report is based on the "Policy adjusted" scenario of the Integrated Resource Plan, published by the South African Department of Energy for promulgation, in March 2011.

The following summary shows the results of the advanced Energy [R]evolution scenario for South Africa, which will be achieved through the following measures:

1. Exploitation of existing large energy efficiency potentials will ensure that primary energy demand decreases - from the current 5,500 PJ/a (2007) to 4,095 PJ/a in 2050, compared to 8,246 PJ/a in the Reference scenario. This dramatic reduction is a crucial prerequisite for achieving a significant share of renewable energy sources in the overall energy supply system, compensating for the phasing out of nuclear energy and reducing the consumption of fossil fuels.

# "The long term scenario has been developed further towards a complete phasing out of fossil fuels in the second half of this century."

**2.** More electric drives are used in the transport sector and hydrogen produced by electrolysis from excess renewable electricity plays a much bigger role in the advanced than in the basic scenario. After 2020, the final energy share of electric vehicles on the road increases to 14% by 2030 and 2050 to 53%. More public transport systems also use electricity, as well as there being a greater shift in transporting freight from road to rail.

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

**4.**The electricity sector will be the pioneer of renewable energy utilisation. By 2030, 49% of electricity will be produced from renewable sources, increasing to 94% by 2050. A capacity of 114 GW will produce 452 TWh/a renewable electricity in 2050. A significant share of the fluctuating power generation from wind and solar photovoltaic will be used to supply electricity to vehicle batteries and produce hydrogen as a secondary fuel in transport and industry. By using load management strategies, excess electricity generation will be reduced and more balancing power made available.

**5.** In the heat supply sector, the contribution of renewables will increase to 51% by 2030 and 84% by 2050. Fossil fuels will be increasingly replaced by more efficient modern technologies, in particular biomass, solar collectors and geothermal. Geothermal heat pumps and, in the world's sunbelt regions, concentrating solar power, will play a growing part in industrial heat production.

**6.** In the transport sector the existing large efficiency potentials will be exploited by a modal shift from road to rail and by using much lighter and smaller vehicles. As biomass is mainly committed to stationary applications, the production of biofuels is limited by the availability of sustainable raw materials. Electric vehicles, powered by renewable energy sources, will play an increasingly important role from 2020 onwards.

**7.** By 2050, 73% of primary energy demand will be covered by renewable energy sources.

To achieve an economically attractive growth of renewable energy sources, the balanced and timely mobilisation of all of the above-mentioned technologies is of great importance. Such mobilisation depends on technical potentials, actual costs, cost reduction potentials and technical maturity.

In order to support the building of capacity in developing countries significant new public financing, especially from industrialised countries, will be needed. It is vital that specific funding mechanisms are developed under the international climate negotiations that can assist the transfer of financial support to climate change mitigation, including technology transfer.

## future costs

Renewable energy will initially cost more to implement than existing fossil fuels. The slightly higher electricity generation costs under the Advanced Energy [R]evolution scenario will be compensated for, however, by reduced demand for fuels in other sectors such as heating and transport. Assuming average costs of 3 $cents/kWh for implementing energy efficiency measures, the additional cost for electricity supply under the Advanced Energy [R]evolution scenario will amount to a maximum of $100 million/a in 2015. These additional costs, which represent society's investment in an environmentally benign, safe and economic energy supply, decrease after 2015. By 2050 the annual costs of electricity supply will be $23 billion/a below those in the Reference scenario.

It is assumed that average crude oil prices will increase from around $80 per barrel in 2009 to $130 per barrel in 2020, and continue to rise to $150 per barrel in 2050. Natural gas import prices are expected to increase by a factor of four between 2008 and 2050, while coal prices will nearly double, reaching $360 per tonne in 2050. A $CO_2$ 'price adder' is applied, which rises from $20 per ton of $CO_2$ in 2020 to $50 per ton in 2050.

## future investment in new power plants

It would require $404 billion in investment for the Advanced Energy [R]evolution scenario to become reality - approximately $5.2 billion annual more than in the Reference scenario ($181 billion). Under the Reference version, the levels of investment in fossil and nuclear power plants add up to almost 60% while approximately 40% would be invested in renewable energy and cogeneration until 2050. Under the Advanced Energy [R]evolution scenario, however, South Africa would shift more than 80% of investment towards renewables and cogeneration by 2050. The fossil fuel share of power sector investment would be focused mainly on combined heat and power and efficient gas-fired power plants. The average annual investment in the power sector under the Advanced Energy [R]evolution scenario between today and 2050 would be approximately $9.4 billion.

Because renewable energy has no fuel costs, however, the fuel cost savings in the Basic Energy [R]evolution scenario reach a total $156 billion, or $3.6 billion per year. The Advanced Energy [R]evolution has even higher fuel cost savings of $283 billion, or $6.6 billion per year. These results are calculated based on hard coal price projections far below the world market prices that were assumed for the global Energy [R]evolution Report 2010, taking into account current special supply conditions in South Africa. Therefore fuel cost savings might be much higher, if the hard coal price of the future is adjusted to a high price scenario of the world market.

Under the Advanced Energy [R]evolution scenario, the average annual additional fuel cost savings are with $6.6 billion per year, 25% higher than the additional annual investment of $5.2 billion. Therefore, fuel cost savings compensate for the entire investment in renewable and cogeneration capacity required to implement the advanced scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies. Part of this money could be used to cover stranded investments in fossil-fuelled power stations in developing countries.


**image** THOUSANDS OF FISH DIE AT THE DRY RIVER BED OF MANAQUIRI LAKE, 150 KILOMETERS FROM AMAZONAS STATE CAPITOL MANAUS, BRAZIL.

## future employment

The analysis undertaken by the Institute for Sustainable Futures indicates that energy sector jobs are set to increase significantly by 2015 under all the energy scenarios presented. In 2010, there are nearly 76,000 electricity sector jobs[8].

- In the Reference scenario, jobs increase 53% by 2015 (40,300 additional jobs), increase by a further 23% by 2020 (17,000 jobs), and then decrease somewhat by 2030 to a total of 111,000[9].
- In the Basic Energy [R]evolution scenario, jobs increase 36% by 2015 (27,000 additional jobs), increase by a further 17% by 2020 (13,000 jobs), and then decrease only slightly by 2030 to a total of 112,000.
- In the Advanced Energy [R]evolution scenario, jobs increase 149% by 2015 (113,000 additional jobs), and then decrease, so that 2020 jobs are almost double 2010 levels (140,000 total jobs). Jobs increase again to 152,000 by 2030.

Solar PV shows particularly strong growth in all three scenarios, with an additional 22,000 jobs created in both the Reference and the Basic Energy [R]evolution scenario by 2020, and nearly 45,000 jobs in the Advanced Energy [R]evolution scenario.

## development of $CO_2$ emissions

$CO_2$ emissions in South Africa will increase under the Reference scenario up to 2020, and are thus very far from a sustainable development path, decreasing by only 29% until 2050. Under the Advanced Energy [R]evolution scenario however the $CO_2$ emissions will decrease from 349 million tonnes in 2008 to 44 million tonnes in 2050. Annual per capita emissions will drop from 7.1 tonnes/capita to 0.8 tonnes/capita. In spite of the phasing out of nuclear energy and a growing electricity demand, $CO_2$ emissions will decrease enormously in the electricity sector from 221 million tonnes of $CO_2$ per year now to only 8 million tonnes of $CO_2$ in 2050. In the long run efficiency gains and the increased use of renewable electric vehicles, as well as a sharp expansion in public transport, will even reduce $CO_2$ emissions in the transport sector. With a share of 38% of total emission in 2050, the transport sector will reduce significantly, but be the largest source of $CO_2$ emissions in 2050 – followed by industry and the power sector.

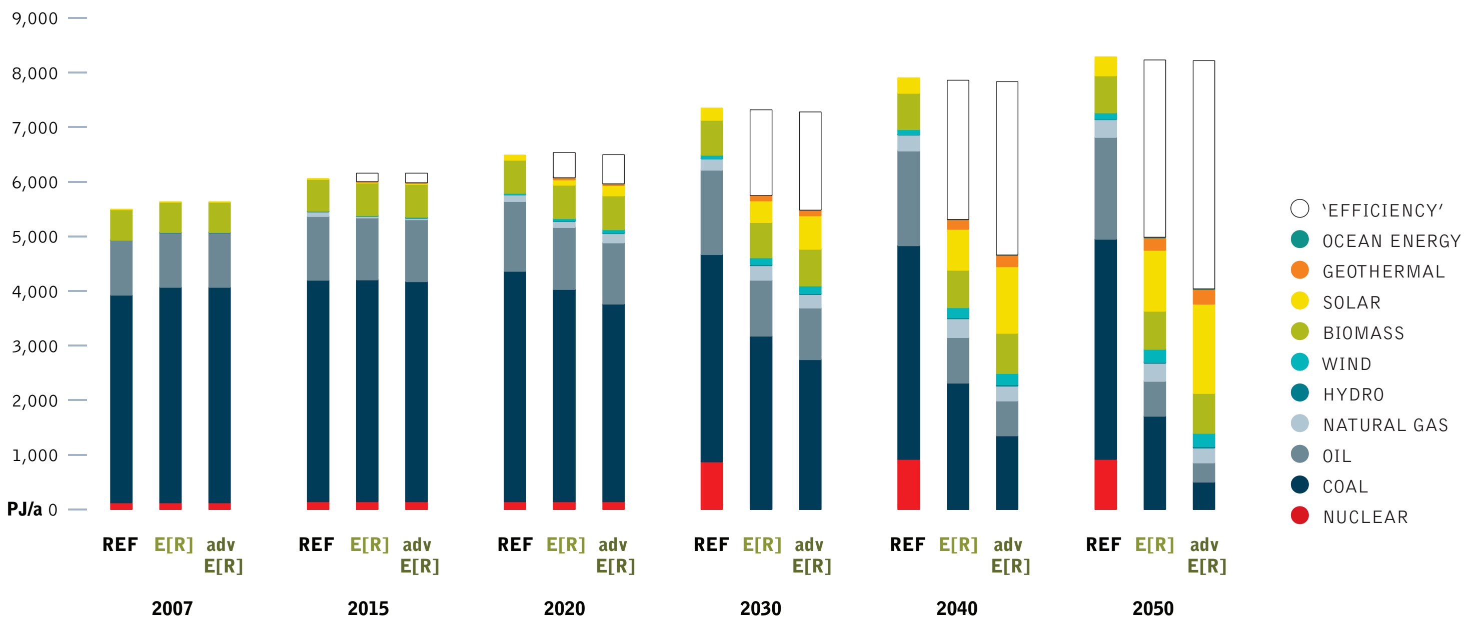
## policy changes

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

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

**figure 0.1: development of primary energy consumption under the advanced energy [r]evolution scenario**

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




**references**
8 INCLUDING JOBS IN COAL MINING FOR EXPORTS AND ENERGY EFFICIENCY JOBS RELATING TO THE DECREASE IN ELECTRICITY RELATIVE TO THE REFERENCE CASE.

**references**
9 THE ADVANCED ENERGY [R]EVOLUTION REFERENCE SCENARIO HAS BEEN MODIFIED FOR THIS JOBS ANALYSIS TO CORRESPOND MORE EXACTLY TO THE INTEGRATED RESOURCE PLAN POLICY ADJUSTED SCENARIO.

## table 0.1: energy [r]evolution: summary for policy makers

| | POLICY | WHO | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Climate** | | | | | | | | | | |
| targets | • Peak global temperature rise well below 2°C | UNFCCC | | | | | | | | | |
| targets | • Reduce ghg emissions by 40% by 2020 (as compared to 1990) in developed countries | UNFCCC | | | | | | | | | |
| targets | • Reduce ghg emissions by 15 to 30% of projected growth by 2020 in developing countries | UNFCCC | | | | | | | | | |
| targets | • Achieve zero deforestation globally by 2020 | UNFCCC | | | | | | | | | |
| targets | • Agree a legally binding global climate deal as soon as possible | UNFCCC | | | | | | | | | |
| | **Energy** | | | | | | | | | | |
| targets | • USA: binding target of at least 20% renewable energy in primary energy consumption by 2020 | USA | | | | | | | | | |
| targets | • G8: min 20% renewable energy by 2020 | G8 | | | | | | | | | |
| targets | • No new construction permits for new coal power plants in Annex 1 countries by 2012 | G8 | | | | | | | | | |
| targets | • Priority access to the grid for renewables | G8 | | | | | | | | | |
| targets | • Establish efficiency targets and strict standards for electric applications | National Governments | | | | | | | | | |
| targets | • Strict efficiency target for vehicles: 80g $CO_2$/km by 2020 | National Governments | | | | | | | | | |
| targets | • Build regulations with mandatory renewable energy shares (e.g. solar collectors) | National Governments | | | | | | | | | |
| targets | • Co-generation law for industry and district heating support program | National Governments | | | | | | | | | |
| | **Finance** | | | | | | | | | | |
| mechanisms | • Phase-out subsidies for fossil and nuclear fuels | G20 | | | | | | | | | |
| mechanisms | • Put in place a Climate Fund under the auspices of the UNFCCC | UNFCCC | | | | | | | | | |
| mechanisms | • Provide at least 140 billion USD/year to the Climate Fund by 2020 | UNFCCC | | | | | | | | | |
| mechanisms | • Ensure priority access to the fund for vulnerable countries and communities | UNFCCC | | | | | | | | | |
| mechanisms | • Establish feed-in law for renewable power generation in Annex 1 countries | National Governments | | | | | | | | | |
| mechanisms | • Establish feed-in law with funding from Annex 1 countries for dev. countries | G8 + G77 | | | | | | | | | |
| | **ENERGY [R]EVOLUTION RESULTS** | | | | | | | | | | |
| | **Renewables & Supply** | | | | | | | | | | |
| power | Global Renewable Power Generation | | | | | | | | | | |
| power | • Shares (max = adv. ER - Min = ER): 30% / 50% / 75% / over 90% | Utilities & RE Industry | | | | | | | | | |
| power | • Implementation of Smart Grids (Policy/Planning/Construction) | National Governments | | | | | | | | | |
| power | • Smart Grids interconnection to Super Grids (Policy/Planning/Construction) | Gov & Grid Operator | | | | | | | | | |
| power | • Renewables cost competitive (max = worst case - min = best case) | RE - Industry | | | | | | | | | |
| power | • Phase out of coal power plants in OECD countries | Utilities | | | | | | | | | |
| power | • Phase out of nuclear power plants in OECD countries | Utilities | | | | | | | | | |
| heating | Global Renewable Heat supply shares | | | | | | | | | | |
| heating | • Shares (max = adv. ER - Min = ER): 30% / 50% / 75% / over 90% | RE Industry | | | | | | | | | |
| heating | • Implementation of district heating (Policy/Planning/Construction) | National Governments | | | | | | | | | |
| heating | • Renewables cost competive (max = worst case - min = best case) | RE Industry | | | | | | | | | |
| final energy | Global Renewable Final Energy shares | | | | | | | | | | |
| final energy | • Shares (max = adv. ER - Min = ER): 30% / 50% / 75% / over 90% | | | | | | | | | | |
| final energy | • Consumer and business (Other Sectors) | | | | | | | | | | |
| final energy | • Industry | | | | | | | | | | |
| final energy | • Transport | | | | | | | | | | |
| final energy | • Total Final Energy | | | | | | | | | | |
| | **Efficiency & Demand** | | | | | | | | | | |
| consumer | Global Statonary Energy Use | | | | | | | | | | |
| consumer | • Efficiency standards reduce OECD household demand to 550 kWh/a per person | Cusumer Product Dev. | | | | | | | | | |
| consumer | • Power demand for IT equipment stablized and start to decrease | IT Industry | | | | | | | | | |
| consumer | • National energy intensity drops to 3 MJ/$GDP (Japan's level today) | Industry + Gov. | | | | | | | | | |
| transport | Global Transport Development | | | | | | | | | | |
| transport | • Shift fright from road to rail and where possible from aviation to ships | Gov. + Logistic Industry | | | | | | | | | |
| transport | • Shift towards more public transport | Regional Governments | | | | | | | | | |
| transport | • Efficient cars become mainstream | Car-Industry | | | | | | | | | |
| emissions | **Energy Related $CO_2$ Emissions** | | | | | | | | | | |
| emissions | • Global $CO_2$ reductions (min = adv. ER - Max = ER): **Emission peak** / -30% / -50% / -80% | | | | | | | | | | |
| emissions | • Annex 1 $CO_2$ reductions (min = adv. ER - Max = ER): **Emission peak** / -30% / -50% / -80% | | | | | | | | | | |
| emissions | • Non Annex 1 $CO_2$ reductions (min = adv. ER - Max = ER): **Emission peak** / -30% / -50% / -80% | | | | | | | | | | |

# 1

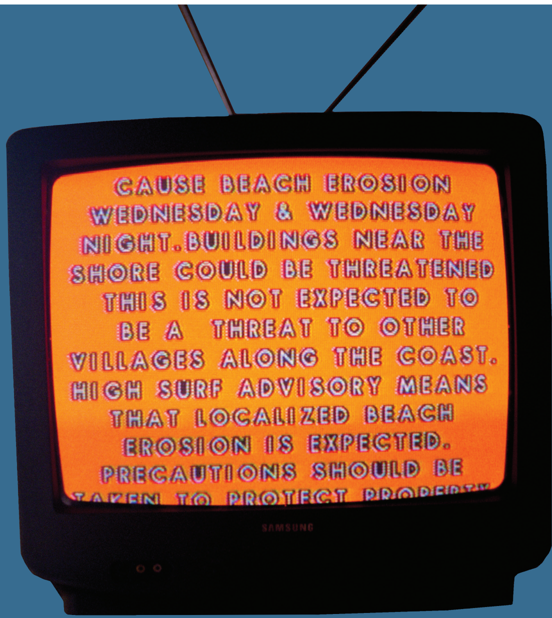



**image** THE LOCAL ALASKAN TELEVISION STATION BROADCASTS A WARNING FOR HIGH TIDES AND EROSION ALONG THE SEASIDE DURING A 2006 OCTOBER STORM WHICH IMPACTS ON THE VILLAGE OF SHISHMAREF. © GP/ROBERT KNOTH

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

**GREENPEACE INTERNATIONAL**
CLIMATE CAMPAIGN

The greenhouse effect is the process by which the atmosphere traps some of the sun's energy, warming the earth and moderating our climate. A human-driven increase in 'greenhouse gases' has enhanced this effect, artificially raising global temperatures and disrupting our climate. These greenhouse gases include carbon dioxide (produced by burning fossil fuels and through deforestation), methane (released from agriculture, animals and landfill sites), and nitrous oxide (resulting from agricultural production plus a variety of industrial chemicals).

Every day we damage our climate by using fossil fuels (oil, coal and gas) for energy and transport. The resulting impacts are likely to destroy the livelihoods of millions of people, especially in the developing world, as well as ecosystems and species, over the coming decades. We therefore need to significantly reduce our greenhouse gas emissions. This makes both environmental and economic sense.

According to the Intergovernmental Panel on Climate Change, the United Nations forum for established scientific opinion, the world's temperature is expected to increase over the next hundred years by up to 6.4° Celsius if no action is taken to reduce greenhouse gas emissions. This is much faster than anything experienced so far in human history. The goal of climate policy should be to keep the global mean temperature rise to less than 2°C above pre-industrial levels. If there is more than a 2°C rise, damage to ecosystems and disruption to the climate system increases dramatically. We have very little time within which we can change our energy system to meet these targets. This means that global emissions will have to peak and start to decline by the end of the next decade at the latest.

The reality of climate change can already be seen in disintegrating polar ice, thawing permafrost, rising sea levels and fatal heat waves. It is not only scientists that are witnessing these changes. From the Inuit in the far north to islanders near the equator, people are already struggling with impacts consistent with climate change. An average global warming of more than 2°C threatens millions of people with an increased risk of hunger, disease, flooding and water shortages. Never before has humanity been forced to grapple with such an immense environmental crisis. If we do not take urgent and immediate action to protect the climate, the damage could become irreversible. This can only happen through a rapid reduction in the emission of greenhouse gases into the atmosphere.

**Below is a summary of some likely effects if we allow current trends to continue.**

**Likely effects of small to moderate warming:**

- 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.
- A greater 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.
- Severe regional impacts such as an increase in river flooding in Europe as well as coastal flooding, erosion and wetland loss. Low-lying areas in developing countries such as Bangladesh and South China are likely to be severely affected by flooding.
- Severe threats to natural systems, including glaciers, coral reefs, mangroves, alpine ecosystems, boreal forests, tropical forests, prairie wetlands and native grasslands.
- Increased risk of species extinction and biodiversity loss.

The greatest impacts will be on poorer countries in sub-Saharan Africa, South Asia, Southeast Asia and Andean South America as well as small islands least able to protect themselves from increasing droughts, rising sea levels, the spread of disease and a decline in agricultural production.

**longer term catastrophic effects** Warming from rising emissions may trigger the irreversible meltdown of the Greenland ice sheet, adding up to seven metres of global sea level rise over several centuries. New evidence shows that the rate of ice discharge from parts of the Antarctic means it is also at risk of meltdown. Slowing, shifting or shutting down of the Atlantic Gulf Stream current would have dramatic effects in Europe, and disrupt the global ocean circulation system. Large releases of methane from melting permafrost and from the oceans would lead to rapid increases of the gas in the atmosphere and consequent warming.

**"climate change has moved from being a predominantly physical phenomenon to being a social one" (hulme, 2009).**


**image** WANG WAN YI, AGE 76, ADJUSTS THE SUNLIGHT POINT ON A SOLAR DEVICE USED TO BOIL HIS KETTLE. HE LIVES WITH HIS WIFE IN ONE ROOM CARVED OUT OF THE SANDSTONE, A TYPICAL DWELLING FOR LOCAL PEOPLE IN THE REGION. DROUGHT IS ONE OF THE MOST HARMFUL NATURAL HAZARDS IN NORTHWEST CHINA. CLIMATE CHANGE HAS A SIGNIFICANT IMPACT ON CHINA'S ENVIRONMENT AND ECONOMY.



## 1.1 the kyoto protocol

Recognising the threats from global warming, the signatories to the 1992 UN Framework Convention on Climate Change (UNFCCC) agreed to the Kyoto Protocol in 1997. The Protocol finally entered into force in early 2005 and its 193 member countries meet twice annually to negotiate further refinement and development of the agreement. Only one major industrialised nation, the United States, has not ratified the Kyoto Protocol.

In the Kyoto Protocol, developed countries take on individual targets to reduce or limit their greenhouse gas emissions by the target period of 2008-2012. Together developed countries agreed to reduce their emissions on average by 5.2% from their 1990 emissions. In the European Union, for instance, the commitment is to an overall reduction of 8%. In order to help reach this target, the EU also agreed to a target to increase its proportion of renewable energy from 6% to 12% by 2010.

At present, the 195 members of the UNFCCC are continuously negotiating a package of new agreements that would put the world on a pathway to prevent dangerous climate change. As the Kyoto Protocol's first commitment period is coming to an end by the end of 2012, a new package needs to ensure a continuation of the Kyoto Protocol in a second commitment period. There also needs to be clear agreement about the provision of climate finance, and support for adaptation, technology transfer and reducing deforestation. At the same time a clear pathway for agreeing stronger and legally binding targets for all should be set.

If the world really wants to prevent dangerous climate change, then we will need to ensure that industrialised countries reduce their emissions on average by at least 40% by 2020, compared to their 1990 level. They will further need to provide funding of at least $140 billion a year to developing countries to enable them to adapt to climate change, protect their forests and achieve their part of the energy revolution. Developing countries need to reduce their greenhouse gas emissions by 15 to 30% compared to their projected growth by 2020. It is clear that governments will need to make the Energy [R]evolution happen in order to be able to achieve such ambitious emission reduction targets, and South Africa is no exception to this.

**"If we do not take urgent and immediate action to protect the climate the damage could become irreversible."**

# implementing the energy [r]evolution in south africa



INTERNATIONAL ENERGY POLICY
SOUTH AFRICA ENERGY POLICY
BACKGROUND
KEY PLAYERS IN THE ENERGY SECTOR
SOUTH AFRICA'S PRIMARY ENERGY SUPPLY
THE RENEWABLE ENERGY FEED-IN TARIFF
GOVERNMENT RESPONSE PLAN
NATIONAL POLICIES AND TRENDS
PRIVATE SECTOR CONTRIBUTION
KEY ISSUES

# 2

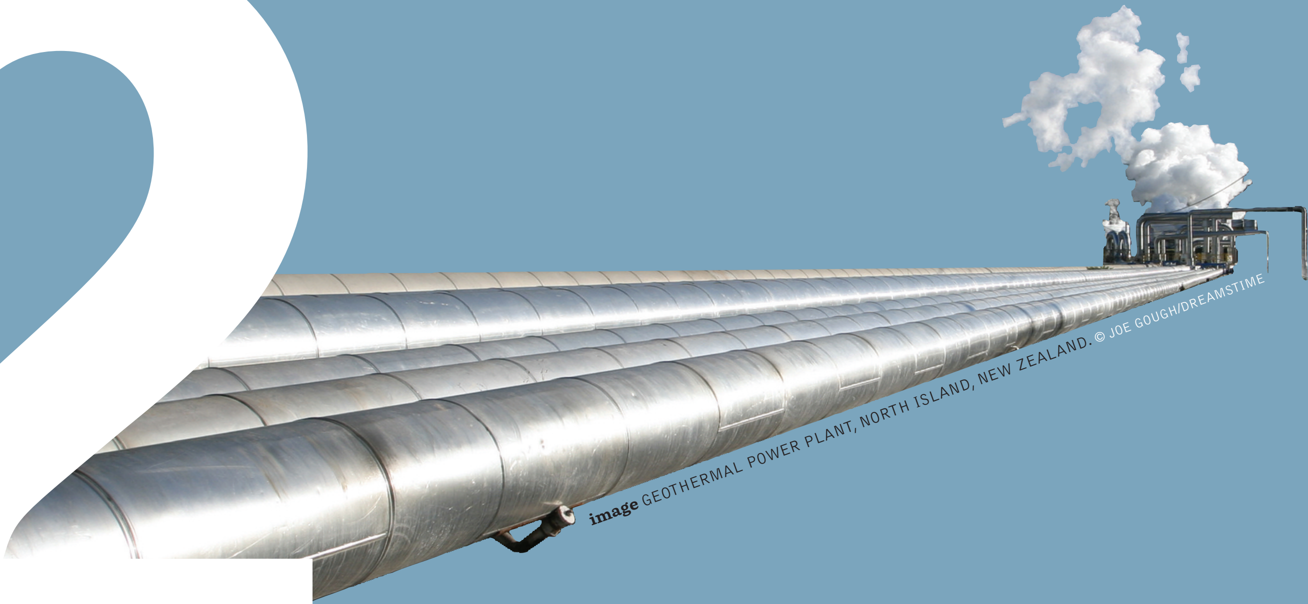


**image** GEOTHERMAL POWER PLANT, NORTH ISLAND, NEW ZEALAND. © JOE GOUGH/DREAMSTIME

## “bridging the gap.”

**GREENPEACE INTERNATIONAL**
CLIMATE CAMPAIGN


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



## 2.1 international energy policy

At present, renewable energy generators have to compete with old nuclear and fossil fuel power stations which produce electricity at marginal cost because consumers and taxpayers have already paid the interest and depreciation on the original investment. 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 will also contribute to sustainable economic growth, high quality jobs, technology development, global competitiveness, as well as industrial and research leadership.

## 2.2 south africa's energy policy

*By Ferrial Adam and Melita Steele*

This section examines the energy sector in South Africa. It provides a short background to the development of the energy sector both during and after apartheid and reviews the energy mix and supply in the country. In addition, the section pays particular attention to electricity supply. Finally, some emphasis is given to the range of government policies on energy have been developed, which have influenced the developments in the energy sector in South Africa.

### 2.2.1 background

It is a fact that South Africa has benefited from an abundant and cheap supply of electricity since the founding of the monopoly public utility, the Electricity Supply Commission, or Eskom, in 1928. Low labour costs under apartheid, combined with South Africa's large reserves of coal, enabled Eskom to subsidize industrial development and to become a surplus producer. The surplus ultimately resulted in Eskom exporting electricity to neighbouring countries and the utility is the largest producer of electricity in Africa.

The apartheid government was principally concerned with security of supply in the face of increasing sanctions. During the 1950s the government focused on the production of synthetic fuels and nuclear energy. In the 1960s and 70s the South African government invested hugely in electricity generation which was mostly coal fired. By the eighties and the nineties economic growth had begun to decline but the supply of electricity remained constant. This resulted in an excess of capacity and in 1992 electricity capacity exceeded peak demand by 63% - another reason for low electricity prices (Winkler[10]). The combination of cheap and abundant coal and the low cost of electricity resulted in South African industries becoming energy intensive. In addition, the low cost of South Africa's electricity has deterred foreign power companies from entering the market. As a result, even today Eskom supplies 95% of the country's power. South Africa has an installed generation capacity of approximately 40,000 MW.

Since the early nineties there has been rapid growth in electricity demand without the necessary growth in capacity development, which is one of the factors that led to the recent electricity crisis. In 2008, South Africa experienced a massive power shortage which resulted in an unreliable supply of electricity as Eskom was forced to switch off parts of the electricity grid to lighten the load (load-shedding). It is believed that the immediate cause was a shortage of coal at Eskom's power stations and a very wet rainy season that had flooded coal mines and impeded transport of coal to the power stations.

South Africa's robust economic growth, the government's most desired outcome, has put additional pressure on South Africa's electricity supply. Furthermore, since 1994, the government's electrification policy has led to the doubling of the population served by electricity. Eskom's 1.2 million customers in 1990 grew to 4 million in 2007. At the same time the government decided not to build more power plants and even mothballed two existing plants, reducing generating capacity from 45,000 megawatts to 37,000-40,000 megawatts.

Some believe that the electricity crisis was a blessing in disguise. It forced the government to review its energy policies and promote generation of power by private enterprises. More importantly the crisis was a step towards giving more serious attention to renewable energy, energy efficiency and greater public awareness of the need to conserve energy.

### 2.2.2 key players in the energy sector

In January 2008, the Department of Minerals and Energy[11] and Eskom announced the National Electricity Emergency Programme and released a new policy document, the "National response to South Africa's electricity shortage" as a response to the electricity crisis facing the country. The policy includes information on the country's electricity distribution structure, and the planned fast-tracking of electricity projects by independent power producers, but to date this fast-tracking has not materialised.

It also involves electricity co-generation projects between Eskom and private industry, where the heat generated as a by-product of industrial processes is captured to produce power that can either be used by industries, or bought by Eskom for the national grid. Despite its importance, progress has been quite slow.

**references**
10 H WINKLER, 2009, CLEANER ENERGY COOLER CLIMATE, SOUTH AFRICA: HSRC.
11 AFTER THE 2009 NATIONAL ELECTIONS THE DEPARTMENT HAS BEEN SEPARATED FROM MINERALS AND IS NOW CALLED THE DEPARTMENT OF ENERGY.

In April 2010, Minister of Energy Dipuo Peters announced energy saving initiatives as part of the National Electricity Emergency Programme. These included:

- The planned introduction of a financial incentive scheme for project developers to claim a rebate for energy they have saved from the electricity system.
- Government aiming to retrofit an estimated 100,000 public buildings to comply with energy efficiency standards.
- A Solar Water Heater (SWH) programme, whereby a million Solar Water Heaters will be progressively deployed in residential dwellings.
- The Working for Energy Programme – the primary objective of this programme is to use the feedstock created from clearing alien vegetation to produce power.

The South African government has also established a national energy efficiency campaign to encourage all sectors to make energy savings.

Until these policies are implemented, the main stakeholders within the energy sector remain government established structures and include the following:

**Department of Energy** President Jacob Zuma announced a new cabinet on 10 May 2009, which necessitated the establishment of the Department of Energy. The department has a legislative mandate to ensure the secure and sustainable provision of energy for socio-economic development, and has a vision of creating "transformed and sustainable energy sector with universal access to modern energy carriers for all by 2014". Energy security is a key priority, together with ensuring access to energy and regulating the energy sector.

**Eskom** South Africa generates over half the electricity used in Africa. This production is dominated by the national public utility, Eskom, which generates 95% of total production. Municipal generators and certain industries like pulp mills, sugar refineries, Sasol and Mossgas also generate small amounts of electricity.

**Central Energy Fund** CEF (Pty) Ltd. is a private company, incorporated in terms of the Companies Act, and is governed by the CEF Act. The State is the primary shareholder and the company is thus controlled by the Minister of Energy. The CEF is involved in the "search for appropriate energy solutions to meet the future energy needs of South Africa, the Southern African Development Community and the sub-Saharan African region." CEF also manages the operation and development of the oil and gas assets and operations of the South African government[12].

**EDI Holdings** Electricity Distribution Industry Holdings (Pty) Ltd was established in March 2003 by the Department of Minerals and Energy for the sole purpose of facilitating the restructuring of the National Electricity Distribution Industry in accordance with the requirement of the Energy White Paper and subsequent Cabinet endorsements in this regard.

**The National Energy Regulator (NERSA)** NERSA is the regulatory authority established in terms of the National Energy Regulator Act, 2004 (Act No. 40 of 2004), with the mandate to regulate the gas, petroleum pipelines and electricity industries. NERSA regulates licenses, monitors compliance, and regulates pricing and tariffs within the electricity supply industry. The regulator is also involved in electricity infrastructure planning and regulatory reform.

### 2.2.3 south africa's primary energy supply

**South Africa's main energy source has always been coal, which the country has had in abundance.** The country also has large reserves of uranium and small reserves of oil and gas. As such, South Africa continues its dependence on coal for the production of electricity. This means that the country's economy is highly dependent on fossil fuels, and South Africa is one of the highest emitters of greenhouse gas per capita in the world. The second biggest energy carrier is imported crude oil, needed for the supply of liquid fuels for transportation. Moderate amounts of nuclear, gas and hydro also contribute to the energy mix.

The current mix of electricity generation capacity continues to be dominated by coal (91%), with nuclear electricity from Koeberg in the Cape making up an additional 5%. Other smaller stations to meet peak requirements are open cycle gas turbines (0.1%) and pumped storage and hydro stations (2%). However, the price of electricity is steadily increasing in South Africa, with NERSA announcing an increase in tariffs to 24.8 percent in 2010/2011, 25.8 percent in 2011/2012 and an increase of 25.4 percent in 2012/2013.

### 2.2.4 the renewable energy feed-in tariff (REFIT)

NERSA approved the REFIT Guidelines on 26 March 2009. The REFIT has been long awaited as it opens the door for the renewable energy sector in South Africa to grow and to become economically viable. Tariffs for various technologies were agreed in 2009 and the initial timeframe for projects under the REFIT was March 2009. However, the first uptake of REFIT projects is yet to commence. In addition, NERSA published a review of these tariffs for public consultation in 2011, with the tariffs being revised downwards:

| TECHNOLOGY UNIT REFIT | REFIT TARIFFS – 2011 |
|---|---|
| Wind | R/kWh 0.938 |
| Small hydro | R/kWh 0.671 |
| Landfill gas | R/kWh 0.539 |
| Concentrated solar | R/kWh 1.836 |

Although at the time of printing this report the revised tariffs had not been finalised, the fact that NERSA is proposing reducing them before there has even been any uptake is worrying, and creates uncertainty in an as yet untested renewable energy sector.

### 2.2.5 government response plan

The response by Government to the energy crisis has seen the immediate need for the country to ensure that energy, specifically the electricity system, is brought back into balance.

The Government's demand side management programme focuses on reducing the amount of energy required by consumers. This is a key focus area for energy efficient measures such as CFLs, efficient transport, solar water heaters, etc.

**references**
**12** WWW.CEF.ORG.ZA

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

© GP/MARKEL REDONDO



In terms of supply side management, the focus here is ensuring that the amount of energy that is available is enough to meet demand. Eskom is undertaking a 'new build programme', which is focused on building additional power stations and major power lines on a massive scale to meet rising electricity demand. Eskom's capacity expansion budget is expected to grow to more than a trillion Rand by 2026. Ultimately, Eskom plans to double its capacity to 80,000 MW by 2026[13]. For example, mothballed power stations have been brought back on line and Eskom is building two of the biggest coal-fired power stations in the world (Medupi and Kusile). Medupi will have an installed capacity of 4,788 MW, and Kusile will have an installed capacity of 4,800 MW. These mega coal-fired power stations will significantly contribute to climate change and continue South Africa along a dirty energy pathway. The annual greenhouse gas equivalent emissions for Kusile are estimated to be 36.8 million tonnes, increasing South African energy sector emissions by 12.8% and the country's total contribution to climate change by 9.7%.

The new build programme also includes a nuclear expansion programme, as the Policy Adjusted Integrated Resource Plan[14] makes provision for six new nuclear power stations to be built over the next two decades.

National treasury will provide Eskom with a R7.6 billion loan – part of the R43 billion costs – for the new power plants over the next five years. Government has also approved guarantees totalling R350 billion over 5 years, in support of Eskom's capital expansion programme. These guarantees are in addition to the R60 billion subordinated loan from Government which was approved in July 2008. A loan for $3.75-billion was obtained from the World Bank for Medupi, and Eskom is currently seeking additional funding from a variety of sources for Kusile.

The South African Government also proposes increasing the share of renewable energy in South Africa, with a focus on solar and wind power. The renewable energy sector would be a major source of green jobs and foreign investment in South Africa. However, the upscaling of renewables needs to be significantly increased, and much more certainty must be created in the market.

Some of the focus areas for planned government action include:

**The roll-out of CFLs -** It is projected that 600 MW could be saved by replacing incandescent light bulbs with CFLs. A key consideration is the need to ensure that whilst the retrofitting is done on the basis of free exchange, this does not result in environmental pollution as a result of mercury contamination. The Department of Water and Environmental Affairs is expected to develop protocols for waste disposal of CFLs. The programme also accommodates a free CFL exchange for low income households until 2015.

**Immediate restriction on the sale of incandescent light bulbs -** To ensure that the use of CFL's is sustained, legislation that restricts the selling of any lamp that has an efficiency level of less than 20 lumens per watt will be introduced. There will be certain exclusions granted for lamps for ovens, microwaves and for sensitive buildings and special cases.

**Solar Water Heating Programme -** On 23 June 2009, the Minister of Energy in her budget vote speech stated that: "The Department will ensure that one million solar water heaters (SWHs) are installed in households and commercial buildings over a period of five years." The programme is managed by Eskom, but there had been a replacement of fewer than 2% of existing electric geysers by December 2010. The current cost of solar water heaters is prohibitive (it is estimated to cost between R7,000 to R20,000), and Eskom has been providing a subsidy of 20-30% depending on the cost of the unit. However, Eskom has recently announced that the subsidy that it provides will soon be reduced. The potential savings of this programme are 650 MW.

**National Housing Specifications -** Energy efficient building standards are to be legislated and implemented by the Department of Housing and Public Works for Government buildings. Local government has indicated that the municipal by-laws will entrench energy efficient behaviour. For example, the Department of Housing will mandate that all new houses that are more than $100m^2$ in area are to be fitted with solar water heaters.

**Smart metering for residential customers (Load management) -** Smart metering allows for the consumers' consumption to be measured remotely. The advantage is that the cost of meter reading is drastically reduced and the accuracy of the reading is improved. In the context of energy management, smart metering provides for the remote connection and disconnection of consumers when their electricity consumption exceeds a threshold level set by the utility. In this case a quick cost benefit analysis indicates that improved communications between the utility and the customer meter will result in big energy savings during peak demand periods.

**Fuel switching -** This refers to the substitution of electricity as a domestic energy source with Liquefied Petroleum Gas (LP Gas), in order to lower the burden of electricity generation.

### 2.2.6 national policies and trends

Energy is a requirement for social and economic development, and therefore a lack of access to energy contributes to poverty. A quarter of the world's population has no access to electricity and most of these people live in South Asia and sub-Saharan Africa. Current figures indicate that 2.4 billion people rely on traditional biomass – wood, agriculture residues and dung – for cooking and heating which accounts for more than 80% of their household energy needs.

Energy poverty is a global problem. However, South Africa is unique in that not only is the country a developing nation but it must also deal with the legacy of apartheid where the majority of South Africans were denied access to basic infrastructure and services. Many people still live in informal settlements and have to use candles or paraffin which are not safe and over the years have led to many fires resulting in homelessness and death. Furthermore the burning of biomass (such as firewood and coal) for cooking or heating as well as the use of paraffin has resulted in high levels of indoor air pollution.

**references**
13 HTTP://WWW.ESKOM.CO.ZA/LIVE/CONTENT.PHP?ITEM_ID=5981
14 HTTP://WWW.DOE-IRP.CO.ZA/CONTENT/IRP2010_2030_FINAL_REPORT_20110325.PDF

There has been significant growth in urbanisation in South Africa. It is estimated that approximately 58% of the population live in urban areas. Informal settlements have been increasing steadily over the past 10 years. Twenty six percent of the population remain without a legal connection to electricity. Unconnected households are expected to grow as rural residents move to urban areas.

Since 1994 South Africa has given impetus to changing and developing legislation in the energy sector as well as identified key socio-economic development projects to deal with the backlogs of the past. Some of the key documents to have emerged include:

**White Paper on Energy Policy (1998)** This document outlined five key objectives: to increase access to affordable energy services particularly to meet the basic needs of the poor, to improve energy governance, to stimulate economic development, to manage energy related environmental impacts particularly focusing on poor households and to secure supply through diversity. In 1998, at the time this paper came out, 40% of all homes and many schools and clinics in South Africa were without access to electricity supply.

**White Paper on Renewable Energy Policy (2003)** This paper sets out the government's vision and objectives for promoting and implementing renewable energy in South Africa. It states clearly that South Africa has relied on cheap coal to meet its energy demands and that given the greenhouse gas emissions from the use of fossil fuels and South Africa's ratification of the Kyoto Protocol it is imperative for government to establish a robust renewable industry. The target set by the White Paper is that South Africa should produce 10,000 GWh (0.8 Mtoe) of renewable energy by 2013. It clearly articulates that South Africa has abundant renewable energy resources and that the South African government must introduce fiscal and financial support mechanisms and legal instruments, develop institutional infrastructure, develop technology and build awareness and capacity, to enable the take up of these resources. This paper also called for a mid-term assessment in 2008, which was scheduled to occur in 2010. However, the review of the renewable energy white paper has not been released for stakeholder comment by mid 2011 and has not informed the integrated resource planning process.

**Energy Efficiency Strategy (2005)** The vision of this strategy is to strive for affordable energy for all, and to minimise the negative effects of energy usage on human health and the environment through sustainable energy development and efficient practices. The strategy sets a target of 12% energy savings by 2015 with 8 goals based on social, environmental and economic sustainability. The Department of Energy is reviewing this document in the light of a significant underachievement of targets.

**National Energy Bill (2008)** The primary objectives of this Bill are to ensure an uninterrupted and diverse supply of energy, facilitate effective management of energy demand, promote energy research and standards, ensure data collection, optimise supply and demand, facilitate universal access to energy at affordable prices and ensure the health and safety of people and the environment. To this end it is proposed that the Minister must annually review and publish an integrated energy plan and set up the South African National Energy Development Institute focusing on energy efficiency and energy research and development.

**South African National Energy Research and Development Strategy** The South African National Energy Research and Development Strategy identified the following medium- to long-term research themes related to renewable energy:

- Energy infrastructure optimisation;
- Energy efficiency and demand-side management;
- The impact of energy use on the environment;
- The use of energy to stimulate socio-economic development;
- Cleaner fossil fuel use, including clean coal;
- Renewable energy;
- Alternative energy sources, including fuel cells and hydrogen;
- Energy planning and modelling; and
- Energy policy research

The South African National Energy Research Institute (SANERI) – established in 2004 – will be responsible for addressing these key themes, and is a wholly owned subsidiary of CEF focusing on research and development within the energy sector. SANERI's challenge is to effectively develop practical guidelines for how South Africa can best take advantage of 'clean and renewable energy' so that technologies can be developed that fully exploit the country's natural resources.

**Long Term Mitigation Scenarios (2008)** The Long Term Mitigation Scenarios (LTMS) is a cabinet-approved document developed by the Department of Environmental Affairs & Tourism. The LTMS has become the country's main backbone to its response to climate change. The document outlined three key scenarios:

1. **Growth without constraints**, which is a scenario whereby there are no constraints to growth and coal expansion, and nothing is done to reduce emissions. This would mean a four-fold increase in emissions by 2050, which means the scenario is entirely unrealistic, given the threat of climate change and the fact that we live in a carbon constrained world.
2. **Current development path**, which will closely track the growth without constraints scenario, and will not be sufficient to combat climate change, and
3. **Required by science**, which models how South Africa would reduce emissions if it joins the world community in taking action to stabilise greenhouse gas concentrations, and negotiates a target as its fair contribution to this shared vision. This scenario includes a major shift towards both nuclear and renewable energy.

The LTMS notes that by 2050 there would be a huge gap of 1,300 Mt $CO_2$ between the growth without constraints and required by science scenarios. The document argues that greenhouse gas emissions should plateau by 2020 and decline by 2030 and identifies two key domestic alternatives to coal: nuclear and renewable energy. In addition, the LTMS outlines the 'immediately implementable' strategic mitigation options, which are: energy efficiency; electricity supply options; CCS and transport efficiency and shifts, together with the introduction of a carbon tax.

**image** A WOMAN STUDIES SOLAR POWER SYSTEMS AT THE BAREFOOT COLLEGE. THE COLLEGE SPECIALISES IN SUSTAINABLE DEVELOPMENT AND PROVIDES A SPACE WHERE STUDENTS FROM ALL OVER THE WORLD CAN LEARN TO UTILISE RENEWABLE ENERGY. THE STUDENTS TAKE THEIR NEW SKILLS HOME AND GIVE THEIR VILLAGES CLEAN ENERGY.




**The Electricity Regulation Act (2006)** This Act was amended in 2008 making provision for energy efficiency measures with respect to lighting, water heating and space heating/cooling and smart metering to be enforced as well as ensuring that incentives and penalties are legislated. These energy efficiency applications included in the Act are largely the responsibility of municipalities to enforce and/or implement by 2012.

**The Policy Adjusted Integrated Resource Plan 2010** The plan was released for promulgation in March 2011, and includes a total of 17.8 GW of renewable energy by 2030. This would include 8.4 GW of solar PV, 1.0 GW concentrating solar power and 8.4 GW of wind. Despite this substantial increase in renewable energy by 2030, the plan does not go far enough to mitigate the impacts of climate change, create green jobs or effectively create the shift towards a clean energy supply for South Africa.

The plan also includes the provision for 6 new nuclear power stations, totalling 9.6 GW of new capacity and the mega coal-fired power stations Medupi and Kusile, as planned.

Not only was this plan developed without a review of the renewable energy white paper, but it was also developed without an over-arching Integrated Energy Plan (IEP) – both of which should inform the electricity planning for the country.

**The Industrial Policy Action Plan (IPAP2)** IPAP2 represents a significant step forward in recognising the need for South Africa to develop its renewable energy industry. The plan includes nuclear into the energy mix as a priority, but also includes a focus on the REFIT tariff to ensure that renewable energy is linked to the development of domestic green manufacturing capacity. It also outlines the need to focus on obtaining international financing to boost renewable energy production.

**The National Climate Change Response Policy Green Paper** The Department of Water and Environmental Affairs released the National Climate Change Response Green Paper for comment in early 2011 which sets out the Government's vision for a response to climate change and the long-term transition to a climate resilient and low-carbon society. This Policy is crucial in terms of driving South Africa's action on climate change forward and must create significant emissions reductions together with the significant uptake of renewable energy and energy efficiency. However, the Green Paper lacked concrete timelines and targets, placed a great deal of emphasis on Carbon Capture and Storage (an as yet unproven technology) and risky nuclear energy as key cornerstones of South Africa's response to climate change. A White Paper is expected in 2011, and it is unclear whether there will be further public participation in the process.

**The National Planning Commission** The National Planning Commission is a new initiative of government. Chaired by the Minister in the Presidency for National Planning, the NPC will be responsible for developing a draft long term vision and strategic plan for South Africa, to be finally accepted by cabinet. The Commission will also advise on cross-cutting issues that impact on South Africa's long term development, including the issue of climate change and a low carbon development pathway.

**Carbon Tax** The National Treasury is investigating the implementation of a carbon tax and released a discussion Paper for public comment entitled "Reducing greenhouse gas emissions: the carbon tax option" in December 2010. South Africa will seek to finalise its carbon tax policy by mid 2011, aiming for implementation in 2012, despite the absence of a global price on carbon. The National Treasury recommends a direct tax on carbon emissions, which the Treasury believes should impose the lowest distortion on the economy. The discussion document argues that a tax of R75/t $CO_2e$, increasing to around R200/t $CO_2e$ "would be both feasible and appropriate to achieve the desired behavioral changes and emissions reduction targets". This process is still ongoing in 2011.

By the end of 2010, South Africa had already introduced a carbon emissions tax on all new passenger vehicles, which is commendable. This tax will add R75 for every gram of carbon dioxide a new car emits above 120 g/km per kilometre.

### 2.2.7 private sector contribution

The private sector in South Africa has increasingly been involved in a range of energy-related initiatives and projects. These projects vary in size and scope. Below is an outline of some of the key areas of impact and agreements made within the private sector in South Africa.

- **Voluntary Energy Efficiency Accord** In 2005, following the adoption of the Energy Efficiency Strategy, a number of South African companies signed a voluntary Energy Efficiency Accord with Government through the Minister of Minerals and Energy. The main aim of the Accord was to assist in implementing the strategy and contributing to the achievement of the announced energy efficiency targets. Currently there are 44 signatories of the Accord comprising 36 companies and 8 key business associations.

  The collective electricity consumption of about 19 Accord signatories is over 56 560 GWh, which is about 24% of the national electricity consumption. The energy efficiency potential of the Accord is thus very significant and could therefore be a central place for collaboration on energy management in coal mining, transportation and consumption.

- **The Carbon Disclosure Project** The National Business Initiative (NBI) has partnered with Incite Sustainability to develop a Carbon Disclosure Project (CDP) in South Africa. The CDP serves as the secretariat for the world's largest institutional collaboration on the business implications of climate change. Through the CDP companies sign a single global request for disclosure of information on Greenhouse Gas Emissions. The CDP is seen as an important step in helping companies identify and strategise around the impacts of Climate Change.

- **Clean Development Mechanism - Registered South Africa projects** The Clean Development Mechanism (CDM) is a component of the Kyoto Protocol, allowing developed companies and governments to invest in projects in developing countries that reduce emissions, thereby helping industrialised countries meet their emissions targets. In theory projects must promote sustainable development in the developing country. The custodian for the CDM in South Africa is the Designated National

Authority (DNA), which was established in 2004. As of 2009 there were 14 active South African CDM projects registered, and a further 14 projects at an advanced stage of development. This is out of the 1,652 projects that have been registered globally.

The projects submitted to the DNA for review and approval cover the following project types: biofuels; energy efficiency; waste management; cogeneration; fuel switching and hydro power. These projects cut across sectors such as manufacturing, mining, agriculture, energy, waste management, housing and residential.

### 2.2.8 key issues

One of the biggest problems in South Africa right now is that the work being done on energy is very disjointed. There are plans at the national, provincial and local levels. None of these plans are linked or relate to each other. In addition, Government has repeatedly been reactive rather than proactive which has meant that finding long term integrated solutions is more difficult.

In an emerging economy like South Africa, development and poverty alleviation are still the primary objectives, and will be for the foreseeable future. As such, security of energy supply is of paramount importance. The pressing social needs relating to energy use and energy access must be addressed. Many people rely on 'dirty' fuels to meet their daily energy needs and transport to and from the workplace is costly due to the urban sprawl created under apartheid. The lack of access to modern energy affects health and development and government is intent on addressing unemployment and increasing GDP growth in the coming years. Economic growth is accompanied by increased demand for energy, which means that supply must meet demand. Scaling up renewable energy production together with the more efficient use of energy would mean that Kusile does not have to be built and new nuclear power could be dropped from electricity planning.

Importantly, the choices that South Africa makes now will determine the country's energy future, affecting standards of living, levels of job creation, the environment and its economic future. The first steps have been taken to move South Africa towards a green development pathway, but there is a great deal left to do for the country to create a better life for all and become a climate leader.

**"There is a great opportunity in the development of industries that combat the negative effects of climate change. South Africa needs to develop strong capacity in green technologies and industries...We must be able to prove that faster economic growth can be achieved alongside the sustainable management of our natural resources"**

**PRESIDENT JACOB ZUMA, KEYNOTE ADDRESS, GREEN ECONOMY SUMMIT, 18 MAY 2010**

### bibliography

Agama Energy (2003), Employment Potential of Renewable Energy in South Africa published by Earthlife Africa Johannesburg.

B. Bekker et al (2008), South Africa's rapid electrification programme: Policy, institutional, planning, financing and technical innovations, Energy Policy 36, 3115–3127

Capacity Building in Energy Efficiency and Renewable Energy (2002): Baseline study - solar energy, Report No. – 2.3.4-13, Department of Minerals and Energy Pretoria

Cape Town Energy Strategy, October 2003, City of Cape Town

Douglas Banks and Jason Schaffler (2007), A Proposed Renewable Energy Plan of Action for the Western Cape - Resource Assessment, Scenarios, Proposed Objectives and Actions, Department of Environmental Affairs and Development Planning

Energising South African Cities and Towns (2003), Sustainable Energy Africa

E[R] 2010, Energy [R]evolution - A sustainable world energy outlook. Greenpeace International, Amsterdam, EREC European Renewable Energy Council, Brussels, June 2010 http://www.energyblueprint.info/fileadmin/media/documents/2010/0910_gpi_E_R__full_report_10_lr.pdf

Groundwork Report (2007), Peak Poison – the elite energy crisis and environmental justice

Gauteng Integrated Energy Strategy (draft), 2009, Department of Local Government and Housing.

Holm, D., Banks, D., Schäffler, J., Worthington, R., and Afrane-Okese, Y. (2008), Renewable Energy Briefing Paper: Potential of Renewable Energy to contribute to National Electricity Emergency Response and Sustainable Development

Mary Haw and Alison Hughes (2007), Clean Energy and Development for South Africa: Background Data, Energy Research Centre, University of Cape Town

South Africa National Energy Bill (2008), DME website

Stanford A. J. Mwakasonda (2004), Policies and Measures for Renewable Energy, V0l 43 Science Forum

Western Cape Sustainable Energy Strategy (2007), Department of Environmental Affairs and Development Planning

### websites

CEF, www.cef.org.za

Daniel O'Flaherty, South Africa's "National Energy Emergency", http://forums.csis.org/africa/?p=92

Department of Energy, Policy Adjusted Integrated Resource Plan, http://www.doe-irp.co.za/content/IRP2010_2030_Final_Report_20110325.pdf

Eskom, http://www.eskom.co.za/live/content.php?Item_ID=5981

Friederich-Ebert-Stiftung (2008), Focus South Africa, www.fes.org.za

Renewable Energy Policy Network for the 21st Century, www.ren21.net

Sustainable Energy Africa, www.sustainable.org.za

# 3

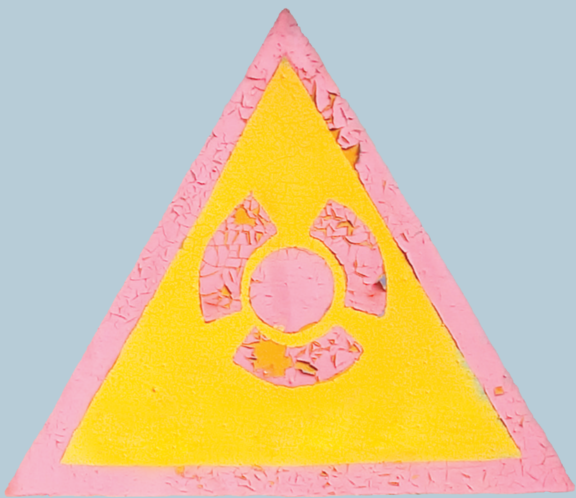


**image** SIGN ON A RUSTY DOOR AT CHERNOBYL ATOMIC STATION.


## "safety and security risks, radioactive waste, nuclear proliferation..."

**GREENPEACE INTERNATIONAL**
CLIMATE CAMPAIGN

Nuclear energy is a relatively minor industry with major problems. It covers just one sixteenth of the world's primary energy consumption, a share set to decline over the coming decades. The average age of operating commercial nuclear reactors is 25 years. The number of operating reactors as of May 2011 was 443, less than at the historical peak of 2002.

In terms of new power stations, the amount of nuclear capacity added annually between 2000 and 2009 was on average 2,500 MWe. This was six times less than wind power (14,500 MWe per annum between 2000 and 2009). In 2009, 37,466 MW of new wind power capacity was added globally to the grid, compared to only 1,068 MW of nuclear. This new wind capacity will generate as much electricity as 12 nuclear reactors; the last time the nuclear industry managed to add this amount of new capacity in a single year was in 1988.

Despite the rhetoric of a 'nuclear renaissance', the industry is struggling with a massive increase in costs and construction delays as well as safety and security problems linked to reactor operation, radioactive waste and nuclear proliferation. The Fukushima nuclear accident (see below) 25 years after the disastrous explosion in the Chernobyl nuclear power plant in former Soviet Union, proves nuclear energy is inherently unsafe and raises additional doubts about the nuclear industry's ability to deliver on their promises of safety and security.

## 3.1 a solution to climate protection?

The nuclear industry's promise of nuclear energy to contribute to both climate protection and energy security needs to be checked against reality. In the most recent Energy Technology Perspectives report published by the International Energy Agency(IEA)[15], for example, its Blue Map scenario outlines a future energy mix which would halve global carbon emissions by the middle of this century. To reach this goal the IEA assumes a massive expansion of nuclear power between now and 2050, with installed capacity increasing four-fold and electricity generation reaching 9,857 TWh/year, compared to 2,608 TWh in 2007. In order to achieve this, the report says that on average 32 large reactors (1,000 MWe each) would have to be built every year from now until 2050. This is not only unrealistic, but also expensive, hazardous and too late to protect the climate. Even if realised, according to the IEA scenario, such a massive nuclear expansion would only cut carbon emissions by less than 5%.

**unrealistic:** Such a rapid nuclear growth is practically impossible given the technical limitations. This scale of development was achieved in the history of nuclear power for only two years at the peak of the state-driven boom of the mid-1980s. It is unlikely to be achieved again, not to mention maintained for 40 consecutive years. While 1984 and 1985 saw 31 GW of newly added nuclear capacity, the decade average was 17 GW each year. In the past ten years, less than three large reactors have been brought on line annually, and the current production capacity of the global nuclear industry cannot deliver more than an annual six units.

**expensive:** The IEA scenario assumes very optimistic investment costs of $2,100/kWe installed, in line with what the industry has been promising. The reality indicates three to four times that much. Recent estimates by US business analysts Moody's (May 2008) put the cost of nuclear investment as high as $7,500/kWe. Price quotes for projects under preparation in the US cover a range from $5,200 to 8,000/kWe[16]. The latest cost estimate for the first French EPR pressurised water reactor being built in Finland is $5,000/kWe, a figure likely to increase for later reactors as prices escalate. Building 1,400 large reactors of 1,000 MWe, even at the current cost of about $7,000/kWe, would require an investment of $9.8 trillion. At this price level, the South African government's plans to build 9,600 MW of new nuclear capacity before 2030 would cost approximately $67 billion.

**hazardous:** Massive expansion of nuclear energy would necessarily lead to a large increase in related hazards. These include the risk of serious reactor accidents like in Fukushima, Japan, the growing stockpiles of deadly high level nuclear waste which will need to be safeguarded for thousands of years, and potential proliferation of both nuclear technologies and materials through diversion to military or terrorist use. The 1,400 large operating reactors in 2050 would generate an annual 35,000 tonnes of dangerous spent nuclear fuel (for light water reactors, the most common design for most new projects). This also means the production of 350,000 kilograms of plutonium each year, enough to build 35,000 crude nuclear weapons.

**slow:** Climate science says that we need to reach a peak of global greenhouse gas emissions in 2015 and reduce them by 20% by 2020. Even in developed countries with established nuclear infrastructure it takes at least a decade from the decision to build a reactor to the delivery of its first electricity, and often much longer. This means that even if the world's governments decided to implement strong nuclear expansion now, only a few reactors would start generating electricity before 2020. The contribution from nuclear power towards reducing emissions would come too late to help save the climate.

**references**

**15** 'ENERGY TECHNOLOGY PERSPECTIVES 2008 - SCENARIOS & STRATEGIES TO 2050', IEA.
**16** PLATTS, 2008; *ENERGY BIZ*, MAY/JUNE 2008

**image** MEASURING RADIATION LEVELS OF A HOUSE IN THE TOWN OF PRIPYAT THAT WAS LEFT ABANDONED AFTER THE CHERNOBYL NUCLEAR DISASTER, UKRAINE.





## 3.2 nuclear power blocks solutions

Even if the ambitious nuclear scenario is implemented, regardless of costs and hazards, the IEA concludes that the contribution of nuclear power to reductions in greenhouse gas emissions from the energy sector would only be 4.6% - less than 3% of the global overall reduction required.

There are other technologies that can deliver much larger emission reductions, and much faster. Their investment costs are lower and they do not create global security risks. Even the IEA finds that the combined potential of efficiency savings and renewable energy to cut emissions by 2050 is more than ten times larger than that of nuclear.

The world has limited time, finance and industrial capacity to change our energy sector and achieve a large reduction in greenhouse emissions. Choosing the pathway of spending $10 trillion on nuclear development would be a fatally wrong decision. This is particularly true for South Africa, a country with some of the best renewable energy resources in the world and enormous economic and job creation potential, when it invests in renewable energy manufacturing industry now. Nuclear energy would not save the climate but it would necessarily take resources away from solutions described in this report and at the same time create serious global security hazards. Therefore new nuclear reactors are a clearly dangerous obstacle to the protection of the climate.

## 3.3 nuclear power in the energy [r]evolution scenario

For the reasons explained above, the Advanced Energy [R]evolution scenario envisages a nuclear phase-out. Existing reactors would be closed at the end of their average operational lifetime of 35 years. We assume that no new construction is started and only two thirds of the reactors currently under construction worldwide will be finally put into operation. In South Africa, the plans for nuclear expansion would be cancelled.

## 3.4 the dangers of nuclear power

Although the generation of electricity through nuclear power produces much less carbon dioxide than fossil fuels, there are multiple threats to people and the environment from its operations.

The main risks are:

- Safety Risks
- Nuclear Waste
- Nuclear Proliferation

This is the background to why nuclear power has been discounted as a future technology in the Advanced Energy [R]evolution scenario.

### 3.4.1 safety risks

Windscale (1957), Three Mile Island (1979), Chernobyl (1986), Tokaimura (1999) and Fukushima (2011) are only a few of the hundreds of nuclear accidents which have occurred to date. The Fukushima nuclear disaster in March 2011 has been a stark wake-up call causing governments all over the world to rethink their nuclear plans. Despite the nuclear industry's assurances that a nuclear accident on the scale of Chernobyl could never happen again, the earthquake and subsequent tsunami in Japan caused leaks and explosions in 4 reactors of the Fukushima nuclear power plant. Large areas around the nuclear power plant have been seriously contaminated by radioactive releases from the plant. An area of 30 km around the facility has been evacuated, and food and water restrictions apply at distances more than 100 km. The impacts on the lives of hundreds of thousands of people as well as the Japanese economy will be felt for decades to come.

Nuclear energy is inherently unsafe because:

- An accident like in Fukushima can happen in many of the existing nuclear reactors, as they all need continuous power to cool the reactors and spent nuclear fuel, even after the reactor has shut down. A simple power failure at a Swedish nuclear plant in 2006 highlighted this problem. Emergency power systems at the Forsmark plant failed for 20 minutes during a power cut and four of Sweden's ten nuclear power stations had to be shut down. If power had not been restored there could have been a major incident within hours.
- A nuclear chain reaction must be kept under control, and harmful radiation must, as far as possible, be contained within the reactor, with radioactive products isolated from humans and carefully managed. Nuclear reactions generate high temperatures, and fluids used for cooling are often kept under pressure. Together with the intense radioactivity, these high temperatures and pressures make operating a reactor a difficult and complex task.
- The risks from operating reactors are increasing and the likelihood of an accident is now higher than ever. Most of the world's reactors are more than 25 years old and therefore more prone to age related failures. Many utilities are attempting to extend their lifespan from the 30 years or so, they were originally designed for, to up to 60 years, posing new risks.
- De-regulation has meanwhile pushed nuclear utilities to decrease safety-related investments and limit staff whilst increasing reactor pressure and operational temperature and the burn-up of the fuel. This accelerates ageing and decreases safety margins.

### 3.4.2 nuclear waste

Despite 50 years of producing radioactive waste, there is no solution for the long term storage and safeguarding of these dangerous materials. Disposal sites of low level radioactive waste have already started leaking after decades, while the highly radioactive waste will need to be safely stored for hundreds of thousands of years. The nuclear industry claims it can 'dispose' of its nuclear waste by burying it deep underground, but this will not isolate the radioactive material from the environment forever. A deep dump only slows down the release of radioactivity into the environment. The industry tries to predict how fast a dump will leak so that it can claim that radiation doses to the public living nearby in the future will be "acceptably low". But scientific understanding is not sufficiently advanced to make such predictions with any certainty.

As part of its campaign to build new nuclear stations around the world, the industry claims that problems associated with burying nuclear waste are to do with public acceptability rather than technical issues. It points to nuclear dumping proposals in Finland, Sweden or the United States to underline its argument, but there is no scientific backing of its claims of safe disposal.

The most hazardous waste is the highly radioactive waste (or spent) fuel removed from nuclear reactors, which stays radioactive for hundreds of thousands of years. In some countries the situation is exacerbated by 'reprocessing' this spent fuel, which involves dissolving it in nitric acid to separate out weapons-usable plutonium. This process leaves behind a highly radioactive liquid waste. There are about 270,000 tonnes of spent nuclear waste fuel in storage, much of it at reactor sites. Spent fuel is accumulating at around 12,000 tonnes per year, with around a quarter of that going for reprocessing[17].

The least damaging currently available option for waste is to store it above ground, in dry storage at the site of origin. However, this option also presents major challenges and threats, as was seen in the Fukushima accident where the cooling of the spent nuclear fuel pools posed major problems. The only real solution is to stop producing the waste.

### 3.4.3 nuclear proliferation

Manufacturing a nuclear bomb requires fissile material - either uranium-235 or plutonium-239. Most nuclear reactors use uranium as a fuel and produce plutonium during their operation. It is impossible to adequately prevent the diversion of plutonium to nuclear weapons. A small-scale plutonium separation plant can be built in four to six months, so any country with an ordinary reactor can produce nuclear weapons relatively quickly.

The result is that nuclear power and nuclear weapons have grown up like Siamese twins. Since international controls on nuclear proliferation began, Israel, India, Pakistan and North Korea have all obtained nuclear weapons, demonstrating the link between civil and military nuclear power. Both the International Atomic Energy Agency (IAEA) and the Nuclear Non-proliferation Treaty (NPT) embody an inherent contradiction - seeking to promote the development of 'peaceful' nuclear power whilst at the same time trying to stop the spread of nuclear weapons.

Israel, India and Pakistan all used their civil nuclear operations to develop weapons capability, operating outside international safeguards. North Korea developed a nuclear weapon even as a signatory of the NPT. A major challenge to nuclear proliferation controls has been the spread of uranium enrichment technology to Iran, Libya and North Korea. The former Director General of the International Atomic Energy Agency, Mohamed ElBaradei, has said that "should a state with a fully developed fuel-cycle capability decide, for whatever reason, to break away from its non-proliferation commitments, most experts believe it could produce a nuclear weapon within a matter of months"[18].

The United Nations Intergovernmental Panel on Climate Change has also warned that the security threat of trying to tackle climate change with a global fast reactor programme (using plutonium fuel) "would be colossal"[19]. All of the reactor designs currently being promoted around the world could be fuelled by MOX (mixed oxide fuel), from which plutonium can be easily separated.

Restricting the production of fissile material to a few 'trusted' countries will not work. It will engender resentment and create a colossal security threat. A new UN agency is needed to tackle the twin threats of climate change and nuclear proliferation by phasing out nuclear power and promoting sustainable energy, in the process promoting world peace rather than threatening it.

**"despite the rhetoric of a 'nuclear-renaissance', the industry is struggling with a massive increase in costs and construction delays as well as safety and security problems."**

**references**
**17** 'WASTE MANAGEMENT IN THE NUCLEAR FUEL CYCLE', WORLD NUCLEAR ASSOCIATION, INFORMATION AND ISSUE BRIEF, FEBRUARY 2006 (WWW.WORLD-NUCLEAR.ORG/INFO/INF04.HTM)
**18** MOHAMED ELBARADEI, 'TOWARDS A SAFER WORLD', ECONOMIST, 18 OCTOBER 2003.
**19** IPCC WORKING GROUP II, 'IMPACTS, ADAPTATIONS AND MITIGATION OF CLIMATE CHANGE: SCIENTIFIC-TECHNICAL ANALYSES', 1995.

**image** NUCLEAR REACTOR IN LIANYUNGANG, CHINA.

**figure 3.1: the nuclear fuel chain**

U#92

### 1. uranium mining

Uranium, used in nuclear power plants, is extracted from mines in a handful of countries. Over 90% of supply comes from just seven countries: Canada, Kazakhstan, Australia, Namibia, Russia, Niger and Uzbekistan. Mine workers breathe in radioactive gas from which they are in danger of contracting lung cancer. Uranium mining produces huge quantities of mining debris, including radioactive particles that can contaminate surface water and food.

### 2. uranium enrichment

Natural uranium and concentrated 'yellow cake' contain just 0.7% of the fissionable uranium isotope 235. To be suitable for use in most nuclear reactors, its share must go up to 3 or 5% via enrichment. This process can be carried out in 16 facilities around the world. 80% of the total volume is rejected as 'tails', a waste product. Enrichment generates massive amounts of 'depleted uranium' that ends up as long-lived radioactive waste or is used in weapons or as tank shielding.

### 3. fuel rod – production

Enriched material is converted into uranium dioxide and compressed to pellets in fuel rod production facilities. These pellets fill 4 metre long tubes called fuel rods. There are 29 fuel rod production facilities globally. The worst accident in this type of facility happened in September 1999 in Tokaimura, Japan, when two workers died. Several hundred workers and villagers were also exposed to radiation.

### 4. power plant operation

Uranium nuclei are split in a nuclear reactor, releasing energy which heats up water. The compressed steam is converted in a turbine generator into electricity. This process creates a radioactive 'cocktail' which involves more than 100 products. One of these is the highly toxic and long-lasting plutonium. Radioactive material can enter the environment through accidents at nuclear power plants. The worst accidents to date happened at Chernobyl in 1986 and Fukushima in 2011. A typical nuclear reactor generates enough plutonium every year for the production of 40 nuclear weapons.

### 5. reprocessing

Reprocessing involves the chemical extraction of contaminated uranium and plutonium from used reactor fuel rods. There are now over 230,000 kilograms of plutonium stockpiled around the world from reprocessing – five kilograms is sufficient for one nuclear bomb. Reprocessing is not the same as recycling: the volume of waste increases many tens of times and millions of litres of radioactive waste are discharged into the sea and air each day. The process also demands the transport of radioactive material and nuclear waste by ship, rail, air and road around the world. An accident or terrorist attack could release vast quantities of nuclear material into the environment. There is no way to guarantee the safety of nuclear transport.

### 6. waste storage

There is not a single final storage facility for highly radioactive nuclear waste available anywhere in the world. Safe secure storage of high level waste over thousands of years remains unproven, leaving a deadly legacy for future generations. Despite this the nuclear industry continues to generate more and more waste each day.

# the energy [r]evolution

**GLOBAL**

KEY PRINCIPLES
FROM PRINCIPLES TO PRACTICE
A SUSTAINABLE DEVELOPMENT PATHWAY

NEW BUSINESS MODEL
THE NEW ELECTRICITY GRID

HYBRID SYSTEMS
SMART GRIDS

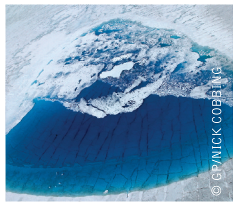
# 4

DECOUPLE GROWTH FROM FOSSIL FUEL USE. © G. POROPAT/DREAMSTIME

## “half the solution to climate change is the smart use of power.”

**GREENPEACE INTERNATIONAL**
CLIMATE CAMPAIGN

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




The climate change imperative demands nothing short of an Energy [R]evolution. The expert consensus is that this fundamental shift must begin immediately and be well underway within the next ten years in order to avert the worst impacts. What is needed is a complete transformation of the way we produce, consume and distribute energy, while at the same time maintaining economic growth. Nothing short of such a revolution will enable us to limit global warming to less than a rise in temperature of 2° Celsius, above which the impacts become devastating.

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. At the core of the Energy [R]evolution there therefore needs to be a change in the way that energy is both produced and distributed.

## 4.1 key principles

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

1. **respect natural limits – phase out fossil fuels by the end of this century** We must learn to respect natural limits. There is only so much carbon that the atmosphere can absorb. Each year humans emit over 25 billion tonnes of carbon equivalent; we are literally filling up the sky. Geological resources of coal could provide several hundred years of fuel, but we cannot burn them and keep within safe limits. Oil and coal development must be ended.

   The global Energy [R]evolution scenario has a target to reduce energy related $CO_2$ emissions to a maximum of 10 Gigatonnes (Gt) by 2050 and phase out fossil fuels by 2085.

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

   The Advanced Energy [R]evolution scenario has a target to achieve energy equity as soon as technically possible. By 2050 the average per capita emission should be between 1 and 2 tonnes of $CO_2$.

3. **implement clean, renewable solutions and decentralise energy systems** There is no energy shortage. All we need to do is use existing technologies to harness energy effectively and efficiently. Renewable energy and energy efficiency measures are ready, viable and increasingly competitive. Wind, solar and other renewable energy technologies have experienced double digit market growth for the past decade.

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

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

***Sheikh Zaki Yamani, former Saudi Arabian oil minister***

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

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

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

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

## 4.2 from principles to practice

In 2008, renewable energy sources accounted for 13% of the world's primary energy demand[20]. Biomass, which is mostly used for heating, was the main renewable energy source. The share of renewable energy in electricity generation was 19%. The contribution of renewables to primary energy demand for heat supply was around 24%. About 80% of primary energy supply today still comes from fossil fuels, and 6% from nuclear power[21].

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,

**references**

**20** WORLD ENERGY OUTLOOK 2010, IEA 2010.

**21** 'ENERGY BALANCE OF NON-OECD COUNTRIES' AND 'ENERGY BALANCE OF OECD COUNTRIES', IEA, 2009.

such as China, India and Brazil, are looking to satisfy the growing energy demand created by their expanding economies.

Within the next ten years, the power sector will decide how this new demand will be met, either by fossil and nuclear fuels or by the efficient use of renewable energy. The Advanced 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 cogeneration – on a large scale and through decentralised, smaller units – have to grow faster than overall global energy demand. Both approaches must replace old generating technologies and deliver the additional energy required in the developing world.

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 plants, is valuable as a transition fuel, and 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 of achieving emissions reductions.

## 4.3 a sustainable development pathway

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

### step 1: energy efficiency

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

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 most inefficient way, can reduce their consumption drastically without the loss of either housing comfort or information and entertainment electronics. The Advanced 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' – shifting 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 Reference scenario – but with the same GDP and population development – is a crucial prerequisite for achieving a significant share of renewable energy sources in the overall energy supply system, compensating for the phasing out of nuclear energy and reducing the consumption of fossil fuels.

### step 2: the renewable Energy [R]evolution

**decentralised energy and large scale renewables** In order to achieve higher fuel efficiencies and reduce distribution losses, the Advanced Energy [R]evolution scenario makes extensive use of Decentralised Energy (DE). This is energy generated at or near the point of use, and this kind of system would be ideal for the delivery of electricity to rural communities in South Africa that are not located near to the grid.

**figure 4.1: energy loss, by centralised generation systems**

61.5 units
LOST THROUGH INEFFICIENT GENERATION AND HEAT WASTAGE

3.5 units
LOST THROUGH TRANSMISSION AND DISTRIBUTION

13 units
WASTED THROUGH INEFFICIENT END USE


100 units >>
ENERGY WITHIN FOSSIL FUEL

38.5 units >>
OF ENERGY FED TO NATIONAL GRID

35 units >>
OF ENERGY SUPPLIED

22 units
OF ENERGY ACTUALLY UTILISED

**image** GREENPEACE OPENS A SOLAR ENERGY WORKSHOP IN BOMA, DEMOCRATIC REPUBLIC OF CONGO. A MOBILE PHONE GETS CHARGED BY A SOLAR ENERGY POWERED CHARGER.


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 nearby buildings, 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, for example heat pumps, solar thermal panels or 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 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, a decreasing demand for heat and the large potential for producing heat directly from renewable energy sources will limit the need for further expansion of CHP.

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

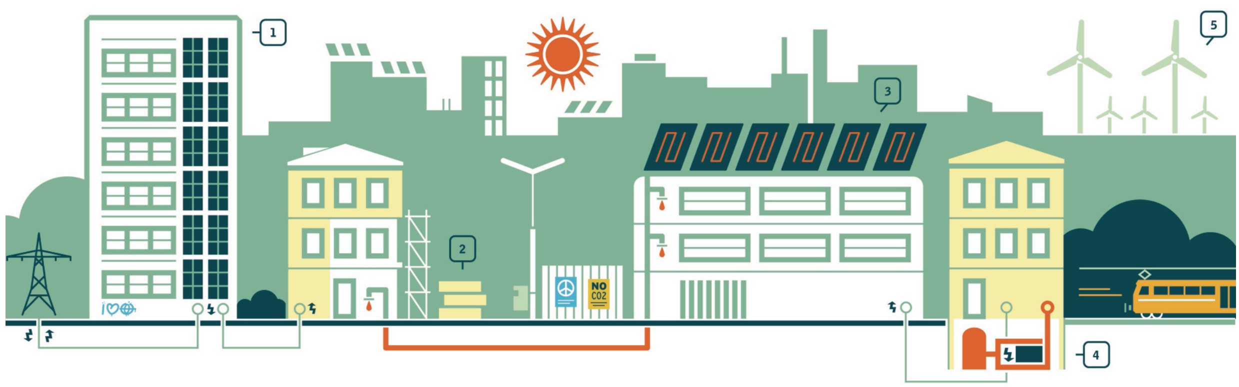
**renewable heating** In the heat supply sector, the contribution of renewables will increase significantly. Growth rates are expected to be similar to those of the renewable electricity sector. Fossil fuels will be increasingly replaced by more efficient modern technologies, in particular biomass, solar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

**transport** Before new technologies, including hybrid or electric cars and new fuels such as 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[22]. Electric vehicles will therefore play an even more important role in improving energy efficiency in transport and substituting for fossil fuels.

**figure 4.2: a decentralised energy future**

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

**city**




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

**references**

22 SEE CHAPTER 8.

Overall, to achieve an economically attractive growth of renewable energy sources, the balanced and timely mobilisation of all technologies is essential. Such a mobilisation depends on the resource availability, cost reduction potential and technological maturity. And alongside technology driven solutions, lifestyle changes - like simply driving less and using more public transport – have a huge potential to reduce greenhouse gas emissions.

## 4.4 new business model

The Advanced Energy [R]evolution scenario will also result in a dramatic change in the business model of energy companies, utilities, fuel suppliers and the manufacturers of energy technologies. Decentralised energy generation and large solar or offshore wind arrays which operate in remote areas, without the need for any fuel, will have a profound impact on the way utilities operate in 2020 and beyond.

While today the entire power supply value chain is broken down into clearly defined players, a global renewable power supply will inevitably change this division of roles and responsibilities. Table 4.1 provides an overview of today's value chain and how it would change in a revolutionised energy mix.

While today a relatively small number of power plants, owned and operated by utilities or their subsidiaries, are needed to generate the required electricity, the Advanced Energy [R]evolution scenario projects a future share of around 60 to 70% of small but numerous decentralised power plants performing the same task.

Ownership will therefore shift towards more private investors and away from centralised utilities. In turn, the value chain for power companies will shift towards project development, equipment manufacturing and operation and maintenance.

Simply selling electricity to customers will play a smaller role, as the power companies of the future will deliver a total power plant to the customer, not just electricity. They will therefore move towards becoming service suppliers for the customer. The majority of power plants will also not require any fuel supply, with the result that mining and other fuel production companies will lose their strategic importance.

The future pattern under the Advanced Energy [R]evolution scenario will see more and more renewable energy companies, such as wind turbine manufacturers, also becoming involved in project development, installation and operation and maintenance, whilst utilities will lose their status. Those traditional energy supply companies which do not move towards renewable project development will either lose market share or drop out of the market completely.

**rural electrification**[23] Energy is central to reducing poverty, providing major benefits in the areas of health, literacy and equity. More than a quarter of the world's population has no access to modern energy services. In sub-Saharan Africa, 80% of people have no electricity supply. For cooking and heating, they depend almost exclusively on burning biomass – wood, charcoal and dung.

**table 4.1: power plant value chain**

| TASK & MARKET PLAYER | (LARGE SCALE) GENERATION | PROJECT DEVELOPMENT | INSTALLATION | PLANT OWNER | OPERATION & MAINTENANCE | FUEL SUPPLY | DISTRIBUTION | SALES |
|---|---|---|---|---|---|---|---|---|
| **STATUS QUO** | | Very few new power plants + central planning | | large scale generation in the hand of few IPP´s & utilities | | global mining operations | grid operation still in the hands of utilities | |
| **MARKET PLAYER** | | | | | | | | |
| Utility | | | | | | | | |
| Mining company | | | | | | | | |
| Component manufacturer | | | | | | | | |
| Engineering companies & project developers | | | | | | | | |
| **ENERGY [R]EVOLUTION POWER MARKET** | | many smaller power plants + decentralized planning | | large number of players e.g. IPP´s, utilities, private consumer, building operators | | no fuel needed (except biomass) | grid operation under state control | |
| **MARKET PLAYER** | | | | | | | | |
| Utility | | | | | | | | |
| Mining company | | | | | | | | |
| Component manufacturer | | | | | | | | |
| Engineering companies & project developers | | | | | | | | |

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


Poor people spend up to a third of their income on energy, mostly to cook food. Women in particular devote a considerable amount of time to collecting, processing and using traditional fuel for cooking. In India, two to seven hours each day can be devoted to the collection of cooking fuel. This is time that could be spent on child care, education or income generation. The World Health Organisation estimates that 2.5 million women and young children in developing countries die prematurely each year from breathing the fumes from indoor biomass stoves.

The Millennium Development Goal of halving global poverty by 2015 will not be reached without adequate energy to increase production, income and education, create jobs and reduce the daily grind involved in having to just survive. Halving hunger will not come about without energy for more productive growing, harvesting, processing and marketing of food. Improving health and reducing death rates will not happen without energy for the refrigeration needed for clinics, hospitals and vaccination campaigns. The world's greatest child killer, acute respiratory infection, will not be tackled without dealing with smoke from cooking fires in the home. Children will not study at night without light in their homes. Clean water will not be pumped or treated without energy.

The UN Commission on Sustainable Development argues that "to implement the goal accepted by the international community of halving the proportion of people living on less than US $1 per day by 2015, access to affordable energy services is a prerequisite". South Africa is a stark example of this, with nearly 40% of the population still living in rural areas, a large proportion of these people have no access to electricity at all.

**the role of sustainable, clean renewable energy** To achieve the dramatic emissions cuts needed to avoid climate change – in the order of 80% in OECD countries by 2050 – will require a massive uptake of renewable energy. The targets for renewable energy must be greatly expanded in industrialised countries both to substitute for fossil fuel and nuclear generation and to create the necessary economies of scale necessary for global expansion. Within the Energy [R]evolution scenario we assume that modern renewable energy sources, such as solar collectors, solar cookers and modern forms of bio energy will replace inefficient, traditional biomass use.

### step 3: optimised integration – renewables 24/7

A complete transformation of the energy system will be necessary to accommodate the significantly higher shares of renewable energy expected under the Advanced Energy [R]evolution scenario. The grid network of cables and sub-stations that brings electricity to our homes and factories was designed for large, centralised generators running at huge loads, usually providing what is known as 'baseload' power. Renewable energy has had to fit in to this system as an additional slice of the energy mix and adapt to the conditions under which the grid currently operates. If the Advanced Energy [R]evolution scenario is to be realised, this will have to change.

Some critics of renewable energy say it is never going to be able to provide enough power for our current energy use, let alone for the projected growth in demand. This is because it relies mostly on natural resources, such as the wind and sun, which are not available 24/7. Existing practice in a number of countries has already shown that this is wrong, and further adaptations to how the grid network operates will enable the large quantities of renewable generating capacity envisaged in this report to be successfully integrated.

We already have sun, wind, geothermal sources and running rivers available right now, whilst ocean energy, biomass and efficient gas turbines are all set to make a massive contribution in the future. Clever technologies can track and manage energy use patterns, provide flexible power that follows demand through the day, use better storage options and group customers together to form 'virtual batteries'. With all these solutions we can secure the renewable energy future needed to avert catastrophic climate change. Renewable energy 24/7 is technically and economically possible, it just needs the right policy and the commercial investment to get things moving and 'keep the lights on'[24].

## 4.5 the new electricity grid

The electricity 'grid' is the collective name for all the cables, transformers and infrastructure that transport electricity from power plants to the end users. In all networks, some energy is lost as it is travels, but moving electricity around within a localised distribution network is more efficient and results in less energy loss.

The existing electricity transmission (main grid lines) and distribution system (local network) was mainly designed and planned 40 to 60 years ago. All over the developed world, the grids were built with large power plants in the middle and high voltage alternating current (AC) transmission power lines connecting up to the areas where the power is used. A lower voltage distribution network then carries the current to the final consumers. This is known as a centralised grid system, with a relatively small number of large power stations mostly fuelled by coal or gas.

In the future we need to change the grid network so that it does not rely on large conventional power plants but instead on clean energy from a range of renewable sources. These will typically be smaller scale power generators distributed throughout the grid. A localised distribution network is more efficient and avoids energy losses during long distance transmission. There will also be some concentrated supply from large renewable power plants. Examples of these large generators of the future are the massive wind farms already being built in Europe's North Sea and the plan for large areas of concentrating solar mirrors to generate energy in Southern Europe or Northern Africa.

The challenge ahead is to integrate new generation sources and at the same time phase out most of the large scale conventional power plants, while still keeping the lights on. This will need novel types of grids and an innovative power system architecture involving both new technologies and new ways of managing the network to ensure a balance between fluctuations in energy demand and supply.

The key elements of this new power system architecture are micro grids, smart grids and an efficient large scale super grid. The three types of system will support and interconnect with each other (see Figure 4.3).

**references**

**23** 'SUSTAINABLE ENERGY FOR POVERTY REDUCTION: AN ACTION PLAN', IT POWER/GREENPEACE INTERNATIONAL, 2002.

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

A major role in the construction and operation of this new system architecture will be played by the IT sector. Because a smart grid has power supplied from a diverse range of sources and locations it relies on the gathering and analysis of a large quantity of data. This requires software, hardware and networks that are capable of delivering data quickly, and responding to the information that they contain. Providing energy users with real time data about their energy consumption patterns and the appliances in their buildings, for example, helps them to improve their energy efficiency, and will allow appliances to be used at a time when a local renewable supply is plentiful, for example when the wind is blowing.

There are numerous IT companies offering products and services to manage and monitor energy. These include IBM, Fujitsu, Google, Microsoft and Cisco. These and other giants of the telecommunications and technology sector have the power to make the grid smarter, and to move us faster towards a clean energy future. Greenpeace has initiated the 'Cool IT' campaign to put pressure on the IT sector to make such technologies a reality.

## 4.6 hybrid systems

The developed world has extensive electricity grids supplying power to nearly 100% of the population. In parts of the developing world, however, many rural areas get by with unreliable grids or polluting electricity, for example from stand-alone diesel generators. This is also very expensive for small communities.

The electrification of rural areas that currently have no access to any power system cannot go ahead as it has in the past. A standard approach in developed countries has been to extend the grid by installing high or medium voltage lines, new substations and a low voltage distribution grid. But when there is low potential electricity demand, and long distances between the existing grid and rural areas, this method is often not economically feasible.

Electrification based on renewable energy systems with a hybrid mix of sources is often the cheapest as well as the least polluting alternative. Hybrid systems connect renewable energy sources such as wind and solar power to a battery via a charge controller, which stores the generated electricity and acts as the main power supply. Back-up supply typically comes from a fossil fuel, for example in a wind-battery-diesel or PV-battery-diesel system. Such decentralised hybrid systems are more reliable, consumers can be involved in their operation through innovative technologies and they can make best use of local resources. They are also less dependent on large scale infrastructure and can be constructed and connected faster, especially in rural areas.

Finance can often be an issue for relatively poor rural communities wanting to install such hybrid renewable systems. Greenpeace has therefore developed a model in which projects are bundled together in order to make the financial package large enough to be eligible for international investment support. In the Pacific region, for example, power generation projects from a number of islands, an entire island state such as the Maldives or even several island states could be bundled into one project package. This would make it large enough for funding as an international project by OECD countries. Funding could come from a mixture of a feed-in tariff and a fund which covers the extra costs, as proposed in the "Renewables 24/7" report - known as a Feed-in Tariff Support Mechanism. In terms of project planning, it is essential that the communities themselves are directly involved in the process.

## 4.7 smart grids

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

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

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

### elements in the new power system architecture

A **hybrid system** based on more than one generating source, for example solar and wind power, is a method of providing a secure supply in remote rural areas or islands, especially where there is no grid-connected electricity. This is particularly appropriate in developing countries. In the future, several hybrid systems could be connected together to form a micro grid in which the supply is managed using smart grid techniques.

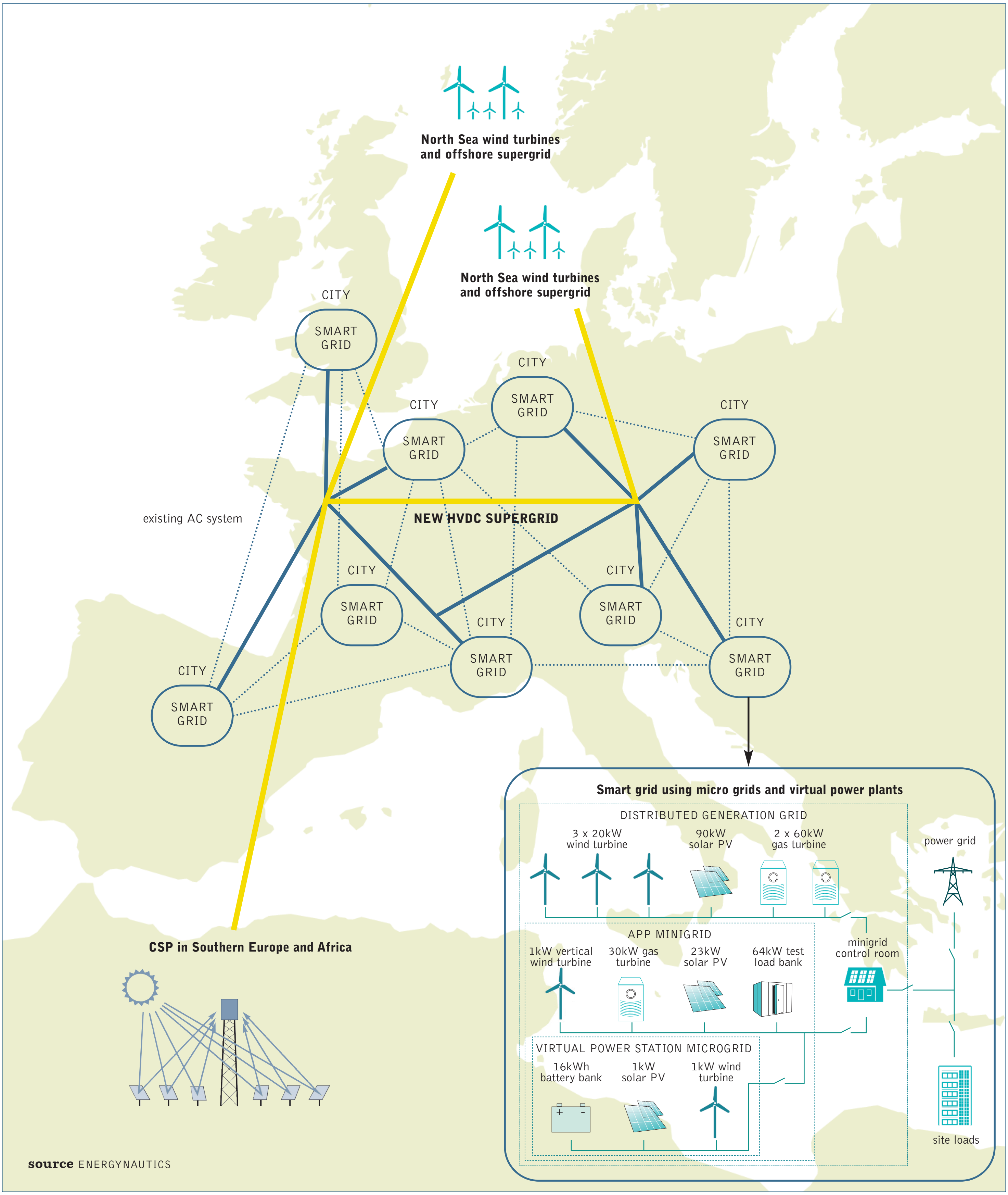
A **smart grid** is an electricity grid that connects decentralised renewable energy sources and cogeneration and distributes power highly efficiently. Advanced communication and control technologies such as smart electricity meters are used to deliver electricity more cost effectively, with lower greenhouse intensity and in response to consumer needs. Typically, small generators such as wind turbines, solar panels or fuels cells are combined with energy management to balance out the load of all the users on the system. Smart grids are a way to integrate massive amounts of renewable energy into the system and enable the decommissioning of older centralised power stations.

A **super grid** is a large scale electricity grid network linking together a number of countries, or connecting areas with a large supply of renewable electricity to an area with a large demand - ideally based on more efficient HVDC (High Voltage Direct Current) cables. An example of the former would be the interconnection of all the large renewable based power plants in the North Sea. An example of the latter would be a connection between Southern Europe and Africa so that renewable energy could be exported from an area with a large renewable resource to urban centres where there is high demand.

**image** THE WIND TURBINES ARE GOING TO BE USED FOR THE CONSTRUCTION OF AN OFFSHORE WINDFARM AT MIDDELGRUNDEN WHICH IS CLOSE TO COPENHAGEN, DENMARK.




**figure 4.3: overview of the future power system with high penetration of renewables**




**source** ENERGYNAUTICS

Integrating renewable energy by using a smart grid means moving away from the issue of baseload power and towards the question as to whether the supply is flexible or inflexible. In a smart grid a portfolio of flexible energy providers can follow the load during both day and night (for example, solar plus gas, geothermal, wind and demand management) without blackouts.

A number of European countries have already shown that it is possible to integrate large quantities of variable renewable power generation into the grid network and achieve a high percentage of the total supply. In Denmark, for example, the average supplied by wind power is about 20%, with peaks of more than 100% of demand. On those occasions surplus electricity is exported to neighbouring countries. In Spain, a much larger country with a higher demand, the average supplied by wind power is 14%, with peaks of more than 50%.

Until now renewable power technology development has put most effort into adjusting its technical performance to the needs of the existing network, mainly by complying with grid codes, which cover such issues as voltage frequency and reactive power. However, the time has come for the power systems themselves to better adjust to the needs of variable generation. This means that they must become flexible enough to follow the fluctuations of variable renewable power, for example by adjusting demand via demand-side management and/or deploying storage systems.

The future power system will no longer consist of a few centralised power plants but instead of tens of thousands of generation units such as solar panels, wind turbines and other renewable generation, partly distributed in the distribution network, partly concentrated in large power plants such as offshore wind parks.

The trade off is that power system planning will become more complex due to the larger number of generation assets and the significant share of variable power generation causing constantly changing power flows. Smart grid technology will be needed to support power system planning. This will operate by actively supporting day-ahead forecasts and system balancing, providing real-time information about the status of the network and the generation units, in combination with weather forecasts. It will also play a significant role in making sure systems can meet the peak demand at all times and make better use of distribution and transmission assets, thereby keeping the need for network extensions to the absolute minimum.

To develop a power system based almost entirely on renewable energy sources will require a new overall power system architecture, including smart grid technology. This concept will need substantial amounts of further work to fully emerge[25]. Figure 4.4 shows a simplified graphic representation of the key elements in future renewable-based power systems using smart grid technology.

A range of options are available to enable the large-scale integration of variable renewable energy resources into the power supply system. These include demand side management, the concept of a Virtual Power Plant and a number of choices for the storage of power.

The level and timing of **demand for electricity** can be managed by providing consumers with financial incentives to reduce or shut off their supply at periods of peak consumption. This system is already used for some large industrial customers. A Norwegian power supplier even involves private household customers by sending them a text message with a signal to shut down. Each household can decide in advance whether or not they want to participate. In Germany, experiments are being conducted with time flexible tariffs so that washing machines operate at night and refrigerators turn off temporarily during periods of high demand.

This type of demand side management has been simplified by advances in communications technology. In Italy, for example, 30 million innovative electricity counters have been installed to allow remote meter reading and control of consumer and service information. Many household electrical products or systems, such as refrigerators, dishwashers, washing machines, storage heaters, water pumps and air conditioning, can be managed either by temporary shut-off or by rescheduling their time of operation, thus freeing up electricity load for other uses and dovetailing it with variations in renewable supply.

A **Virtual Power Plant** (VPP) interconnects a range of real power plants (for example solar, wind and hydro) as well as storage options distributed in the power system using information technology. A real life example of a VPP is the Combined Renewable Energy Power Plant developed by three German companies[26]. This system interconnects and controls 11 wind power plants, 20 solar power plants, four CHP plants based on biomass and a pumped storage unit, all geographically spread around Germany. The VPP combines the advantages of the various renewable energy sources by carefully monitoring (and anticipating through weather forecasts) when the wind turbines and solar modules will be generating electricity. Biogas and pumped storage units are then used to make up the difference, either delivering electricity as needed in order to balance short term fluctuations or temporarily storing it[27]. Together the combination ensures sufficient electricity supply to cover demand.

A number of mature and emerging technologies are viable options for storing electricity. Of these, pumped storage can be considered the most established technology. Pumped storage is a type of hydroelectric power station that can store energy. Water is pumped from a lower elevation reservoir to a higher elevation during times of low cost, off-peak electricity. During periods of high electrical demand, the stored water is released through turbines. Taking into account evaporation losses from the exposed water surface and conversion losses, roughly 70 to 85% of the electrical energy used to pump the water into the elevated reservoir can be regained when it is released. Pumped storage plants can also respond to changes in the power system load demand within seconds.

Another way of 'storing' electricity is to use it to directly meet the demand from electric vehicles. The number of electric cars and trucks is expected to increase dramatically under the Advanced Energy [R]evolution scenario. The Vehicle-to-Grid (V2G) concept, for example, is based on electric cars equipped with batteries that

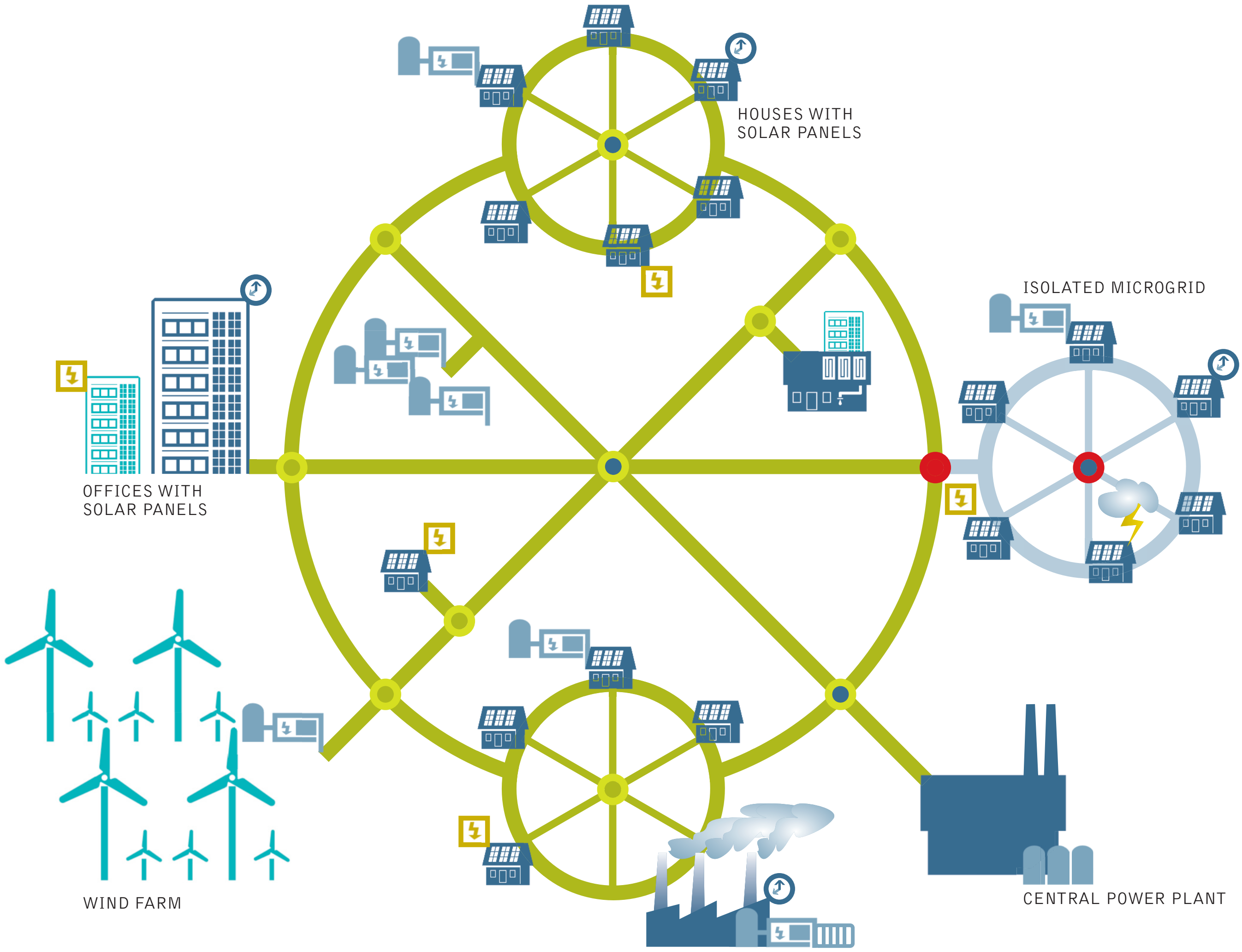
**references**
**25** SEE ALSO ECOGRID PHASE 1 SUMMARY REPORT, AVAILABLE AT: HTTP://WWW.ENERGINET.DK/NR/RDONLYRES/8B1A4A06-CBA3-41DA-9402-B56C2C288FB0/0/ECOGRIDDK_PHASE1_SUMMARYREPORT.PDF
**26** SEE ALSO HTTP://WWW.KOMBIKRAFTWERK.DE/INDEX.PHP?ID=27
**27** SEE ALSO HTTP://WWW.SOLARSERVER.DE/SOLARMAGAZIN/ANLAGEJANUAR2008_E.HTML

**image** CHECKING THE SOLAR PANELS ON TOP OF THE GREENPEACE POSITIVE ENERGY TRUCK IN BRAZIL.




**figure 4.4: the smart-grid vision for the energy [r]evolution**

A VISION FOR THE FUTURE – A NETWORK OF INTEGRATED MICROGRIDS THAT CAN MONITOR AND HEAL ITSELF.




- **PROCESSORS** EXECUTE SPECIAL PROTECTION SCHEMES IN MICROSECONDS
- **SENSORS** ON 'STANDBY' – DETECT FLUCTUATIONS AND DISTURBANCES, AND CAN SIGNAL FOR AREAS TO BE ISOLATED
- **SENSORS** 'ACTIVATED' – DETECT FLUCTUATIONS AND DISTURBANCES, AND CAN SIGNAL FOR AREAS TO BE ISOLATED
- **SMART APPLIANCES** CAN SHUT OFF IN RESPONSE TO FREQUENCY FLUCTUATIONS
- **DEMAND MANAGEMENT** USE CAN BE SHIFTED TO OFF-PEAK TIMES TO SAVE MONEY
- **GENERATORS** ENERGY FROM SMALL GENERATORS AND SOLAR PANELS CAN REDUCE OVERALL DEMAND ON THE GRID
- **STORAGE** ENERGY GENERATED AT OFF-PEAK TIMES COULD BE STORED IN BATTERIES FOR LATER USE
- **DISTURBANCE IN THE GRID**

can be charged during times when there is surplus renewable generation and then discharged to supply peaking capacity or ancillary services to the power system while they are parked. During peak demand times cars are often parked close to main load centres, for instance outside factories, so there would be no network issues. Within the V2G concept a Virtual Power Plant would be built using ICT technology to aggregate the electric cars participating in the relevant electricity markets and to meter the charging/de-charging activities. In 2009 the EDISON demonstration project was launched to develop and test the infrastructure for integrating electric cars into the power system of the Danish island of Bornholm.

# scenarios for a future energy supply

GLOBAL

PRICE PROJECTIONS FOR FOSSIL FUELS AND BIOASS
COST OF $CO_2$ EMISSIONS

COST PROJECTIONS FOR EFFICIENT FOSSIL FUEL GENERATION

COST PROJECTIONS FOR RENEWABLE ENERGY TECHNOLOGIES

# 5

**image** WIND TURBINE IN SAMUT SAKHON, THAILAND. 

**“towards a sustainable global energy supply system.”**

**GREENPEACE INTERNATIONAL**
CLIMATE CAMPAIGN

**image** THE MARANCHON WIND TURBINE FARM IN GUADALAJARA, SPAIN IS THE LARGEST IN EUROPE WITH 104 GENERATORS, WHICH COLLECTIVELY PRODUCE 208 MEGAWATTS OF ELECTRICITY, ENOUGH POWER FOR 590,000 PEOPLE, ANUALLY.

## 5.1 price projections for fossil fuels and biomass

The recent dramatic fluctuations in global oil prices have resulted in slightly higher forward price projections for fossil fuels. Under the 2004 'high oil and gas price' scenario from the European Commission, for example, an oil price of just $34 per barrel was assumed in 2030. More recent projections of oil prices by 2030 in the IEA's WEO 2009 range from $2008 80/bbl in the lower prices sensitivity case up to $2008 150/bbl in the higher prices sensitivity case. The reference scenario in WEO 2009 predicts an oil price of $2008 115/bbl.

Since the first Energy [R]evolution study was published in 2007, however, the actual price of oil has moved over $100/bbl for the first time, and in July 2008 reached a record high of more than $140/bbl. Although oil prices fell back to $100/bbl in September 2008 and around $80/bbl in April 2010, the projections in the IEA reference scenario might still be considered too conservative. Taking into account the growing global demand for oil we have assumed a price development path for fossil fuels based on the IEA WEO 2009 higher prices sensitivity case extrapolated forward to 2050 (see Table 5.1).

As the supply of natural gas is limited by the availability of pipeline infrastructure, there is no world market price for gas. In most regions of the world the gas price is directly tied to the price of oil. Gas prices are therefore assumed to increase to $24-29/GJ by 2050.

For the Advanced Energy [R]evolution scenario, the local coal price projections are assumed, which are significantly lower than world market price projections. Due to the current special supply conditions in South Africa, a price path significantly below the world market prices is assumed also for the long term future. Therefore fuel cost savings of renewable generation technologies and average generation costs for power and heat might be much higher, if the hard coal price is adjusted to a high price scenario of the world market.

## 5.2 cost of $CO_2$ emissions

Assuming that a $CO_2$ emissions trading system is established across all world regions in the longer term, the cost of $CO_2$ allowances needs to be included in the calculation of electricity generation costs. Projections of emissions costs are even more uncertain than energy prices, however, and available studies span a broad range of future estimates. As in the previous Energy [R]evolution study we assume $CO_2$ costs of $10/t$CO_2$ in 2010, rising to $50/t$CO_2$ by 2050. Additional $CO_2$ costs are applied in Kyoto Protocol Non-Annex B (developing) countries only after 2020.

**table 5.1: development projections for fossil fuel prices in 2008**

| | UNIT | 2000 | 2005 | 2007 | 2008 | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Crude oil imports** | | | | | | | | | | | | |
| IEA WEO 2009 "Reference" | barrel | 34.30 | 50.00 | 75.00 | 97.19 | | 86.67 | 100 | 107.5 | 115 | | |
| USA EIA 2008 "Reference" | barrel | | | | | 86.64 | | 69.96 | | 82.53 | | |
| USA EIA 2008 "High Price" | barrel | | | | | 92.56 | | 119.75 | | 138.96 | | |
| Energy [R]evolution 2010 | barrel | | | | | | 110.56 | 130.00 | 140.00 | 150.00 | 150.00 | 150.00 |
| **Natural gas imports** | | | | | | | | | | | | |
| IEA WEO 2009 "Reference" | | | | | | | | | | | | |
| United States | GJ | 5.00 | 2.32 | 3.24 | 8.25 | | 7.29 | 8.87 | 10.04 | 11.36 | | |
| Europe | GJ | 3.70 | 4.49 | 6.29 | 10.32 | | 10.46 | 12.10 | 13.09 | 14.02 | | |
| Japan LNG | GJ | 6.10 | 4.52 | 6.33 | 12.64 | | 11.91 | 13.75 | 14.83 | 15.87 | | |
| Energy [R]evolution 2010 | | | | | | | | | | | | |
| United States | GJ | | | 3.24 | | 8.70 | | 10.70 | 12.40 | 14.38 | 18.10 | 23.73 |
| Europe | GJ | | | 6.29 | | 10.89 | | 16.56 | 17.99 | 19.29 | 22.00 | 26.03 |
| Japan LNG | GJ | | | 6.33 | | 13.34 | | 18.84 | 20.37 | 21.84 | 24.80 | 29.30 |
| **Hard coal imports** | | | | | | | | | | | | |
| Energy [R]evolution 2010 | tonne | 41.22 | 49.61 | 69.45 | | 120.59 | 116.15 | 135.41 | 139.50 | 142.70 | 160.00 | 172.30 |
| South African hard coal E [R] 2011 | tonne | | | 17.60 | | 31.40 | 39.20 | 52.40 | | 61.20 | 64.50 | 72.30 |
| **Biomass (solid)** | | | | | | | | | | | | |
| Energy [R]evolution 2010 | | | | | | | | | | | | |
| OECD Europe | GJ | | | 7.4 | | 7.7 | 8.2 | 9.2 | | 10.0 | 10.3 | 10.5 |
| OECD Pacific and North America | GJ | | | 3.3 | | 3.4 | 3.5 | 3.8 | | 4.3 | 4.7 | 5.2 |
| Other regions | GJ | | | 2.7 | | 2.8 | 3.2 | 3.5 | | 4.0 | 4.6 | 4.9 |

**source** 2000-2030, IEA WEO 2009 HIGHER PRICES SENSITIVITY CASE FOR CRUDE OIL, GAS AND STEAM COAL; 2040-2050 AND OTHER FUELS, OWN ASSUMPTIONS.

**table 5.2: assumptions on $CO_2$ emissions cost development**

($/t$CO_2$)

| COUNTRIES | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| Kyoto Annex B countries | 10 | 20 | 30 | 40 | **50** |
| Non-Annex B countries | | 20 | 30 | 40 | **50** |

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

While the fossil fuel power technologies in use today for coal, gas, lignite and oil are established and at an advanced stage of market development, further cost reduction potentials are assumed. The potential for cost reductions is limited, however, and will be achieved mainly through an increase in efficiency[28].

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

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

Cost estimates for CCS vary considerably, depending on factors such as power station configuration, technology, fuel costs, size of project and location. One thing is certain, however: CCS is expensive. It requires significant funds to construct the power stations and the necessary infrastructure to transport and store carbon. The IPCC assesses costs at $15-75 per ton of captured $CO_2$[29], while a recent US Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs[30]. These costs are estimated to increase the price of electricity in a range from 21-91%[31].

Pipeline networks will also need to be constructed to move $CO_2$ to storage sites. This is likely to require a considerable outlay of capital[32]. Costs will vary depending on a number of factors, including pipeline length, diameter and manufacture from corrosion-resistant steel, as well as the volume of $CO_2$ to be transported. Pipelines built near population centres or on difficult terrain, such as marshy or rocky ground, are more expensive[33].

The Intergovernmental Panel on Climate Change estimates a cost range for pipelines of $1-8/ton of $CO_2$ transported. A United States Congressional Research Services report calculated capital costs for an 11 mile pipeline in the Midwestern region of the US at approximately $6 million. The same report estimates that a dedicated interstate pipeline network in North Carolina would cost upwards of $5 billion due to the limited geological sequestration potential in that part of the country[34]. Storage and subsequent monitoring and verification costs are estimated by the IPCC to range from $0.5-8/t$CO_2$ (for storage) and $0.1-0.3/t$CO_2$ (for monitoring). The overall cost of CCS could therefore serve as a major barrier to its deployment[35].

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

Table 5.3 summarises our assumptions on the technical and economic parameters of future fossil-fuelled power plant technologies. In spite of growing raw material prices, we assume that further technical innovation will result in a moderate reduction of future investment costs as well as improved power plant efficiencies. These improvements are, however, outweighed by the expected increase in fossil fuel prices, resulting in a significant rise in electricity generation costs.

**table 5.3: development of efficiency and investment costs for selected power plant technologies**

| | | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|
| Coal-fired condensing power plant | Efficiency (%) | 45 | 46 | 48 | 50 | 52 | **53** |
| | Investment costs ($/kW) | 1,320 | 1,230 | 1,190 | 1,160 | 1,130 | **1,100** |
| | Electricity generation costs including $CO_2$ emission costs ($cents/kWh) | 6.6 | 9.0 | 10.8 | 12.5 | 14.2 | **15.7** |
| | $CO_2$ emissions [a)](g/kWh) | 744 | 728 | 697 | 670 | 644 | **632** |
| Lignite-fired condensing power plant | Efficiency (%) | 41 | 43 | 44 | 44.5 | 45 | **45** |
| | Investment costs ($/kW) | 1,570 | 1,440 | 1,380 | 1,350 | 1,320 | **1,290** |
| | Electricity generation costs including $CO_2$ emission costs ($cents/kWh) | 5.9 | 6.5 | 7.5 | 8.4 | 9.3 | **10.3** |
| | $CO_2$ emissions [a)](g/kWh) | 975 | 929 | 908 | 898 | 888 | **888** |
| Natural gas combined cycle | Efficiency (%) | 57 | 59 | 61 | 62 | 63 | **64** |
| | Investment costs ($/kW) | 690 | 675 | 645 | 610 | 580 | **550** |
| | Electricity generation costs including $CO_2$ emission costs ($cents/kWh) | 7.5 | 10.5 | 12.7 | 15.3 | 17.4 | **18.9** |
| | $CO_2$ emissions [a)](g/kWh) | 354 | 342 | 330 | 325 | 320 | **315** |

**source** DLR, 2010 [a)] $CO_2$ EMISSIONS REFER TO POWER STATION OUTPUTS ONLY; LIFE-CYCLE EMISSIONS ARE NOT CONSIDERED.

**references**
**28** 'GREENPEACE INTERNATIONAL BRIEFING: CARBON CAPTURE AND STORAGE', GOERNE, 2007.
**29** ABANADES, J C ET AL., 2005, PG 10.
**30** NATIONAL ENERGY TECHNOLOGY LABORATORIES, 2007.
**31** RUBIN ET AL., 2005A, PG 40.
**32** RAGDEN, P ET AL., 2006, PG 18.
**33** HEDDLE, G ET AL., 2003, PG 17.
**34** PARFOMAK, P & FOLGER, P, 2008, PG 5 AND 12.
**35** RUBIN ET AL., 2005B, PG 4444.

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


## 5.4 cost projections for renewable energy technologies

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 being generated and used locally to the consumer - the future will also see large-scale applications in the form of offshore wind parks, photovoltaic power plants or concentrating solar power 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 transport fuels.

Many of the renewable technologies employed today are at a relatively early stage of market development. As a result, the costs of electricity, heat and fuel production are generally higher than those of competing conventional systems - a reminder that the external (environmental and social) costs of conventional power production are not included in market prices. It is expected, however, that compared with conventional technologies, large cost reductions can be achieved through technical advances, manufacturing improvements and large-scale production. Especially when developing long-term scenarios spanning periods of several decades, the dynamic trend of cost developments over time plays a crucial role in identifying economically sensible expansion strategies.

To identify long-term cost developments, learning curves have been applied which reflect the correlation between cumulative production volumes of a particular technology and a reduction in its 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. Empirical data shows, for example, that the learning factor for PV solar modules has been fairly constant at 0.8 over 30 years whilst that for wind energy varies from 0.75 in the UK to 0.94 in the more advanced German market.

Assumptions on future costs for renewable electricity technologies in the Advanced Energy [R]evolution scenario are derived from a review of learning curve studies, for example by Lena Neij and others[36], from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS project (New Energy Externalities Developments for Sustainability)[37] or the IEA Energy Technology Perspectives 2008, projections by the European Renewable Energy Council published in April 2010 ("Re-Thinking 2050") and discussions with experts from a wide range of different sectors of the renewable energy industry.

### 5.4.1 photovoltaics (pv)

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

The learning factor for PV modules has been fairly constant over the last 30 years, with a cost reduction of 20% each time the installed capacity doubles, indicating a high rate of technical learning. Assuming a globally installed capacity of 1,000 GW between 2030 and 2040 in the Basic Energy [R]evolution scenario, and with an electricity output of 1,400 TWh/a , we can expect that generation costs of around 5-10 $cents/kWh (depending on the region) will be achieved. During the following five to ten years, PV will become competitive with retail electricity prices in many parts of the world, and competitive with fossil fuel costs by 2030. The Advanced Energy [R]evolution version shows faster growth, with PV capacity reaching 1,000 GW by 2025 – five years ahead of the Basic Energy [R]evolution scenario.

**table 5.4: photovoltaics (pv) cost assumptions**

| | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Energy [R]evolution** | | | | | | |
| Global installed capacity (GW) | 6 | 98 | 335 | 1,036 | 1,915 | **2,968** |
| Investment costs ($/kWp) | 3,746 | 2,610 | 1,776 | 1,027 | 785 | **761** |
| Operation & maintenance costs ($/kW/a) | 66 | 38 | 16 | 13 | 11 | **10** |
| **Advanced Energy [R]evolution** | | | | | | |
| Global installed capacity (GW) | 6 | 108 | 439 | 1,330 | 2,959 | **4,318** |
| Investment costs ($/kWp) | 3,746 | 2,610 | 1,776 | 1,027 | 761 | **738** |
| Operation & maintenance costs ($/kW/a) | 66 | 38 | 16 | 13 | 11 | **10** |

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

### 5.4.2 concentrating solar power (CSP)

Solar thermal 'concentrating' power stations (CSP) can only use direct sunlight and are therefore dependent on high irradiation locations. North Africa, for example, has a technical potential which far exceeds local demand. The various solar thermal technologies (parabolic trough, power towers and parabolic dish concentrators) offer good prospects for further development and cost reductions. Because of their more simple design, 'Fresnel' collectors are considered as an option for additional cost trimming. The efficiency of central receiver systems can be increased by producing compressed air at a temperature of up to 1,0000C, which is then used to run a combined gas and steam turbine.

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

Depending on the level of irradiation and mode of operation, it is expected that long term future electricity generation costs of 6-10 $cents/kWh can be achieved. This presupposes rapid market introduction in the next few years.

### 5.4.3 wind power

Within a short period of time, the dynamic development of wind power has resulted in the establishment of a flourishing global market. While favourable policy incentives have made Europe the main driver for the global wind market, in 2009 more than three quarters of the annual capacity installed was outside Europe. This trend is likely to continue. The boom in demand for wind power technology has nonetheless led to supply constraints. As a consequence, the cost of new systems has increased. Because of the continuous expansion of production capacities, the industry is already resolving the bottlenecks in the supply chain, however. Taking into account market development projections, learning curve analysis and industry expectations, we assume that investment costs for wind turbines will reduce by 30% for onshore and 50% for offshore installations up to 2050.

**table 5.5: concentrating solar power (csp) cost assumptions**

| | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Energy [R]evolution** | | | | | | |
| Global installed capacity (GW) | 1 | 25 | 105 | 324 | 647 | **1,002** |
| Investment costs ($/kW)* | 7,250 | 5,576 | 5,044 | 4,263 | 4,200 | **4,160** |
| Operation & maintenance costs ($/kW/a) | 300 | 250 | 210 | 180 | 160 | **155** |
| **Advanced Energy [R]evolution** | | | | | | |
| Global installed capacity (GW) | 1 | 28 | 225 | 605 | 1,173 | **1,643** |
| Investment costs ($/kW)* | 7,250 | 5,576 | 5,044 | 4,200 | 4,160 | **4,121** |
| Operation & maintenance costs ($/kW/a) | 300 | 250 | 210 | 180 | 160 | **155** |

* INCLUDING HIGH TEMPERATURE HEAT STORAGE.

**table 5.6: wind power cost assumptions**

| | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Energy [R]evolution** | | | | | | |
| Installed capacity (on+offshore) | 95 | 407 | 878 | 1,733 | 2,409 | **2,943** |
| **Wind onshore** | | | | | | |
| Investment costs ($/kWp) | 1,510 | 1,255 | 998 | 952 | 906 | **894** |
| O&M costs ($/kW/a) | 58 | 51 | 45 | 43 | 41 | **41** |
| **Wind offshore** | | | | | | |
| Investment costs ($/kWp) | 2,900 | 2,200 | 1,540 | 1,460 | 1,330 | **1,305** |
| O&M costs ($/kW/a) | 166 | 153 | 114 | 97 | 88 | **83** |
| **Advanced Energy [R]evolution** | | | | | | |
| Installed capacity (on+offshore) | 95 | 494 | 1,140 | 2,241 | 3,054 | **3,754** |
| **Wind onshore** | | | | | | |
| Investment costs ($/kWp) | 1,510 | 1,255 | 998 | 906 | 894 | **882** |
| O&M costs ($/kW/a) | 58 | 51 | 45 | 43 | 41 | **41** |
| **Wind offshore** | | | | | | |
| Investment costs ($/kWp) | 2,900 | 2,200 | 1,540 | 1,460 | 1,330 | **1,305** |
| O&M costs ($/kW/a) | 166 | 153 | 114 | 97 | 88 | **83** |


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



### 5.4.4 biomass

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

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

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

### 5.4.5 geothermal

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

As a large part of the costs for a geothermal power plant come from deep underground drilling, further development of innovative drilling technology is expected. Assuming a global average market growth for geothermal power capacity of 9% per year up to 2020, adjusting to 4% beyond 2030, the result would be a cost reduction potential of 50% by 2050:

**table 5.7: biomass cost assumptions**

| | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Energy [R]evolution** | | | | | | |
| **Biomass (electricity only)** | | | | | | |
| Global installed capacity (GW) | 28 | 48 | 62 | 75 | 87 | **107** |
| Investment costs ($/kW) | 2,818 | 2,452 | 2,435 | 2,377 | 2,349 | **2,326** |
| O&M costs ($/kW/a) | 183 | 166 | 152 | 148 | 147 | **146** |
| **Biomass (CHP)** | | | | | | |
| Global installed capacity (GW) | 18 | 67 | 150 | 261 | 413 | **545** |
| Investment costs ($/kW) | 5,250 | 4,255 | 3,722 | 3,250 | 2,996 | **2,846** |
| O&M costs ($/kW/a) | 404 | 348 | 271 | 236 | 218 | **207** |
| **Advanced Energy [R]evolution** | | | | | | |
| **Biomass (electricity only)** | | | | | | |
| Global installed capacity (GW) | 28 | 50 | 64 | 78 | 83 | **81** |
| Investment costs ($/kW) | 2,818 | 2,452 | 2,435 | 2,377 | 2,349 | **2,326** |
| O&M costs ($/kW/a) | 183 | 166 | 152 | 148 | 147 | **146** |
| **Biomass (CHP)** | | | | | | |
| Global installed capacity (GW) | 18 | 65 | 150 | 265 | 418 | **540** |
| Investment costs ($/kW) | 5,250 | 4,255 | 3,722 | 3,250 | 2,996 | **2,846** |
| O&M costs ($/kW/a) | 404 | 348 | 271 | 236 | 218 | **207** |

**table 5.8: geothermal cost assumptions**

| | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Energy [R]evolution** | | | | | | |
| **Geothermal (electricity only)** | | | | | | |
| Global installed capacity (GW) | 10 | 19 | 36 | 71 | 114 | **144** |
| Investment costs ($/kW) | 12,446 | 10,875 | 9,184 | 7,250 | 6,042 | **5,196** |
| O&M costs ($/kW/a) | 645 | 557 | 428 | 375 | 351 | **332** |
| **Geothermal (CHP)** | | | | | | |
| Global installed capacity (GW) | 1 | 3 | 13 | 37 | 83 | **134** |
| Investment costs ($/kW) | 12,688 | 11,117 | 9,425 | 7,492 | 6,283 | **5,438** |
| O&M costs ($/kW/a) | 647 | 483 | 351 | 294 | 256 | **233** |
| **Advanced Energy [R]evolution** | | | | | | |
| **Geothermal (electricity only)** | | | | | | |
| Global installed capacity (GW) | 10 | 21 | 57 | 191 | 337 | **459** |
| Investment costs ($/kW) | 12,446 | 10,875 | 9,184 | 5,196 | 4,469 | **3,843** |
| O&M costs ($/kW/a) | 645 | 557 | 428 | 375 | 351 | **332** |
| **Geothermal (CHP)** | | | | | | |
| Global installed capacity (GW) | 0 | 3 | 13 | 47 | 132 | **234** |
| Investment costs ($/kW) | 12,688 | 11,117 | 9,425 | 7,492 | 6,283 | **5,438** |
| O&M costs ($/kW/a) | 647 | 483 | 351 | 294 | 256 | **233** |

- for conventional geothermal power, from 7 $cents/kWh to about 2 $cents/kWh;
- for EGS, despite the presently high figures (about 20 $cents/kWh), electricity production costs - depending on the payments for heat supply - are expected to come down to around 5 $cents/kWh in the long term.

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

### 5.4.6 ocean energy

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

The cost of energy from initial tidal and wave energy farms has been estimated to be in the range of 15-55 $cents/kWh, and for initial tidal stream farms in the range of 11-22 $cents/kWh. Generation costs of 10-25 $cents/kWh are expected by 2020. Key areas for development will include concept design, optimisation of the device configuration, reduction of capital costs by exploring the use of alternative structural materials, economies of scale and learning from operation. According to the latest research findings, the learning factor is estimated to be 10-15% for offshore wave and 5-10% for tidal stream. In the medium term, ocean energy has the potential to become one of the most competitive and cost effective forms of generation. In the next few years a dynamic market penetration is expected, following a similar curve to wind energy.

Because of the early development stage any future cost estimates for ocean energy systems are uncertain. Present cost estimates are based on analysis from the European NEEDS project[38].

### 5.4.7 hydro power

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

**table 5.9: ocean energy cost assumptions**

| | 2007 | 2015 | 2020 | 2030 | 2040 | **2050** |
|---|---|---|---|---|---|---|
| **Energy [R]evolution** | | | | | | |
| Global installed capacity (GW) | 0 | 9 | 29 | 73 | 168 | **303** |
| Investment costs ($/kW) | 7,216 | 3,892 | 2,806 | 2,158 | 1,802 | **1,605** |
| Operation & maintenance costs ($/kW/a) | 360 | 207 | 117 | 89 | 75 | **66** |
| **Advanced Energy [R]evolution** | | | | | | |
| Global installed capacity (GW) | 0 | 9 | 58 | 180 | 425 | **748** |
| Investment costs ($/kW) | 7,216 | 3,892 | 2,806 | 1,802 | 1,605 | **1,429** |
| Operation & maintenance costs ($/kW/a) | 360 | 207 | 117 | 89 | 75 | **66** |

**table 5.10: hydro power cost assumptions**

| | 2007 | 2015 | 2020 | 2030 | 2040 | **2050** |
|---|---|---|---|---|---|---|
| **Energy [R]evolution** | | | | | | |
| Global installed capacity (GW) | 922 | 1,043 | 1,206 | 1,307 | 1,387 | **1,438** |
| Investment costs ($/kW) | 2,705 | 2,864 | 2,952 | 3,085 | 3,196 | **3,294** |
| Operation & maintenance costs ($/kW/a) | 110 | 115 | 123 | 128 | 133 | **137** |
| **Advanced Energy [R]evolution** | | | | | | |
| Global installed capacity (GW) | 922 | 1,111 | 1,212 | 1,316 | 1,406 | **1,451** |
| Investment costs ($/kW) | 2,705 | 2,864 | 2,952 | 3,085 | 3,196 | **3,294** |
| Operation & maintenance costs ($/kW/a) | 110 | 115 | 123 | 128 | 133 | **137** |

38 WWW.NEEDS-PROJECT.ORG

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


### 5.4.8 summary of renewable energy cost development

Figure 5.1 summarises the cost trends for renewable energy technologies as derived from the respective learning curves. It should be emphasised that the expected cost reduction is basically not a function of time, but of cumulative capacity, so dynamic market development is required. Most of the technologies will be able to reduce their specific investment costs to between 30% and 70% of current levels by 2020, and to between 20% and 60% once they have achieved full maturity (after 2040).

Reduced investment costs for renewable energy technologies lead directly to reduced heat and electricity generation costs, as shown in Figure 5.2. Generation costs today are around 8 to 26 $cents/kWh for the most important technologies, with the exception of photovoltaics. In the long term, costs are expected to converge at around 5-12 $cents/kWh. These estimates depend on site-specific conditions such as the local wind regime or solar irradiation, the availability of biomass at reasonable prices or the credit granted for heat supply in the case of combined heat and power generation.

**figure 5.1: future development of renewable energy investment costs** (NORMALISED TO CURRENT COST LEVELS) FOR RENEWABLE ENERGY TECHNOLOGIES

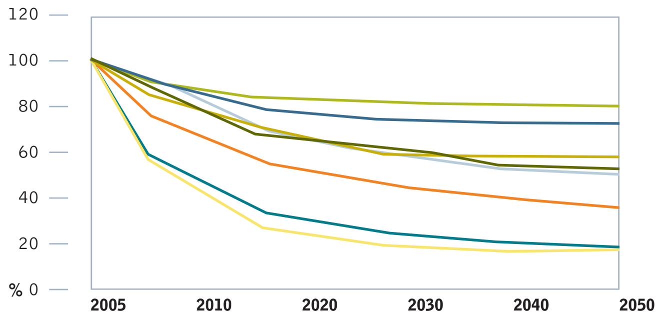
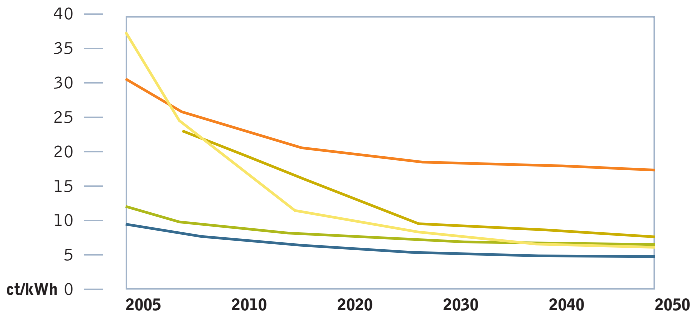


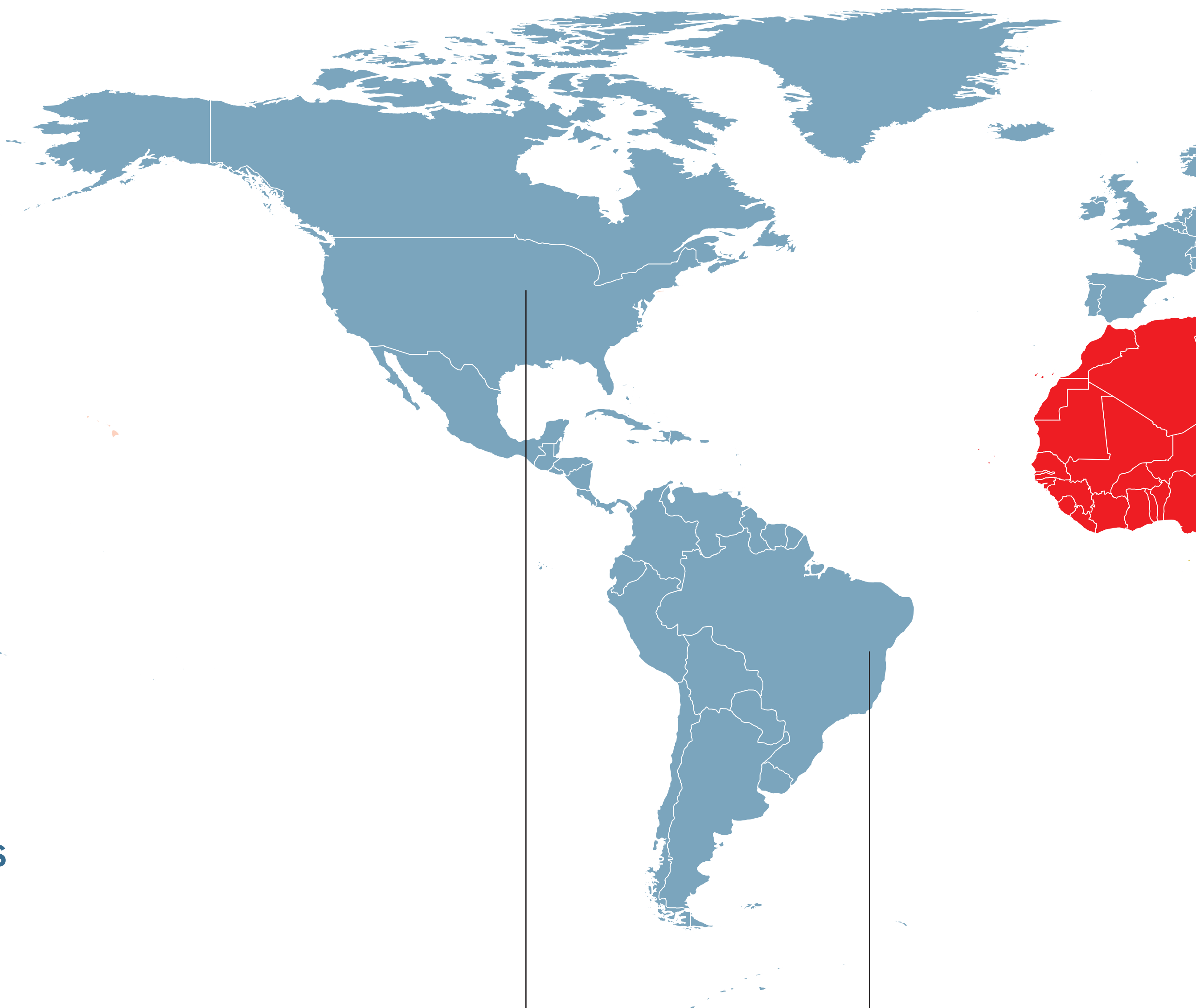

**figure 5.2: expected development of electricity generation costs**



## map 5.1: $CO_2$ emissions reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO





## EMISSIONS

# $CO_2$

### LEGEND

100-75 | 75-50 | 50-25 | 25-0 — % OF 1990 EMISSIONS IN THE 2050 ADVANCED ENERGY [R]EVOLUTION SCENARIO

REF — REFERENCE SCENARIO

E[R] — ADVANCED ENERGY [R]EVOLUTION SCENARIO

0 — 1000 KM

$CO_2$ — **EMISSIONS TOTAL** MILLION TONNES [mio t] | % OF 1990 EMISSIONS

**EMISSIONS PER PERSON** TONNES [t]

**H** HIGHEST | **M** MIDDLE | **L** LOWEST

### OECD NORTH AMERICA

| | | REF mio t | REF % | E[R] mio t | E[R] % |
|---|---|---|---|---|---|
| $CO_2$ | 2007 | 6,686H | 165 | 6,686 | 165 |
| | 2050 | 6,822 | 169 | 215M | 5 |
| | | t | | t | |
| Per person | 2007 | 14.89H | | 14.89 | |
| | 2050 | 11.82H | | 0.37 | |

### LATIN AMERICA

| | | REF mio t | REF % | E[R] mio t | E[R] % |
|---|---|---|---|---|---|
| $CO_2$ | 2007 | 1,010 | 167M | 1,010 | 167 |
| | 2050 | 2,006 | 332M | 119L | 20 |
| | | t | | t | |
| Per person | 2007 | 2.18 | | 2.18 | |
| | 2050 | 3.34 | | 0.20L | |

## OECD EUROPE

| | | REF | | E[R] | |
|---|---|---|---|---|---|
| | | mio t | % | mio t | % |
| $CO_2$ | 2007 | 4,017M | 100 | 4,017 | 100 |
| | 2050 | 3,798 | 94 | 215 | 5 |
| | | t | | t | |
| | 2007 | 7.44 | | 7.44 | |
| | 2050 | 6.61M | | 0.36 | |

## MIDDLE EAST

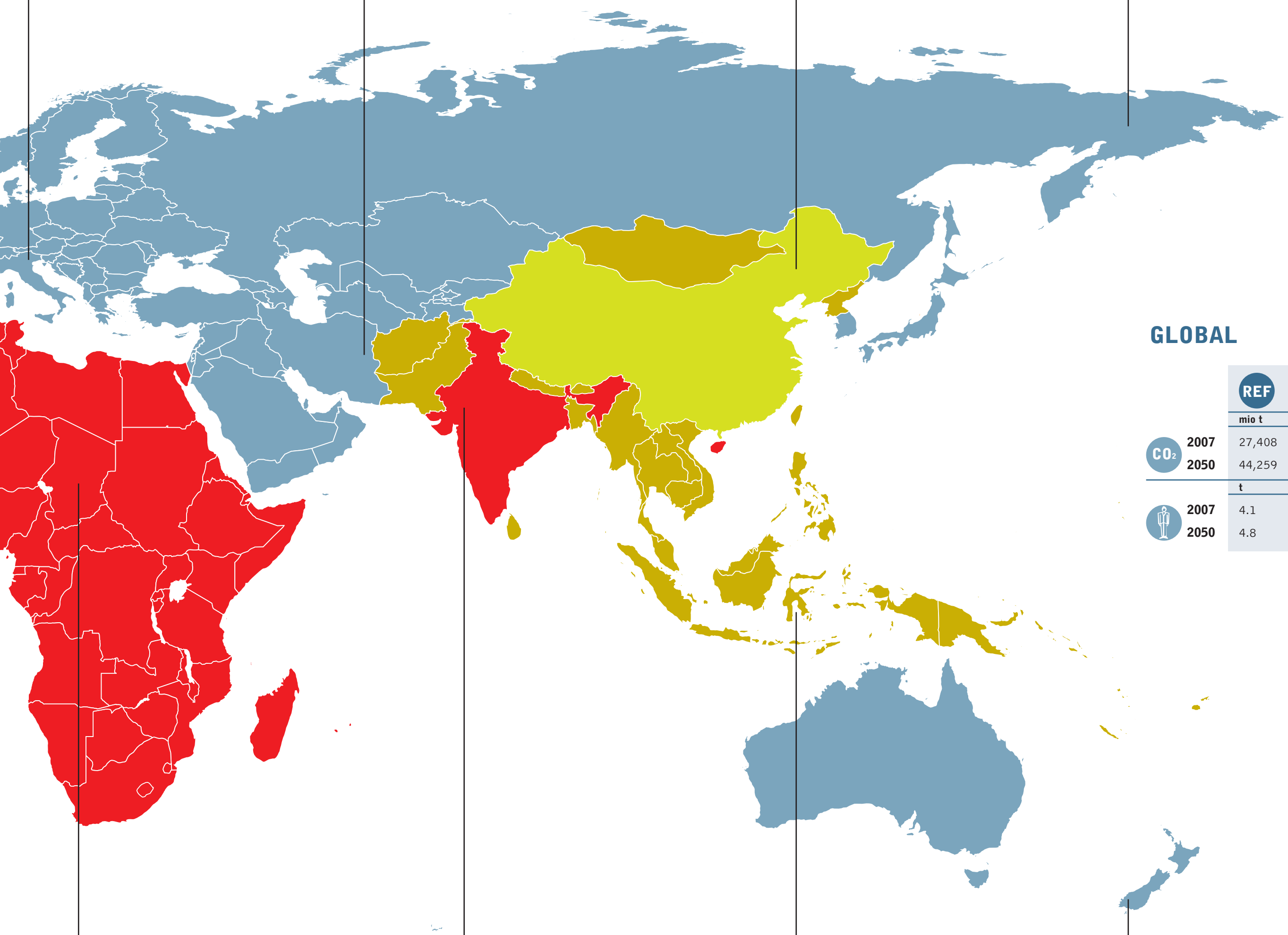
| | | REF | | E[R] | |
|---|---|---|---|---|---|
| | | mio t | % | mio t | % |
| $CO_2$ | 2007 | 1,374 | 234 | 1,374 | 234 |
| | 2050 | 3,208 | 546 | 122 | 21 |
| | | t | | t | |
| | 2007 | 6.79M | | 6.79 | |
| | 2050 | 9.08 | | 0.35 | |

## CHINA

| | | REF | | E[R] | |
|---|---|---|---|---|---|
| | | mio t | % | mio t | % |
| $CO_2$ | 2007 | 5,852 | 261 | 5,852 | 261 |
| | 2050 | 12,460H | 555 | 925H | 41 |
| | | t | | t | |
| | 2007 | 4.38 | | 4.38 | |
| | 2050 | 8.74 | | 0.65 | |

## TRANSITION ECONOMIES

| | | REF | | E[R] | |
|---|---|---|---|---|---|
| | | mio t | % | mio t | % |
| $CO_2$ | 2007 | 2,650 | 66 | 2,650 | 66 |
| | 2050 | 3,564 | 88 | 258 | 6 |
| | | t | | t | |
| | 2007 | 7.79 | | 7.79 | |
| | 2050 | 11.47 | | 0.83H | |



## GLOBAL

| | | REF | | E[R] | |
|---|---|---|---|---|---|
| | | mio t | % | mio t | % |
| $CO_2$ | 2007 | 27,408 | 131 | 27,408 | 131 |
| | 2050 | 44,259 | 211 | 3,267 | 16 |
| | | t | | t | |
| | 2007 | 4.1 | | 4.1 | |
| | 2050 | 4.8 | | 0.4 | |

## AFRICA

| | | REF | | E[R] | |
|---|---|---|---|---|---|
| | | mio t | % | mio t | % |
| $CO_2$ | 2007 | 881L | 161 | 881 | 161 |
| | 2050 | 1,622L | 297 | 423 | 77 |
| | | t | | t | |
| | 2007 | 0.91L | | 0.91 | |
| | 2050 | 0.81L | | 0.21 | |

## INDIA

| | | REF | | E[R] | |
|---|---|---|---|---|---|
| | | mio t | % | mio t | % |
| $CO_2$ | 2007 | 1,307 | 222 | 1,307 | 222 |
| | 2050 | 5,110 | 868 | 449 | 85 |
| | | t | | t | |
| | 2007 | 1.12 | | 1.12 | |
| | 2050 | 3.17 | | 0.31 | |

## DEVELOPING ASIA

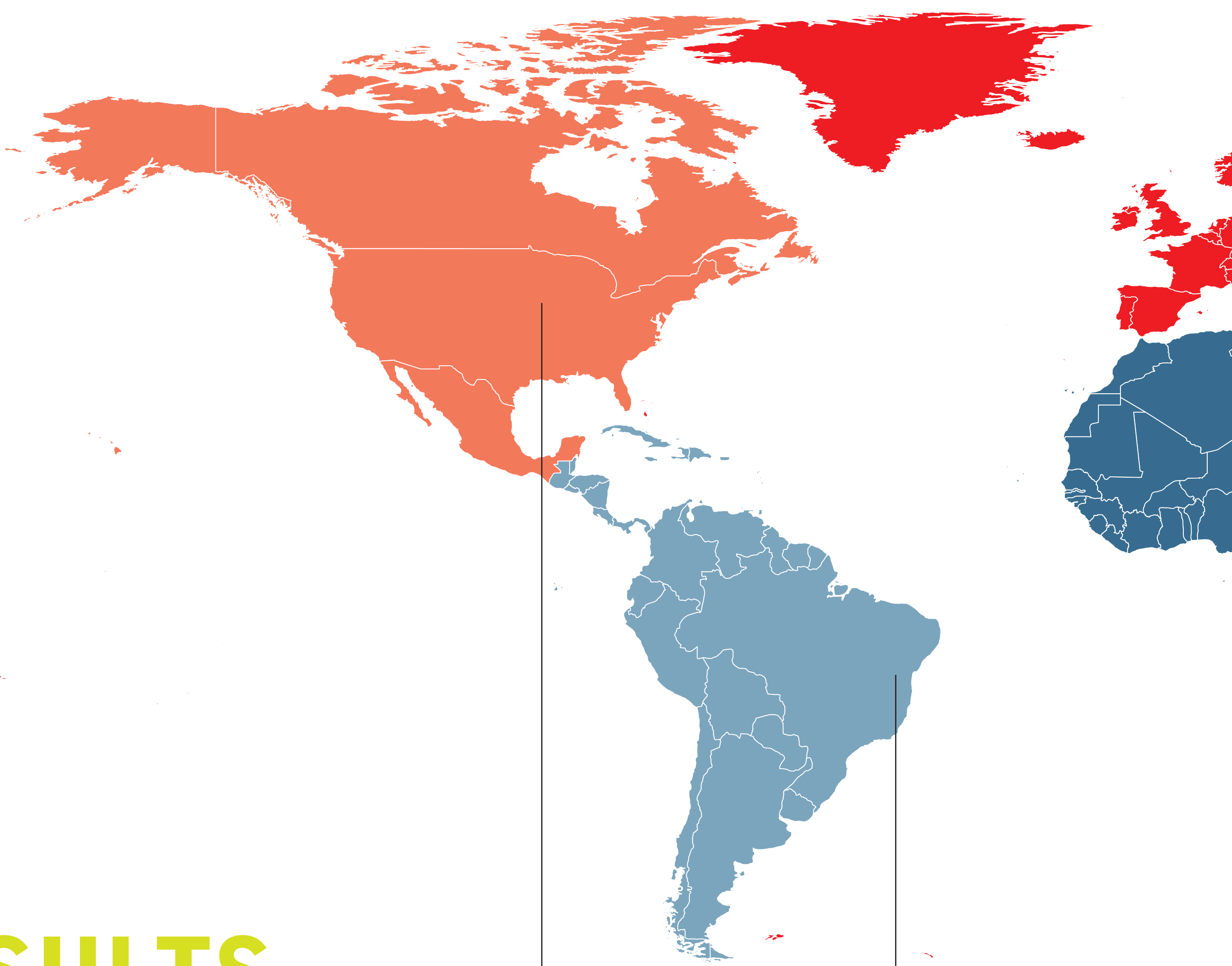
| | | REF | | E[R] | |
|---|---|---|---|---|---|
| | | mio t | % | mio t | % |
| $CO_2$ | 2007 | 1,488 | 216 | 1,488 | 216 |
| | 2050 | 3,846M | 557 | 428 | 62 |
| | | t | | t | |
| | 2007 | 1.47 | | 1.47 | |
| | 2050 | 2.54 | | 0.28 | |

## OECD PACIFIC

| | | REF | | E[R] | |
|---|---|---|---|---|---|
| | | mio t | % | mio t | % |
| $CO_2$ | 2007 | 2,144 | 136 | 2,144 | 136 |
| | 2050 | 1,822 | 116 | 74 | 5 |
| | | t | | t | |
| | 2007 | 10.70 | | 10.70 | |
| | 2050 | 10.14 | | 0.41M | |

## map 5.2: results reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO



# SCENARIO RESULTS

### OECD NORTH AMERICA

| | | REF PE PJ | REF EL TWh | E[R] PE PJ | E[R] EL TWh |
|---|---|---|---|---|---|
| | 2007 | 115,758H | 5,221H | 115,758H | 5,221 |
| | 2050 | 129,374 | 7,917 | 70,227 | 7,925 |
| | | % | | % | |
| Renewables | 2007 | 7 | 15 | 7 | 15 |
| | 2050 | 15 | 25 | 85 | 98 |
| | | % | | % | |
| Fossil fuels | 2007 | 85 | 67M | 85 | 67M |
| | 2050 | 75 | 59M | 9 | 2 |
| | | % | | % | |
| Nuclear | 2007 | 8 | 18 | NUCLEAR POWER PHASED OUT BY 2040 | |
| | 2050 | 10 | 16 | | |

### LATIN AMERICA

| | | REF PE PJ | REF EL TWh | E[R] PE PJ | E[R] EL TWh |
|---|---|---|---|---|---|
| | 2007 | 22,513L | 998 | 22,513L | 998 |
| | 2050 | 40,874 | 2,480 | 27,311 | 2,927 |
| | | % | | % | |
| Renewables | 2007 | 29 | 70H | 29 | 70H |
| | 2050 | 28 | 57H | 88H | 98 |
| | | % | | % | |
| Fossil fuels | 2007 | 70L | 28L | 70L | 28L |
| | 2050 | 69 | 40L | 12L | 2 |
| | | % | | % | |
| Nuclear | 2007 | 1 | 2 | NUCLEAR POWER PHASED OUT BY 2030 | |
| | 2050 | 3 | 2 | | |

## LEGEND

> -50 > -40 > -30
> -20 > -10 > 0
> +10 > +20 > +30
> +40 > +50

% CHANGE OF ENERGY CONSUMPTION IN THE ADVANCED ENERGY [R]EVOLUTION SCENARIO 2050 COMPARED TO CURRENT CONSUMPTION 2007

REF REFERENCE SCENARIO

E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

0 1000 KM

SHARE OF RENEWABLES %

SHARE OF FOSSIL FUELS %

SHARE OF NUCLEAR ENERGY %

**H** HIGHEST | **M** MIDDLE | **L** LOWEST

**PE** PRIMARY ENERGY PRODUCTION/DEMAND IN PETA JOULE [PJ]

**EL** ELECTRICITY PRODUCTION/GENERATION IN TERAWATT HOURS [TWh]

## OECD EUROPE

| | REF PE PJ | REF EL TWh | E[R] PE PJ | E[R] EL TWh |
|---|---|---|---|---|
| 2007 | 79,599 | 3,576 | 79,599 | 3,576 |
| 2050 | 82,634 | 5,351 | 46,754 | 4,233 |
| | % | | % | |
| 2007 | 10 | 20 | 10 | 20 |
| 2050 | 21 | 42 | 85 | 97 |
| | % | | % | |
| 2007 | 77 | 54 | 77 | 54 |
| 2050 | 71 | 46 | 16 | 2 |
| | % | | % | |
| 2007 | 13 | 26H | NUCLEAR POWER PHASED OUT BY 2030 | |
| 2050 | 8 | 12 | | |

## MIDDLE EAST

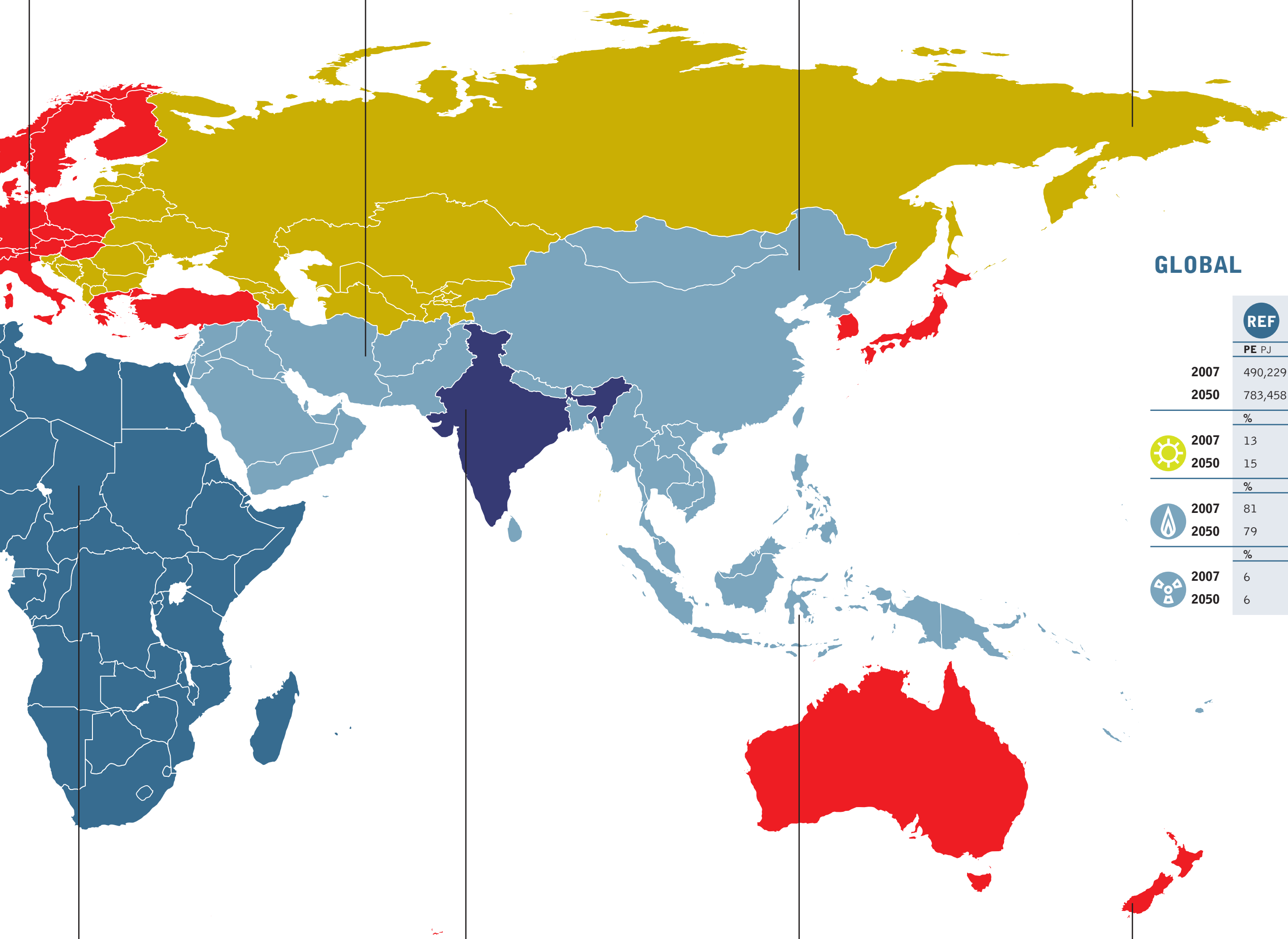
| | REF PE PJ | REF EL TWh | E[R] PE PJ | E[R] EL TWh |
|---|---|---|---|---|
| 2007 | 21,372 | 715 | 21,372 | 715 |
| 2050 | 51,281 | 2,404 | 27,475 | 2,786L |
| | % | | % | |
| 2007 | 1L | 3 | 1L | 3L |
| 2050 | 2L | 7 | 76 | 99H |
| | % | | % | |
| 2007 | 99H | 97 | 99H | 97H |
| 2050 | 97H | 92 | 23 | 1L |
| | % | | % | |
| 2007 | 0L | 0 | NO NUCLEAR ENERGY DEVELOPMENT | |
| 2050 | 0L | 0 | | |

## CHINA

| | REF PE PJ | REF EL TWh | E[R] PE PJ | E[R] EL TWh |
|---|---|---|---|---|
| 2007 | 83,922 | 3,319 | 83,922 | 3,319 |
| 2050 | 183,886H | 12,188H | 107,104H | 10,190H |
| | % | | % | |
| 2007 | 12M | 15 | 12M | 15 |
| 2050 | 10 | 18 | 77L | 90 |
| | % | | % | |
| 2007 | 87 | 83 | 87 | 83 |
| 2050 | 85 | 75 | 23H | 10H |
| | % | | % | |
| 2007 | 1 | 2 | NUCLEAR POWER PHASED OUT BY 2045 | |
| 2050 | 5 | 7 | | |

## TRANSITION ECONOMIES

| | REF PE PJ | REF EL TWh | E[R] PE PJ | E[R] EL TWh |
|---|---|---|---|---|
| 2007 | 48,111M | 1,685 | 48,111M | 1,685 |
| 2050 | 64,449 | 3,110 | 34,710 | 2,438 |
| | % | | % | |
| 2007 | 4 | 17M | 4 | 17M |
| 2050 | 7 | 22M | 76 | 93 |
| | % | | % | |
| 2007 | 89 | 65 | 89 | 65 |
| 2050 | 85 | 63 | 24 | 7 |
| | % | | % | |
| 2007 | 7M | 17 | NUCLEAR POWER PHASED OUT BY 2045 | |
| 2050 | 8 | 15 | | |



## GLOBAL

| | REF PE PJ | REF EL TWh | E[R] PE PJ | E[R] EL TWh |
|---|---|---|---|---|
| 2007 | 490,229 | 19,773 | 490,229 | 19,773 |
| 2050 | 783,458 | 46,542 | 480,861 | 43,922 |
| | % | | % | |
| 2007 | 13 | 18 | 13 | 18 |
| 2050 | 15 | 24 | 80 | 95 |
| | % | | % | |
| 2007 | 81 | 68 | 81 | 68 |
| 2050 | 79 | 67 | 20 | 5 |
| | % | | % | |
| 2007 | 6 | 14 | NUCLEAR POWER PHASED OUT BY 2045 | |
| 2050 | 6 | 10 | | |

## AFRICA

| | REF PE PJ | REF EL TWh | E[R] PE PJ | E[R] EL TWh |
|---|---|---|---|---|
| 2007 | 26,355 | 615L | 26,355 | 615L |
| 2050 | 43,173 | 1,826L | 35,805 | 2,490L |
| | % | | % | |
| 2007 | 48H | 16 | 48H | 16 |
| 2050 | 45H | 36 | 79M | 94 |
| | % | | % | |
| 2007 | 51 | 82 | 51 | 82 |
| 2050 | 54L | 62 | 20M | 6 |
| | % | | % | |
| 2007 | 0L | 2 | NUCLEAR POWER PHASED OUT BY 2025 | |
| 2050 | 0L | 2 | | |

## INDIA

| | REF PE PJ | REF EL TWh | E[R] PE PJ | E[R] EL TWh |
|---|---|---|---|---|
| 2007 | 25,159 | 814 | 25,159 | 814 |
| 2050 | 77,7610M | 4,918 | 52,120 | 5,062 |
| | % | | % | |
| 2007 | 29 | 17 | 29 | 17 |
| 2050 | 13 | 12 | 78 | 93L |
| | % | | % | |
| 2007 | 70 | 81 | 70 | 81 |
| 2050 | 84 | 85 | 22 | 7 |
| | % | | % | |
| 2007 | 1 | 2 | NUCLEAR POWER PHASED OUT BY 2045 | |
| 2050 | 3 | 3 | | |

## DEVELOPING ASIA

| | REF PE PJ | REF EL TWh | E[R] PE PJ | E[R] EL TWh |
|---|---|---|---|---|
| 2007 | 31,903 | 978 | 31,903 | 978 |
| 2050 | 69,233 | 3,721 | 40,639 | 3,548 |
| | % | | % | |
| 2007 | 27 | 16 | 27 | 16 |
| 2050 | 19 | 21 | 73L | 94 |
| | % | | % | |
| 2007 | 72 | 79 | 72 | 79 |
| 2050 | 79 | 77 | 27 | 6 |
| | % | | % | |
| 2007 | 1 | 5M | NUCLEAR POWER PHASED OUT BY 2045 | |
| 2050 | 2 | 2 | | |

## OECD PACIFIC

| | REF PE PJ | REF EL TWh | E[R] PE PJ | E[R] EL TWh |
|---|---|---|---|---|
| 2007 | 37,588 | 1,851M | 37,588 | 1,851M |
| 2050 | 40,793 | 2,626 | 21,299L | 2,322 |
| | % | | % | |
| 2007 | 4 | 8 | 4 | 8 |
| 2050 | 10 | 16 | 84 | 98M |
| | % | | % | |
| 2007 | 84 | 70 | 84 | 70 |
| 2050 | 66 | 51 | 16 | 2M |
| | % | | % | |
| 2007 | 12H | 22 | NUCLEAR POWER PHASED OUT BY 2045 | |
| 2050 | 24H | 33H | | |

DESIGN WWW.ONEHEMISPHERE.SE CONCEPT SVEN TESKE/GREENPEACE INTERNATIONAL.

# key results of the south africa energy [r]evolution scenario

SOUTH AFRICA

ENERGY DEMAND BY SECTOR
ECONOMIC GROWTH
DEVELOPMENT OF ENERGY DEMAND TO 2050
ELECTRICITY GENERATION
FUTURE COSTS OF ELECTRICITY GENERATION
FUTURE INVESTMENT
HEATING AND COOLING SUPPLY
TRANSPORT
DEVELOPMENT OF $CO_2$ EMISSIONS
PRIMARY ENERGY CONSUMPTION

# 6

**image** SOLAR PANEL. © BERND JUERGENS/DREAMSTIME

## "its effects are giving rise to a frighteningly new global phenomenon: the man-made natural disaster."

**BARACK OBAMA**
PRESIDENT OF THE UNITED STATES

**image** WIND TURBINES IN SOUTH AFRICA.

**image** STUDENTS OF THE MADIBA-A-TOLOANE HIGH SCHOOL, IN JERICHO, SOUTH AFRICA, INSTALL 26 120W SOLAR PANELS ON THE ROOF OF THE SCHOOL HALL.





## 6.1 energy demand by sector

One important underlying factor in 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. World Energy Outlook 2009 uses the United Nations Development Programme (UNDP) projections for population development. For this study the most recent population projections from UNDP up to 2050 are applied[39].

Table 6.1 shows that, based on UNDP's 2009 assessment, the world's population is expected to grow by 0.86% on average over the period 2007 to 2050, from 6.7 billion people in 2007 to more than 9.1 billion by 2050. Population growth will slow over the projection period, from 1.2% per year during 2007-2010 to 0.4% per year during 2040-2050. The updated projections show a small decrease in population by 2050 of around 40,000 compared to the previous edition. This will scarcely reduce 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 after a short while by the OECD Pacific countries. OECD Europe and OECD North America are expected to maintain their population, with a peak in around 2020/2030 and a slight decline afterwards. The share of the population living in today's non-OECD countries will increase from the current 82% to 85% in 2050. China's contribution to world population will drop from 20% today to 16% in 2050. Africa will remain the region with the highest growth rate, leading to a share of 22% of the world's 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. The South African population is projected to grow from 49 million people in 2007 to 57 million in 2050.

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

Although PPP assessments are still relatively imprecise compared to statistics based on national income and product trade and national price indexes, they are considered to provide a better basis for global scenario development[40]. Thus all data on economic development in WEO 2009 refers to purchasing power adjusted GDP. However, as WEO 2009 only covers the time period up to 2030, the projections for 2030-2050 are based on our own estimates. Prospects for GDP growth have decreased considerably since the previous study, due to the financial crisis at the beginning of 2009, although underlying growth trends continue much the same. GDP growth in all regions is expected to slow gradually over the coming decades. For South Africa this study assumes a 4%/year GDP increase after 2010 and 3.5%/year after 2040.

**table 6.1: population development projections in million**

| | 2007 | 2010 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|
| World | 6,671 | 6,909 | 7,302 | 7,675 | 8,309 | 8,801 | **9,150** |
| OECD Europe | 540 | 548 | 558 | 566 | 575 | 578 | **575** |
| OECD North America | 449 | 462 | 483 | 503 | 537 | 561 | **577** |
| OECD Pacific | 200 | 201 | 202 | 201 | 197 | 190 | **180** |
| Transition Economies | 340 | 339 | 339 | 337 | 331 | 321 | **311** |
| India | 1,165 | 1,214 | 1,294 | 1,367 | 1,485 | 1,565 | **1,614** |
| China | 1,336 | 1,361 | 1,403 | 1,439 | 1,471 | 1,464 | **1,426** |
| Other Developing Asia | 1,011 | 1,056 | 1,131 | 1,203 | 1,333 | 1,439 | **1,516** |
| Latin America | 462 | 478 | 503 | 526 | 563 | 588 | **600** |
| Africa | 965 | 1,033 | 1,153 | 1,276 | 1,524 | 1,770 | **1,998** |
| South Africa | 49 | 50 | 52 | 53 | 55 | 56 | **57** |
| Middle East | 202 | 215 | 235 | 255 | 293 | 326 | **353** |

**source** UN WORLD POPULATION PROSPECTS - 2008 REVISION.

## 6.3 development of energy demand to 2050

Future development pathways for South Africa´s energy demand are shown in Figure 6.1 for the Reference and both Energy [R]evolution scenarios. Under the Reference scenario, total primary energy demand in South Africa increases by more than 50% from the current 5,500 PJ/a to 8,246 PJ/a in 2050. In both Energy [R]evolution scenarios a decrease from the current consumption level is expected by 2050, reaching 5,020 PJ/a and 4,095 PJ/a in the advanced scenario. Under the Advanced Energy [R]evolution scenario, electricity demand in South Africa is expected to increase disproportionately, with households and services the main source of growing consumption (see Figure 6.2). With the exploitation of efficiency measures, however an even higher increase can be avoided, leading in the Basic Energy [R]evolution scenario to final electricity demand of 400 TWh/a in the year 2050. Compared to the Reference scenario, efficiency measures avoid the generation of about 135 TWh/a in the advanced scenario. The Advanced Energy [R]evolution scenario introduces electric vehicles earlier and more transport - both from freight and passengers - is shifted to electric trains and public transport. Fossil fuels for industrial process heat generation are also phased out more quickly and replaced by electric geothermal heat pumps and hydrogen. This means that electricity demand in the advanced version is higher and reaches 431 TWh/a in 2050, still 10% below the Reference case.

**39** 'WORLD POPULATION PROSPECTS: THE 2008 REVISION', UNITED NATIONS, POPULATION DIVISION, DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS (UNDP), 2009.
**40** NORDHAUS, W, 'ALTERNATIVE MEASURES OF OUTPUT IN GLOBAL ECONOMIC-ENVIRONMENTAL MODELS: PURCHASING POWER PARITY OR MARKET EXCHANGE RATES?', REPORT PREPARED FOR IPCC EXPERT MEETING ON EMISSION SCENARIOS, US-EPA WASHINGTON DC, JANUARY 12-14, 2005.

Efficiency gains in the heat supply sector are also significant. Under the Energy [R]evolution scenarios, final demand for heat supply can even be reduced (see Figure 6.3). Compared to the Reference scenario, consumption equivalent to 272 PJ/a are avoided through efficiency gains by 2050.

In the transport sector, it is assumed under the Basic Energy [R]evolution scenario that energy demand will reach 732 PJ/a by 2050, saving 40% compared to the Reference scenario. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns. Because South Africa, as a developing country, has a relatively low starting point for transport demand, the outcome (in terms of kilometres travelled per person and freight volumes) has not been reduced in the Advanced Energy [R]evolution scenario any further than in the basic version. Due to a wider use of more efficient electric drives, however, the overall final energy demand in transport can be even reduced to 642 PJ/a, 48% lower than in the Reference case and also lower than current consumption.

**figure 6.1: projection of total final energy demand by sector under three scenarios**

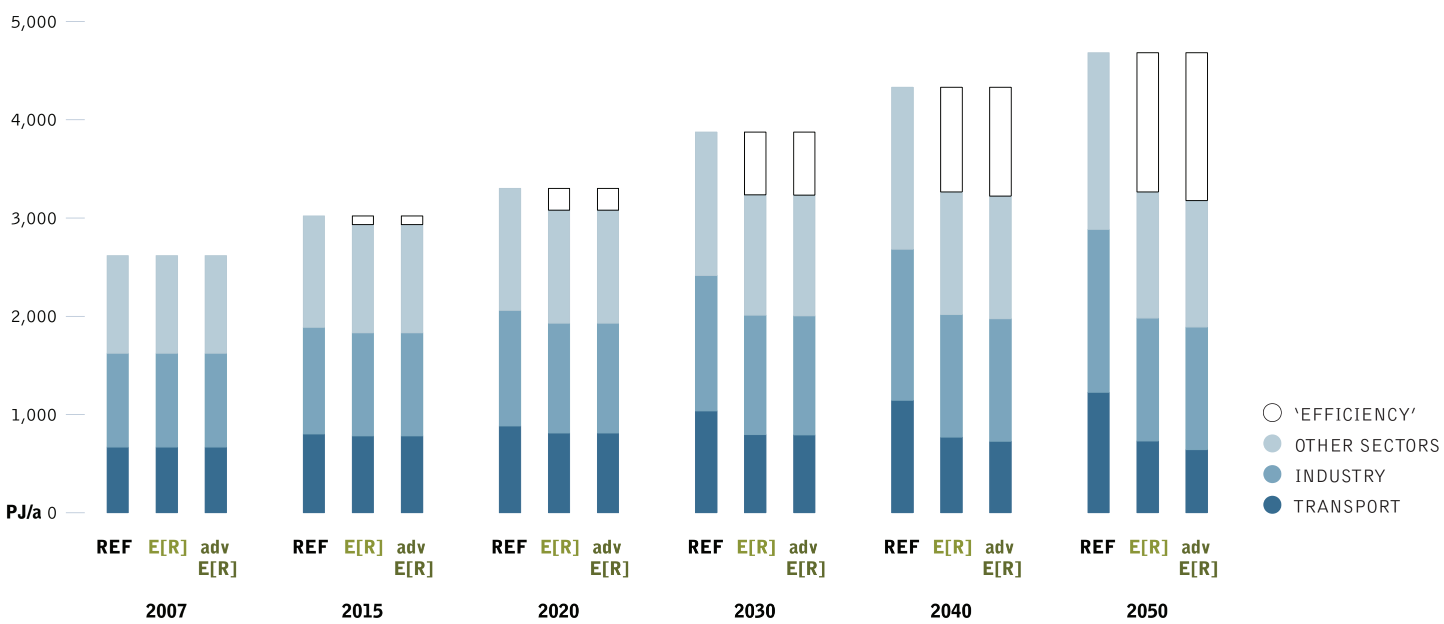



**figure 6.2: development of electricity demand by sector under both energy [r]evolution scenarios**

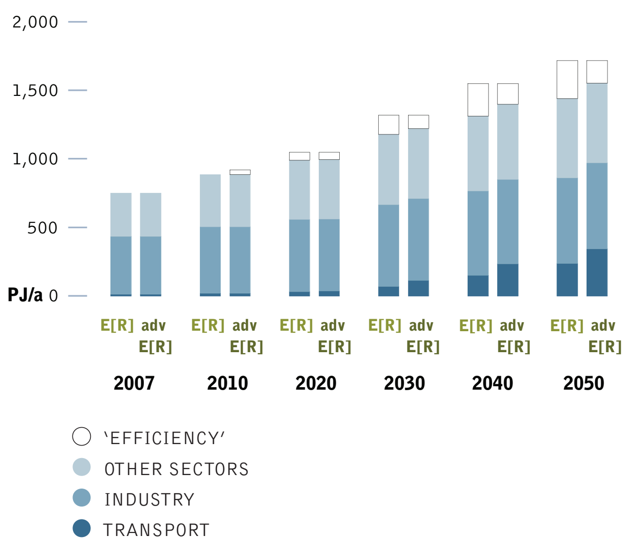



**figure 6.3: development of heat demand by sector under both energy [r]evolution scenarios**

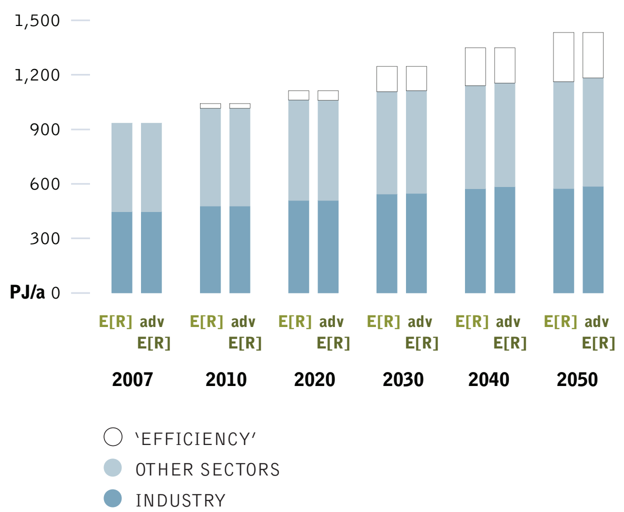


**image** A SOLAR-POWERED COMMUNICATIONS DEVICE IN THE CEDERBERG MOUNTAINS OF SOUTH AFRICA.

**image** A YOUNG BOY IN SOUTH AFRICA FROM THE LOCAL COMMUNITY OF MAGUQA PLAYS IN AND AROUND A STINKING STREAM FILLED WITH SEWAGE, AND ACID MINE DRAINAGE WHICH IS LEACHING FROM A WORKING OPEN COAL MINE IN THE BRUGSPRUIT VALLEY.





## 6.4 electricity generation

The development of the electricity supply sector in the Advanced Energy [R]evolution scenario is characterised by a dynamically growing renewable energy market and an increasing share of renewable electricity. By 2050, 77% of the electricity produced in South Africa will come from renewable sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 67% of electricity generation. The installed capacity of renewable energy technologies will grow under the Advanced Energy [R]evolution scenario from the current 0.7 GW to 80 GW in 2050, increasing renewable capacity by a factor of 114.

The advanced version projects a faster market development with higher annual growth rates achieving a renewable electricity share of 49% by 2030 and 94% by 2050. The installed capacity of renewables will reach 59 GW in 2030 and 114 GW by 2050, 43% higher than in the basic version.

None of these numbers - even in the Advanced Energy [R]evolution scenario - utilise the maximum known technical potential of all the renewable resources. While the deployment rate compared to the technical potential for hydro power, for example, is relatively high at about 40% in the Advanced Energy [R]evolution scenario, for concentrated solar power only 1% has been used.

Figure 6.4 shows the comparative evolution of the renewable technologies over time. After 2020, the continuing growth of wind, biomass and photovoltaics will be complemented by electricity from solar thermal (CSP) energy which will develop into the major energy source for power generation in South Africa.

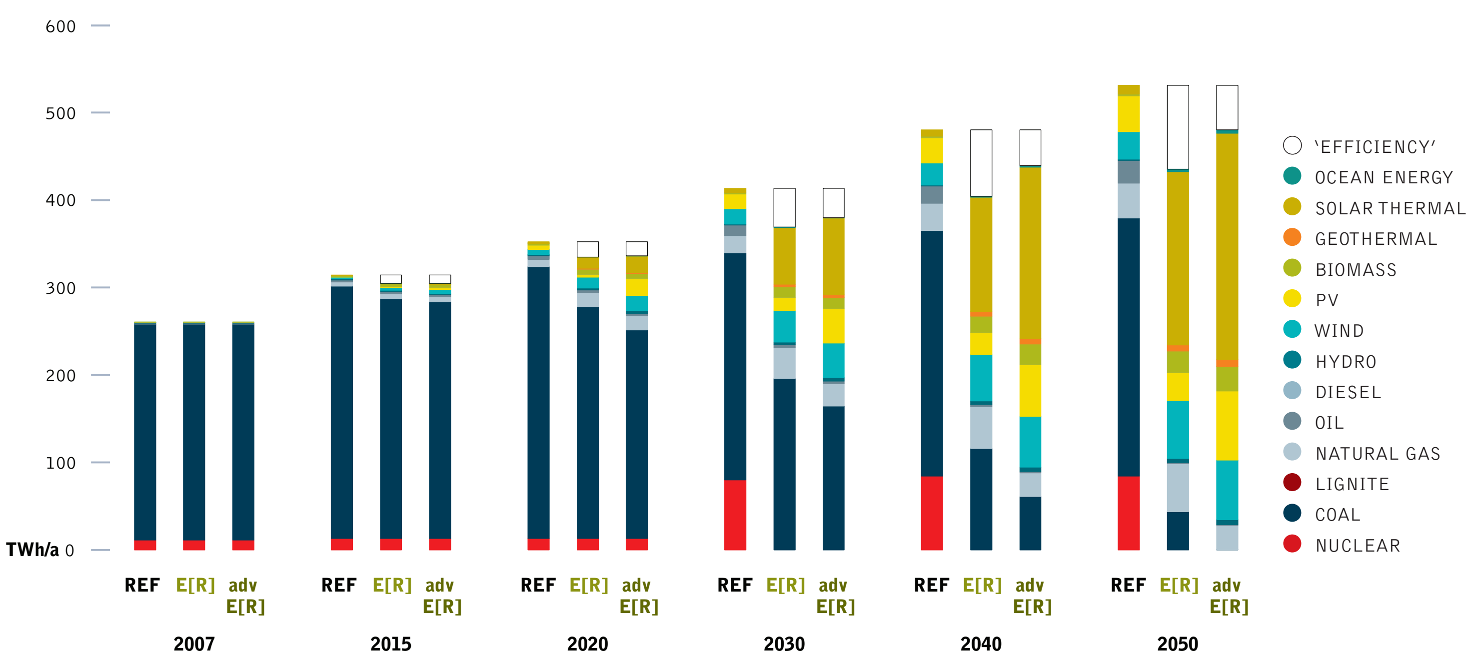
### table 6.2: projection of renewable electricity generation capacity under both energy [r]evolution scenarios

IN GW

| | | 2007 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| Hydro | E[R] | 1 | 1 | 2 | 3 | 3 |
| | advanced E[R] | 1 | 2 | 3 | 3 | 4 |
| Biomass | E[R] | 0 | 1 | 2 | 3 | 5 |
| | advanced E[R] | 0 | 1 | 2 | 4 | 5 |
| Wind | E[R] | 0 | 7 | 18 | 24 | 26 |
| | advanced E[R] | 0 | 10 | 20 | 26 | 27 |
| Geothermal | E[R] | 0 | 0 | 1 | 1 | 1 |
| | advanced E[R] | 0 | 0 | 1 | 1 | 2 |
| PV | E[R] | 0 | 2 | 8 | 13 | 16 |
| | advanced E[R] | 0 | 10 | 20 | 30 | 40 |
| CSP | E[R] | 0 | 3 | 10 | 18 | 27 |
| | advanced E[R] | 0 | 4 | 14 | 27 | 35 |
| Ocean energy | E[R] | 0 | 0 | 0 | 0 | 1 |
| | advanced E[R] | 0 | 0 | 0 | 1 | 1 |
| **Total** | **E[R]** | **1** | **14** | **41** | **62** | **80** |
| | **advanced E[R]** | **1** | **27** | **59** | **92** | **114** |

### figure 6.4: development of electricity generation structure under three scenarios

(REFERENCE, ENERGY [R]EVOLUTION AND ADVANCED ENERGY [R]EVOLUTION) ["EFFICIENCY" = REDUCTION COMPARED TO THE REFERENCE SCENARIO]



## 6.5 future costs of electricity generation

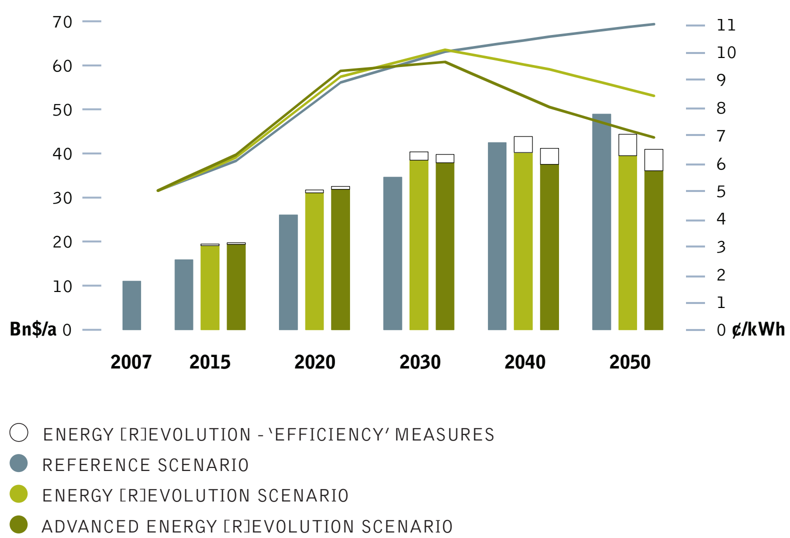
Figure 6.5 shows that the introduction of renewable technologies under the Advanced Energy [R]evolution scenario significantly decreases the future costs of electricity generation compared to the Reference scenario. This difference will be less than 0.2 $cents/kWh up to 2020, however. Because of the lower $CO_2$ intensity of electricity generation, electricity generation costs will become economically favourable under the Advanced Energy [R]evolution scenario by 2020, and by 2050 costs will be more than 3 $cents/kWh below those in the Reference scenario.

Under the Reference scenario, by contrast, unchecked demand growth, an increase in fossil fuel prices and the cost of $CO_2$ emissions result in total electricity supply costs rising from today's $11 billion per year to more than $49 bn in 2050. Figure 6.5 shows that the Advanced Energy [R]evolution scenario not only complies with South Africa's $CO_2$ reduction targets but also helps to stabilise energy costs. Increasing energy efficiency and shifting energy supply to renewables leads to long term costs for electricity supply that are significantly lower than in the Reference scenario.

In both Energy [R]evolution scenarios the specific generation costs are almost the same up to 2025. In 2050, however, the advanced version results in a reduction of 1.5 $cents/kWh, mainly because of lower fossil fuel consumption and better economics of scale in renewable power equipment.

In spite of the increased demand for electricity, especially in the transport and industry sector, the overall supply costs in the advanced version are $2.7 bn in 2030 and $3.4 bn in 2050 lower than in the Basic Energy [R]evolution scenario.

**figure 6.5: development of total electricity supply costs & development of specific electricity generation costs under three scenarios**




## 6.6 future investment

It would require $404 billion in investment for the Advanced Energy [R]evolution scenario to become reality - approximately $5.2 billion annual more than in the Reference scenario ($181 billion). Under the Reference version, the levels of investment in fossil and nuclear power plants add up to almost 60% while approx 40% would be invested in renewable energy and cogeneration until 2050. Under the Advanced scenario, however, South Africa would shift more than 80% of investment towards renewables and cogeneration by 2050. The fossil fuel share of power sector investment would be focused mainly on combined heat and power and efficient gas-fired power plants. The average annual investment in the power sector under the Advanced Energy [R]evolution scenario between today and 2050 would be approximately $9.4 billion.

Because renewable energy has no fuel costs, however, the fuel cost savings in the Basic Energy [R]evolution scenario reach $156 billion, or $3.6 billion per year. The Advanced Energy [R]evolution has even higher fuel cost savings of $283 billion, or $6.6 billion per year. The savings would be significantly higher if world market price projections are assumed instead of local coal price projections.

Under the Advanced Energy [R]evolution scenario, the average annual additional fuel cost savings are with $6.6 billion per year, 25% higher than the additional annual investment of $5.2 billion. Therefore fuel cost savings compensate for the entire investment in renewable and cogeneration capacity required to implement the advanced scenario. These renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, while the costs for coal and gas will continue to be a burden on national economies. Part of this money could be used to cover stranded investments in fossil-fuelled power stations in developing countries.

**image** SINGLE WIND TURBINE ON A WIND FARM, WESTERN CAPE, SOUTH AFRICA.

**image** A BOY LOOKS AT A SOLAR PANEL DURING A SOLAR POWER TRAINING ON THE DAY OF THE WORLD CUP FINAL MATCH AT THE JERICHO COMMUNITY CENTER. THE JERICHO PROJECT, A SOLAR POWERED PUBLIC VIEWING AREA FOR THE WORLD CUP, WAS INITIATED BY GREENPEACE AFRICA, PROVING HOW SOLAR POWER HAS TO BE THE SOLUTION FOR SOUTH AFRICA'S ENERGY CRISIS.



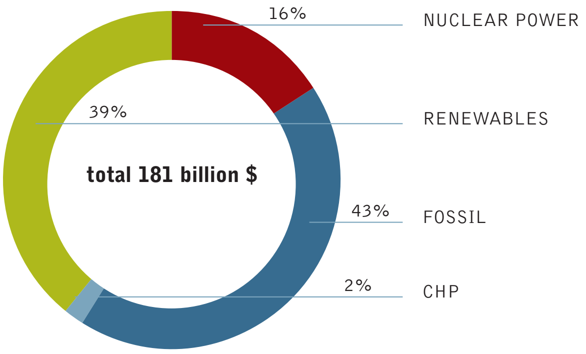


## table 6.3: fuel cost savings and investment costs under three scenarios

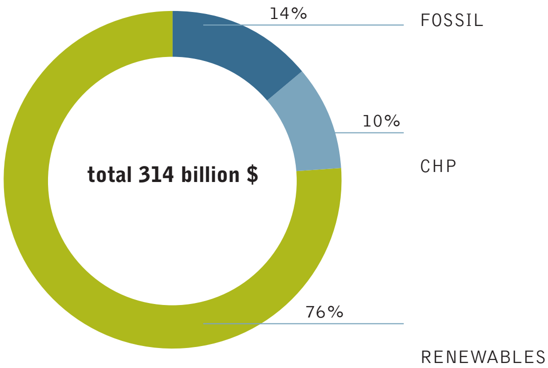
| INVESTMENT COST | DOLLAR | 2007-2010 | 201-2020 | 2021-2030 | 2031-2040 | 2041-2050 | 2007-2050 | 2007-2050 AVERAGE PER YEAR |
|---|---|---|---|---|---|---|---|---|
| SOUTH AFRICA (2011) DIFFERENCE E[R] VERSUS REF | | | | | | | | |
| Conventional (fossil & nuclear) | billion $ | 0 | -8 | -32 | -11 | -10 | -61 | -1.4 |
| Renewables (incl. CHP) | billion $ | 0 | 22 | 44 | 50 | 78 | 194 | 4.5 |
| Total | billion $ | | **13** | **13** | **38** | **69** | **133** | **3.1** |
| SOUTH AFRICA (2011) DIFFERENCE ADV E[R] VERSUS REF | | | | | | | | |
| Conventional (fossil & nuclear) | billion $ | 0 | -13 | -34 | -13 | -10 | -70 | -1.6 |
| Renewables (incl. CHP) | billion $ | 0 | 52 | 60 | 92 | 90 | 293 | 6.8 |
| Total | billion $ | | **39** | **26** | **78** | **80** | **223** | **5.2** |
| CUMULATED FUEL COST SAVINGS | | | | | | | | |
| SAVINGS E[R] CUMULATED IN € | | | | | | | | |
| Fuel oil | billion $/a | | 1.1 | 16.9 | 41.4 | 64.0 | 123 | 2.9 |
| Gas | billion $/a | | -4.0 | -20.2 | -30.3 | -31.5 | -86 | -2.0 |
| Hard coal | billion $/a | | 4.7 | 15.6 | 34.6 | 63.1 | 118 | 2.7 |
| Total | billion $/a | | **1.9** | **12.3** | **45.8** | **95.6** | **156** | **3.6** |
| SAVINGS ADV E[R] CUMULATED IN € | | | | | | | | |
| Fuel oil | billion $/a | | 1.1 | 16.9 | 42.9 | 65.9 | 127 | 3.0 |
| Gas | billion $/a | | -4.0 | -11.0 | -0.9 | 15.9 | 0 | 0.0 |
| Hard coal | billion $/a | | 7.0 | 23.9 | 47.5 | 77.6 | 156 | 3.6 |
| Total | | | **4.2** | **29.7** | **89.6** | **159.4** | **283** | **6.6** |

## figure 6.6: investment shares - reference versus energy [r]evolution scenarios

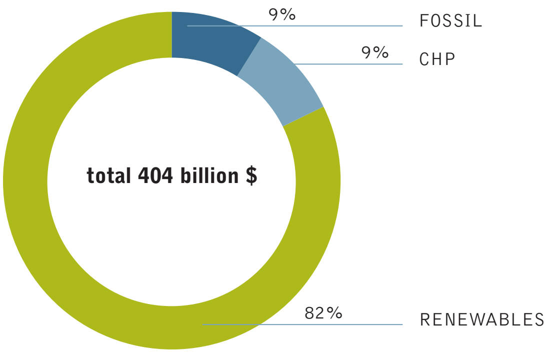
**reference scenario 2007 - 2050**



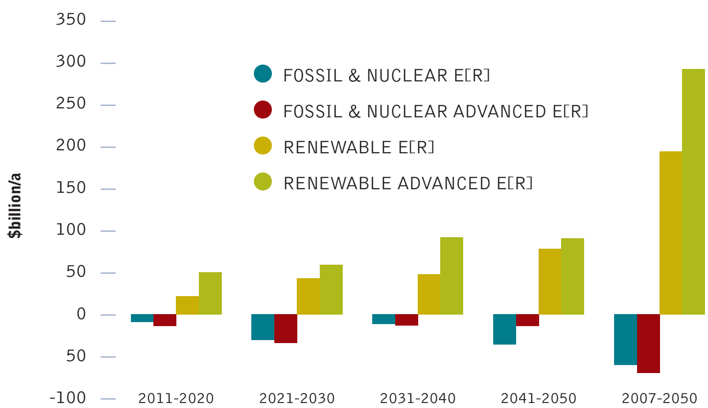

**energy [r]evolution scenario 2007 - 2050**




**advanced energy [r]evolution scenario 2007 - 2050**




## figure 6.7: change in cumulative power plant investment in both energy [r]evolution scenarios



## 6.7 heating and cooling supply

Today, renewables provide 32% of South Africa's energy demand for heat supply, the main contribution coming from the use of traditional and often unsustainable biomass. The availability of less 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. Dedicated support instruments are required to ensure a continuously dynamic development of renewables in the heat market.

In the Advanced Energy [R]evolution scenario renewables provide 67% of South Africa's total heating and cooling demand in 2050.

- Energy efficiency measures can restrict the future energy demand for heat and cooling supply to a 24% increase, in spite of improving living standards.
- In the industry sector solar collectors, biomass/biogas as well as geothermal energy are increasingly substituted for conventional fossil-fired heating systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction of $CO_2$ emissions.

The Advanced Energy [R]evolution scenario introduces renewable heating and cooling systems around five years ahead of the Basic Energy [R]evolution scenario. Compared to the Reference scenario, 251 PJ/a or 17% are saved by 2050. South Africa can even use solar heat directly for industrial process heat. Together with the large potential for economic use of geothermal energy in the immediate future, the renewables share can rise to 51% under the advanced version by 2030 and 84% by 2050.

## 6.8 transport

In the transport sector, it is assumed under the Basic Energy [R]evolution scenario that energy demand will rise to 732 PJ/a by 2050, saving 40% compared to the Reference scenario. This reduction can be achieved by the introduction of highly efficient vehicles, by shifting the transport of goods from road to rail and by changes in mobility-related behaviour patterns. The South African vehicle stock, however, is projected to grow in all scenarios significantly. Development of fuel efficiency is also delayed by 20 years in the Basic Energy [R]evolution scenario and by ten years in the advanced version compared to other world regions for economic reasons. By 2030, electricity will provide 9% of the transport sector's total energy demand in the Basic Energy [R]evolution, while in the advanced version the share will already be 14% in 2030 and 53% by 2050.

**figure 6.8: development of heat supply structure under three scenarios**

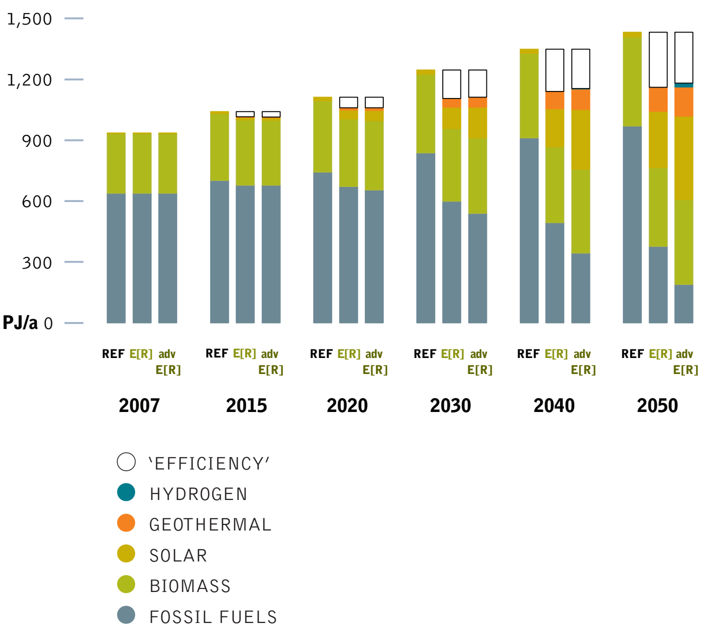



**figure 6.9: transport under three scenarios**

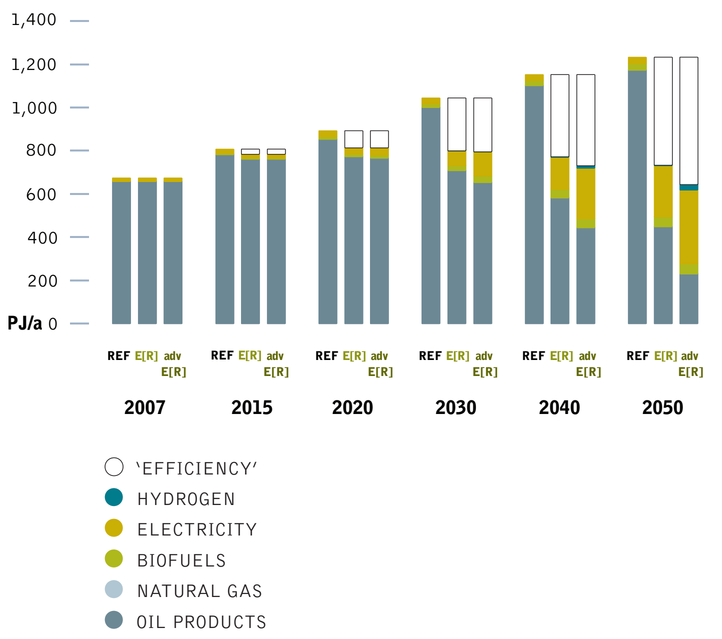


**image** A SOLAR WATER HEATER WITH A 200 LITRE CAPACITY TANK ON A CORRUGATED IRON ROOF, SOUTH AFRICA.

**image** COAL STOCK IN A COAL WASHING PLANT BEING PREPARED CLEAN FOR EXPORT. WITBANK, SOUTH AFRICA.



## 6.9 development of $CO_2$ emissions

Whilst South Africa's emissions of $CO_2$ will increase by 29% under the Reference scenario by 2050, under the Basic Energy [R]evolution scenario they will decrease from 349 million tonnes in 2007 to 123 million tonnes in 2050. Annual per capita emissions will drop from 7.1 tonnes to 2.2 tonnes. In spite of increasing demand, $CO_2$ emissions will decrease in the electricity sector. In the long run efficiency gains and the increased use of renewable electricity in vehicles will reduce emissions in the transport sector. With a share of 41% of total $CO_2$ in 2050, the power sector will remain the largest sources of emissions.

The Advanced Energy [R]evolution scenario will shift the emissions peak for energy related $CO_2$ about 10 years earlier than in the basic version, leading to 4.7 tonnes per capita by 2030 and 0.8 tonnes by 2050. By 2050, South Africa's $CO_2$ emissions are 15% of 1990 levels.

## 6.10 primary energy consumption

Taking into account the assumptions discussed above, the resulting primary energy consumption under the three scenarios is shown in Figure 6.11. Compared to the Reference scenario, overall energy demand will be reduced by 40% in 2050. Around 47% of the remaining demand will be covered by renewable energy sources. The advanced version phases out coal and oil about 10 to 15 years faster than the Basic Energy [R]evolution scenario. This is made possible by leapfrogging directly to a renewable energy future. This leads to a renewable primary energy share of 29% in 2030 and 73% in 2050. Nuclear energy is phased out in both Energy [R]evolution scenarios before 2030.

**figure 6.10: development of $CO_2$ emissions by sector under both energy [r]evolution scenarios**

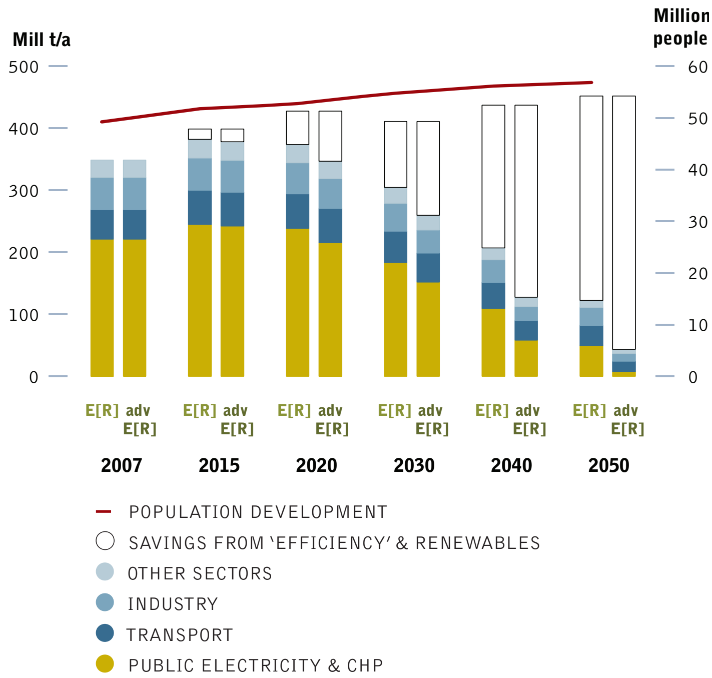
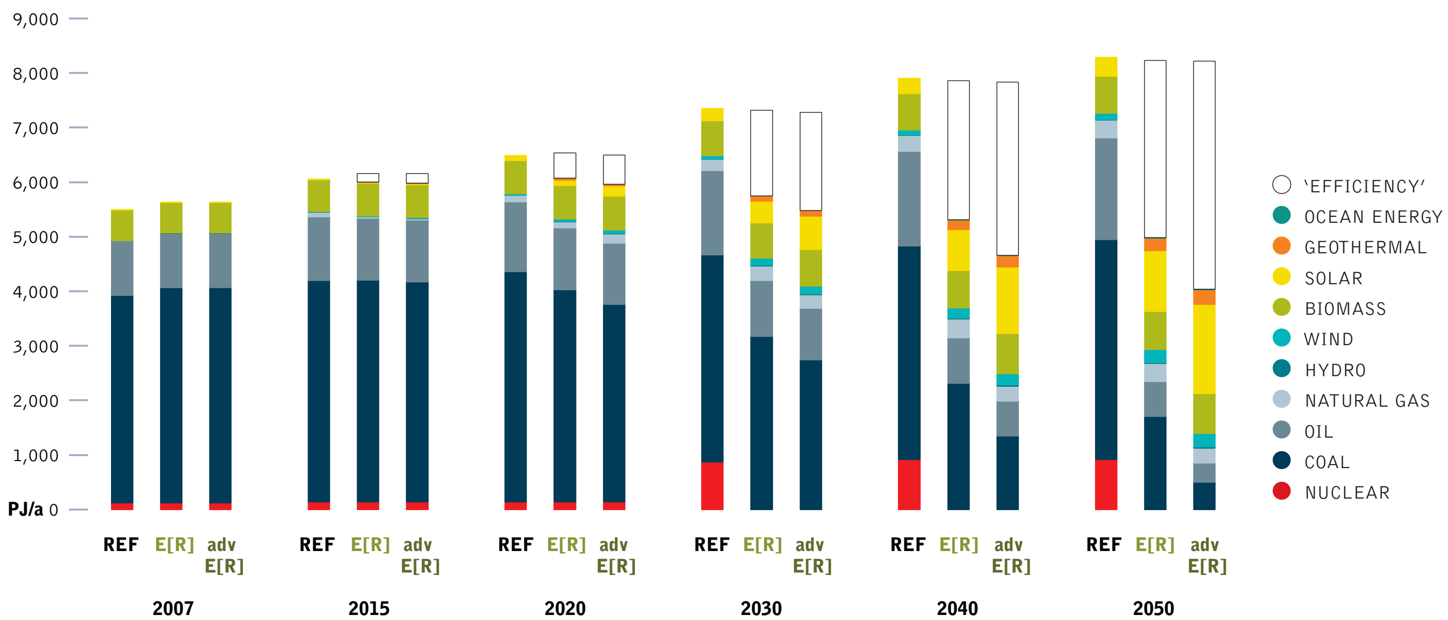



**figure 6.11: development of primary energy consumption under three scenarios**



# employment



# 7

image SOLAR POWER SYSTEM INSTALLED IN A COASTAL VILLAGE IN ACEH, INDONESIA.


## “Renewable energy is becoming an increasingly viable alternative...”

**PRESIDENT JACOB ZUMA**
GREEN ECONOMY SUMMIT, 2010

**image** CONSTRUCTION OF WIND TURBINES.




## 7.1 future employment

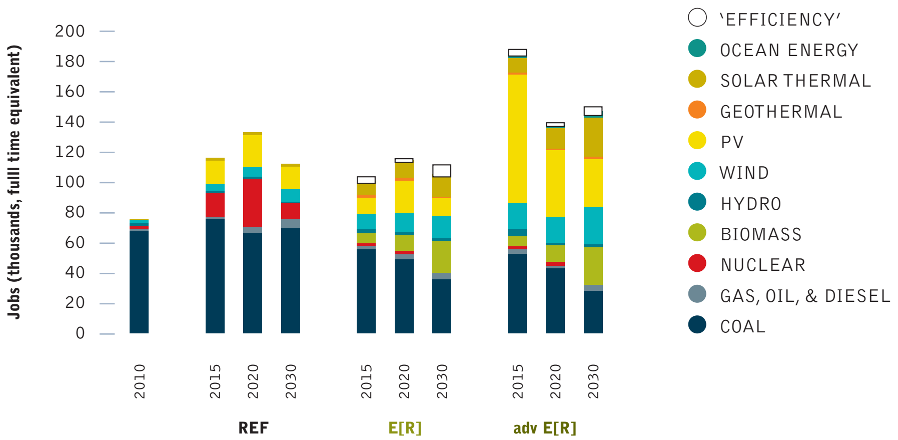
Energy sector jobs are set to increase significantly by 2015 under all the energy scenarios presented. In 2010, there are nearly 76,000 electricity sector jobs[41]. Figure 7.1 shows the increase in job numbers under both Energy [R]evolution scenarios and the Reference scenario for each technology up to 2030, with details given in Table 7.1.

- In the Reference scenario, jobs increase 53% by 2015 (40,300 additional jobs), increase by a further 23% by 2020 (17,000 jobs), and then decrease somewhat by 2030 to a total of 111,000[42].
- In the Basic Energy [R]evolution scenario, jobs increase 36% by 2015 (27,000 additional jobs), increase by a further 17% by 2020 (13,000 jobs), and then decrease only slightly by 2030 to a total of 112,000.
- In the Advanced Energy [R]evolution scenario, jobs increase 149% by 2015 (113,000 additional jobs), and then decrease, so that 2020 jobs are almost double the 2010 levels (140,000 total jobs). Jobs increase again to 2030, with a total of 149,000 in that year.
- Solar PV shows particularly strong growth in all three scenarios, with an additional 22,000 jobs created in both the Reference and the Basic Energy [R]evolution scenario at 2020, and nearly 45,000 jobs in the Advanced Energy [R]evolution scenario.

The Reference scenario increase of 40,300 jobs by 2015 is mainly divided between solar PV (15,500 jobs) and the nuclear industry (15,200 jobs). Overall jobs growth is maintained to 2020, with an additional 17,000 jobs created. These are once again mainly in solar PV and the nuclear industry. Job numbers in both industries fall significantly between 2020 and 2030, bringing about a decline over which takes the total numbers back to 111,000 by 2030. This is still 47% above 2010 levels.

The Basic Energy [R]evolution scenario increase of 27,000 jobs by 2015 includes significant growth across the renewable sector (34,000 jobs), with solar PV closely followed by wind energy and concentrating solar thermal. There is a reduction in construction jobs in the coal sector as current projects finish around 2014, and these are replaced by extensive construction in renewable energy The renewable sector expands rapidly to 2020, with 21,000 jobs added, and continues to grow slowly to 2030. By 2030 there are 112,000 electricity sector jobs, 48% above 2010 levels.

### figure 7.1: jobs by technology under three scenarios




### table 7.1: electricity sector jobs in the three scenarios

| Thousand Jobs | 2010 | REFERENCE 2015 | 2020 | 2030 | ENERGY [R]EVOLUTION 2015 | 2020 | 2030 | ADVANCED ENERGY [R]EVOLUTION 2015 | 2020 | 2030 |
|---|---|---|---|---|---|---|---|---|---|---|
| Coal | 67.8 | 75.1 | 66.9 | 69.7 | 55.4 | 49.6 | 35.9 | 53.0 | 42.7 | 28.6 |
| Gas, oil and diesel | 1.8 | 1.8 | 4.1 | 6.4 | 3.0 | 3.2 | 3.8 | 3.0 | 2.7 | 3.5 |
| Nuclear | 1.3 | 16.5 | 31.7 | 9.9 | 1.3 | 1.3 | 0.0 | 1.3 | 1.3 | 0.0 |
| Renewables | 4.8 | 22.6 | 30.3 | 25.3 | 38.5 | 58.9 | 64.4 | 123.9 | 85.8 | 97.4 |
| Manufacturing (export) | - | - | - | - | - | - | - | 2.7 | 5.1 | 14.5 |
| Energy efficiency | - | - | - | - | 4.6 | 2.8 | 7.6 | 4.6 | 2.4 | 5.5 |
| **Total Jobs** | **75.7** | **116.0** | **133.0** | **111.3** | **102.8** | **115.8** | **111.6** | **188.4** | **140.0** | **149.5** |

**41** INCLUDING JOBS IN COAL MINING FOR EXPORTS AND ENERGY EFFICIENCY JOBS RELATING TO THE DECREASE IN ELECTRICITY RELATIVE TO THE REFERENCE CASE.
**42** THE ENERGY [R]EVOLUTION REFERENCE CASE HAS BEEN MODIFIED TO CORRESPOND MORE EXACTLY TO THE INTEGRATED RESOURCE PLAN POLICY ADJUSTED SCENARIO.

The massive growth in jobs by 2015 in the Advanced Energy [R]evolution scenario is mainly concentrated in the PV industry, which accounts for 77% of the increase (87,000 jobs). These are not maintained, and by 2020 have fallen to 45,000, with overall electricity sector numbers at 140,000 – almost double the 2010 level. From 2010 to 2030, overall numbers increase again, and the distribution of jobs becomes more diverse. Solar PV still accounts for the highest numbers of jobs at 2030 (32,000), followed by coal, concentrating solar thermal, biomass, and wind energy, all significant employment creators. This scenario includes an enhanced renewable technology manufacturing effort, which accounts for 14,500 export jobs by 2030. Overall electricity sector employment in 2030 is 149,000 – more than double 2010 levels.

## 7.2 methodology overview

Greenpeace engaged the Australian-based Institute for Sustainable Futures (ISF) to model the employment effects of the 2009 and 2010 global energy scenarios and the 2009 South African Energy [R]evolution. These were published as "Working for the climate – Renewable Energy & The Green Job [R]evolution (2009)"[43], and the "South African Energy Sector Jobs to 2030 (2010)"[44]. The modelling methodology was updated and published in 2010[45], with an improved method to calculate construction employment, and some updated global employment factors. This analysis uses the newer methodology, South African factors from the previous analysis, and 2010 global Energy [R]evolution data.

The model calculates indicative numbers for jobs that would either be created or lost under the two Energy [R]evolution scenarios and the Reference scenario, with the aim of showing the effect on employment if the world re-invents its energy mix to dramatically cut carbon emissions.

The Reference ('business as usual') scenario is based on the Integrated Resource Plan Policy Adjusted scenario, and has been slightly modified for the jobs analysis so that it corresponds more exactly to the IRP scenario. The Reference scenario year by year capacities have been modified using those from the IRP Table 3 (Policy Adjusted IRP), and the 2010 capacities in all scenarios have been set as the existing capacities in Table 27 of the IRP (Existing South African Generating capacity)[46].

To calculate how many jobs will either be lost or created under the three scenarios requires a series of assumptions or calculations. These are summarised below.

- Installed electrical capacity and generation by technology for each year, from the two Energy [R]evolution scenarios and the Reference scenario.
- "Employment factors" for each technology, which give the number of jobs per unit of electrical capacity.
- A regional multiplier to adjust the employment factor when a local one not available. Employment factors from OECD data are adjusted upwards using a multiplier to allow for the fact that economic activities in regions with lower GDP per capita are generally more labour intensive.
- Decline factors, or learning adjustment rates, which are used to reduce the employment factors by a specific percentage each year, as employment per unit of capacity reduces as technologies mature.
- The percentage of manufacturing for each technology which occurs within South Africa.
- Projected South African exports of coal and renewable technologies for each scenario.

Only direct employment is included, namely jobs in construction, manufacturing, operations and maintenance, and fuel supply associated with electricity generation.

An indicative result for energy efficiency jobs is calculated, although the associated uncertainty is even greater than for energy supply. Energy efficiency employment is only calculated for the reduction in electricity generation in the [R]evolution scenarios compared to the Reference scenario, with ten per cent of this assumed to be solar water heating.

Employment numbers are indicative only, as a large number of assumptions are required to make calculations. However, within the limits of data availability, the figures presented are indicative of employment levels under the three scenarios.

More information on the employment factors is given in the Appendix, and a detailed discussion can be found in Rutovitz (2010)[44] and Rutovitz and Usher (2010)[45].

The calculation of energy supply jobs is summarised in Table 7.2.

**43** GREENPEACE INTERNATIONAL AND EUROPEAN RENEWABLE ENERGY COUNCIL. 2009. WORKING FOR THE CLIMATE.
**44** RUTOVITZ, J. 2010. SOUTH AFRICAN ENERGY SECTOR JOBS TO 2030. PREPARED FOR GREENPEACE AFRICA BY THE INSTITUTE OF SUSTAINABLE FUTURES, UNIVERSITY OF TECHNOLOGY, SYDNEY.
**45** RUTOVITZ, J AND USHER, J. 2010. METHODOLOGY FOR CALCULATING ENERGY SECTOR JOBS. PREPARED FOR GREENPEACE INTERNATIONAL BY THE INSTITUTE OF SUSTAINABLE FUTURES, UNIVERSITY OF TECHNOLOGY, SYDNEY.
**46** INTEGRATED RESOURCE PLAN FOR ELECTRICITY 2010-2030. REVISION 2 FINAL REPORT. MARCH 2011.

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


**table 7.2: methodology to calculate employment**

| | | | | | | |
|---|---|---|---|---|---|---|
| **MANUFACTURING JOBS** (FOR DOMESTIC USE) | = | MW INSTALLED PER YEAR | × | MANUFACTURING EMPLOYMENT FACTOR | × | % OF LOCAL MANUFACTURING |
| **MANUFACTURING JOBS** (FOR EXPORT, ADVANCED SCENARIO ONLY) | = | MW EXPORTED PER YEAR | × | MANUFACTURING EMPLOYMENT FACTOR | × | % OF LOCAL MANUFACTURING |
| **CONSTRUCTION JOBS** | = | MW INSTALLED PER YEAR | × | CONSTRUCTION EMPLOYMENT FACTOR | | |
| **OPERATION & MAINTENANCE JOBS** | = | CUMULATIVE CAPACITY | × | O&M EMPLOYMENT FACTOR | | |
| **FUEL SUPPLY JOBS** | = | ELECTRICITY GENERATION | × | FUEL EMPLOYMENT FACTOR | | |
| **COAL EXPORT JOBS** | = | COAL EXPORT TONNES | × | FUEL EMPLOYMENT FACTOR | | |
| **JOBS IN REGION** 2010 | = | **JOBS (AS ABOVE)** | | | | |
| **JOBS IN REGION** 2020 | = | **JOBS (AS ABOVE)** × TECHNOLOGY DECLINE FACTOR$^{\text{(years after start)}}$ | | | | |
| **JOBS IN REGION** 2030 | = | **JOBS (AS ABOVE)** × TECHNOLOGY DECLINE FACTOR$^{\text{(years after start)}}$ | | | | |

### 7.2.1 manufacturing and enhanced manufacturing

The proportion of manufacturing that occurs within South Africa is estimated in order to calculate local jobs. In the Reference and [R]evolution scenarios, it is assumed that only 20% of manufacturing occurs within the country for all technologies other than solar water heating, where 50% of manufacturing occurs within the country.

Enhanced manufacturing has been included in the Advanced Energy [R]evolution scenario, as it is assumed that such high growth in renewable energy would be accompanied by increased manufacturing. In this scenario, 30% of renewable manufacturing occurs within South Africa at 2030, and 50% of renewable manufacturing occurs within the country by 2030. This scenario also includes some export of renewable technologies. By 2020 it is assumed that 20% of the growth in renewable capacity in the rest of the continent is supplied by South African manufacturing, and by 2030 it is assumed that this has grown to 30%.

The overall percentage of manufacturing is applied to the export market as well as the domestic market. For example, by 2030 in the Advanced Energy [R]evolution scenario, South Africa is assumed to supply 30% of the African wind energy market, and to manufacture 50% of the components for that market, thereby supplying 15% of the components in total.

### 7.2.2 energy efficiency

Base case energy efficiency jobs are not calculated, so the energy efficiency jobs reported are only those additional to the reference scenarios, which contribute to reducing electricity consumption. The factor for energy efficiency other than solar water heating is taken from a US study[47], and is multiplied by 2.15 for use in the South African context.

### 7.2.3 coal trade

Jobs in coal mining have been calculated after taking international trade into account. The projected growth in coal exports is a combination of inter-regional trade, to destinations outside the African contintent, and exports to other African countries.

Inter-regional trade in the Reference scenario is derived by applying the projection for South Africa's proportion of inter-regional trade (from the from the International Energy World Energy Outlook 2009, Table 1.6) to the quantity of inter-regionally imported coal (from the Greenpeace Global Reference scenario), with the changes in regional coal production (from the International Energy Agency projections in WEO 2009, Table 1.7) determining the proportion each region imports.

South Africa's projected proportion of inter-regional trade is applied to inter-regionally traded coal in the Basic Energy [R]evolution and Advanced Energy [R]evolution scenario. The assumption is made that as countries' coal consumption decline they import less, as they are able to meet a higher proportion of their requirements with domestically produced coal.

South African coal exports to other African countries are derived from the 2006 export figures (from the International Energy Agency Coal information, Table 1.1, Part 4). The 2005 data is adjusted for subsequent years according to the changes in primary coal consumption in each of the Greenpeace scenarios. Thus, in the Advanced Energy [R]evolution scenario, coal exports to the rest of Africa fall from 6.3 million tonnes in 2010 to 1.6 million tonnes by 2030, while in the Reference scenario coal exports rise to 19.6 million tonnes.

**47** EHRHARDT-MARTINEZ, K. AND LAITNER, J.A.S. 2008. THE SIZE OF THE U.S. ENERGY EFFICIENCY MARKET: GENERATING A MORE COMPLETE PICTURE. ACEEE MAY 2008 REPORT NUMBER E083.

# energy resources & security of supply

**GLOBAL** | OIL | GAS | COAL | NUCLEAR | RENEWABLE ENERGY

# 8


AROUND 80% OF GLOBAL ENERGY DEMAND IS MET BY FINITE FOSSIL FUELS. © R. KASPRZAK/DREAMSTIME

## “the issue of security of supply is now at the top of the energy policy agenda.”

**GREENPEACE INTERNATIONAL**
CLIMATE CAMPAIGN

**image** BROWN COAL SURFACE MINING IN HAMBACH, GERMANY. GIANT COAL EXCAVATOR AND SPOIL PILE.

The issue of security of supply is now at the top of the energy policy agenda. Concern is focused both on price security and the security of physical 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 resources. At the same time, the global distribution of oil and gas resources does not match the distribution of demand. Some countries have to rely almost entirely on fossil fuel imports. The maps on the following pages provide an overview of the availability of different fuels and their regional distribution. Information in this chapter is based partly on the report 'Plugging the Gap'[48], as well as information from the International Energy Agency's World Energy Outlook 2008 and 2009 reports.

## 8.1 oil

Oil is the lifeblood of the modern global economy, as the effects of the supply disruptions of the 1970s made clear. It is the number one source of energy, providing 32% of the world's needs and the fuel employed almost exclusively for essential uses such as transportation. However, a passionate debate has developed over the ability of supply to meet increasing consumption, a debate obscured by poor information and stirred by recent soaring prices.

### 8.1.1 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 have 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, mostly represented by OPEC (Organisation of Petroleum Exporting Countries), have taken a very different approach. They are not subject to any sort of accountability and their reporting practices are even less clear. In the late 1980s, the 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 apparent 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 their information is as unsatisfactory as ever. Their conclusions should therefore 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.

### 8.1.2 non-conventional oil reserves

A large share of the world's remaining oil resources is classified as 'non-conventional'. Potential fuel sources such as oil sands, extra heavy oil and oil shale are generally more costly to exploit and their recovery involves enormous environmental damage. The reserves of oil sands and extra heavy oil in existence worldwide are estimated to amount to around 6 trillion barrels, of which between 1 and 2 trillion barrels are believed to be recoverable if the oil price is high enough and the environmental standards low enough.

One of the worst examples of environmental degradation resulting from the exploitation of unconventional oil reserves is the oil sands that lie beneath the Canadian province of Alberta and form the world's second-largest proven oil reserves after Saudi Arabia. Producing crude oil from these 'tar sands' - a heavy mixture of bitumen, water, sand and clay found beneath more than 54,000 square miles[49] of prime forest in northern Alberta, an area the size of England and Wales - generates up to four times more carbon dioxide, the principal global warming gas, than conventional drilling. The booming oil sands industry will produce 100 million tonnes of $CO_2$ a year (equivalent to a fifth of the UK's entire annual emissions) by 2012, ensuring that Canada will miss its emission targets under the Kyoto treaty. The oil rush is also scarring a wilderness landscape: millions of tonnes of plant life and top soil are scooped away in vast opencast mines and millions of litres of water diverted from rivers. Up to five barrels of water are needed to produce a single barrel of crude and the process requires huge amounts of natural gas. It takes two tonnes of the raw sands to produce a single barrel of oil.

## 8.2 gas

Natural gas has been the fastest growing fossil energy source over the last two decades, boosted by its increasing share in the electricity generation mix. Gas is generally regarded as an 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, and a few massive fields make up 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.

**48** 'PLUGGING THE GAP - A SURVEY OF WORLD FUEL RESOURCES AND THEIR IMPACT ON THE DEVELOPMENT OF WIND ENERGY', GLOBAL WIND ENERGY COUNCIL/RENEWABLE ENERGY SYSTEMS, 2006.
**49** *THE INDEPENDENT*, 10 DECEMBER 2007

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, with ambiguities arising over the amount produced, partly because flared and vented gas is not always accounted for. As opposed to published reserves, the technical reserves have been almost constant since 1980 because discoveries have roughly matched production.

### 8.2.1 shale gas[50]

Natural gas production, especially in the United States, has recently involved a growing contribution from non-conventional gas supplies such as shale gas. In South Africa, three oil companies are eyeing the exploration of natural gas trapped in the underground shale formations in the Karoo. Conventional natural gas deposits have a well-defined geographical area, the reservoirs are porous and permeable, the gas is produced easily through a wellbore and does not generally require artificial stimulation. Non-conventional deposits, on the other hand, are often lower in resource concentration, more dispersed over large areas and require well stimulation or some other extraction or conversion technology. They are also usually more expensive to develop per unit of energy.

Research and investment in non-conventional gas resources has increased significantly in recent years due to the rising price of conventional natural gas. In some areas the technologies for economic production have already been developed, in others it is still at the research stage. Extracting shale gas, however, usually goes hand in hand with environmentally hazardous processes. In South Africa hydraulic fracturing, also called "fracking", is proposed as the process to exploit shale gas reserves. This extraction method poses a threat to ground and surface water, bringing a significant risk of contamination. Also, fracking uses huge volumes of water. Given that many parts of South Africa already experience water shortages, the prospect of further stressing water supplies could pose serious problems at a local and regional level.

**table 8.1: 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 | | WEO 2009, WEO 2008, WEO 2007 EJ | BROWN, 2002 EJ | IEA, 2002c EJ | | IPCC, 2001a EJ | | NAKICENOVIC ET AL., 2000 EJ | | UNDP ET AL., 2000 EJ | | BGR, 1998 EJ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gas** | reserves | 182 tcm[a] | 5,600 | 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 | 405 tcm[a] | 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[d] | 111,900 |
| | additional occurrences | 921 tcm[a] | | | | 796,000 | | 799,700 | | 930,000 | | |
| **Oil** | reserves | 2,369 bb[b] | 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 | 847 bill tonnes[c] | 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 | 921 tcm[c] | | | | 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** | | |

**sources & notes** A) WEO 2009, B) OIL WEO 2008, PAGE 205 TABLE 9.1
C) IEA WEO 2008, PAGE 127 & WEC 2007. D) INCLUDING GAS HYDRATES.
SEE TABLE FOR ALL OTHER SOURCES.

**50** INTERSTATE NATURAL GAS ASSOCIATION OF AMERICA (INGAA), "AVAILABILITY, ECONOMICS AND PRODUCTION POTENTIAL OF NORTH AMERICAN UNCONVENTIONAL NATURAL GAS SUPPLIES", NOVEMBER 2008.

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

**image** ON A LINFEN STREET, TWO MEN LOAD UP A CART WITH COAL THAT WILL BE USED FOR COOKING. LINFEN, A CITY OF ABOUT 4.3 MILLION, IS ONE OF THE MOST POLLUTED CITIES IN THE WORLD. CHINA'S INCREASINGLY POLLUTED ENVIRONMENT IS LARGELY A RESULT OF THE COUNTRY'S RAPID DEVELOPMENT AND CONSEQUENTLY A LARGE INCREASE IN PRIMARY ENERGY CONSUMPTION, WHICH IS ALMOST ENTIRELY PRODUCED BY BURNING COAL.



## table 8.2: assumptions on fossil fuel use in the three scenarios

| **Oil** | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| Reference [PJ] | 155,920 | 161,847 | 170,164 | 192,431 | 209,056 | 224,983 |
| Reference [million barrels] | 25,477 | 26,446 | 27,805 | 31,443 | 34,159 | 36,762 |
| E[R] [PJ] | | 153,267 | 143,599 | 123,756 | 101,186 | 81,833 |
| E[R] [million barrels] | | 25,044 | 23,464 | 20,222 | 16,534 | 13,371 |
| Adv E[R] [PJ] | | 152,857 | 142,747 | 115,002 | 81,608 | 51,770 |
| Adv E[R] [million barrels] | | 24,977 | 23,325 | 18,791 | 13,335 | 8,459 |
| **Gas** | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
| Reference [PJ] | 104,845 | 112,931 | 121,148 | 141,706 | 155,015 | 166,487 |
| Reference [billion cubic metres = 10E9m$^3$] | 2,759 | 2,972 | 3,188 | 3,729 | 4,079 | 4,381 |
| E[R] [PJ] | | 116,974 | 121,646 | 122,337 | 99,450 | 71,383 |
| E[R] [billion cubic metres = 10E9m$^3$] | | 3,078 | 3,201 | 3,219 | 2,617 | 1,878 |
| Adv E[R] [PJ] | | 118,449 | 119,675 | 114,122 | 79,547 | 34,285 |
| Adv E[R] [billion cubic metres = 10E9m$^3$] | | 3,117 | 3,149 | 3,003 | 2,093 | 902 |
| **Coal** | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
| Reference [PJ] | 135,890 | 162,859 | 162,859 | 204,231 | 217,356 | 225,245 |
| Reference [million tonnes] | 7,319 | 8,306 | 8,306 | 9,882 | 10,408 | 10,751 |
| E[R] [PJ] | | 140,862 | 140,862 | 96,846 | 64,285 | 37,563 |
| E[R] [million tonnes] | | 7,217 | 7,217 | 4,407 | 2,810 | 1,631 |
| Adv E[R] [PJ] | | 135,005 | 135,005 | 69,871 | 28,652 | 7,501 |
| Adv E[R] [million tonnes] | | 6,829 | 6,829 | 3,126 | 1,250 | 326 |

## 8.3 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 in the context of both energy security and global warming.

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 coal. 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 forward, the world will consume 20% of its current reserves by 2030 and 40% by 2050. Hence, if current trends are maintained, coal would still last several hundred years.

South Africa's proven coal reserves have recently been downgraded from 48 Gt in 2008 to 30 Gt in 2009[51].

## 8.4 nuclear

Uranium, the fuel used in nuclear power plants, is a finite resource whose economically available reserves are limited. Its distribution is almost as concentrated as oil and does not match global 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.

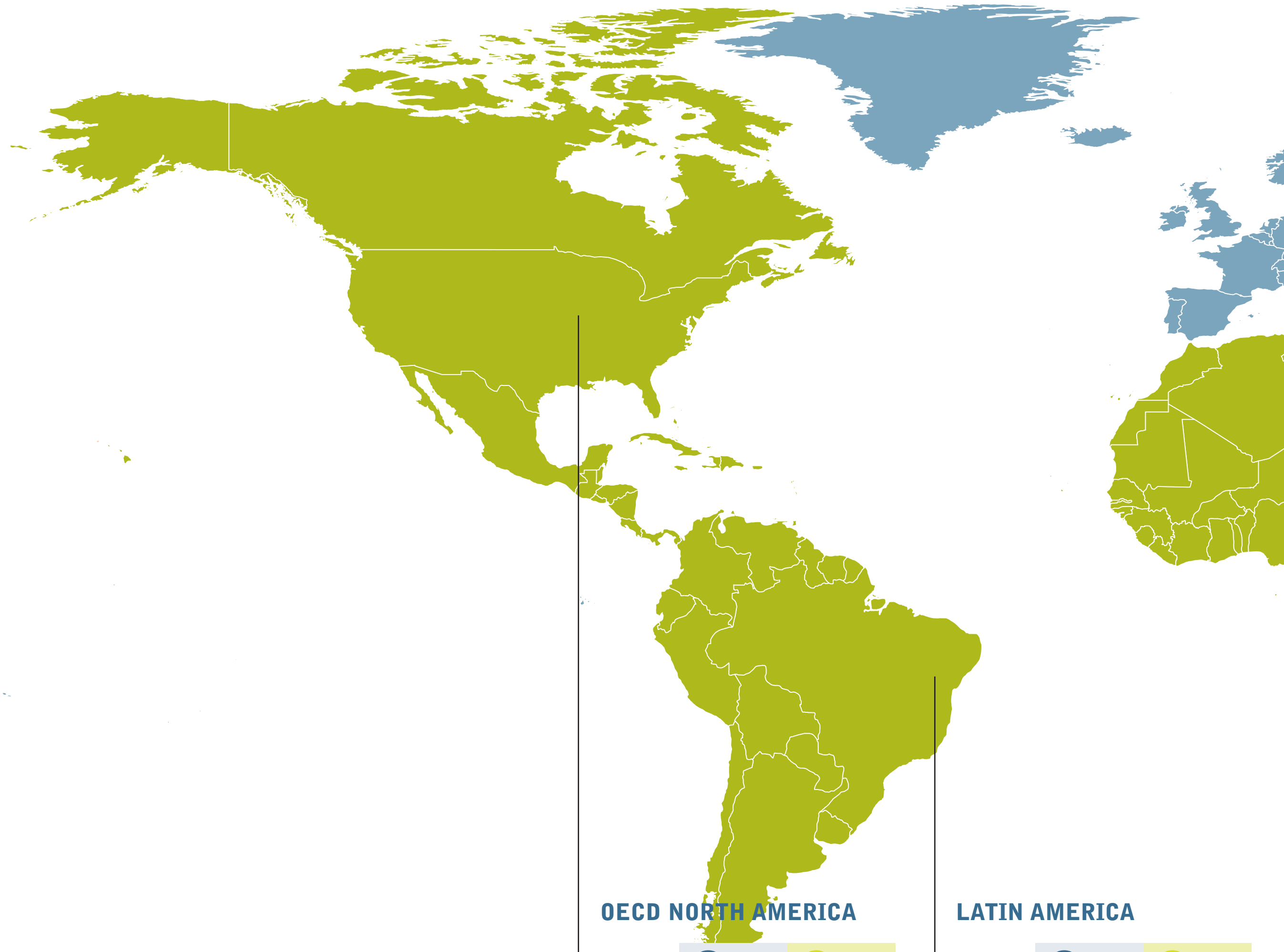
Secondary sources, such as old deposits, currently make up nearly half of worldwide uranium reserves. These will soon be used up, however. Mining capacities will have to be nearly doubled in the next few years to meet current needs.

A joint report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency[52] estimates that all existing nuclear power plants will have used up their nuclear fuel, employing current technology, within less than 70 years. Given the range of scenarios for the worldwide development of nuclear power, it is likely that uranium supplies will be exhausted sometime between 2026 and 2070. This forecast includes the use of mixed oxide fuel (MOX), a mixture of uranium and plutonium.

**51** BP STATISTICAL REVIEW OF WORLD ENERGY, JUNE 2010.
**52** 'URANIUM 2003: RESOURCES, PRODUCTION AND DEMAND'

## map 8.1: oil reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO





### OECD NORTH AMERICA

| | | REF TMB | REF % | E[R] TMB | E[R] % |
|---|---|---|---|---|---|
| Reserves | 2007 | 69.3 | 5.6% | 69.3 | 5.6% |
| | | **MB** | **PJ** | **MB** | **PJ** |
| Consumption per region | 2007 | 7,429H | 45,466H | 7,429H | 45,466H |
| | 2050 | 6,594H | 40,352H | 1,225 | 7,494 |
| | | **L** | | **L** | |
| Consumption per person | 2007 | 2,707H | | 2,707H | |
| | 2050 | 1,816H | | 337 | |

### LATIN AMERICA

| | | REF TMB | REF % | E[R] TMB | E[R] % |
|---|---|---|---|---|---|
| Reserves | 2007 | 111.2 | 9.0% | 111.2 | 9.0% |
| | | **MB** | **PJ** | **MB** | **PJ** |
| Consumption per region | 2007 | 1,691 | 10,349 | 1,691 | 10,349 |
| | 2050 | 2,597 | 15,895 | 292 | 1,788 |
| | | **L** | | **L** | |
| Consumption per person | 2007 | 598 | | 598 | |
| | 2050 | 653 | | 73 | |

## NON RENEWABLE RESOURCE

# OIL

### LEGEND

>60 | 50-60 | 40-50 | 30-40 | 20-30 | 10-20 | 5-10 | 0-5 — % RESOURCES GLOBALLY

REF — REFERENCE SCENARIO

E[R] — ADVANCED ENERGY [R]EVOLUTION SCENARIO

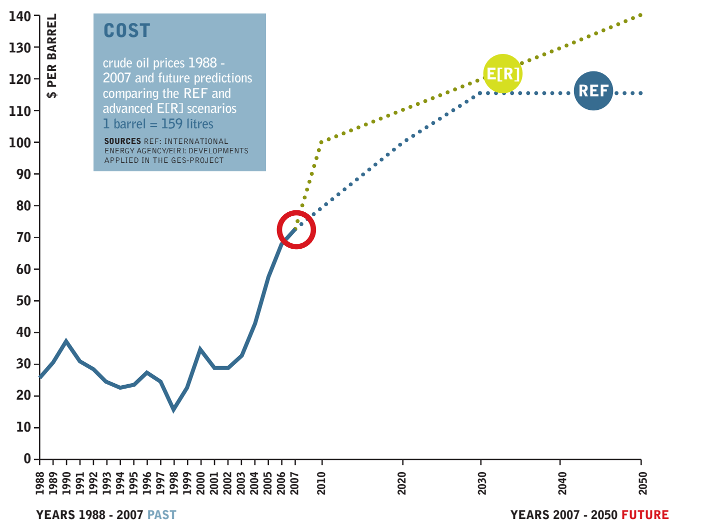
0 — 1000 KM

**RESERVES TOTAL** THOUSAND MILLION BARRELS [TMB] | SHARE IN % OF GLOBAL TOTAL [END OF 2007]

**CONSUMPTION PER REGION** MILLION BARRELS [MB] | PETA JOULE [PJ]

**CONSUMPTION PER PERSON** LITERS [L]

**H** HIGHEST | **M** MIDDLE | **L** LOWEST



## OECD EUROPE

| | REF | | E[R] | |
|---|---|---|---|---|
| | TMB | % | TMB | % |
| 2007 | 16.9 | 1.4%M | 16.9 | 1.4%M |
| | MB | PJ | MB | PJ |
| 2007 | 4,337 | 26,541 | 4,337 | 4,418 |
| 2050 | 3,590M | 21,970M | 722M | 9,361M |
| | L | | L | |
| 2007 | 1,285 | | 1,285 | |
| 2050 | 1,013M | | 204 | |

## MIDDLE EAST

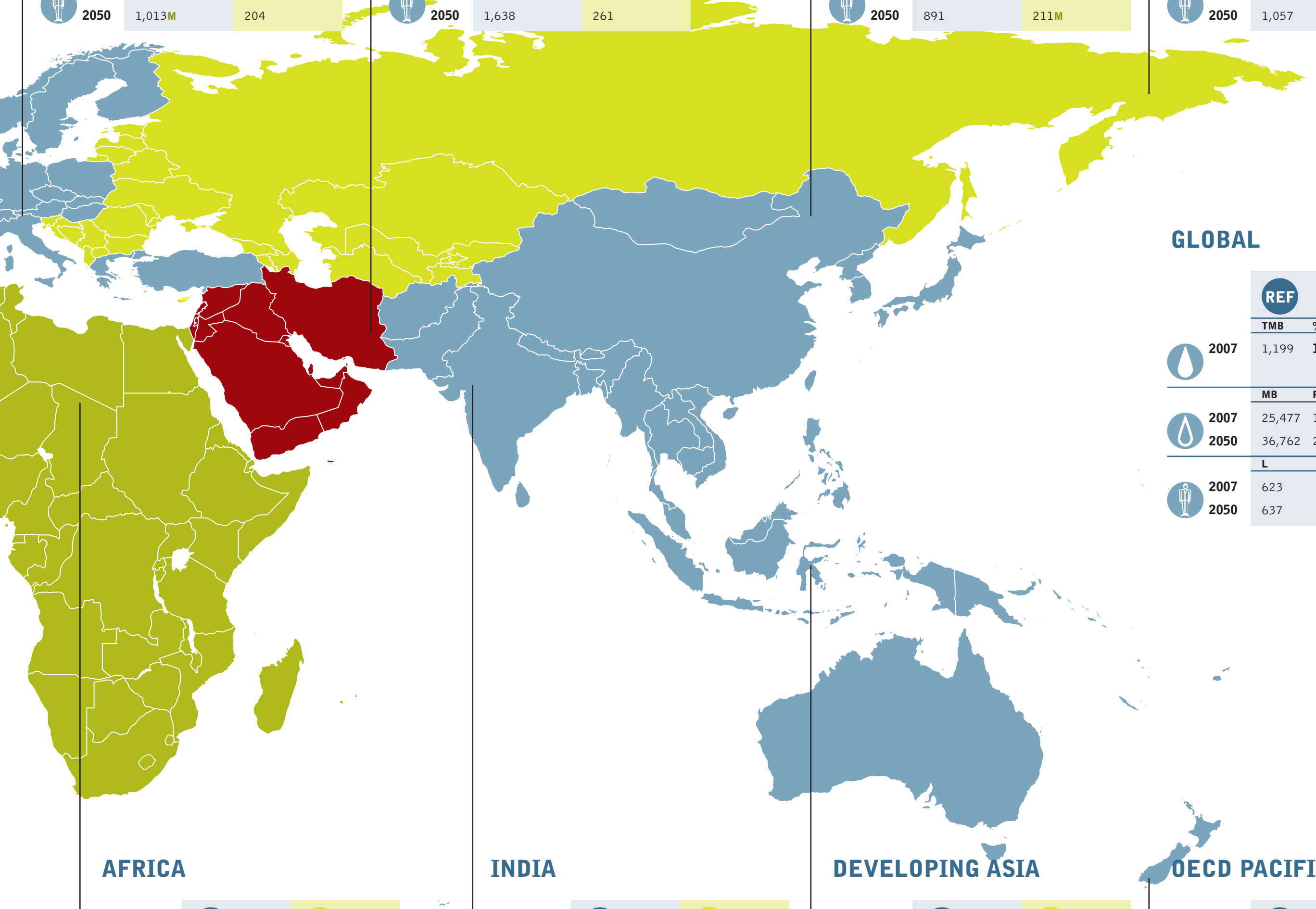
| | REF | | E[R] | |
|---|---|---|---|---|
| | TMB | % | TMB | % |
| 2007 | 755.3H | 61.0%H | 755.3H | 61.0%H |
| | MB | PJ | MB | PJ |
| 2007 | 1,913 | 11,709 | 1,913 | 11,709 |
| 2050 | 3,574 | 21,871 | 569 | 3,482 |
| | L | | L | |
| 2007 | 1,617 | | 1,617 | |
| 2050 | 1,638 | | 261 | |

## CHINA

| | REF | | E[R] | |
|---|---|---|---|---|
| | TMB | % | TMB | % |
| 2007 | 15.5 | 1.3% | 15.5 | 1.3% |
| | MB | PJ | MB | PJ |
| 2007 | 2,445 | 14,966 | 2,445 | 14,966 |
| 2050 | 7,946 | 48,629 | 1,881H | 11,513H |
| | L | | L | |
| 2007 | 294 | | 294 | |
| 2050 | 891 | | 211M | |

## TRANSITION ECONOMIES

| | REF | | E[R] | |
|---|---|---|---|---|
| | TMB | % | TMB | % |
| 2007 | 87.6 | 10.1%L | 87.6 | 10.1%L |
| | MB | PJ | MB | PJ |
| 2007 | 1,605 | 9,826 | 1,605 | 9,826 |
| 2050 | 1,953L | 11,955L | 441L | 2,701L |
| | L | | L | |
| 2007 | 748M | | 748M | |
| 2050 | 1,057 | | 239 | |



## GLOBAL

| | REF | | E[R] | |
|---|---|---|---|---|
| | TMB | % | TMB | % |
| 2007 | 1,199 | 100% | 1,199 | 100% |
| | MB | PJ | MB | PJ |
| 2007 | 25,477 | 155,919 | 25,477 | 155,919 |
| 2050 | 36,762 | 224,981 | 8,459 | 51,770 |
| | L | | L | |
| 2007 | 623 | | 623 | |
| 2050 | 637 | | 147 | |

## AFRICA

| | REF | | E[R] | |
|---|---|---|---|---|
| | TMB | % | TMB | % |
| 2007 | 117.5M | 9.5% | 117.5M | 9.5% |
| | MB | PJ | MB | PJ |
| 2007 | 924 | 5,654 | 924 | 5,654 |
| 2050 | 1,667 | 10,202 | 689 | 4,214 |
| | L | | L | |
| 2007 | 159 | | 159 | |
| 2050 | 133L | | 55L | |

## INDIA

| | REF | | E[R] | |
|---|---|---|---|---|
| | TMB | % | TMB | % |
| 2007 | 5.5 | 0.5% | 5.5 | 0.5% |
| | MB | PJ | MB | PJ |
| 2007 | 1,011L | 6,187L | 1,011 | 6,187 |
| 2050 | 3,669 | 22,455 | 1,169 | 7,152 |
| | L | | L | |
| 2007 | 142L | | 142L | |
| 2050 | 352 | | 112 | |

## DEVELOPING ASIA

| | REF | | E[R] | |
|---|---|---|---|---|
| | TMB | % | TMB | % |
| 2007 | 14.8 | 1.2% | 14.8 | 1.2% |
| | MB | PJ | MB | PJ |
| 2007 | 1,656 | 10,136 | 1,656 | 10,136 |
| 2050 | 3,448 | 21,099 | 1,014 | 6,204 |
| | L | | L | |
| 2007 | 270 | | 270 | |
| 2050 | 365 | | 107 | |

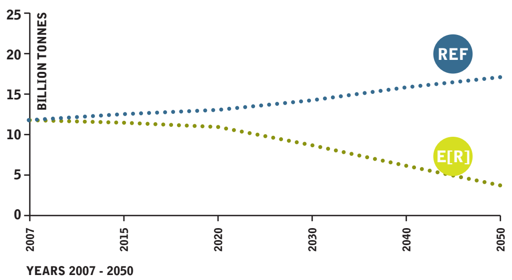
## OECD PACIFIC

| | REF | | E[R] | |
|---|---|---|---|---|
| | TMB | % | TMB | % |
| 2007 | 5.1L | 0.4% | 5.1L | 0.4% |
| | MB | PJ | MB | PJ |
| 2007 | 2,465M | 15,089M | 2,465 | 15,086 |
| 2050 | 1,724 | 10,552 | 458 | 2,805 |
| | L | | L | |
| 2007 | 1,958 | | 1,958 | |
| 2050 | 1,539 | | 409H | |

## $CO_2$ EMISSIONS FROM OIL

comparison between the REF and advanced E[R] scenarios 2007 - 2050 billion tonnes

SOURCE GPI/EREC




## RESERVES AND CONSUMPTION

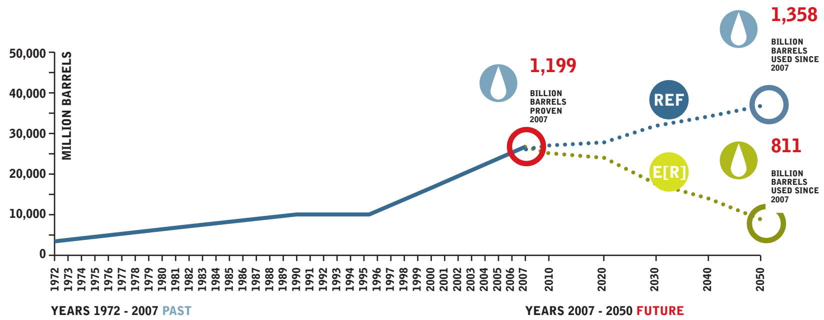
oil reserves versus global demand, production and consumption. global consumption comparison between the REF and advanced E[R] scenarios.

million barrels. 1 barrel = 159 litres

SOURCE BP 2008

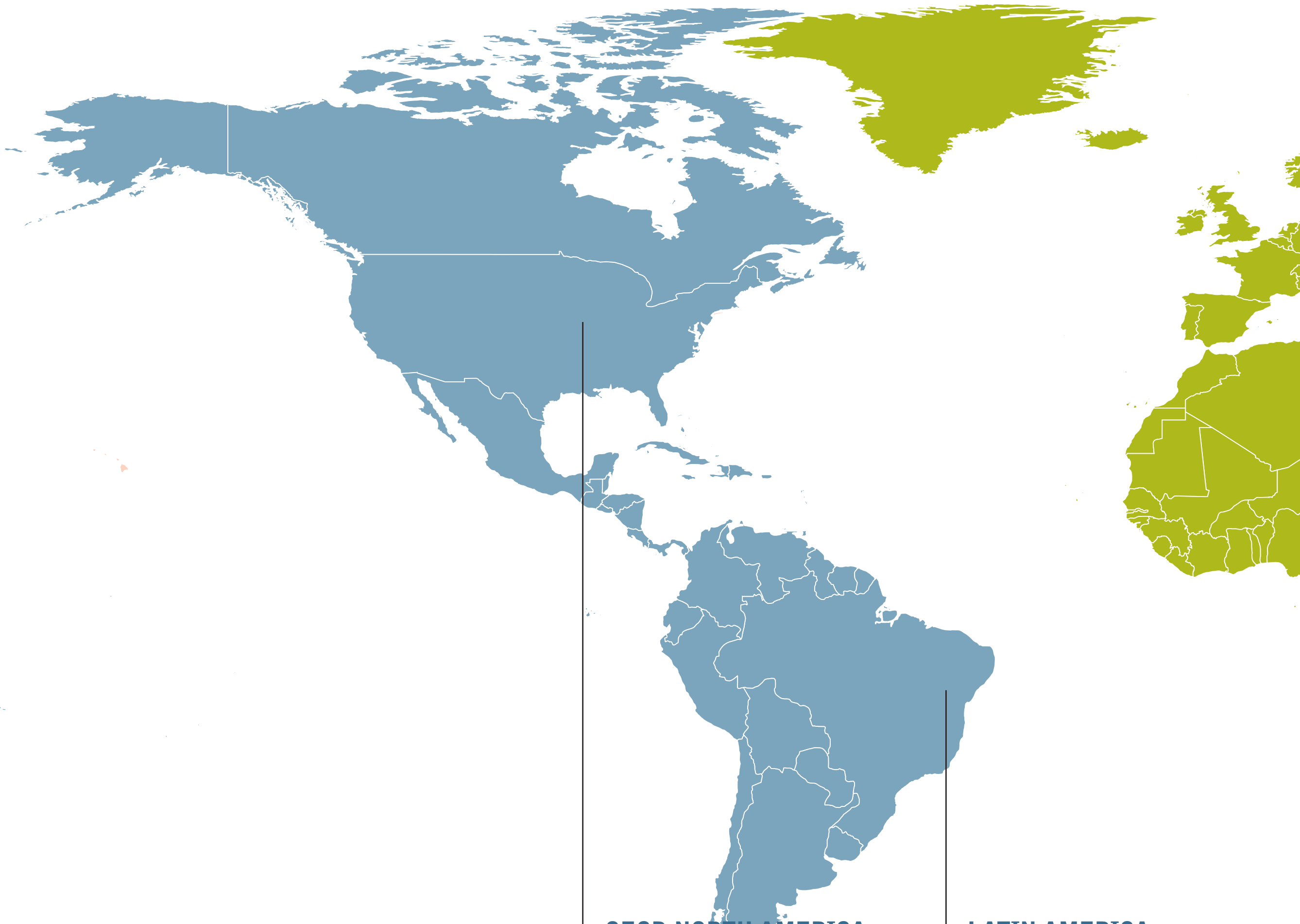
REF global consumption

ADV E[R] global consumption



## map 8.2: gas reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO



### OECD NORTH AMERICA

| | | REF | | E[R] | |
|---|---|---|---|---|---|
| Reserves total | | tn m³ | % | tn m³ | % |
| | 2007 | 8.0 | 4.4% | 8.0 | 4.4% |
| Consumption per region | | bn m³ | PJ | bn m³ | PJ |
| | 2007 | 722H | 27,435H | 722H | 27,435H |
| | 2050 | 767H | 29,144H | 71H | 2,688H |
| Consumption per person | | m³ | | m³ | |
| | 2007 | 1,608 | | 1,608 | |
| | 2050 | 1,328 | | 123 | |

### LATIN AMERICA

| | | REF | | E[R] | |
|---|---|---|---|---|---|
| Reserves total | | tn m³ | % | tn m³ | % |
| | 2007 | 7.7 | 4.3% | 7.7 | 4.3% |
| Consumption per region | | bn m³ | PJ | bn m³ | PJ |
| | 2007 | 117 | 4,465 | 117 | 4,465 |
| | 2050 | 246M | 9,358M | 34 | 1,303 |
| Consumption per person | | m³ | | m³ | |
| | 2007 | 254 | | 254 | |
| | 2050 | 410 | | 57 | |

## NON RENEWABLE RESOURCE

# GAS

### LEGEND

>50 | 40-50 | 30-40 | 20-30 | 10-20 | 5-10 | 0-5 % RESOURCES GLOBALLY

REF REFERENCE SCENARIO

E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

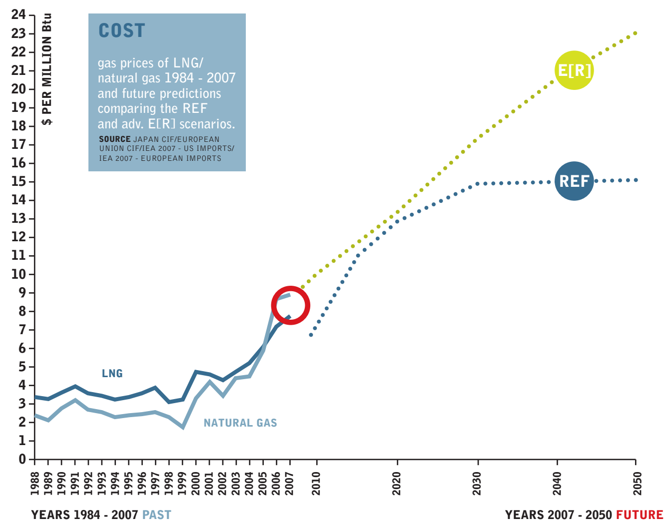
0 1000 KM

**RESERVES TOTAL** TRILLION CUBIC METRES [tn m³] | SHARE IN % OF GLOBAL TOTAL [END OF 2007]

**CONSUMPTION PER REGION** BILLION CUBIC METRES [bn m³] | PETA JOULE [PJ]

**CONSUMPTION PER PERSON** CUBIC METRES [m³]

**H** HIGHEST | **M** MIDDLE | **L** LOWEST



## OECD EUROPE

| | REF tn m³ | REF % | E[R] tn m³ | E[R] % |
|---|---|---|---|---|
| 2007 | 9.8 | 5.4% | 9.8 | 5.4% |
| | bn m³ | PJ | bn m³ | PJ |
| 2007 | 504 | 19,170 | 504 | 19,170 |
| 2050 | 644 | 24,469 | 69 | 2,613 |
| | m³ | | m³ | |
| 2007 | 934 | | 934 | |
| 2050 | 1,120M | | 120 | |

## MIDDLE EAST

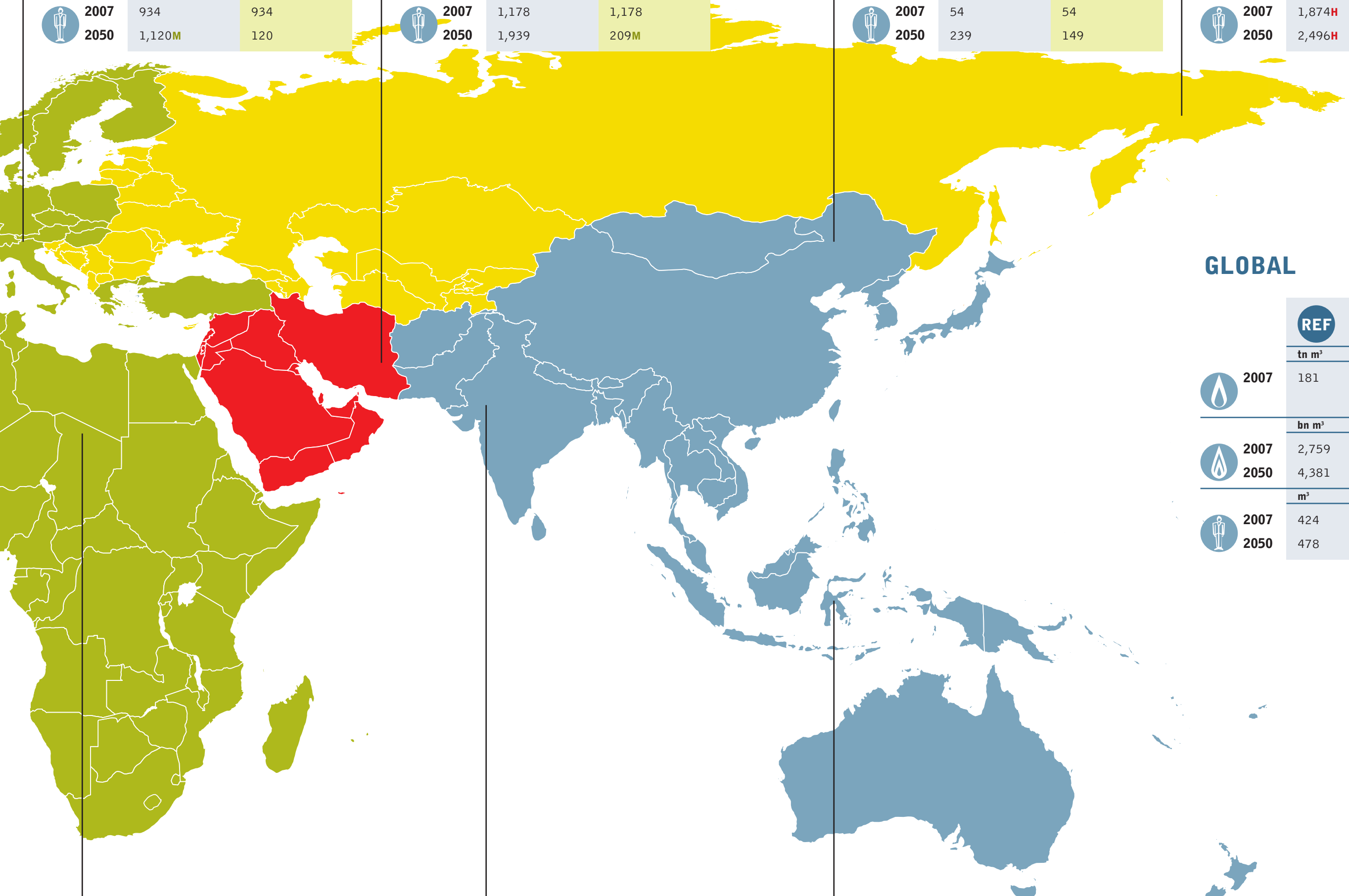
| | REF tn m³ | REF % | E[R] tn m³ | E[R] % |
|---|---|---|---|---|
| 2007 | 73.2H | 40.4%H | 73.2H | 40.4%H |
| | bn m³ | PJ | bn m³ | PJ |
| 2007 | 238M | 9,056M | 239 | 9,056 |
| 2050 | 685 | 26,034 | 74 | 2,805 |
| | m³ | | m³ | |
| 2007 | 1,178 | | 1,178 | |
| 2050 | 1,939 | | 209M | |

## CHINA

| | REF tn m³ | REF % | E[R] tn m³ | E[R] % |
|---|---|---|---|---|
| 2007 | 1.9 | 1.0% | 1.9 | 1.0% |
| | bn m³ | PJ | bn m³ | PJ |
| 2007 | 71 | 2,716 | 71 | 2,716 |
| 2050 | 341 | 12,953 | 212 | 8,061 |
| | m³ | | m³ | |
| 2007 | 54 | | 54 | |
| 2050 | 239 | | 149 | |

## TRANSITION ECONOMIES

| | REF tn m³ | REF % | E[R] tn m³ | E[R] % |
|---|---|---|---|---|
| 2007 | 53.3 | 29.4% | 53.3 | 29.4% |
| | bn m³ | PJ | bn m³ | PJ |
| 2007 | 638 | 24,225 | 638 | 24,225 |
| 2050 | 776 | 29,478 | 138 | 5,248 |
| | m³ | | m³ | |
| 2007 | 1,874H | | 1,874H | |
| 2050 | 2,496H | | 444H | |



## GLOBAL

| | REF tn m³ | REF % | E[R] tn m³ | E[R] % |
|---|---|---|---|---|
| 2007 | 181 | 100% | 181 | 100% |
| | bn m³ | PJ | bn m³ | PJ |
| 2007 | 2,759 | 104,846 | 2,759 | 104,846 |
| 2050 | 4,381 | 166,489 | 902 | 34,285 |
| | m³ | | m³ | |
| 2007 | 424 | | 424 | |
| 2050 | 478 | | 99 | |

## AFRICA

| | REF tn m³ | REF % | E[R] tn m³ | E[R] % |
|---|---|---|---|---|
| 2007 | 14.6M | 8.0%M | 14.6M | 8.0%M |
| | bn m³ | PJ | bn m³ | PJ |
| 2007 | 91 | 3,472 | 91 | 3,472 |
| 2050 | 167 | 6,338 | 65 | 2,456 |
| | m³ | | m³ | |
| 2007 | 95 | | 95 | |
| 2050 | 83 | | 32L | |

## INDIA

| | REF tn m³ | REF % | E[R] tn m³ | E[R] % |
|---|---|---|---|---|
| 2007 | 1.1L | 0.6%L | 1.1L | 0.6%L |
| | bn m³ | PJ | bn m³ | PJ |
| 2007 | 37L | 1,397L | 37L | 1,397L |
| 2050 | 164L | 6,227L | 107M | 4,075M |
| | m³ | | m³ | |
| 2007 | 32L | | 32L | |
| 2050 | 102L | | 66 | |

## DEVELOPING ASIA

| | REF tn m³ | REF % | E[R] tn m³ | E[R] % |
|---|---|---|---|---|
| 2007 | 8.6 | 4.8% | 8.6 | 4.8% |
| | bn m³ | PJ | bn m³ | PJ |
| 2007 | 184 | 6,998 | 184 | 6,998 |
| 2050 | 422 | 16,020 | 115 | 4,368 |
| | m³ | | m³ | |
| 2007 | 182 | | 182 | |
| 2050 | 278 | | 76 | |

## OECD PACIFIC

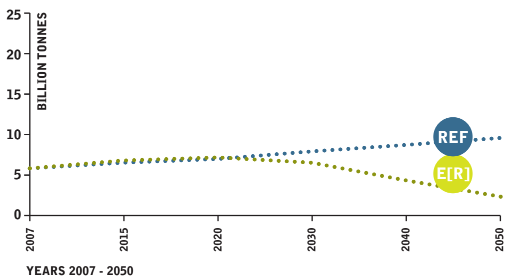
| | REF tn m³ | REF % | E[R] tn m³ | E[R] % |
|---|---|---|---|---|
| 2007 | 2.9 | 1.6% | 2.9 | 1.6% |
| | bn m³ | PJ | bn m³ | PJ |
| 2007 | 156 | 5,912 | 156 | 5,912 |
| 2050 | 170 | 6,467 | 18L | 667L |
| | m³ | | m³ | |
| 2007 | 776M | | 776M | |
| 2050 | 946 | | 98 | |

## $CO_2$ EMISSIONS FROM GAS

comparison between the REF and adv. E[R] scenarios 2007 - 2050

billion tonnes

**SOURCE** GPI/EREC



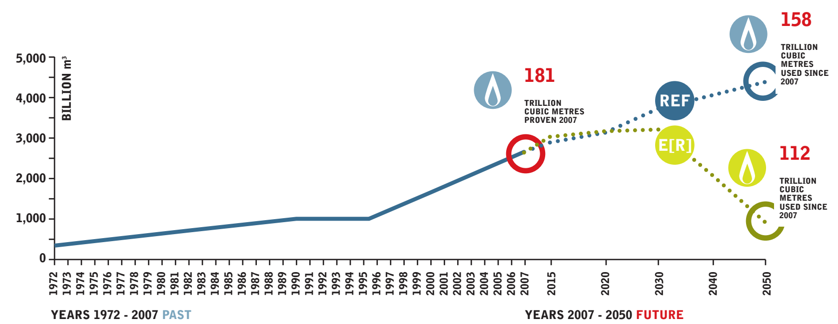

## RESERVES AND CONSUMPTION

gas reserves versus global demand, production and consumption. global consumption comparison between the REF and advanced E[R] scenarios.

billion cubic metres

**SOURCE** 1970-2008 BP, 2007-2050 GPI/EREC

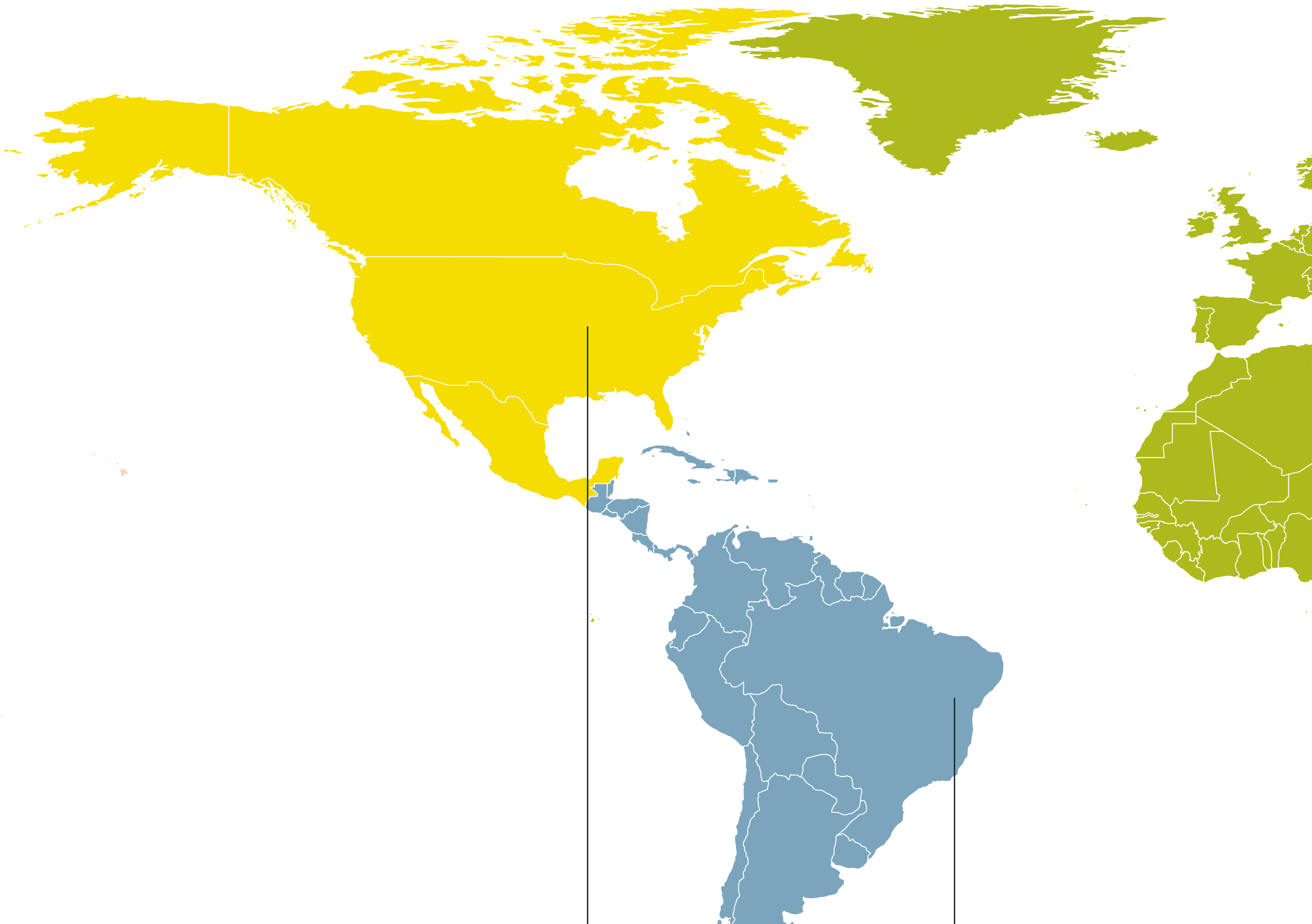
REF global consumption
ADV E[R] global consumption




**DESIGN** WWW.ONEHEMISPHERE.SE **CONCEPT** SVEN TESKE/GREENPEACE INTERNATIONAL.

## map 8.3: coal reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO



### OECD NORTH AMERICA

| | | REF | | E[R] | |
|---|---|---|---|---|---|
| | | mn t | % | mn t | % |
| Reserves total | 2007 | 250,510 | 29.6% | 250,510 | 29.6% |
| | | mn t | PJ | mn t | PJ |
| Consumption per region | 2007 | 1,882 | 24,923 | 1,882 | 24,923 |
| | 2050 | 1,351 | 27,255 | 6 | 134 |
| | | t | | t | |
| Consumption per person | 2007 | 2.4 | | 2.4 | |
| | 2050 | 2.0 | | 0.0 | |

### LATIN AMERICA

| | | REF | | E[R] | |
|---|---|---|---|---|---|
| | | mn t | % | mn t | % |
| Reserves total | 2007 | 16,276 | 1.9% | 16,276 | 1.9% |
| | | mn t | PJ | mn t | PJ |
| Consumption per region | 2007 | 45 | 891 | 45 | 891 |
| | 2050 | 165 | 3,122 | 11 | 247 |
| | | t | | t | |
| Consumption per person | 2007 | 0.1 | | 0.1 | |
| | 2050 | 0.2 | | 0.0 | |

## NON RENEWABLE RESOURCE

# COAL

### LEGEND

>60 | 50-60 | 40-50 | 30-40 | 20-30 | 10-20 | 5-10 | 0-5 % RESOURCES GLOBALLY

REF REFERENCE SCENARIO

E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

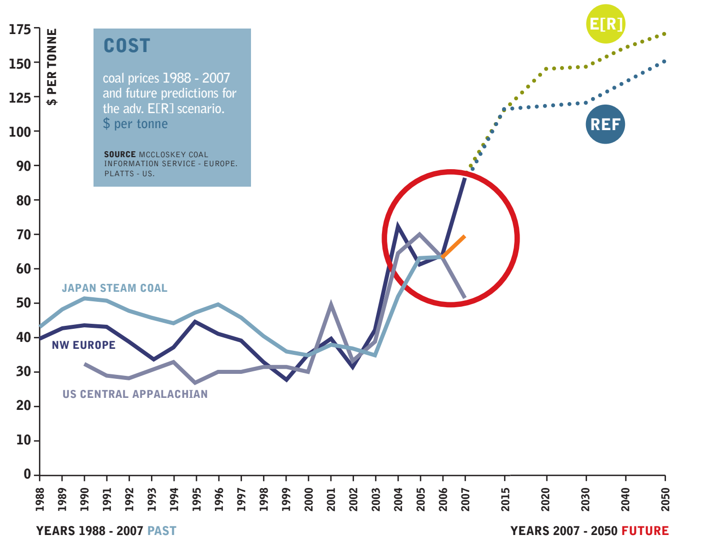
0 1000 KM

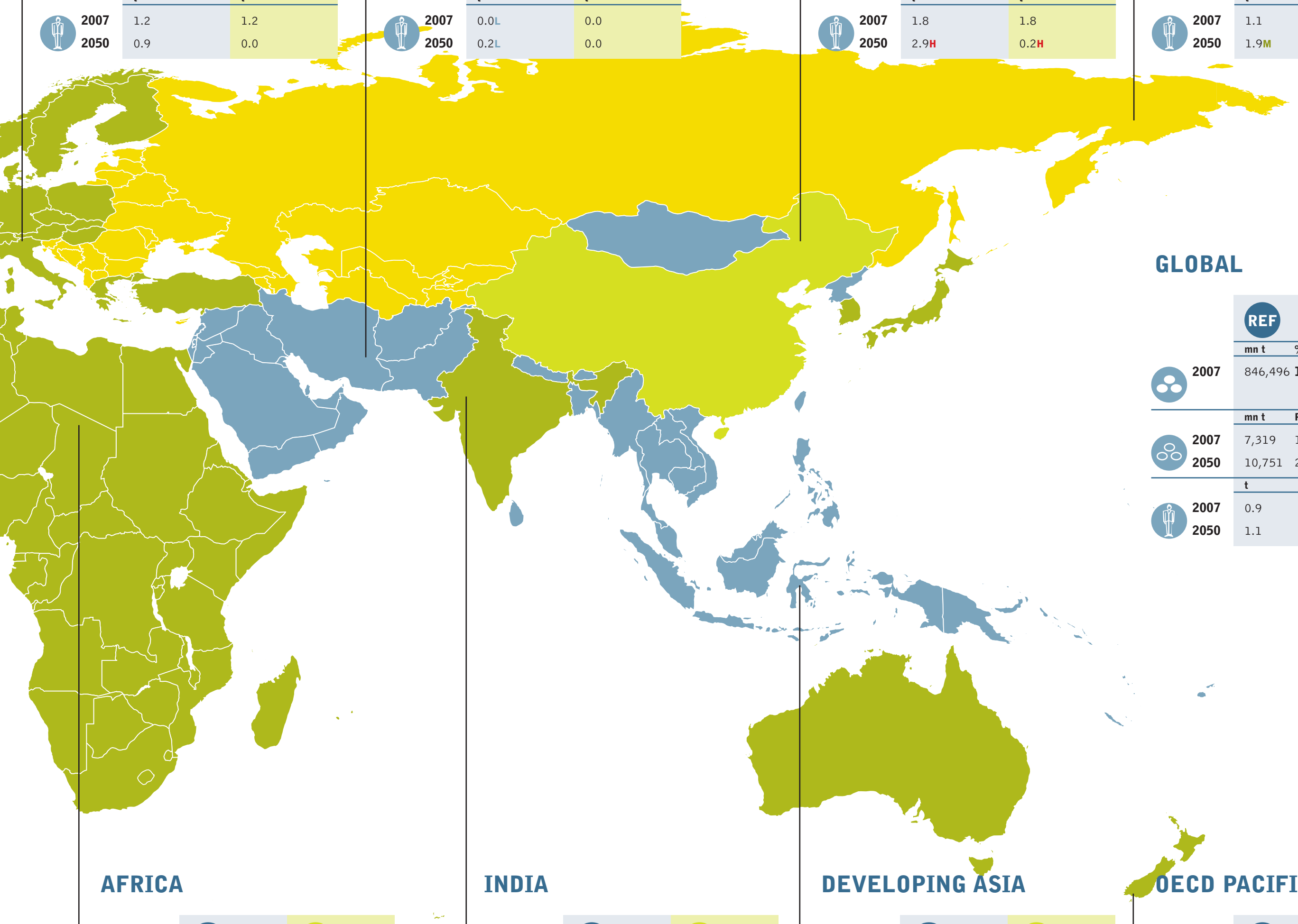
**RESERVES TOTAL** MILLION TONNES [mn t] | SHARE IN % OF GLOBAL TOTAL [END OF 2007]

**CONSUMPTION PER REGION** MILLION TONNES [mn t] | PETA JOULE [PJ]

**CONSUMPTION PER PERSON** TONNES [t]

**H HIGHEST | M MIDDLE | L LOWEST**





## OECD EUROPE

| | REF | | E[R] | |
| --- | --- | --- | --- | --- |
| | mn t | % | mn t | % |
| 2007 | 50,063 | 5.9% | 50,063 | 5.9% |
| | mn t | PJ | mn t | PJ |
| 2007 | 897 | 14,371 | 897 | 14,371 |
| 2050 | 710 | 11,899 | 10 | 231 |
| | t | | t | |
| 2007 | 1.2 | | 1.2 | |
| 2050 | 0.9 | | 0.0 | |

## MIDDLE EAST

| | REF | | E[R] | |
| --- | --- | --- | --- | --- |
| | mn t | % | mn t | % |
| 2007 | 1,386 | 0.2%L | 1,386 | 0.2%L |
| | mn t | PJ | mn t | PJ |
| 2007 | 19L | 437L | 19 | 437 |
| 2050 | 91L | 2,092L | 1L | 13 |
| | t | | t | |
| 2007 | 0.0L | | 0.0 | |
| 2050 | 0.2L | | 0.0 | |

## CHINA

| | REF | | E[R] | |
| --- | --- | --- | --- | --- |
| | mn t | % | mn t | % |
| 2007 | 114,500 | 13.5% | 114,500 | 13.5% |
| | mn t | PJ | mn t | PJ |
| 2007 | 2,403H | 55,333H | 2,403 | 55,333 |
| 2050 | 4,148H | 95,527H | 218H | 5,027H |
| | t | | t | |
| 2007 | 1.8 | | 1.8 | |
| 2050 | 2.9H | | 0.2H | |

## TRANSITION ECONOMIES

| | REF | | E[R] | |
| --- | --- | --- | --- | --- |
| | mn t | % | mn t | % |
| 2007 | 222,183 | 26% | 222,183 | 26% |
| | mn t | PJ | mn t | PJ |
| 2007 | 532 | 9,003 | 532 | 9,003 |
| 2050 | 904 | 13,665 | 14 | 327 |
| | t | | t | |
| 2007 | 1.1 | | 1.1 | |
| 2050 | 1.9M | | 0.0 | |

## GLOBAL

| | REF | | E[R] | |
| --- | --- | --- | --- | --- |
| | mn t | % | mn t | % |
| 2007 | 846,496 | 100% | 846,496 | 100% |
| | mn t | PJ | mn t | PJ |
| 2007 | 7,319 | 135,890 | 7,319 | 135,890 |
| 2050 | 10,751 | 225,244 | 326 | 7,501 |
| | t | | t | |
| 2007 | 0.9 | | 0.9 | |
| 2050 | 1.1 | | 0.0 | |

## AFRICA

| | REF | | E[R] | |
| --- | --- | --- | --- | --- |
| | mn t | % | mn t | % |
| 2007 | 49,605 | 5.9% | 49,605 | 5.9% |
| | mn t | PJ | mn t | PJ |
| 2007 | 188 | 4,330 | 188 | 4,330 |
| 2050 | 303 | 6,977 | 19 | 427 |
| | t | | t | |
| 2007 | 0.2 | | 0.2 | |
| 2050 | 0.2 | | 0.0 | |

## INDIA

| | REF | | E[R] | |
| --- | --- | --- | --- | --- |
| | mn t | % | mn t | % |
| 2007 | 56,498 | 6.7%M | 56,498 | 6.7%M |
| | mn t | PJ | mn t | PJ |
| 2007 | 459 | 10,126 | 459 | 10,126 |
| 2050 | 1,692 | 36,709 | 37 | 851 |
| | t | | t | |
| 2007 | 0.4 | | 0.4 | |
| 2050 | 1.0 | | 0.0 | |

## DEVELOPING ASIA

| | REF | | E[R] | |
| --- | --- | --- | --- | --- |
| | mn t | % | mn t | % |
| 2007 | 7,814 | 0.9% | 7,814 | 0.9% |
| | mn t | PJ | mn t | PJ |
| 2007 | 330 | 5,824 | 330 | 5,824 |
| 2050 | 868M | 17,902 | 9 | 217 |
| | t | | t | |
| 2007 | 0.3 | | 0.3 | |
| 2050 | 0.5 | | 0.0 | |

## OECD PACIFIC

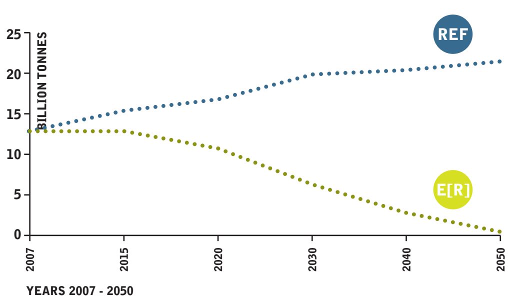
| | REF | | E[R] | |
| --- | --- | --- | --- | --- |
| | mn t | % | mn t | % |
| 2007 | 77,661 | 9% | 77,661 | 9% |
| | mn t | PJ | mn t | PJ |
| 2007 | 565 | 10,652 | 565 | 10,652 |
| 2050 | 518 | 10,097 | 1L | 27 |
| | t | | t | |
| 2007 | 2.3 | | 2.3 | |
| 2050 | 2.4 | | 0.0 | |

## $CO_2$ EMISSIONS FROM COAL

comparison between the REF and adv. E[R] scenarios 2007 - 2050

billion tonnes

**SOURCE** GPI/EREC

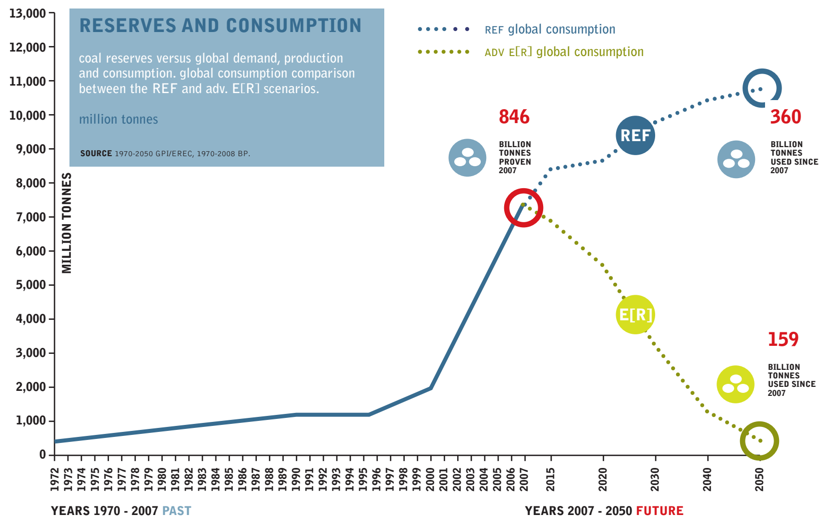



## RESERVES AND CONSUMPTION

coal reserves versus global demand, production and consumption. global consumption comparison between the REF and adv. E[R] scenarios.

million tonnes

**SOURCE** 1970-2050 GPI/EREC, 1970-2008 BP.

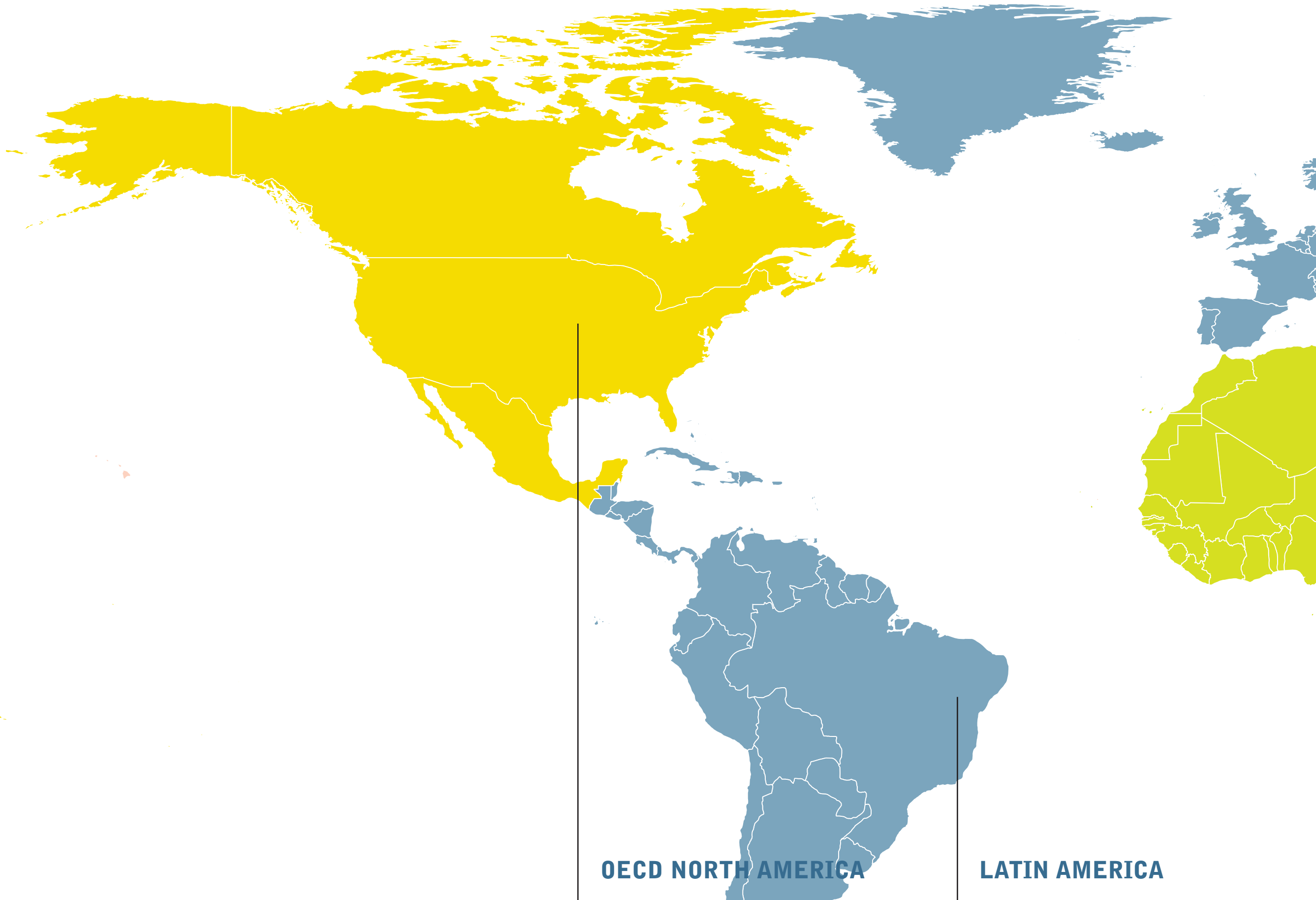





**DESIGN** WWW.ONEHEMISPHERE.SE **CONCEPT** SVEN TESKE/GREENPEACE INTERNATIONAL.

## map 8.4: nuclear reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO



### OECD NORTH AMERICA

| | Year | REF | | E[R] | |
|---|---|---|---|---|---|
| | | t | % | t | % |
| Reserves | 2007 | 680,109 | 21.5% | 680,109 | 21.5% |
| | | TWh | | TWh | |
| Generation | 2007 | 941H | | NUCLEAR POWER PHASED OUT BY 2040 | |
| | 2050 | 1,259H | | | |
| | | PJ | | PJ | |
| Consumption | 2007 | 10,260H | | 10,260H | |
| | 2050 | 13,735H | | 0 | |
| | | kWh | | kWh | |
| Per person | 2007 | 2,094H | | 2,094H | |
| | 2050 | 2,181 | | 0 | |

### LATIN AMERICA

| | Year | REF | | E[R] | |
|---|---|---|---|---|---|
| | | t | % | t | % |
| Reserves | 2007 | 95,045 | 3% | 95,045 | 3% |
| | | TWh | | TWh | |
| Generation | 2007 | 20 | | PHASED OUT BY 2030 | |
| | 2050 | 60 | | | |
| | | PJ | | PJ | |
| Consumption | 2007 | 214 | | 214 | |
| | 2050 | 655 | | 0 | |
| | | kWh | | kWh | |
| Per person | 2007 | 42 | | 42 | |
| | 2050 | 100 | | 0 | |

## NON RENEWABLE RESOURCE

# NUCLEAR

## LEGEND

>30 | 20-30 | 10-20 | 5-10 | 0-5 % RESOURCES GLOBALLY

REF REFERENCE SCENARIO

E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

0 1000 KM

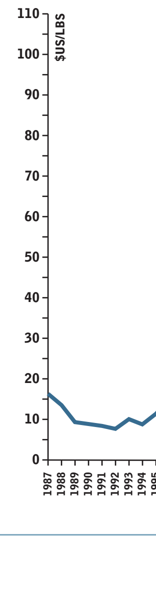
**RESERVES TOTAL** TONNES | SHARE IN % OF GLOBAL TOTAL [END OF 2007]

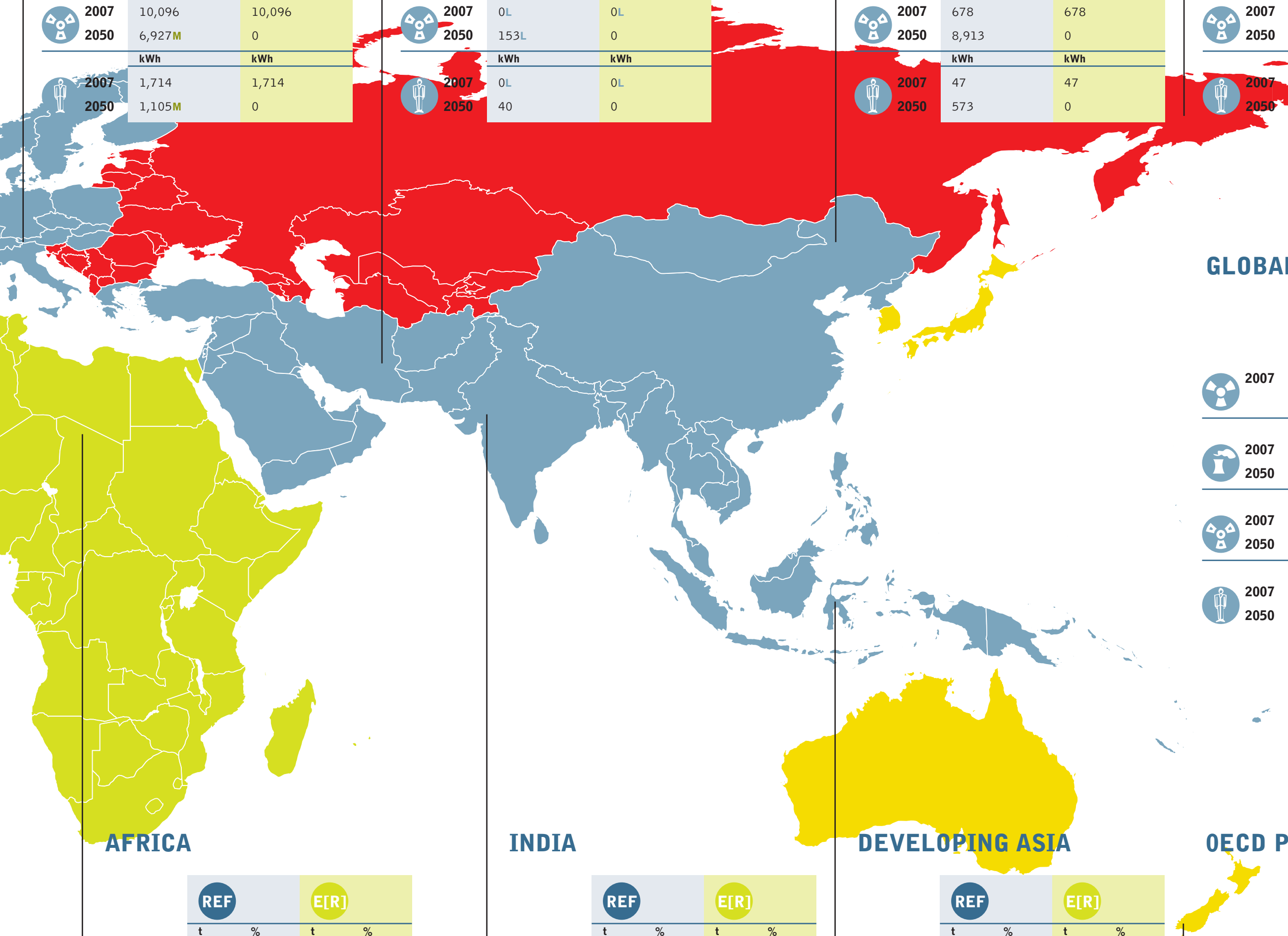
**GENERATION PER REGION** TERAWATT HOURS [TWh]

**CONSUMPTION PER REGION** PETA JOULE [PJ]

**CONSUMPTION PER PERSON** KILOWATT HOURS [kWh]

H HIGHEST | M MIDDLE | L LOWEST





## OECD EUROPE

| | | REF | E[R] |
|---|---|---|---|
| t / % | 2007 | 56,445 1.8% | 56,445 1.8% |
| TWh | 2007 | 925 | PHASED OUT BY 2030 |
| | 2050 | 635M | |
| PJ | 2007 | 10,096 | 10,096 |
| | 2050 | 6,927M | 0 |
| kWh | 2007 | 1,714 | 1,714 |
| | 2050 | 1,105M | 0 |

## MIDDLE EAST

| | | REF | E[R] |
|---|---|---|---|
| t / % | 2007 | 370L 0%L | 370L 0%L |
| TWh | 2007 | 0L | NO NUCLEAR ENERGY DEVELOPMENT |
| | 2050 | 14L | |
| PJ | 2007 | 0L | 0L |
| | 2050 | 153L | 0 |
| kWh | 2007 | 0L | 0L |
| | 2050 | 40 | 0 |

## CHINA

| | | REF | E[R] |
|---|---|---|---|
| t / % | 2007 | 35,060 1.1% | 35,060 1.1% |
| TWh | 2007 | 62 | NUCLEAR POWER PHASED OUT BY 2045 |
| | 2050 | 817 | |
| PJ | 2007 | 678 | 678 |
| | 2050 | 8,913 | 0 |
| kWh | 2007 | 47 | 47 |
| | 2050 | 573 | 0 |

## TRANSITION ECONOMIES

| | | REF | E[R] |
|---|---|---|---|
| t / % | 2007 | 1,043,687H 32.9%H | 1,043,687H 32.9%H |
| TWh | 2007 | 293M | NUCLEAR POWER PHASED OUT BY 2045 |
| | 2050 | 463 | |
| PJ | 2007 | 3,197M | 3,197M |
| | 2050 | 5,051 | 0 |
| kWh | 2007 | 861M | 861M |
| | 2050 | 1,490 | 0 |

## GLOBAL

| | | REF | E[R] |
|---|---|---|---|
| t / % | 2007 | 3,169,238 100% | 3,169,238 100% |
| TWh | 2007 | 2,719 | NUCLEAR POWER PHASED OUT BY 2045 |
| | 2050 | 4,413 | |
| PJ | 2007 | 29,664 | 29,664 |
| | 2050 | 48,142 | 0 |
| kWh | 2007 | 418 | 418 |
| | 2050 | 481 | 0 |

## AFRICA

| | | REF | E[R] |
|---|---|---|---|
| t / % | 2007 | 470,312M 14.8%M | 470,312M 14.8%M |
| TWh | 2007 | 11 | NUCLEAR POWER PHASED OUT BY 2025 |
| | 2050 | 45 | |
| PJ | 2007 | 123 | 123 |
| | 2050 | 491 | 0 |
| kWh | 2007 | 12 | 12 |
| | 2050 | 23L | 0 |

## INDIA

| | | REF | E[R] |
|---|---|---|---|
| t / % | 2007 | 40,980 1.3% | 40,980 1.3% |
| TWh | 2007 | 17 | NUCLEAR POWER PHASED OUT BY 2045 |
| | 2050 | 172 | |
| PJ | 2007 | 183 | 183 |
| | 2050 | 1,876 | 0 |
| kWh | 2007 | 17 | 17 |
| | 2050 | 172 | 0 |

## DEVELOPING ASIA

| | | REF | E[R] |
|---|---|---|---|
| t / % | 2007 | 5,630 0.2% | 5,630 0.2% |
| TWh | 2007 | 44 | NUCLEAR POWER PHASED OUT BY 2045 |
| | 2050 | 80 | |
| PJ | 2007 | 476 | 476 |
| | 2050 | 873 | 0 |
| kWh | 2007 | 43 | 43 |
| | 2050 | 53 | 0 |

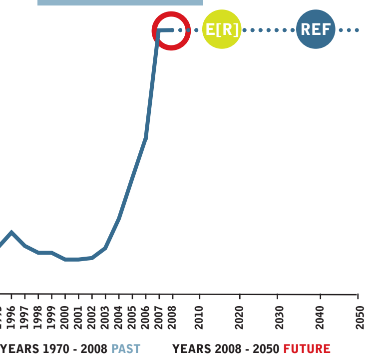
## OECD PACIFIC

| | | REF | E[R] |
|---|---|---|---|
| t / % | 2007 | 741,600 23.4% | 741,600 23.4% |
| TWh | 2007 | 407 | NUCLEAR POWER PHASED OUT BY 2045 |
| | 2050 | 868 | |
| PJ | 2007 | 4,437 | 4,437 |
| | 2050 | 9,469 | 0 |
| kWh | 2007 | 2,030 | 2,030 |
| | 2050 | 4,827H | 0 |

### COST

yellow cake prices 1987 - 2008 and future predictions comparing the REF and adv. E[R] scenarios
tonnes

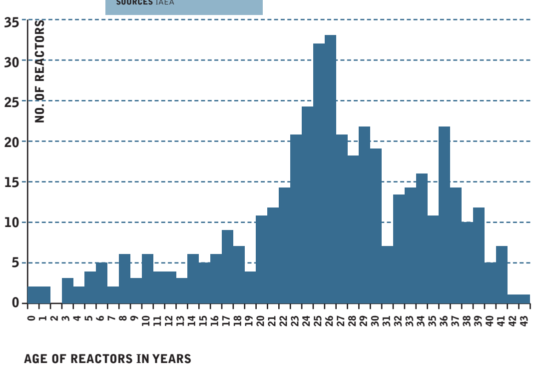
SOURCES REF: INTERNATIONAL ENERGY AGENCY/E[R]: DEVELOPMENTS APPLIED IN THE GES-PROJECT




### REACTORS

age and number of reactors worldwide

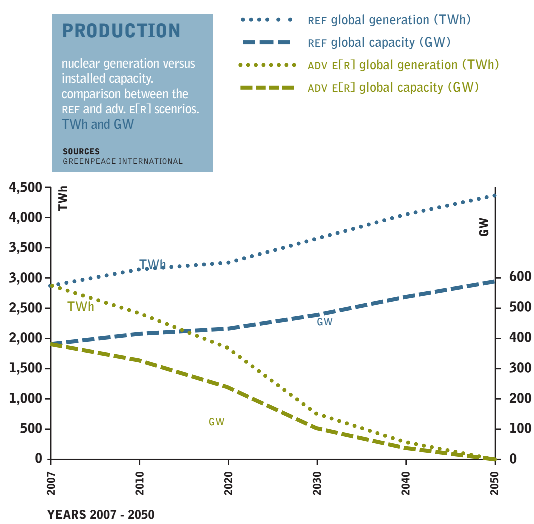
SOURCES IAEA




### PRODUCTION

nuclear generation versus installed capacity. comparison between the REF and adv. E[R] scenrios. TWh and GW

SOURCES GREENPEACE INTERNATIONAL




GREENPEACE
DESIGN WWW.ONEHEMISPHERE.SE CONCEPT SVEN TESKE/GREENPEACE INTERNATIONAL.

## 8.5 renewable energy

Nature offers a variety of freely available options for producing energy. Their exploitation 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. 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.

Before looking at the role renewable energies can play in the range of scenarios in this report, however, it is worth understanding the upper limits of their potential. To start with, the overall technical potential of renewable energy – the amount that can be produced taking into account the primary resources, the socio-geographical constraints and the technical losses in the conversion process – is huge and several times higher than current total energy demand. Assessments of the global technical potential vary significantly from 2,477 Exajoules per annum (EJ/a) (Nitsch 2004) up to 15,857 EJ/a (UBA 2009). Based on the global primary energy demand in 2007 (IEA 2009) of 503 EJ/a, the total technical potential of renewable energy sources at the upper limit would exceed demand by a factor of 32. However, barriers to the growth of renewable energy technologies may come from economical, political and infrastructural constraints. That is why the technical potential will never be realised in total.

Assessing long term technical potentials is subject to various uncertainties. The distribution of the theoretical resources, such as the global wind speed or the productivity of energy crops, is not always well analysed. The geographical availability is subject to variations such as land use change, future planning decisions on where certain technologies are allowed, and accessibility of resources, for example underground geothermal energy. Technical performance may take longer to achieve than expected. There are also uncertainties in terms of the consistency of the data provided in studies, and underlying assumptions are often not explained in detail.

The meta study by the DLR (German Aerospace Agency), Wuppertal Institute and Ecofys, commissioned by the German Federal Environment Agency, provides a comprehensive overview of the technical renewable energy potential by technologies and world region[54]. This survey analysed ten major studies of global and regional potentials by organisations such as the United Nations Development Programme and a range of academic institutions. Each of the major renewable energy sources was assessed, with special attention paid to the effect of environmental constraints on their overall potential. The study provides data for the years 2020, 2030 and 2050 (see Table 8.3).

The complexity of calculating renewable energy potentials is particularly great because these technologies are comparatively young and their exploitation involves changes to the way in which energy is both generated and distributed. Whilst a calculation of the theoretical and geographical potentials has only a few dynamic parameters, the technical potential is dependent on a number of uncertainties.

### definition of types of energy resource potential[53]

**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.

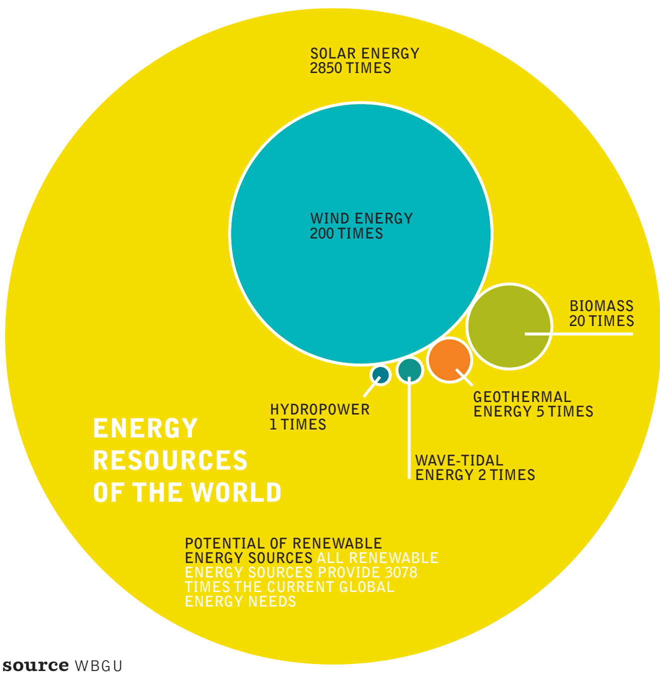
**conversion potential** This is derived from the annual efficiency of the respective conversion technology. It is therefore not a strictly defined value, since the efficiency of a particular technology depends on technological progress.

**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.

**figure 8.1: energy resources of the world**




**source** WBGU

**53** WBGU (GERMAN ADVISORY COUNCIL ON GLOBAL CHANGE).
**54** DLR, WUPPERTAL INSTITUTE, ECOFYS, 'ROLE AND POTENTIAL OF RENEWABLE ENERGY AND ENERGY EFFICIENCY FOR GLOBAL ENERGY SUPPLY', COMMISSIONED BY GERMAN FEDERAL ENVIRONMENT AGENCY, FKZ 3707 41 108, MARCH 2009;

**image** SOLON AG PHOTOVOLTAICS FACILITY IN ARNSTEIN OPERATING 1,500 HORIZONTAL AND VERTICAL SOLAR "MOVERS". LARGEST TRACKING SOLAR FACILITY IN THE WORLD. EACH "MOVER" CAN BE BOUGHT AS A PRIVATE INVESTMENT FROM THE S.A.G. SOLARSTROM AG, BAYERN, GERMANY.

**image** WIND ENERGY PARK NEAR DAHME. WIND TURBINE IN THE SNOW OPERATED BY VESTAS.



## table 8.3: technical potential by renewable energy technology for 2020, 2030 and 2050

| | TECHNICAL POTENTIAL ELECTRICITY EJ/YEAR ELECTRIC POWER | | | | | | | TECHNICAL POTENTIAL HEAT EJ/A | | TECHNICAL POTENTIAL PRIMARY ENERGY EJ/A | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SOLAR CSP | SOLAR PV | HYDRO POWER | WIND ON-SHORE | WIND OFF-SHORE | OCEAN ENERGY | GEO-THERMAL ELECTRIC | GEO-THERMAL DIRECT USES | SOLAR WATER HEATING | BIOMASS RESIDUES | BIOMASS ENERGY CROPS | TOTAL |
| World 2020 | 1,125.9 | 5,156.1 | 47.5 | 368.6 | 25.6 | 66.2 | 4.5 | 498.5 | 113.1 | 58.6 | 43.4 | 7,505 |
| World 2030 | 1,351.0 | 6,187.3 | 48.5 | 361.7 | 35.9 | 165.6 | 13.4 | 1,486.6 | 117.3 | 68.3 | 61.1 | 9,897 |
| World 2050 | 1,688.8 | 8,043.5 | 50.0 | 378.9 | 57.4 | 331.2 | 44.8 | 4,955.2 | 123.4 | 87.6 | 96.5 | 15,857 |
| **World energy demand 2007: 502.9 EJ/a**[a] | | | | | | | | | | | | |
| Technical potential in 2050 versus world primary energy demand 2007. | 3.4 | 16.0 | 0.1 | 0.8 | 0.1 | 0.7 | 0.1 | 9.9 | 0.2 | 0.2 | 0.2 | 32 |

**source** DLR, WUPPERTAL INSTITUTE, ECOFYS; ROLE AND POTENTIAL OF RENEWABLE ENERGY AND ENERGY EFFICIENCY FOR GLOBAL ENERGY SUPPLY; COMMISSIONED BY THE GERMAN FEDERAL ENVIRONMENT AGENCY FKZ 3707 41 108, MARCH 2009; POTENTIAL VERSUS ENERGY DEMAND: S. TESKE
**a** IEA 2009

A technology breakthrough, for example, could have a dramatic impact, changing the technical potential assessment within a very short time frame. Considering the huge dynamic of technology development, many existing studies are based on out of date information. The estimates in the DLR study could therefore be updated using more recent data, for example significantly increased average wind turbine capacity and output, which would increase the technical potentials still further.

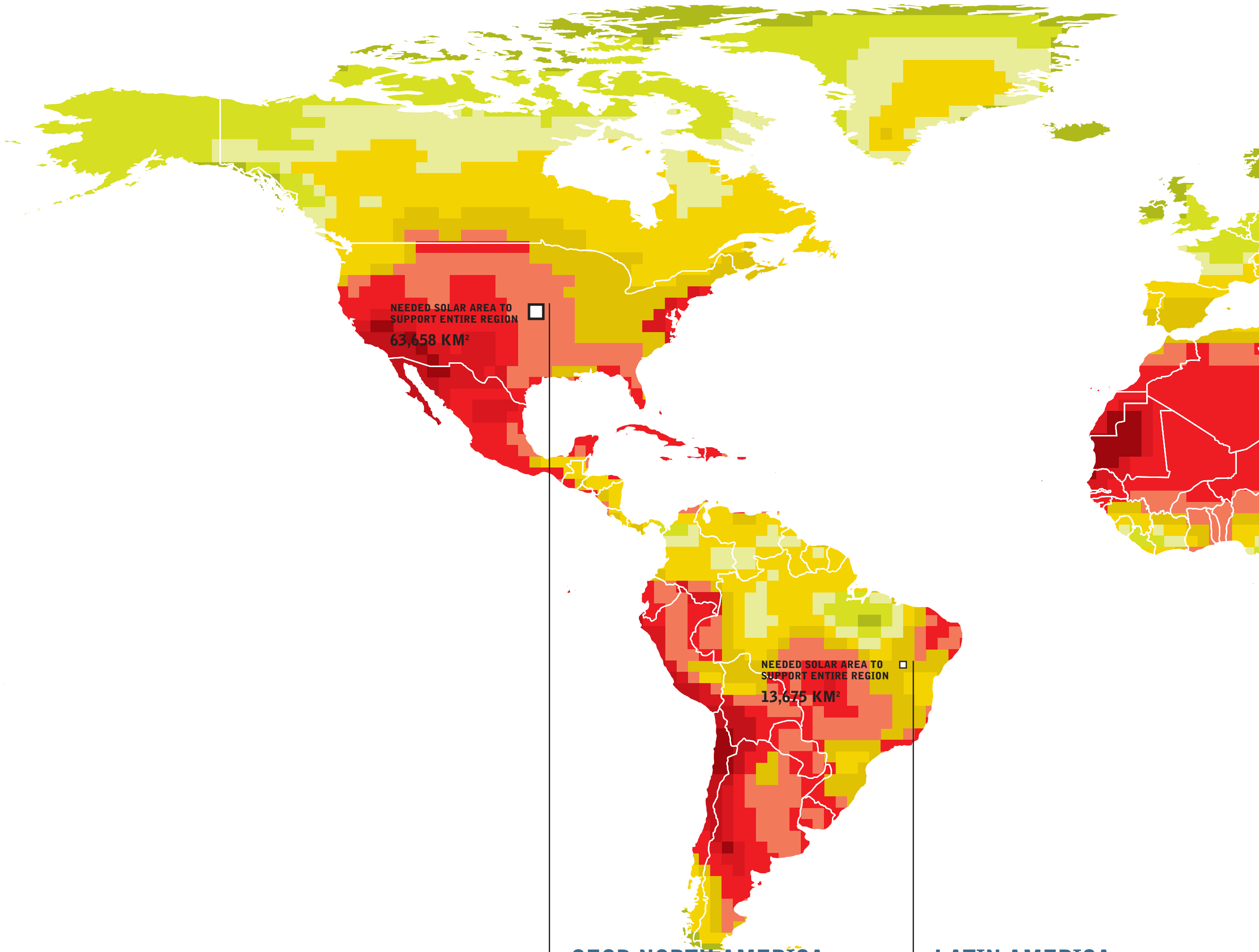
Given the large unexploited resources which exist, even without having reached the full development limits of the various technologies, it can be concluded that the technical potential is not a limiting factor to expansion of renewable energy generation.

It will not be necessary to exploit the entire technical potential, however, nor would this be unproblematic. Implementation of renewable energies has to respect sustainability criteria in order to achieve a sound future energy supply. Public acceptance is crucial, especially bearing in mind that the decentralised character of many renewable energy technologies will move their operations closer to consumers. Without public acceptance, market expansion will be difficult or even impossible. The use of biomass, for example, has become controversial in recent years as it is seen as competing with other land uses, food production or nature conservation. Sustainability criteria will have a huge influence on whether bio-energy in particular can play a central role in future energy supply.

As important as the technical potential of worldwide renewable energy sources is their market potential. This term is often used in different ways. The general understanding is that market potential means the total amount of renewable energy that can be implemented in the market taking into account the demand for energy, competing technologies, any subsidies available as well as the current and future costs of renewable energy sources. The market potential may therefore in theory be larger than the economic potential. To be realistic, however, market potential analyses have to take into account the behaviour of private economic agents under specific prevailing conditions, which are of course partly shaped by public authorities. The energy policy framework in a particular country or region will have a profound impact on the expansion of renewable energies.

## map 7.5: solar reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO




### OECD NORTH AMERICA

| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.06M | 64H | | |
| 2050 | 1.04M | 1,343 | 25M | 17,683 |
| | | kWh | | kWh |
| 2007 | | 40 | | |
| 2050 | | 646 | | 8,508 |

### LATIN AMERICA

| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.03 | 6 | | |
| 2050 | 0.52 | 214 | 14L | 3,799L |
| | | kWh | | kWh |
| 2007 | | 4 | | |
| 2050 | | 99 | | 1,758 |

## RENEWABLE RESOURCE

# SOLAR

### LEGEND

2600-2800 | 2400-2600 | 2200-2400 | 2000-2200 | 1800-2000 | 1600-1800 | 1400-1600 | 1200-1400 | 1000-1200 | 800-1000 | 600-800 | 400-600 | 200-400 | 0-200

RADIATION IN kW/h PER SQUARE METER SOURCE DLR

REF REFERENCE SCENARIO

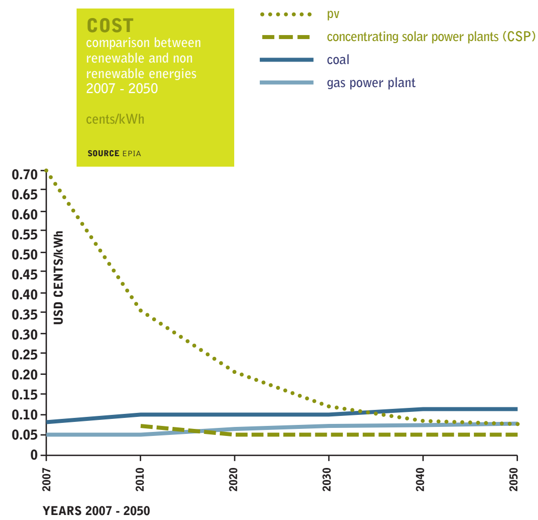
E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

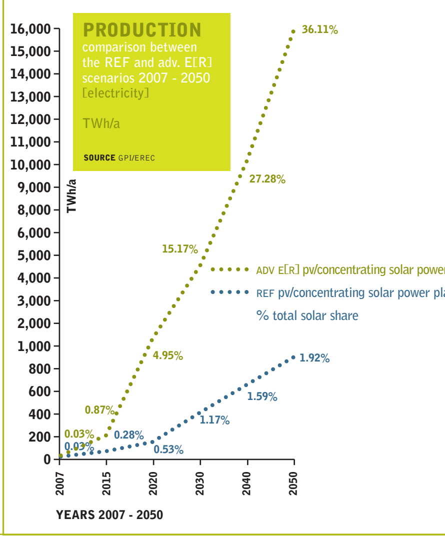
0 1000 KM

PRODUCTION PER REGION % OF GLOBAL SHARE | PETA JOULE [PJ]

PRODUCTION PER PERSON KILOWATT HOUR [kWh]

H HIGHEST | M MIDDLE | L LOWEST



## OECD EUROPE

| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.09M | 70 | | |
| 2050 | 1.42H | 1,173 | 23 | 10,680 |
| | | kWh | | kWh |
| 2007 | | 36M | | |
| 2050 | | 567 | | 5,160M |

## MIDDLE EAST

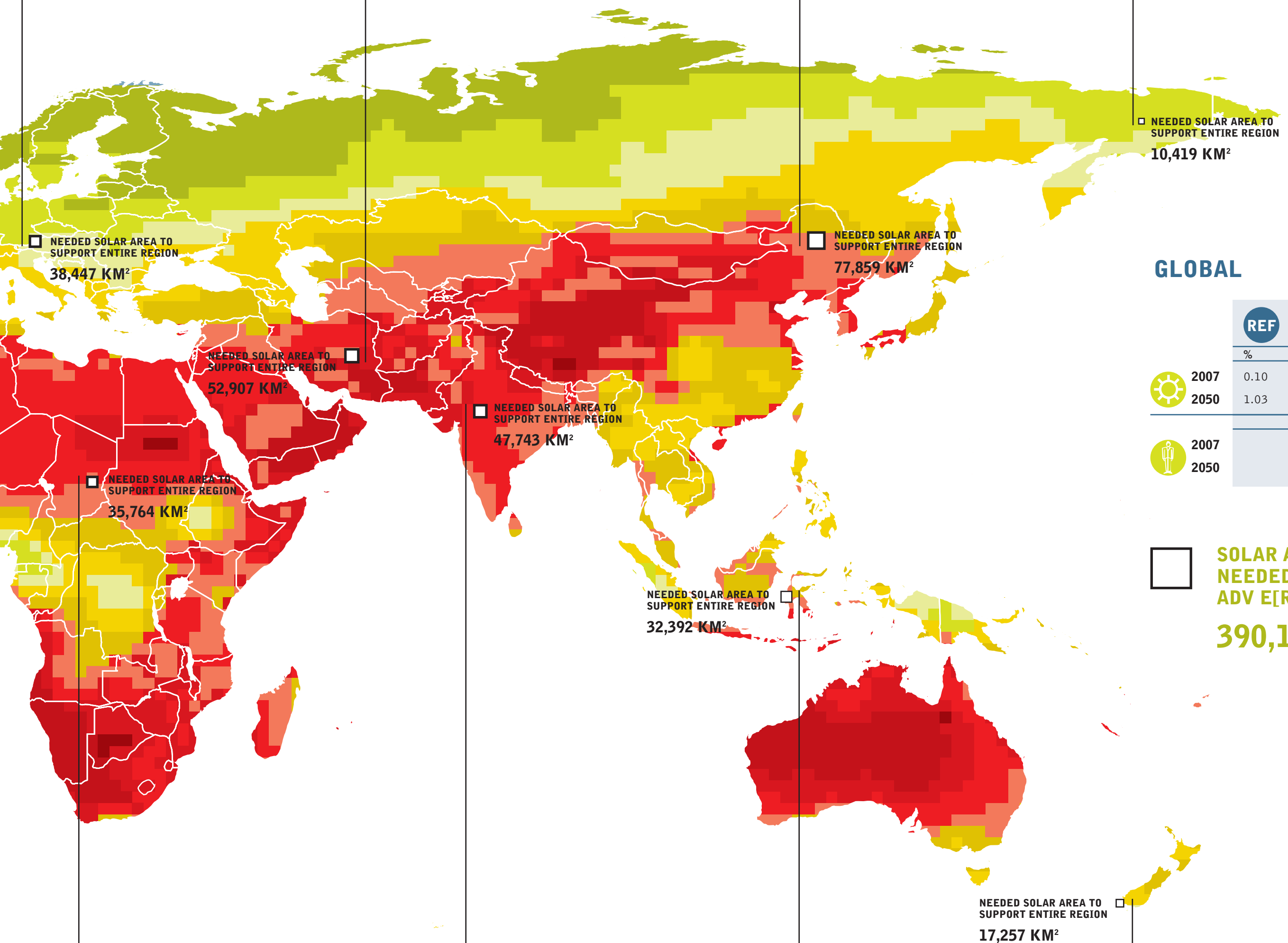
| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.17H | 36 | | |
| 2050 | 0.62 | 319 | 53H | 14,696 |
| | | kWh | | kWh |
| 2007 | | 50H | | |
| 2050 | | 251 | | 11,552H |

## CHINA

| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.22L | 182L | | |
| 2050 | 0.95 | 1,754H | 20 | 21,628H |
| | | kWh | | kWh |
| 2007 | | 38 | | |
| 2050 | | 342M | | 4,213 |

## TRANSITION ECONOMIES

| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.01L | 2 | | |
| 2050 | 0.10L | 63L | 8,34 | 2,894 |
| | | kWh | | kWh |
| 2007 | | 2 | | |
| 2050 | | 56 | | 2,586 |




## GLOBAL

| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.10 | 402 | | |
| 2050 | 1.03 | 6,322 | 23.26 | 108,367 |
| | | kWh | | kWh |
| 2007 | | 17 | | |
| 2050 | | 192 | | 2,468 |

SOLAR AREA NEEDED TO SUPPORT ADV E[R] 2050 SCENARIO

390,122 KM²

## AFRICA

| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.00 | 1 | | |
| 2050 | 0.94 | 405 | 28 | 9,934 |
| | | kWh | | kWh |
| 2007 | | 0.2 | | |
| 2050 | | 56L | | 1,380 |

## INDIA

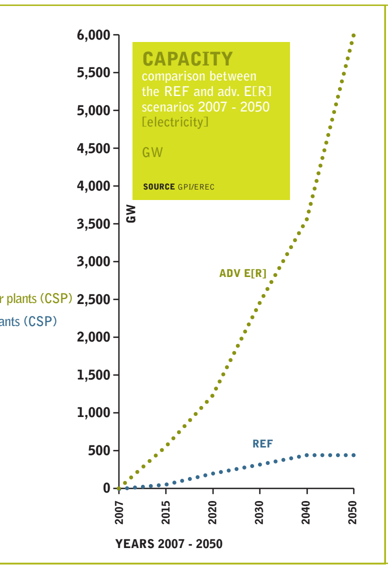
| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.02L | 6L | | |
| 2050 | 0.23 | 182 | 24 | 13,262M |
| | | kWh | | kWh |
| 2007 | | 1 | | |
| 2050 | | 31 | | 2,282 |

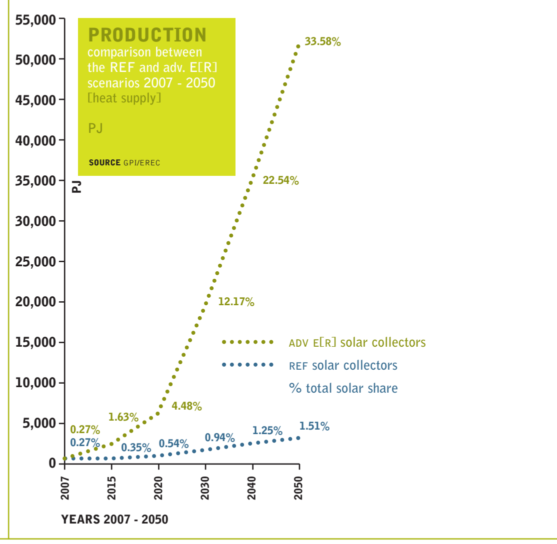
## OTHER ASIA

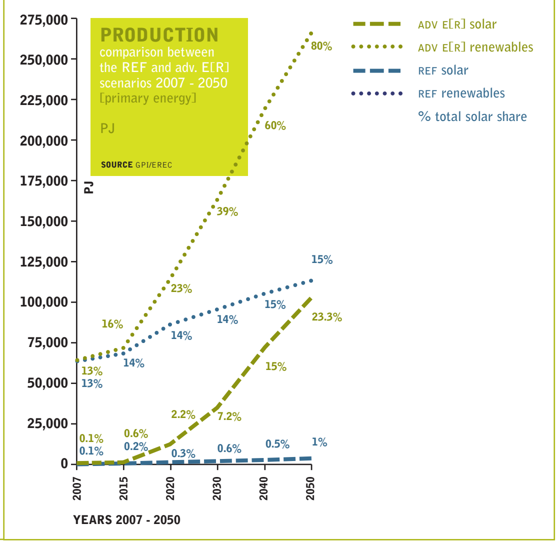
| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.01L | 4L | | |
| 2050 | 0.58 | 405 | 22 | 8,998 |
| | | kWh | | kWh |
| 2007 | | 1L | | |
| 2050 | | 74 | | 1,649L |

## OECD PACIFIC

| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.08 | 30M | | |
| 2050 | 1.14 | 466M | 23 | 4,794 |
| | | kWh | | kWh |
| 2007 | | 42 | | |
| 2050 | | 719H | | 7,405 |



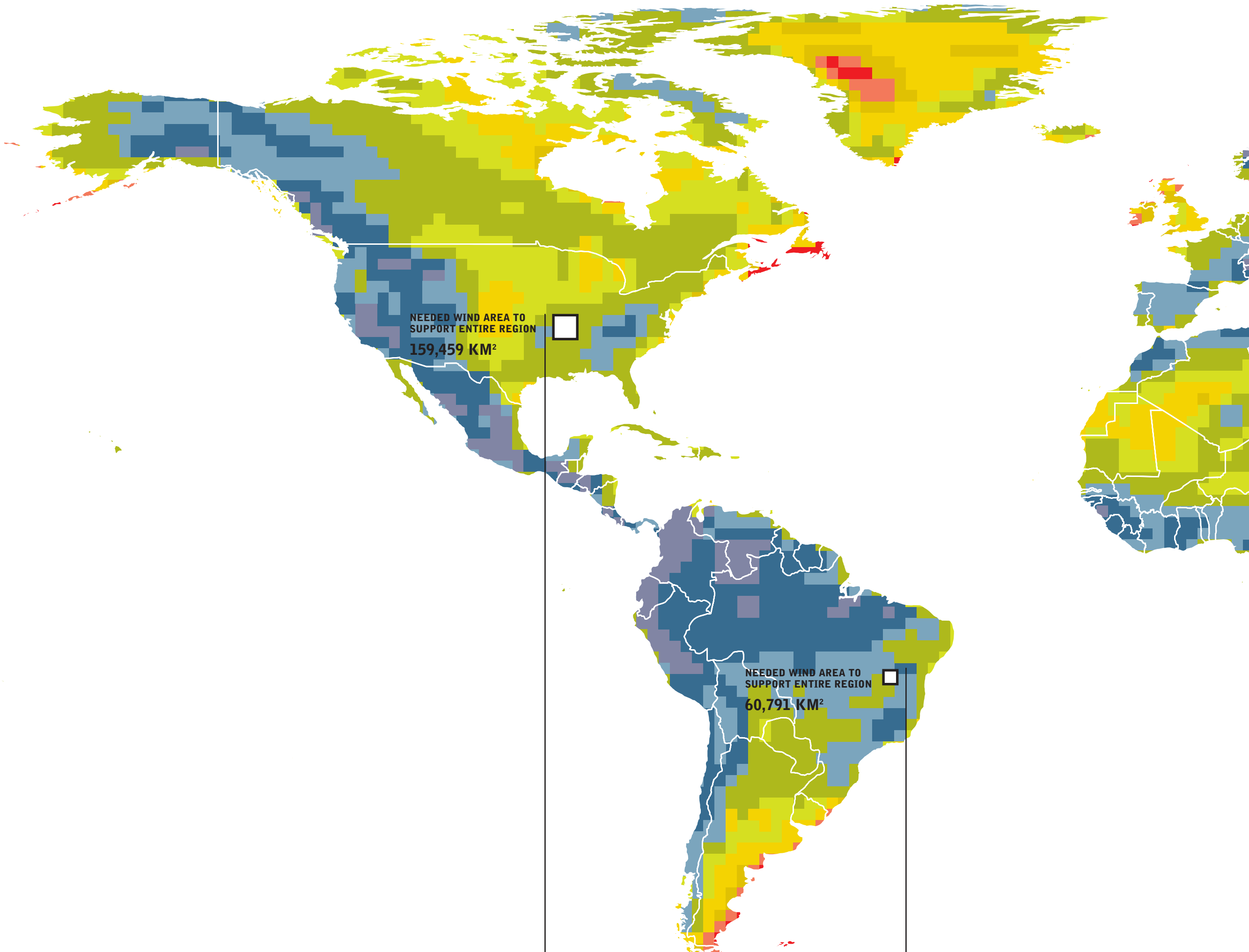




GREENPEACE

DESIGN WWW.ONEHEMISPHERE.SE CONCEPT SVEN TESKE/GREENPEACE INTERNATIONAL.

## map 8.6: wind reference scenario and the advanced energy [r]evolution scenario

WORLDWIDE SCENARIO




### OECD NORTH AMERICA

| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| Production per region 2007 | 0.12M | 136 | | |
| Production per region 2050 | 1.71 | 2,210 | 11.11 | 7,805H |
| | | kWh | | kWh |
| Production per person 2007 | | 84 | | |
| Production per person 2050 | | 1,064 | | 3,755 |

### LATIN AMERICA

| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| Production per region 2007 | 0.02 | 3 | | |
| Production per region 2050 | 0.65 | 266 | 10.54 | 2,878 |
| | | kWh | | kWh |
| Production per person 2007 | | 2 | | |
| Production per person 2050 | | 123 | | 1,332 |

## RENEWABLE RESOURCE

# WIND

### LEGEND

>11 | 10-11 | 9-10 | 8-9 | 7-8 | 6-7 | 5-6 | 4-5 | 3-4 | 1-2 | 0-1

AVERAGE WIND SPEED IN METRES PER SECOND
SOURCE DLR

REF REFERENCE SCENARIO

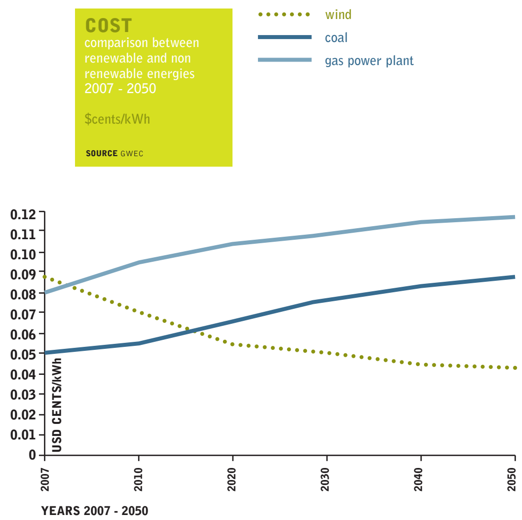
E[R] ADVANCED ENERGY [R]EVOLUTION SCENARIO

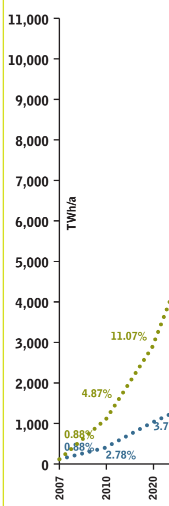
0 1000 KM

**PRODUCTION PER REGION** % OF GLOBAL SHARE | PETA JOULE [PJ]

**PRODUCTION PER PERSON** KILOWATT HOUR [kWh]

**H HIGHEST | M MIDDLE | L LOWEST**



## OECD EUROPE

| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.49H | 379H | | |
| 2050 | 4.14H | 3,420H | 10.41 | 4,867 |
| | | kWh | | kWh |
| 2007 | | 195H | | |
| 2050 | | 1,652H | | 2,352M |

## MIDDLE EAST

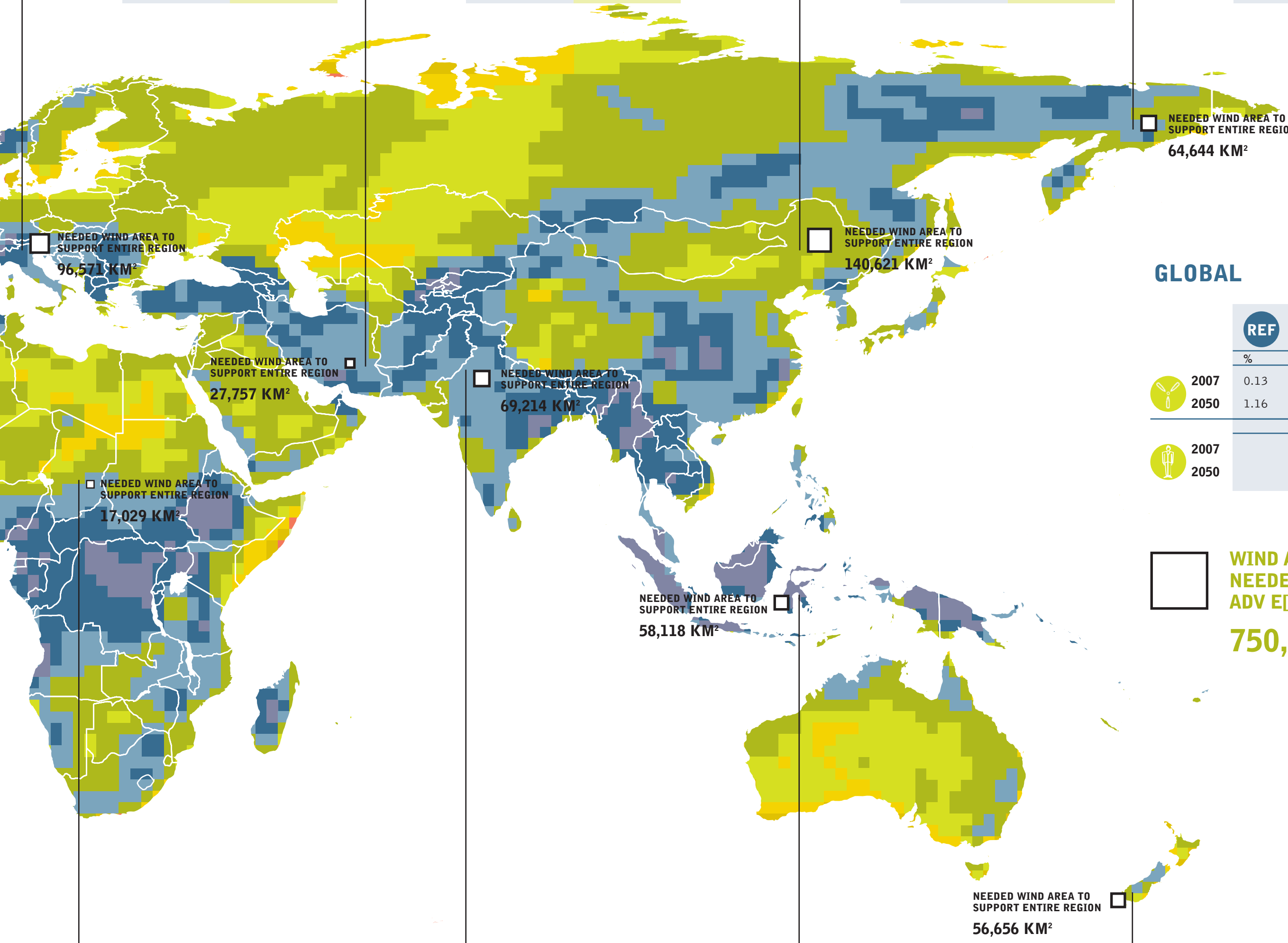
| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.00L | 1L | | |
| 2050 | 0.26L | 133L | 4.78 | 1,314 |
| | | kWh | | kWh |
| 2007 | | 1 | | |
| 2050 | | 105 | | 1,033 |

## CHINA

| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.04 | 32 | | |
| 2050 | 0.66 | 1,220M | 6.85M | 7,340 |
| | | kWh | | kWh |
| 2007 | | 7 | | |
| 2050 | | 238 | | 1,430 |

## TRANSITION ECONOMIES

| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.00 | 1 | | |
| 2050 | 0.56 | 360 | 9.83 | 3,413 |
| | | kWh | | kWh |
| 2007 | | 1 | | |
| 2050 | | 322M | | 3,050 |




## GLOBAL

| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.13 | 624 | | |
| 2050 | 1.16 | 9,058 | 8.38 | 39,029 |
| | | kWh | | kWh |
| 2007 | | 26 | | |
| 2050 | | 275 | | 1,182 |

WIND AREA NEEDED TO SUPPORT ADV E[R] 2050 SCENARIO

**750,859 KM²**

## AFRICA

| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.02 | 4 | | |
| 2050 | 0.47 | 202 | 3.00L | 1,073L |
| | | kWh | | kWh |
| 2007 | | 1 | | |
| 2050 | | 28L | | 149L |

## INDIA

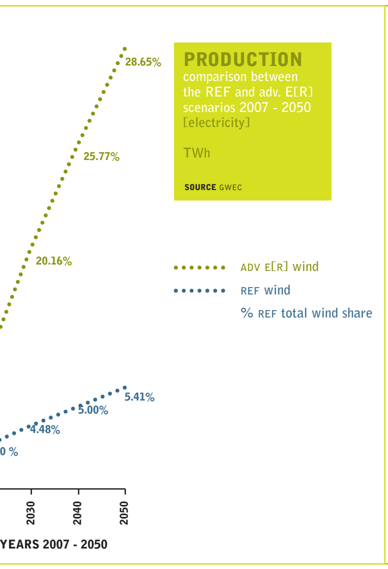
| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.17 | 42M | | |
| 2050 | 0.48 | 374 | 6.38 | 3,488 |
| | | kWh | | kWh |
| 2007 | | 10 | | |
| 2050 | | 64 | | 600 |

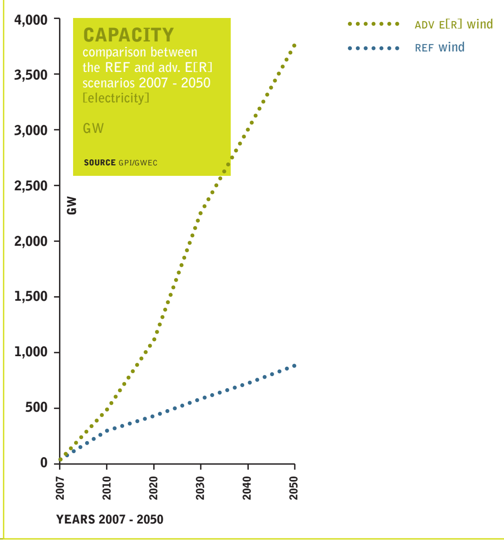
## ASIA

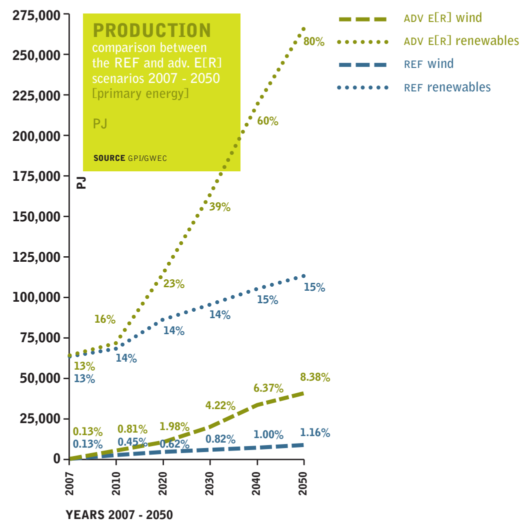
| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.01 | 2L | | |
| 2050 | 0.69 | 475 | 8.75 | 3,557 |
| | | kWh | | kWh |
| 2007 | | 0L | | |
| 2050 | | 87 | | 652 |

## OECD PACIFIC

| | REF % | REF PJ | E[R] % | E[R] PJ |
|---|---|---|---|---|
| 2007 | 0.06 | 24 | | |
| 2050 | 0.97M | 396 | 15.47H | 3,294M |
| | | kWh | | kWh |
| 2007 | | 33M | | |
| 2050 | | 611 | | 5,089H |



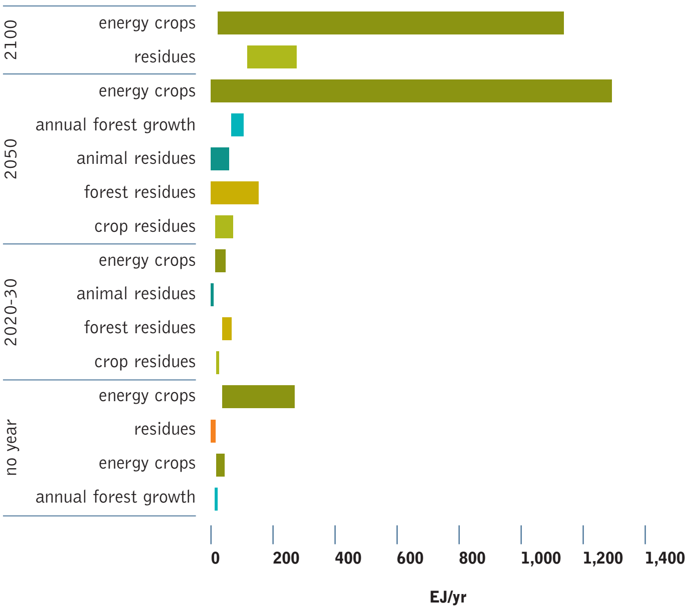




GREENPEACE

DESIGN WWW.ONEHEMISPHERE.SE CONCEPT SVEN TESKE/GREENPEACE INTERNATIONAL.

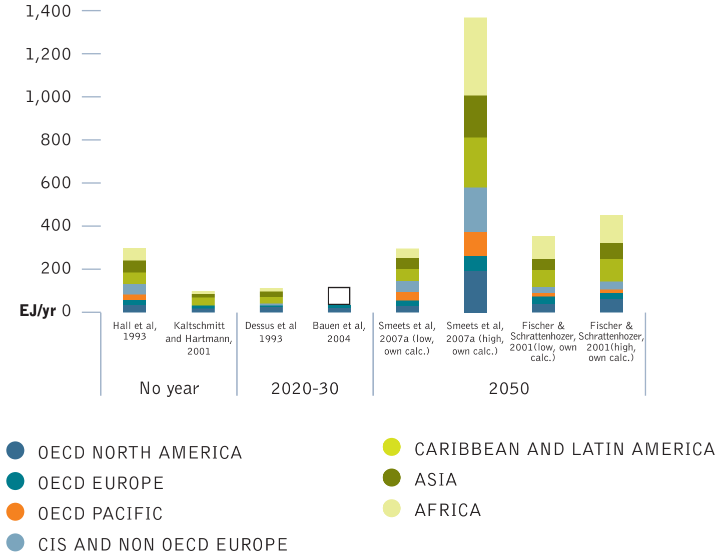
**figure 8.2: ranges of potential for different biomass types**




**source** GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

**figure 8.3: bio energy potential analysis from different authors**

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




**source** GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

## 8.5.1 the global potential for sustainable biomass

As part of background research for the Advanced Energy [R]evolution Scenario, Greenpeace commissioned the German Biomass Research Centre, the former Institute for Energy and Environment, to investigate the worldwide potential for energy crops up to 2050. In addition, information has been compiled from scientific studies of the global potential and from data derived from state of the art remote sensing techniques, such as satellite images. A summary of the report's findings is given below; references can be found in the full report[55].

## 8.5.2 assessment of biomass potential studies

Various studies have looked historically at the potential for bio energy and come up with widely differing results. Comparison between them is difficult because they use different definitions of the various biomass resource fractions. This problem is particularly significant in relation to forest derived biomass. Most research has focused almost exclusively on energy crops, as their development is considered to be more significant for satisfying the demand for bio energy. The result is that the potential for using forest residues (wood left over after harvesting) is often underestimated.

Data from 18 studies has been examined, with a concentration on those which report the potential for biomass residues. Among these there were ten comprehensive assessments with more or less detailed documentation of the methodology. The majority focus on the long-term potential for 2050 and 2100. Little information is available for 2020 and 2030. Most of the studies were published within the last ten years. Figure 8.2 shows the variations in potential by biomass type from the different studies.

Looking at the contribution of different types of material to the total biomass potential, the majority of studies agree that the most promising resource is energy crops from dedicated plantations. Only six give a regional breakdown, however, and only a few quantify all types of residues separately. Quantifying the potential of minor fractions, such as animal residues and organic wastes, is difficult as the data is relatively poor.

## 8.5.3 potential of energy crops

Apart from the utilisation of biomass from residues, the cultivation of energy crops in agricultural production systems is of greatest significance. The technical potential for growing energy crops has been calculated on the assumption that demand for food takes priority. As a first step the demand for arable and grassland for food production has been calculated for each of 133 countries in different scenarios. These scenarios are:

- Business as usual (BAU) scenario: Present agricultural activity continues for the foreseeable future
- Basic scenario: No forest clearing; reduced use of fallow areas for agriculture
- Sub-scenario 1: Basic scenario plus expanded ecological protection areas and reduced crop yields
- Sub-scenario 2: Basic scenario plus food consumption reduced in industrialised countries
- Sub-scenario 3: Combination of sub-scenarios 1 and 2

**55** SEIDENBERGER T., THRÄN D., OFFERMANN R., SEYFERT U., BUCHHORN M. AND ZEDDIES J. (2008). GLOBAL BIOMASS POTENTIALS. INVESTIGATION AND ASSESSMENT OF DATA. REMOTE SENSING IN BIOMASS POTENTIAL RESEARCH. COUNTRY-SPECIFIC ENERGY CROP POTENTIAL. GERMAN BIOMASS RESEARCH CENTRE (DBFZ). FOR GREENPEACE INTERNATIONAL. 137 P.

**image** THE BIOENERGY VILLAGE OF JUEHNDE WHICH WAS THE FIRST COMMUNITY IN GERMANY TO PRODUCE ALL ITS ENERGY NEEDED FOR HEATING AND ELECTRICITY, WITH $CO_2$ NEUTRAL BIOMASS.

**image** A NEWLY DEFORESTED AREA WHICH HAS BEEN CLEARED FOR AGRICULTURAL EXPANSION IN THE AMAZON, BRAZIL.



In a next step the surpluses of agricultural areas were classified either as arable land or grassland. On grassland, hay and grass silage are produced, on arable land fodder silage and Short Rotation Coppice (SRC) (such as fast-growing willow or poplar) are cultivated. Silage of green fodder and grass are assumed to be used for biogas production, wood from SRC and hay from grasslands for the production of heat, electricity and synthetic fuels. Country specific yield variations were taken into consideration.

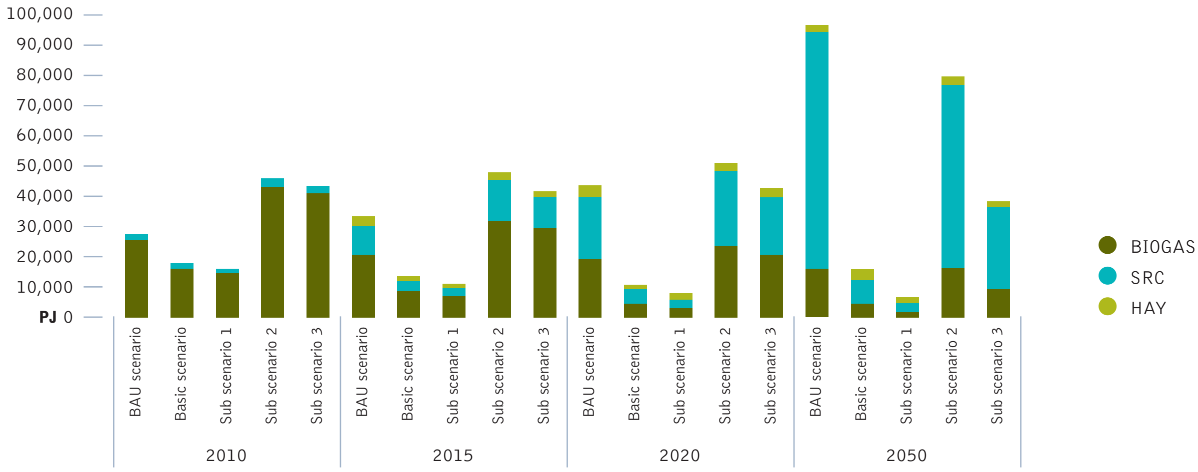
The result is that the global biomass potential from energy crops in 2050 falls within a range from 6 EJ in Sub-scenario 1 up to 97 EJ in the BAU scenario.

The best example of a country that would see a very different future under these scenarios in 2050 is Brazil. Under the BAU scenario large agricultural areas would be released by deforestation, whereas in the Basic and Sub 1 scenarios this would be forbidden, and no agricultural areas would be available for energy crops. By contrast a high potential would be available under Sub-scenario 2 as a consequence of reduced meat consumption. Because of their high populations and relatively small agricultural areas, no surplus land is available for energy crop production in Central America, Asia and Africa. The EU, North America and Australia, however, have relatively stable potentials.

The results of this exercise show that the availability of biomass resources is not only driven by the effect on global food supply but the conservation of natural forests and other biospheres. So the assessment of future biomass potential is only the starting point of a discussion about the integration of bioenergy into a renewable energy system.

The total global biomass potential (energy crops and residues) therefore ranges in 2020 from 66 EJ (Sub-scenario 1) up to 110 EJ (Sub-scenario 2), and in 2050 from 94 EJ (Sub-scenario 1) to 184 EJ (BAU scenario). These numbers are conservative and include a level of uncertainty, especially for 2050. The reasons for this uncertainty are the potential effects of climate change, possible changes in the worldwide political and economic situation, a higher yield as a result of changed agricultural techniques and/or faster development in plant breeding.

**figure 8.4: world wide energy crop potentials in different scenarios**




The Energy [R]evolution takes a precautionary approach to the future use of biofuels. This reflects growing concerns about the greenhouse gas balance of many biofuel sources, and also the risks posed by expanded biofuels crop production to biodiversity (forests, wetlands and grasslands) and food security. In particular, research commissioned by Greenpeace in the development of the Energy [R]evolution suggests that there will be acute pressure on land for food production and habitat protection in 2050. As a result, the Energy [R]evolution does not include any biofuels from energy crops at 2050, restricting feedstocks to a limited quantity of forest and agricultural residues. It should be stressed, however, that this conservative approach is based on an assessment of today's technologies and their associated risks. The development of advanced forms of biofuels which do not involve significant land-take, are demonstrably sustainable in terms of their impacts on the wider environment, and have clear greenhouse gas benefits, should be an objective of public policy, and would provide additional flexibility in the renewable energy mix.

Concerns have also been raised about how countries account for the emissions associated with biofuels production and combustion. The lifecycle emissions of different biofuels can vary enormously. Rules developed under the Kyoto Protocol mean that under many circumstances, countries are not held responsible for all the emissions associated with land-use change or management. At the same time, under the Kyoto Protocol and associated instruments such as the European Emissions Trading scheme, biofuels is 'zero-rated' for emissions as an energy source. To ensure that biofuels are produced and used in ways which maximize its greenhouse gas saving potential, these accounting problems will need to be resolved in future.

# renewable energy technologies

**GLOBAL** RENEWABLE ENERGY TECHNOLOGIES

# 9

## "the technology is here, all we need is political will."

**CHRIS**
SUPORTER, AUSTRALIA

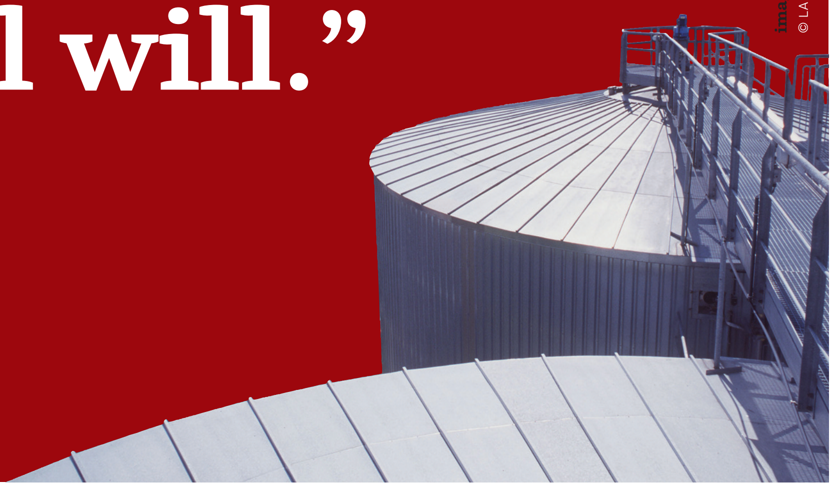


image BIOGAS FACILITY "SCHRADEN BIOGAS" IN GROEDEN NEAR DRESDEN, GERMANY.

**image** WIND TURBINES AT THE NAN WIND FARM IN NAN'AO. GUANGDONG PROVINCE HAS ONE OF THE BEST WIND RESOURCES IN CHINA AND IS ALREADY HOME TO SEVERAL INDUSTRIAL SCALE WIND FARMS.

© GP/XUAN CANXIONG

## 9.1 renewable energy technologies

Renewable energy covers a range of natural sources which are constantly renewed and therefore, unlike fossil fuels and uranium, will never be exhausted. Most of them derive from the effect of the sun and moon on the earth's weather patterns. They also produce none of the harmful emissions and pollution associated with 'conventional' fuels. Although hydroelectric power has been used on an industrial scale since the middle of the last century, the serious exploitation of other renewable sources has a more recent history.

### 9.1.1 solar power (photovoltaics)

There is more than enough solar radiation available all over the world to satisfy a vastly increased demand for solar power systems. The sunlight which reaches the earth's surface is enough to provide 2,850 times as much energy as we can currently use. On a global average, each square metre of land is exposed to enough sunlight to produce 1,700 kWh of power every year. The average irradiation in Europe is about 1,000 kWh per square metre, however, compared with 1,800 kWh in the Middle East.

Photovoltaic (PV) technology involves the generation of electricity from light. The essence of this process is the use of a semiconductor material which can be adapted to release electrons, the negatively charged particles that form the basis of electricity. The most common semiconductor material used in photovoltaic cells is silicon, an element most commonly found in sand. All PV cells have at least two layers of such semiconductors, one positively charged and one negatively charged. When light shines on the semiconductor, the electric field across the junction between these two layers causes electricity to flow. The greater the intensity of the light, the greater the flow of electricity. A photovoltaic system does not therefore need bright sunlight in order to operate, and can generate electricity even on cloudy days. Solar PV is different from a solar thermal collecting system (see below) where the sun's rays are used to generate heat, usually for hot water in a house, swimming pool etc.

The most important parts of a PV system are the cells which form the basic building blocks, the modules which bring together large numbers of cells into a unit, and, in some situations, the inverters used to convert the electricity generated into a form suitable for everyday use. When a PV installation is described as having a capacity of 3 kWp (peak), this refers to the output of the system under standard testing conditions, allowing comparison between different modules. In central Europe a 3 kWp rated solar electricity system, with a surface area of approximately 27 square metres, would produce enough power to meet the electricity demand of an energy conscious household.

There are several different PV technologies and types of installed system.

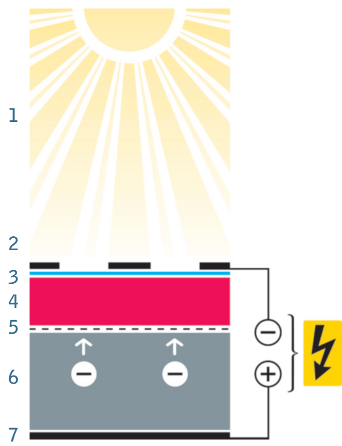
**technologies**

- **crystalline silicon technology** Crystalline silicon cells are made from thin slices cut from a single crystal of silicon (mono crystalline) or from a block of silicon crystals (polycrystalline or multi crystalline). This is the most common technology, representing about 80% of the market today. In addition, this technology also exists in the form of ribbon sheets.
- **thin film technology** Thin film modules are constructed by depositing extremely thin layers of photosensitive materials onto a substrate such as glass, stainless steel or flexible plastic. The latter opens up a range of applications, especially for building integration (roof tiles) and end-consumer purposes. Four types of thin film modules are commercially available at the moment: Amorphous Silicon, Cadmium Telluride, Copper Indium/Gallium Diselenide/Disulphide and multi-junction cells.
- **other emerging cell technologies** (at the development or early commercial stage): These include Concentrated Photovoltaic, consisting of cells built into concentrating collectors that use a lens to focus the concentrated sunlight onto the cells, and Organic Solar Cells, whereby the active material consists at least partially of organic dye, small, volatile organic molecules or polymer.

**systems**

- **grid connected** The most popular type of solar PV system for homes and businesses in the developed world. Connection to the local electricity network allows any excess power produced to be sold to the utility. Electricity is then imported from the network outside daylight hours. An inverter is used to convert the DC power produced by the system to AC power for running normal electrical equipment.
- **grid support** A system can be connected to the local electricity network as well as a back-up battery. Any excess solar electricity produced after the battery has been charged is then sold to the network. This system is ideal for use in areas of unreliable power supply.
- **off-grid** Completely independent of the grid, the system is connected to a battery via a charge controller, which stores the electricity generated and acts as the main power supply. An inverter can be used to provide AC power, enabling the use of normal appliances. Typical off-grid applications are repeater stations for mobile phones or rural electrification. Rural electrification means either small solar home systems covering basic electricity needs or solar mini grids, which are larger solar electricity systems providing electricity for several households.
- **hybrid system** A solar system can be combined with another source of power - a biomass generator, a wind turbine or diesel generator - to ensure a consistent supply of electricity. A hybrid system can be grid connected, stand alone or grid support.

**figure 9.1: photovoltaics technology**




1. LIGHT (PHOTONS)
2. FRONT CONTACT GRID
3. ANTI-REFLECTION COATING
4. N-TYPE SEMICONDUCTOR
5. BOARDER LAYOUT
6. P-TYPE SEMICONDUCTOR
7. BACKCONTACT

### 9.1.2 concentrating solar power (CSP)

Concentrating solar power (CSP) plants, also called solar thermal power plants, produce electricity in much the same way as conventional power stations. They obtain their energy input by concentrating solar radiation and converting it to high temperature steam or gas to drive a turbine or motor engine. Large mirrors concentrate sunlight into a single line or point. The heat created there is used to generate steam. This hot, highly pressurised steam is used to power turbines which generate electricity. In sun-drenched regions, CSP plants can guarantee a large proportion of electricity production.

Four main elements are required: a concentrator, a receiver, some form of transfer medium or storage, and power conversion. Many different types of system are possible, including combinations with other renewable and non-renewable technologies, but there are four main groups of solar thermal technologies:

- **parabolic trough** Parabolic trough plants use rows of parabolic trough collectors, each of which reflect the solar radiation into an absorber tube. Synthetic oil circulates through the tubes, heating up to approximately 400°C. This heat is then used to generate electricity. Some of the plants under construction have been designed to produce power not only during sunny hours but also to store energy, allowing the plant to produce an additional 7.5 hours of nominal power after sunset, which dramatically improves their integration into the grid. Molten salts are normally used as storage fluid in a hot-and-cold two-tank concept. Plants in operation in Europe: Andasol 1 and 2 (50 MW +7.5 hour storage each); Puertollano (50 MW); Alvarado (50 MW) and Extresol 1 (50 MW + 7.5 hour storage).
- **central receiver or solar tower** A circular array of heliostats (large individually tracking mirrors) is used to concentrate sunlight on to a central receiver mounted at the top of a tower. A heat-transfer medium absorbs the highly concentrated radiation reflected by the heliostats and converts it into thermal energy to be used for the subsequent generation of superheated steam for turbine operation. To date, the heat transfer media demonstrated include water/steam, molten salts, liquid sodium and air. If pressurised gas or air is used at very high temperatures of about 1,000°C or more as the heat transfer medium, it can even be used to directly replace natural gas in a gas turbine, thus making use of the excellent efficiency (60%+) of modern gas and steam combined cycles.

  After an intermediate scaling up to 30 MW capacity, solar tower developers now feel confident that grid-connected tower power plants can be built up to a capacity of 200 MWe solar-only units. Use of heat storage will increase their flexibility. Although solar tower plants are considered to be further from commercialisation than parabolic trough systems, they have good longer-term prospects for high conversion efficiencies. Projects are being developed in Spain, South Africa and Australia.
- **parabolic dish** A dish-shaped reflector is used to concentrate sunlight on to a receiver located at its focal point. The concentrated beam radiation is absorbed into the receiver to heat a fluid or gas to approximately 750°C. This is then used to generate electricity in a small piston, Stirling engine or micro turbine attached to the receiver. The potential of parabolic dishes lies primarily for decentralised power supply and remote, stand-alone power systems. Projects are currently planned in the United States, Australia and Europe.
- **linear fresnel systems** Collectors resemble parabolic troughs, with a similar power generation technology, using a field of horizontally mounted flat mirror strips, collectively or individually tracking the sun. There is one plant currently in operation in Europe: Puerto Errado (2 MW).

**figures 9.2: csp technologies: parabolic trough, central receiver/solar tower and parabolic dish**

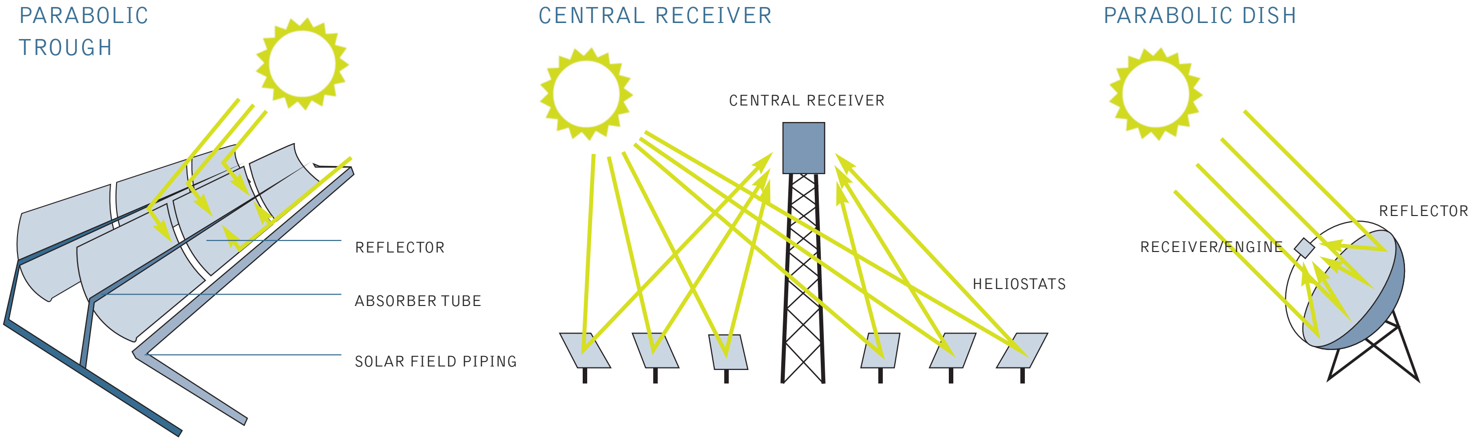


**image** SOLAR PROJECT IN PHITSANULOK, THAILAND. SOLAR FACILITY OF THE INTERNATIONAL INSTITUTE AND SCHOOL FOR RENEWABLE ENERGY.

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


### 9.1.3 solar thermal collectors

Solar thermal collecting systems are based on a centuries-old principle: the sun heats up water contained in a dark vessel. Solar thermal technologies on the market now are efficient and highly reliable, providing energy for a wide range of applications - from domestic hot water and space heating in residential and commercial buildings to swimming pool heating, solar-assisted cooling, industrial process heat and the desalination of drinking water.

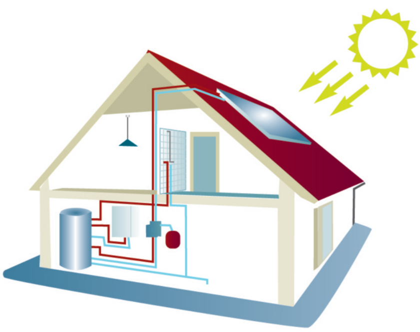
Although mature products exist to provide domestic hot water and space heating using solar energy, in most countries they are not yet the norm. Integrating solar thermal technologies into buildings at the design stage or when the heating (and cooling) system is being replaced is crucial, thus lowering the installation cost. Moreover, the untapped potential in the non-residential sector will be opened up as newly developed technology becomes commercially viable.

**solar domestic hot water and space heating** Domestic hot water production is the most common application. Depending on the conditions and the system's configuration, most of a building's hot water requirements can be provided by solar energy. Larger systems can additionally cover a substantial part of the energy needed for space heating. There are two main types of technology:

- **vacuum tubes** The absorber inside the vacuum tube absorbs radiation from the sun and heats up the fluid inside. Additional radiation is picked up from the reflector behind the tubes. Whatever the angle of the sun, the round shape of the vacuum tube allows it to reach the absorber. Even on a cloudy day, when the light is coming from many angles at once, the vacuum tube collector can still be effective.
- **flat panel** This is basically a box with a glass cover which sits on the roof like a skylight. Inside is a series of copper tubes with copper fins attached. The entire structure is coated in a black substance designed to capture the sun's rays. These rays heat up a water and antifreeze mixture which circulates from the collector down to the building's boiler.

**solar assisted cooling** Solar chillers use thermal energy to produce cooling and/or dehumidify the air in a similar way to a refrigerator or conventional air-conditioning. This application is well-suited to solar thermal energy, as the demand for cooling is often greatest when there is most sunshine. Solar cooling has been successfully demonstrated and large-scale use can be expected in the future.

**figure 9.3: flat panel solar technology**



### 9.1.4 wind power

Over the last 20 years, wind energy has become the world's fastest growing energy source. Today's wind turbines are produced by a sophisticated mass production industry employing a technology that is efficient, cost effective and quick to install. Turbine sizes range from a few kW to over 5,000 kW, with the largest turbines reaching more than 100m in height. One large wind turbine can produce enough electricity for about 5,000 households. State-of-the-art wind farms today can be as small as a few turbines and as large as several hundred MW.

The global wind resource is enormous, capable of generating more electricity than the world's total power demand, and well distributed across the five continents. Wind turbines can be operated not just in the windiest coastal areas but in countries which have no coastlines, including regions such as central Eastern Europe, central North and South America, and central Asia. The wind resource out at sea is even more productive than on land, encouraging the installation of offshore wind parks with foundations embedded in the ocean floor. In Denmark, a wind park built in 2002 uses 80 turbines to produce enough electricity for a city with a population of 150,000.

Smaller wind turbines can produce power efficiently in areas that otherwise have no access to electricity. This power can be used directly or stored in batteries. New technologies for using the wind's power are also being developed for exposed buildings in densely populated cities.

**wind turbine design** Significant consolidation of wind turbine design has taken place since the 1980s. The majority of commercial turbines now operate on a horizontal axis with three evenly spaced blades. These are attached to a rotor from which power is transferred through a gearbox to a generator. The gearbox and generator are contained within a housing called a nacelle. Some turbine designs avoid a gearbox by using direct drive. The electricity output is then channelled down the tower to a transformer and eventually into the local grid network.

Wind turbines can operate from a wind speed of 3-4 metres per second up to about 25 m/s. Limiting their power at high wind speeds is achieved either by 'stall' regulation – reducing the power output – or 'pitch' control – changing the angle of the blades so that they no longer offer any resistance to the wind. Pitch control has become the most common method. The blades can also turn at a constant or variable speed, with the latter enabling the turbine to follow more closely the changing wind speed.

The main design drivers for current wind technology are:

- high productivity at both low and high wind sites
- grid compatibility
- acoustic performance
- aerodynamic performance
- visual impact
- offshore expansion

Although the existing offshore market represents only just over 1% of the world's land-based installed wind capacity, the latest developments in wind technology are primarily driven by this emerging potential. This means that the focus is on the most effective ways to make very large turbines.

Modern wind technology is available for a range of sites - low and high wind speeds, desert and arctic climates. European wind farms operate with high availability, are generally well integrated into the environment and accepted by the public. In spite of repeated predictions of a levelling off at an optimum mid-range size, and the fact that wind turbines cannot get larger indefinitely, turbine size has increased year on year - from units of 20-60 kW in California in the 1980s up to the latest multi-MW machines with rotor diameters over 100 m. The average size of turbine installed around the world during 2009 was 1,599 kW, whilst the largest machine in operation is the Enercon E126, with a rotor diameter of 126 metres and a power capacity of 6 MW.

This growth in turbine size has been matched by the expansion of both markets and manufacturers. More than 150,000 wind turbines now operate in over 50 countries around the world. The US market is currently the largest, but there has also been impressive growth in Germany, Spain, Denmark, India and China.

### 9.1.5 biomass energy

Biomass is a broad term used to describe material of recent biological origin that can be used as a source of energy. This includes wood, crops, algae and other plants as well as agricultural and forest residues. Biomass can be used for a variety of end uses: heating, electricity generation or as fuel for transportation. The term 'bio energy' is used for biomass energy systems that produce heat and/or electricity and 'bio fuels' for liquid fuels used in transport. Biodiesel manufactured from various crops has become increasingly used as vehicle fuel, especially as the cost of oil has risen.

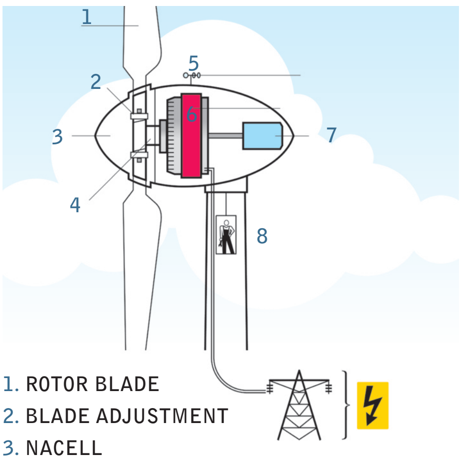
Biological power sources are renewable, easily stored, and, if sustainably harvested, $CO_2$ neutral. This is because the gas emitted during their transfer into useful energy is balanced by the carbon dioxide absorbed when they were growing plants.

Electricity generating biomass power plants work just like natural gas or coal power stations, except that the fuel must be processed before it can be burned. These power plants are generally not as large as coal power stations because their fuel supply needs to grow as near as possible to the plant. Heat generation from biomass power plants can result either from utilising a Combined Heat and Power (CHP) system, piping the heat to nearby homes or industry, or through dedicated heating systems. Small heating systems using specially produced pellets made from waste wood, for example, can be used to heat single family homes instead of natural gas or oil.

**biomass technology** A number of processes can be used to convert energy from biomass. These divide into thermal systems, which involve direct combustion of solids, liquids or a gas via pyrolysis or gasification, and biological systems, which involve decomposition of solid biomass to liquid or gaseous fuels by processes such as anaerobic digestion and fermentation.

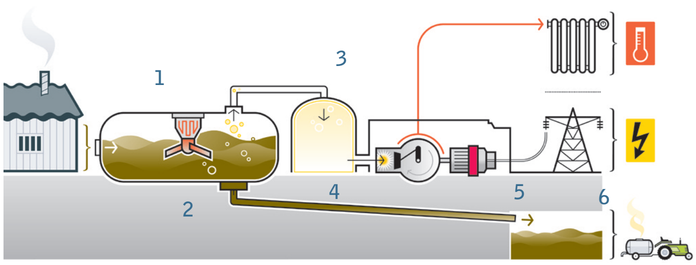


**figure 9.4: wind turbine technology**




1. ROTOR BLADE
2. BLADE ADJUSTMENT
3. NACELL
4. ROTOR SHAFT
5. WIND MEASUREMENT
6. GENERATOR
7. SYSTEM CONTROL
8. LIFT

**figure 9.5: biomass technology**




1. HEATED MIXER
2. CONTAINMENT FOR FERMENTATION
3. BIOGAS STORAGE
4. COMBUSTION ENGINE
5. GENERATOR
6. WASTE CONTAINMENT

**image** SOLAR PANELS FEATURED IN A RENEWABLE ENERGY EXHIBIT ON BORACAY ISLAND, ONE OF THE PHILIPPINES' PREMIER TOURIST DESTINATIONS.

**image** VESTAS VM 80 WIND TURBINES AT AN OFFSHORE WIND PARK IN THE WESTERN PART OF DENMARK.


- **thermal systems** *Direct combustion* is the most common way of converting biomass into energy, for heat as well as electricity. Worldwide it accounts for over 90% of biomass generation. Technologies can be distinguished as either fixed bed, fluidised bed or entrained flow combustion. In **fixed bed combustion**, such as a grate furnace, primary air passes through a fixed bed, in which drying, gasification and charcoal combustion takes place. The combustible gases produced are burned after the addition of secondary air, usually in a zone separated from the fuel bed. In **fluidised bed combustion**, the primary combustion air is injected from the bottom of the furnace with such high velocity that the material inside the furnace becomes a seething mass of particles and bubbles. **Entrained flow combustion** is suitable for fuels available as small particles, such as sawdust or fine shavings, which are pneumatically injected into the furnace.

  *Gasification* Biomass fuels are increasingly being used with advanced conversion technologies, such as gasification systems, which offer superior efficiencies compared with conventional power generation. Gasification is a thermochemical process in which biomass is heated with little or no oxygen present to produce a low energy gas. The gas can then be used to fuel a gas turbine or combustion engine to generate electricity. Gasification can also decrease emission levels compared to power production with direct combustion and a steam cycle.

  *Pyrolysis* is a process whereby biomass is exposed to high temperatures in the absence of air, causing the biomass to decompose. The products of pyrolysis always include gas ('biogas'), liquid ('bio-oil') and solid ('char'), with the relative proportions of each depending on the fuel characteristics, the method of pyrolysis and the reaction parameters, such as temperature and pressure. Lower temperatures produce more solid and liquid products and higher temperatures more biogas.

- **biological systems** These processes are suitable for very wet biomass materials such as food or agricultural wastes, including farm animal slurry.

  *Anaerobic digestion* Anaerobic digestion means the breakdown of organic waste by bacteria in an oxygen-free environment. This produces a biogas typically made up of 65% methane and 35% carbon dioxide. Purified biogas can then be used both for heating and electricity generation.

  *Fermentation* Fermentation is the process by which growing plants with a high sugar and starch content are broken down with the help of micro-organisms to produce ethanol and methanol. The end product is a combustible fuel that can be used in vehicles.

  Biomass power station capacities typically range up to 15 MW, but larger plants are possible of up to 400 MW capacity, with part of the fuel input potentially being fossil fuel, for example pulverised coal. The world's largest biomass fuelled power plant is located at Pietarsaari in Finland. Built in 2001, this is an industrial CHP plant producing steam (100 MWth) and electricity (240 MWe) for the local forest industry and district heat for the nearby town. The boiler is a circulating fluidised bed boiler designed to generate steam from bark, sawdust, wood residues, commercial bio fuel and peat.

  A 2005 study commissioned by Greenpeace Netherlands concluded that it was technically possible to build and operate a 1,000 MWe biomass fired power plant using fluidised bed combustion technology and fed with wood residue pellets [56].

### 9.1.6 biofuels

Converting crops into ethanol and bio diesel made from rapeseed methyl ester (RME) currently takes place mainly in Brazil, the USA and Europe. Processes for obtaining synthetic fuels from 'biogenic synthesis' gases will also play a larger role in the future. Theoretically biofuels can be produced from any biological carbon source, although the most common are photosynthetic plants. Various plants and plant-derived materials are used for biofuel production.

Globally biofuels are most commonly used to power vehicles, but can also be used for other purposes. The production and use of biofuels must result in a net reduction in carbon emissions compared to the use of traditional fossil fuels to have a positive effect in climate change mitigation. Sustainable biofuels can reduce the dependency on petroleum and thereby enhance energy security.

- **bioethanol** is a fuel manufactured through the fermentation of sugars. This is done by accessing sugars directly (sugar cane or beet) or by breaking down starch in grains such as wheat, rye, barley or maize. In the European Union bio ethanol is mainly produced from grains, with wheat as the dominant feedstock. In Brazil the preferred feedstock is sugar cane, whereas in the USA it is corn (maize). Bio ethanol produced from cereals has a by-product, a protein-rich animal feed called Dried Distillers Grains with Solubles (DDGS). For every tonne of cereals used for ethanol production, on average one third will enter the animal feed stream as DDGS. Because of its high protein level this is currently used as a replacement for soy cake. Bio ethanol can either be blended into gasoline (petrol) directly or be used in the form of ETBE (Ethyl Tertiary Butyl Ether).

- **biodiesel** is a fuel produced from vegetable oil sourced from rapeseed, sunflower seeds or soybeans as well as used cooking oils or animal fats. If used vegetable oils are recycled as feedstock for bio diesel production this can reduce pollution from discarded oil and provides a new way of transforming a waste product into transport energy. Blends of bio diesel and conventional hydrocarbon-based diesel are the most common products distributed in the retail transport fuel market.

  Most countries use a labelling system to explain the proportion of bio diesel in any fuel mix. Fuel containing 20% biodiesel is labelled B20, while pure bio diesel is referred to as B100. Blends of 20% bio diesel with 80% petroleum diesel (B20) can generally be used in unmodified diesel engines. Used in its pure form (B100) an engine may require certain modifications. Bio diesel can also be used as a heating fuel in domestic and commercial boilers. Older furnaces may contain rubber parts that would be affected by bio diesel's solvent properties, but can otherwise burn it without any conversion.

**56** 'OPPORTUNITIES FOR 1,000 MWE BIOMASS-FIRED POWER PLANT IN THE NETHERLANDS', GREENPEACE NETHERLANDS, 2005

### 9.1.7 geothermal energy

Geothermal energy is heat derived from deep underneath the earth's crust. In most areas, this heat reaches the surface in a very diffuse state. However, due to a variety of geological processes, some areas, including the western part of the USA, west and central Eastern Europe, Iceland, Asia and New Zealand are underlain by relatively shallow geothermal resources. These are classified as either low temperature (less than 90°C), moderate temperature (90° - 150°C) or high temperature (greater than 150°C). The uses to which these resources can be put depend on the temperature. The highest temperature is generally used only for electric power generation. Current global geothermal generation capacity totals approximately 10,700 MW, and the leading country is currently the USA, with over 3,000 MW, followed by the Philippines (1,900 MW) and Indonesia (1,200 MW). Low and moderate temperature resources can be used either directly or through ground-source heat pumps.

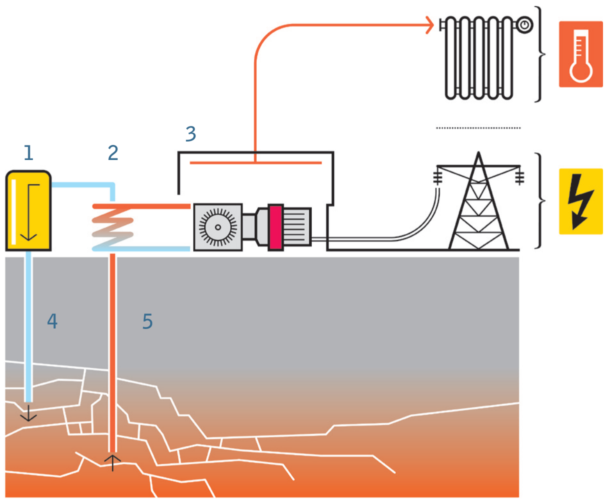
**Geothermal power plants** use the earth's natural heat to vaporise water or an organic medium. The steam created then powers a turbine which produces electricity. In the USA, New Zealand and Iceland this technique has been used extensively for decades. In Germany, where it is necessary to drill many kilometres down to reach the necessary temperatures, it is only in the trial stages. **Geothermal heat plants** require lower temperatures and the heated water is used directly.

### 9.1.8 hydro power

Water has been used to produce electricity for about a century. Today, around one fifth of the world's electricity is produced from hydro power. Large hydroelectric power plants with concrete dams and extensive collecting lakes often have very negative effects on the environment, however, requiring the flooding of habitable areas. Smaller 'run-of-the-river' power stations, which are turbines powered by one section of running water in a river, can produce electricity in an environmentally friendly way.

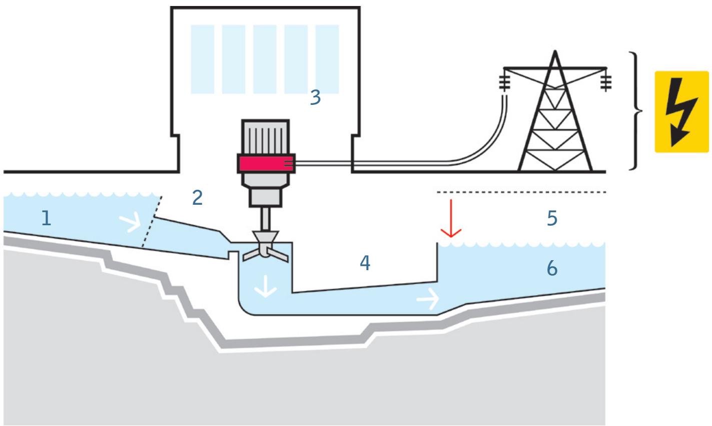
The main requirement for hydro power is to create an artificial head so that water, diverted through an intake channel or pipe into a turbine, discharges back into the river downstream. Small hydro power is mainly 'run-of-the-river' and does not collect significant amounts of stored water, requiring the construction of large dams and reservoirs. There are two broad categories of turbines. In an impulse turbine (notably the Pelton), a jet of water impinges on the runner designed to reverse the direction of the jet and thereby extracts momentum from the water. This turbine is suitable for high heads and 'small' discharges. Reaction turbines (notably Francis and Kaplan) run full of water and in effect generate hydrodynamic 'lift' forces to propel the runner blades. These turbines are suitable for medium to low heads and medium to large discharges.

**figure 9.6: geothermal technology**




1. PUMP
2. HEAT EXCHANGER
3. GAS TURBINE & GENERATOR
4. DRILLING HOLE FOR COLD WATER INJECTION
5. DRILLING HOLE FOR WARM WATER EXTRACTION

**figure 9.7: hydro technology**




1. INLET
2. SIEVE
3. GENERATOR
4. TURBINE
5. HEAD
6. OUTLET


**image** THROUGH BURNING OF WOOD CHIPS THE POWER PLANT GENERATES ELECTRICITY, ENERGY OR HEAT. HERE WE SEE THE STOCK OF WOOD CHIPS WITH A CAPACITY OF 1000 $M^3$ ON WHICH THE PLANT CAN RUN, UNMANNED, FOR ABOUT 4 DAYS. LELYSTAD, THE NETHERLANDS.

### 9.1.9 ocean energy

**tidal power** Tidal power can be harnessed by constructing a dam or barrage across an estuary or bay with a tidal range of at least five metres. Gates in the barrage allow the incoming tide to build up in a basin behind it. The gates then close so that when the tide flows out the water can be channelled through turbines to generate electricity. Tidal barrages have been built across estuaries in France, Canada and China but a mixture of high cost projections coupled with environmental objections to the effect on estuarial habitats has limited the technology's further expansion.

**wave and tidal stream power** In wave power generation, a structure interacts with the incoming waves, converting this energy to electricity through a hydraulic, mechanical or pneumatic power take-off system. The structure is kept in position by a mooring system or placed directly on the seabed/seashore. Power is transmitted to the seabed by a flexible submerged electrical cable and to shore by a sub-sea cable.

In tidal stream generation, a machine similar to a wind turbine rotor is fitted underwater to a column fixed to the sea bed; the rotor then rotates to generate electricity from fast-moving currents. 300 kW prototypes are in operation in the UK.

Wave power converters can be made up from connected groups of smaller generator units of 100 – 500 kW, or several mechanical or hydraulically interconnected modules can supply a single larger turbine generator unit of 2 – 20 MW. The large waves needed to make the technology more cost effective are mostly found at great distances from the shore, however, requiring costly sub-sea cables to transmit the power. The converters themselves also take up large amounts of space. Wave power has the advantage of providing a more predictable supply than wind energy and can be located in the ocean without much visual intrusion.

There is no commercially leading technology on wave power conversion at present. Different systems are being developed at sea for prototype testing. The largest grid-connected system installed so far is the 2.25 MW Pelamis, with linked semi-submerged cyclindrical sections, operating off the coast of Portugal. Most development work has been carried out in the UK.

Wave energy systems can be divided into three groups, described below.

- **shoreline devices** are fixed to the coast or embedded in the shoreline, with the advantage of easier installation and maintenance. They also do not require deep-water moorings or long lengths of underwater electrical cable. The disadvantage is that they experience a much less powerful wave regime. The most advanced type of shoreline device is the oscillating water column (OWC). One example is the Pico plant, a 400 kW rated shoreline OWC equipped with a Wells turbine constructed in the 1990s. Another system that can be integrated into a breakwater is the Seawave Slot-Cone converter.
- **near shore devices** are deployed at moderate water depths (~20-25 m) at distances up to ~500 m from the shore. They have the same advantages as shoreline devices but are exposed to stronger, more productive waves. These include 'point absorber systems'.
- **offshore devices** exploit the more powerful wave regimes available in deep water (>25 m depth). More recent designs for offshore devices concentrate on small, modular devices, yielding high power output when deployed in arrays. One example is the AquaBuOY system, a freely floating heaving point absorber system that reacts against a submersed tube, filled with water. Another example is the Wave Dragon, which uses a wave reflector design to focus the wave towards a ramp and fill a higher-level reservoir.




**images 1.** BIOMASS CROPS. **2.** OCEAN ENERGY. **3.** CONCENTRATING SOLAR POWER (CSP).

# climate and energy policy

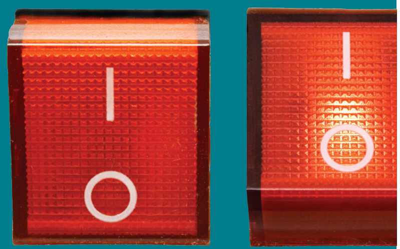
**GLOBAL**

CLIMATE POLICY
ENERGY POLICY AND MARKET REGULATION

TARGETS AND INCENTIVES FOR RENEWABLES

ENERGY EFFICIENCY AND INNOVATION

# 10



STANDBY POWER IS WASTED POWER. GLOBALLY, WE HAVE 50 DIRTY POWER PLANTS RUNNING JUST FOR OUR WASTED STANDBY POWER. OR: IF WE WOULD REDUCE OUR STANDBY TO JUST 1 WATT, WE CAN AVOID THE BUILDING OF 50 NEW DIRTY POWER PLANTS.



## "The poor, the vulnerable and the hungry are exposed to the harsh edge of climate change every day of their lives."

**ARCHBISHOP EMERITUS DESMOND TUTU**
THE GUARDIAN, 2007

If the Energy [R]evolution is to happen, then governments around the world need to play a major role. Their contribution will include regulating the energy market, both on the supply and demand side, educating everyone from consumers to industrialists, and stimulating the market for renewable energy and energy efficiency through a range of economic mechanisms. Governments in countries like South Africa, where renewable energy forms a miniscule portion of the electricity supply, should be looking to learn from and build on the successful policies already adopted by other countries.

To start with, developed countries need to agree on further binding emission reduction commitments in the second phase of the Kyoto Protocol. Only by setting stringent greenhouse gas emission reduction targets will the cost of carbon become sufficiently high to properly reflect its impact on society. This will in turn stimulate investments in renewable energy. Through massive funding for mitigation and technology cooperation, industrialised countries will also stimulate the development of renewable energy and energy efficiency in developing countries. South Africa has a responsibility to take a progressive role in the international negotiations, and it is crucial that emerging economies such as South Africa begin to take responsibility for their domestic emissions. The only solution to climate change is comprehensive, global and coordinated action, which means that countries with high emission levels must take concrete and immediate steps towards a green development pathway.

Alongside these measures specific support for the introduction of feed-in tariffs in the developing world - the extra costs of which could be funded by industrialised countries - could create similar incentives to those seen in countries like Germany and Spain, where the growth of renewable energy has boomed. The actual implementation of REFIT in South Africa has become urgent. Energy efficiency measures should also be more strongly supported through the Kyoto process and its financial mechanisms.

Carbon markets can also play a distinctive role in making the Energy [R]evolution happen, although the functioning of the carbon market needs a thorough revision in order to ensure that the price of carbon is sufficiently high to reflect its real cost. Only then can we create a level playing field for renewable energy and be able to calculate the economic benefits of energy efficiency. South Africa is one of the world's least energy efficient nations, and greater demand-side management combined with large-scale energy efficiency measures are crucial to reduce the country's energy intensity.

Industrialised countries should ensure that all financial flows to energy projects in developing countries are targeted towards renewable energy and energy efficiency. All financial assistance, whether through grants, loans or trade guarantees, directed towards supporting fossil fuel and nuclear power production, should be phased out in the next two to five years. International financial institutions, export credit agencies and development agencies should provide the required finance and infrastructure to create systems and networks to deliver the seed capital, institutional support and capacity to facilitate the implementation of the Energy [R]evolution in developing countries.

While all energy policies need to be adapted to the local situation, we are proposing the following policies to encourage the Energy [R]evolution that all countries should adopt:

## 10.1 climate policy

Policies to limit the effects of climate change and move towards a renewable energy future must be based on penalising energy sources that contribute to global pollution.

### Action: Phase out subsidies for fossil fuel and nuclear power production and inefficient energy use

The United Nations Environment Programme (UNEP) estimates (August 2008) the annual bill for worldwide energy subsidies at about $300 billion, or 0.7% of global GDP[57]. Approximately 80% of this is spent on funding fossil fuels and more than 10% to support nuclear energy. The lion's share is used to artificially lower the real price of fossil fuels. Subsidies (including loan guarantees) make energy efficiency less attractive, keep renewable energy out of the market place and prop up non-competitive and inefficient technologies.

Eliminating direct and indirect subsidies to fossil fuels and nuclear power would help move us towards a level playing field across the energy sector. Scrapping these payments would, according to UNEP, reduce greenhouse gas emissions by as much as 6% a year, while contributing 0.1% to global GDP. Many of these seemingly well intentioned subsidies rarely make economic sense anyway, and hardly ever address poverty, thereby challenging the widely held view that such subsidies assist the poor.

Instead, governments should use subsidies to stimulate investment in energy-saving measures and the deployment of renewable energy by reducing their investment costs. Such support could include grants, favourable loans and fiscal incentives such as reduced taxes on energy efficient equipment, accelerated depreciation, tax credits and tax deductions.

The G-20 countries, meeting in Philadelphia in September 2009, called for world leaders to eliminate fossil fuel subsidies, but hardly any progress has been made since then towards implementing the resolution.

### Action: Introduce the "polluter pays" principle

A substantial indirect form of subsidy comes from the fact that the energy market does not incorporate the external, societal costs of the use of fossil fuels and nuclear power. Pricing structures in the energy markets should reflect the full costs to society of producing energy.

This requires that governments apply a 'polluter pays' system that charges the emitters accordingly, or applies suitable compensation to non-emitters. Adoption of 'polluter pays' taxation to electricity sources, or equivalent compensation to renewable energy sources, and exclusion of renewables from environment-related energy taxation, is essential to achieve fairer competition in the world's electricity markets.

**references**
**57** "REFORMING ENERGY SUBSIDIES: OPPORTUNITIES TO CONTRIBUTE TO THE CLIMATE CHANGE AGENDA", UNEP, 2008.

The real cost of conventional energy production includes expenses absorbed by society, such as health impacts and local and regional environmental degradation - from mercury pollution to acid rain – as well as the global negative impacts of climate change. Hidden costs include the waiving of nuclear accident insurance that is too expensive to be covered by the nuclear power plant operators. The Price Anderson Act, for instance, limits the liability of US nuclear power plants in the case of an accident to an amount of up to $98 million per plant, and only $15 million per year per plant, with the rest being drawn from an industry fund of up to $10 billion. After that the taxpayer becomes responsible[58]. This kind of system would clearly be potentially crippling for a country like South Africa.

Although environmental damage should, in theory, be rectified by forcing polluters to pay, the environmental impacts of electricity generation can be difficult to quantify. How do you put a price on lost homes on Pacific Islands as a result of melting icecaps or on deteriorating health and human lives?

An ambitious project, funded by the European Commission - ExternE – has tried to quantify the full environmental costs of electricity generation. It estimates that the cost of producing electricity from coal or oil would double and that from gas would increase by 30% if external costs, in the form of damage to the environment and health, were taken into account. If those environmental costs were levied on electricity generation according to its impact, many renewable energy sources would not need any support. If, at the same time, direct and indirect subsidies to fossil fuels and nuclear power were removed, the need to support renewable electricity generation would seriously diminish or cease to exist.

One way to achieve this is by a carbon tax that ensures a fixed price is paid for each unit of carbon that is released into the atmosphere. Such taxes have, or are being, implemented in countries such as Sweden and the state of British Columbia, and South Africa is currently considering such an approach. Another approach is through cap and trade, as operating in the European Union and planned in New Zealand and several US states. This concept gives pollution reduction a value in the marketplace.

In theory, cap and trade prompts technological and process innovations that reduce pollution down to the required levels. A stringent cap and trade system can harness market forces to achieve cost-effective greenhouse gas emission reductions. But this will only happen if governments implement true 'polluter pays' schemes that charge emitters accordingly.

Government programmes that allocate a maximum amount of emissions to industrial plants have proved to be effective in promoting energy efficiency in certain industrial sectors. To be successful, however, these allowances need to be strictly limited and their allocation auctioned.

## 10.2 energy policy and market regulation

Essential reforms are necessary in the electricity sector if new renewable energy technologies are to be implemented more widely.

### Action: Reform the electricity market to allow better integration of renewable energy technologies

Complex licensing procedures and bureaucratic hurdles constitute one of the most difficult obstacles faced by renewable energy in many countries. A clear timetable for approving renewable energy projects should be set for all administrations at all levels, and they should receive priority treatment. Governments should propose more detailed procedural guidelines to strengthen the existing legislation and at the same time streamline the licensing procedures. In South Africa, the establishment of an Independent Market and Systems Operator is crucial to begin the process of integrating Independent Power Producers into the market and creating access to the grid. The actual uptake of the REFIT is also a crucial step forward that needs to be made within the South African context, as a support mechanism for the establishment of a robust renewable energy industry.

Other general barriers include the lack of long term and integrated resource planning at national, regional and local level; the lack of predictability and stability in the markets; the complete grid ownership by Eskom and the absence of (access to) grids for large scale renewable energy sources, such as offshore wind power or concentrating solar power plants. The International Energy Agency has identified Denmark, Spain and Germany as examples of best practice in a reformed electricity market that supports the integration of renewable energy.

In order to remove these market barriers, the South African government should consider how to:

- streamline planning procedures and permit systems and integrate least cost network planning;
- ensure access to the grid at fair and transparent prices;
- ensure priority access and transmission security for electricity generated from renewable energy resources, including fina;
- unbundle all utilities into separate generation, distribution and selling companies;
- ensure that the costs of grid infrastructure development and reinforcement are borne by the grid management authority rather than individual renewable energy projects;
- ensure the disclosure of fuel mix and environmental impact to end users;
- establish progressive electricity and final energy tariffs so that the price of a kWh costs more for those who consume more;
- set up demand-side management programmes designed to limit energy demand, reduce peak loads and maximise the capacity factor of the generation system. Demand-side management should also be adapted to facilitate the maximum possible share of renewable energies in the power mix;
- introduce pricing structures in the energy markets to reflect the full costs to society of producing energy.

**references**
58 HTTP://EN.WIKIPEDIA.ORG/WIKI/PRICE-ANDERSON_NUCLEAR_INDUSTRIES_INDEMNITY_ACT

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


## 10.3 targets and incentives for renewables

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 which guarantee stable tariffs over a period of up to 20 years. The fact that the South African REFIT is subject to review and revision downwards before it has even been implemented is cause for concern, particularly within the context of creating a stable environment within which renewables can develop.

At present new renewable energy generators have to compete with old nuclear and fossil fuelled 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.

Support mechanisms for different sectors and technologies can vary according to regional characteristics, priorities or starting points, but some general principles should apply. These are:

- **Long term stability:** Policy makers need to make sure that investors can rely on the long-term stability of any support scheme. It is absolutely crucial to avoid stop-and-go markets by changing the system or the level of support frequently.
- **Encouraging local and regional benefits and public acceptance:** A support scheme should encourage local/regional development, employment and income generation. It should also encourage public acceptance of renewables, including increased stakeholder involvement.

Incentives can be provided for renewable energy through both targets and price support mechanisms.

**Action: Establish legally binding targets for renewable energy and combined heat and power generation**

An increasing number of countries have established targets for renewable energy, either as a general target or broken down by sector for power, transport and heating. These are either expressed in terms of installed capacity or as a percentage of energy consumption. China and the European Union have a target for 20% renewable energy by 2020, for example, and New Zealand has a 90% by 2025 target.

Although these targets are not always legally binding, they have served as an important catalyst for increasing the share of renewable energy throughout the world. The electricity sector clearly needs a long term horizon, as investments are often only paid back after 20 to 40 years. Renewable energy targets therefore need to have short, medium and long term stages and must be legally binding in order to be effective. In order for the proportion of renewable energy to increase significantly, targets must also be set in accordance with the potential for each technology (wind, solar, biomass etc) and taking into account existing and planned infrastructure. Every government should carry out a detailed analysis of the potential and feasibility of renewable energies in its own country, and define, based on that analysis, the deadline for reaching, either individually or in cooperation with other countries, a 100% renewable energy supply.

**Action: Provide a stable return for investors through price support mechanisms**

Price support mechanisms for renewable energy are a practical means of correcting market failures in the electricity sector. Their aim is to support market penetration of those renewable energy technologies, such as wind and solar thermal, that currently suffer from unfair competition due to direct and indirect support to fossil fuel use and nuclear energy, and to provide incentives for technology improvements and cost reductions so that technologies such as PV, wave and tidal can compete with conventional sources in the future.

Overall, there are two types of incentives to promote the deployment of renewable energy. These are Fixed Price Systems where the government dictates the electricity price (or premium) paid to the producer and lets the market determine the quantity, and Renewable Quota Systems (in the USA referred to as Renewable Portfolio Standards) where the government dictates the quantity of renewable electricity and leaves it to the market to determine the price. Both systems create a protected market against a background of subsidised, depreciated conventional generators whose external environmental costs are not accounted for. Their aim is to provide incentives for technology improvements and cost reductions, leading to cheaper renewables that can compete with conventional sources in the future.

The main difference between quota based and price based systems is that the former aims to introduce competition between electricity producers. However, competition between technology manufacturers, which is the most crucial factor in bringing down electricity production costs, is present regardless of whether government dictates prices or quantities. Prices paid to wind power producers are currently higher in many European quota based systems (UK, Belgium, Italy) than in fixed price or premium systems (Germany, Spain, Denmark).

The European Commission has concluded that fixed price systems are to be preferred above quota systems. If implemented well, fixed price systems are a reliable, bankable support scheme for renewable energy projects, providing long term stability and leading to lower costs. In order for such systems to achieve the best possible results, however, priority access to the grid must be ensured.

### 10.3.1 fixed price systems

Fixed price systems include investment subsidies, fixed feed-in tariffs, fixed premium systems and tax credits.

- **Investment subsidies** are capital payments usually made on the basis of the rated power (in kW) of the generator. It is generally acknowledged, however, that systems which base the amount of support on generator size rather than electricity output can lead to less efficient technology development. There is therefore a global trend away from these payments, although they can be effective when combined with other incentives.

- **Fixed feed-in tariffs (FITs)** widely adopted in Europe, have proved extremely successful in expanding wind energy in Germany, Spain and Denmark. Operators are paid a fixed price for every kWh of electricity they feed into the grid. In Germany the price paid varies according to the relative maturity of the particular technology and reduces each year to reflect falling costs. The additional cost of the system is borne by taxpayers or electricity consumers.

  The main benefit of a FIT is that it is administratively simple and encourages better planning. Although the FIT is not associated with a formal Power Purchase Agreement, distribution companies are usually obliged to purchase all the production from renewable installations. Germany has reduced the political risk of the system being changed by guaranteeing payments for 20 years. The main problem associated with a fixed price system is that it does not lend itself easily to adjustment – whether up or down - to reflect changes in the production costs of renewable technologies.

- **Fixed premium systems** sometimes called an "environmental bonus" mechanism, operate by adding a fixed premium to the basic wholesale electricity price. From an investor perspective, the total price received per kWh is less predictable than under a feed-in tariff because it depends on a constantly changing electricity price. From a market perspective, however, it is argued that a fixed premium is easier to integrate into the overall electricity market because those involved will be reacting to market price signals. Spain is the most prominent country to have adopted a fixed premium system.

- **Tax credits** as operated in the US and Canada, offer a credit against tax payments for every kWh produced. In the United States the market has been driven by a federal Production Tax Credit (PTC) of approximately 1.8 $cents per kWh. It is adjusted annually for inflation.

### 10.3.2 renewable quote systems

Two types of renewable quota systems have been employed - tendering systems and green certificate systems.

- **Tendering systems** involve competitive bidding for contracts to construct and operate a particular project, or a fixed quantity of renewable capacity in a country or state. Although other factors are usually taken into account, the lowest priced bid invariably wins. This system has been used to promote wind power in Ireland, France, the UK, Denmark and China.

  The downside is that investors can bid an uneconomically low price in order to win the contract, and then not build the project. Under the UK's NFFO (Non-Fossil Fuel Obligation) tender system, for example, many contracts remained unused. It was eventually abandoned. If properly designed, however, with long contracts, a clear link to planning consent and a possible minimum price, tendering for large scale projects could be effective, as it has been for offshore oil and gas extraction in Europe's North Sea.

- **Tradable green certificate (TGC) systems** operate by offering "green certificates" for every kWh generated by a renewable producer. The value of these certificates, which can be traded on a market, is then added to the value of the basic electricity. A green certificate system usually operates in combination with a rising quota of renewable electricity generation. Power companies are bound by law to purchase an increasing proportion of renewables input. Countries which have adopted this system include the UK and Italy in Europe and many individual states in the US, where it is known as a Renewable Portfolio Standard.

  Compared with a fixed tender price, the TGC model is more risky for the investor, because the price fluctuates on a daily basis, unless effective markets for long-term certificate (and electricity) contracts are developed. Such markets do not currently exist. The system is also more complex than other payment mechanisms.

## 10.4 energy efficiency and innovation

**Action: Set stringent efficiency and emissions standards for appliances, buildings, power plants and vehicles**

Policies and measures to promote energy efficiency exist in many countries, and there are huge potential gains from the implementation of ambitious energy efficiency policies in South Africa. Energy and information labels, mandatory minimum energy performance standards and voluntary efficiency agreements are the most popular measures. Effective government policies usually contain two elements - those that push the market through standards and those that pull through incentives - and have proved to be an effective, low cost way to coordinate a transition to more energy efficiency.

The Japanese front-runner programme, for example, is a regulatory scheme with mandatory targets which gives incentives to manufacturers and importers of energy-consuming equipment to continuously improve the efficiency of their products. It operates by allowing today's best models on the market to set the level for future standards.

In the residential sector in industrialised countries, standby power consumption ranges from 20 to 60 watts per household, equivalent to 4 to 10% of total residential energy consumption. Yet the technology is available to reduce standby power to 1 watt. A global standard, as proposed by the IEA, could mandate this reduction. Japan, South Korea and the state of California have not waited for this international approach and have already adopted standby standards.

Governments should mandate the phase-out of incandescent and inefficient light bulbs and replace them with the most efficient lighting. Countries like Cuba, Venezuela and Australia have already banned incandescent light bulbs.

Governments should also set emissions standards for cars and power plants, such as those proposed in Europe for passenger cars of 120g $CO_2$/km and 350 g/kWh for power plants. Similar emissions standards, as already implemented in China, Japan and the states of Washington and California, will support innovation and ensure that inefficient vehicles and power plants are outlawed.

**image** A YOUNG INDIGENOUS NENET BOY PRACTICES WITH HIS ROPE. THE BOYS ARE GIVEN A ROPE FROM PRETTY MUCH THE MOMENT THEY ARE BORN. BY THE AGE OF SIX THEY ARE OUT HELPING LASSOING THE REINDEER. THE INDIGENOUS NENETS PEOPLE MOVE EVERY 3 OR 4 DAYS SO THAT THEIR REINDEER DO NOT OVER GRAZE THE GROUND AND THEY DO NOT OVER FISH THE LAKES. THE YAMAL PENINSULA IS UNDER HEAVY THREAT FROM GLOBAL WARMING AS TEMPERATURES INCREASE AND RUSSIAS ANCIENT PERMAFROST MELTS.




**Action: Support innovation in energy efficiency, low carbon transport systems and renewable energy production**

Innovation will play an important role in making the Energy [R]evolution happen, and is needed to realise the ambition of ever-improving efficiency and emissions standards. Programmes supporting renewable energy and energy efficiency development and diffusion are a traditional focus of energy and environmental policies because energy innovations face barriers all along the energy supply chain (from R&D to demonstration projects to widespread deployment). Direct government support through a variety of fiscal instruments, such as tax incentives, is vital to hasten deployment of radically new technologies due to a lack of industry investment. This suggests that there is a role for the public sector in increasing investment directly and in correcting market and regulatory obstacles that inhibit investment in new technology.

Governments need to invest in research and development for more efficient appliances and building techniques, in new forms of insulation, in new types of renewable energy production (such as tidal and wave power) as well as in a low carbon transport future, through the development of better batteries for plug-in electric cars or fuels for aviation from renewable sources. Governments need to engage in innovation themselves, both through publicly funded research and by supporting private research and development.

There are numerous ways to support innovation. The most important policies are those that reduce the cost of research and development, such as tax incentives, staff subsidies or project grants. Financial support for research and development on 'dead end' energy solutions such as nuclear fusion should be diverted to supporting renewable energy, energy efficiency and decentralised energy solutions.

Specific proposals for efficiency and innovation measures include:

### 10.4.1 appliances and lighting

Two types of renewable quota systems have been employed - tendering systems and green certificate systems.

- **Efficiency standards** Governments should set ambitious, stringent and mandatory efficiency standards for all energy consuming appliances that constantly respond to technical innovation and enforce the phase-out of the most inefficient appliances. These standards should allow the banning of inefficient products from the market, with penalties for non-compliance.
- **Consumer awareness** Governments should inform consumers and/or set up systems that compel retailers and manufacturers to do so, about the energy efficiency of the products they use and buy, including awareness-raising and educational programmes. Consumers often make their choices based on non-financial factors but lack the necessary information.
- **Energy labelling** Labels provide the means to inform consumers of the product's relative or absolute performance and energy operating costs. Governments should support the development of endorsement and comparison labels for electrical appliances.

### 10.4.2 buildings

- **Residential and commercial building codes** Governments should set mandatory building codes that require the use of a set share of renewable energy for heating and cooling and compliance with a limited annual energy consumption level. These codes should be regularly upgraded in order to make use of fresh products on the market and non-compliance should be penalised.
- **Financial incentives** Given that investment costs are often a barrier to implementing energy efficiency measures, in particular for retrofitting renewable energy options, governments should offer financial incentives including tax reductions schemes, investment subsidies and preferential loans.
- **Energy intermediaries and audit programmes** Governments should develop strategies and programmes to promote the education of architects, engineers and other professionals in the building sector as well as end-users about energy efficiency opportunities in new and existing buildings. As part of this strategy governments should invest in 'energy intermediaries' and energy audit programmes in order to assist professionals and consumers in identifying opportunities for improving the efficiency of their buildings.

### 10.4.3 transport

- **Emissions standards** Governments should regulate the efficiency of private cars and other transport vehicles in order to push manufacturers to reduce emissions through downsizing, design and technology improvement. Improvements in efficiency will reduce $CO_2$ emissions irrespective of the fuel used. South Africa introduced such a carbon emissions tax on all new passenger vehicles in 2010, which is commendable.

  After this further reductions could be achieved by using low-emission fuels. Emissions standards should provide for an average reduction of 5g $CO_2$/km/year in industrialised countries. These standards need to be mandatory. To dissuade car makers from overpowering high end cars a maximum $CO_2$ emissions limit for individual car models should be introduced.
- **Electric vehicles** Governments should develop incentives to promote the further development of electric cars and other efficient and sustainable low carbon transport technologies. Linking electric cars to a renewable energy grid is the best possible option to reduce emissions from the transport sector.
- **Transport demand management** Governments should invest in developing, improving and promoting low emission transport options, such as public and non-motorised transport, freight transport management programmes, teleworking and more efficient land use planning in order to limit journeys.

# glossary & appendix

**GLOBAL**

GLOSSARY OF COMMONLY USED TERMS AND ABBREVIATIONS

DEFINITIONS OF SECTORS

METHODOLOGY TO CALCULATE EMPLOYMENT

# 11

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

**GREENPEACE INTERNATIONAL**
CLIMATE CAMPAIGN

**image** COAL FIRED POWER PLANT.
© F. FUXA/DREAMSTIME

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


## 11.1 glossary of commonly used terms and abbreviations

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

**J** Joule, a measure of energy:
**kJ** = 1,000 Joules,
**MJ** = 1 million Joules,
**GJ** = 1 billion Joules,
**PJ** = $10^{15}$ Joules,
**EJ** = $10^{18}$ Joules

**W** Watt, measure of electrical capacity:
**kW** = 1,000 watts,
**MW** = 1 million watts,
**GW** = 1 billion watts

**kWh** Kilowatt-hour, measure of electrical output: TWh = $10^{12}$ watt-hours
**t/Gt** Tonnes, measure of weight: Gt = 1 billion tonnes

### table 11.1: conversion factors - fossil fuels

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

### table 11.2: conversion factors - different energy units

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

## 11.2 definition of sectors

The definition of different sectors below is the same as the sectoral breakdown in the IEA World Energy Outlook series.

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

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

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

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

**Other sectors:** 'Other sectors' covers agriculture, forestry, fishing, residential, commercial and public services.

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

## 11.3 methodology to calculate employment

### 11.3.1 employment factors

Electricity sector employment is calculated by using employment factors, which give the jobs created per unit of capacity (MW) or per unit of generation (GWh). The employment factors are the most important inputs to employment calculations. Local employment factors are used where possible, but are only available for operations and maintenance employment in coal, nuclear, and hydro generation, for construction employment for coal, for coal mining, and for employment in all aspects of solar water heating. Where local factors are not available, OECD factors are used after adjustment for the fact that projects tend to be more labour intensive where wage levels are lower.

The factors used in the modelling are presented in the following table, with the local factors identified. Non-local factors are from the US or Europe, and are adjusted by a factor of 2.15 to take account of the higher labor intensity which tends to occur when wage levels are lower. Employment factors are further adjusted to take account of the reduction in technology costs and the corresponding fall in employment per MW by using decline factors.

The derivation of the local factors and the regional adjustment factor of 2.15 is given in detail in the 2010 South African jobs analysis report[59]. The derivation of the global factors and the updated decline factors are given in Rutovitz and Usher, 2010[60].

The methodology to calculate construction employment has been improved since the previous employment analysis, as construction is now allocated to the years prior to capacity coming on line taking account of the construction time for that technology. For example, all the PV employment will occur in the year immediately prior generation, while the employment associated with a new coal fired power station will occur in the five years prior to generation.

**table 11.3: employment factors for use in south african analysis (note 1)**

| FUEL | CONSTRUCTION & INSTALLATION *Job years/MW* | MANUFACTURING *Job years/MW* | OPERATION & MAINTENANCE *Jobs/MW* | FUEL *Jobs/GWh* | NOTES |
|---|---|---|---|---|---|
| Coal (existing) | n/a | n/a | 0.3 (local) | 0.13 (local) | Note 2 |
| Coal (new) | 10.4 (local) | 3.2 | 0.294 (local) | 0.11 (local) | Note 2 |
| Gas, oil and diesel | 3.0 | 0.2 | 0.1 | 0.3 | Note 3 |
| Nuclear | 31.0 | 3.4 | 0.66 (local) | 0.002 | Note 4 |
| Biomass | 8.3 | 0.9 | 6.6 | 0.5 | Note 5 |
| Hydro | 23.2 | 1.1 | 0.04 (local) | | Note 6 |
| Wind | 5.4 | 26.9 | 0.9 | | Note 7 |
| PV | 62.4 | 20.0 | 0.9 | | Note 8 |
| Geothermal | 6.7 | 7.1 | 1.6 | | Note 9 |
| Solar thermal | 12.9 | 8.6 | 0.6 | | Note 10 |
| Ocean | 19.4 | 2.2 | 0.7 | | Note 11 |
| Solar water heating | 11.7 (local) | 10.7 (local) | | | Note 12 |
| Energy efficiency | | **0.5 jobs per GWH** | | | Note 13 |

59 RUTOVITZ, J. 2010. SOUTH AFRICAN ENERGY SECTOR JOBS TO 2030. PREPARED FOR GREENPEACE AFRICA BY THE INSTITUTE OF SUSTAINABLE FUTURES, UNIVERSITY OF TECHNOLOGY, SYDNEY.
60 RUTOVITZ, J AND USHER, J. 2010. METHODOLOGY FOR CALCULATING ENERGY SECTOR JOBS. PREPARED FOR GREENPEACE INTERNATIONAL BY THE INSTITUTE OF SUSTAINABLE FUTURES, UNIVERSITY OF TECHNOLOGY, SYDNEY


**image** MINOTI SINGH AND HER SON AWAIT FOR CLEAN WATER SUPPLY BY THE RIVERBANK IN DAYAPUR VILLAGE IN SATJELLIA ISLAND, INDIA: "WE DO NOT HAVE CLEAN WATER AT THE MOMENT AND ONLY ONE TIME WE WERE LUCKY TO BE GIVEN SOME RELIEF. WE ARE NOW WAITING FOR THE GOVERNMENT TO SUPPLY US WITH WATER TANKS".

## notes

1. Where local factors are not available, OECD factors have been multiplied by 2.15. Local factors are in bold and noted as local in brackets.
2. **Coal**: Construction is a local factor, and has been calculated from the estimates for Medupi and Kusile power stations (from ESKOM 2009 Annual Report Additional Information. Medupi power station facts.), assuming an average of 5,000 people employed for ten years. O&M is a local factor. Fuel is a local factor, and is calculated from coal production and use in electricity (IEA production statistics), electricity production from coal (from ESKOM 2009 Annual Report), and employment in coal mining (DME 2008 Minerals Statistical Tables 1986 - 2007. Table 52). Manufacturing is from the USA NREL JEDI model, downloaded 30/4/09.
3. **Gas**: All factors are from the USA publicly available NRELJEDI model, downloaded 30/4/09 with default values used for all variables. Note that the factors have been altered since the 2009 global analysis as an ambiguity within the NREL model has been clarified. Default values from the model were used for all variables, and are multiplied by 2.15. Oil and diesel use the same factors as gas.
4. **Nuclear**: O&M is a local factor, and is calculated from employees and capacity at South Africa's Koeburg nuclear station (ESKOM website, Koeburg nuclear power station, downloaded 5/1/2010. (1200 employees, capacity 1800 MW). Fuel and CMI employment is derived from USA and Australian industry data, and are multiplied by 2.15 for use in the South African context (see Rutovitz, J., Atherton, A. 2009, Energy sector jobs to 2030: a global analysis. Prepared for Greenpeace International by the Institute for Sustainable Futures, University of Technology, Sydney for details).
5. **Biomass**: Only biomass for power generation is considered in this analysis (it does not include bio-fuels). Construction and manufacturing factors are from a USA study (EPRI (Electric Power Research Institute). 2001. California Renewable Technology Market and Benefits Assessment. California Energy Commission, 2001), and O&M and fuel factors are from a detailed UK analysis (UK Department for Trade and Industry. 2004. Renewable Supply Chain Gap Analysis: Summary Report). Both are multiplied by 2.15 for use in the South African context.
6. **Hydro**: O&M is a local factor calculated from employment and capacity data for Gariep and Vanderkloof power stations. CMI is from a Canadian study (Pembina Institute. 2004. Canadian Renewable Electricity Development: Employment Impacts. Prepared for Clean Air Renewable Energy Coalition), multiplied by 2.15 for use in the South African context.
7. **Wind**: All factors are from the European Wind Energy Association (2009) *Wind at work. Wind energy and job creation in the EU*, and are multiplied by 2.15 for use in the South African context.
8. **Solar PV**: CMI factors are from the European Photovoltaic Industry Association and Greenpeace (2008). Solar Generation V – 2008, and O&M factors are from Germany industry data (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. 2008. Short-and Long-Term Impacts of the Expansion of Renewable Energy on the German Labour Market. Gross Employment 2007 - A first estimate - March 14, 2008). Factors are multiplied by 2.15.
9. **Geothermal**: All factors are from the USA Geothermal Energy Association (2005) *Geothermal industry employment: survey results and analysis*. (Cédric Nathanaël Hance for the Department of Energy - Geothermal Program), and are multiplied by 2.15 for use in the South African context.
10. **Solar thermal electricity**: All factors are from the European Renewable Energy Council (2008) *Renewable Energy Technology Roadmap 20% by 2020*, and are multiplied by 2.15.
11. **Ocean (includes wave and tidal)**: All factors use United Kingdom (UK) data, taken from two research studies[61], and are multiplied by 2.15 for use in the South African context.
12. **Solar water heating**: Energy efficiency is divided into solar water heating (SWH) and other efficiency, as SWH is expected to contribute significant energy savings. This report does not calculate total employment in SWH in South Africa; instead 10% of the energy efficiency savings are assumed to come from SWH, and employment calculated for that portion of SWH. CMI employment is a local factor derived from AGAMA (2008) *Employment Potential of Renewable Energy In South Africa*. In this analysis retailing and distribution have been included in installation.



**61** W.M.J. BATTEN AND A.S. BAHAJ. 2007. AN ASSESSMENT OF GROWTH SCENARIOS AND IMPLICATIONS FOR OCEAN ENERGY INDUSTRIES IN EUROPE, SUSTAINABLE ENERGY RESEARCH GROUP, SCHOOL OF CIVIL ENGINEERING AND THE ENVIRONMENT, UNIVERSITY OF SOUTHAMPTON, AND CO-ORDINATION ACTION ON OCEAN ENERGY (CA-OE). 2008, WORK SESSION 5 ENVIRONMENTAL, ECONOMICS, DEVELOPMENT POLICY AND PROMOTION OF OPPORTUNITIES. PROJECT NO. 502701.

# south africa: reference scenario



## table 11.1: south africa: electricity generation

| TWh/a | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Power plants** | **261** | **312** | **349** | **404** | **469** | **519** |
| Coal | 247 | 288 | 311 | 260 | 281 | 295 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 3 | 5 | 11 | 20 | 28 |
| Oil | 1 | 2 | 4 | 12 | 20 | 26 |
| Diesel | 0 | 0 | 0 | 0 | 0 | 0 |
| Nuclear | 11 | 13 | 13 | 80 | 84 | 84 |
| Biomass | 0 | 2 | 2 | 2 | 2 | 2 |
| Hydro | 1 | 1 | 1 | 1 | 1 | 1 |
| Wind | 0 | 2 | 6 | 17 | 25 | 32 |
| PV | 0 | 0 | 5 | 17 | 29 | 41 |
| Geothermal | 0 | 0 | 0 | 0 | 0 | 0 |
| Solar thermal power plants | 0 | 1 | 2 | 5 | 7 | 10 |
| Ocean energy | 0 | 0 | 0 | 0 | 0 | 0 |
| **Combined heat & power production** | **0** | **2** | **3** | **9** | **11** | **12** |
| Coal | 0 | 0 | 0 | 0 | 0 | 0 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 2 | 3 | 9 | 11 | 12 |
| Oil | 0 | 0 | 0 | 0 | 0 | 0 |
| Biomass | 0 | 0 | 0 | 0 | 0 | 0 |
| Geothermal | 0 | 0 | 0 | 0 | 0 | 0 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 0 |
| *CHP by producer* | | | | | | |
| Main activity producers | 0 | 0 | 0 | 0 | 0 | 0 |
| Autoproducers | 0 | 2 | 3 | 9 | 11 | 12 |
| **Total generation** | **261** | **314** | **352** | **413** | **480** | **531** |
| Fossil | 248 | 295 | 323 | 291 | 332 | 361 |
| Coal | 247 | 288 | 311 | 260 | 281 | 295 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 5 | 8 | 20 | 31 | 40 |
| Oil | 1 | 2 | 4 | 12 | 20 | 26 |
| Diesel | 0 | 0 | 0 | 0 | 0 | 0 |
| Nuclear | 11 | 13 | 13 | 80 | 84 | 84 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 0 |
| **Renewables** | **1** | **6** | **16** | **42** | **64** | **86** |
| Hydro | 1 | 1 | 1 | 1 | 1 | 1 |
| Wind | 0 | 2 | 6 | 17 | 25 | 32 |
| PV | 0 | 0 | 5 | 17 | 29 | 41 |
| Biomass | 0 | 2 | 2 | 2 | 2 | 2 |
| Geothermal | 0 | 0 | 0 | 0 | 0 | 0 |
| Solar thermal | 0 | 1 | 2 | 5 | 7 | 10 |
| Ocean energy | 0 | 0 | 0 | 0 | 0 | 0 |
| Distribution losses | 22 | 25 | 26 | 29 | 31 | 32 |
| Own consumption electricity | 28 | 31 | 33 | 36 | 38 | 41 |
| Electricity for hydrogen production | 0 | 0 | 0 | 0 | 0 | 0 |
| **Final energy consumption (electricity)** | **208** | **256** | **291** | **367** | **430** | **477** |
| Fluctuating RES (PV, Wind, Ocean) | 0 | 2 | 11 | 34 | 54 | 72 |
| Share of fluctuating RES | 0.0% | 0.7% | 3.0% | 8.3% | 11.2% | 13.6% |
| **RES share** | **0.5%** | **1.8%** | **4.5%** | **10.2%** | **13.4%** | **16.1%** |

## table 11.2: south africa: heat supply

| PJ/a | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **District heating plants** | **0** | **0** | **0** | **0** | **0** | **0** |
| Fossil fuels | 0 | 0 | 0 | 0 | 0 | 0 |
| Biomass | 0 | 0 | 0 | 0 | 0 | 0 |
| Solar collectors | 0 | 0 | 0 | 0 | 0 | 0 |
| Geothermal | 0 | 0 | 0 | 0 | 0 | 0 |
| **Heat from CHP** | **0** | **10** | **13** | **36** | **43** | **43** |
| Fossil fuels | 0 | 10 | 13 | 36 | 43 | 43 |
| Biomass | 0 | 0 | 0 | 0 | 0 | 0 |
| Geothermal | 0 | 0 | 0 | 0 | 0 | 0 |
| Fuel cell (hydrogen) | 0 | 0 | 0 | 0 | 0 | 0 |
| **Direct heating[1]** | **934** | **1,032** | **1,100** | **1,210** | **1,306** | **1,390** |
| Fossil fuels | 639 | 694 | 731 | 802 | 869 | 928 |
| Biomass | 294 | 328 | 351 | 389 | 416 | 440 |
| Solar collectors | 1 | 10 | 17 | 19 | 21 | 22 |
| Geothermal[2] | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total heat supply[1]** | **934** | **1,042** | **1,112** | **1,246** | **1,349** | **1,433** |
| Fossil fuels | 639 | 703 | 743 | 838 | 912 | 971 |
| Biomass | 294 | 328 | 351 | 389 | 416 | 440 |
| Solar collectors | 1 | 10 | 17 | 19 | 21 | 22 |
| Geothermal[2] | 0 | 0 | 0 | 0 | 0 | 0 |
| Fuel cell ((hydrogen) | 0 | 0 | 0 | 0 | 0 | 0 |
| **RES share (including RES electricity)** | **31.6%** | **32.5%** | **33.2%** | **32.8%** | **32.4%** | **32.2%** |

1) including cooling. 2) including heat pumps

## table 11.3: south africa: $CO_2$ emissions

| MILL t/a | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Condensation power plants** | **221** | **257** | **278** | **240** | **252** | **255** |
| Coal | 220 | 254 | 271 | 223 | 224 | 220 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 1 | 3 | 5 | 10 | 12 |
| Oil | 1 | 2 | 4 | 12 | 18 | 23 |
| Diesel | 0 | 0 | 0 | 0 | 0 | 0 |
| **Combined heat & power production** | **0** | **1** | **1** | **4** | **5** | **5** |
| Coal | 0 | 0 | 0 | 0 | 0 | 0 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 1 | 1 | 4 | 5 | 5 |
| Oil | 0 | 0 | 0 | 0 | 0 | 0 |
| **$CO_2$ emissions power generation (incl. CHP public)** | **221** | **258** | **279** | **244** | **257** | **260** |
| Coal | 220 | 254 | 271 | 223 | 224 | 220 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 2 | 4 | 10 | 15 | 17 |
| Oil & diesel | 1 | 2 | 4 | 12 | 18 | 23 |
| **$CO_2$ emissions by sector** | **349** | **398** | **427** | **410** | **437** | **451** |
| % of 1990 emissions | 124% | 142% | 152% | 146% | 155% | 161% |
| Industry | 37 | 40 | 41 | 46 | 49 | 52 |
| Other sectors | 29 | 31 | 33 | 37 | 40 | 42 |
| Transport | 47 | 56 | 61 | 72 | 79 | 84 |
| Power generation (incl. CHP public) | 221 | 257 | 278 | 240 | 252 | 255 |
| Other conversion | 14 | 14 | 14 | 16 | 17 | 18 |
| Population (Mill.) | 49.2 | 51.7 | 52.7 | 54.7 | 56.0 | 56.8 |
| **$CO_2$ emissions per capita (t/capita)** | **7.1** | **7.7** | **8.1** | **7.5** | **7.8** | **7.9** |

## table 11.4: south africa: installed capacity

| GW | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Power plants** | **41** | **51** | **62** | **84** | **99** | **112** |
| Coal | 38 | 43 | 49 | 44 | 45 | 45 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 0.8 | 1.2 | 1.9 | 3.7 | 5.0 |
| Oil | 1.0 | 2.2 | 2.4 | 6.2 | 9.7 | 12 |
| Diesel | 0 | 0 | 0 | 0 | 0 | 0 |
| Nuclear | 1.9 | 1.9 | 1.9 | 12 | 12 | 12 |
| Biomass | 0.05 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 |
| Hydro | 0.7 | 0.9 | 0.9 | 0.9 | 0.9 | 0.8 |
| Wind | 0.02 | 1.3 | 3.3 | 9.2 | 12 | 14 |
| PV | 0.01 | 0.02 | 2.4 | 8.4 | 14 | 20 |
| Geothermal | 0 | 0 | 0 | 0 | 0 | 0 |
| Solar thermal power plants | 0 | 0.2 | 0.6 | 1.2 | 1.8 | 1.9 |
| Ocean energy | 0 | 0 | 0 | 0 | 0 | 0 |
| **Combined heat & power production** | **0** | **0.6** | **0.7** | **1.6** | **2.0** | **2.2** |
| Coal | 0 | 0 | 0 | 0 | 0 | 0 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 0.6 | 0.7 | 1.6 | 2.0 | 2.2 |
| Oil | 0 | 0 | 0 | 0 | 0 | 0 |
| Biomass | 0 | 0 | 0 | 0 | 0 | 0 |
| Geothermal | 0 | 0 | 0 | 0 | 0 | 0 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 0 |
| *CHP by producer* | | | | | | |
| Main activity producers | 0 | 0 | 0 | 0 | 0 | 0 |
| Autoproducers | 0 | 0.6 | 0.7 | 1.6 | 2.0 | 2.2 |
| **Total generation** | **41** | **51** | **62** | **86** | **101** | **114** |
| Fossil | 39 | 47 | 53 | 54 | 60 | 64 |
| Coal | 38 | 43 | 49 | 44 | 45 | 45 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 1.4 | 1.9 | 3.6 | 5.7 | 7.2 |
| Oil | 1.0 | 2.2 | 2.4 | 6.2 | 9.7 | 12.4 |
| Diesel | 0 | 0 | 0 | 0 | 0 | 0 |
| Nuclear | 1.9 | 1.9 | 1.9 | 12.3 | 12.2 | 12.2 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 0 |
| **Renewables** | **0.7** | **2.7** | **7.5** | **20** | **29** | **37** |
| Hydro | 0.7 | 0.9 | 0.9 | 0.9 | 0.9 | 0.8 |
| Wind | 0.02 | 1.3 | 3.3 | 9.2 | 12 | 14 |
| PV | 0.01 | 0.02 | 2.4 | 8.4 | 14 | 20 |
| Biomass | 0.05 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 |
| Geothermal | 0 | 0 | 0 | 0 | 0 | 0 |
| Solar thermal | 0 | 0.2 | 0.6 | 1.2 | 1.8 | 1.9 |
| Ocean energy | 0 | 0 | 0 | 0 | 0 | 0 |
| Fluctuating RES (PV, Wind, Ocean) | 0.03 | 1.3 | 5.7 | 18 | 26 | 34 |
| Share of fluctuating RES | 0.1% | 2.5% | 9.1% | 20.4% | 26.0% | 30.0% |
| **RES share** | **1.8%** | **5.3%** | **12.1%** | **23.3%** | **28.9%** | **32.8%** |

## table 11.5: south africa: primary energy demand

| PJ/a | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Total** | **5,602** | **6,180** | **6,561** | **7,358** | **7,915** | **8,305** |
| **Fossil** | **4,922** | **5,431** | **5,743** | **5,686** | **6,091** | **6,384** |
| Hard coal | 3,927 | 4,185 | 4,348 | 3,941 | 4,069 | 4,200 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Natural gas | 0 | 83 | 121 | 209 | 294 | 327 |
| Crude oil | 995 | 1,163 | 1,274 | 1,535 | 1,727 | 1,857 |
| **Nuclear** | **124** | **145** | **145** | **872** | **920** | **920** |
| **Renewables** | **557** | **604** | **672** | **800** | **904** | **1,001** |
| Hydro | 3 | 5 | 5 | 5 | 5 | 5 |
| Wind | 0 | 8 | 21 | 63 | 90 | 114 |
| Solar | 1 | 12 | 42 | 96 | 150 | 204 |
| Biomass | 552 | 579 | 604 | 636 | 659 | 679 |
| Geothermal | 0 | 0 | 0 | 0 | 0 | 0 |
| Ocean Energy | 0 | 0 | 0 | 0 | 0 | 0 |
| **RES share** | **10.8%** | **10.7%** | **11.2%** | **12.6%** | **13.2%** | **13.8%** |

## table 11.6: south africa: final energy demand

| PJ/a | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Total (incl. non-energy use)** | **2,722** | **3,153** | **3,443** | **4,025** | **4,491** | **4,851** |
| **Total (energy use)** | **2,617** | **3,020** | **3,302** | **3,874** | **4,332** | **4,681** |
| **Transport** | **669** | **802** | **886** | **1,038** | **1,146** | **1,226** |
| Oil products | 656 | 779 | 850 | 995 | 1098 | 1169 |
| Natural gas | 0 | 0 | 0 | 0 | 0 | 0 |
| Biofuels | 0 | 4 | 13 | 17 | 22 | 28 |
| Electricity | 13 | 19 | 23 | 26 | 27 | 28 |
| *RES electricity* | 0 | 0 | 1 | 3 | 4 | 5 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 0 |
| **RES share Transport** | **0.0%** | **0.6%** | **1.5%** | **1.9%** | **2.2%** | **2.7%** |
| **Industry** | **955** | **1,084** | **1,174** | **1,377** | **1,538** | **1,660** |
| Electricity | 422 | 510 | 575 | 708 | 814 | 887 |
| *RES electricity* | 2 | 9 | 26 | 72 | 109 | 143 |
| District heat | 0 | 10 | 13 | 36 | 43 | 43 |
| *RES district heat* | 0 | 0 | 0 | 0 | 0 | 0 |
| Coal | 291 | 280 | 270 | 270 | 269 | 268 |
| Oil products | 38 | 41 | 42 | 46 | 49 | 53 |
| Gas | 131 | 168 | 196 | 232 | 271 | 311 |
| Solar | 0 | 0 | 0 | 0 | 0 | 0 |
| Biomass and waste | 73 | 76 | 78 | 85 | 91 | 98 |
| Geothermal | 0 | 0 | 0 | 0 | 0 | 0 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 0 |
| **RES share Industry** | **7.8%** | **7.8%** | **8.9%** | **11.4%** | **13.0%** | **14.5%** |
| **Other Sectors** | **992** | **1,134** | **1,242** | **1,460** | **1,648** | **1,796** |
| Electricity | 314 | 391 | 451 | 587 | 709 | 803 |
| *RES electricity* | 1 | 7 | 20 | 60 | 95 | 130 |
| District heat | 0 | 0 | 0 | 0 | 0 | 0 |
| *RES district heat* | 0 | 0 | 0 | 0 | 0 | 0 |
| Coal | 225 | 246 | 261 | 289 | 312 | 331 |
| Oil products | 102 | 111 | 117 | 130 | 140 | 149 |
| Gas | 1 | 2 | 3 | 4 | 5 | 7 |
| Solar | 1 | 10 | 17 | 19 | 21 | 22 |
| Biomass and waste | 350 | 374 | 392 | 431 | 461 | 485 |
| Geothermal | 0 | 0 | 0 | 0 | 0 | 0 |
| **RES share Other Sectors** | **35.5%** | **34.5%** | **34.6%** | **34.9%** | **35.0%** | **35.4%** |
| **Total RES** | **427** | **481** | **548** | **686** | **802** | **910** |
| **RES share** | **16.3%** | **15.9%** | **16.6%** | **17.7%** | **18.5%** | **19.4%** |
| **Non energy use** | **106** | **133** | **141** | **150** | **160** | **169** |
| Oil | 52 | 66 | 70 | 75 | 79 | 84 |
| Gas | 0 | 0 | 0 | 0 | 0 | 0 |
| Coal | 53 | 67 | 71 | 76 | 81 | 85 |

# south africa: energy [r]evolution scenario

## table 11.7: south africa: electricity generation

| TWh/a | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Power plants** | **261** | **302** | **324** | **347** | **369** | **393** |
| Coal | 247 | 274 | 265 | 196 | 116 | 44 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 3 | 8 | 24 | 31 | 37 |
| Oil | 1 | 2 | 3 | 3 | 2 | 1 |
| Diesel | 0 | 0 | 0 | 0 | 0 | 0 |
| Nuclear | 11 | 13 | 13 | 0 | 0 | 0 |
| Biomass | 0 | 3 | 4 | 4 | 4 | 5 |
| Hydro | 1 | 2 | 2 | 3 | 4 | 5 |
| Wind | 0 | 4 | 13 | 36 | 53 | 66 |
| PV | 0 | 1 | 3 | 15 | 25 | 32 |
| Geothermal | 0 | 0 | 1 | 1 | 2 | 2 |
| Solar thermal power plants | 0 | 1 | 13 | 65 | 131 | 198 |
| Ocean energy | 0 | 0 | 0 | 1 | 1 | 3 |
| **Combined heat & power production** | **0** | **3** | **11** | **22** | **35** | **42** |
| Coal | 0 | 0 | 0 | 0 | 0 | 0 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 3 | 8 | 12 | 17 | 17 |
| Oil | 0 | 0 | 0 | 0 | 0 | 0 |
| Biomass | 0 | 0 | 2 | 8 | 14 | 20 |
| Geothermal | 0 | 0 | 0 | 2 | 4 | 5 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 0 |
| *CHP by producer* | | | | | | |
| Main activity producers | 0 | 0 | 0 | 0 | 0 | 0 |
| Autoproducers | 0 | 3 | 11 | 22 | 35 | 42 |
| **Total generation** | **261** | **305** | **335** | **369** | **404** | **435** |
| Fossil | 248 | 282 | 284 | 234 | 166 | 100 |
| Coal | 247 | 274 | 265 | 196 | 116 | 44 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 6 | 16 | 36 | 48 | 55 |
| Oil | 1 | 2 | 3 | 3 | 3 | 1 |
| Diesel | 0 | 0 | 0 | 0 | 0 | 0 |
| Nuclear | 11 | 13 | 13 | 0 | 0 | 0 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 0 |
| **Renewables** | **1** | **10** | **38** | **135** | **238** | **336** |
| Hydro | 1 | 2 | 2 | 3 | 4 | 5 |
| Wind | 0 | 4 | 13 | 36 | 53 | 66 |
| PV | 0 | 1 | 3 | 15 | 25 | 32 |
| Biomass | 0 | 4 | 6 | 12 | 19 | 25 |
| Geothermal | 0 | 0 | 1 | 3 | 5 | 7 |
| Solar thermal | 0 | 1 | 13 | 65 | 131 | 198 |
| Ocean energy | 0 | 0 | 0 | 1 | 1 | 3 |
| Distribution losses | 22 | 25 | 26 | 29 | 32 | 36 |
| Own consumption electricity | 28 | 31 | 32 | 31 | 26 | 17 |
| Electricity for hydrogen production | 0 | 0 | 0 | 0 | 1 | 2 |
| **Final energy consumption (electricity)** | **208** | **246** | **275** | **327** | **365** | **400** |
| Fluctuating RES (PV, Wind, Ocean) | 0 | 4 | 16 | 52 | 79 | 101 |
| Share of fluctuating RES | 0.0% | 1.3% | 4.6% | 14.0% | 19.5% | 23.2% |
| **RES share** | **0.5%** | **3.2%** | **11.2%** | **36.5%** | **58.8%** | **77.1%** |
| **'Efficiency' savings (compared to Ref.)** | **0** | **9** | **18** | **51** | **100** | **135** |

## table 11.8: south africa: heat supply

| PJ/a | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **District heating plants** | **0** | **0** | **0** | **0** | **0** | **0** |
| Fossil fuels | 0 | 0 | 0 | 0 | 0 | 0 |
| Biomass | 0 | 0 | 0 | 0 | 0 | 0 |
| Solar collectors | 0 | 0 | 0 | 0 | 0 | 0 |
| Geothermal | 0 | 0 | 0 | 0 | 0 | 0 |
| **Heat from CHP** | **0** | **15** | **47** | **95** | **150** | **170** |
| Fossil fuels | 0 | 14 | 34 | 48 | 67 | 62 |
| Biomass | 0 | 1 | 9 | 31 | 52 | 66 |
| Geothermal | 0 | 0 | 3 | 16 | 32 | 42 |
| Fuel cell (hydrogen) | 0 | 0 | 0 | 0 | 0 | 0 |
| **Direct heating[1)]** | **934** | **1,002** | **1,014** | **1,012** | **991** | **992** |
| Fossil fuels | 639 | 665 | 638 | 551 | 428 | 316 |
| Biomass | 294 | 321 | 324 | 328 | 322 | 322 |
| Solar collectors | 1 | 12 | 43 | 105 | 187 | 277 |
| Geothermal[2)] | 0 | 3 | 9 | 28 | 54 | 77 |
| **Total heat supply[1)]** | **934** | **1,016** | **1,061** | **1,107** | **1,141** | **1,161** |
| Fossil fuels | 639 | 679 | 672 | 600 | 495 | 378 |
| Biomass | 294 | 321 | 334 | 359 | 374 | 388 |
| Solar collectors | 1 | 12 | 43 | 105 | 187 | 277 |
| Geothermal[2)] | 0 | 4 | 12 | 44 | 86 | 118 |
| Fuel cell (hydrogen) | 0 | 0 | 0 | 0 | 0 | 0 |
| **RES share (including RES electricity)** | **31.6%** | **33.2%** | **36.6%** | **45.8%** | **56.6%** | **67.5%** |
| **'Efficiency' savings (compared to Ref.)** | **0** | **26** | **52** | **139** | **208** | **272** |

1) including cooling. 2) including heat pumps

## table 11.9: south africa: $CO_2$ emissions

| MILL t/a | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Condensation power plants** | **221** | **245** | **238** | **183** | **109** | **50** |
| Coal | 220 | 241 | 231 | 168 | 92 | 33 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 1 | 4 | 12 | 15 | 16 |
| Oil | 1 | 2 | 3 | 3 | 2 | 1 |
| Diesel | 0 | 0 | 0 | 0 | 0 | 0 |
| **Combined heat & power production** | **0** | **1** | **4** | **6** | **8** | **8** |
| Coal | 0 | 0 | 0 | 0 | 0 | 0 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 1 | 4 | 6 | 8 | 8 |
| Oil | 0 | 0 | 0 | 0 | 0 | 0 |
| **$CO_2$ emissions power generation (incl. CHP public)** | **221** | **246** | **242** | **189** | **118** | **58** |
| Coal | 220 | 241 | 231 | 168 | 92 | 33 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 3 | 8 | 18 | 23 | 24 |
| Oil & diesel | 1 | 2 | 3 | 3 | 2 | 1 |
| **$CO_2$ emissions by sector** | **349** | **381** | **373** | **304** | **207** | **123** |
| % of 1990 emissions | 124% | 136% | 133% | 108% | 74% | 44% |
| Industry | 37 | 39 | 38 | 33 | 28 | 23 |
| Other sectors | 29 | 30 | 29 | 26 | 19 | 12 |
| Transport | 47 | 55 | 55 | 51 | 42 | 32 |
| Power generation (incl. CHP public) | 221 | 245 | 238 | 183 | 109 | 50 |
| Other conversion | 14 | 13 | 12 | 11 | 8 | 6 |
| Population (Mill.) | 49.2 | 52 | 53 | 55 | 56 | 57 |
| **$CO_2$ emissions per capita (t/capita)** | **7.1** | **7.4** | **7.1** | **5.6** | **3.7** | **2.2** |

## table 11.10: south africa: installed capacity

| GW | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Power plants** | **41** | **50** | **60** | **78** | **91** | **99** |
| Coal | 38 | 41 | 41 | 33 | 26 | 15 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 0.9 | 1.9 | 4.3 | 5.8 | 9.3 |
| Oil | 1.0 | 2.2 | 1.7 | 1.6 | 1.2 | 0.5 |
| Diesel | 0 | 0 | 0 | 0 | 0 | 0 |
| Nuclear | 1.9 | 1.9 | 1.9 | 0 | 0 | 0 |
| Biomass | 0.05 | 0.6 | 0.7 | 0.7 | 0.7 | 0.6 |
| Hydro | 0.7 | 1.1 | 1.4 | 2.1 | 2.8 | 3.2 |
| Wind | 0.02 | 2.1 | 6.9 | 18 | 24 | 26 |
| PV | 0.01 | 0.3 | 1.5 | 7.5 | 13 | 16 |
| Geothermal | 0 | 0.03 | 0.1 | 0.2 | 0.3 | 0.4 |
| Solar thermal power plants | 0 | 0.2 | 2.9 | 10 | 18 | 27 |
| Ocean energy | 0 | 0 | 0.01 | 0.2 | 0.3 | 0.8 |
| **Combined heat & power production** | **0** | **0.9** | **2.4** | **4.0** | **6.6** | **8.0** |
| Coal | 0 | 0 | 0 | 0 | 0 | 0 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 0.9 | 1.9 | 2.2 | 3.1 | 3.1 |
| Oil | 0 | 0 | 0 | 0 | 0 | 0 |
| Biomass | 0 | 0.03 | 0.4 | 1.5 | 2.7 | 4.0 |
| Geothermal | 0 | 0.01 | 0.1 | 0.4 | 0.7 | 0.9 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 0 |
| *CHP by producer* | | | | | | |
| Main activity producers | 0 | 0 | 0 | 0 | 0 | 0 |
| Autoproducers | 0 | 0.9 | 2.4 | 4.0 | 6.6 | 8.0 |
| **Total generation** | **41** | **51** | **63** | **82** | **98** | **107** |
| Fossil | 39 | 45 | 47 | 41 | 36 | 28 |
| Coal | 38 | 41 | 41 | 33 | 26 | 15 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 1.7 | 3.8 | 6.5 | 9.0 | 12 |
| Oil | 1.0 | 2.2 | 1.7 | 1.6 | 1.2 | 0.5 |
| Diesel | 0 | 0 | 0 | 0 | 0 | 0 |
| Nuclear | 1.9 | 1.9 | 1.9 | 0 | 0 | 0 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 0 |
| **Renewables** | **0.7** | **4.3** | **14** | **41** | **62** | **80** |
| Hydro | 0.7 | 1.1 | 1.4 | 2.1 | 2.8 | 3.2 |
| Wind | 0.02 | 2.1 | 6.9 | 18 | 24 | 26 |
| PV | 0.01 | 0.3 | 1.5 | 7.5 | 13 | 16 |
| Biomass | 0.05 | 0.6 | 1.1 | 2.2 | 3.4 | 4.6 |
| Geothermal | 0 | 0.04 | 0.2 | 0.5 | 1.0 | 1.4 |
| Solar thermal | 0 | 0.2 | 2.9 | 10 | 18 | 27 |
| Ocean energy | 0 | 0 | 0.01 | 0.2 | 0.3 | 0.8 |
| Fluctuating RES (PV, Wind, Ocean) | 0.03 | 2 | 8 | 26 | 37 | 43 |
| Share of fluctuating RES | 0.1% | 4.6% | 13.5% | 31.8% | 37.7% | 40.3% |
| **RES share** | **1.8%** | **8.5%** | **22.4%** | **49.8%** | **63.3%** | **74.2%** |

## table 11.11: south africa: primary energy demand

| PJ/a | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Total** | **5,602** | **6,028** | **6,095** | **5,766** | **5,315** | **4,980** |
| **Fossil** | **4,922** | **5,246** | **5,157** | **4,488** | **3,505** | **2,682** |
| Hard coal | 3,927 | 4,044 | 3,866 | 3,160 | 2,303 | 1,704 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Natural gas | 0 | 77 | 161 | 309 | 371 | 344 |
| Crude oil | 995 | 1,125 | 1,129 | 1,019 | 832 | 634 |
| **Nuclear** | **124** | **145** | **145** | **0** | **0** | **0** |
| **Renewables** | **557** | **637** | **793** | **1,278** | **1,810** | **2,298** |
| Hydro | 3 | 5 | 7 | 11 | 14 | 18 |
| Wind | 0 | 13 | 45 | 130 | 191 | 238 |
| Solar | 1 | 16 | 100 | 393 | 748 | 1,105 |
| Biomass | 552 | 594 | 606 | 645 | 677 | 696 |
| Geothermal | 0 | 9 | 34 | 98 | 175 | 230 |
| Ocean Energy | 0 | 0 | 0 | 2 | 4 | 11 |
| **RES share** | **10.8%** | **0** | **0** | **0** | **0** | 0 |
| **'Efficiency' savings (compared to Ref.)** | **0** | **151** | **458** | **1,558** | **2,534** | **3,226** |

## table 11.12: south africa: final energy demand

| PJ/a | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Total (incl. non-energy use)** | **2,722** | **3,065** | **3,222** | **3,388** | **3,425** | **3,436** |
| **Total (energy use)** | **2,617** | **2,932** | **3,081** | **3,238** | **3,265** | **3,267** |
| **Transport** | **669** | **782** | **812** | **798** | **769** | **732** |
| Oil products | 656 | 759 | 770 | 705 | 580 | 447 |
| Natural gas | 0 | 0 | 0 | 0 | 0 | 0 |
| Biofuels | 0 | 4 | 11 | 24 | 38 | 45 |
| Electricity | 13 | 19 | 31 | 69 | 150 | 235 |
| *RES electricity* | 0 | 1 | 3 | 25 | 88 | 181 |
| Hydrogen | 0 | 0 | 0 | 0 | 1 | 4 |
| **RES share Transport** | **0.0%** | **0.6%** | **1.8%** | **6.1%** | **16.5%** | **31.4%** |
| **Industry** | **955** | **1,051** | **1,119** | **1,214** | **1,248** | **1,250** |
| Electricity | 422 | 486 | 527 | 598 | 617 | 626 |
| *RES electricity* | 2 | 16 | 59 | 218 | 363 | 483 |
| District heat | 0 | 15 | 47 | 95 | 150 | 170 |
| *RES district heat* | 0 | 1 | 12 | 46 | 83 | 108 |
| Coal | 291 | 283 | 252 | 180 | 102 | 62 |
| Oil products | 38 | 35 | 32 | 29 | 22 | 17 |
| Gas | 131 | 152 | 157 | 159 | 159 | 152 |
| Solar | 0 | 2 | 21 | 54 | 85 | 101 |
| Biomass and waste | 73 | 76 | 77 | 81 | 81 | 83 |
| Geothermal | 0 | 2 | 6 | 20 | 31 | 39 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 0 |
| **RES share Industry** | **7.8%** | **9.2%** | **15.7%** | **34.5%** | **51.6%** | **65.1%** |
| **Other Sectors** | **992** | **1,099** | **1,150** | **1,226** | **1,248** | **1,285** |
| Electricity | 314 | 381 | 433 | 512 | 547 | 579 |
| *RES electricity* | 1 | 12 | 49 | 187 | 322 | 446 |
| District heat | 0 | 0 | 0 | 0 | 0 | 0 |
| *RES district heat* | 0 | 0 | 0 | 0 | 0 | 0 |
| Coal | 225 | 238 | 226 | 187 | 128 | 51 |
| Oil products | 102 | 103 | 98 | 85 | 65 | 47 |
| Gas | 1 | 3 | 13 | 33 | 47 | 64 |
| Solar | 1 | 10 | 22 | 51 | 102 | 176 |
| Biomass and waste | 350 | 363 | 357 | 354 | 345 | 343 |
| Geothermal | 0 | 1 | 2 | 5 | 14 | 26 |
| **RES share Other Sectors** | **35.5%** | **35.2%** | **37.4%** | **48.6%** | **62.7%** | **77.1%** |
| **Total RES** | **427** | **488** | **620** | **1,063** | **1,553** | **2,035** |
| **RES share** | **16.3%** | **16.7%** | **20.1%** | **32.8%** | **47.6%** | **62.3%** |
| **Non energy use** | **106** | **133** | **141** | **150** | **160** | **169** |
| Oil | 52 | 66 | 70 | 75 | 79 | 84 |
| Gas | 0 | 0 | 0 | 0 | 0 | 0 |
| Coal | 53 | 67 | 71 | 76 | 81 | 85 |

# south africa: advanced energy [r]evolution scenario

## table 11.13: south africa: electricity generation

| TWh/a | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Power plants** | **261** | **302** | **326** | **358** | **404** | **438** |
| Coal | 247 | 270 | 238 | 164 | 61 | 0 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 3 | 9 | 15 | 17 | 16 |
| Oil | 1 | 2 | 3 | 3 | 2 | 1 |
| Diesel | 0 | 0 | 0 | 0 | 0 | 0 |
| Nuclear | 11 | 13 | 13 | 0 | 0 | 0 |
| Biomass | 0 | 3 | 3 | 3 | 3 | 3 |
| Hydro | 1 | 2 | 3 | 4 | 5 | 6 |
| Wind | 0 | 5 | 17 | 40 | 58 | 68 |
| PV | 0 | 2 | 19 | 39 | 59 | 79 |
| Geothermal | 0 | 0 | 1 | 1 | 2 | 3 |
| Solar thermal power plants | 0 | 2 | 19 | 88 | 196 | 259 |
| Ocean energy | 0 | 0 | 0 | 1 | 2 | 4 |
| **Combined heat & power production** | **0** | **3** | **11** | **22** | **35** | **42** |
| Coal | 0 | 0 | 0 | 0 | 0 | 0 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 3 | 7 | 10 | 11 | 12 |
| Oil | 0 | 0 | 0 | 0 | 0 | 0 |
| Biomass | 0 | 0 | 3 | 10 | 21 | 25 |
| Geothermal | 0 | 0 | 0 | 2 | 4 | 5 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 0 |
| *CHP by producer* | | | | | | |
| Main activity producers | 0 | 0 | 0 | 0 | 0 | 0 |
| Autoproducers | 0 | 3 | 11 | 22 | 35 | 42 |
| **Total generation** | **261** | **305** | **336** | **380** | **439** | **480** |
| Fossil | 248 | 278 | 257 | 193 | 90 | 29 |
| Coal | 247 | 270 | 238 | 164 | 61 | 0 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 6 | 16 | 26 | 27 | 28 |
| Oil | 1 | 2 | 3 | 3 | 2 | 1 |
| Diesel | 0 | 0 | 0 | 0 | 0 | 0 |
| Nuclear | 11 | 13 | 13 | 0 | 0 | 0 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 0 |
| **Renewables** | **1** | **13** | **66** | **187** | **350** | **452** |
| Hydro | 1 | 2 | 3 | 4 | 5 | 6 |
| Wind | 0 | 5 | 17 | 40 | 58 | 68 |
| PV | 0 | 2 | 19 | 39 | 59 | 79 |
| Biomass | 0 | 4 | 6 | 13 | 24 | 28 |
| Geothermal | 0 | 0 | 1 | 3 | 6 | 8 |
| Solar thermal | 0 | 2 | 19 | 88 | 196 | 259 |
| Ocean energy | 0 | 0 | 0 | 1 | 2 | 4 |
| Distribution losses | 22 | 25 | 26 | 29 | 40 | 37 |
| Own consumption electricity | 28 | 31 | 32 | 30 | 24 | 14 |
| Electricity for hydrogen production | 0 | 0 | 0 | 0 | 6 | 17 |
| **Final energy consumption (electricity)** | **208** | **246** | **276** | **339** | **389** | **431** |
| Fluctuating RES (PV, Wind, Ocean) | 0 | 7 | 36 | 79 | 119 | 151 |
| Share of fluctuating RES | 0.0% | 2.1% | 10.8% | 20.8% | 27.1% | 31.4% |
| **RES share** | **0.5%** | **4.3%** | **19.5%** | **49.2%** | **79.6%** | **94.0%** |
| **'Efficiency' savings (compared to Ref.)** | **0** | **9** | **18** | **51** | **99** | **134** |

## table 11.14: south africa: heat supply

| PJ/a | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **District heating plants** | **0** | **0** | **0** | **0** | **0** | **0** |
| Fossil fuels | 0 | 0 | 0 | 0 | 0 | 0 |
| Biomass | 0 | 0 | 0 | 0 | 0 | 0 |
| Solar collectors | 0 | 0 | 0 | 0 | 0 | 0 |
| Geothermal | 0 | 0 | 0 | 0 | 0 | 0 |
| **Heat from CHP** | **0** | **15** | **47** | **95** | **150** | **170** |
| Fossil fuels | 0 | 14 | 32 | 40 | 41 | 42 |
| Biomass | 0 | 1 | 12 | 37 | 74 | 82 |
| Geothermal | 0 | 0 | 3 | 18 | 35 | 45 |
| Fuel cell (hydrogen) | 0 | 0 | 0 | 0 | 0 | 0 |
| **Direct heating[1)]** | **934** | **1,001** | **1,013** | **1,017** | **1,003** | **993** |
| Fossil fuels | 639 | 665 | 624 | 499 | 304 | 147 |
| Biomass | 294 | 320 | 329 | 336 | 339 | 336 |
| Solar collectors | 1 | 12 | 51 | 150 | 295 | 412 |
| Geothermal[2)] | 0 | 3 | 9 | 31 | 65 | 98 |
| Hydrogen | 0 | 0 | 0 | 0 | 2 | 19 |
| **Total heat supply[1)]** | **934** | **1,015** | **1,060** | **1,112** | **1,155** | **1,183** |
| Fossil fuels | 639 | 678 | 656 | 539 | 345 | 190 |
| Biomass | 294 | 321 | 341 | 373 | 414 | 418 |
| Solar collectors | 1 | 12 | 51 | 150 | 295 | 412 |
| Geothermal[2)] | 0 | 4 | 12 | 49 | 100 | 143 |
| Fuel cell (hydrogen) | 0 | 0 | 0 | 0 | 2 | 19 |
| **RES share (including RES electricity)** | **31.6%** | **33.2%** | **38.1%** | **51.5%** | **70.1%** | **83.9%** |
| **'Efficiency' savings (compared to Ref.)** | **0** | **27** | **52** | **134** | **194** | **251** |

1) including cooling. 2) including heat pumps

## table 11.15: south africa: $CO_2$ emissions

| MILL t/a | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Condensation power plants** | **221** | **242** | **215** | **152** | **58** | **8** |
| Coal | 220 | 238 | 208 | 141 | 49 | 0 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 1 | 4 | 8 | 8 | 7 |
| Oil | 1 | 2 | 3 | 3 | 1 | 1 |
| Diesel | 0 | 0 | 0 | 0 | 0 | 0 |
| **Combined heat & power production** | **0** | **1** | **3** | **5** | **5** | **5** |
| Coal | 0 | 0 | 0 | 0 | 0 | 0 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 1 | 3 | 5 | 5 | 5 |
| Oil | 0 | 0 | 0 | 0 | 0 | 0 |
| **$CO_2$ emissions power generation (incl. CHP public)** | **221** | **243** | **219** | **157** | **63** | **13** |
| Coal | 220 | 238 | 208 | 141 | 49 | 0 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 3 | 8 | 13 | 13 | 12 |
| Oil & diesel | 1 | 2 | 3 | 3 | 1 | 1 |
| **$CO_2$ emissions by sector** | **349** | **377** | **346** | **259** | **127** | **44** |
| % of 1990 emissions | 124% | 134% | 123% | 92% | 45% | 15% |
| Industry | 37 | 39 | 38 | 29 | 18 | 11 |
| Other sectors | 29 | 30 | 28 | 24 | 15 | 7 |
| Transport | 47 | 55 | 55 | 47 | 32 | 17 |
| Power generation (incl. CHP public) | 221 | 242 | 215 | 152 | 58 | 8 |
| Other conversion | 14 | 12 | 10 | 8 | 5 | 2 |
| Population (Mill.) | 49.2 | 52 | 53 | 55 | 56 | 57 |
| **$CO_2$ emissions per capita (t/capita)** | **7.1** | **7.3** | **6.6** | **4.7** | **2.3** | **0.8** |

## table 11.16: south africa: installed capacity

| GW | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Power plants** | **41** | **51** | **69** | **89** | **108** | **119** |
| Coal | 38 | 40 | 37 | 28 | 14 | 0 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 0.9 | 2.0 | 3.0 | 5.9 | 10 |
| Oil | 1.0 | 2.2 | 1.7 | 1.6 | 0.8 | 0.3 |
| Diesel | 0 | 0 | 0 | 0 | 0 | 0 |
| Nuclear | 1.9 | 1.9 | 1.9 | 0 | 0 | 0 |
| Biomass | 0.05 | 0.6 | 0.6 | 0.5 | 0.5 | 0.4 |
| Hydro | 0.7 | 1.1 | 2.1 | 2.9 | 3.4 | 3.9 |
| Wind | 0.02 | 2.7 | 9.7 | 20 | 26 | 27 |
| PV | 0.01 | 1.0 | 9.5 | 20 | 30 | 40 |
| Geothermal | 0 | 0.03 | 0.1 | 0.1 | 0.4 | 0.5 |
| Solar thermal power plants | 0 | 0.5 | 4.2 | 14 | 27 | 35 |
| Ocean energy | 0 | 0 | 0 | 0.2 | 0.6 | 1.1 |
| **Combined heat & power production** | **0** | **0.9** | **2.3** | **4.1** | **6.6** | **8.1** |
| Coal | 0 | 0 | 0 | 0 | 0 | 0 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 0.9 | 1.8 | 1.8 | 1.9 | 2.1 |
| Oil | 0 | 0 | 0 | 0 | 0 | 0 |
| Biomass | 0 | 0.03 | 0.5 | 1.8 | 3.9 | 5.0 |
| Geothermal | 0 | 0 | 0.1 | 0.4 | 0.8 | 1.0 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 0 |
| *CHP by producer* | | | | | | |
| Main activity producers | 0 | 0 | 0 | 0 | 0 | 0 |
| Autoproducers | 0 | 0.9 | 2.3 | 4.1 | 6.6 | 8.1 |
| **Total generation** | **41** | **52** | **71** | **93** | **114** | **127** |
| Fossil | 39 | 44 | 43 | 34 | 22 | 13 |
| Coal | 38 | 40 | 37 | 28 | 14 | 0 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 1.7 | 3.8 | 4.8 | 7.8 | 12 |
| Oil | 1.0 | 2.2 | 1.7 | 1.6 | 0.8 | 0.3 |
| Diesel | 0 | 0 | 0 | 0 | 0 | 0 |
| Nuclear | 1.9 | 1.9 | 1.9 | 0 | 0 | 0 |
| Hydrogen | 0 | 0 | 0 | 0 | 0 | 0 |
| **Renewables** | **0.7** | **6.0** | **27** | **59** | **92** | **114** |
| Hydro | 0.7 | 1.1 | 2.1 | 2.9 | 3.4 | 3.9 |
| Wind | 0.02 | 2.7 | 9.7 | 20 | 26 | 27 |
| PV | 0.01 | 1.0 | 9.5 | 20 | 30 | 40 |
| Biomass | 0.05 | 0.6 | 1.1 | 2.3 | 4.4 | 5.4 |
| Geothermal | 0 | 0.04 | 0.2 | 0.5 | 1.2 | 1.5 |
| Solar thermal | 0 | 0.5 | 4.2 | 14 | 27 | 35 |
| Ocean energy | 0 | 0 | 0 | 0.2 | 0.6 | 1.1 |
| Fluctuating RES (PV, Wind, Ocean) | 0.03 | 3.7 | 19.2 | 40 | 56 | 68 |
| Share of fluctuating RES | 0.1% | 7.1% | 26.9% | 42.8% | 49.3% | 53.5% |
| **RES share** | **1.8%** | **11.5%** | **37.6%** | **63.4%** | **80.6%** | **90.0%** |

## table 11.17: south africa: primary energy demand

| PJ/a | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Total** | **5,602** | **6,008** | **5,938** | **5,450** | **4,635** | **4,023** |
| **Fossil** | **4,922** | **5,214** | **4,883** | **3,913** | **2,248** | **1,122** |
| Hard coal | 3,927 | 4,011 | 3,600 | 2,733 | 1,344 | 503 |
| Lignite | 0 | 0 | 0 | 0 | 0 | 0 |
| Natural gas | 0 | 79 | 166 | 237 | 265 | 271 |
| Crude oil | 995 | 1,124 | 1,117 | 944 | 640 | 348 |
| **Nuclear** | **124** | **145** | **145** | **0** | **0** | **0** |
| **Renewables** | **557** | **648** | **910** | **1,537** | **2,386** | **2,902** |
| Hydro | 3 | 5 | 11 | 14 | 18 | 22 |
| Wind | 0 | 16 | 63 | 143 | 209 | 245 |
| Solar | 1 | 25 | 188 | 608 | 1,213 | 1,627 |
| Biomass | 552 | 593 | 614 | 667 | 736 | 727 |
| Geothermal | 0 | 9 | 34 | 103 | 203 | 266 |
| Ocean Energy | 0 | 0 | 0 | 2 | 7 | 14 |
| **RES share** | **10.8%** | **11.7%** | **15.3%** | **28.9%** | **52.1%** | **72.5%** |
| **'Efficiency' savings (compared to Ref.)** | **0** | **170** | **524** | **1,786** | **3,155** | **4,151** |

## table 11.18: south africa: final energy demand

| PJ/a | 2007 | 2015 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| **Total (incl. non-energy use)** | **2,722** | **3,065** | **3,222** | **3,383** | **3,385** | **3,346** |
| **Total (energy use)** | **2,617** | **2,932** | **3,081** | **3,232** | **3,225** | **3,177** |
| **Transport** | **669** | **782** | **812** | **793** | **729** | **642** |
| Oil products | 656 | 759 | 762 | 650 | 443 | 230 |
| Natural gas | 0 | 0 | 0 | 0 | 0 | 0 |
| Biofuels | 0 | 4 | 15 | 31 | 41 | 45 |
| Electricity | 13 | 19 | 35 | 111 | 233 | 343 |
| *RES electricity* | 0 | 1 | 7 | 55 | 186 | 322 |
| Hydrogen | 0 | 0 | 0 | 1 | 12 | 25 |
| **RES share Transport** | **0.0%** | **0.6%** | **2.6%** | **10.8%** | **32.4%** | **60.8%** |
| **Industry** | **955** | **1,051** | **1,119** | **1,214** | **1,248** | **1,250** |
| Electricity | 422 | 486 | 527 | 598 | 618 | 628 |
| *RES electricity* | 2 | 21 | 103 | 294 | 492 | 591 |
| District heat | 0 | 15 | 47 | 95 | 150 | 170 |
| *RES district heat* | 0 | 1 | 15 | 55 | 109 | 128 |
| Coal | 291 | 283 | 245 | 145 | 41 | 2 |
| Oil products | 38 | 35 | 32 | 28 | 16 | 3 |
| Gas | 131 | 152 | 158 | 155 | 136 | 92 |
| Solar | 0 | 2 | 24 | 83 | 152 | 177 |
| Biomass and waste | 73 | 76 | 80 | 90 | 97 | 107 |
| Geothermal | 0 | 2 | 6 | 20 | 35 | 49 |
| Hydrogen | 0 | 0 | 0 | 0 | 3 | 22 |
| **RES share Industry** | **7.8%** | **9.7%** | **20.4%** | **44.6%** | **71.1%** | **85.7%** |
| **Other Sectors** | **992** | **1,099** | **1,150** | **1,226** | **1,248** | **1,285** |
| Electricity | 314 | 381 | 433 | 513 | 549 | 581 |
| *RES electricity* | 1 | 17 | 84 | 252 | 437 | 546 |
| District heat | 0 | 0 | 0 | 0 | 0 | 0 |
| *RES district heat* | 0 | 0 | 0 | 0 | 0 | 0 |
| Coal | 225 | 237 | 216 | 177 | 99 | 29 |
| Oil products | 102 | 102 | 95 | 72 | 42 | 11 |
| Gas | 1 | 5 | 17 | 34 | 46 | 58 |
| Solar | 1 | 10 | 26 | 68 | 143 | 236 |
| Biomass and waste | 350 | 363 | 360 | 355 | 352 | 337 |
| Geothermal | 0 | 1 | 2 | 7 | 18 | 33 |
| **RES share Other Sectors** | **35.5%** | **35.5%** | **41.2%** | **55.6%** | **76.1%** | **89.6%** |
| **Total RES** | **427** | **498** | **723** | **1,309** | **2,073** | **2,613** |
| **RES share** | **16.3%** | **17.0%** | **23.5%** | **40.5%** | **64.3%** | **82.3%** |
| **Non energy use** | **106** | **133** | **141** | **150** | **160** | **169** |
| Oil | 52 | 66 | 70 | 75 | 79 | 84 |
| Gas | 0 | 0 | 0 | 0 | 0 | 0 |
| Coal | 53 | 67 | 71 | 76 | 81 | 85 |

# south africa: total new investment by technology

## table 11.19: south africa: total investment

| MILLION $ | 2007-2010 | 2011-2020 | 2021-2030 | 2031-2040 | 2041-2050 | 2007-2050 | 2007-2050 AVERAGE PER YEAR |
|---|---|---|---|---|---|---|---|
| **Reference scenario** | | | | | | | |
| **Conventional (fossil & nuclear)** | **14,981** | **25,392** | **35,833** | **19,075** | **14,171** | **109,453** | **2,545** |
| **Renewables** | **1,231** | **13,980** | **19,189** | **17,876** | **22,166** | **74,442** | **1,731** |
| Biomass | 312 | 484 | 257 | 454 | 51 | 1,558 | 36 |
| Hydro | 195 | 1,102 | 480 | 401 | 165 | 2,343 | 54 |
| Wind | 686 | 3,330 | 6,626 | 5,697 | 8,140 | 24,478 | 569 |
| PV | 20 | 5,078 | 8,175 | 7,355 | 9,246 | 29,875 | 695 |
| Geothermal | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Solar thermal power plants | 0 | 3,391 | 2,879 | 3,132 | 3,698 | 13,100 | 305 |
| Ocean energy | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Energy [R]evolution** | | | | | | | |
| **Conventional (fossil & nuclear)** | **14,981** | **18,302** | **3,786** | **9,168** | **3,902** | **50,140** | **1,166** |
| **Renewables** | **1,231** | **35,521** | **63,503** | **67,651** | **100,450** | **268,356** | **6,241** |
| Biomass | 312 | 3,004 | 4,048 | 6,400 | 6,880 | 20,644 | 480 |
| Hydro | 195 | 2,629 | 2,641 | 2,436 | 1,495 | 9,395 | 218 |
| Wind | 686 | 7,694 | 12,396 | 12,467 | 14,477 | 47,721 | 1,110 |
| PV | 20 | 3,332 | 8,192 | 5,740 | 7,335 | 24,619 | 573 |
| Geothermal | 0 | 1,940 | 2,788 | 3,658 | 4,556 | 12,943 | 301 |
| Solar thermal power plants | 0 | 15,297 | 32,813 | 34,468 | 64,403 | 146,981 | 3,418 |
| Ocean energy | 0 | 23 | 366 | 257 | 1,059 | 1,706 | 40 |
| **Advanced Energy [R]evolution** | | | | | | | |
| **Conventional (fossil & nuclear)** | **14,981** | **13,444** | **1,407** | **6,176** | **3,471** | **39,478** | **918** |
| **Renewables** | **1,231** | **65,571** | **78,797** | **109,839** | **112,444** | **367,883** | **8,555** |
| Biomass | 312 | 3,250 | 4,746 | 9,196 | 6,889 | 24,393 | 567 |
| Hydro | 195 | 4,712 | 2,641 | 2,359 | 1,380 | 11,286 | 262 |
| Wind | 686 | 10,915 | 11,490 | 15,715 | 12,018 | 50,824 | 1,182 |
| PV | 20 | 20,782 | 13,649 | 16,972 | 15,443 | 66,865 | 1,555 |
| Geothermal | 0 | 1,940 | 2,829 | 4,883 | 4,714 | 14,367 | 334 |
| Solar thermal power plants | 0 | 22,471 | 42,989 | 58,465 | 70,708 | 194,632 | 4,526 |
| Ocean energy | 0 | 23 | 366 | 818 | 1,046 | 2,253 | 52 |

# notes

# notes

# notes


## GREENPEACE

Greenpeace is a global organisation that uses non-violent direct action to tackle the most crucial threats to our planet's biodiversity and environment. Greenpeace is a non-profit organisation, present in 40 countries across Europe, the Americas, Africa, Asia and the Pacific. It speaks for 2.8 million supporters worldwide, and inspires many millions more to take action every day. To maintain its independence, Greenpeace does not accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants.

Greenpeace has been campaigning against environmental degradation since 1971 when a small boat of volunteers and journalists sailed into Amchitka, an area west of Alaska, where the US Government was conducting underground nuclear tests. This tradition of 'bearing witness' in a non-violent manner continues today, and ships are an important part of all its campaign work.

**greenpeace africa**
10A and 10B Clamart Road, Clamart House
Richmond, Johannesburg
South Africa 2092
t +27 (0)11 482 4696 f +27 (0 11 482 8157
iafrica@greenpeace.org
**www.greenpeace.org/africa/en/**

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

EREC is composed of the following non-profit associations and federations: AEBIOM (European Biomass Association); EGEC (European Geothermal Energy Council); EPIA (European Photovoltaic Industry Association); ESHA (European Small Hydro power Association); ESTIF (European Solar Thermal Industry Federation); EUBIA (European Biomass Industry Association); EWEA (European Wind Energy Association); EUREC Agency (European Association of Renewable Energy Research Centers); EREF (European Renewable Energies Federation); EU-OEA (European Ocean Energy Association); ESTELA (European Solar Thermal Electricity Association).

**EREC European Renewable Energy Council**
Renewable Energy House, 63-67 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 MELTING ON A BERG ON THE GREENLANDIC COAST. GREENPEACE AND AN INDEPENDENT NASA-FUNDED SCIENTIST COMPLETED MEASUREMENTS OF MELT LAKES ON THE GREENLAND ICE SHEET THAT SHOW ITS VULNERABILITY TO WARMING TEMPERATURES. **front cover images** BRIGHT BLUE-GREEN WATER FLOWS INTO THE OLIFANTS RIVER. THE WATER CONTAINS A MIXTURE OF ACID MINE DRAINAGE FROM LOCAL COAL MINES AND SEWAGE FROM THE LOCAL MUNICIPALITY'S DYSFUNCTIONAL SEWAGE WORKS. © G WILLIAMS/PANOS/GREENPEACE. WIND TURBINES IN SOUTH AFRICA© DANIE NEL/DREAMSTIME.COM. WAVES IN SOUTH AFRICA © KAZ2/DREAMSTIME.COM