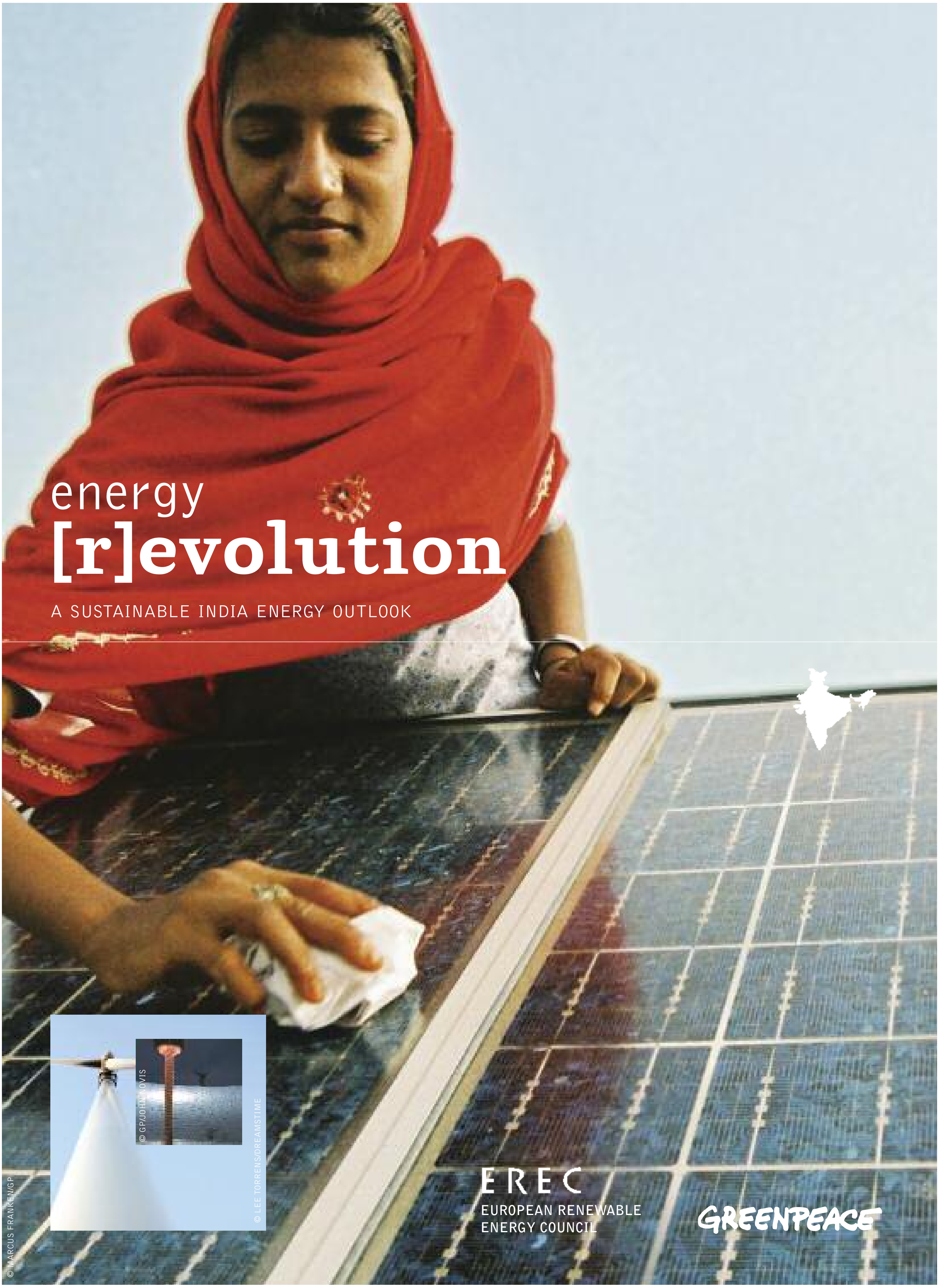


energy [r]evolution

A SUSTAINABLE INDIA ENERGY OUTLOOK

EREC
EUROPEAN RENEWABLE ENERGY COUNCIL

GREENPEACE

report national energy scenario

foreword

Of all the sectors of a modern economic system, the one that appears to be getting the maximum attention currently is the energy sector. While the volatility in oil prices certainly requires some temporary measures to tide over the problem of increasing costs of oil consumption particularly for oil importing countries, there are several reasons why the focus must now shift towards longer term solutions. First and foremost, of course, are the growing uncertainties related to oil imports both in respect of quantities and prices, but there are several other factors that require a totally new approach to planning energy supply and consumption in the future. Perhaps, the most crucial of these considerations is the threat of global climate change which has been caused overwhelmingly in recent decades by human actions that have resulted in the build up of greenhouse gases (GHGs) in the Earth's atmosphere.

"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?"**

contents

image CHECKING THE SOLAR PANELS ON TOP OF THE GREENPEACE POSITIVE ENERGY TRUCK IN BRAZIL.
cover image A WOMAN CLEANS SOLAR PANELS AT THE BAREFOOT COLLEGE IN TILONIA, RAJASTHAN, INDIA.

Impacts of climate change are diverse and serious, and unless the emissions of GHGs are effectively mitigated these would threaten to become far more serious over time. There is now, therefore, a renewed interest in renewable sources of energy, because by creating and using low carbon substitutes to fossil fuels, we may be able to reduce emissions of GHGs significantly while at the same time ensuring economic growth and development and the enhancement of human welfare across the world. As it happens, there are major disparities in the levels of consumption of energy across the world, with some countries using large quantities per capita and others being deprived of any sources of modern energy forms. Solutions in the future would, therefore, also have to come to grips with the reality of lack of access to modern forms of energy for hundreds of millions of people. For instance, there are 1.6 billion people in the world who have no access to electricity. Households, in which these people reside, therefore, lack a single electric bulb for lighting purposes, and whatever substitutes they use provide inadequate lighting and environmental pollution, since these include inefficient lighting devices using various types of oil or the burning of candles.

Future policies can be guided by the consideration of different scenarios that can be linked to specific developments. This publication advocates the need for something in the nature of an energy revolution. This is a view that is now shared by several people across the world, and it is also expected that energy plans would be based on a clear assessment of specific scenarios related to clearly identified policy initiatives and technological developments. This edition of Energy [R]evolution Scenarios provides a detailed analysis of the energy efficiency potential and choices in the transport sector. The material presented in this publication provides a useful basis for considering specific policies and developments that would be of value not only to the world but for different countries as they attempt to meet the global challenge confronting them. The work carried out in the following pages is comprehensive and rigorous, and even those who may not agree with the analysis presented would, perhaps, benefit from a deep study of the underlying assumptions that are linked with specific energy scenarios for the future.

Dr. R. K. Pachauri

DIRECTOR-GENERAL, THE ENERGY AND RESOURCES INSTITUTE (TERI) AND CHAIRMAN, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)

OCTOBER 2008

Greenpeace International, European Renewable Energy Council (EREC)

date December 2008. **EREC** Oliver Schäfer, Arthouros Zervos. **Greenpeace India** Vinuta Gopal, Srinivas Krishnaswamy. **Greenpeace International** Sven Teske, Project Manager. **authors** Sven Teske, Vinuta Gopal, Srinivas Krishnaswamy. **editor** Crispin Aubrey. **research** DLR, Institute of Technical Thermodynamics, Department of Systems Analysis and Technology Assessment, Stuttgart, Germany: Dr. Wolfram Krewitt, Dr. Sonja Simon, Dr. Thomas Pregger. Ecofys BV, Utrecht, The Netherlands: Wina Graus, Eliane Blomen. **design & layout** onehemishere, sweden, www.onehemisphere.se **contact** EREC Christine Lins, lins@erec.org Greenpeace India: Vinuta Gopal; vgopal@greenpeace.org, Srinivas Krishnaswamy; ksriniva@greenpeace.org Greenpeace International: Sven Teske; sven.teske@greenpeace.org **for further information** about the global, regional and national scenarios please visit the energy [r]evolution website: **www.energyblueprint.info/** Published by Greenpeace International.

introduction

"NOW IS THE TIME TO COMMIT TO A TRULY SECURE AND SUSTAINABLE ENERGY FUTURE – A FUTURE BUILT ON CLEAN TECHNOLOGIES, ECONOMIC DEVELOPMENT AND THE CREATION OF MILLIONS OF NEW JOBS."

image WORKERS EXAMINE PARABOLIC TROUGH COLLECTORS IN THE PS10 CONCENTRATING SOLAR TOWER PLANT IN SEVILLA, SPAIN. EACH PARABOLIC TROUGH HAS A LENGTH OF 150 METERS AND CONCENTRATES SOLAR RADIATION INTO A HEAT-ABSORBING PIPE INSIDE WHICH A HEAT-BEARING FLUID FLOWS. THE HEATED FLUID IS THEN USED TO HEAT STEAM IN A STANDARD TURBINE GENERATOR.

Energy supply has become a subject of major universal concern. Volatile oil and gas prices, threats to a secure and stable supply and not least climate change have all pushed it high up the international agenda. In order to avoid dangerous climate change, global CO_2 emissions must peak no later than 2015 and rapidly decrease after that. The technology to do this is available. The renewables industry is ready for take off and opinion polls show that the majority of people support this move. There are no real technical obstacles in the way of an Energy [R]evolution, all that is missing is political support. But we have no time to waste. To achieve an emissions peak by 2015 and a net reduction afterwards, we need to start rebuilding the energy sector now.

There is now irrefutable scientific opinion that climate change is happening, is caused in large part by human activities (such as burning fossil fuels), and if left unchecked will have disastrous consequences. Furthermore, there is solid scientific evidence that we should act now. This is reflected in the conclusions, published in 2007, of the Intergovernmental Panel on Climate Change (IPCC), a UN institution of more than 1,000 scientists providing advice to policy makers.

The effects of climate change have in fact already begun. In 2008, the melting of the Arctic ice sheet almost matched the record set on September 16, 2007. The fact that this has now happened two years in a row reinforces the strong decreasing trend in the amount of summertime ice observed over the past 30 years. The Himalayan Glaciers are melting at an alarming rate and this poses a threat to the river systems in the country, including the iconic Ganges.

"renewable energy, combined with the smart use of energy, can deliver half of the world's energy needs by 2050."

image ICEBERG MELTING ON GREENLAND'S COAST.

In response to this threat, the Kyoto Protocol has committed its signatories to reduce their greenhouse gas emissions by 5.2% from their 1990 levels by 2008-2012. The Kyoto signatories are currently negotiating the second phase of the agreement, covering the (preliminary) period from 2013-2017. Time is quickly running out. Signatory countries agreed a negotiating 'mandate', known as the Bali Action Plan, which they must complete with a final agreement on the second Kyoto commitment period by the end of 2009. By choosing renewable energy and energy efficiency, developing countries can virtually stabilise their CO_2 emissions, whilst at the same time increasing energy consumption through economic growth. Industrialised countries, on the other hand, will have to reduce their emissions domestically by at least 30% by 2020 and up to 80% by 2050. The Energy [R]evolution concept provides a practical blueprint on how to put this into practice.

Renewable energy, combined with the smart use of energy, can deliver at least half of the world's energy needs by 2050. This report, 'Energy [R]evolution: A Sustainable India Energy Outlook', shows that it is economically beneficial to reduce future Indian CO_2 emissions from fossil fuels so as to maintain India's emissions at current levels within the next 42 years. It also concludes that a massive uptake of renewable energy sources is technically and economically possible. Wind power alone could produce about 90 times more power than it does today, and total Indian renewable energy generation share could more than triple by then.

renewed energy [r]evolution

This is the second edition of the Energy [R]evolution. Since we published the first edition in January 2007, we have experienced an overwhelming wave of support from governments, the renewables industry and non-governmental organisations. Since than we have broken down the global regional scenarios into country specific plans for Canada, the USA, Brazil, the European Community, Japan, South East Asia, Australia and India among many others.

More and more countries are seeing the environmental and economic benefits provided by renewable energy. The Brent crude oil price was at $55 per barrel when we launched the first Energy [R]evolution report. By mid-2008 it had reached a record peak of over $140 per barrel and has subsequently fallen to around $40 and is certain to go up again. Other fuel prices have also shot up. Coal, gas and uranium have doubled or even tripled in the same timeframe. By contrast, most renewable energy sources don't need any fuel. Once installed, they deliver energy independently from the global energy markets and at predictable prices. Every day that another community switches to renewable energy is an independence day.

The Energy [R]evolution Scenario concludes that the restructuring of the global electricity sector requires an investment of $14.7 trillion up to 2030. This compares with $11.3 trillion under the Reference Scenario based on International Energy Agency projections. While the average annual investment required to implement the Energy [R]evolution Scenario would need just under 1% of global GDP, it would lower fuel costs by 25% - saving an annual amount in the range of $750 billion.

In fact, the additional costs for coal power generation alone from today up to 2030 under the Reference Scenario could be as high as $15.9 trillion: this would cover the entire investment needed in renewable and cogeneration capacity to implement the Energy [R]evolution Scenario. These renewable sources will produce energy without any further fuel costs beyond 2030, while the costs for coal and gas will continue to be a burden on national and global economies.

global energy scenario

The European Renewable Energy Council (EREC) and Greenpeace International have produced this global energy scenario as a practical blueprint for how to urgently meet CO_2 reduction targets and secure an affordable energy supply on the basis of steady worldwide economic development. Both of these goals are possible at the same time. The urgent need for change in the energy sector means that this scenario is based only on proven and sustainable technologies, such as renewable energy sources and efficient decentralised cogeneration. It therefore excludes so-called 'CO_2-free coal power plants', which are not in fact CO_2 free and would create another burden in trying to store the gas under the surface of the Earth with unknown consequences. For multiple safety and environmental reasons, nuclear energy is also excluded.

Commissioned from the Department of Systems Analysis and Technology Assessment (Institute of Technical Thermodynamics) at the German Aerospace Centre (DLR), the report develops a global sustainable energy pathway up to 2050. The future potential for renewable energy sources has been assessed with input from all sectors of the renewables industry around the world. The new Energy [R]evolution Scenario also takes a closer look for the first time at the transport sector, including future technologies and how to implement energy efficiency.

The energy supply scenarios adopted in this report, which extend beyond and enhance projections made by the International Energy Agency, have been calculated using the MESAP/PlaNet simulation model. The demand side projection has been developed by the Ecofys consultancy to take into account the future potential for energy efficiency measures. This study envisages an ambitious development pathway for the exploitation of energy efficiency potential, focused on current best practice as well as technologies available in the future. The result is that under the Energy [R]evolution Scenario, worldwide final energy demand can be reduced by 38% in 2050 compared to the Reference Scenario.

image THE PS10 CONCENTRATING SOLAR TOWER PLANT IN SEVILLA, SPAIN, USES 624 LARGE MOVABLE MIRRORS CALLED HELIOSTATS. THE MIRRORS CONCENTRATE THE SUN'S RAYS TO THE TOP OF A 115 METER (377 FOOT) HIGH TOWER WHERE A SOLAR RECEIVER AND A STEAM TURBINE ARE LOCATED. THE TURBINE DRIVES A GENERATOR, PRODUCING ELECTRICITY.

the potential for renewable energy

The good news is that the global market for renewables is booming. Decades of technical progress have seen renewable energy technologies such as wind turbines, solar photovoltaic panels, biomass power plants, solar thermal collectors and many others move steadily into the mainstream. The global market for renewable energy is growing dramatically; in 2007 its turnover was over $70 billion, almost twice as high as the previous year. The time window for making the shift from fossil fuels to renewable energy, however, is still relatively short. Within the next decade many of the existing power plants in the OECD countries will come to the end of their technical lifetime and will need to be replaced. But a decision taken to construct a coal or gas power plant today will result in the production of CO_2 emissions and dependency on the resource and its future costs lasting until 2050.

The power industry and utilities need to take more responsibility because today's investment decisions will define the energy supply of the next generation. We strongly believe that this should be the 'solar generation'. Politicians from the industrialised world urgently need to rethink their energy strategy, while the developing world should learn from past mistakes and build economies on the strong foundations of a sustainable energy supply.

Renewable energy could more than double its share of the world's energy supply - reaching at least 30% by 2030. All that is lacking is the political will to promote its large scale deployment in all sectors at a global level, coupled with far reaching energy efficiency measures. By 2030 about half of global electricity could come from renewable energies.

The future of renewable energy development will strongly depend on political choices made by both individual governments and the international community. At the same time strict technical standards will ensure that only the most efficient fridges, heating systems, computers and vehicles will be on sale. Consumers have a right to buy products that don't increase their energy bills and won't destroy the climate.

In this report we have also expanded the time horizon for the Energy [R]evolution concept beyond 2050, to see when we could phase out fossil fuels entirely. Once the pathway of this scenario has been implemented, renewable energy could provide all global energy needs by 2090. A more radical scenario – which takes the advanced projections of the renewables industry into account – could even phase out coal by 2050. Dangerous climate change might force us to accelerate the development of renewables faster. We believe that this would be possible, but to achieve it more resources must go into research and development. Climate change and scarcity of fossil fuel resources puts our world as we know it at risk; we must start to think the unthinkable. To tap into the fast potential for renewables and to phase out fossil fuels as soon as possible are amongst the most pressing tasks for the next generation of engineers and scientists.

implementing the energy [r]evolution

Business as usual is not an option for future generations. The Reference Scenario based on the IEA's 'World Energy Outlook 2007' projection would almost double global CO_2 emissions by 2050 and the climate would heat up by well over 2°C. This would have catastrophic consequences for the environment, the economy and human society. In addition, it is worth remembering that the former chief economist of the World Bank, Sir Nicholas Stern, pointed out clearly in his landmark report that the countries which invest in energy saving technologies and renewable energies today will be the economic winners of tomorrow.

As Stern emphasised, inaction will be much more expensive in the long run. We therefore call on all decision makers yet again to make this vision a reality. The world cannot afford to stick to the 'business as usual' energy development path: relying on fossil fuels, nuclear energy and other outdated technologies. Renewable energy can and will play a leading role in our collective energy future. For the sake of a sound environment, political stability and thriving economies, now is the time to commit to a truly secure and sustainable energy future – a future built on clean technologies, economic development and the creation of millions of new jobs.

Arthouros Zervos
EUROPEAN RENEWABLE ENERGY COUNCIL (EREC)
MARCH 2009

K Srinivas
POLITICAL & BUSINESS UNIT
GREENPEACE INDIA

Sven Teske
CLIMATE & ENERGY UNIT
GREENPEACE INTERNATIONAL

"by 2030 about 35% of India's electricity could come from renewable energies."

executive summary

"AN AVERAGE GLOBAL WARMING OF 2°C THREATENS MILLIONS OF PEOPLE WITH AN INCREASED RISK OF HUNGER, MALARIA, FLOODING AND WATER SHORTAGES. IF RISING TEMPERATURES ARE TO BE KEPT WITHIN ACCEPTABLE LIMITS THEN WE NEED TO SIGNIFICANTLY REDUCE OUR GREENHOUSE GAS EMISSIONS."

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

climate threats and climate solutions

Global climate change caused by the relentless build-up of greenhouse gases in the Earth's atmosphere is already disrupting ecosystems, resulting in about 150,000 additional deaths each year. An average global warming of 2°C threatens millions of people with an increased risk of hunger, malaria, flooding and water shortages. If rising temperatures are 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 large increases in the price of oil, the issue of security of supply is now at the top of the energy policy agenda. One reason for these price increases is the fact that supplies of all fossil fuels – oil, gas and coal – are becoming scarcer and more expensive to produce. 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, photovoltaic, 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 sources for their 'fuel'. Some of these technologies are already competitive. Their economics will further improve as they develop technically, as the price of fossil fuels continues to rise and as their saving of carbon dioxide emissions is given a monetary value.

image IN 2005 THE WORST DROUGHT IN MORE THAN 40 YEARS DAMAGED THE WORLD'S LARGEST RAIN FOREST IN THE BRAZILIAN AMAZON, WITH WILDFIRES BREAKING OUT, POLLUTED DRINKING WATER AND THE DEATH OF MILLIONS FISH AS STREAMS DRY UP.

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

Although nuclear power produces little CO_2, there are multiple threats to people and the environment from its operations. These include the risks and environmental damage from uranium mining, processing and transport, the risk of nuclear weapons proliferation, the unsolved problem of nuclear waste and the potential hazard of a serious accident. The nuclear option is therefore discounted in this analysis. The solution to our future energy needs lies instead in greater use of renewable energy sources for both heat and power.

the energy [r]evolution

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

the five key principles behind this shift will be to:

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

Decentralised energy systems, where power and heat are produced close to the point of final use, avoid the current waste of energy during conversion and distribution. They will be central to the Energy [R]evolution, as will the need to provide electricity to the two billion people around the world to whom access is presently denied.

Two scenarios up to the year 2050 are outlined in this report. The Reference Scenario is based on the Reference Scenario published by the International Energy Agency in World Energy Outlook 2007, extrapolated forward from 2030. Compared to the 2004 IEA projections, World Energy Outlook 2007 (WEO 2007) assumes a slightly higher average annual growth rate of world Gross Domestic Product (GDP) of 3.6%, instead of 3.2%, over the period 2005-2030. At the same time, WEO 2007 expects final energy consumption in 2030 to be 4% higher than in WEO 2004.

India and China are expected to grow faster than other regions, followed by the Developing Asia group of countries, Africa and the Transition Economies (mainly the former Soviet Union). The OECD share of global purchasing power parity (PPP) adjusted GDP will decrease from 55% in 2005 to 29% by 2050.

The Energy [R]evolution Scenario has a target for worldwide carbon dioxide emissions to be reduced by 50% below 1990 levels by 2050, with per capita emissions reduced to less than 1.3 tonnes per year. This is necessary if the increase in global temperature is to remain below 2°C. A second objective is the global phasing out of nuclear energy. To achieve these targets, the scenario is characterised by significant efforts to fully exploit the large potential for energy efficiency. At the same time, all cost-effective renewable energy sources are accessed for both heat and electricity generation, as well as the production of sustainable bio fuels.

the energy [r]evolution india

Today, renewable energy sources account for 31% of the India's primary energy demand. Biomass, which is mostly used in the heat sector, is the main renewable energy source. The share of renewable energies for electricity generation is 15,5%. The contribution of renewables to heat supply is around 63%, to a large extent accounted for by traditional uses such as collected firewood. About 68% of the primary energy supply today still comes from fossil fuels. The Energy [R]evolution Scenario describes a development pathway which turns the present situation into a sustainable energy supply through the following measures:

- Exploitation of the existing large energy efficiency potentials will ensure that primary energy demand grows much slower despite a very high GDP growth of 10% per year assumed in the Energy [R]evolution Scenario for India. The demand under this economic development pathgway will increase from the current 22,344 PJ/a (2005) to 62,577PJ/a in 2050, compared to 109,698 PJ/a in the Reference Scenario. Efficiency is a crucial prerequisite for achieving a significant share of renewable energy sources in the overall energy supply system, for compensating the phasing out of nuclear energy and for reducing the consumption of fossil fuels.
- The increased use of combined heating/cooling and power generation (CHP) also improves the supply system's energy conversion efficiency, increasingly using natural gas and biomass.
- The electricity sector will be the pioneer of renewable energy utilisation. By 2050, around 69%of electricity will be produced from renewable energy sources (including only existing large hydro). A capacity of 1,659 GW will produce 3,860 TWh/a renewable electricity in 2050.
- In the heating/cooling supply sector, the contribution of renewables will increase to 70% by 2050. Fossil fuels will be increasingly replaced by more efficient modern technologies, in particular biomass, solar collectors and geothermal.
- Before sustainable bio fuels are introduced in the transport sector, the existing large efficiency potentials have to be exploited. As biomass is mainly committed to stationary applications, the production of bio fuels 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.
- By 2050, 54% of primary energy demand will be covered by renewable energy sources.

image VILLAGER ANIL CHANDRA DAS IS ON THE AREA WHERE HIS HOUSE USED TO STAND ON GHORAMARA ISLAND. TODAY, DURING HIGH TIDES HIS FORMER HOME IS SUBMERGED DUE TO RISING SEA LEVELS.

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

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

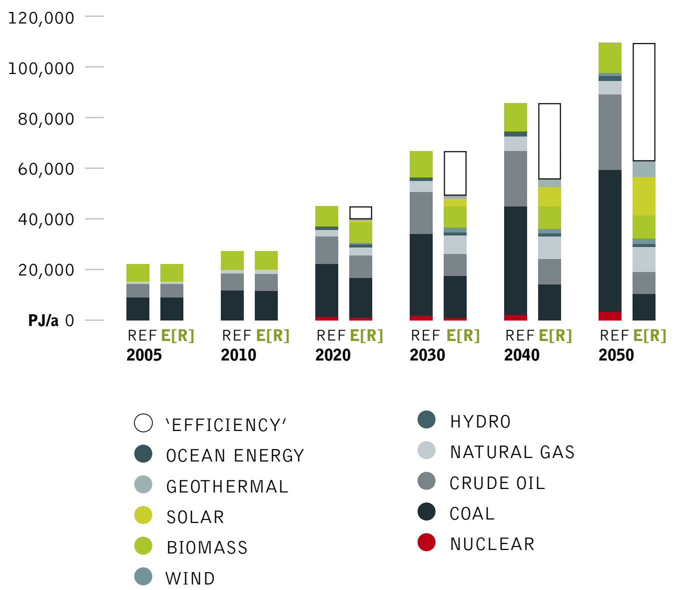
costs

The electricity generation costs (compared to conventional fuels) under the Energy [R]evolution Scenario are lower from 2010 onwards due to independence from (world market) fossil fuels prices. By 2050, the specific elkectricity generation costs are 5 cents/kWh under those of the reference scenario. Assuming average costs of 3 cents/kWh for implementing energy efficiency measures, the additional cost for electricity supply under the Reference Scenario will amount to a maximum of $462 billion/a in 2050. The energy [R]evolution Scenario shows, that the society's investment in an environmentally benign, safe and economic energy supply pay of. By 2050 the annual costs of electricity supply will be $462 billion/a below those in the Reference Scenario.

It is assumed that average crude oil prices will increase from $52.5 per barrel in 2005 to $100 per barrel in 2010, and continue to rise to $140 per barrel in 2050. Natural gas import prices are expected to increase by a factor of four between 2005 and 2050, while coal prices will nearly double, reaching $360 per tonne in 2050. A CO_2 'price adder' is applied, which rises from $10 per tonne of CO_2 in 2010 to $50 per tonne of in 2050.

figure 0.1: india: development of primary energy consumption under the two scenarios

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



development of CO_2 emissions from fossil fuels

While CO_2 emissions in India will increase by factor seven under the Reference Scenario up to 2050, and is thus far removed from a sustainable development path, under the Energy [R]evolution Scenario they will increase from 1,074 million tonnes in 2005 to 1,689 m/t in 2050, with a peak of 2,235 m/t in 2030. Annual per capita emissions will remain on roughly the same level, from 0.9 tonnes/capita to 1.0 t/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. 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 42% of total emissions in 2050, the power sector will reduce significantly but remain the largest source of CO_2 emissions - followed by industry and transport.

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

1. Phase out all subsidies and other measures that encourage inefficient energy use and support fossil fuel use and nuclear power production.
2. Set stringent and ever-improving efficiency and emissions standards for appliances, buildings, power plants and vehicles.
3. Establish legally defined targets for renewable energy and combined heat and power generation.
4. Reform of the electricity market to allow better integration of renewable energy technologies on the market.
5. Provide stable return for investors through fixed price mechanisms for renewable energy.
6. Develop and implement market transformation policies that overcome current barriers and other market failures to reduce energy demand.
7. Support innovation in energy efficiency, low-carbon transport systems, and renewable energy production.

climate protection

1

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

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

© GP/ROBERT KNOTH

international energy policy

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

At a time when governments around the world are in the process of liberalising their electricity markets, the increasing competitiveness of renewable energy should lead to higher demand. Without political support, however, renewable energy remains at a disadvantage, marginalised by distortions in the world's electricity markets created by decades of massive financial, political and structural support to conventional technologies. Developing renewables will therefore require strong political and economic efforts, especially through laws that guarantee stable tariffs over a period of up to 20 years. Renewable energy will also contribute to sustainable economic growth, high quality jobs, technology development, global competitiveness and industrial and research leadership.

renewable energy targets

In recent years, in order to reduce greenhouse emissions as well as increase energy security, a growing number of countries have established targets for renewable energy. These are either expressed in terms of installed capacity or as a percentage of energy consumption. These targets have served as important catalysts for increasing the share of renewable energy throughout the world.

A time period of just a few years is not long enough in the electricity sector, however, where the investment horizon can be up to 40 years. Renewable energy targets therefore need to have short, medium and long term steps and must be legally binding in order to be effective. They should also be supported by mechanisms such as feed-in tariffs for renewable electricity generation. In order for the proportion of renewable energy to increase significantly, targets must be set in accordance with the local potential for each technology (wind, solar, biomass etc) and be complemented by policies that develop the skills and manufacturing bases to deliver the agreed quantity of renewable energy.

In recent years the wind and solar power industries have shown that it is possible to maintain a growth rate of 30 to 35% in the renewables sector. In conjunction with the European Photovoltaic Industry Association[1], the European Solar Thermal Power Industry Association[2] and the Global Wind Energy Council[3], the European Renewable Energy Council and Greenpeace have documented the development of those industries from 1990 onwards and outlined a prognosis for growth up to 2020 and 2040.

demands for the energy sector

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

1. Phase out all subsidies and other measures that encourage inefficient energy use and support fossil fuel use and nuclear power production.
2. Set stringent and ever-improving efficiency and emissions standards for appliances, buildings, power plants and vehicles.
3. Establish legally defined targets for renewable energy and combined heat and power generation.
4. Reform of the electricity market to allow better integration of renewable energy technologies on the market.
5. Provide stable return for investors through fixed price mechanisms for renewable energy.
6. Develop and implement market transformation policies that overcome current barriers and other market failures to reduce energy demand.
7. Support innovation in energy efficiency, low-carbon transport systems, and renewable energy production.

Conventional energy sources receive an estimated $250-300 billion[4] in subsidies per year worldwide, resulting in heavily distorted markets. Subsidies artificially reduce the price of power, keep renewable energy out of the market place and prop up non-competitive technologies and fuels. Eliminating direct and indirect subsidies to fossil fuels and nuclear power would help move us towards a level playing field across the energy sector. Renewable energy would not need special provisions if markets factored in the cost of climate damage from greenhouse gas pollution. Subsidies to polluting technologies are perverse in that they are economically as well as environmentally detrimental. Removing subsidies from conventional electricity would not only save taxpayers' money. It would also dramatically reduce the need for renewable energy support.

references
1 SOLAR GENERATION, SEPTEMBER 2007
2 CONCENTRATED SOLAR POWER –NOW! NOVEMBER 2005
3 GLOBAL WIND ENERGY OUTLOOK, OCTOBER 2008
4 'WORLD ENERGY ASSESSMENT: ENERGY AND THE CHALLENGE OF SUSTAINABILITY', UNITED NATIONS DEVELOPMENT PROGRAMME, 2000

image OFF SHORE WINDFARM, MIDDELGRUNDEN, COPENHAGEN, DENMARK.

© LANGROCK/ZENIT/GP

india's energy policy

India has gone through immense changes in its institutional structure with relation to power. In 1991, India broke away from the 'license raj' regime and entered a phase of liberalization of its economy. Under this, erstwhile Ministry of energy was bifurcated into ministry of power, ministry of coal and ministry of new and renewable energy. These three ministries look after the entire energy policy of India.

Electricity in India is a concurrent subject at entry 38 in list III of the 7th schedule of the constitution of India. This implies that both the Union and the States have power to legislate on matters relating to electricity.

Post liberalization, government sector entities still dominate electricity sector in India, while in some cities distribution has been handed over to private sector companies but generation and transmission are still controlled primarily by public sector.

power generation and transmission companies

The main actor in the field of power generation is The National Thermal Power Corporation (NTPC limited). It is the largest power generation company of India. NTPC currently accounts for about 20% of the country's total installed capacity. In addition to NTPC there are other public sector undertakings like National Hydroelectric Power Corporation, Nuclear Power Corporation Limited which operate power plants in India. There are also power plants operated and owned by various state governments which fulfill the demand for electricity in India. Private companies are allowed captive generation and in the Electricity Act 2003 the government has made liberal provisions for power trading with these private companies at times of deficit in generation.

Power Grid Corporation of India Limited handles one of the largest transmission utilities in the world. POWERGRID wheels about 45% of the total power generated in the country on its transmission networks. While currently India does not have a unified National grid, the government under POWERGRID is trying to integrate regional grids into a unified national grid.

power distribution

Power Distribution in India is handled by various statutory bodies called State Electricity Boards (SEBs) under Electricity Supply Act of 1948, each state has its own board. Power distribution is one area where the government is trying to bring immediate reforms. Due to huge Transmission & Distribution losses, the government has come out with Accelerated Power Development and Reform Programme (APDRP) in 2003. With the Ministry of Power heading the reforms 29 states have signed the Memorandum of Understandings with the Ministry to take various steps in order to undertake distribution reforms in a time bound manner.

other actors in the electricity sector

One of the most important institutions determining energy policy is the Planning Commission. To deal with various aspects of reforms in the energy sector, Planning Commission has come out with a policy prescription called Integrated Energy Policy 2006 which envisions a road map for sustainable growth and energy security over a reasonable amount of time. The policy seeks to make energy markets more competitive, have market-determined energy pricing and resource allocation, transparent and targeted subsidy disbursal and improved efficiency.

The Ministry of Power has also initiated steps towards efficiency by establishing a regulatory body called Bureau of Energy Efficiency (BEE) which would assist in developing policies and strategies with thrust on self regulation and market principles within the framework of Energy Conservation Act 2001. The main objective of BEE is to reduce energy intensity of the Indian economy.

Along with Ministry of Power, Ministry of Coal and Ministry of Oil and Natural Gas, The Ministry of New and Renewable Energy is the nodal ministry for all matters relating to new and renewable energy. The ministry was established in 1992 with the aim to build energy self sufficiency for India.

legal framework

The Electricity Act 2003 was a landmark piece of legislature which was to bring every thing related to electricity under one umbrella. It was an act to consolidate the laws relating to generation, transmission, distribution, trading and use of electricity and generally for taking measures conducive to development of electricity industry, promoting competition therein protecting interest of consumers and supply of electricity to all areas, rationalization of electricity tariff, ensuring transparent policies regarding subsidies, constituting the constitution of central electricity authority, regulatory commission, and an appellate tribunal.

Post implementation of the electricity act 2003, various arms of the government have been established such as the Central Electricity Regulatory Commission which looks at reviewing tariffs which state regulatory commissions keep as a benchmark. The electricity act has also changed procurement policies for trading power along with coming out with a more integrated rural electrification policy. These reforms also brought about a National Electricity Policy 2005 and a National Electricity Plan for improving delivery and access to electricity.

tariff policy

The Electricity Regulatory Commission Act 1999 mandates the formation of State Electricity Regulatory Commissions by each state. The SERC will have the ultimate power in deciding tariffs within a state. This is an attempt to eliminate political whims in tariff fixation. Power tariffs in India are characterized by zero to nominal agricultural tariffs, low domestic tariffs, reasonable to high industrial tariffs, high commercial tariffs and very high railway tariffs. Central Electricity Regulatory Commission handles the tariff policy for India and comes out with tariff notifications which are updated periodically. In 2006 the Ministry of Power came out with a Tariff Policy in continuation with the National Electricity Policy 2005. The objectives of this tariff policy were to:

a. Ensure availability of electricity to consumers at reasonable and competitive rates.

b. Ensure financial viability of the sector and attract investments.

c. Promote transparency, consistency and predictability in regulatory approaches across jurisdictions and minimize perceptions of regulatory risks.

d. Promote competition, efficiency in operations and improvement in quality of supply.

policy promoting renewable energy sources

Renewable energy gained significance in India with growing concern for 'energy security'. Energy self sufficiency has been identified as the major driver for renewable energy in India with great importance being given to the two oil shocks and the rising insecurity in relation to fluctuating oil prices.

India does not have any integrated renewable energy policy but within various other policies relating to electrification some incentives for renewable energy have been given.

- Within the electricity act 2003, it requires each State regulatory commission to specify the minimum percentage of electricity that each distribution utility must source from renewable energy sources.
- The National Electricity Policy 2005 stipulates that progressively the share of electricity from non-conventional sources would need to be increased; such purchase by distribution companies shall be through competitive bidding process; considering the fact that it will take some time before non-conventional technologies compete, in terms of cost, with conventional sources, the commission may determine an appropriate deferential in prices to promote these technologies.
- Under the National Rural electrification policy also For villages/habitations where grid connectivity would not be feasible or not cost effective, off-grid solutions based on stand-alone systems may be taken up for supply of electricity. Where these also are not feasible and if only alternative is to use isolated lighting technologies like solar photovoltaic, these may be adopted.
- Various states give financial subsidies on renewable energy utilities like PV, home lighting systems, solar water heater etc. The ministry of new and renewable energy also gives various incentives to individuals for installing various such utilities.

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

rural electrification

Rural Electrification is one of the top priorities of the government of India. In April 2005 Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) was launched. Under the programme 90% grant is provided by Govt. of India and 10% as loan by Rural Electrification Corporation Limited to the State Governments for electrification of villages. Under this scheme the government is trying to fulfill the commitment of 'electricity for all by 2012', 18 lakh houses (Below poverty line) have already been electrified. RGGVY also envisions using renewable energy to meet the electricity requirements of remote villages which cannot be connected to the grid because of their geographic isolation.

civilian nuclear energy programme

Nuclear Energy currently forms only 3% of India's installed electricity generation capacity. However, post the Indian – US nuclear deal and the waiver that the Nuclear Suppliers Group (NSG) granted India in 2008, the country came out of 34 years of nuclear isolation and is planning to embark on an ambitious nuclear energy program. The Government plans to rewrite the Integrated Energy Policy to reflect these ambitions. Statements from various high level officials from the Indian government place the expectations at about 60,000 MW by 2030 and 20,000MW by 2020. The government is even working on amending the Atomic Energy Act of 1962 to enable private participation in the civil nuclear programme that the Act had originally barred.

clean development mechanism

India signed and ratified the Kyoto Protocol in August 2002. Responsibility as the Designated National Authority (DNA) has been assumed by Ministry of Environment and Forests. As such, it acts among other things as the final approving authority in a four stage process that has been set up at the national level to access and approve CDM Projects. India has 28.20% of total registered projects (392 projects). India has generated 58,089,377 CERs aggregating to about 23.05% of the total CERs generated. The greatest potential for CDM projects is considered to be in the field of renewable energy sources, in particular, in use of hydro power, wind power, and biomass.

The composition of the NCDMA is such that it has representations from foreign secretary, finance secretary, ministry of new of renewable energy, ministry of power, planning commission. The composition of the DNA gives it an informed and complete outlook for taking decisions on prospective CDM projects.

references

MINISTRY OF POWER – WWW.POWERMIN.NIC.IN
NTPC – WWW.NTPC.CO.IN
POWER GRID - WWW.POWERGRIDINDIA.COM
BEE - WWW.BEE-INDIA.NIC.IN
MINISTRY OF NEW AND RENEWABLE ENERGY – WWW. MNES.NIC.IN
CERC - WWW.CERCIND.GOV.IN
CDM – WWW. CDMINDIA.NIC.IN
RURAL ELECTRIFICATION CORPORATION –WWW.RECINDIA.NIC.IN
RGGVY- WWW.RGGVY.GOV.IN
ECONOMIC TIMES 26 DEC 2008 – ELECTRICITY FOR ALL 2012

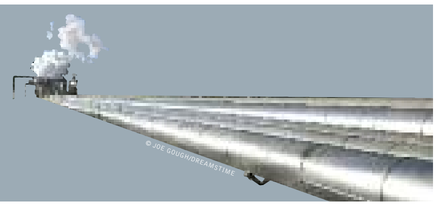
2

implementing the energy [r]evolution

2

"bridging the gap."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN



This chapter outlines a Greenpeace proposal for a feed-in tariff system in developing countries like India which would provide the financing to enable massive renewable energy uptake. The scheme provides for a mechanism where the additional costs of renewable energies are financed by a combination of new sectoral emissions trading mechanisms and direct finance from technology funds to be developed in the Copenhagen climate deal.

The Energy [R]evolution Scenario shows that renewable electricity generation has huge environmental and economic benefits. However RE investment and hence total generation costs, especially in developing countries, remains higher than those of existing coal or gas-fired power stations and is likely to remain so for the next five to ten years. To bridge this investment and cost gap between conventional fossil fuel-based power generation and renewables, a support mechanism is required. The Feed in Tariff Support Mechanism (FTSM) is a concept conceived by Greenpeace International.[5] The aim is the expansion of renewable energy in developing countries with financial support from industrialised nations. It is a mechanism that would allow for rapid deployment of renewable energy technologies via a new sectoral no-lose mechanism or through a Technology Transfer fund under the UNFCCC.

With countries currently negotiating the second phase of the Kyoto agreement, covering the period from 2013-2017 it provides developing countries the opportunity to propose such a mechanism through the new sectoral no-lose mechanisms that are being discussed. Emission units could be generated for sale from a sectoral no-lose mechanism in a developing country's power sector and proceeds used to fund the additional costs of the Feed in Tariff system in that country. For some countries a directly funded Feed in Tariff Support Mechanism may be more appropriate than a sectoral no-lose mechanism.

need for bankable renewable energy support schemes

Since the early development of renewable energies within the power sector, there has been an ongoing debate about the best and most effective type of support scheme to boost the uptake of RE. The European Commission published a survey in December 2005 which provided a good overview of the experience and according to this report, feed-in tariffs were by far the most efficient and successful mechanism. Globally more than 40 countries have adopted some version of this system.

Although the modalities employed to implement these tariffs differs from country to country, there are certain clear criteria which emerge as essential for creating a successful renewable energy policy. At the heart of these is a reliable, bankable support scheme for renewable energy projects which provides long term stability and certainty.[6] Bankable support schemes result in lowering the cost of the projects because they lower the risk for both investors and equipment suppliers. For example, the cost of wind-powered electricity in Germany is up to 40% cheaper than in the United Kingdom,[7] because the support system is more secure and reliable.

For developing countries, feed-in laws would be an ideal mechanism for the implementation of new renewable energies. In order to enable technology transfer from Annex 1 countries to developing countries, a mix of a feed-in law, international finance and emissions trading could be used to establish a locally based renewable energy infrastructure and industry with the assistance of OECD countries. This would succeed in removing the price barrier that is one of the major stumbling blocks in ensuring massive RE uptake.

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

- Clear, bankable pricing system.
- Priority access to the grid with clear identification of who's responsible for what in terms of interconnection and transition, and how it is incentivised.
- Clear, simple administrative and planning permission procedures.
- Public acceptance/support.

The first is fundamentally important, but it won't help if you don't have the other 3.

learning from experience

The FTSM program brings together three different support mechanisms and builds on the experience from 20 years of renewable energy support programmes.

experience of feed in tariffs

- Feed-in tariffs are seen as the best way forward and very popular, especially in developing countries.
- The main argument against them is the increase in electricity prices for households and industry, as the extra costs are shared across all customers. This is particularly difficult for developing countries, where many people can't afford to spend more money for electricity services.

references
5 IMPLEMENTING THE ENERGY [R]EVOLUTION, OCTOBER 2008, SVEN TESKE, GREENPEACE INTERNATIONAL
6 'THE SUPPORT OF ELECTRICITY FROM RENEWABLE ENERGY SOURCES', EUROPEAN COMMISSION, 2005
7 SEE ABOVE REPORT, P. 27, FIGURE 4

image GREENPEACE INSTALLED 40 PHOTOVOLTAIC SOLAR PANELS THAT MUST SUPPLY 30% TO 60% OF THE DAILY DEMAND OF ELECTRICITY IN THE GREENPEACE OFFICE IN SAO PAULO. THE PANELS ARE CONNECTED TO THE NATIONAL ENERGY GRID, WHICH IS NOT ALLOWED BY LAW IN BRAZIL. ONLY ABOUT 20 SYSTEMS OF THIS TYPE EXIST IN BRAZIL AS THEY REQUIRE A SPECIAL LICENSE TO FUNCTION.

image PLANT NEAR REYKJAVIK WHERE ENERGY IS PRODUCED FROM THE GEOTHERMAL ACTIVITY.

experience of international financing

Finance for renewable energy projects is one of the main obstacles in developing countries. While large scale projects have fewer funding problems, small, community based projects, whilst having a high degree of public acceptance, face financing difficulties. The experiences from micro credits for small hydro projects in Bangladesh, for example, as well as wind farms in Denmark and Germany, show how strong local participation and acceptance can be achieved. The main reasons for this are the economic benefits flowing to the local community and careful project planning based on good local knowledge and understanding. When the community identifies the project rather than the project identifying the community, the result is generally faster bottom-up growth of the renewables sector.

feed in tariff support mechanism

The basic aims of the Feed in Tariff Support Mechanism are to facilitate the implementation of feed-in laws for developing countries by providing additional financial resources to a scale appropriate to the circumstances of each developing country. For countries with higher levels of capacity the creation of a new sectoral no-lose mechanism that can generate emission reduction units for sale to Annex I counties, with the proceeds being used to offset part of the additional cost of the Feed in Tariff system could be appropriate. For other countries a more directly funded approach to paying for the additional costs to consumers of the Feed in Tariff system would be appropriate.

The aim of the Feed in Tariff Support Mechanism would be to provide bankable and long term stable support for the development of a local renewable energy market in developing countries. The tariffs should bridge the gap between conventional power generation costs and those of renewable energy generation.

the key parameters for feed in tariffs under FTSM are:

- Variable tariffs for different renewable energy technologies, depending on their costs and technology maturity, paid for 20 years.
- Payments based on actual generation in order to achieve properly maintained projects with high performance ratios.
- Payment of the 'additional costs' for renewable generation will be based on the Spanish system of the wholesale electricity price plus a fixed premium.

A developing country which wants to take part in the FTSM would need to establish clear regulations for the following:

- Guaranteed access to the electricity grid for renewable electricity projects.
- Establishment of a feed-in law based on successful examples.
- Transparent access to all data needed to establish the feed-in tariff, including full records of generated electricity.
- Clear planning and licensing procedures.

Funding could come through the connection of the FTSM to the international emission trading system via new no-lose sectoral trading mechanisms to be developed in the Copenhagen Agreement. The Energy [R]evolution scenario shows that the average additional costs (under the proposed energy mix) between 2008 and 2015 are between 1 and 4 $cents per kilowatt-hour so the cost per tonne of CO_2 avoided would be between $10 and $40, indicating that emission reduction units generated under a no-lose mechanism designed to support FTSM would be competitive in the post 2012 carbon market.

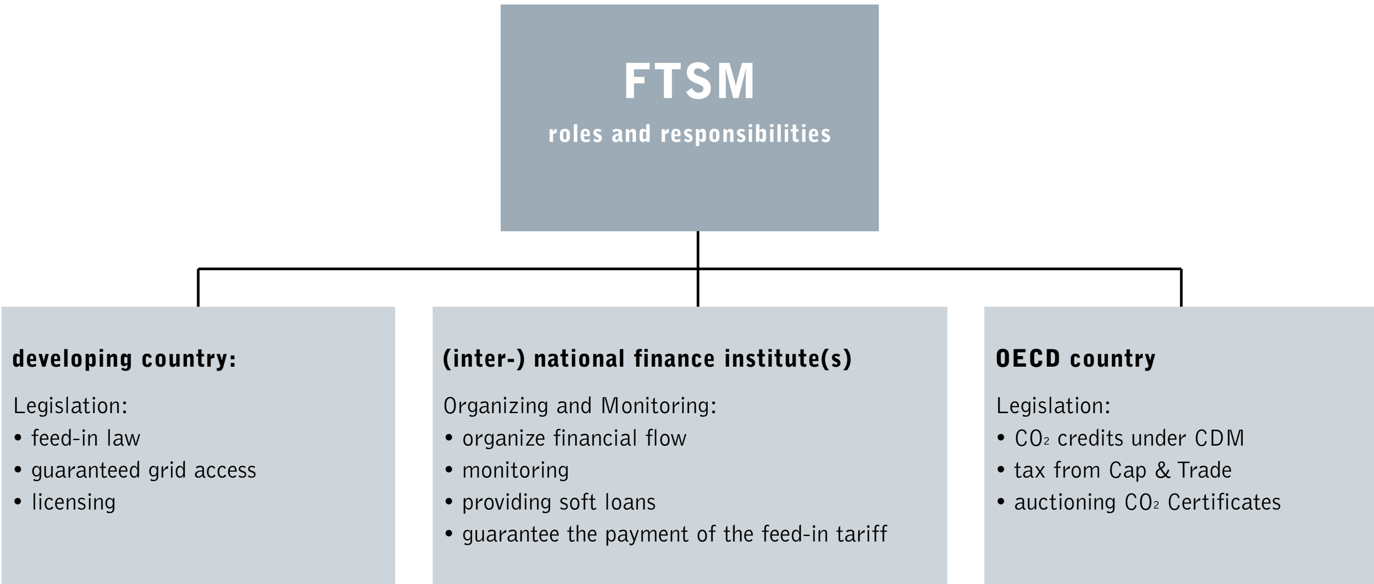
The design of the FTSM would need to ensure that there were stable flows of funds to the renewable energy suppliers and hence there may need to be a buffer between fluctuating CO_2 emissions prices and stable long term feed-in tariffs. The FTSM will need to secure the payment of the required feed-in tariffs during the whole period (about 20 years) for each project.

All renewable energy projects must have a clear set of environmental criteria which are part of the national licensing procedure in the country where the project will generate electricity. Those criteria will have to meet a minimum environmental standard defined by an independent monitoring group. If there are already acceptable criteria developed, for example for CDM projects, they should be adopted rather than reinventing the wheel. The board members will come from NGOs, energy and finance experts as well as members of the governments involved. The fund will not be able to use the money for speculative investments. It can only provide soft loans for FTSM projects.

the key parameters for the FTSM fund will be:

- The fund will guarantee the payment of the total feed-in tariffs over a period of 20 years if the project is operated properly.
- The fund will receive annual income from emissions trading or from direct funding.
- The fund will pay feed-in tariffs annually only on the basis of generated electricity.
- Every FTSM project must have a professional maintenance company to ensure high availability.
- The grid operator must do its own monitoring and send generation data to the FTSM fund. Data from the project and grid operators will be compared regularly to check consistency.

figure 2.1: ftsm scheme



financing the energy [r]evolution for india with a ftsm program

Based on the Energy [R]evolution Scenario for India, the following calculation for a FTSM program has been done with the following assumptions:

table 2.1: assumptions for the calculation for a ftsm in india

KEY PARAMETER	CONVENTIONAL POWER GENERATION COSTS (ct/kWh)	AVERAGE FEED-IN TARIFF EXCL. SOLAR PV (ct/kWh)	AVERAGE FEED-IN TARIFF FOR SOLAR PV (ct/kWh)	SPECIFIC CO_2 REDUCTION PER KWH (gCO_2/kWh)
2010	5	12	32	1,015
2020	10	11	20	1,015
2030	10	10	10	1,015

power generation costs

The average feed-in tariffs – excluding solar – have been calculated on the basis of the assumption, that the majority of renewable energy sources require feed-in tariffs between 7 to 15 $cents per kilowatt-hour. While wind- and bio energy power generation will need feed-in tariffs below 10 $cents per kWh, other technologies such as geothermal and concentrated solar power will need slightly higher tariffs. In case the FTSM will be implemented in India, exact tariffs should be calculated on the basis of specific market prices in India. The feed-in tariff for solar photovoltaic reflects current market price projection. The average conventional power generation costs are based on new coal and gas power plants without direct or indirect subsidies.

specific CO_2 reduction per kwh

The assumed specific CO_2 reduction per kWh is crucial for the result of specific CO_2 costs per tonne. In India the current specific CO_2 emission is 1,160 gCO2/kWh and will go down to 878 gCO_2/kWh by 2030 (see Reference scenario, page 50). Therefore the average specific CO_2 emission is 1,015 gCO_2/kWh.

financial parameters

With the beginning of the financial crisis in mid 2008, it became clear that inflation rates and capital costs can change very fast. The cost calculation of this program does not include any interest rates, capital costs or inflation rates, and all cost parameters are nominal and on the basis of 2009 level.

key results

The FTSM program would cover 18,800 TWh new renewable electricity generation and save 1.9 Gt CO_2 between 2010 and 2030. With an average CO_2 price of 13.5 dollar per ton the total program would cost $195 billion or $9.3 billion annually.

The FTSM will bridge the gap between now and 2030 when specific electricity generation costs for all renewable energy technologies are projected to be lower than conventional power generation such as coal and gas power plants. However this case study has calculated even lower generation costs for conventional power generation than we have assumed in our price projections for the Energy [R]evolution Scenario (see Chapter 5, page 35, table 5.4.) as we excluded CO_2 emission costs. In this case coal power plants would have generation costs of 10.8 $cents/kWh by 2020 and 12.5 $cents/kWh by 2030, the FTSM assumed costs of 10 $cents/kWh by 2020 and 2030 for new coal power plants.

image ICE AND WATER IN THE NORTH POLE. GREENPEACE EXPLORERS, LONNIE DUPRE AND ERIC LARSEN MAKE HISTORY AS THEY BECOME THE FIRST-EVER TO COMPLETE A TREK TO THE NORTH POLE IN SUMMER. THE DUO UNDERTAKE THE EXPEDITION TO BRING ATTENTION TO THE PLIGHT OF THE POLAR BEAR WHICH SCIENTISTS CLAIM COULD BE EXTINCT AS EARLY AS 2050 DUE TO THE EFFECTS OF GLOBAL WARMING.

The FTSM program is divided into 2 periods of 10 years. While the annual costs for the first period is of $8.6 billion per year and $10 billion per year for the second period, the annual costs are among the same order of magnitude. As the difference between renewable and coal electricity generation is projected to decrease, more renewable electricity can be financed with roughly the same amount of money.

figure 2.2: feed-in tariffs versus conventional power generation

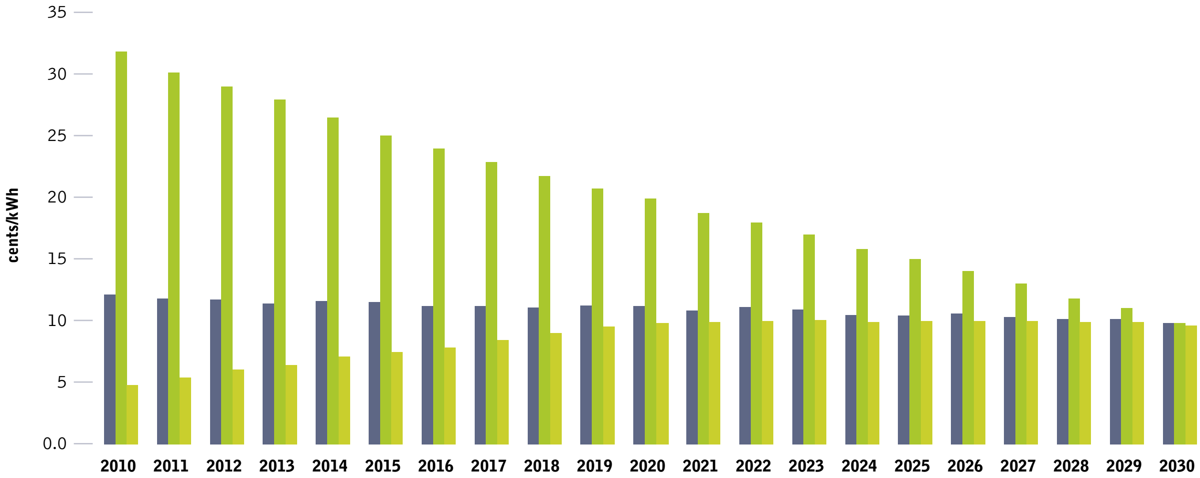


table 2.2: ftsm program

KEY RESULTS INDIA	YEAR	TOTAL RENEWABLE ELECTRICITY GENERATION UNDER FTSM PROGRAM (TWh)	AVERAGE ANNUAL CO_2 EMISSION CREDITS (MILLION T CO_2)	TOTAL CO_2 CERTIFICATES PER PERIOD (MILLION T CO_2)	AVERAGE CO_2 COST PER TON ($/T$CO_2$)	TOTAL ANNUAL COSTS (BILLION $)	TOTAL COSTS PER PERIOD (BILLION $)
Period 1	2010-2019	4,327	439.2	4,392	19.5	8.6	85.6
Period 2	2020-2030	14,491	1,337.2	14,709	7.5	10.0	109.8
Period 1+2	2010-2030	18,818	888.2	19,101	13.5	9.3	195

table 2.3: renewable power for india under ftsm program

ELECTRICITY GENERATION (TWh/a)	2005	2010	2015	2020	2030
Wind	6.2	25.5	65.0	169.5	350.0
PV	0	0.3	3.0	13.0	165.0
Biomass	1.9	4.1	18.0	39.0	95.0
Geothermal	0	0	0.2	9.0	30.0
Solar Thermal	0	0	1.2	10.1	135.0
Ocean Energy	0	0	0.4	4.2	9.0
Total - new RE	**8.1**	**29.9**	**87.8**	**244.8**	**784.0**

INSTALLED CAPACITY (GW)	2005	2010	2015	2020	2030
Wind	4	12	29	69	143
PV	0	0	2	10	118
Biomass	0	1	4	8	19
Geothermal	0	0	0	2	6
Solar Thermal	0	0	0.5	3	23
Ocean Energy	0	0	0	1	3
Total - new RE	**4**	**13**	**35**	**92**	**310**

the energy [r]evolution

3

"half the solution to climate change is the smart use of power."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

The climate change imperative demands nothing short of an energy revolution. The expert consensus is that this fundamental change must begin very soon and be well underway within the next ten years in order to avert the worst impacts. What we need is a complete transformation in the way we produce, consume and distribute energy and at the same time maintain economic growth. Nothing short of such a revolution will enable us to limit global warming to far less than a rise in temperature of 2°C, 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.

key principles

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

1. **respect natural limits – phase out fossil fuels by the end of this century** We must learn to respect natural limits. There is only so much carbon that the atmosphere can absorb. Each year we emit over 25 billion tonnes of CO_2; 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 Energy [R]evolution Scenario has a target to reduce energy related CO_2 emissions to a maximum of 10 Gt (Giga tonnes) by 2050 and phase out fossil fuels by 2085.

2. **equity and fairness** It is imperative to have a fair distribution of benefits and costs within societies. At one extreme, a third of the world's population has no access to electricity, whilst the most industrialised countries consume much more than their fair share.

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

   The 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 fully decouple from fossil fuels. It is a fallacy to suggest that economic growth must be predicated on their increased combustion.

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

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.

image SEVEN YEAR OLD RAHUL SARKAR, SITS ON A TREE STUMP NEAR HIS HOME ON VIJAYNAR ISLAND. RAHUL'S ISLAND HOME IS UNDER SEVERE THREAT BY RISING SEA LEVELS THAT HAVE ALREADY FORCED RAHUL'S FAMILY TO MOVE 3 TIMES SINCE HE WAS BORN.

© PETER CATON

from principles to practice

In 2005, renewable energy sources accounted for 13% of the world's primary energy demand. Biomass, which is mostly used for heating, is the main renewable energy source. The share of renewable energy in electricity generation was 18%. 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.[8]

The time is right to make substantial structural changes in the energy and power sector within the next decade. Many power plants in industrialised countries, such as the USA, Japan and the European Union, are nearing retirement; more than half of all operating power plants are over 20 years old. At the same time developing countries, such as China, India and Brazil, are looking to satisfy the growing energy demand created by expanding economies.

Within the next ten years, the power sector will decide how this new demand will be met, either by fossil and nuclear fuels or by the efficient use of renewable energy. The Energy [R]evolution Scenario is based on a new political framework in favour of renewable energy and cogeneration combined with energy efficiency.

To make this happen both renewable energy and 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 plant, 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 to achieve emissions reductions.

a development pathway

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

step 1: energy efficiency The Energy [R]evolution is aimed at the ambitious exploitation of the potential for energy efficiency. It focuses on current best practice and technologies which 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 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 IEA's "Reference Scenario" (see Chapter 6) – 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: structural changes

decentralised energy and large scale renewables In order to achieve higher fuel efficiencies and reduce distribution losses, the Energy [R]evolution Scenario makes extensive use of Decentralised Energy (DE).This is energy generated at or near the point of use.

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

DE also includes stand-alone systems entirely separate from the public networks, 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, decreasing demand for heat and the large potential for producing heat directly from renewable energy sources will limit the further expansion of CHP.

references

8 'ENERGY BALANCE OF NON-OECD COUNTRIES' AND 'ENERGY BALANCE OF OECD COUNTRIES', IEA, 2007

renewable electricity The electricity sector will be the pioneer of renewable energy utilisation. All renewable electricity technologies have been experiencing steady growth over the past 20 to 30 years of up to 35% annually and are expected to consolidate at a high level between 2030 and 2050. By 2050, the majority of electricity will be produced from renewable energy sources. Expected 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.

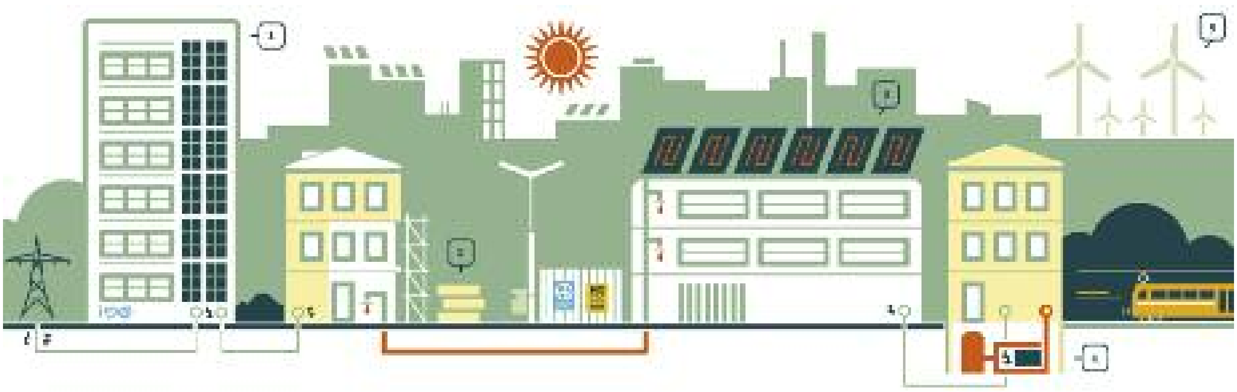
transport Before new technologies such as hybrid or electric cars or new fuels such as bio fuels can play a substantial role in the transport sector, the existing large efficiency potentials have to be exploited. In this study, biomass is primarily committed to stationary applications; the use of bio fuels for transport is limited by the availability of sustainably grown biomass.[9] Electric vehicles will therefore play an even more important role in improving energy efficiency in transport and substituting for fossil fuels.

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

figure 3.1: 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

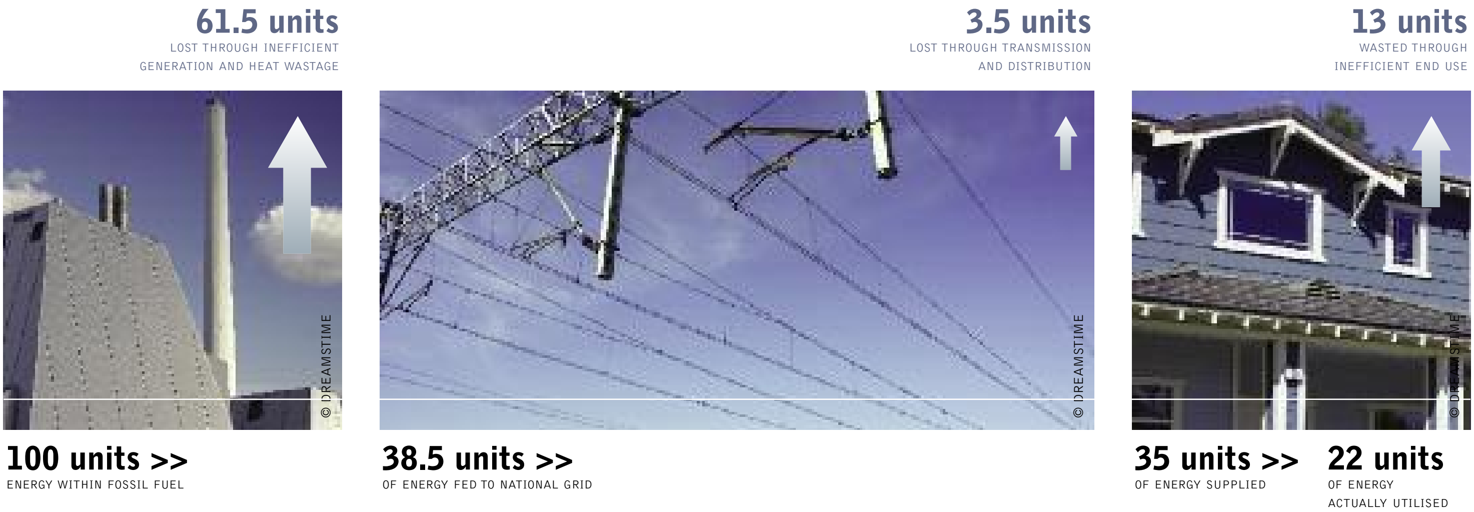


1. **PHOTOVOLTAIC, SOLAR FAÇADES** WILL BE A DECORATIVE ELEMENT ON OFFICE AND APARTMENT BUILDINGS. PHOTOVOLTAIC SYSTEMS WILL BECOME MORE COMPETITIVE AND IMPROVED DESIGN WILL ENABLE ARCHITECTS TO USE THEM MORE WIDELY.
2. **RENOVATION CAN CUT ENERGY CONSUMPTION OF OLD BUILDINGS** BY AS MUCH AS 80% - WITH 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
9 SEE CHAPTER 4

image A COW INFRONT 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.

figure 3.2: **centralised energy infrastructures waste more than two thirds of their energy**



optimised integration of renewable energy

Modification of the energy system will be necessary to accommodate the significantly higher shares of renewable energy expected under the Energy [R]evolution Scenario. This is not unlike what happened in the 1970s and 1980s, when most of the centralised power plants now operating were constructed in OECD countries. New high voltage power lines were built, night storage heaters marketed and large electric-powered hot water boilers installed in order to sell the electricity produced by nuclear and coal-fired plants at night.

Several OECD countries have demonstrated that it is possible to smoothly integrate a large proportion of decentralised energy, including variable sources such as wind. A good example is Denmark, which has the highest percentage of combined heat and power generation and wind power in Europe. With strong political support, 50% of electricity and 80% of district heat is now supplied by cogeneration plants. The contribution of wind power has reached more than 18% of Danish electricity demand. At certain times, electricity generation from cogeneration and wind turbines even exceeds demand. The load compensation required for grid stability in Denmark is managed both through regulating the capacity of the few large power stations and through import and export to neighbouring countries. A three tier tariff system enables balancing of power generation from the decentralised power plants with electricity consumption on a daily basis.

It is important to optimise the energy system as a whole through intelligent management by both producers and consumers, by an appropriate mix of power stations and through new systems for storing electricity.

appropriate power station mix: The power supply in OECD countries is mostly generated by coal and – in some cases – nuclear power stations, which are difficult to regulate. Modern gas power stations, by contrast, are not only highly efficient but easier and faster to regulate and thus better able to compensate for fluctuating loads. Coal and nuclear power stations have lower fuel and operating costs but comparably high investment costs. They must therefore run round-the-clock as 'base load' in order to earn back their investment. Gas power stations have lower investment costs and are profitable even at low output, making them better suited to balancing out the variations in supply from renewable energy sources.

load management: 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. Control technology can be used to manage the arrangement. 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 load 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.

generation management: Renewable electricity generation systems can also be involved in load optimisation. Wind farms, for example, can be temporarily switched off when too much power is available on the network.

energy storage: Another method of balancing out electricity supply and demand is through intermediate storage. This storage can be decentralised, for example by the use of batteries, or centralised. So far, pumped storage hydro power stations have been the main method of storing large amounts of electric power. In a pumped storage system, energy from power generation is stored in a lake and then allowed to flow back when required, driving turbines and generating electricity. 280 such pumped storage plants exist worldwide. They already provide an important contribution to security of supply, but their operation could be better adjusted to the requirements of a future renewable energy system.

In the long term, other storage solutions are beginning to emerge. One promising solution besides the use of hydrogen is the use of compressed air. In these systems, electricity is used to compress air into deep salt domes 600 metres underground and at pressures of up to 70 bar. At peak times, when electricity demand is high, the air is allowed to flow back out of the cavern and drive a turbine. Although this system, known as CAES (Compressed Air Energy Storage) currently still requires fossil fuel auxiliary power, a so-called "adiabatic" plant is being developed which does not. To achieve this, the heat from the compressed air is intermediately stored in a giant heat store. Such a power station can achieve a storage efficiency of 70%.

The **forecasting** of renewable electricity generation is also continually improving. Regulating supply is particularly expensive when it has to be found at short notice. However, prediction techniques for wind power generation have become considerably more accurate in recent years and are still being improved. The demand for balancing supply will therefore decrease in the future.

the "virtual power station"[10]

The rapid development of information technologies is helping to pave the way for a decentralised energy supply based on cogeneration plants, renewable energy systems and conventional power stations. Manufacturers of small cogeneration plants already offer internet interfaces which enable remote control of the system. It is now possible for individual householders to control their electricity and heat usage so that expensive electricity drawn from the grid can be minimised – and the electricity demand profile is smoothed. This is part of the trend towards the 'smart house' where its mini cogeneration plant becomes an energy management centre. We can go one step further than this with a 'virtual power station'. Virtual does not mean that the power station does not produce real electricity. It refers to the fact that there is no large, spatially located power station with turbines and generators. The hub of the virtual power station is a control unit which processes data from many decentralised power stations, compares them with predictions of power demand, generation and weather conditions, retrieves the available power market prices and then intelligently optimises the overall power station activity. Some public utilities already use such systems, integrating cogeneration plants, wind farms, photovoltaic systems and other power plants. The virtual power station can also link consumers into the management process.

> "it is important to optimise the energy system as a whole through intelligent management by both producers and consumers..."

references
10 'RENEWABLE ENERGIES - INNOVATIONS FOR THE FUTURE', GERMAN MINISTRY FOR THE ENVIRONMENT, NATURE CONSERVATION AND NUCLEAR SAFETY (BMU), 2006

image GREENPEACE DONATES A SOLAR POWER SYSTEM TO A COASTAL VILLAGE IN ACEH, INDONESIA, ONE OF THE WORST HIT AREAS BY THE TSUNAMI IN DECEMBER 2004. IN COOPERATION WITH UPLINK, A LOCAL DEVELOPMENT NGO, GREENPEACE OFFERED ITS EXPERTISE ON ENERGY EFFICIENCY AND RENEWABLE ENERGY AND INSTALLED RENEWABLE ENERGY GENERATORS FOR ONE OF THE BADLY HIT VILLAGES BY THE TSUNAMI.

© GP/SIMANJUNTAK

rural electrification[11]

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.

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 $1 per day by 2015, access to affordable energy services is a prerequisite".

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.

references
11 'SUSTAINABLE ENERGY FOR POVERTY REDUCTION: AN ACTION PLAN', IT POWER/GREENPEACE INTERNATIONAL, 2002

© GP/MARKEL REDONDO

scenario principles in a nutshell

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

image THE PS10 CONCENTRATING SOLAR TOWER PLANT USES 624 LARGE MOVABLE MIRRORS CALLED HELIOSTATS. THE MIRRORS CONCENTRATE THE SUN'S RAYS TO THE TOP OF A 115 METER (377 FOOT) HIGH TOWER WHERE A SOLAR RECEIVER AND A STEAM TURBINE ARE LOCATED. THE TURBINE DRIVES A GENERATOR, PRODUCING ELECTRICITY, SEVILLA, SPAIN.

Moving from principles to action on energy supply and climate change mitigation requires a long-term perspective. Energy infrastructure takes time to build up; new energy technologies take time to develop. Policy shifts often also need many years to have an effect. Any analysis that seeks to tackle energy and environmental issues therefore needs to look ahead at least half a century.

Scenarios are important in describing possible development paths, to give decision-makers an overview of future perspectives and to indicate how far they can shape the future energy system. Two different scenarios are used here to characterise the wide range of possible paths for the future energy supply system: a Reference Scenario, reflecting a continuation of current trends and policies, and the Energy [R]evolution Scenario, which is designed to achieve a set of dedicated environmental policy targets.

The **reference scenario** is based on the Reference Scenario published by the International Energy Agency in World Energy Outlook 2007 (WEO 2007).[12] This only takes existing international energy and environmental policies into account. The assumptions include, for example, continuing progress in electricity and gas market reforms, the liberalisation of cross-border energy trade and recent policies designed to combat environmental pollution. The Reference Scenario does not include additional policies to reduce greenhouse gas emissions. As the IEA's scenario only covers a time horizon up to 2030, it has been extended by extrapolating its key macroeconomic indicators. This provides a baseline for comparison with the Energy [R]evolution Scenario.

The **energy [r]evolution scenario** has a key target for the reduction of worldwide carbon dioxide emissions down to a level of around 10 Gigatonnes per year by 2050 in order for the increase in global temperature to remain under 2°C. A second objective is the global phasing out of nuclear energy. To achieve these targets, the scenario is characterised by significant efforts to fully exploit the large potential for energy efficiency. At the same time, all cost-effective renewable energy sources are used for heat and electricity generation as well as the production of bio fuels. The general framework parameters for population and GDP growth remain unchanged from the Reference Scenario.

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

scenario background The scenarios in this report were jointly commissioned by Greenpeace and the European Renewable Energy Council from the Institute of Technical Thermodynamics, part of the German Aerospace Center (DLR). The supply scenarios were calculated using the MESAP/PlaNet simulation model used for the previous Energy [R]evolution study.[13] Energy demand projections were developed by Ecofys Netherlands, based on an analysis of the future potential for energy efficiency measures. The biomass potential, using Greenpeace sustainability criteria, has been developed especially for this scenario by the German Biomass Research Centre. The future development pathway for car technologies is based on a special report produced in 2008 by the Institute of Vehicle Concepts, DLR for Greenpeace International.

energy efficiency study

The aim of the Ecofys study was to develop a low energy demand scenario for the period 2005 to 2050 for the IEA regions as defined in the World Energy Outlook report series. Calculations were made for each decade from 2010 onwards. Energy demand was split up into electricity and fuels. The sectors which were taken into account were industry, transport and other consumers, including households and services.

Under the low energy demand scenario, worldwide final energy demand is reduced by 38% in 2050 in comparison to the Reference Scenario, resulting in a final energy demand of 350 EJ (ExaJoules). The energy savings are fairly equally distributed over the three sectors of industry, transport and other uses. The most important energy saving options are efficient passenger and freight transport and improved heat insulation and building design. Chapter 11 provides more details about this study.

"moving from principles to action.."

references
12 INTERNATIONAL ENERGY AGENCY, 'WORLD ENERGY OUTLOOK 2007', 2007
13 'ENERGY [R]EVOLUTION: A SUSTAINABLE WORLD ENERGY OUTLOOK', GREENPEACE INTERNATIONAL, 2007

energy resources & security of supply

4

"the issue of security of supply is now at the top of the energy policy agenda."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

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 sources. The regional distribution of oil and gas resources, on the other hand, 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'.[14]

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 36% 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.

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), are not subject to any sort of accountability, so their reporting practices are even less clear. In the late 1980s, OPEC countries blatantly overstated their reserves while competing for production quotas, which were allocated as a proportion of the reserves. Although some revision was needed after the companies were nationalised, between 1985 and 1990, OPEC countries increased their joint reserves by 82%. Not only were these dubious revisions never corrected, but many of these countries have reported untouched reserves for years, even if no sizeable discoveries were made and production continued at the same pace. Additionally, the Former Soviet Union's oil and gas reserves have been overestimated by about 30% because the original assessments were later misinterpreted.

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

references
14 '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

gas

Natural gas has been the fastest growing fossil energy source in the last two decades, boosted by its increasing share in the electricity generation mix. Gas is generally regarded as 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.

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 ones have been almost constant since 1980 because discoveries have roughly matched production.

coal

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

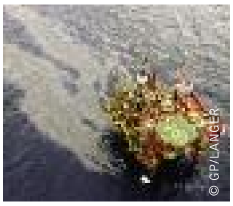
table 4.1: overview of fossil fuel reserves and resources

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

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

source SEE TABLE [a)] INCLUDING GAS HYDRATES 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.


© GP/LANGER


© N. BEHRING-CHISHOLM/GP

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 regional consumption. Five countries - Canada, Australia, Kazakhstan, Russia and Niger - control three quarters of the world's supply. As a significant user of uranium, however, Russia's reserves will be exhausted within ten years.

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

A joint report by the OECD Nuclear Energy Agency[15] and the International Atomic Energy Agency 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.


© HANSEN/DREAMSTIME

image NUCLEAR REACTOR IN LIANYUNGANG, CHINA.

references
15 'URANIUM 2003: RESOURCES, PRODUCTION AND DEMAND'

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.

definition of types of energy resource potential[16]

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.

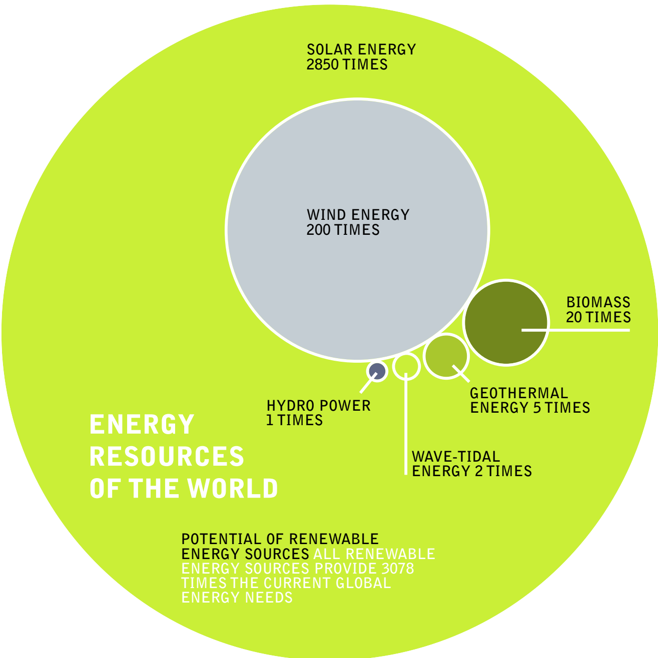
conversion potential This is derived from the annual efficiency of the respective conversion technology. It is therefore not a strictly defined value, since the efficiency of a particular technology depends on technological progress.

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 4.2: energy resources of the world



source WBGU

table 4.1: technically accessible today

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

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

source DR. JOACHIM NITSCH

references
16 WBGU (GERMAN ADVISORY COUNCIL ON GLOBAL CHANGE)'

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.

renewable energy potential by region and technology

Based on the report 'Renewable Energy Potentials' from REN 21, a global policy network[17], we can provide a more detailed overview of renewable energy prospects by world region and technology. The table below focuses on large economies, which consume 80% of the world's primary energy and produce a similar share of the world's greenhouse gas emissions.

Solar photovoltaic (PV) technology can be harnessed almost everywhere, and its technical potential is estimated at over 1,500 EJ/year, closely followed by concentrating solar thermal power (CSP). These two cannot simply be added together, however, because they would require much of the same land resources. The onshore wind potential is equally vast, with almost 400 EJ/year available beyond the order of magnitude of future electricity consumption. The estimate for offshore wind potential (22 EJ/year) is cautious, as only wind intensive areas on ocean shelf areas, with a relatively shallow water depth, and outside shipping lines and protected areas, are included. The various ocean or marine energy potentials also reach a similar magnitude, most of it from ocean waves. Cautious estimates reach a figure of around 50 EJ/year. The estimates for hydro and geothermal resources are well established, each having a technical potential of around 50 EJ/year. Those figures should be seen in the context of a current global energy demand of around 500 EJ.

In terms of heating and cooling, apart from using biomass, there is the option of using direct geothermal energy. The potential is extremely large and could cover 20 times the current world energy demand for heat. The potential for solar heating, including passive solar building design, is virtually limitless. However, heat is costly to transport and one should only consider geothermal heat and solar water heating potentials which are sufficiently close to the point of consumption. Passive solar technology, which contributes enormously to the provision of heating services, is not considered as a (renewable energy) supply source in this analysis but as an efficiency factor to be taken into account in the demand forecasts.

table 4.2: technical renewable energy potential by region

EXCL. BIO ENERGY

	ELECTRICITY [EJ/YEAR]							HEATING [EJ/YEAR]		
	SOLAR CSP	SOLAR PV	HYDRO POWER	WIND ON-SHORE	WIND OFF-SHORE	OCEAN POWER	GEO-THERMAL ELECTRIC	GEO-THERMAL DIRECT USES	SOLAR WATER HEATING	TOTAL
OECD North America	21	72	4	156	2	68	5	626	23	976
Latin America	59	131	13	40	5	32	11	836	12	1,139
OECD Europe	1	13	2	16	5	20	2	203	23	284
Non OCED Europe & Transition Economies	25	120	5	67	4	27	6	667	6	926
Africa & Middle East	679	863	9	33	1	19	5	1,217	12	2,838
East & South Asia	22	254	14	10	3	103	12	1,080	45	1,543
Oceania	187	239	1	57	3	51	4	328	2	872
World	**992**	**1,693**	**47**	**379**	**22**	**321**	**45**	**4,955**	**123**	**8,578**

source REN21

references

17 'RENEWABLE ENERGY POTENTIALS: OPPORTUNITIES FOR THE RAPID DEPLOYMENT OF RENEWABLE ENERGY IN LARGE ENERGY ECONOMIES', REN 21, 2007

the global potential for sustainable biomass

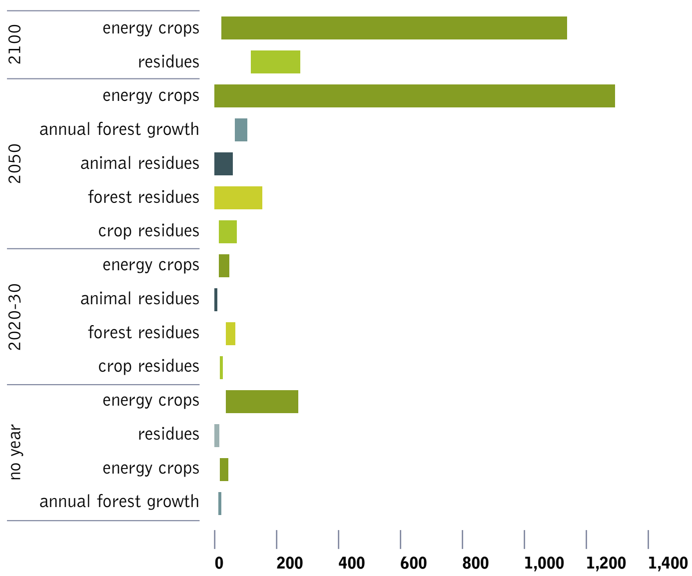
As part of background research for the Energy [R]evolution Scenario, Greenpeace commissioned the German Biomass Research Centre, the former Institute for Energy and Environment, to investigate the worldwide potential for energy crops in different scenarios up to 2050. In addition, information has been compiled from scientific studies of the worldwide 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.

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 studies 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 4.3 shows the variations in potential by biomass type from the different studies.

figure 4.3: ranges of potentials for different resource categories

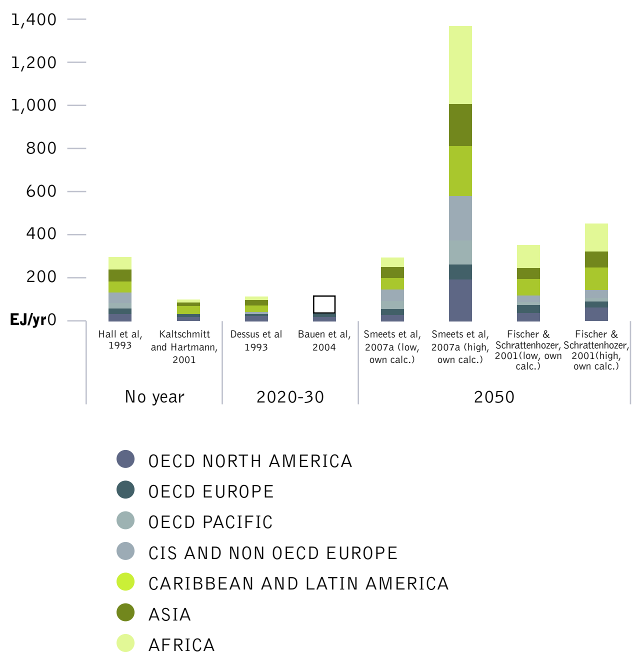


source GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

Looking at the contribution of individual resources 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.

figure 4.4: bio energy potential analysis from different authors

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



source GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

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.

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:

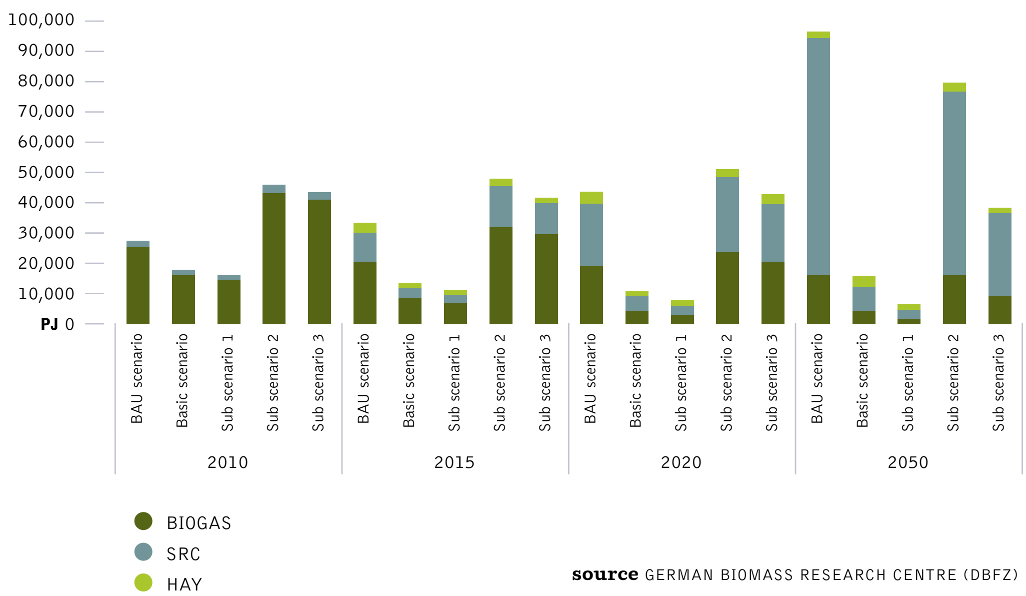
- Business as usual (BAU) scenario: Present agricultural activity continues for the foreseeable future
- Basic scenario: No forest clearing; reduced use of fallow areas for agriculture
- Sub-scenario 1: Basic scenario plus expanded ecological protection areas and reduced crop yields
- Sub-scenario 2: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

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 (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 which 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.

figure 4.5: world wide energy crop potentials in different scenarios



source GERMAN BIOMASS RESEARCH CENTRE (DBFZ)

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.

scenarios for a future energy supply

5

"towards a sustainable global energy supply system."

GREENPEACE INTERNATIONAL
CLIMATE CAMPAIGN

1. population development

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 2007 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.[18]

Table 5.1 summarises this study's assumptions on world population development. The world's population is expected to grow by 0.77% on average over the period 2005 to 2050, from 6.5 billion people in 2005 to more than 9.1 billion in 2050. Population growth will slow over the projection period, from 1.2% during 2005-2010 to 0.4% during 2040-2050. However, the updated projections show an increase in population of almost 300 million compared to the previous edition. This will further increase 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 86% in 2050. China's contribution to world population will drop from 20% today to 15% in 2050. Africa will remain the region with the highest growth rate, leading to a share of 21% of world population in 2050.

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

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.[19] Thus all data on economic development in WEO 2007 refers to purchasing power adjusted GDP. However, as WEO 2007 only covers the time period up to 2030, the projections for 2030-2050 are based on our own estimates.

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

table 5.1: GDP development projections

(AVERAGE ANNUAL GROWTH RATES)

REGION	2005 - 2010	2010 - 2020	2020 - 2030	2030 - 2040	2040 - 2050	**2005 - 2050**
World	4.6%	3.6%	3.2%	3.0%	2.9%	**3.3%**
OECD Europe	2.6%	2.1%	1.7%	1.3%	1.1%	**1.7%**
OECD North America	2.7%	2.4%	2.2%	2.0%	1.8%	**2.2%**
OECD Pacific	2.5%	1.8%	1.5%	1.3%	1.2%	**1.6%**
Transition Economies	5.6%	3.6%	2.7%	2.5%	2.4%	**3.1%**
India	8.0%	6.2%	5.7%	5.4%	5.0%	**5.8%**
India, high GDP	10.0%	10.0%	10.0%	5.4%	5.0%	**8.0%**
China	9.2%	5.7%	4.7%	4.2%	3.6%	**5.0%**
Developing Asia	5.1%	3.8%	3.1%	2.7%	2.4%	**3.2%**
Latin America	4.3%	3.2%	2.8%	2.6%	2.4%	**2.9%**
Africa	5.0%	3.9%	3.5%	3.2%	3.0%	**3.6%**
Middle East	5.1%	4.2%	3.2%	2.9%	2.6%	**3.4%**

source (2005-2030, IEA 2007; 2030-2050, OWN ASSUMPTIONS)

references
18 'WORLD POPULATION PROSPECTS: THE 2006 REVISION', UNITED NATIONS, POPULATION DIVISION, DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS (UNDP), 2007
19 NORDHAUS, W, 'ALTERNATIVE MEASURES OF OUTPUT IN GLOBAL ECONOMIC-ENVIRONMENTAL MODELS: PURCHASING POWER PARITY OR MARKET EXCHANGE RATES?', REPORT PREPARED FOR IPCC EXPERT MEETING ON EMISSION SCENARIOS, US-EPA WASHINGTON DC, JANUARY 12-14, 2005

image GROUP OF YOUNG PEOPLE TOUCHING SOLAR PANELS IN BRAZIL.

figure 5.1: relative GDP$_{PPP}$ growth by world regions

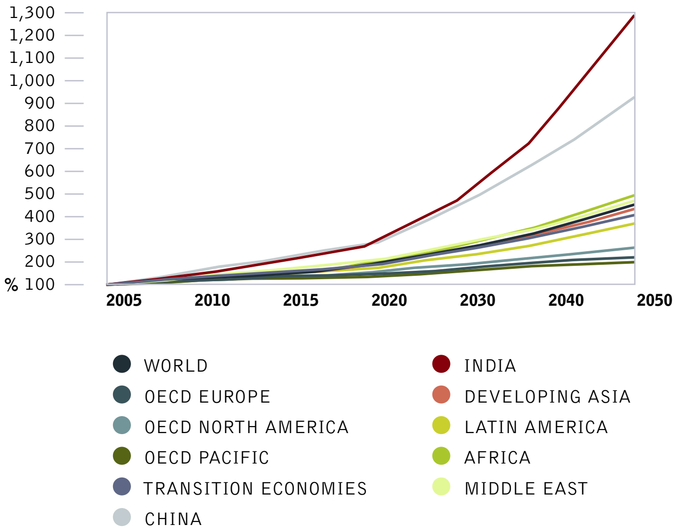
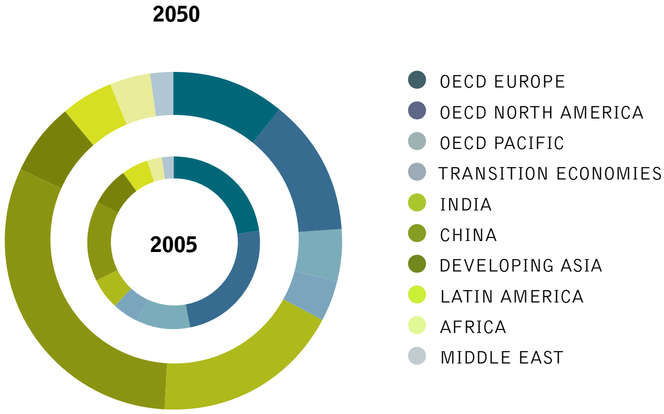


figure 5.2: development of world GDP$_{PPP}$ by regions



3. fossil fuel and biomass price projections

The recent dramatic increase in global oil prices has resulted in much 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 in 2030 range from the IEA's $$_{2006}$62/bbl ($$_{2005}$60/bbl) (WEO 2007) up to $$_{2006}$119/bbl ($$_{2005}$115/bbl) in the 'high price' scenario of the US Energy Information Administration's Annual Energy Outlook 2008.

Since the last Energy [R]evolution study was published, however, the price of oil has moved over $100/bbl for the first time (at the end of 2007), and in July 2008 reached a record high of more than $140/bbl. Although oil prices fell back to $100/bbl in September 2008, the above projections might still be considered too conservative. Considering the growing global demand for oil and gas we have assumed a price development path for fossil fuels in which the price of oil reaches $120/bbl by 2030 and $140/bbl in 2050.

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

table 5.2: assumptions on fuel price development

	2005	2006	2007	2010	2015	2020	2030	2040	2050
Crude oil import prices in $2005 per barrel	52.5	60.1	71.2						
IEA WEO 2007 ETP 2008				57.2	55.5		60.1		63
US EIA 2008 'Reference'				71.7		57.9	68.3		
US EIA 2008 'High Price'				76.6		99.1	115.0		
Energy [R]evolution 2008				100	105	110	120	130	140
Gas import prices in $2005 per GJ	2000	2005	2006						
IEA WEO 2007/ ETP 2008									
US imports	4.59		7.38	7.52	7.52		8.06		8.18
European imports	3.34		7.47	6.75	6.78		7.49		7.67
Japan imports	5.61		7.17	7.48	7.49		8.01		8.18
Energy [R]evolution 2008									
US imports		5.7		11.5	12.7	14.7	18.4	21.9	24.6
European imports		5.8		10.0	11.4	13.3	17.2	20.6	23.0
Asia imports		5.6		11.5	12.6	14.7	18.3	21.9	24.6
Hard coal import prices in $2005 per tonne	2000	2005	2006						
IEA WEO 2007/ ETP 2008	37.8		60.9	54.3	55.1		59.3		59.3
Energy [R]evolution 2008				142.7	167.2	194.4	251.4	311.2	359.1
Biomass (solid) prices in $2005 per GJ	2005								
Energy [R]evolution 2008									
OECD Europe	7.5			7.9	8.5	9.4	10.3	10.6	10.8
OECD Pacific, NA	3			3.3	3.5	3.8	4.3	4.7	5.2
Other regions	2.5			2.8	3.2	3.5	4.0	4.6	4.9

4. cost of CO_2 emissions

Assuming that a CO_2 emissions trading system is established in all world regions in the long term, the cost of CO_2 allowances needs to be included in the calculation of electricity generation costs. Projections of emissions costs are even more uncertain than energy prices, and available studies span a broad range of future CO_2 cost estimates. As in the previous Energy [R]evolution study we assume CO_2 costs of $10/tCO_2 in 2010, rising to $50/tCO_2 in 2050. Additional CO_2 costs are applied in Kyoto Protocol Non-Annex B (developing) countries only after 2020.

table 5.3: assumptions on CO_2 emissions cost development

($/tCO₂)

COUNTRIES	2010	2020	2030	2040	**2050**
Kyoto Annex B countries	10	20	30	40	**50**
Non-Annex B countries		20	30	40	**50**

5. power plant investment costs

fossil fuel technologies 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, bringing down investment costs.[20]

There is much speculation about the potential for carbon capture and storage (CCS) technology 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[21], while a recent US Department of Energy report found installing carbon capture systems to most modern plants resulted in a near doubling of costs[22]. These costs are estimated to increase the price of electricity in a range from 21-91%.[23]

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.[24] 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.[25]

The IPCC 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.[26] Storage and subsequent monitoring and verification costs are estimated by the IPCC to range from $0.5-8/tCO_2 injected and $0.1-0.3/tCO_2 injected, respectively. The overall cost of CCS could therefore serve as a major barrier to its deployment.[27]

For the above reasons, CCS power plants are not included in our financial analysis. Table 5.4 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.

references

20 'GREENPEACE INTERNATIONAL BRIEFING: CARBON CAPTURE AND STORAGE', GOERNE, 2007
21 ABANADES, J C ET AL., 2005, PG 10
22 NATIONAL ENERGY TECHNOLOGY LABORATORIES, 2007
23 RUBIN ET AL., 2005A, PG 40 **24** RAGDEN, P ET AL., 2006, PG 18
25 HEDDLE, G ET AL., 2003, PG 17 **26** PARFOMAK, P & FOLGER, P, 2008, PG 5 AND 12
27 RUBIN ET AL., 2005B, PG 4444

table 5.4: development of efficiency and investment costs for selected power plant technologies

		2005	2010	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, 2008 **a)** CO_2 EMISSIONS REFER TO POWER STATION OUTPUTS ONLY; LIFE-CYCLE EMISSIONS ARE NOT CONSIDERED.

image TRANSPORT POLLUTION.

6. 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 the 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 Energy [R]evolution Scenario are derived from a review of learning curve studies, for example by Lena Neij and others[28], from the analysis of recent technology foresight and road mapping studies, including the European Commission funded NEEDS (New Energy Externalities Developments for Sustainability)[29] project or the IEA Energy Technology Perspectives 2008, and a discussion with experts from the renewable energy industry.

"large cost reductions can be achieved through technical advances, manufacturing improvements and large-scale production."

references

28 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

29 WWW.NEEDS-PROJECT.ORG

photovoltaics (pv)

The worldwide photovoltaics (PV) market has been growing at over 35% per annum in recent years and the contribution it can make to electricity generation is starting to become significant. 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 1,600 GW by between 2030 and 2040, and with an electricity output of 2,600 TWh, 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 2050. The importance of photovoltaics comes from its decentralised/centralised character, its flexibility for use in an urban environment and huge potential for cost reduction.

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 reduction. The efficiency of central receiver systems can be increased by producing compressed air at a temperature of up to 1,000°C, 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.

table 5.5: photovoltaics (pv)

	2005	2010	2020	2030	2040	**2050**
Global installed capacity (GW)	5.2	21	269	921	1,799	**2,911**
Investment costs ($/kW)	6,600	3,760	1,660	1,280	1,140	**1,080**
Operation & maintenance costs ($/kWa)	66	38	16	13	11	**10**

table 5.6: concentrating solar power (csp)

	2005	2010	2020	2030	2040	**2050**
Global installed capacity (GW)	0.53	5	83	199	468	**801**
Investment costs ($/kW)	7,530	6,340	5,240	4,430	4,360	**4,320**
Operation & maintenance costs ($/kWa)	300	250	210	180	160	**155**

image THE PS10 SOLAR TOWER PLANT AT SAN LUCAR LA MAYOR OUTSIDE SEVILLE, SPAIN, APRIL 29, 2008.

wind power

Within a short period of time, the dynamic development of wind power has resulted in the establishment of a flourishing global market. The world's largest wind turbines, several of which have been installed in Germany, have a capacity of 6 MW. While favourable policy incentives have made Europe the main driver for the global wind market, in 2007 more than half of the annual market 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 stagnated or even increased. Because of the continuous expansion of production capacities, the industry expects to resolve the bottlenecks in the supply chain over the next few years. 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.

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

table 5.7: wind power

	2005	2010	2020	2030	2040	**2050**
Installed capacity (on+offshore)	59	164	893	1,622	2,220	**2,733**
Wind onshore						
Global installed capacity (GW)	59	162	866	1,508	1,887	**2,186**
Investment costs ($/kW)	1,510	1,370	1,180	1,110	1,090	**1,090**
O&M costs ($/kWa)	58	51	45	43	41	**41**
Wind offshore						
Global installed capacity (GW)	0,3	1,6	27	114	333	**547**
Investment costs ($/kW)	3,760	3,480	2,600	2,200	1,990	**1,890**
O&M costs ($/kWa)	166	153	114	97	88	**83**

table 5.8: biomass

	2005	2010	2020	2030	2040	**2050**
Biomass (electricity only)						
Global installed capacity (GW)	21	35	56	65	81	**99**
Investment costs ($/kW)	3,040	2,750	2,530	2,470	2,440	**2,415**
O&M costs ($/kWa)	183	166	152	148	147	**146**
Biomass (CHP)						
Global installed capacity (GW)	32	60	177	275	411	**521**
Investment costs ($/kW)	5,770	4,970	3,860	3,380	3,110	**2,950**
O&M costs ($/kWa)	404	348	271	236	218	**207**

geothermal

Geothermal energy has long been used worldwide for supplying heat, and since the beginning of the last century for electricity generation as well. 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 anyywhere. 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:

- 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. Until now we have just used a marginal part of the geothermal heating and cooling potential. Shallow geothermal drilling makes possible the delivery of heating and cooling at any time anywhere, and can be used for thermal energy storage.

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 them 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, and no learning curve data is available. Present cost estimates are based on analysis from the European NEEDS project.[30]

table 5.9: geothermal

	2005	2010	2020	2030	2040	**2050**
Geothermal (electricity only)						
Global installed capacity (GW)	8.7	12	33	71	120	**152**
Investment costs ($/kW)	17,440	15,040	11,560	10,150	9,490	**8,980**
O&M costs ($/kWa)	645	557	428	375	351	**332**
Geothermal (CHP)						
Global installed capacity (GW)	0.24	1.7	13	38	82	**124**
Investment costs ($/kW)	17,500	13,050	9,510	7,950	6,930	**6,310**
O&M costs ($/kWa)	647	483	351	294	256	**233**

table 5.10: ocean energy

	2005	2010	2020	2030	2040	**2050**
Global installed capacity (GW)	0.27	0.9	17	44	98	**194**
Investment costs ($/kW)	9,040	5,170	2,910	2,240	1,870	**1,670**
Operation & maintenance costs ($/kWa)	360	207	117	89	75	**66**

references
30 WWW.NEEDS-PROJECT.ORG

image 100 KW PV GENERATING PLANT NEAR BELLINZONA-LOCARNO RAILWAY LINE. GORDOLA, SWITZERLAND.

image THE POWER OF THE OCEAN.

hydro power

Hydro power is a mature technology with a significant part of its potential already exploited. There is still, however, some potential left both for new schemes (especially small scale run-of-river projects with little or no reservoir impoundment) and for repowering of existing sites. The significance of hydro power is also likely to be encouraged by the increasing need for flood control and 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 5.11: hydro

	2005	2010	2020	2030	2040	**2050**
Global installed capacity (GW)	878	978	1178	1300	1443	**1565**
Investment costs ($/kW)	2760	2880	3070	3200	3320	**3420**
Operation & maintenance costs ($/kWa)	110	115	123	128	133	**137**

summary of renewable energy cost development

Figure 5.3 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 development (after 2040).

Reduced investment costs for renewable energy technologies lead directly to reduced heat and electricity generation costs, as shown in Figure 5.4. Generation costs today are around 8 to 25 $cents/kWh (10-25 $cents/kWh) for the most important technologies, with the exception of photovoltaics. In the long term, costs are expected to converge at around 4 to 10 $cents/kWh (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 5.3: future development of investment costs

(NORMALISED TO CURRENT COST LEVELS) FOR RENEWABLE ENERGY TECHNOLOGIES

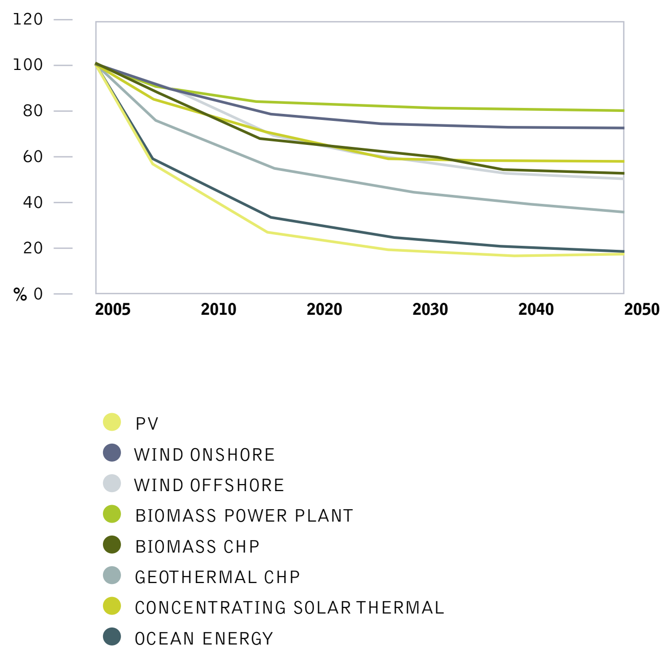
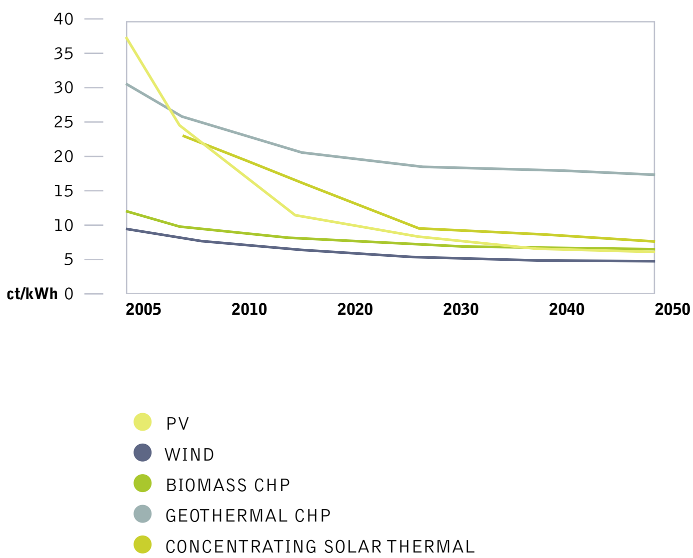


figure 5.4: expected development of electricity generation costs from fossil fuel and renewable options

EXAMPLE FOR OECD NORTH AMERICA

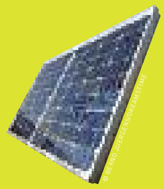


key results of the india energy [r]evolution scenario

6

"for us to develop in a sustainable way, strong measures have to be taken to combat climate change."

HU JINTAO,
PRESIDENT OF CHINA



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

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

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

projection of energy intensity

An increase in economic activity and a growing population does not necessarily have to result in an equivalent increase in energy demand. There is still a large potential for exploiting energy efficiency measures. Under the Reference Scenario, we assume that energy intensity will be reduced by 1.25% on average per year, leading to a reduction in final energy demand per unit of GDP of about 56% between 2005 and 2050. Under the Energy [R]evolution Scenario, it is assumed that active policy and technical support for energy efficiency measures will lead to an even higher reduction in energy intensity of almost 73%.

figure 6.1: india: projection of average energy intensity under the reference and energy [r]evolution scenarios

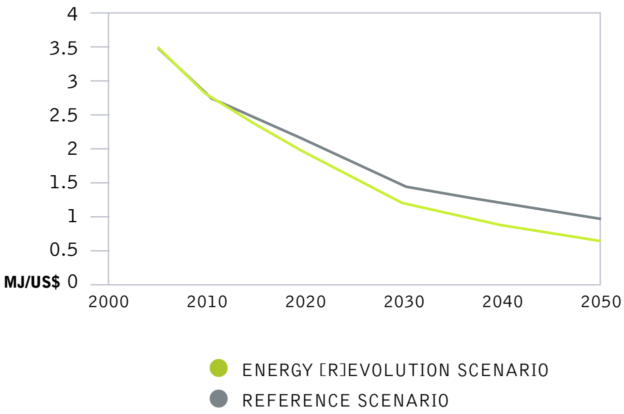


figure 6.2: india: GDP per capita projection

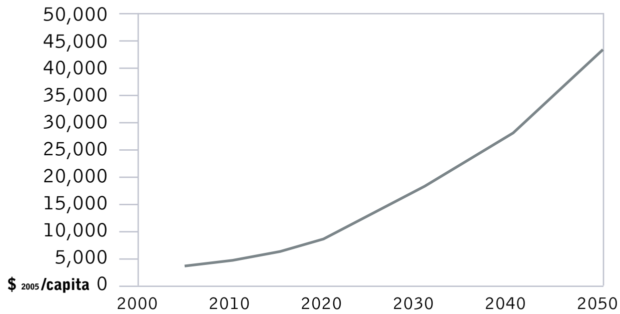


image A LOCAL BENGALI WOMAN PLANTS A MANGROVE (SUNDARI) SAPLING ON SAGAR ISLAND IN THE ECOLOGICALLY SENSITIVE SUNDERBANS RIVER DELTA REGION, IN WEST BENGAL. THOUSANDS OF LOCAL PEOPLE WILL JOIN THE MANGROVE PLANTING INITIATIVE LED BY PROFESSOR SUGATA HAZRA FROM JADAVAPUR UNIVERSITY, WHICH WILL HELP TO PROTECT THE COAST FROM EROSION AND WILL ALSO PROVIDE NUTRIENTS FOR FISH AND CAPTURE CARBON IN THEIR EXTENSIVE ROOT SYSTEMS.

image FEMALE WORKER CLEANING A SOLAR OVEN AT A COLLEGE IN TILONIA, RAJASTHAN, INDIA.

energy demand by sector

The potential future development pathways for India's primary energy demand are shown in Figure 6.3 for both the Reference and Energy [R]evolution Scenarios. Under the Reference Scenario, total primary energy demand quadruples from the current 22,300 PJ/a to 108,491 PJ/a in 2050. In the Energy [R]evolution Scenario, by contrast, demand will increase by about 230% and is expected to reach 62,577 PJ/a by 2050.

Under the Energy [R]evolution Scenario, electricity demand is expected to increase substantially (see Figure 6.4). With the exploitation of efficiency measures, however, a higher increase can be avoided, leading to demand of around 5,591 TWh/a in 2050. Compared to the Reference Scenario, efficiency measures avoid the generation of about 1,582 TWh/a. This reduction can be achieved in particular by introducing highly efficient electronic devices using the best available technology in all demand sectors.

Efficiency gains for heat and cooling supply are also significant. Under the Energy [R]evolution Scenario, final demand for heating and cooling can even be reduced (see Figure 6.5). Compared to the Reference Scenario, consumption equivalent to 4,558 PJ/a is avoided through efficiency gains by 2050.

In the transport sector it is assumed that a fast growing economy will see energy demand, even under the Energy [R]evolution Scenario, increase dramatically - from 1,550 PJ/a in 2005 to 9,478 PJ/a by 2050. This still saves 46% compared to the Reference Scenario. This reduction can be achieved by the introduction of highly efficient vehicles, shifting freight transport from road to rail and by changes in travel behaviour.

figure 6.3: india: projection of total final energy demand by sector for the two scenarios

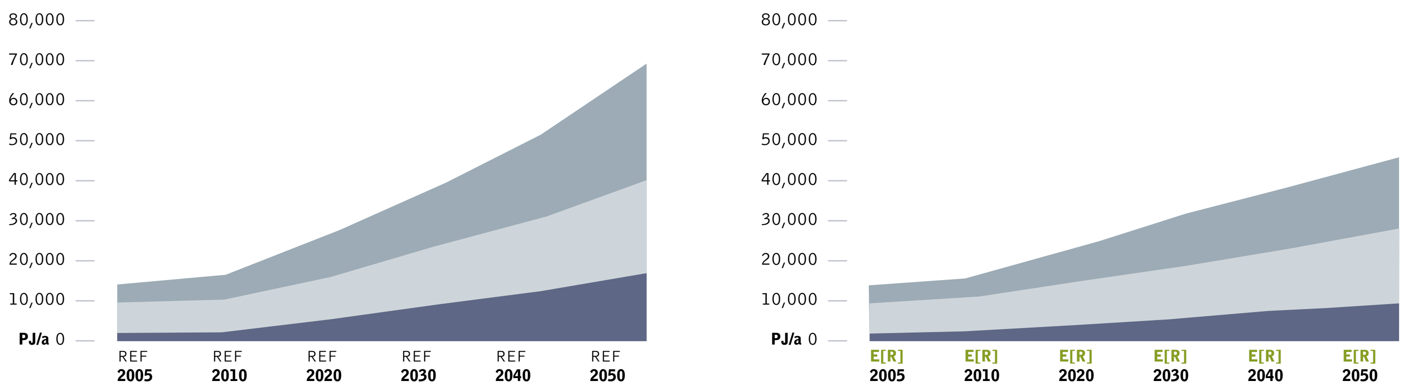


figure 6.4: india: development of electricity demand by sector

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

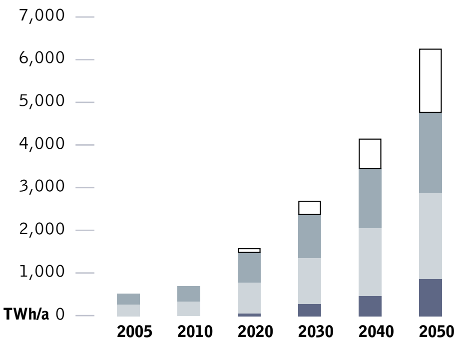
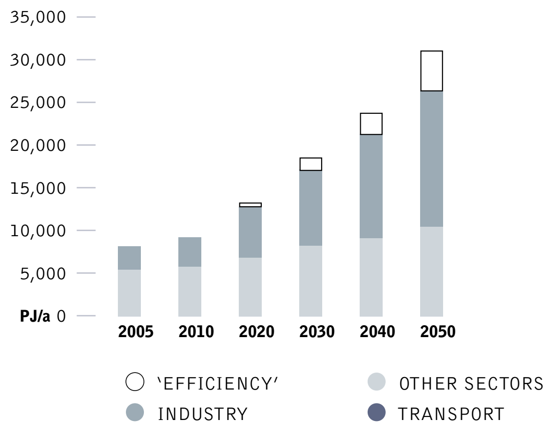


figure 6.5: india: development of heat demand by sector

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



electricity generation

By 2050, about 69% of the electricity produced in India will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute almost 40%. The installed capacity of renewable energy technologies will grow from the current 38 GW to 1,659 GW in 2050, a substantial increase over the next 42 years.

Figure 6.7 shows the comparative evolution of different renewable technologies over time. Up to 2030, wind will remain the main new power source. After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaics and solar thermal (CSP) energy.

table 6.1: india: projection of renewable electricity generation capacity under the energy [r]evolution scenario

IN GW

	2005	2010	2015	2020	2030	2040	2050
Wind	4	12	29	69	143	200	224
PV	0	0	2	10	118	486	1,093
Biomass	0	1	4	8	19	41	70
Geothermal	0	0	0	2	6	18	30
Solarthermal	0	0	0.5	3	23	70	151
Ocean energy	0	0	0	1	3	5	11
Total	**4**	**13**	**35**	**92**	**310**	**819**	**1,579**

figure 6.6: india: development of electricity generation structure under the two scenarios

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

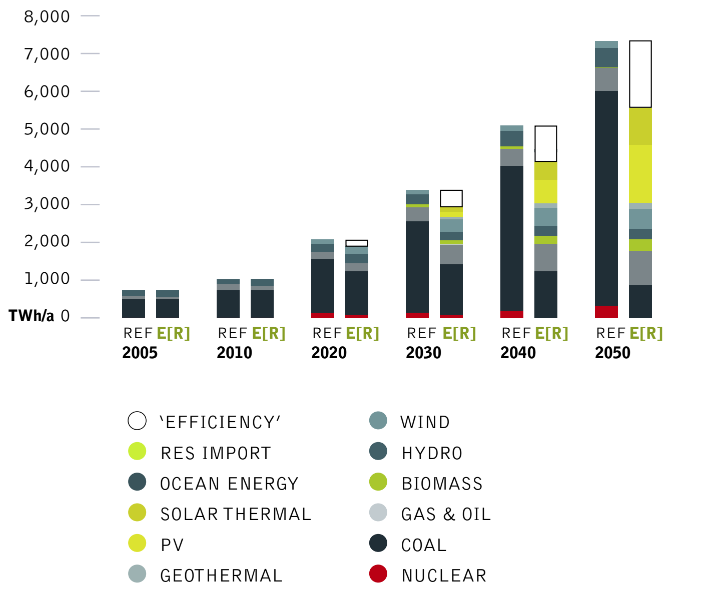


figure 6.7: india: growth of renewable electricity generation capacity under the energy [r]evolution scenario

BY INDIVIDUAL SOURCE

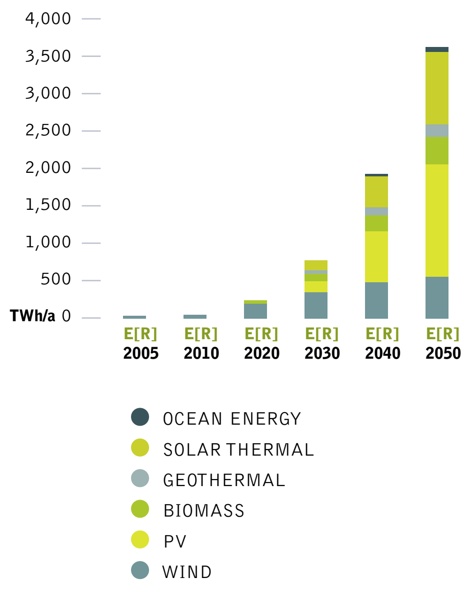


image NANLINIKANT BISWAS, FARMER AGE 43. FIFTEEN YEARS AGO NANLINIKANT'S FAMILY ONCE LIVED WHERE THE SEA IS NOW. THEY WERE AFFLUENT AND OWNED 4 ACRES OF LAND. BUT RISING SEAWATER INCREASED THE SALINITY OF THE SOIL UNTIL THEY COULD NO LONGER CULTIVATE IT, KANHAPUR, ORISSA, INDIA.

image A SOLAR DISH WHICH IS ON TOP OF THE SOLAR KITCHEN AT AUROVILLE,TAMIL NADU, INDIA.

future costs of electricity generation

Figure 6.8 shows that the introduction of renewable technologies under the Energy [R]evolution Scenario significantly decreases the future costs of electricity generation compared to the Reference Scenario. Because of the lower CO_2 intensity, electricity generation costs will become economically favourable under the Energy [R]evolution Scenario and by 2050 will be more than 5 cents/kWh below those in the Reference Scenario.

Under the Reference Scenario, a massive growth in demand, increased fossil fuel prices and the cost of CO_2 emissions result in total electricity supply costs rising from today's $64 billion per year to more than $1,145 bn in 2050. Figure 6.9 shows that the Energy [R]evolution Scenario not only complies with India'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 that are one third lower than in the Reference Scenario.

figure 6.8: india: development of specific electricity generation costs under the two scenarios

(CO_2 EMISSION COSTS IMPOSED FROM 2020, WITH AN INCREASE FROM 20 $/$T_{CO_2}$ IN 2020 TO 50 $/$T_{CO_2}$ IN 2050)

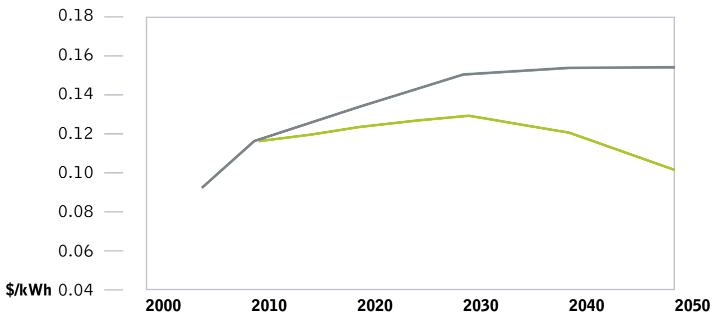
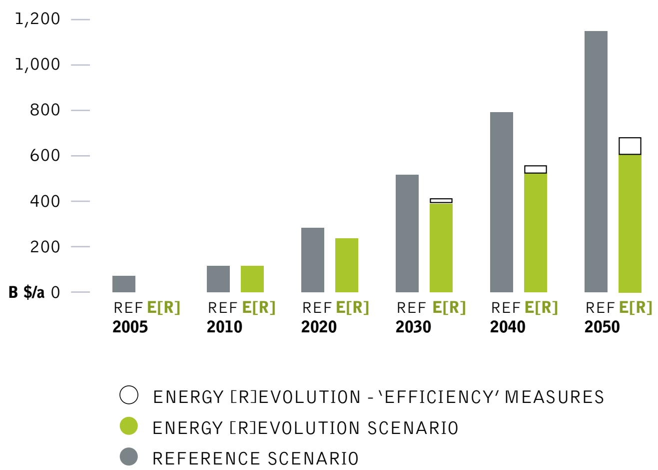


figure 6.9: india: development of total electricity supply costs



heat and cooling supply

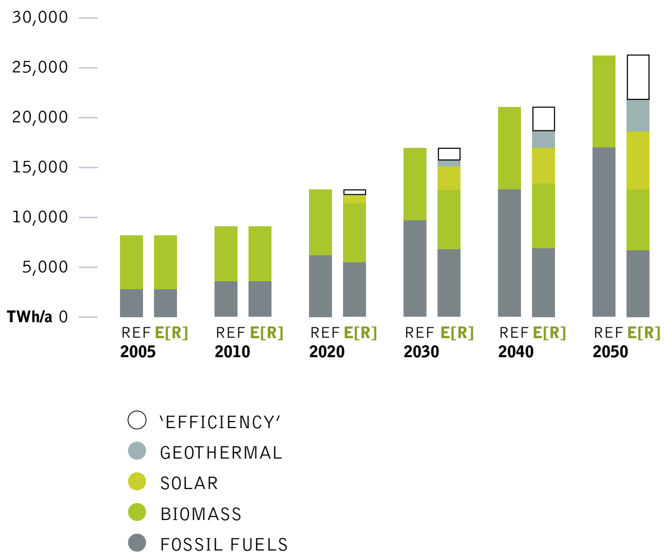
Renewables presently provide 63% of primary energy demand for heat and cooling supply in India, the main contribution coming from the use of biomass. Dedicated support instruments are required to ensure a continuously dynamic development of renewables in the heat market.

In the Energy [R]evolution Scenario, renewables will provide 70% of India's heating and cooling demand by 2050.

- Energy efficiency measures will restrict future primary energy demand for heat and cooling supply to an increase of 270% by 2005, in spite of improving living standards. This compares to 320% in the Reference Scenario.
- In the industry sector solar collectors, biomass/biogas and geothermal energy are increasingly replacing 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.

figure 6.10: india: development of heat supply structure under the two scenarios

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

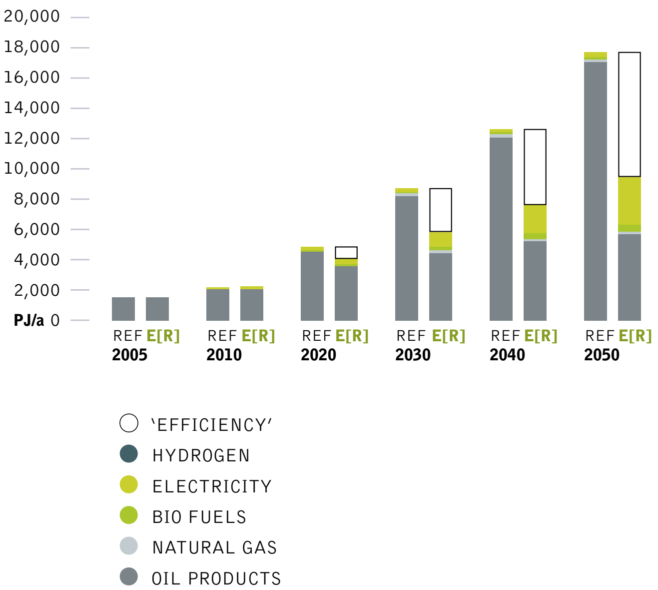


transport

India's car fleet is projected to grow by a factor of 16 from 2000 to 2050. Presently characterised by small cars (70%), this will stay the same up to 2050. Although India will remain a low price car market, the key to efficiency lies in electrified powertrains (hybrid, plug-in and battery electric). Biofuels will take over 5.7% and electricity 32% of total transport energy demand. Stringent energy efficiency measures will help limit growth of transport energy demand by 2050 to about a factor of 6 compared to 2005.

figure 6.11: india: transport under the two scenarios

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

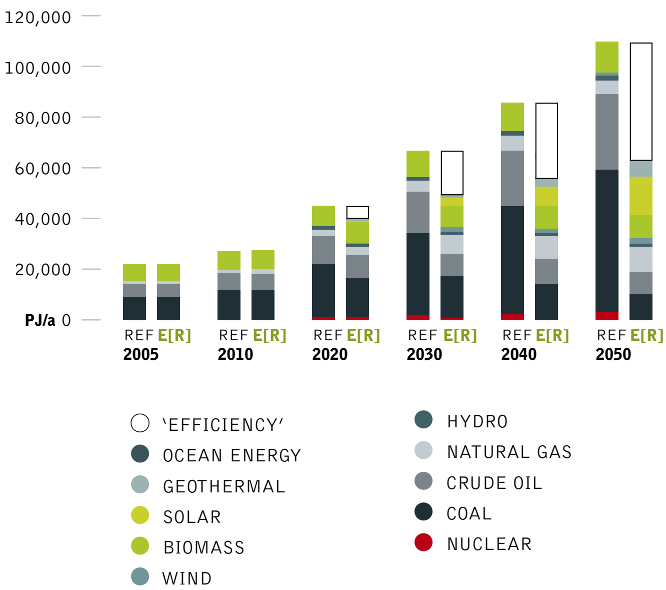


primary energy consumption

Taking into account the above assumptions, the resulting primary energy consumption under the Energy [R]evolution Scenario is shown in Figure 6.12. Compared to the Reference Scenario, overall demand will be reduced by about 42% in 2050. More than half of this will be covered by renewable energy sources.

figure 6.12: india: development of primary energy consumption under the two scenarios

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



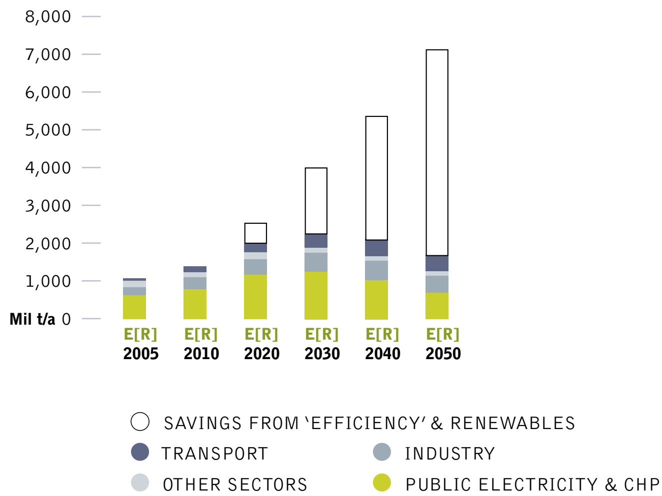
development of CO_2 emissions

While CO_2 emissions in India will increase under the Reference Scenario by a factor of 7 up to 2050, and are thus far removed from a sustainable development path, under the Energy [R]evolution Scenario they will increase from the current 1,074 million tonnes in 2005 to reach a peak of 2,235 m/t in 2030. After that they will decrease to 1,689 m/t in 2050. Annual per capita emissions will increase to 1.5 tonnes/capita in 2030 and fall again to 1.0 t/capita in 2050. In spite of the phasing out of nuclear energy and increasing electricity demand, CO_2 emissions will decrease in the electricity sector.

After 2030, efficiency gains and the increased use of renewables in all sectors will soften the still increasing CO_2 emissions in transport, the power sector and industry. Although its share is decreasing, the power sector will remain the largest source of emissions in India, contributing 42% of the total in 2050, followed by transport.

figure 6.13: india: development of CO_2 emissions by sector under the energy [r]evolution scenario

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

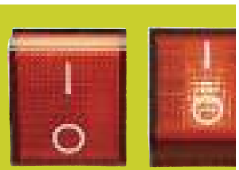


policy recommendations

7

"...so I urge the government to act and to act quickly."

LYN ALLISON,
LEADER OF THE AUSTRALIAN DEMOCRATS, SENATOR 2004-2008



© M. DIETRICH/DREAMSTIME

overarching principles:

India faces the challenge of meeting its economic growth potential in a manner that meets the aspirations of its people, addresses poverty alleviation and also does not jeopardize the sustainability of the environment, especially the catastrophic threat posed by run away climate change. The National Action Plan on Climate Change, released in June 2008, which laid out the broad framework for climate action in India, identified the following as its guiding principles.

- Protecting the poor and vulnerable sections of society through an inclusive and sustainable development strategy, sensitive to climate change.
- Achieving national growth objectives through a qualitative change in direction that enhances ecological sustainability, leading to further mitigation of greenhouse gas emissions.
- Devising efficient and cost-effective strategies for end use Demand Side Management.
- Deploying appropriate technologies for both adaptation and mitigation of greenhouse gas emissions extensively as well as at an accelerated pace.
- Engineering new and innovative forms of market, regulatory and voluntary mechanisms to promote sustainable development.

While we believe that these are laudable principles, the document did not provide details on policies, targets or timelines by which India would actually embark on low carbon sustainable and inclusive development pathway. To actually ensure that these don't remain merely principles Greenpeace recommends that the following policy shifts are implemented by the Indian Government, especially in the energy sectors.

energy sector reforms

The Indian electricity sector today is at the cusp of massive growth plans aiming to multiply the current capacity by a factor 4–5. It is also burdened with a multitude of problems, such as poor efficiencies, huge T&D losses, low renewable energy uptake, demand side losses, peak hour power shortages, unrealistic pricing systems and so on. Additionally addressing the climate threat is a challenge this sector needs to meet as it is the leading contributor to green house gas emissions in the country.

India is also in a unique position of still having to build its energy infrastructure as against the developed world which has to rebuild its systems. In this context India should ensure that the energy policy that the country promotes ensures investment in state-of-the-art transmission and distribution infrastructure, policy mechanisms for encouraging energy conservation and efficiency as well as policy measures and incentives that allow consumers to also be producers of energy.

energy efficiency: plugging into 'smart power'

Energy Efficiency and energy modesty needs to become the centre piece of the national and state energy policy since energy saved is as good as energy produced. The only way to balance economic growth and satisfy domestic consumption needs without endangering the future of life on the planet is by mandating levels of energy efficiency of all domestic and commercial usage and providing incentives and mechanisms that support this shift at the earliest.

Starting with the areas of highest energy consumption, the government should put legislation in place to promote innovations towards energy efficiency and phase out wasteful uses and practices. Specifically, India should implement progressive and mandatory energy efficiency standards cutting across all energy applications in the country. These standards should have clear time lines.

Policy measures for energy efficiency should include:

- Reforms in the banking sector to ensure that energy efficiency projects are made financially viable.
- Substantive government investment to promote efficiency, especially in enabling the small and medium enterprises (SME) sector to change over from energy inefficient production and products to efficient ones.
- An accelerated depreciation for energy efficient equipment in the first year to help their deployment.
- Regulatory systems to implement and monitor efficiency.
- Tax incentives for promotion of energy efficiency including differential taxation on appliances that are certified as energy efficient.
- Mandated specific energy consumption decreases in large energy consuming industries with a framework to certify energy savings in excess of mandated savings. The certified excess savings will then be traded amongst companies to meet their mandated compliance requirements.

renewable energy: no fuel, no emissions, no problems

India has very high potentials for Renewable Energy, which currently forms only 4% of the energy mix in the country. While some states have in place a portfolio standard which requires a certain quantum of renewable energy uptake in the state, a number of states do not, furthermore, there is also no national portfolio standards. Currently despite a 'Solar Mission' in the National Action Plan on Climate Change, which seeks to tap the solar energy potential in the country there are no policies in place that actually meet the ambitions of this mission as yet. Only a few states have put in place a special tariff scheme for renewable energy (Feed in Tariff) and even then there is cap - a measly 50 MW!

To effectively harness the renewable energy potential in the country and spur an energy revolution there is an urgent need for the following:

- Enact a Renewable Energy Law with time bound legal targets for RE uptake both at the grid, and at stand alone level, in every state as well as at the nationally. The proposed time bound RE uptake targets are:
  - 10% by 2010
  - 20% by 2020
  - 60% by 2050.
- The law should provide incentives for investment in RE technologies such as offering preferential tariffs, open transmission as well as incentives for buying green energy.
  - An immediate shift in subsidies from fossil fuels to renewable energy.
  - National feed-in-tariffs for renewable energy, without a cap.
  - Incentives for rooftop solar photo-voltaics, the feed-in-tariff is made applicable even for small quantum of excess supply to the grid from the buildings.
  - A national trading scheme wherein States are encouraged to promote generation of renewable energy in excess of the State standards, for which certificate are issued and which may be tradable amongst other states which fail to meet their renewable standard obligations.
- A massive increase in the Research and Development expenditure to Solar by a factor of 8 at the very least.
- Phasing out high potential greenhouse gases is essential and extremely urgent. Hence, India needs to enact legislation that completely phases out coolants in air conditioning and refrigerating products consisting of Hydro-fluoro-Carbons (HFCs) and Hydro-Chloro-Fluoro Carbons (HCFCs) by 2009 and substituted with safer Hydro–Carbon coolants.

image 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. MASSIVE INVESTMENT IN WIND POWER WILL HELP CHINA OVERCOME ITS RELIANCE ON CLIMATE DESTROYING FOSSIL FUEL POWER AND SOLVE ITS ENERGY SUPPLY PROBLEM.

glossary & appendix

8

"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

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

conversion factors - fossil fuels

FUEL				
Coal	23.03	GJ/t	1 cubic	0.0283 m^3
Lignite	8.45	GJ/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

conversion factors - different energy units

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

image LOCALS AND GREENPEACE SETTING UP WIND TURBINES IN THAILAND.

definition of sectors

The definition of different sectors is analog to the sectorial break down of the IEA World Energy Outlook series.

All definitions below are from the IEA Key World Energy Statistics

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

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

Transport sector: The Transport sector includes all fuels from transport such as road, railway, aviation, domestic and 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: This category covers use of other petroleum products such as paraffin waxes, lubricants, bitumen etc.

appendix: india reference scenario

table 8.1: india: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**699**	**988**	**2,007**	**3,310**	**4,960**	**7,176**
Coal	464	661	1,325	2,231	3,522	5,372
Lignite	16	24	48	81	126	199
Gas	62	85	212	357	452	527
Oil	31	34	37	38	39	40
Diesel	0	0	0	0	0	0
Nuclear	17	24	94	156	219	281
Biomass	2	4	16	35	55	74
Hydro	100	131	213	315	418	521
Wind	6	26	58	84	111	137
PV	0	0	4	10	16	22
Geothermal	0	0	0	1	2	3
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**9**	**45**	**84**	**123**	**162**
Coal	0	9	45	84	123	162
Lignite	0	0	0	0	0	0
Gas	0	0	0	0	0	0
Oil	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	9	45	84	123	162
Total generation	**699**	**997**	**2,052**	**3,394**	**5,082**	**7,338**
Fossil	574	813	1,667	2,791	4,262	6,299
Coal	464	670	1,370	2,315	3,645	5,534
Lignite	16	24	48	81	126	199
Gas	62	85	212	357	452	527
Oil	31	34	37	38	39	40
Diesel	0	0	0	0	0	0
Nuclear	17	24	94	156	219	281
Renewables	**108**	**160**	**291**	**446**	**602**	**757**
Hydro	100	131	213	315	418	521
Wind	6	26	58	84	111	137
PV	0	0	4	10	16	22
Biomass	2	4	16	35	55	74
Geothermal	0	0	0	1	2	3
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Import	1.8	2.5	5.8	10	15.6	23.3
Import RES	0.3	0.4	0.9	1.5	2.4	3.5
Export	0.1	0.1	0.2	0.4	0.6	0.9
Distribution losses	175	243	392	551	710	870
Own consumption electricity	48	67	108	151	195	239
Electricity for hydrogen production	0	0	0	0	0.1	0.4
Final energy consumption (electricity)	**478**	**690**	**1,558**	**2,701**	**4,192**	**6,251**
Fluctuating RES (PV, Wind, Ocean)	6	26	62	94	127	159
Share of fluctuating RES	0.9%	2.6%	3.0%	2.8%	2.5%	2.2%
RES share	**15.5%**	**16.1%**	**14.2%**	**13.1%**	**11.8%**	**10.3%**

table 8.2: india: heat supply

PJ/A	2005	2010	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**	**48**	**204**	**315**	**398**	**497**
Fossil fuels	0	48	204	315	398	497
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Direct heating[1]	**8,082**	**8,980**	**12,496**	**16,646**	**20,667**	**25,870**
Fossil fuels	2,958	3,645	6,192	9,344	12,436	16,364
Biomass	5,125	5,335	6,277	7,224	8,091	9,281
Solar collectors	0	0	12	33	62	103
Geothermal	0	0	14	44	78	121
Total heat supply[1]	**8,082**	**9,028**	**12,700**	**16,961**	**21,065**	**26,367**
Fossil fuels	2,958	3,693	6,396	9,660	12,835	16,861
Biomass	5,125	5,335	6,277	7,224	8,091	9,281
Solar collectors	0	0	12	33	62	103
Geothermal	0	0	14	44	78	121
RES share (including RES electricity)	**63.4%**	**59.1%**	**49.6%**	**43.0%**	**39.1%**	**36.1%**

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

table 8.3: india: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**666**	**865**	**1,540**	**2,390**	**3,122**	**4,121**
Coal	585	765	1,364	2,134	2,808	3,747
Lignite	25	32	54	78	116	177
Gas	30	40	96	153	173	171
Oil	26	27	27	25	25	26
Diesel	0	0	0	0	0	0
Combined heat & power production	**0**	**8**	**37**	**61**	**77**	**87**
Coal	0	8	37	61	77	87
Lignite	0	0	0	0	0	0
Gas	0	0	0	0	0	0
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**666**	**873**	**1,578**	**2,451**	**3,199**	**4,208**
Coal	585	774	1,401	2,195	2,885	3,834
Lignite	25	32	54	78	116	177
Gas	30	40	96	153	173	171
Oil & diesel	26	27	27	25	25	26
CO_2 emissions by sector	**1,074**	**1,394**	**2,541**	**4,001**	**5,336**	**7,089**
% of 1990 emissions	187%	243%	442%	696%	929%	1,234%
Industry	181	255	500	801	1,099	1,467
Other sectors	119	126	167	208	236	262
Transport	108	149	334	602	880	1,238
Electricity & steam generation	666	865	1,540	2,390	3,122	4,121
District heating	0	0	0	0	0	0
Population (Mill.)	1,134	1,220	1,379	1,506	1,597	1,658
CO_2 emissions per capita (t/capita)	**0.9**	**1.1**	**1.8**	**2.7**	**3.3**	**4.3**

table 8.4: india: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**147**	**205**	**387**	**626**	**923**	**1,299**
Coal	77	110	204	333	526	802
Lignite	2	3	7	12	19	31
Gas	16	21	52	97	122	143
Oil	10	11	13	13	26	33
Diesel	0	0	0	0	0	0
Nuclear	3	4	13	21	29	37
Biomass	0	1	2	5	7	10
Hydro	34	44	70	104	138	171
Wind	4	12	24	34	45	56
PV	0	0	3	7	11	16
Geothermal	0	0	0	0	0	0
Solar thermal power plants	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Combined heat & power production	**0**	**2**	**11**	**21**	**30**	**40**
Coal	0	2	11	21	30	40
Lignite	0	0	0	0	0	0
Gas	0	0	0	0	0	0
Oil	0	0	0	0	0	0
Biomass	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	2	11	21	30	40
Total generation	**147**	**207**	**398**	**647**	**954**	**1,339**
Fossil	105	147	286	475	723	1,048
Coal	77	112	215	354	556	842
Lignite	2	3	7	12	19	31
Gas	16	21	52	97	122	143
Oil	10	11	13	13	26	33
Diesel	0	0	0	0	0	0
Nuclear	3.0	4	13	21	29	37
Renewables	**38**	**56**	**99**	**150**	**202**	**253**
Hydro	34	44	70	104	138	171
Wind	4	12	24	34	45	56
PV	0	0	3	7	11	16
Biomass	0.4	1	2	5	7	10
Geothermal	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0
Ocean energy	0	0	0	0	0	0
Fluctuating RES (PV, Wind, Ocean)	4.0	11.8	26.2	41.4	56.5	71.8
Share of fluctuating RES	2.7%	5.7%	6.6%	6.4%	5.9%	5.4%
RES share	**26.2%**	**27.2%**	**24.9%**	**23.2%**	**21.1%**	**18.9%**

table 8.5: india: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**22,344**	**27,303**	**45,270**	**66,804**	**85,681**	**109,491**
Fossil	**15,150**	**19,601**	**34,967**	**53,591**	**70,377**	**91,760**
Hard coal	8,449	11,213	20,131	31,304	41,215	54,581
Lignite	221	293	488	701	1,048	1,590
Natural gas	1,208	1,542	3,036	4,647	5,464	6,025
Crude oil	5,272	6,554	11,313	16,939	22,650	29,564
Nuclear	**189**	**262**	**1,026**	**1,706**	**2,387**	**3,069**
Renewables	**7,005**	**7,440**	**9,277**	**11,507**	**12,917**	**14,662**
Hydro	360	470	765	1,135	1,505	1,875
Wind	22	92	209	303	398	492
Solar	0	1	25	69	120	184
Biomass	6,623	6,878	8,254	9,926	10,769	11,924
Geothermal	0	0	24	74	125	186
Ocean Energy	0	0	0	0	0	0
RES share	**31.3%**	**27.2%**	**20.5%**	**17.2%**	**15.1%**	**13.4%**

table 8.6: india: final energy demand

PJ/a	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**14,908**	**17,620**	**28,404**	**42,155**	**56,777**	**75,820**
Total (energy use)	**13,569**	**16,009**	**26,101**	**39,015**	**52,800**	**71,005**
Transport	**1,549**	**2,156**	**4,819**	**8,632**	**12,588**	**17,670**
Oil products	1,480	2,040	4,581	8,256	12,083	17,025
Natural gas	28	40	77	124	171	219
Biofuels	4	21	56	84	111	144
Electricity	38	55	104	169	222	282
RES electricity	6	9	15	22	26	29
Hydrogen	0	0	0	0	0.10	0.29
RES share Transport	**0.7%**	**1.4%**	**1.5%**	**1.2%**	**1.1%**	**1.0%**
Industry	**4,145**	**5,431**	**9,843**	**15,207**	**21,315**	**29,398**
Electricity	756	1,193	2,670	4,532	7,167	10,791
RES electricity	117	192	378	596	848	1,114
District heat	0	48	204	315	398	497
RES district heat	0	0	0	0	0	0
Coal	1,093	1,617	3,369	5,837	8,285	11,426
Oil products	798	985	1,559	2,079	2,743	3,501
Gas	355	396	577	734	817	987
Solar	0	0	6	17	34	61
Biomass and waste	1,143	1,192	1,457	1,691	1,865	2,122
Geothermal	0	0	1	3	6	12
RES share Industry	**30.4%**	**25.5%**	**18.7%**	**15.2%**	**12.9%**	**11.3%**
Other Sectors	**7,875**	**8,422**	**11,439**	**15,175**	**18,897**	**23,937**
Electricity	927	1,235	2,834	5,022	7,701	11,433
RES electricity	143	199	401	660	911	1,180
District heat	0	0	0	0	0	0
RES district heat	0	0	0	0	0	0
Coal	345	295	276	264	311	327
Oil products	1,143	1,275	1,790	2,241	2,469	2,695
Gas	32	53	137	292	393	538
Solar	0	0	7	16	28	42
Biomass and waste	5,427	5,565	6,384	7,300	7,925	8,797
Geothermal	0	0	12	40	70	105
RES share Other Sectors	**70.7%**	**68.4%**	**59.5%**	**52.8%**	**47.3%**	**42.3%**
Total RES	**6,840**	**7,177**	**8,717**	**10,428**	**11,825**	**13,606**
RES share	**50.4%**	**44.8%**	**33.4%**	**26.7%**	**22.4%**	**19.2%**
Non energy use	**1,339**	**1,611**	**2,303**	**3,140**	**3,977**	**4,815**
Oil	1,028	1,174	1,614	2,201	2,788	3,375
Gas	311	437	688	939	1,189	1,439
Coal	0	0	0	0	0	0

appendix: india energy [r]evolution scenario

table 8.7: india: electricity generation

TWh/a	2005	2010	2020	2030	2040	2050
Power plants	**699**	**988**	**1,834**	**2,816**	**3,771**	**4,921**
Coal	464	661	1,133	1,344	1,140	748
Lignite	16	24	13	8	4	0
Gas	62	85	188	488	688	781
Oil	31	34	12	3	0	0
Diesel	0	0	0	0	0	0
Nuclear	17	24	53	43	24	0
Biomass	2	4	15	20	25	30
Hydro	100	131	220	243	243	243
Wind	6	26	170	350	490	550
PV	0	0	13	165	680	1,530
Geothermal	0	0	4	8	18	21
Solar thermal power plants	0	0	10	135	440	980
Ocean energy	0	0	4	9	19	37
Combined heat & power production	**0**	**9**	**60**	**150**	**370**	**670**
Coal	0	9	21	31	59	87
Lignite	0	0	0	0	0	0
Gas	0	0	10	22	52	114
Oil	0	0	0	0	0	0
Biomass	0	0	24	75	185	335
Geothermal	0	0	5	23	74	134
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	9	60	150	370	670
Total generation	**699**	**997**	**1,894**	**2,966**	**4,141**	**5,591**
Fossil	574	813	1,376	1,896	1,943	1,731
Coal	464	670	1,154	1,375	1,199	836
Lignite	16	24	13	8	4	0
Gas	62	85	198	510	740	895
Oil	31	34	12	3	0	0
Diesel	0	0	0	0	0	0
Nuclear	17	24	53	43	24	0
Renewables	**108**	**160**	**465**	**1,027**	**2,174**	**3,860**
Hydro	100	131	220	243	243	243
Wind	6	26	170	350	490	550
PV	0	0	13	165	680	1,530
Biomass	2	4	39	95	210	365
Geothermal	0	0	9	30	92	155
Solar thermal	0	0	10	135	440	980
Ocean energy	0	0	4	9	19	37
Import	1.8	3	5	8	11	15
Import RES	0.3	0	2	3	6	10
Export	0.1	0.1	0.2	0.3	0.4	0.6
Distribution losses	175	243	352	453	554	654
Own consumption electricity	48	67	97	124	152	180
Electricity for hydrogen production	0	0	0	0.7	42.3	101.2
Final energy consumption (electricity)	**478**	**690**	**1,450**	**2,396**	**3,403**	**4,669**
Fluctuating RES (PV, Wind, Ocean)	6	26	187	524	1189	2,117
Share of fluctuating RES	0.9%	2.6%	9.9%	17.7%	28.7%	37.9%
RES share	**15.5%**	**16.1%**	**24.6%**	**34.6%**	**52.5%**	**69.0%**
'Efficiency' savings (compared to Ref.)	**0**	**0**	**108**	**305**	**789**	**1,582**

table 8.8: india: heat supply

PJ/A	2005	2010	2020	2030	2040	2050
District heating plants	**0**	**0**	**32**	**110**	**324**	**741**
Fossil fuels	0	0	0	0	0	0
Biomass	0	0	23	55	81	89
Solar collectors	0	0	8	48	201	482
Geothermal	0	0	2	7	42	170
Heat from CHP	**0**	**48**	**292**	**681**	**1,626**	**2,855**
Fossil fuels	0	48	140	197	360	618
Biomass	0	0	108	281	600	1,031
Geothermal	0	0	43	203	666	1,206
Direct heating[1]	**8,082**	**8,980**	**11,889**	**14,898**	**16,530**	**18,213**
Fossil fuels	2,958	3,645	5,278	6,531	6,552	6,008
Biomass	5,125	5,335	5,842	5,852	5,700	5,244
Solar collectors	0	0	664	2,096	3,385	5,203
Geothermal	0	0	105	418	894	1,758
Total heat supply[1]	**8,082**	**9,028**	**12,213**	**15,688**	**18,480**	**21,809**
Fossil fuels	2,958	3,693	5,419	6,728	6,912	6,626
Biomass	5,125	5,335	5,972	6,188	6,381	6,363
Solar collectors	0	0	672	2,145	3,586	5,685
Geothermal	0	0	150	627	1,602	3,134
RES share (including RES electricity)	**63.4%**	**59.1%**	**55.6%**	**57.1%**	**62.6%**	**69.6%**
'Efficiency' savings (compared to Ref.)		**0**	**487**	**1,273**	**2,586**	**4,558**

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

table 8.9: india: CO_2 emissions

MILL t/a	2005	2010	2020	2030	2040	2050
Condensation power plants	**666**	**865**	**1,196**	**1,291**	**1,081**	**710**
Coal	585	766	1,088	1,072	830	464
Lignite	25	32	15	8	4	0
Gas	30	40	85	209	248	246
Oil	26	27	9	2	0	0
Diesel	0	0	0	0	0	0
Combined heat & power production	**0**	**8**	**22**	**32**	**57**	**84**
Coal	0	8	17	22	37	47
Lignite	0	0	0	0	0	0
Gas	0	0	5	10	20	37
Oil	0	0	0	0	0	0
CO_2 emissions electricity & steam generation	**666**	**873**	**1,218**	**1,323**	**1,138**	**794**
Coal	585	774	1,105	1,094	867	511
Lignite	25	32	15	8	4	0
Gas	30	40	90	219	267	283
Oil & diesel	26	27	9	2	0	0
CO_2 emissions by sector	**1,074**	**1,394**	**1,977**	**2,235**	**2,083**	**1,689**
% of 1990 emissions	187%	243%	344%	389%	363%	294%
Industry	181	255	394	479	485	455
Other sectors	119	126	133	139	133	111
Transport	108	149	254	326	385	414
Electricity & steam generation	666	865	1,196	1,291	1,081	710
District heating	0	0	0	0	0	0
Population (Mill.)	1,134	1,220	1,379	1,506	1,597	1,658
CO_2 emissions per capita (t/capita)	**1.0**	**1.1**	**1.4**	**1.5**	**1.3**	**1.0**

table 8.10: india: installed capacity

GW	2005	2010	2020	2030	2040	2050
Power plants	**147**	**205**	**392**	**731**	**1,235**	**1,912**
Coal	77	110	174	221	198	135
Lignite	2	3	2	1	1	0
Gas	16	21	46	132	186	211
Oil	10	11	4	1	0	0
Diesel	0	0	0	0	0	0
Nuclear	3	4	7	6	3	0
Biomass	0	1	2	3	3	4
Hydro	34	44	73	80	80	80
Wind	4	12	69	143	200	224
PV	0	0	10	118	486	1093
Geothermal	0	0	1	1	3	3
Solar thermal power plants	0	0	3	23	70	151
Ocean energy	0	0	1	3	5	11
Combined heat & power production	**0**	**2**	**14**	**33**	**77**	**138**
Coal	0	2	5	8	15	22
Lignite	0	0	0	0	0	0
Gas	0	0	2	5	10	23
Oil	0	0	0	0	0	0
Biomass	0	0	5	16	37	66
Geothermal	0	0	1	5	15	27
CHP by producer						
Main activity producers	0	0	0	0	0	0
Autoproducers	0	2	14	33	77	138
Total generation	**147**	**208**	**406**	**763**	**1,313**	**2,050**
Fossil	105	147	234	367	410	391
Coal	77	112	180	228	213	157
Lignite	2	3	2	1	1	0
Gas	16	21	48	137	197	234
Oil	10	11	4	1	0	0
Diesel	0	0	0	0	0	0
Nuclear	3.0	4	7	6	3	0
Renewables	**38**	**56**	**165**	**390**	**899**	**1,659**
Hydro	34	44	73	80	80	80
Wind	4	12	69	143	200	224
PV	0	0	10	118	486	1,093
Biomass	0.4	1	8	19	41	70
Geothermal	0	0	2	6	18	30
Solar thermal	0	0	3	23	70	151
Ocean energy	0	0	1	3	5	11
Fluctuating RES (PV, Wind, Ocean)	4.0	12	80	263	691	1,328
Share of fluctuating RES	2.7%	5.7%	19.7%	34.5%	52.7%	64.8%
RES share	**26.2%**	**27.2%**	**40.7%**	**51.1%**	**68.5%**	**80.9%**

table 8.11: india: primary energy demand

PJ/A	2005	2010	2020	2030	2040	2050
Total	**22,344**	**27,304**	**39,288**	**49,292**	**56,274**	**62,577**
Fossil	**15,150**	**19,602**	**28,106**	**33,210**	**32,695**	**28,775**
Hard coal	8,449	11,216	15,863	16,164	13,464	9,176
Lignite	221	293	131	69	33	0
Natural gas	1,208	1,543	3,845	7,688	9,188	9,983
Crude oil	5,272	6,550	8,267	9,289	10,009	9,617
Nuclear	**189**	**262**	**576**	**467**	**260**	**0**
Renewables	**7,005**	**7,441**	**10,606**	**15,615**	**23,320**	**33,802**
Hydro	360	470	792	875	875	875
Wind	22	92	610	1,260	1,764	1,980
Solar	0	1	757	3,225	7,618	14,721
Biomass	6,623	6,878	8,051	8,892	9,350	9,766
Geothermal	0	0	381	1,331	3,645	6,327
Ocean Energy	0	0	15	32	68	133
RES share	**31.3%**	**27.2%**	**27.0%**	**31.7%**	**41.4%**	**54.0%**
'Efficiency' savings (compared to Ref.)	**0**	**0**	**5,993**	**17,544**	**29,477**	**47,043**

table 8.12: india: final energy demand

PJ/a	2005	2010	2020	2030	2040	2050
Total (incl. non-energy use)	**14,908**	**17,617**	**25,798**	**34,434**	**42,004**	**50,295**
Total (energy use)	**13,569**	**16,008**	**23,832**	**31,934**	**38,987**	**46,995**
Transport	1,549	2,156	3,986	5,817	7,647	9,478
Oil products	1,480	2,040	3,468	4,438	5,244	5,644
Natural gas	28	40	74	105	118	123
Biofuels	4	21	118	269	394	546
Electricity	38	55	326	1,005	1,861	3,089
RES electricity	6	9	80	348	977	2,133
Hydrogen	0	0	0	0.5	30.9	75.9
RES share Transport	**0.7%**	**1.4%**	**5.0%**	**10.6%**	**18.1%**	**28.8%**
Industry	**4,145**	**5,431**	**8,897**	**12,398**	**15,405**	**18,917**
Electricity	756	1,193	2,380	3,642	5,058	6,760
RES electricity	117	192	584	1,261	2,655	4,667
District heat	0	48	317	750	1,859	3,286
RES district heat	0	0	317	750	1,859	3,286
Coal	1,093	1,617	2,261	2,494	2,267	1,825
Oil products	798	985	1,191	1,164	912	480
Gas	355	396	1,282	2,297	2,659	2,947
Solar	0	0	255	759	1,203	1,896
Biomass and waste	1,143	1,192	1,144	1,012	837	710
Geothermal	0	0	67	281	611	1,013
RES share Industry	**30.4%**	**25.5%**	**26.6%**	**32.8%**	**46.5%**	**61.2%**
Other Sectors	**7,875**	**8,422**	**10,948**	**13,719**	**15,934**	**18,601**
Electricity	927	1,235	2,515	3,980	5,442	7,224
RES electricity	143	199	618	1,378	2,857	4,988
District heat	0	0	7	41	91	310
RES district heat	0	0	7	41	91	310
Coal	345	295	296	309	278	255
Oil products	1,143	1,273	1,062	932	807	415
Gas	32	54	468	728	844	1,009
Solar	0	0	409	1,337	2,182	3,307
Biomass and waste	5,427	5,565	6,154	6,280	6,065	5,459
Geothermal	0	0	36	111	224	620
RES share Other Sectors	**70.7%**	**68.4%**	**66.0%**	**66.7%**	**71.7%**	**78.9%**
Total RES	**6,840**	**7,166**	**9,789**	**13,827**	**19,971**	**28,988**
RES share	**50.4%**	**44.8%**	**41.1%**	**43.3%**	**51.2%**	**61.7%**
Non energy use	**1,339**	**1,609**	**1,966**	**2,500**	**3,017**	**3,300**
Oil	1,028	1,172	1,433	1,800	2,167	2,350
Gas	311	437	533	700	850	950
Coal	0	0	0	0	0	0

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, 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 India
#60, Wellington Street, Richmond Town, Bangalore 560 025
t +91 80 41154861 f +91 80 41154862
ksriniva@greenpeace.org, vgopal@greenpeace.org
www.greenpeaceindia.org

EREC

european renewable energy council - [EREC]
Created on 13 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 represents thus 40 billion € turnover and provides jobs to around 350,000 people!

EREC is composed of the following non-profit associations and federations: AEBIOM (European Biomass Association); eBIO (European Bioethanol Fuel 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) and Associate Member: EBB (European Biodiesel Board)

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 ICEBERGS CALVING FROM THE ILUISSAT GLACIER IN GREENLAND. MEASUREMENTS OF THE MELT LAKES ON THE GREENLAND ICE SHEET SHOW ITS VULNERABILITY TO WARMING TEMPERATURES.