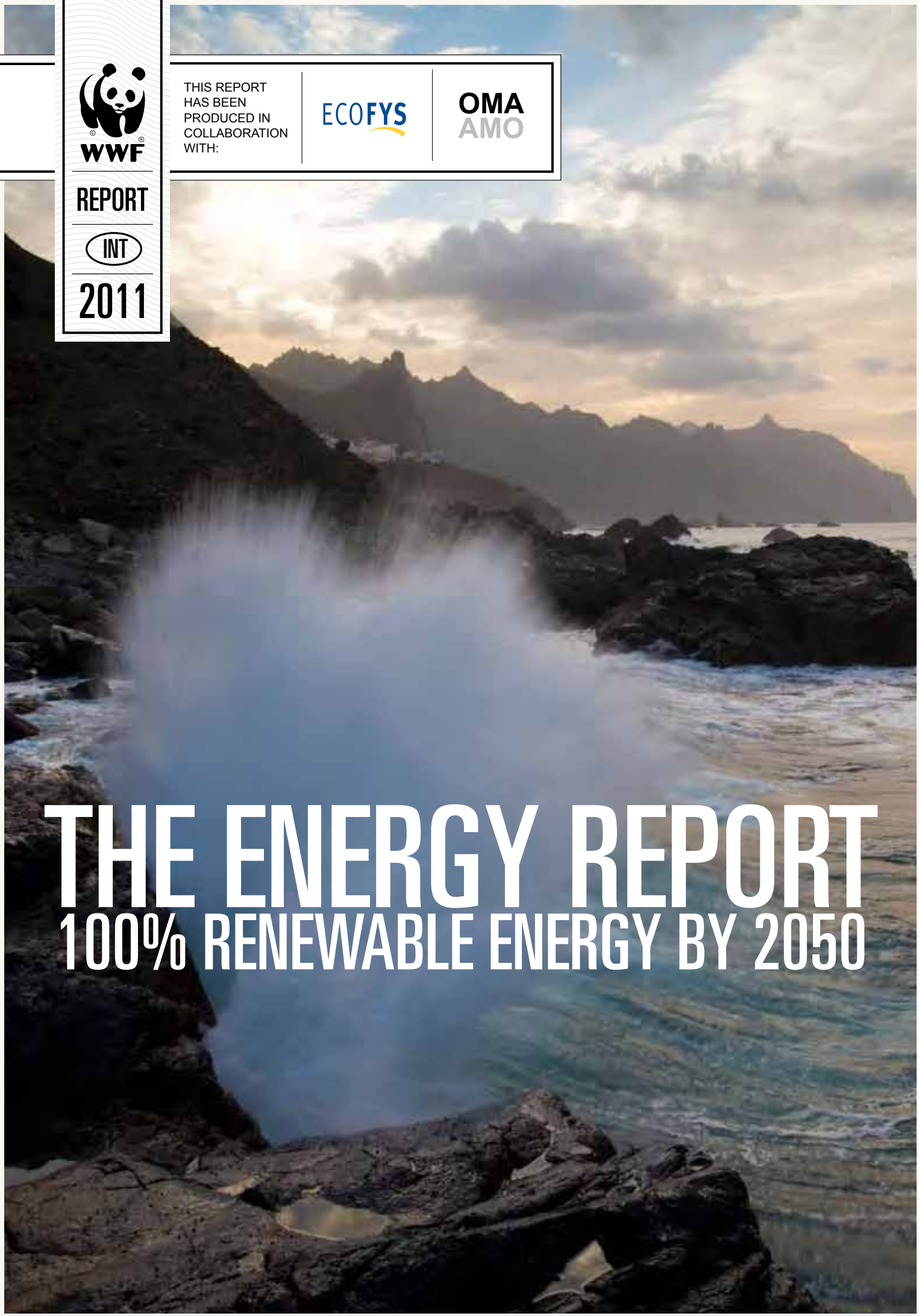

WWF

REPORT

INT

2011

THIS REPORT HAS BEEN PRODUCED IN COLLABORATION WITH:

ECOFYS

OMA AMO

THE ENERGY REPORT

100% RENEWABLE ENERGY BY 2050

WWF

WWF is one of the world's largest and most experienced independent conservation organizations, with over 5 million supporters and a global Network active in more than 100 countries.
WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

ECOFYS

Established in 1984 with the mission of achieving a sustainable energy supply for everyone, Ecofys has become a leader in energy saving, sustainable energy solutions and climate policies. The unique synergy between our fields of competence is the key to this success. We create smart, effective, practical and sustainable solutions for and with our clients.

OMA

The Office for Metropolitan Architecture (OMA) is a leading international partnership practicing contemporary architecture, urbanism, and cultural analysis. The counterpart to OMA's architectural practice is the company's research-based think tank, AMO. While OMA remains dedicated to the realization of buildings and master plans, AMO operates in areas beyond the boundaries of architecture and urbanism such as media, politics, sociology, technology, energy, fashion, publishing and graphic design.

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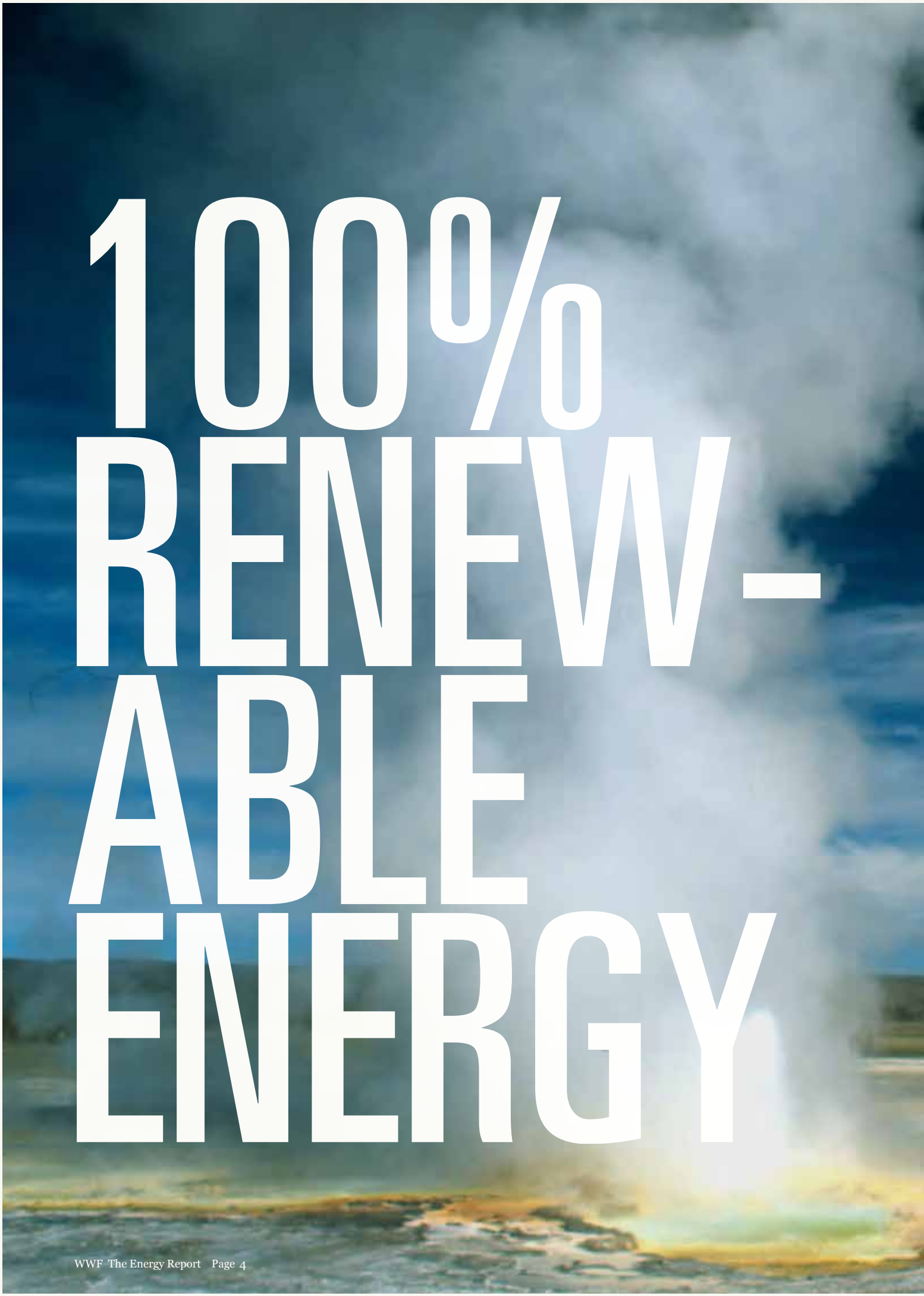
100%
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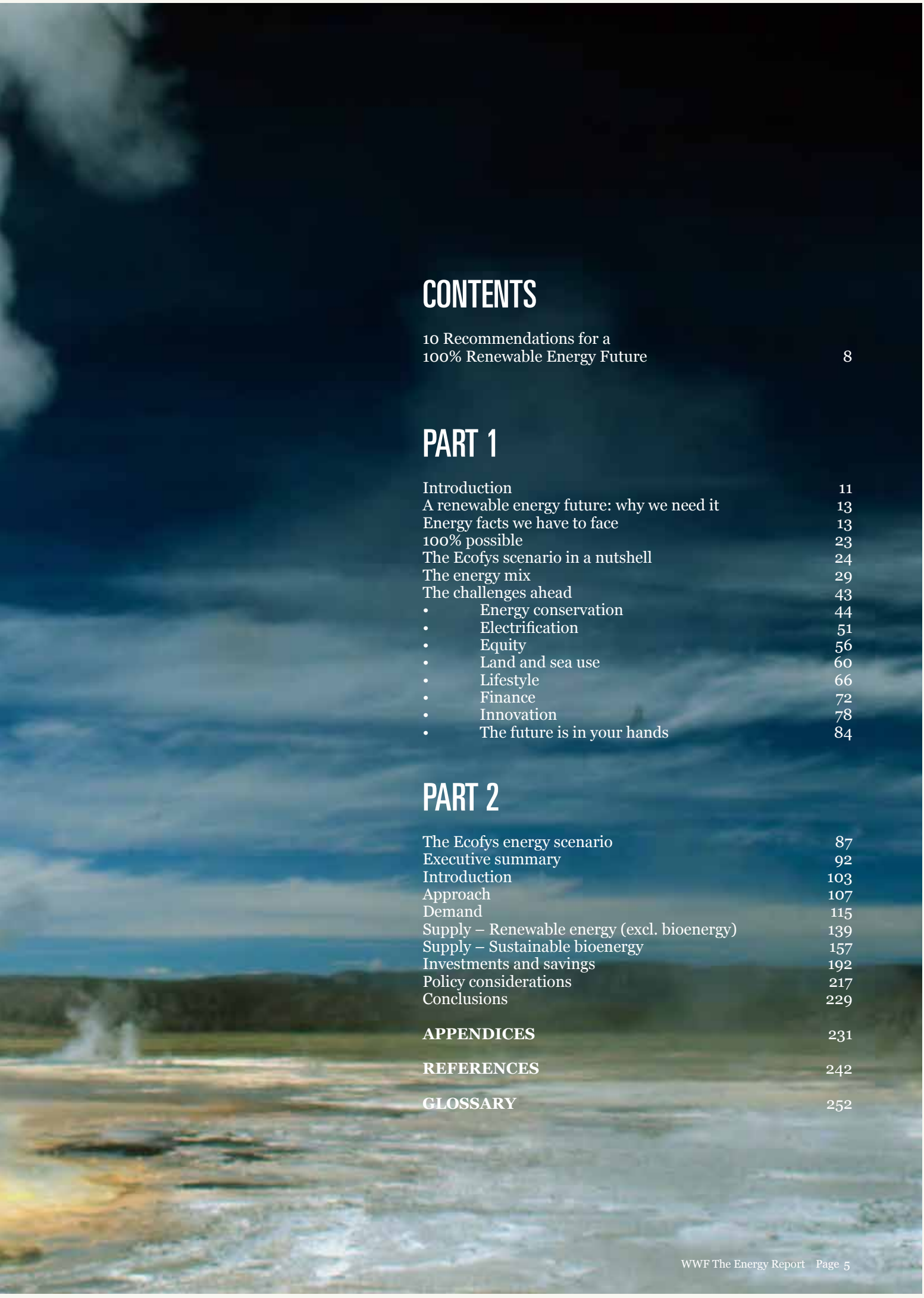
ENERGY



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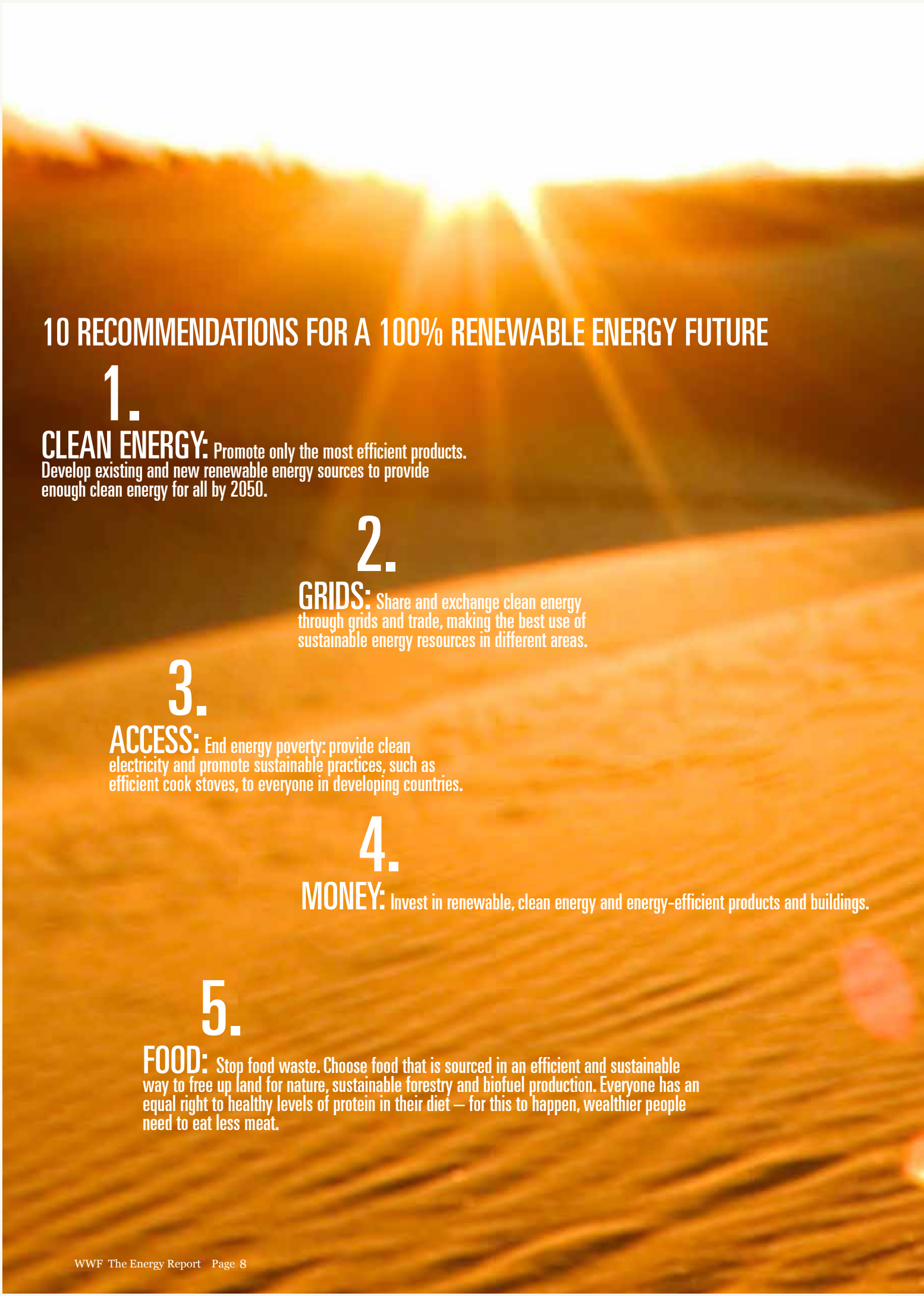
Map 1: A new perspective on the world - looking towards 2050. *Global GIS Database: Complete GlobaL Set, 2002*
© AMO

"By 2050, we could get all the energy we need from renewable sources. This report shows that such a transition is not only possible but also cost-effective, providing energy that is affordable for all and producing it in ways that can be sustained by the global economy and the planet. The transition will present significant challenges, but I hope this report will inspire governments and business to come to grips with those challenges and, at the same time, to move boldly to bring the renewable economy into reality. There is nothing more important to our ability to create a sustainable future."

James P. Leape
Director General
WWF International



10 RECOMMENDATIONS FOR A 100% RENEWABLE ENERGY FUTURE

1.

CLEAN ENERGY: Promote only the most efficient products. Develop existing and new renewable energy sources to provide enough clean energy for all by 2050.

2.

GRIDS: Share and exchange clean energy through grids and trade, making the best use of sustainable energy resources in different areas.

3.

ACCESS: End energy poverty: provide clean electricity and promote sustainable practices, such as efficient cook stoves, to everyone in developing countries.

4.

MONEY: Invest in renewable, clean energy and energy-efficient products and buildings.

5.

FOOD: Stop food waste. Choose food that is sourced in an efficient and sustainable way to free up land for nature, sustainable forestry and biofuel production. Everyone has an equal right to healthy levels of protein in their diet – for this to happen, wealthier people need to eat less meat.

6.

MATERIALS: Reduce, re-use, recycle – to minimize waste and save energy. Develop durable materials. And avoid things we don't need.

7.

TRANSPORT: Provide incentives to encourage greater use of public transport, and to reduce the distances people and goods travel. Promote electrification wherever possible, and support research into hydrogen and other alternative fuels for shipping and aviation.

8.

TECHNOLOGY: Develop national, bilateral and multilateral action plans to promote research and development in energy efficiency and renewable energy.

9.

SUSTAINABILITY: Develop and enforce strict sustainability criteria that ensure renewable energy is compatible with environmental and development goals.

10.

AGREEMENTS: Support ambitious climate and energy agreements to provide global guidance and promote global cooperation on renewable energy and efficiency efforts.

"WWF HAS A VISION OF A WORLD THAT IS POWERED BY 100 PER CENT RENEWABLE ENERGY SOURCES BY THE MIDDLE OF THIS CENTURY"

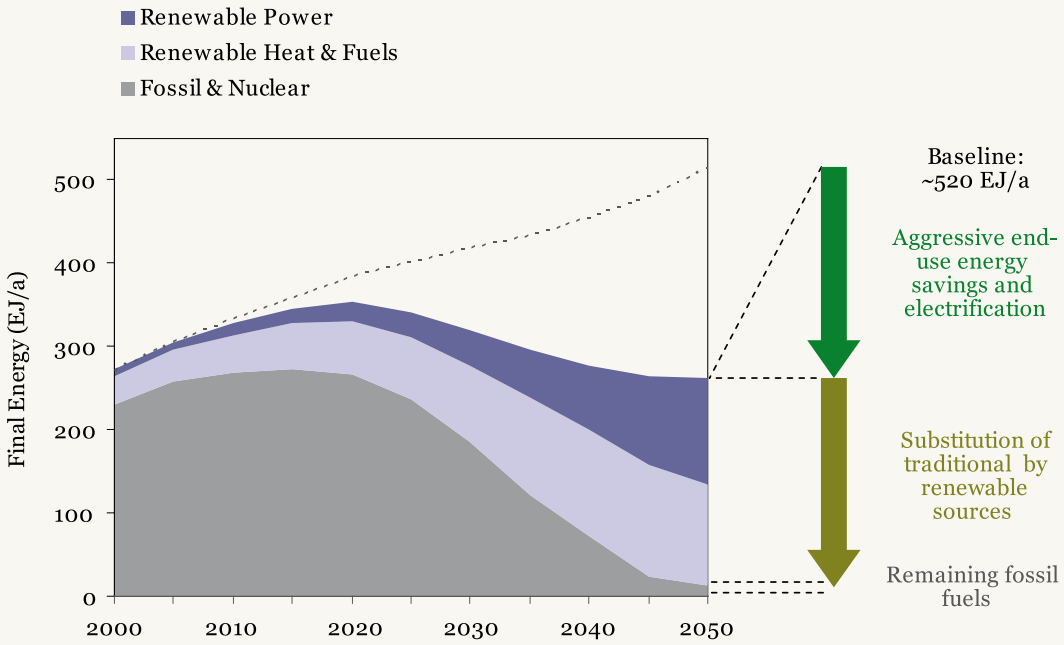


Figure 1
Evolution of energy supply in the Energy Scenario, showing the key developments.
Source: The Ecofys Energy Scenario, December 2010.

100 PER CENT RENEWABLE ENERGY BY 2050

WWF has a vision of a world that is powered by 100 per cent renewable energy sources by the middle of this century. Unless we make this transition, the world is most unlikely to avoid predicted escalating impacts of climate change.

But is it possible to achieve 100 per cent renewable energy supplies for everyone on the planet by 2050? WWF called upon the expertise of respected energy consultancy Ecofys to provide an answer to this question. In response, Ecofys has produced a bold and ambitious scenario - which demonstrates that it is technically possible to achieve almost 100 per cent renewable energy sources within the next four decades. The ambitious outcomes of this scenario, along with all of the assumptions, opportunities, detailed data and sources, are presented as Part 2 of this report.

The Ecofys scenario raises a number of significant issues and challenges. The Energy Report investigates the most critically important political, economic, environmental and social choices and challenges – and encourages their further debate.

How are we going to provide for all of the world's future needs, on energy, food, fibre, water and others, without running into such huge issues as: conflicting demands on land/water availability and use; rising, and in some cases, unsustainable consumption of commodities; nuclear waste; and regionally appropriate and adequate energy mixes?

The world needs to seriously consider what will be required to transition to a sustainable energy future, and to find solutions to the dilemmas raised in this report. Answering these challenges - the solutions to the energy needs of current and future generations – is one of the most important, challenging and urgent political tasks ahead.


"1.4 BILLION
PEOPLE HAVE
NO ACCESS
TO RELIABLE
ELECTRICITY"

© Cat Holloway / WWF-Canon

A RENEWABLE ENERGY FUTURE: WHY WE NEED IT

Switching to renewable energy isn't just the best choice. It's our only option.

The way we produce and use energy today is not sustainable. Our main fossil fuel sources – oil, coal and gas – are finite natural resources, and we are depleting them at a rapid rate. Furthermore they are the main contributors to climate change, and the race to the last 'cheap' fossil resources evokes disasters for the natural environment as seen recently in the case of the BP oil spill in the Gulf of Mexico. In the developing world, regional and local desertification is caused by depletion of fuelwood and other biomass sources that are often used very inefficiently causing substantive in-door pollution and millions of deaths annually. A fully sustainable renewable power supply is the only way we can secure energy for all and avoid environmental catastrophe.

ENERGY FACTS WE HAVE TO FACE

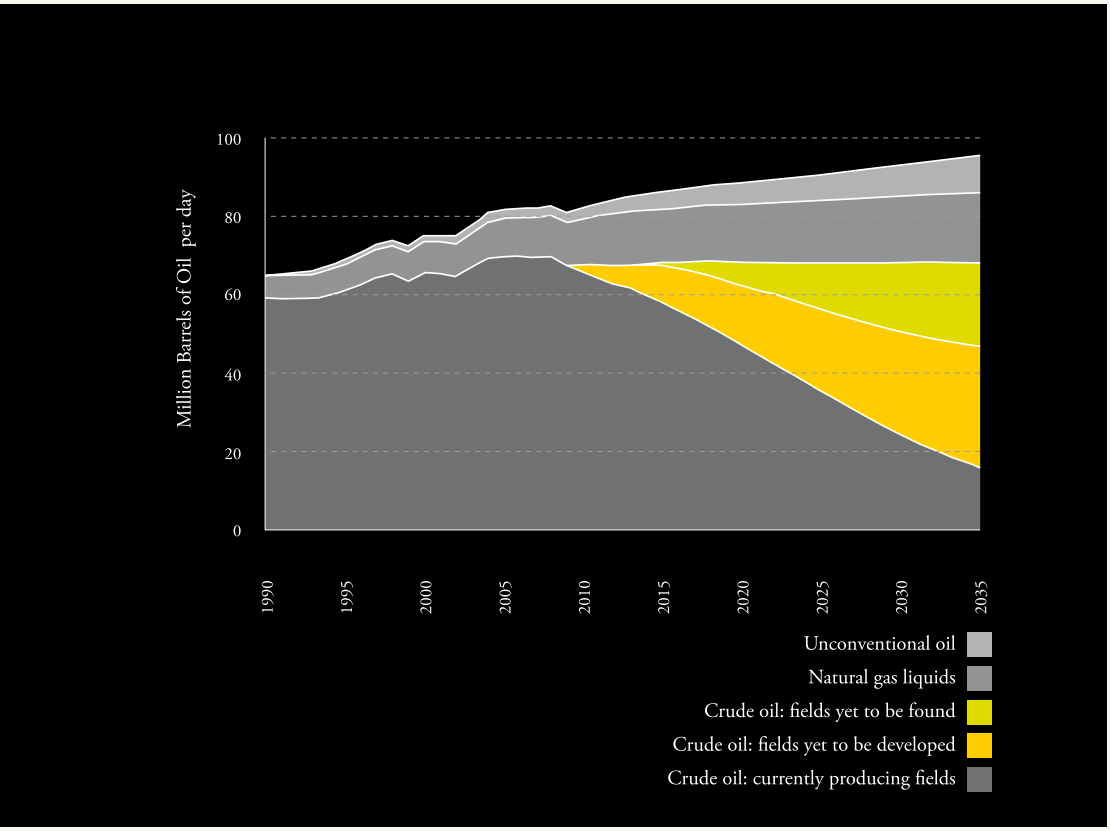
1.4 billion people have no access to reliable electricity[1].

While most of us take energy for granted as a basic right, a fifth of the world's population still has no access to reliable electricity – drastically reducing their chances of getting an education and earning a living. As energy prices increase, the world's poor will continue to be excluded.

At the same time, more than 2.7 billion people are dependent on traditional bioenergy (mainly from wood, crop residues and animal dung) as their main source of cooking and heating fuel[2] . This is often harvested unsustainably, causing soil erosion and increasing the risk of flooding, as well as threatening biodiversity and adding to greenhouse gas emissions. Traditional stoves are also a significant health problem: the World Health Organization (WHO) estimates that 2.5 million women and young children die prematurely each year from inhaling their fumes[3]. With many developing societies becoming increasingly urban, air quality in cities will decline further.

Finite and increasingly expensive fossil fuels are not the answer for developing countries. But renewable energy sources offer the potential to transform the quality of life and improve the economic prospects of billions.

1. IEA, World Energy Outlook (WEO) 2010, Paris
2. IEA, World Energy Outlook (WEO) 2010, Paris.
3. http://www.iaea.org/Publications/Magazines/Bulletin/Bull442/44204002429.pdf



"IF EVERYONE CONSUMED AS MUCH ENERGY AS THE AVERAGE SINGAPOREAN AND U.S. RESIDENT, THE WORLD'S OIL RESERVES WOULD BE DEPLETED IN 9 YEARS"*

Figure 2: World oil production by type
http://www.worldenergyoutlook.org/docs/weo2010/key_graphs.pdf

OIL AND GAS ARE RUNNING OUT

Supplies of cheap, conventional oil and gas are declining while our energy demands continue to increase. It is clear that our reliance on fossil fuels cannot continue indefinitely. With the world's population projected to increase to over nine billion over the next 40 years, "business-as-usual" is not an option.

According to the International Energy Agency (IEA)[4] , production from known oil and gas reserves will fall by around 40-60 per cent by 2030. Yet the developed world's thirst for energy is unabated, while demand is rocketing in emerging economies, such as China, India and Brazil. If everyone in the world used oil at the same rate as the average Saudi, Singaporean or U.S. resident, the world's proven oil reserves would be used up in less than 10 years[5]. Competition for fossil fuel resources is a source of international tension, and potentially conflict.

Energy companies are increasingly looking to fill the gap with unconventional sources of oil and gas, such as shale gas, oil from deep water platforms like BP's Deepwater Horizon, or the Canadian tar sands. But these come at an unprecedented cost – and not just in economic terms. Many reserves are located in some of the world's most pristine places – such as tropical rainforests and the Arctic – that are vital for biodiversity and the ecosystem services that we all depend on, from freshwater to a healthy atmosphere. Extracting them is difficult and dangerous, and costly to businesses, communities and economies when things go wrong.

Processing and using unconventional fossil sources produces large quantities of greenhouse gasses and chemical pollution, and puts unsustainable demands on our freshwater resources, with severe impacts on biodiversity and ecosystem services.

4. IEA, World Energy Outlook (WEO), 2009, Paris.
5. Per capita oil consumption in the U.S. and Canada is about 3 tons annually, in Saudi Arabia about 5 tons and in Singapore 10 tons. Proven oil reserves are estimated at about 205 billion tons in 2010 (BP, Statistical Review, 2010)

*Proven oil reserves are estimated 1,349 billion barrels. Oil consumption in the U. S. 18.86 million barrels per day. World population is 6.9 billion.

FOSSIL FUEL SOURCING

Map 2: *Oil Claims in Africa : P. Hearn, Jr., T. Hare, et. al., Global GIS Database: Complete Global Set, 2002 © AMO*

CLIMATE CHANGE IS ALREADY A REALITY

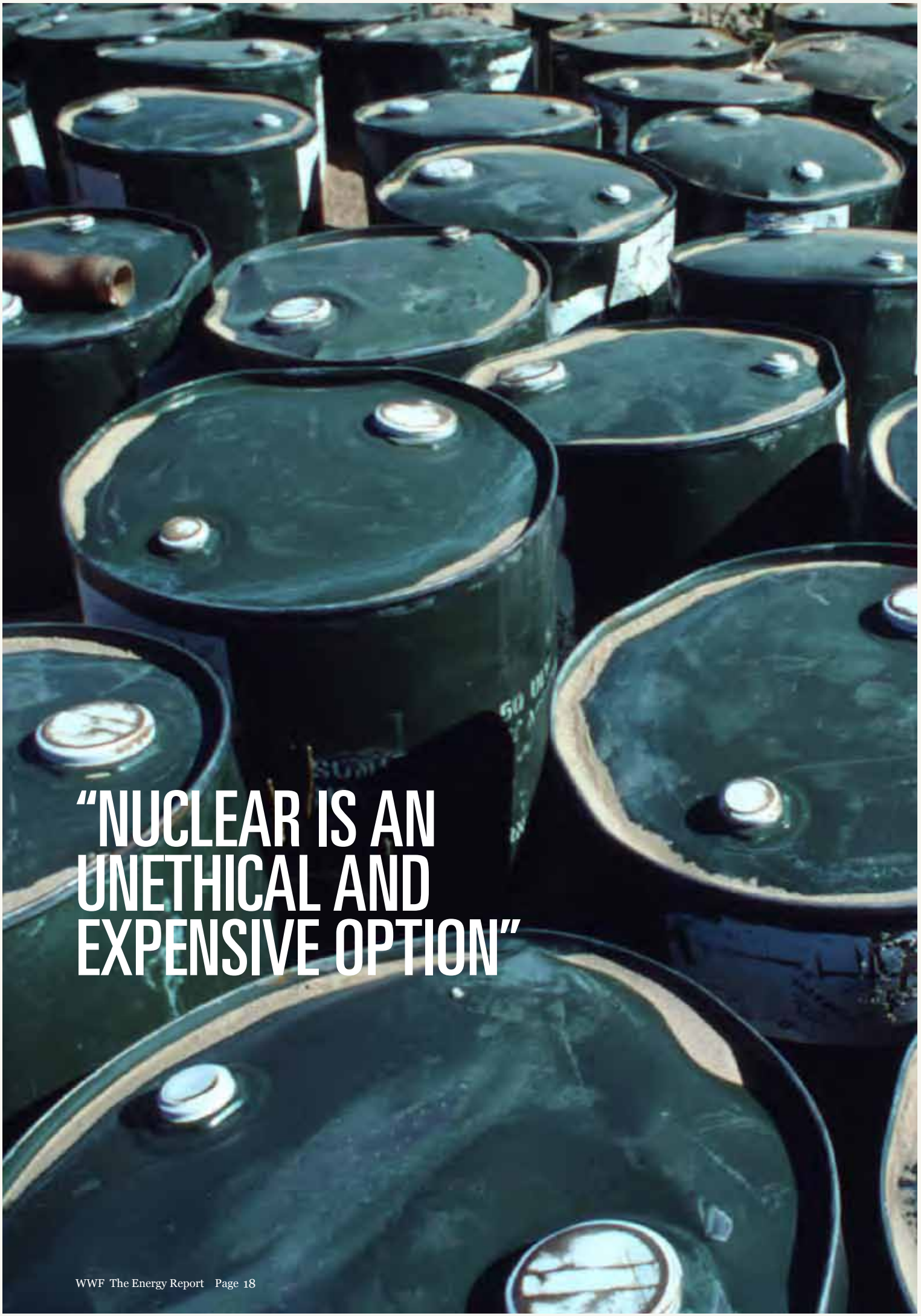
Even if fossil fuel supplies were infinite, we would have another compelling reason for an urgent switch to renewable energy: climate change. Hundreds of millions of people worldwide are already affected by water shortages, crop failures, tropical diseases, flooding and extreme weather events – conditions that are likely to be made worse by increasing concentrations of greenhouse gasses in the Earth's atmosphere. The WHO estimates that climate change is already causing more than 150,000 deaths a year[6].

Global warming threatens the fragile balance of our planet's ecosystems, and could consign a quarter of all species to extinction[7]. The loss of ecological services from forests, coral reefs and other ecosystems will also have huge economic implications[8].The costs of adapting to climate change will be colossal: a recent report suggests that by 2030, the world may need to spend more than €200 billion a year on measures such as building flood defences, transporting water for agriculture and rebuilding infrastructure affected by climate change[9].To avoid devastating consequences, we must keep eventual global warming below 1.5°C compared to pre-Industrial temperatures. To have a chance of doing that, global greenhouse gas emissions need to start falling within the next five years, and we need to cut them by at least 80 per cent globally by 2050 (from 1990 levels) – and even further beyond that date.

The global energy sector holds the key. It is responsible for around two-thirds of global greenhouse gas emissions, an amount that is increasing at a faster rate than for any other sector. Coal is the most carbon-intensive fuel and the single largest source of global greenhouse gas emissions. Embracing renewable energy, along with ambitious energy-saving measures, is the best way to achieve the rapid emissions reductions we need.

6. http://www.who.int/globalchange/news/fsclimandhealth/en/index.html
7. http://www.nature.com/nature/journal/v427/n6970/abs/nature02121.html
8. For a report on the effects of climate change on ecosystem services, see The Economics of Ecosystems and Biodiversity (TEEB) TEEB Climate Issues Update. September 2009
9. Martin Parry, Nigel Arnell, Pam Berry, David Dodman, Samuel Fankhauser, Chris Hope, Sari Kovats, Robert Nicholls, David Satterthwaite, Richard Tiffin, Tim Wheeler (2009) Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates, International Institute for Environment and Development and Grantham Institute for Climate Change, London.

CLIMATE CHANGE IS ALREADY A REALITY



© Donald Miller / WWF-Canon

"NUCLEAR IS AN UNETHICAL AND EXPENSIVE OPTION"

NUCLEAR WASTE WILL BE DANGEROUS FOR 10,000 YEARS

For some, nuclear power is seen to be a part of the solution to the energy crisis. It produces large-scale electricity with low carbon emissions – although mining and enriching uranium is very energy intensive.

But we cannot escape the reality that nuclear fission produces dangerous waste that remains highly toxic for thousands of years – and there is nowhere in the world where it can be stored safely. The United States and Germany alone have accumulated more than 50,000 and 12,000 tonnes respectively, of highly radioactive waste which has not yet been disposed of securely. According to the U.S. Environmental Protection Agency, it will be at least 10,000 years before its threat to public health is substantively reduced.

Equally troubling, the materials and technology needed for nuclear energy can also be used to produce nuclear weapons. In a politically unstable world, spreading nuclear capability is a dangerous course to take.

Nuclear is no 'easy' technology. It requires a highly sophisticated and trained staff, and only works on a large scale, providing power around the clock. It is certainly not a viable way to provide electricity for the 1.4 billion people whom are currently denied it[10], many of whom live in remote places in fragile states.

Nuclear power is also an extremely expensive option. Before pouring billions into creating a new generation of nuclear power stations, we need to ask whether that money would be better invested in other, sustainable energy technologies.

10. IEA, World Energy Outlook (WEO), 2010, Paris

Map 3: Operational nuclear reactors
P. Hearn, Jr., T. Hare, et. al., Global GIS Database: Complete Global Set, 2002

WWF'S PERSPECTIVE

Climate change threatens to undo everything that conservation organizations like WWF have achieved over the last half-century. Polar bears may make the headlines, but in reality very few species will be unaffected by a changing climate. Many species could become extinct. Even entire ecosystems – such as coral reefs, mountain habitats, and large blocks of tropical rainforests such as the Amazon – could completely disappear.

Many plants and animals that have adapted to their environment over millions of years are vulnerable to even slight changes in temperature and rainfall. Warming and acidifying seas threaten coral reefs and krill – the basis of the marine food chain in many parts of the world. Large mammals like whales and elephants may be forced to travel further in search of food, leaving the safety of the protected areas that WWF and others have fought so hard to secure.

As part of the interwoven web of life, humans will not be immune to the consequences of a changing climate. WWF's mission is to protect the magnificent array of living things that inhabit our planet and to create a healthy and prosperous future in which humans live in harmony with nature. Solving the energy crisis is fundamental to this, whatever tough choices and challenges it brings.

"WE PREDICT, ON THE BASIS OF MID-RANGE CLIMATE-WARMING SCENARIOS FOR 2050, THAT 15–37% OF SPECIES IN OUR SAMPLE OF REGIONS AND TAXA WILL BE 'COMMITTED TO EXTINCTION'"*

** Thomas C.D. et al, 2004, Extinction risk from climate change. Nature, Vol 427, No. 8*

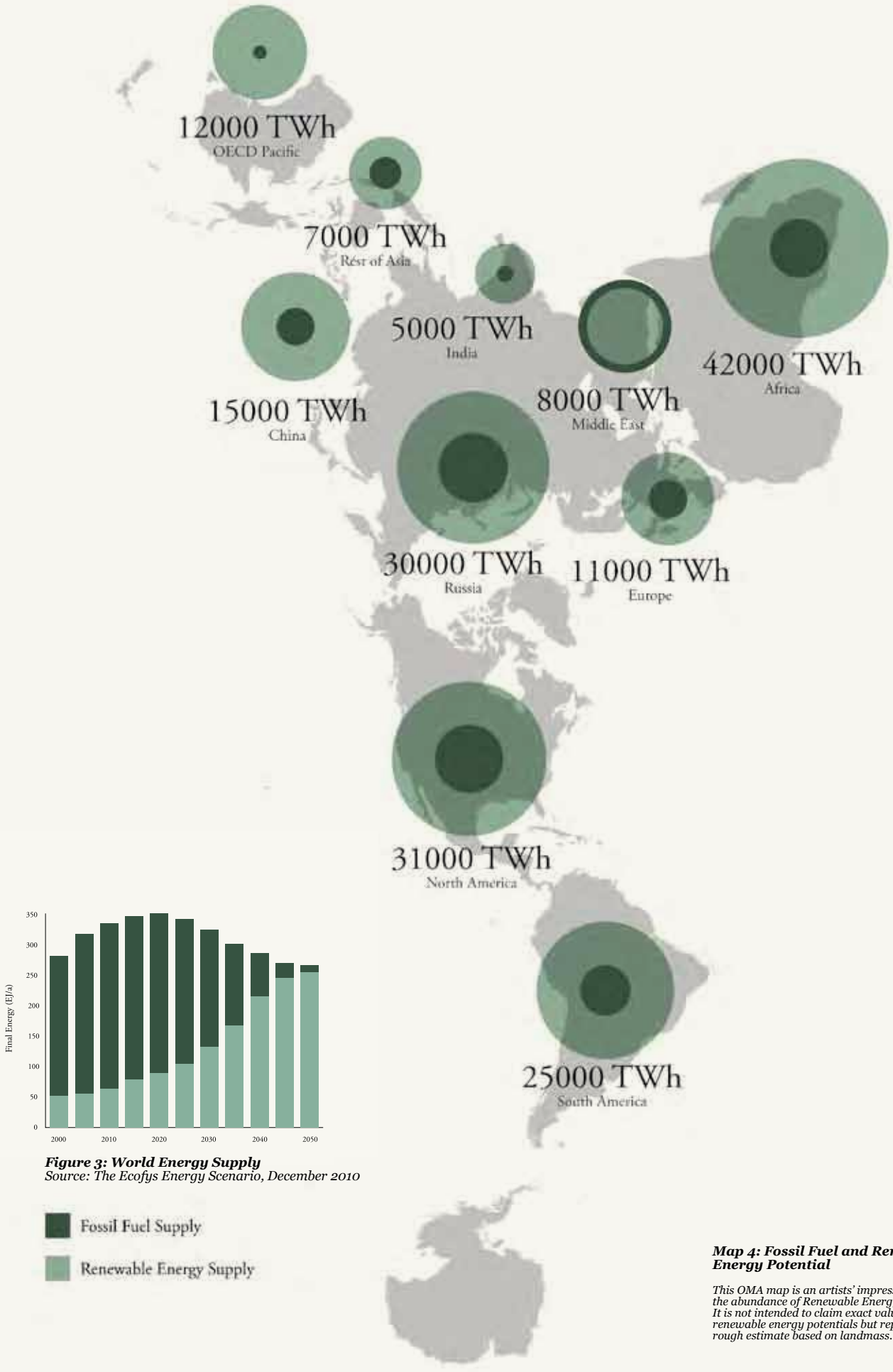


Figure 3: World Energy Supply
Source: The Ecofys Energy Scenario, December 2010

Map 4: Fossil Fuel and Renewable Energy Potential

This OMA map is an artists' impression showing the abundance of Renewable Energy potentials. It is not intended to claim exact values for renewable energy potentials but represents a rough estimate based on landmass.

100% POSSIBLE

Switching to a fully renewable energy supply by 2050 is achievable, but there are challenges to overcome.

The global energy crisis is a daunting challenge. Yet we do not have to look far for the solutions. Energy derived from the sun, the wind, the Earth's heat, water and the sea has the potential to meet the world's electricity needs many times over, even allowing for fluctuations in supply and demand. We can greatly reduce the amount of energy we use through simple measures like insulating buildings, recycling materials and installing efficient biomass stoves. Biomass from waste, crops and forest resources has potential to provide a renewable source of energy – although this raises significant social and environmental issues, which we will discuss later in this report.

Around the world, people are taking steps in the right direction. In 2009, China added 37GW of renewable energy, bringing its total renewable capacity to 226GW – equivalent to four times the capacity required to satisfy the total peak electrical power consumption of Great Britain[11] or over twice the total electric capacity of Africa![12] In Europe and the U.S., more than half of all new power capacity installed in 2009 came from renewable sources. In the developing world, more than 30 million households have their own biogas generators for cooking and lighting. Over 160 million use "improved" biomass stoves, which are more efficient and produce less greenhouse gas and other pollutants. Solar water heating is used by 70 million households around the world. Wind power capacity has grown by 70 per cent, and solar power (PV) by a massive 190 per cent in the last two years (2008 and 2009). During the same period, total investment into all renewables has increased from about $US 100 billion in 2007 to more than $US 150 billion in 2009[13].

But the pace of change is far too slow. Non-hydro renewables still only comprise a mere 3 per cent of all electricity consumed. Huge quantities of fossil fuels continue to be extracted and used, and global carbon emissions are still rising. Government subsidies and private investments in fossil fuels and nuclear power ventures still vastly outweigh those into renewable energy and energy efficiency, even though the latter would give a far greater long-term return. While thousands of houses throughout the world, especially in Germany and Scandinavia, have been built to "passive house" standards that require almost no energy for heating and cooling, many more construction projects follow old-fashioned, energy-inefficient designs.

Moving to a fully renewable energy future by 2050 is a radical departure from humanity's current course. It is an ambitious goal. But WWF believes that it is a goal we can and must achieve. This conviction led us to establish a collaborative partnership with Ecofys, one of the world's leading climate and energy consultancies. We commissioned Ecofys to assess whether it would be possible to secure a fully renewable, sustainable energy supply for everyone on the planet by 2050.

The Ecofys scenario, which forms the second part of this report, is the most ambitious analysis of its kind to date. It demonstrates that it is technically feasible to supply everyone on the planet in 2050 with the energy they need, with 95 per cent of this energy coming from renewable sources. This would reduce greenhouse gas emissions from the energy sector by about 80 per cent while taking account of residual land-based emissions from bioenergy production.

The task ahead is, of course, a huge one, raising major challenges. However, the scenario Ecofys has mapped out is practically possible. It is based only on the technologies the world already has at its disposal, and is realistic about the rate at which these can be brought up to scale. Although significant investment will be required, the economic outlay is reasonable, with net costs never rising above 2 per cent of global GDP. The Ecofys scenario accounts for projected increases in population, long-distance travel and increased economic wealth – it does not demand radical changes to the way we live.

The scenario detailed by Ecofys for this report is not the only solution, nor is it intended to be a prescriptive plan. Indeed, it raises a number of major challenges and difficult questions – particularly for a conservation organization like WWF – which we will discuss in more detail on the following pages. To realize our vision of a 100 per cent renewable and sustainable energy supply, we need to further advance the Ecofys scenario; and we propose some of the social and technological changes that could help us do this.

In presenting the Ecofys scenario, WWF aims to show that a fully renewable energy future is not an unattainable utopia. It is technically and economically possible, and there are concrete steps we can take – starting right now – to achieve it.

11. Figures for UK energy demand come from the National Grid's website: http://www.nationalgrid.com/uk/Electricity/Data/Demand+Data/
12. EIA World Electric Data 2006 http://www.eia.doe.gov/iea/elec.html
13. Renewables 2010 Global Status Report, REN 21.

"WE CAN REDUCE OUR RELIANCE ON FOSSIL FUELS BY 70% BY 2040"*

** Source: The Ecofys Energy Scenario, December 2010*

THE ECOFYS SCENARIO IN A NUTSHELL[14]

In 2050, energy demand is 15 per cent lower than in 2005. Although population, industrial output, passenger travel and freight transport continue to rise as predicted, ambitious energy-saving measures allow us to do more with less. Industry uses more recycled and energy-efficient materials, buildings are constructed or upgraded to need minimal energy for heating and cooling, and there is a shift to more efficient forms of transport.

As far as possible, we use electrical energy rather than solid and liquid fuels. Wind, solar, biomass and hydropower are the main sources of electricity, with solar and geothermal sources, as well as heat pumps providing a large share of heat for buildings and industry. Because supplies of wind and solar power vary, "smart" electricity grids have been developed to store and deliver energy more efficiently.

Bioenergy (liquid biofuels and solid biomass) is used as a last resort where other renewable energy sources are not viable – primarily in providing fuels for aeroplanes, ships and trucks, and in industrial processes that require very high temperatures. We can meet part of this demand from waste products, but it would still be necessary to grow sustainable biofuel crops and take more wood from well-managed forests to meet demand. Careful land-use planning and better international cooperation and governance are essential to ensure we do this without threatening food and water supplies or biodiversity, or increasing atmospheric carbon.

By 2050, we save nearly €4 trillion per year through energy efficiency and reduced fuel costs compared to a "business-as-usual" scenario. But big increases in capital expenditure are needed first – to install renewable energy-generating capacity on a massive scale, modernize electricity grids, transform goods and public transport and improve the energy efficiency of our existing buildings. Our investments begin to pay off around 2040, when the savings start to outweigh the costs. If oil prices rise faster than predicted, and if we factor in the costs of climate change and the impact of fossil fuels on public health, the pay-off occurs much earlier.

14. A table summarising all energy data is provided on pages 231 and 232 of the Ecofys scenario.

"BY 2050, WE SAVE NEARLY €4 TRILLION PER YEAR THROUGH ENERGY EFFICIENCY AND REDUCED FUEL COSTS"

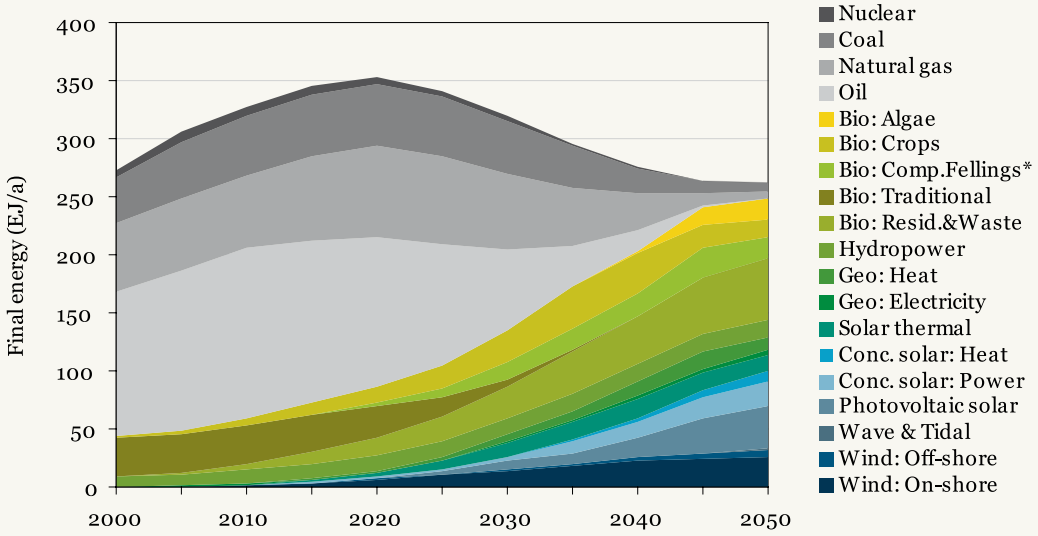
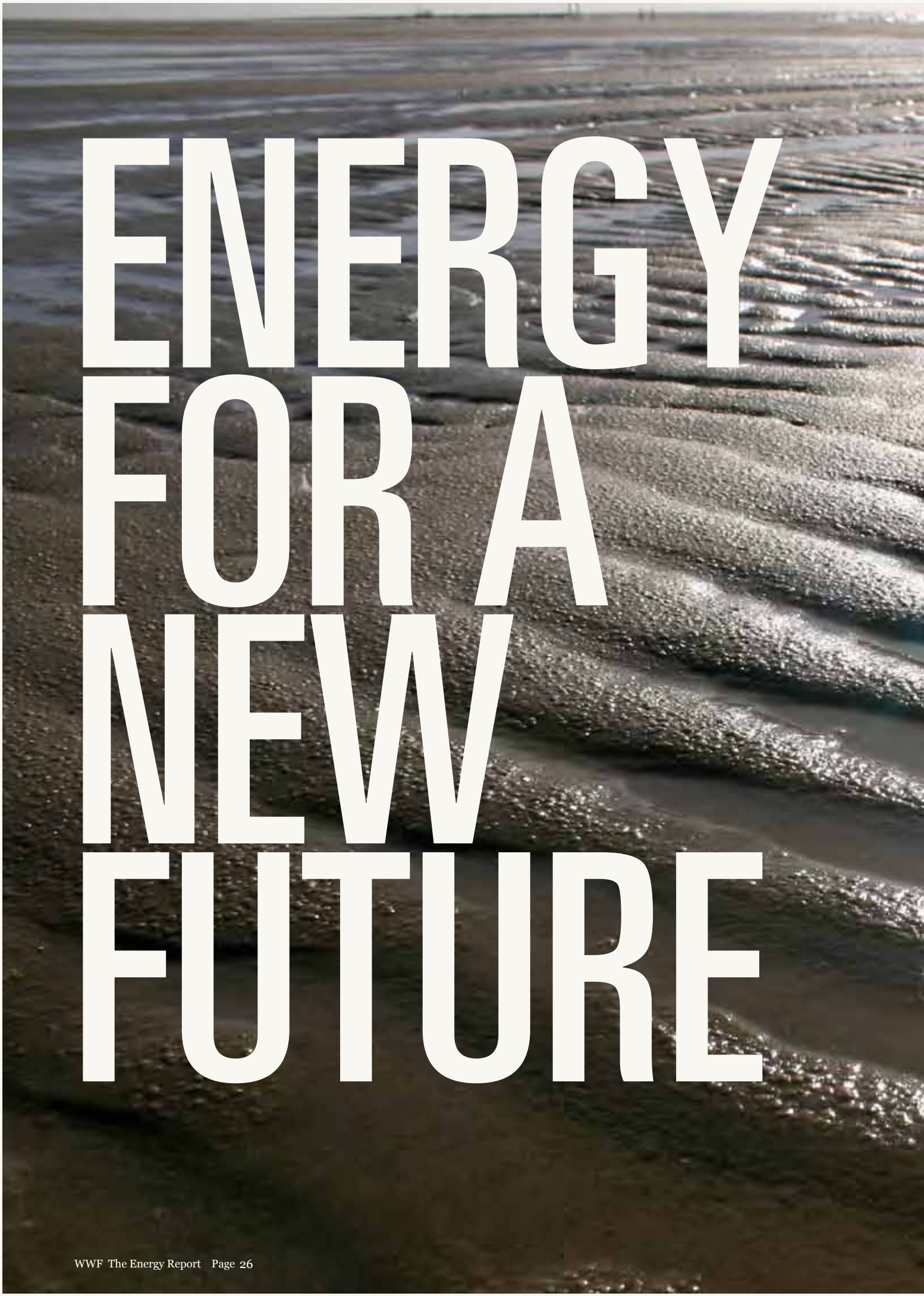


Figure 4: World Energy Supply by Source.
The Ecofys Energy Scenario, December 2010

Map 5: Global Population Density 2010

Gridded Population of the World, version 3 (GPWv3) and the Global Rural-Urban Mapping Project (GRUMP) produced by the Center for International Earth Science Information Network (CIESIN) of the Earth Institute at Columbia University.


ENERGY
FOR A
NEW
FUTURE

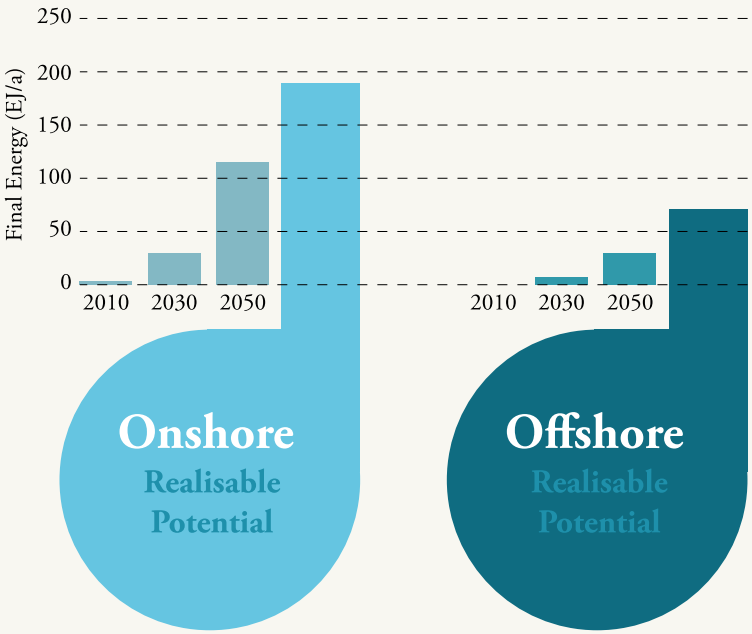
THE ENERGY MIX

Introducing the energy sources of the future

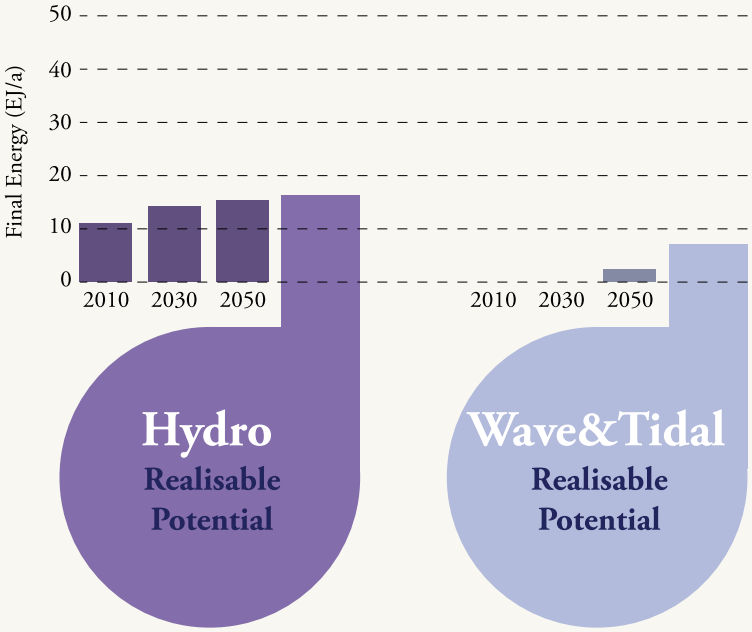
At the moment, more than 80 per cent of our global energy comes from fossil fuels (oil, gas and coal). The remainder comes from nuclear and renewable energy sources, mainly hydropower, and traditional biomass fuels such as charcoal, which are often used inefficiently and unsustainably. Under the Ecofys scenario, fossil fuels, nuclear power and traditional biomass are almost entirely phased-out by 2050, to be replaced with a more varied mixture of renewable energy sources.

The Ecofys scenario takes into account each resource's overall potential, current growth rates, selected sustainability criteria, and other constraints and opportunities such as variability of wind and solar sources. Technological breakthroughs, market forces and geographic location will all influence the ways in which renewable energies are developed and deployed, so the final energy breakdown could well look very different - while still based on 100 per cent sustainable renewables.

Global potential of wind power



Global potential of water power



ENERGY OF THE FUTURE

"IN ORDER TO CUT GLOBAL GREENHOUSE GAS EMISSIONS BY AT LEAST 80% BY 2050, THE WORLD WILL NEED TO TRANSITION TO RENEWABLE ENERGY"

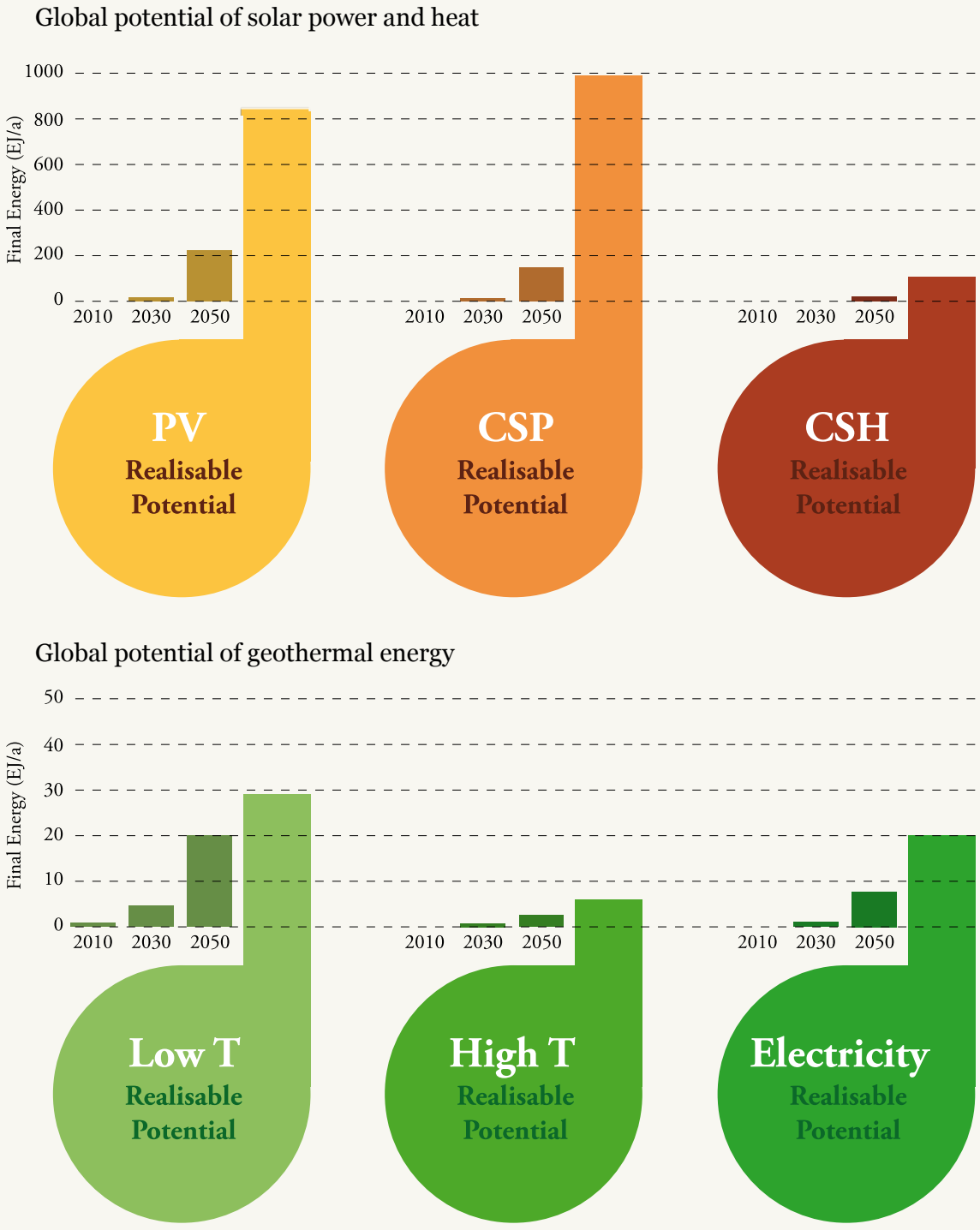
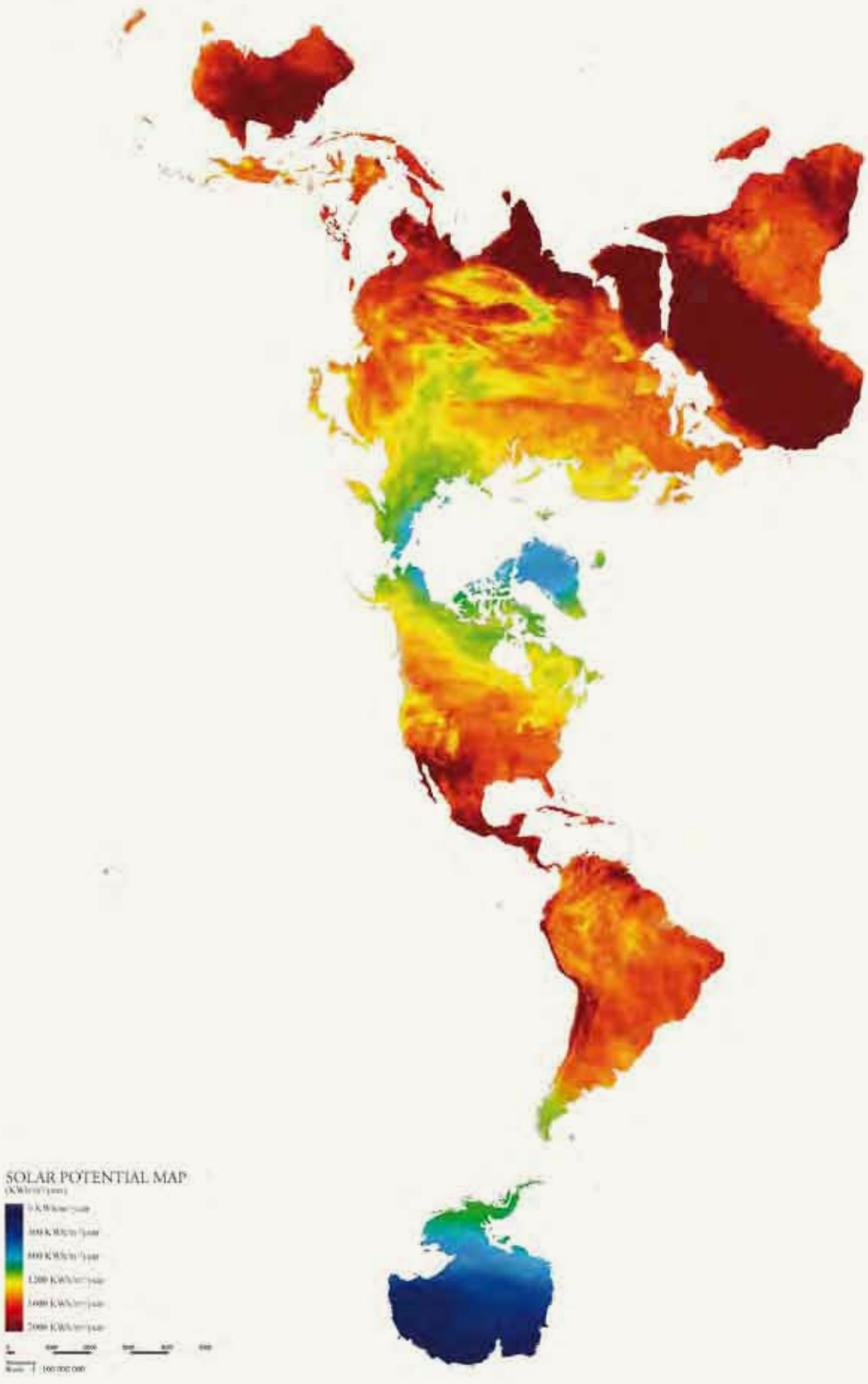
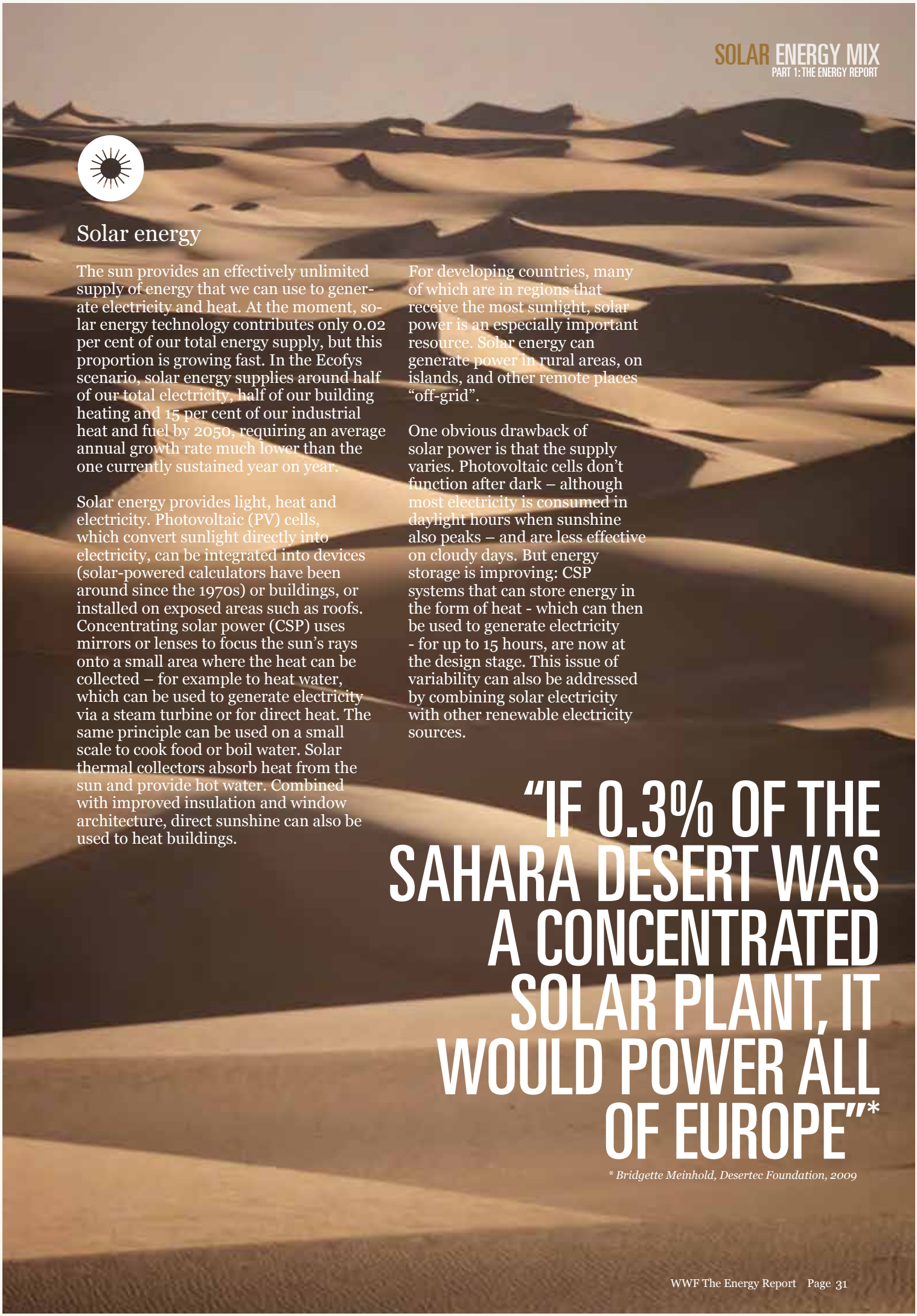


Figure 5: World Renewable Production Potential
The Ecofys Energy Scenario, December 2010
PV - Solar power from photovoltaics
CSP - Concentrating solar power
CSH - Concentrating solar high-temperature heat for industry
Low T - Low temperature heat
Hight T - High temperature heat



Map 6: Global Solar Potential
NASA Map of World Solar Energy Potential



Solar energy

The sun provides an effectively unlimited supply of energy that we can use to generate electricity and heat. At the moment, solar energy technology contributes only 0.02 per cent of our total energy supply, but this proportion is growing fast. In the Ecofys scenario, solar energy supplies around half of our total electricity, half of our building heating and 15 per cent of our industrial heat and fuel by 2050, requiring an average annual growth rate much lower than the one currently sustained year on year.

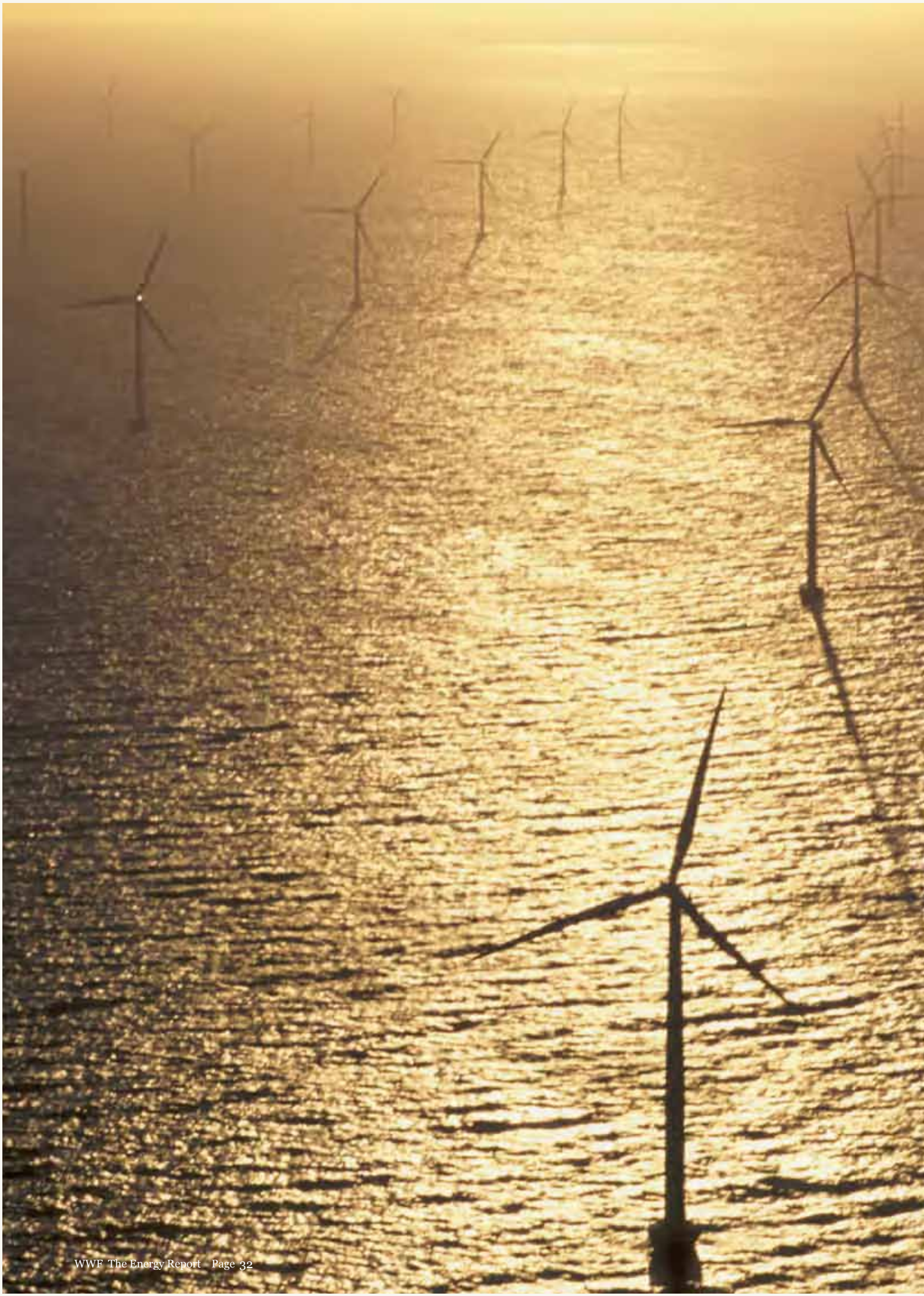
Solar energy provides light, heat and electricity. Photovoltaic (PV) cells, which convert sunlight directly into electricity, can be integrated into devices (solar-powered calculators have been around since the 1970s) or buildings, or installed on exposed areas such as roofs. Concentrating solar power (CSP) uses mirrors or lenses to focus the sun's rays onto a small area where the heat can be collected – for example to heat water, which can be used to generate electricity via a steam turbine or for direct heat. The same principle can be used on a small scale to cook food or boil water. Solar thermal collectors absorb heat from the sun and provide hot water. Combined with improved insulation and window architecture, direct sunshine can also be used to heat buildings.

For developing countries, many of which are in regions that receive the most sunlight, solar power is an especially important resource. Solar energy can generate power in rural areas, on islands, and other remote places "off-grid".

One obvious drawback of solar power is that the supply varies. Photovoltaic cells don't function after dark – although most electricity is consumed in daylight hours when sunshine also peaks – and are less effective on cloudy days. But energy storage is improving: CSP systems that can store energy in the form of heat - which can then be used to generate electricity - for up to 15 hours, are now at the design stage. This issue of variability can also be addressed by combining solar electricity with other renewable electricity sources.

"IF 0.3% OF THE SAHARA DESERT WAS A CONCENTRATED SOLAR PLANT, IT WOULD POWER ALL OF EUROPE"*

** Bridgette Meinhold, Desertec Foundation, 2009*



Wind energy

Wind power currently supplies around 2 per cent of global electricity demand, with capacity more than doubling in the last four years. In Denmark, wind already accounts for one-fifth of the country's electricity production. Wind could meet a quarter of the world's electricity needs by 2050 if current growth rates continue – requiring an additional 1,000,000 onshore and 100,000 offshore turbines. Electricity from offshore wind is less variable, and turbines can be bigger.

Although wind farms have a very visible effect on the landscape, their environmental impact is minimal if they are planned sensitively. When turbines are sited on farmland, almost all of the land can still be used for agriculture, such as grazing or crops. Unlike fossil fuel and nuclear power plants, wind farms don't need any water for cooling. Both on- and offshore wind developments need to be sensitively planned to minimise the impact on marine life and birds, and more research is needed in this area. Floating turbines, which would have less impact on the seabed and could be sited in deeper water, are being trialled.

"AN ADDITIONAL 1,000,000 ONSHORE AND 100,000 OFFSHORE WIND TURBINES WOULD MEET A QUARTER OF THE WORLD'S ELECTRICITY NEEDS BY 2050"*

** Source: The Ecofys Energy Scenario, December 2010*

Geothermal energy

The ancient Romans used the heat from beneath the Earth's crust to heat buildings and water, but only relatively recently have we begun to rediscover its potential. Under the Ecofys scenario, more than a third of building heat comes from geothermal sources by 2050. This is not restricted to volcanically active areas: direct geothermal heat can provide central heating for buildings in almost all parts of the world[15].

When temperatures are high enough, geothermal energy can be used to generate electricity and local heating, including high-temperature heat for industrial processes. Unlike wind or solar power, which vary with the weather, geothermal energy provides a constant supply of electricity. Iceland already gets a quarter of its electricity and almost all of its heating from its molten "basement". In the Philippines, geothermal plants generate almost a fifth of total electricity[16].

Geothermal electric capacity is growing at around 5 per cent each year; the Ecofys analysis suggests we could reasonably hope to at least double this growth rate to provide about 4 per cent of our total electricity in 2050. Geothermal would also provide 5 per cent of our industrial heat needs. Exploiting geothermal resources will undoubtedly affect the surrounding environment and the people who live there. Geothermal steam or hot water used for generating electricity contains toxic compounds, but "closed loop" systems can prevent these from escaping. If sites are well chosen and systems are in place to control emissions, they have little negative environmental impact. In fact, because geothermal plants need healthy water catchment areas, they may actually strengthen efforts to conserve surrounding ecosystems[17].

15.Direct geothermal heat should not be confused with heat pumps, which are included on the demand-side in the Ecofys scenario and provide heat in addition to geothermal energy.
16. http://www.geo-energy.org/pdf/reports/GEA_International_Market_Report_Final_May_2010.pdf
17. See: Geothermal Projects in National Parks in the Philippines: The Case of the Mt. Apo Geothermal Project,
Francis M. Dolor, PNOC Energy Development Corporation

"BY 2050, MORE THAN A THIRD OF BUILDING HEAT COULD COME FROM GEOTHERMAL SOURCES"*

**Ecofys Energy Scenario, 2010*


"IF WE COULD HARNESS 0.1% OF THE ENERGY IN THE OCEAN, WE COULD SUPPORT THE ENERGY NEEDS OF 15 BILLION PEOPLE"*

Ocean power

The motion of the ocean, through both waves and tides, provides a potentially vast and reliable source of energy – but there are significant challenges in converting it into electricity. Several pilot projects are underway to harness wave energy and to design sustainable tidal systems, but this is a relatively new technology. Recognising this constraint, the Ecofys scenario assumes that ocean power accounts for only 1 per cent of global electricity supply by 2050. However, it is likely to provide a significantly larger percentage in some particularly suitable areas, like America's Pacific Northwest and the British Isles.

Wave and tidal power installations could affect the local marine environment, coastal communities, as well as maritime industries such as shipping and fishing. It is critical that appropriate sites are selected and technologies developed that minimize any negative impacts.

** M.M. Bernitsas, et al., Vortex Induced Vibration Aquatic Clean Energy): A New Concept in Generation of Clean and Renewable Energy from Fluid Flow" OMAE '06*

Hydropower

Hydropower is currently the world's largest renewable power source, providing nearly one-fifth of all electricity worldwide. Large-scale hydropower plants store water in a reservoir behind a dam, and then regulate the flow according to electricity demand. Hydropower can provide a relatively reliable source of power on demand, helping to balance variable sources like wind and solar PV.

However, hydropower can have severe environmental and social impacts. By changing water flow downstream, dams threaten freshwater ecosystems and the livelihoods of millions of people who depend on fisheries, wetlands, and regular deposits of sediment for agriculture. They fragment habitats and cut-off fish access to traditional spawning grounds. Creating reservoirs means flooding large areas of land: 40-80 million people worldwide have been displaced as a result of hydroelectric schemes[18].

The Ecofys scenario reflects these concerns with a relatively small increase in hydropower. Hydropower would provide 12 per cent of our electricity in 2050 compared with 15 per cent today. New hydropower schemes would need to meet stringent environmental sustainability and human rights criteria, and minimize any negative impacts on river flows and freshwater habitats.

18. http://www.internationalrivers.org/en/way-forward/world-commission-dams/world-commission-dams-framework-brief-introduction

"NEW HYDROPOWER SCHEMES WOULD NEED TO MEET STRINGENT ENVIRONMENTAL SUSTAINABILITY AND HUMAN RIGHTS CRITERIA"

Bio energy

Energy from biomass – materials derived from living or recently living organisms, such as plant materials or animal waste – is potentially the most challenging part of the Ecofys scenario. Bioenergy comes from a large variety of sources and is used in many different ways. Wood and charcoal have traditionally provided the main source of fuel for cooking and heating for hundreds of millions of people in the developing world. More recently, biofuels have begun to replace some petrol and diesel in vehicles.

In principle, biomass is a renewable resource – it is possible to grow new plants to replace the ones we use. Greenhouse gas emissions are lower than from fossil fuels, provided there is enough regrowth to absorb the carbon dioxide released, and good management practices are applied. Bioenergy also has potential to provide sustainable livelihoods for millions of people, particularly in Africa, Asia and Latin America. However, if produced unsustainably its environmental and social impacts can be devastating. We need comprehensive policies and mandatory certification to ensure bioenergy is produced to the highest standards.

Although the Ecofys scenario favours other renewable resources wherever possible, there are some applications where bioenergy is currently the only suitable replacement for fossil fuels. Aviation, shipping and long-haul trucking require liquid fuels with a high energy density; they cannot, with current technology and fuelling infrastructure, be electrified or powered by hydrogen. Some industrial processes, such as steel manufacturing, require fuels not only for their energy content, but as feedstocks with specific material properties. By 2050, 60 per cent of industrial fuels and heat will come from biomass. 13 per cent of building heat will come from biomass and some biomass will still be needed in the electricity mix (about 13 per cent), for balancing purposes with other renewable energy technologies.

We can derive a significant proportion of the bioenergy needs in the Ecofys scenario from products that would otherwise go to waste. These include some plant residues from agriculture and food processing; sawdust and residues from forestry and wood processing; manure; and municipal waste. Using these resources up to a sustainable level has other environmental benefits, such as cutting methane and nitrogen emissions and water pollution from animal slurry, and reducing the need for landfill. In developing countries, more than 30 million households have their own biogas digesters for cooking and lighting. Some residues and waste products are already used, for example as soil conditioners; the Ecofys scenario accounts for these.

The second major source of biomass comes from forests. According to the Ecofys scenario, we will need more than 4.5 billion cubic metres of wood products for energy purposes by 2050 coming from harvesting and processing residues, wood waste and "complementary fellings" – the difference between the amount of wood we use and the maximum amount that we could sustainably harvest in forests that are already used commercially. This is preferable to taking wood from virgin forests and disturbing important habitats, although more intensive forestry is bound to affect biodiversity. In addition, some of the biomass traditionally used for heating and cooking in the developing world, which will largely be replaced by renewable energy sources such as solar energy, can also be used for more efficient bioenergy uses. All the same, meeting demand sustainably will be a huge challenge.

Bioenergy crops provide a possible source of liquid fuel – either vegetable oils from plants such as rapeseed, or in the form of ethanol derived from crops high in sugar, starch or cellulose. The Ecofys scenario suggests we will need around 250 million hectares of bioenergy crops – equal to about one-sixth of total global cropland – to meet projected demand. This has the potential to cause deforestation, food and water shortages, and other social and environmental impacts, so must be considered with utmost care.

With an expected 2 billion more mouths to feed by 2050, it is vital that increased biofuel cultivation does not use land and water that is needed to grow food for people or to sustain biodiversity. This is no easy challenge. While Ecofys has applied a series of safeguards in its analysis, land and water implications of bioenergy feedstock production will need further research, especially at the landscape level.

A possible long-term alternative source of high-density fuel included in this scenario is algae. Algae can be grown in vats of saltwater or wastewater on land not suitable for agriculture. Large-scale cultivation of algae for biofuel is currently in development. In the Ecofys scenario, algae begins to appear as a viable energy source around 2030, and only a fraction of its potential is included by 2050.

The apparent need for large amounts of land for bioenergy is the aspect of the Ecofys scenario that produces the hardest challenges and raises the hardest questions. We will discuss these further on pages 60-61.

Map 7: World biomass potential
Artist's impression, OMA

THE CHAL-LENGES AHEAD

THE CHALLENGES AHEAD

The Ecofys analysis shows that the world can technically meet its energy needs from renewable sources by 2050. But it throws up some difficult challenges – and not just technical ones. The social, environmental, economic and political issues this report raises are equally pressing.

On the technical side, two key factors will enable the world to meet its energy needs from renewable sources: (i) We need to reduce demand by improving energy efficiency and reducing wasteful use of energy; and (ii) because electricity and heat are the forms of energy most easily generated by renewables, we need to maximize the use of electricity and direct heat, with improvements to electricity grids to support this.

A sustainable energy future must be an equitable one. Its impact on people and nature will greatly depend on the way we use our land, seas and water resources. Changes in lifestyle also have a critical role to play.

Moving to a renewable future will mean rethinking our current finance systems. It will also require innovation.

Local, national and regional governance will need to be greatly strengthened to secure an equitable energy future. We need international cooperation and collaboration on an unprecedented level to bridge the gap between the energy-rich and energy-poor, both within and between countries.

These challenges are outlined on the following pages.

ENERGY CONSERVATION

How can we do more while using less energy?

Under the Ecofys scenario, global energy demand in 2050 is 15 per cent lower than in 2005. This is in striking contrast to "business-as-usual" projections, which predict energy demand will at least double. This difference is not based on any reduction in activity – industrial output, domestic energy use, passenger travel and freight transport continue to grow, particularly in developing countries. Instead, reductions come from using energy as efficiently as possible.

Energy conservation is one of the prerequisites of a future powered by renewables. We will not be able to meet the needs of our planet's expected nine billion inhabitants if we continue to use it as wastefully as we do today. It is the single most important element in the Ecofys scenario.

In every sector, solutions already exist that can deliver the massive energy savings we need. The challenge will be in rolling them out on a global scale as soon as possible.

In manufacturing, using recycled materials greatly reduces energy consumption. For example, making new products from recovered aluminium instead of primary aluminium cuts total energy use by more than two-thirds. Stocks of materials that take a lot of energy to produce, such as steel and aluminium, have grown over the past decades, making recycling and reusing materials increasingly viable. Finding alternatives to materials that take the most energy to produce, such as cement and steel, will mean further energy savings.

Product design also has considerable implications for energy use. Making cars with lighter (although not weaker) frames and with new materials, for example, and producing smaller cars reduces both the need for energy-intensive steel in manufacturing and their fuel consumption. Despite some very innovative models on markets already, there is still huge potential to tap into much higher efficiency levels for all energy-hungry appliances.

In the developing world, more than 160 million households now use improved biomass cooking stoves. Simply using a ceramic lining instead of an all-metal design can improve efficiency by up to a half. The stoves cost little, reduce carbon emissions and deforestation from charcoal production, and have immense health benefits. Even more efficient are solar cookers, which simply use and concentrate the heat from the sun. Distributed widely enough, these small-scale solutions add up to a significant reduction in energy demand.

The world already has the architectural and construction expertise to create buildings that require almost no conventional energy for heating or cooling, through airtight construction, heat pumps and sunlight. The Ecofys scenario foresees all new buildings achieving these standards by 2030.

At the same time, we need to radically improve the energy efficiency of our existing buildings. We could reduce heating needs by 60 per cent by insulating walls, roofs and ground floors, replacing old windows and installing ventilation systems that recover heat. Local solar thermal systems and heat pumps would fulfil the remaining heating and hot water needs. For all buildings to meet these energy efficiency standards by 2050, we will need to retrofit 2-3 per cent of floor area every year. This is ambitious, but not impossible – Germany has already achieved annual retrofit rates in this range.

The world will also need to use less energy for transport. That means making more fuel-efficient models of all forms of transport, and operating them more effectively. Improved air traffic management could reduce congestion and allow planes to follow more efficient routes and landing approaches, making a small but significant reduction in aviation fuel demands. Similarly, better port, route and weather planning, along with reduced speeds, can significantly reduce fuel use in cargo ships.

But we will also need to move to more efficient modes of transport; making greater use of buses, bikes, trams and trains, sending more freight by rail and sea, and swapping short-haul flights for high-speed trains. Indeed, WWF would argue that we need to go further than this, by reducing the number and length of journeys we need to take – by improving urban planning, logistics and communication technology, and reassessing our priorities.

The more energy we save, the easier the task of moving to a renewable energy future will become. It is one area where everyone can play a part.

"THE GLOBAL COST OF LIGHTING IS $230 BILLION PER YEAR. MODERNIZING WASTEFUL TECHNOLOGY COULD SAVE 60%"*

** Mills, E. 2002, "The $230-billion Global Lighting Energy Bill.", International Association for Energy-Efficient Lighting, Stockholm*

DO MORE WITH LESS

"ENERGY EFFICIENCY AND RENEWABLE ENERGY CAN REDUCE OUR DEPENDENCE ON FOSSIL FUELS BY 70% BY 2040"*

** The Ecofys Energy Scenario, December 2010*

WHAT NOW?

- We must introduce legally binding minimum efficiency standards worldwide for all products that consume energy, including buildings, along the lines of the Japanese "Top Runner" scheme and the European EcoDesign requirements. Governments, companies and experts will need to agree standards based on Best-Available-Technology (BAT) benchmarks, which should be monitored and strengthened regularly.

- Energy conservation should be built into every stage of product design. Wherever possible we should use energy-efficient, highly-durable and recyclable materials. Alternatives to materials like cement, steel and plastic that take a lot of energy to produce should be a focus for research and development. We should adopt a "cradle to cradle" design philosophy, where all of a product's components can be reused or recycled once it reaches the end of its life.

- We need strict energy-efficiency criteria for all new buildings, aiming toward near-zero energy use, equivalent to "Passive House" standards. Retrofitting rates must increase quickly to improve the energy efficiency of existing buildings. Governments must provide legislation and incentives to enable this.

- Energy taxation is a realistic option, particularly in wealthier countries. Taxes on petrol, electricity and fuels are already commonplace. Shifting taxes to products and cars that use more energy will help to steer demand toward more efficient alternatives.

- Developing countries must phase-out the inefficient use of traditional biomass, and pursue alternatives such as improved biomass cooking stoves, solar cookers and small-scale biogas digesters. Industrialized countries should facilitate this by providing financial assistance, as part of international development commitments and global efforts to reduce greenhouse gas emissions.

- Substantial investment is needed into public transport to provide convenient and affordable energy-efficient alternatives to private cars. We particularly need to improve rail infrastructure: high-speed trains, powered by electricity from renewable sources, should replace air travel as much as possible, and a maximum proportion of freight should be delivered by rail. Sustainable and public transport modes for all distances, particularly for rail-based transport, must be made cheaper than road- and air-borne traffic.

- Individuals, businesses, communities and nations all need to be more aware of the energy they use, and try to save energy wherever possible. Driving more slowly and smoothly, buying energy-efficient appliances and switching them off when not in use, turning down heating and air conditioning, and increased reusing and recycling are just some ways to make a contribution.

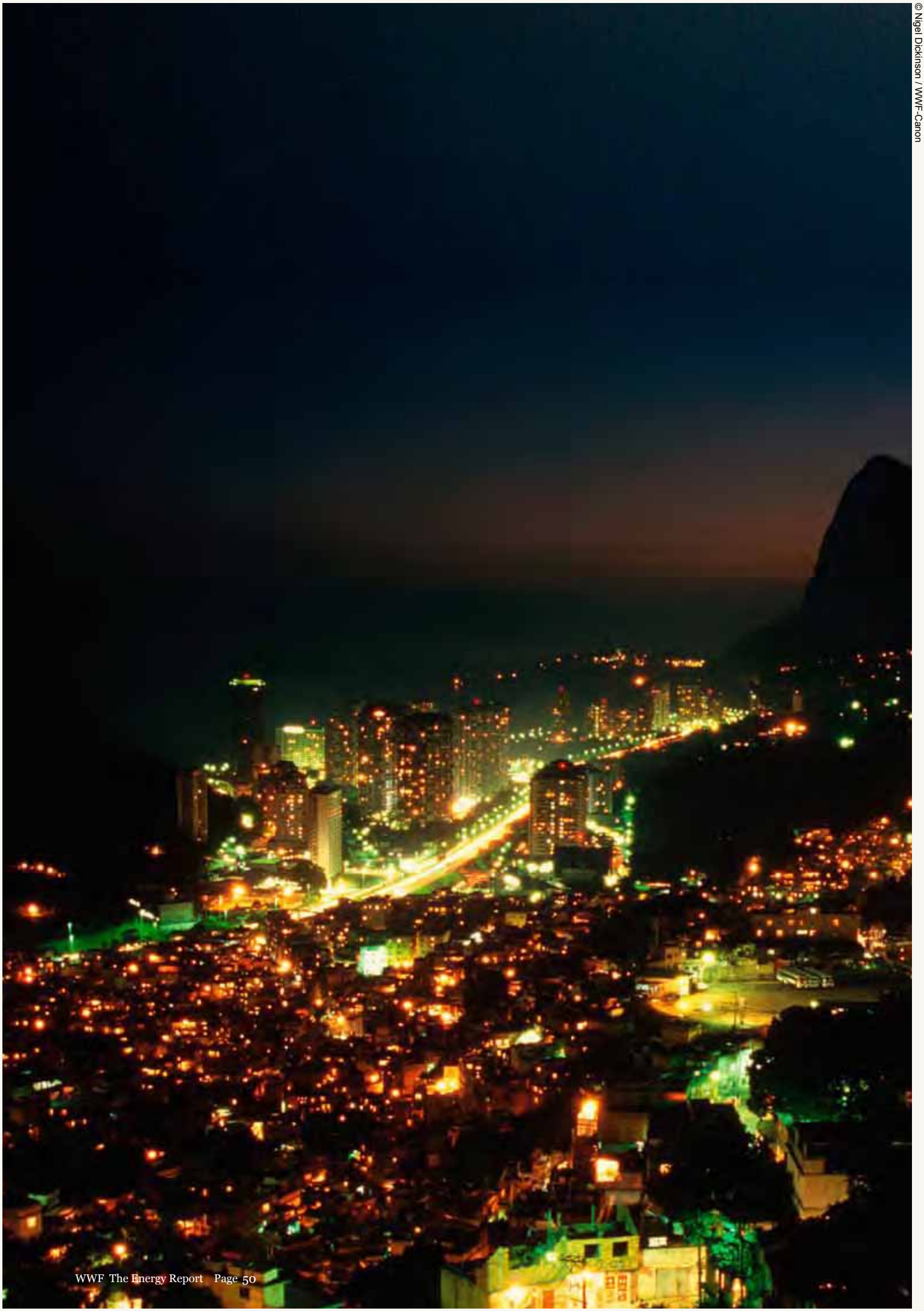
CASE STUDY

© National Geographic Stock / Tyrone Turner / WWF

"WWF HELPED DEVELOP TOPTEN, AN ONLINE SEARCH TOOL THAT IDENTIFIES THE MOST ENERGY-EFFICIENT APPLIANCES ON THE MARKET"

TopTen.info

Consumers and retailers can put pressure on manufacturers to be more energy efficient through their buying choices. WWF helped develop Topten (www.topten.info), an online search tool that identifies the most energy-efficient appliances on the market. Discerning buyers can compare energy-efficiency ratings for a growing number of items, including cars and vans, household appliances, office equipment, lighting, water heaters and air conditioners. Topten now operates in 17 countries across Europe and has recently been launched in the USA and China.



ELECTRIFICATION

Renewable sources could provide effectively unlimited power, but how do we switch onto them?

The Ecofys scenario for a renewable energy future depends upon using electrical power from clean, renewable sources in place of fossil fuels and nuclear wherever possible. Currently, electricity makes up less than one-fifth of our total final energy demand; by 2050, under the Ecofys scenario, it accounts for almost half. Cars and trains, for example, will become fully electrified, while other energy uses (such as fuel to heat buildings) will be minimized.

Using more renewable electricity presents several challenges. First, of course, we need to generate it. That will mean massively increasing our capacity to produce power from the renewable resources with the least environmental impact – through wind, solar and geothermal power technologies in particular. While we will need many more large-scale renewable power plants, we will also generate more power at a local level, using solar PV roof tiles, water wheels and individual wind turbines, for example.

We are going to need massive investment to extend and modernize our electricity grids to cope with increased loads and different energy sources. We need to transmit power efficiently from offshore wind turbines, desert solar parks or remote geothermal plants to urban centres – while minimizing the impact of new power lines or subterranean cables. Efficient international networks will also help balance variable renewable sources from different regions. Within Europe, for example, wind and ocean power from the North Sea area could complement Alpine hydropower and solar power from the Mediterranean and even North Africa.

While solar and wind have the potential to supply an effectively unlimited amount of power, this is constrained by the capacity of electricity grids to deliver it. Our existing grid infrastructure can only manage a limited amount of these variable, supply-driven sources. Grids need to keep electrical voltage and frequency steady to avoid dangerous power surges, and need the capacity to meet peaks in demand. Today, we keep some power stations, notably coal and nuclear, working around the clock to provide a permanent supply of electricity (or "base load"). These power stations cannot simply be switched-off when renewable energy supplies are high, meaning some of this energy goes to waste.

The Ecofys analysis estimates that networks in industrialized countries could take about 20-30 per cent of total electricity from variable sources without further modernization. At a conservative estimate, this will rise to 60 per cent by 2050 through improvements in technology and grid management. The other 40 per cent would come from hydropower, biomass, geothermal electricity and CSP with storage.

The combination of large ("super") and "smart" grids holds the key. Power companies and consumers will get information on energy supply, and price, to help manage demand. Put simply, it will be cheaper to run your washing machine when the wind is blowing or the sun is shining. Households, offices or factories would programme smart meters to operate certain appliances or processes automatically when power supplies are plentiful. Utility companies would adjust electricity flow – for example, by tweaking thermostat temperatures – to cope with spikes in demand. We could also take advantage of times when supply outstrips demand to charge car batteries and to generate hydrogen fuel.

At the same time, we need to bring electricity to those who are not connected to the grid – particularly in rural areas in developing countries. We can do this by extending existing grids, or generating power at the household or community level through solar, micro-hydro, wind power or small-scale biomass plants. Providing the 1.4 billion who have no reliable electricity[19] with a basic supply of 50-100 kWh per year would require investments of about €25 billion per year between now and 2030[20] , or 0.05 per cent of global GDP.

The electricity networks that power our world are one of the great engineering feats of the 20th century. The work we need to do to modernize them over the coming decades will be one of the great feats of the 21st.

19. IEA, World Energy Outlook (WEO), 2010, Paris .
20. IEA, World Energy Outlook (WEO), 2009, Paris

© Adam Oswell / WWF-Canon

WHAT NOW?

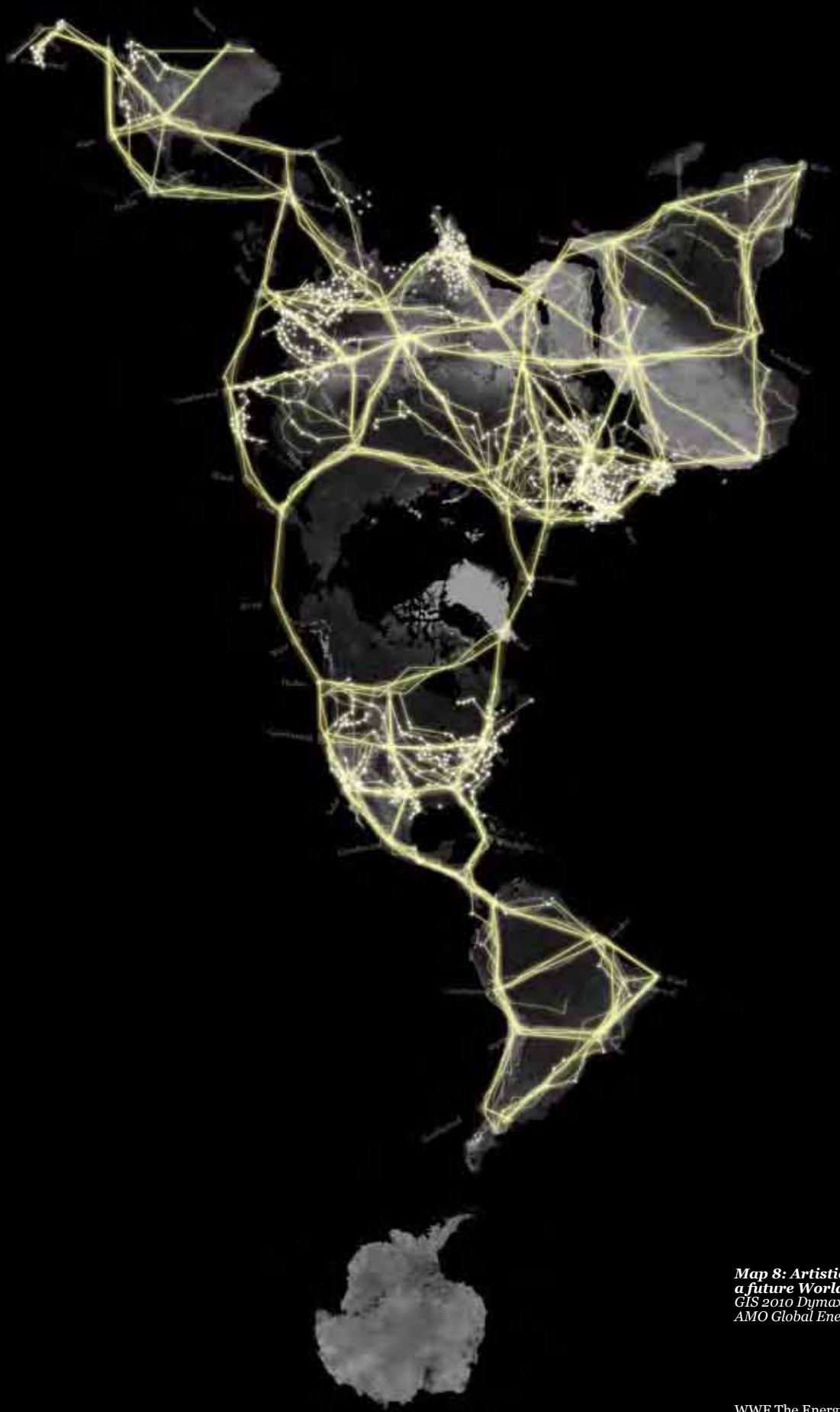
- We need to massively expand our capacity for generating electricity from renewable resources. Large-scale renewable power plants need to be built, before we divert investment into building a new generation of costly and unsustainable fossil fuel and nuclear power plants that could set us back decades. We also need to support local micro-generation, especially in areas where people have limited or no connection to electricity grids.

- Countries need to work together to extend electricity networks to bring power from centres of production to centres of consumption as efficiently as possible. International networks will help meet demand by balancing variable power sources (such as solar PV and wind), supported by constant sources (geothermal, stored CSP, hydro, biomass).

- We need urgent investment into smart grids to help manage energy demand and allow for a significantly higher proportion of electricity to come from variable and decentralized sources. This will help energy companies balance supply and demand more efficiently, and enable consumers to make more informed choices about their electricity use.

- More research is needed into efficient ways to store energy, including batteries, hydrogen and heat storage for solar power. We also need efficient grid management to release this energy when it is needed, and dispatch it over large distances.

- By 2050, all cars, vans and trains globally should run on electricity. We need legislation, investment and incentives to encourage manufacturers and consumers to switch to electric cars. Improvements in battery technology, and emergence of efficient fuel cells, could allow us to run electric trucks, and possibly even ships, reducing our dependence on biofuels. This is a long-term aim, but research and development is needed now.



Map 8: Artistic impression of a future World Energy Grid
GIS 2010 Dymaxion Projection-AMO Global Energy Grid Anaylsis

CASE STUDY

Micro-hydroelectricity

Near the village of Chaurikharka in Nepal, WWF installed a micro-hydroelectricity system as the demand for wood for cooking and heating was leading to deforestation in the area. Water is diverted from a stream to run a generator, then flows back into the stream, with minimal impact. More than 100 households in six villages now use electricity for cookstoves, microwaves, rice cookers, fridges and room heaters. Four more similar schemes are now operating in the area, saving hundreds of tonnes of fuel wood and improving daily life.

"WWF INSTALLED A MICRO-HYDROELECTRICITY SYSTEM AS THE DEMAND FOR WOOD FOR COOKING AND HEATING WAS LEADING TO DEFORESTATION IN THE AREA"

EQUITY

Everyone has the right to energy. So how are we going to provide it?

Historically, the world's energy consumption has not been fairly balanced. Rich countries have built their economies on cheap, plentiful fossil fuels, and continue to consume the vast majority of global energy supplies. With fossil fuel supplies dwindling, the rest of the world will not have this resource to fuel its own development. Adding to this inequity, poorer countries will suffer most from climate change, which is largely driven by the fossil fuel use of wealthier countries.

A sustainable energy future must be a fair one, in which the equal right of every person to benefit from the world's energy resources is recognized. The scale of the challenge is daunting. Around 1.4 billion people – a fifth of the world's population – have no access to reliable electricity[21]. And the population of developing countries continues to rise rapidly. Investments required for universal access to clean cooking for those 2.7 billion in developing countries who have no access to these services will be around €43 billion in total, or around €2 billion annually between 2010 and 2030, less than 0.005 per cent of global GDP[22].

In the absence of alternative sources of energy, hundreds of millions of people today use biomass as their primary source of fuel for cooking and heating. As a result, trees are cut down at unsustainable rates, leading to biodiversity loss, increasing carbon emissions, harming soil quality and leaving communities vulnerable to flooding. Biomass stoves are also a major health problem. Fumes from traditional cooking fires kill almost as many people in the developing world than malaria[23] – about two million women and children die prematurely each year from indoor pollution.

To move to a fully renewable future, in which people live in harmony with nature, we must end unsustainable biomass use. But we cannot do this without providing people with better alternatives. Efficient cookstoves are one simple, cost-effective way to significantly reduce the amount of biomass people use, and the carbon and "black soot" emissions and health impacts this causes. Planting fast-growing tree species for energy production also reduces the need to cut down or degrade primary forests – WWF's New Generation Plantation Initiative outlines sustainable management practices for doing this. These are, though, only part of the solution.

From solar power across Africa, to geothermal power in Indonesia, developing countries have great potential to power economic growth with renewable energy. Large-scale wind, solar and geothermal plants are beginning to appear. Renewables also offer hope to the hundreds of millions of people trapped in energy poverty. WWF is just one of many organizations helping to develop renewable energy projects across the developing world – particularly in rural areas, where approximately 85 per cent of people who have no access to reliable electricity live. As a result of these initiatives, thousands of communities now benefit from electricity from solar power, wind turbines, micro-hydro, and biogas plants fuelled by farming residues and manure.

Access to reliable energy can make a phenomenal difference. Electric pumps provide clean water. Refrigerators store food and medicines. Farms run more productively. Women who used to spend many hours every day collecting firewood and water have more time to devote to education, childcare or advancing their own livelihoods. Children get a better education through access to learning resources like the Internet, or simply by having electric lighting to read in the evenings. Historically, women's emancipation, better education and secure livelihoods have coincided with increased family incomes and hence falling birth rates, so access to sustainable renewable energy can also contribute to curbing population growth.

Biofuels can offer opportunities for developing countries – but they also pose a threat. Grown sustainably and traded fairly, they can provide a valuable cash crop for farmers and jobs for local communities. Without proper safeguards, however, they may displace food crops and drive deforestation, as well as compete for increasingly scarce water. We cannot abide a situation where developing countries grow large amounts of biofuel crops to support the lifestyles of the rich, while their own people do not have enough food to eat.

Renewable energy has tremendous potential to end poverty and transform lives for hundreds of millions of people. Ending energy poverty is at the heart of our energy vision.

WHAT NOW?

Developing countries need investment to develop their own renewable energy capacity. Countries with advanced renewable energy technology need to share their knowledge and expertise with developing countries. They should also support them to develop their own renewable industries and innovations.

WWF and other NGOs have demonstrated ways in which communities can successfully generate their own electricity from renewable sources. Governments, aid agencies and investors should provide support to replicate projects like these on a much larger scale. Experience suggests that schemes are more successful when communities also pay some of the costs, as this increases their ownership of the project. Microfinance schemes and other financial innovations are needed to enable this.

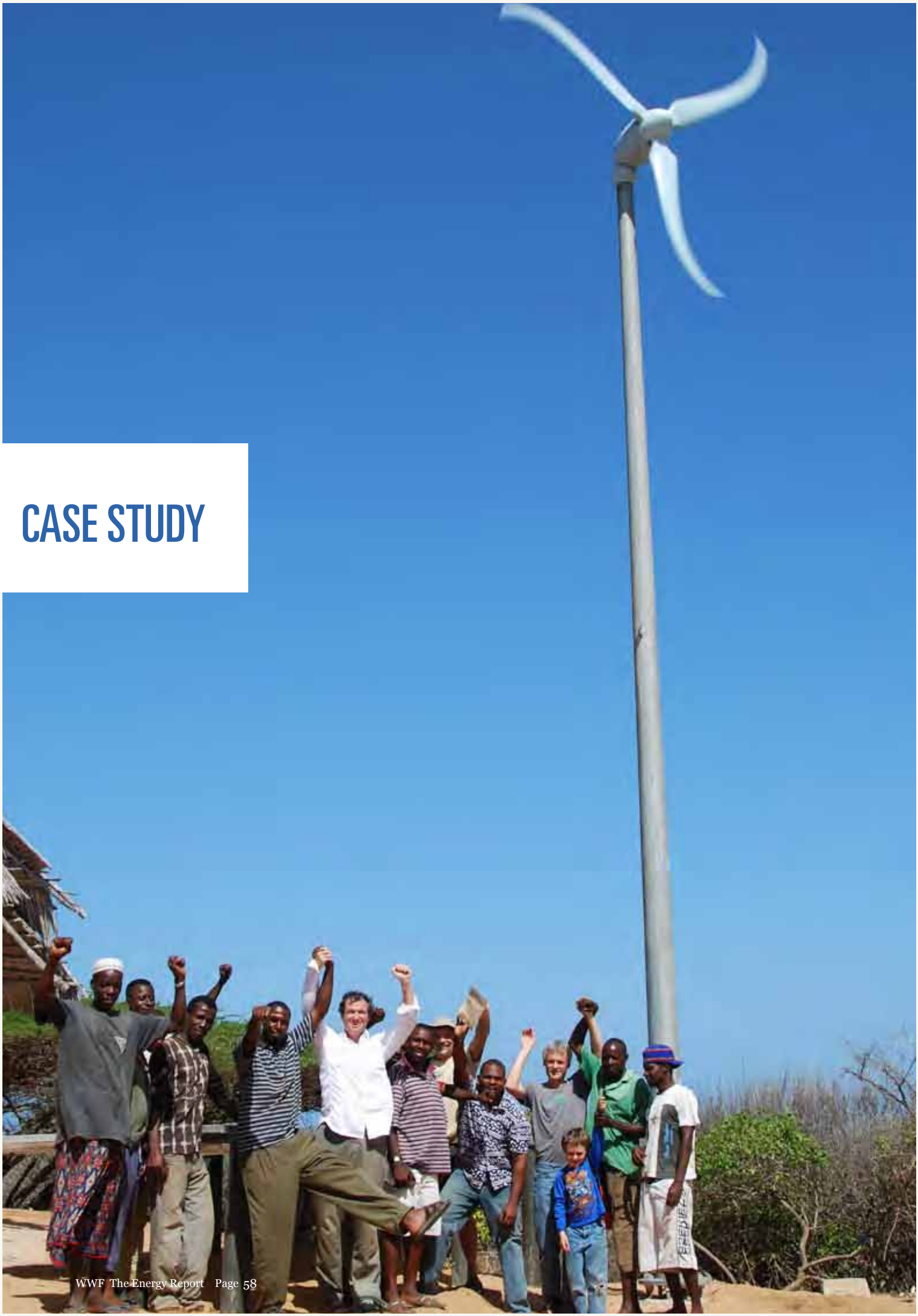
The world needs to begin phasing-out the unsustainable use of biomass. Where communities still use traditional biomass inefficiently as a source of fuel, they need support to switch to modern clean energy solutions. These include solar cooking, more efficient cookstoves, biogas from digesters and improved charcoal-burning techniques. They should also use biomass sources with less environmental impact, such as crop residues or fast-growing tree species. This should form part of a wider programme to enable people to benefit from managing their own forests and natural resources in a sustainable way.

If land in developing countries is used to meet a growing demand for biofuels, we need to tackle the issues of food security, land-use planning, governance, water use, deforestation, loss of biodiversity, and the resulting loss of ecosystem services. We need a fair and sustainable system of trade and investment. Biofuels must not be grown where they threaten people's food and water supplies, or cause biodiversity loss.

Poorer countries need financing to move to a renewable energy future. Multi- and bilateral agreements must include support from richer countries to help poorer countries develop sustainable energy projects. Renewable energy must be at the heart of sustainable development policy and international aid programmes.

21. IEA, World Energy Outlook (WEO), 2010
22. IEA, World Energy Outlook (WEO), 2010
23. Global Alliance for Clean Cookstoves, UN Foundation, http://www.unfoundation.org/assets/pdf/global-alliance-for-clean-cookstoves-factsheet.pdf , retrieved 21 December 2010

CASE STUDY



"WWF HELPED INSTALL SOLAR PV AND WIND POWER, WHICH HAS IMPROVED THE LIVELIHOODS AND HEALTH OF LOCAL PEOPLE"

SOLAR PV AND WIND POWER

There is no grid access in the remote coastal outpost of Kiunga, Kenya, where WWF supports a marine reserve protected area conservation programme. In 2009, WWF helped install solar PV and wind power, which has improved the livelihoods and health of local people. Benefits include a freezer for storing fish, electricity for health centres and charging points for cell phones.

LAND AND SEA USE

Our energy needs require land and sea surfaces. What can we do to limit the impact on people and nature?

Sustainability means living within the capacity of humanity's one and only planet, without jeopardising the ability of future generations to do the same. We need space for buildings and infrastructure, land to grow food and fibres and raise livestock, forests for timber and paper, and seas for food and leisure. More importantly, we need to leave space for nature – and not just because the millions of other species that inhabit our planet are important in themselves. We need healthy ecosystems to supply our natural resources, provide clean air and water, regulate our climate, pollinate our crops, keep our soils and seas productive, prevent flooding, and much more. The way we use our land and sea is key to securing a renewable energy future and perhaps the hardest challenge we face.

Over the coming decades, we will need to develop an extensive renewable energy infrastructure, and it will be essential that we put the right technologies in the right places. Solar farms, for example, can make use of unproductive desert areas, but it is important that no water is used merely for cooling solar power plants in arid areas. Geothermal fields are often found in unspoilt areas, so we need to choose sites carefully to minimize the environmental and social impact, and make sure surrounding areas are well protected. As discussed above, we need to assess all new hydropower plants especially rigorously, and should choose sites for offshore wind and ocean power carefully to minimize the impact on marine life. We also need to carefully plan the routes of the long-distance, high-voltage power lines and undersea cables we will need to transmit electricity from new production centres.

The thorniest issue, however, is the role of bioenergy[24]. The Ecofys scenario for a near-complete phase-out of fossil fuels relies on a substantial increase in the amount of bioenergy. In the absence of alternative technologies, this is based on organic waste, biomass from existing forests and biofuel crops on agricultural land.

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The Ecofys analysis suggests that it is technically possible to do this in a sustainable way. According to the scenario, we can meet the increased need for solid biomass by taking more wood from forests than is already used commercially. If people in the developed world ate half as much meat as they do today, we would need less land for growing animal feed and grazing. That would free-up enough land to grow enough biofuel crops without threatening food security, clearing forests, increasing irrigation or losing biodiversity.

On a global level, there may be enough agriculture and forest land available to grow biofuels sustainably. Ecofys estimates that we would need around 250 million hectares of agriculture land, which is equivalent to about one-sixth of the total global cropland today, as well as 4.5 billion cubic metres of biomass from already disturbed forests. But what is possible on paper, even after the most rigorous analysis, is a different matter in practice. We have yet to identify where this land is, and how it is being used at the moment. We need to consider the rights of communities, including indigenous people, the movements of migratory species, the effect on water supplies, the type of infrastructure and governance systems in place, and a host of other constraints. In fact, the huge pressure we're placing on our planet means we need to take these considerations into account with all agriculture and forestry, and not only with bioenergy.

The land availability in the Ecofys scenario also rests on the assumption of a constrained growth in meat consumption. To achieve this equitably, people in richer countries would need to cut their meat consumption in half, with the rest of the world eating no more than 25 percent more meat than they do now. A diet that is high in animal protein requires far more land than a largely vegetarian diet – it is more efficient to eat plant protein directly than to feed it to animals first. Today, nearly a third of global land area (excluding Antarctica) is used for feeding livestock, either through grazing or growing animal fodder.

As the global population grows, the world is going to need to produce and consume food more efficiently and fairly: this will become even more urgent if our demand for biofuels grows too. Ecofys' calculations are based on crop yields rising by 1 per cent per year. This is less than the 1.5 per cent growth that the UN Food and Agriculture Organization predicts; however, climate change will increase the likelihood of crop failures.

Extracting more wood from forests will have an impact on biodiversity. Many of the world's commercial forests are already intensively used, so expansion will have to happen in areas with untapped sustainable potential. There is the potential to increase yields by using fertilizers and fast-growing species, although this too has implications on wildlife habitats, and water and soil quality. Some privately owned plots could sustainably provide more biomass, but there are economic and logistical hurdles. Any increase in forest biomass use must be coupled with efforts to reduce emissions from deforestation and degradation, and promote more forest growth. In other words, we must not release more forest carbon than we replace, even in the short term.

Because of the concerns bioenergy raises, WWF believes we need to take urgent action to reduce the demand for liquid fuels that the Ecofys scenario predicts, and to pursue alternatives. Further reductions in meat consumption, aviation and long-distance freight transport would help to reduce demand. Bioenergy from algae and hydrogen produced with renewable electricity are potential sustainable fuel technologies. In the meantime, better land-use planning, from the local to the global level, will be vital in securing a sustainable energy supply.

24. For more information on WWF's position on bioenergy, see www.panda.org/renewables

"THE WAY WE USE OUR LAND AND SEA IS KEY TO SECURING A RENEWABLE ENERGY FUTURE, AND PERHAPS THE HARDEST CHALLENGE WE FACE"

WHAT NOW?

- All large-scale energy infrastructure developments must satisfy independent, in-depth, social and environmental impact assessments. They should also meet – or exceed – the best social and environmental management practices and performance standards. The Gold Standard for best practice in projects delivering carbon credits provides a good example. For hydropower, WWF has participated in the development of the International Hydropower Association Sustainability Guidelines.

- To safeguard habitats and food supplies, water supplies and ecosystem services, world governments must stop the scramble for land for biofuels,. "Land-grabbing" – where rich countries buy or lease large tracts of land, especially in Africa, to grow biofuels or food – should be outlawed. Instead, we need to carefully analyze, country by country, what land and water is available for bioenergy, taking into account social, environmental and economic issues.

- Forestry companies, governments and conservationists need to identify areas of idle land (forests that have been cleared already but are no longer in use) where it may be possible to increase yields of biomass with the least impact on biodiversity. South East Asia, Russia and the Americas hold the most potential. WWF is supporting the Responsible Cultivation Area concept, which aims to identify land where production could expand without unacceptable biodiversity, carbon or social impacts. WWF is also helping to identify areas that should be maintained as natural ecosytems and primarily managed for conservation purposes through schemes such as the High Conservation Value Framework.

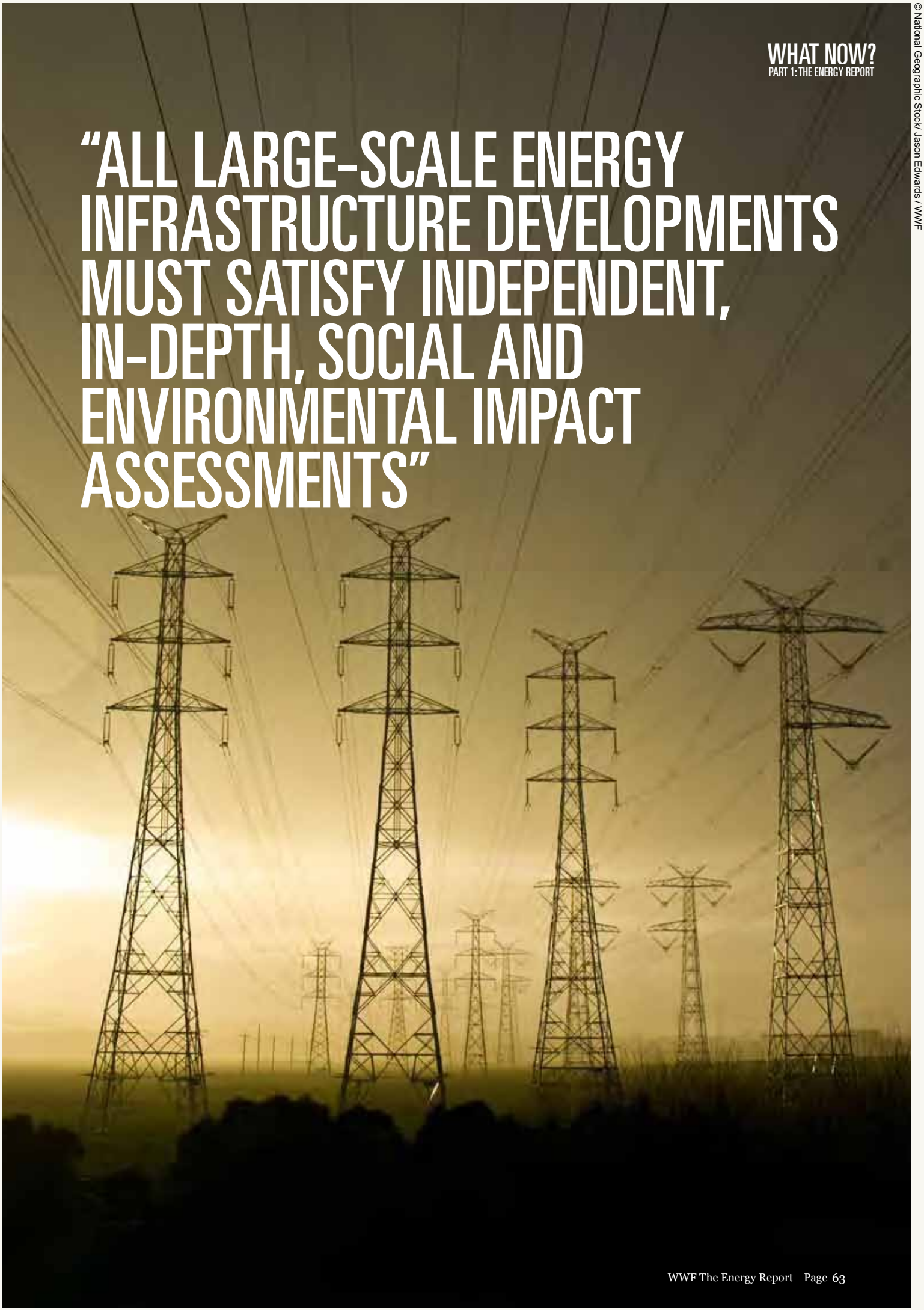
- We need to offset increased forest carbon emissions by stopping unsustainable fellings and deforestation. Schemes such as REDD (Reducing Emissions from Deforestation and Degradation), which offer developing countries incentives to conserve their forest carbon, will play an important role in this. We also need to promote and adopt community forest management and other sustainable forestry practices.

- Bioenergy production has to be based on sustainability criteria with strong legal controls – binding legislation and strict enforcement – at national and international levels. Voluntary standards and certification schemes, along the lines of the Forest Stewardship Council, the Roundtable on Sustainable Biofuels and the Better Sugarcane Initiative, also have a role to play. Because much bioenergy will be produced in developing countries, they will need support to develop and implement these standards effectively.

- As individuals, we need to make more considered choices about the food we eat, the transport we use, and other lifestyle factors that influence global land use. Public policy should help to guide these choices.

- We should limit growth in areas that depend on liquid fuels – notably aviation, shipping and heavy goods vehicles – at least until we have established a secure and sustainable supply of bioenergy. That means finding smarter ways to transport goods and people. These include using modes of transport that don't depend on liquid fuels, and reducing the length and number of journeys, for example by producing more goods locally or working remotely instead of commuting. We also urgently need to research and develop energy alternatives for sectors that rely on bioenergy as the only alternative to fossil fuels.

"ALL LARGE-SCALE ENERGY INFRASTRUCTURE DEVELOPMENTS MUST SATISFY INDEPENDENT, IN-DEPTH, SOCIAL AND ENVIRONMENTAL IMPACT ASSESSMENTS"



“THE SUGARCANE IS USED TO PRODUCE BIOETHANOL. CANE RESIDUES ARE FED TO THE COWS, MAKING-UP FOR THE LOSS OF PASTURE”

BIOETHANOL

In the Brazilian region of Ribeirão Preto, cattle farmers grow sugarcane on some of their land that was previously used for grazing. The sugarcane is used to produce bioethanol. Cane residues are fed to the cows, making-up for the loss of pasture. As there are still only a few cattle per hectare, animal welfare doesn’t suffer, and farmers get an extra source of income.

CASE STUDY

CRITICAL LIFE-STYLE CHOICES

LIFESTYLE

How do the choices we make in our own lives affect energy supplies?

Moving to a renewable energy future doesn't mean sacrificing our quality of life.

The Ecofys scenario shows that we can supply almost all of our energy needs from renewable sources by 2050 while maintaining rates of economic growth and leading prosperous, healthy lifestyles. Indeed, quality of life for many will improve immeasurably with access to electricity and clean energy.

We will, though, need to make wiser choices about the way we use energy. Lifestyle changes will allow us to reach a renewable energy future while reducing our impact on the planet. Since the anticipated need for bioenergy may push our forests, agricultural land and freshwater ecosystems to the limit, we particularly need to look at what we can do to limit bioenergy demand and land-use while aiming at 100 per cent renewables and make more land and water available to sustain people and nature.

To grow enough food to nourish a growing global population, while also having enough land available to meet potential demand for biofuels, many of us will need to change our diets. As mentioned, the Ecofys scenario places limits on meat consumption growth. If future meat consumption is to be split more equitably, this would mean a halving of meat consumption per person by 2050 in OECD countries, and an increase by a quarter elsewhere. If we eat even less meat than this, then more land will be available to grow food or biofuel crops, or to return to nature.

Wasting less food will also save energy and free-up more land. According to Tristram Stuart[25], around half of our food is lost between field and fork...

"Rich countries use up to four times more food than the minimum requirements of their populations (after adding/subtracting imports and exports); surplus is either fed inefficiently to livestock, causing a net loss in food calories, or it is wasted in the supply chain, or eaten in excess of dietary requirements. ... Poor countries have much smaller food supplies: fewer arable crops are fed to livestock, and less is wasted in the home".

Reducing the distance that we transport food and other goods will also reduce the need for biofuels. The Ecofys scenario is based on established "business-as-usual" projections that predict steep rises in freight transport by 2050 – more than doubling in OECD countries and increasing fivefold elsewhere. If we cut rises in long-haul freight transport by a third compared to these projections, it would reduce the land needed for growing crops for transport by around 8 per cent, or 21 million hectares.

Personal mobility is also predicted to rise by 2050. Projections show the overall distance people travel will increase by half in OECD countries, and treble in the rest of the world. Ecofys suggests we can manage these increases if we move towards more efficient forms of transport – walking or cycling short distances, taking buses, and taking the train instead of flying. Improved communications technology will make work more flexible and home-working more viable in many jobs, reducing the need to commute. This would reduce congestion and improve the work-life balance for many. All the same, we will need massive investment in efficient public transport systems, along with fundamental changes in attitudes and behaviour.

Particularly sharp increases are expected in aviation transport, in rich and poor countries alike, and the Ecofys scenario includes these. Flying less would reduce the need for biofuels in the future, and substantially reduce carbon emissions today. A cut in passenger air travel by a third compared to Ecofys projections would reduce the land needed for growing crops for transport by an additional 19 million hectares. Videoconferencing and emerging innovative technologies could reduce the need for business travel. People may also choose to travel more slowly, or holiday closer to home.

Making lifestyle changes will take time. Communities that have collected firewood from forests for centuries will not switch to biogas cookers overnight. The attachment to large and fast cars runs deep in Western society. But history shows that people will change their behaviour when they understand the benefits and when policies steer them in the right direction: recycling is now second nature in many countries, while smoking rates have fallen with growing knowledge of the health risks. A better understanding of the impact of our own choices will help us move toward a fair and fully renewable future in which people live in harmony with nature.

25. Waste - Uncovering the Global Food Scandal. Tristram Stuart, 2009

© Jeffrey A. Sayer / WWF-Canon

Source: placeholder

WHAT NOW?

- Every item we buy, all the food we eat, every journey we take uses energy. All people need to be more aware of the impact their lifestyle has, and what they can do about it. Public policy should help direct people to make wiser choices.

- Wealthier people everywhere should eat less meat, as part of a healthy, balanced diet. Governments, NGOs, individuals and the media need to raise awareness of the connection between our diets and energy needs, ecosystems and climate change. Regulations and pricing should reflect the true environmental and social costs of meat and animal products.

- Food waste by richer people needs to be minimized, and we need to raise awareness that about 50 per cent of all food is wasted and lost worldwide[26]. Consumers can help by only buying and cooking what they need, while food companies and retailers should reassess the way they package and promote perishable items. At a global level we need to re-examine the way we produce and distribute food to rebalance a system in which some regions have more food than they can use, while people in other places struggle.

- Big investments in public transport systems, particularly in emerging economies where personal mobility is growing fastest, are needed to provide an attractive alternative to private cars. Long-distance, high-speed trains powered by electricity from renewable sources need to be developed as an alternative to air travel.

- We need to explore other ways to optimize the distances that people and products travel to deliver the least GHG emissions over the life-cycle of a service or product. In part this means promoting regional economies and the use of local materials. Restaurants and retailers could equally source more regionally produced food that is in season - reducing the need for refrigerated storage. In many walks of life, Internet and mobile phone transactions can reduce the need for travel; employers should support home-working. International businesses should invest in videoconferencing and emerging communication technologies.

- Not everything should be grown or manufactured regionally, and trade between nations is essential to ensure the most effective (and energy efficient) use of resources and goods. Production and consumption of certified sustainable products, e.g. Rainforest Alliance, UTZ Certified, Organic or Fair-Trade, particularly from developing countries, needs to be encouraged. The social and environmental benefits for communities producing these products, and associated environmental benefits, are frequently greater than the environmental impact of the long-distance transport.

26. Lundqvist, J., C. de Fraiture and D. Molden. Saving Water: From Field to Fork - Curbing Losses and Wastage in the Food Chain. SIWI Policy Brief. SIWI, 2008.

CASE STUDY

CUTTING AIR TRAVEL

Curbing the growth in air travel would mean less land is needed for growing biofuels. Under WWF-UK's One in Five Challenge, businesses and organizations are committing to cut 20 per cent of their business flights within five years. A dozen large employers have signed up to the programme, including the Scottish government. Audio, video and web conferencing provide alternatives to face-to-face meetings. It is no coincidence that a telecom firm, BT, became the first company to successfully meet the challenge.

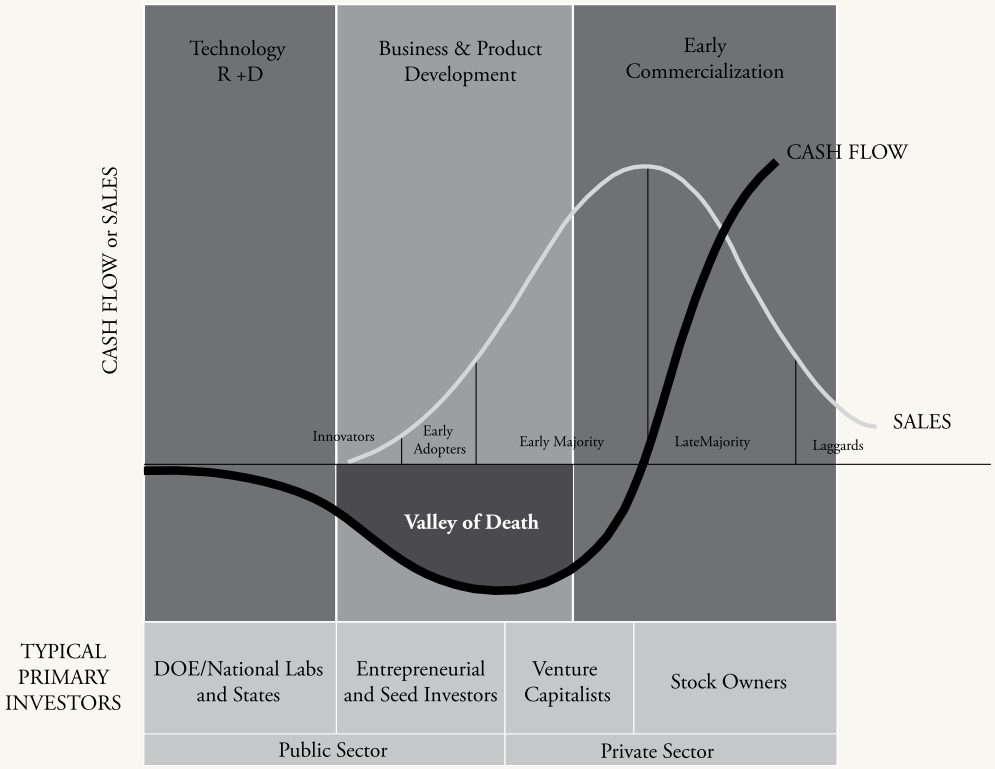


Figure 6: Pay back timeline of research and development in business
LM. Murphy and P.I Edwards, Bridging the Valley of Death: Transitioning from Public to Private Sector Financing, National Renewable Energy Laboratory May, 2003

LONG-TERM OPPORTUNITIES

FINANCE

Renewable energy makes long-term economic sense, but how do we raise the capital needed?

The world is emerging from the worst financial crisis for generations, and many nations are still feeling the effects. Governments are desperate to reduce budget deficits. Banks are reluctant to give credit. Financiers are looking for safe investments. Household budgets are already stretched.

It is not the best time to be looking for an extra €1 trillion a year. But that is what we need to find – now – if we're to move toward a fully renewable energy supply for everyone by 2050.

The investment will pay-off handsomely in the long run. By 2050, we will be saving nearly €4 trillion every year, according to the Ecofys analysis compared to a "business-as-usual" scenario. And that is purely the financial savings that come from reduced operating expenses – mainly fuel – costs. It doesn't take into account the costs we could incur from climate change – up to one-fifth of global GDP, according to the

Stern Review[27]– if we don't radically reduce our greenhouse gas emissions by moving to a renewable energy supply. Nor does it include the added value of the millions of jobs created, or the health and social benefits – such as better air quality and well-being.

But we will need to invest significant capital before we start seeing these returns. Large sums will be needed to install renewable energy-generating capacity on a massive scale, to modernize electricity grids, transform public transport infrastructure and improve the energy efficiency of our existing buildings. Global capital expenditure will need to continue to grow for the next 25 years to around €3.5 trillion a year, but will not rise above 2 per cent of global GDP. At the same time, energy savings and reduced fuel costs mean operating expenditure will soon start to fall. The savings will begin to outweigh the costs by 2040.

Unfortunately, our current financial system is not suited to taking the long view. Investors expect a return within a couple of years. New power developments cannot be left entirely to the free market as long as it is often cheaper to build a coal or gas power station than a wind farm or solar array. We need new financing models, such as public-private partnerships with shared risks, to encourage long-term investment in renewables and energy efficiency. Legislation and stable political frameworks will also help to stimulate investment: in Europe, for example, investors remain wary of supporting offshore wind projects as long as countries continue to squabble over who is responsible for the necessary grid upgrades.

Feed-in tariffs are a key means of creating a more favourable climate for renewable energy. Under these schemes, payments are guaranteed to households, businesses, communities and other organizations that generate their own electricity from renewable sources, such as solar PV or wind power. By guaranteeing a return, feed-in tariffs have proved to be an effective way of encouraging people to invest in renewable energy, and are helping to bring down the price of generating electricity from renewable sources. They now operate in more than 50 countries, plus about 25 U.S. states and parts of China and India[28].

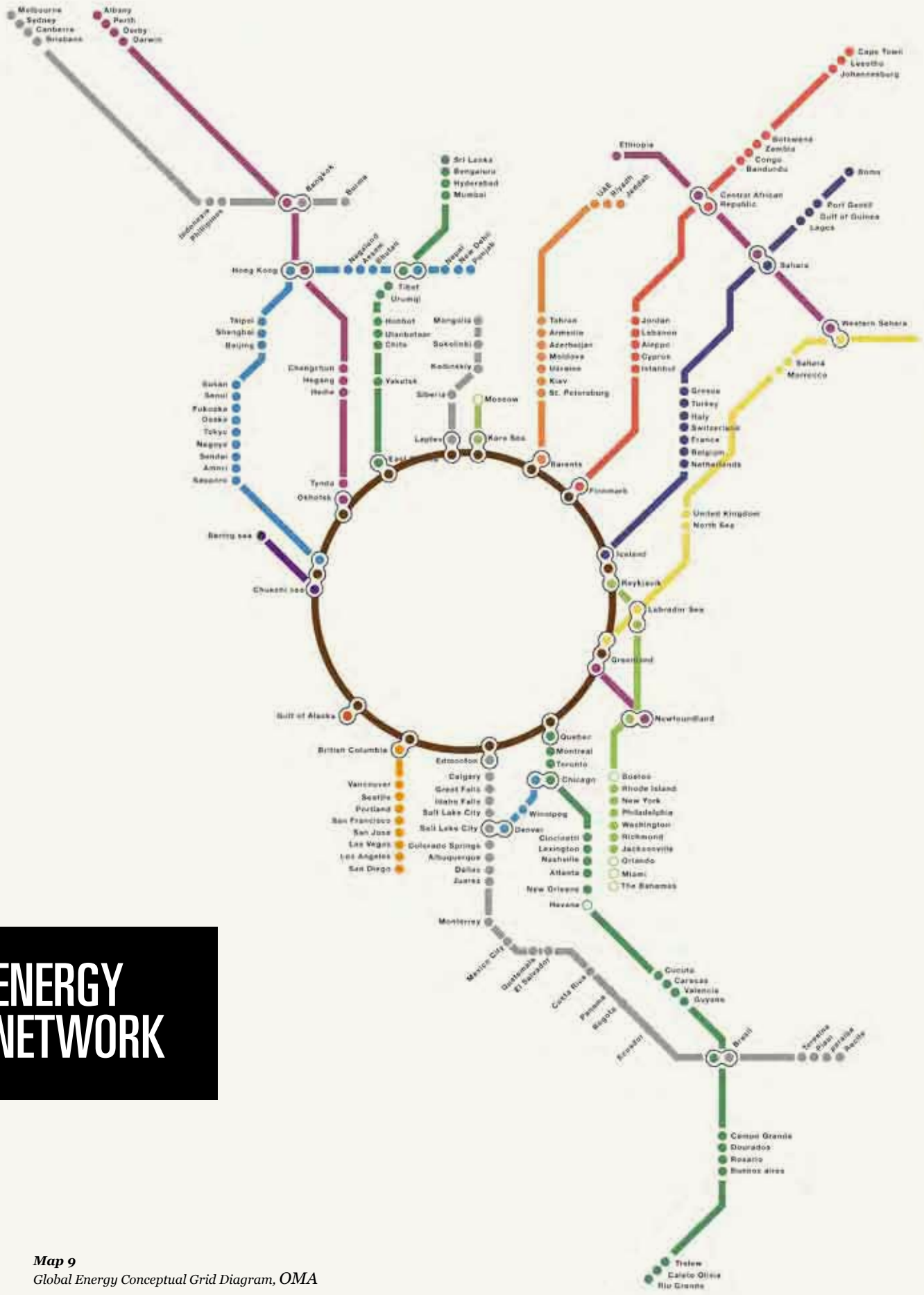
Growing support for renewable energy however, needs to be compared with the subsidies for conventional energy, which still dwarf clean power investment. A recent OECD report calculated the value of global fossil fuel subsidies at US$700 billion per year[29], with around two-thirds of this in developing countries. The aim of these subsidies is often to provide affordable fuel and electricity for poorer people, so they should not be cut outright; instead, the money could be reinvested into providing renewable energy and energy-efficiency measures.

While many governments are cutting public spending, investing in renewable energy could help stimulate economic growth, creating many "green collar" jobs. China recently announced plans to invest 5 trillion yuan (€580 billion) in a new 10-year alternative energy programme that will create 15 million jobs. Germany already employs about 300,000 people[30] in the renewable energy sector. Energy efficiency savings, especially in industry, can also help spur economic competitiveness and innovation.

The economic arguments in favour of moving toward a fully renewable energy supply are persuasive. When we also take into account the environmental and social costs and benefits, the case is undeniable. The challenge now is to overcome the clamour for short-term profits and recognize the long-term opportunities.

27. http://webarchive.nationalarchives.gov.uk/+/http://www.hm-treasury.gov.uk/stern_review_report.htm
28. Renewables 2010, Status Report; REN 21, Paris 2010
29. http://www.worldenergyoutlook.org/docs G20_Subsidy_Joint_Report.pdf
30. http://www.erneuerbare-energien.

ENERGY NETWORK



Map 9
Global Energy Conceptual Grid Diagram, OMA

WHAT NOW?

- We urgently need to create a level playing field for sustainable renewable energy.
Or, even better, one that is tilted in its favour – to reflect the potential long-term benefits. Feed-in tariffs should be extended, with similar schemes introduced for renewable heating. We need to end direct and hidden subsidies to the fossil fuel and nuclear sectors, but without increasing energy prices for the poorest.

- Financial support for renewable energies can only be truly effective if it allows open access to the market, to consumers. Unfortunately, monopolists of existing power supply often prevent exactly that. Thus, proactive, "preferred grid access" for renewables must be a part of any legislation - as currently enacted in the European Union. In most countries and regions that showed an increase in clean power in recent years, this legal provision was critically important.

- We need ambitious cap-and-trade regimes, nationally and internationally, that cover all large polluters, such as coal-fired power stations and energy-intensive industries. Setting a high price on carbon will help to encourage investment in renewable energy and energy efficiency, as well as reducing emissions.

- Global climate negotiations need a strong focus on providing finance and technology to help developing countries build their capacity for generating renewable energy and improving energy efficiency.

- People everywhere should install any effective micro-generation and energy-efficiency measures they can afford – in their own homes, businesses or communities – assuming these make environmental and economic sense. Governments, energy companies and entrepreneurs can encourage this.

- Policy-makers and financial institutions globally need to develop financial instruments that encourage investment in renewable energy.

- Investors should divest from fossil fuel and nuclear energy firms, and buy shares in renewable energy and efficiency-related companies. Anyone with savings can help to tip the balance by choosing banks, pension providers or trust funds that favour renewables.

- Politicians need to clearly support renewable energy and energy efficiency, and create supportive legislation to build investor confidence. Political parties need to reassure investors that broad energy policies will survive a change of government. Throughout the world, national legislation needs to overcome the bias toward the energy status quo, through measures such as legally binding energy-efficiency standards.

- More market incentives could encourage energy efficiency – such as reduced VAT on the most energy-efficient appliances, or varying rates of tax for cars and properties according to their efficiency.

"GEOTHERMAL ENERGY CAN PROVIDE UP TO TEN TIMES CURRENT GLOBAL ENERGY PRODUCTION"*

Green Geothermal

WWF's "Ring of Fire" programme is supporting Indonesia, the Philippines, Malaysia and Papua New Guinea to develop their geothermal potential in a sustainable way. The programme's vision is to increase the countries' geothermal capacity threefold by 2020, through green geothermal investment in the range of €18-40 billion. It may help to create 450,000 extra jobs compared to coal by 2015, and 900,000 by 2020.

*Source: IPCC, Working Group III, "Mitigation of Climate Change", 2007

CASE STUDY

INNOVATION

What advances will make our renewable energy vision a reality?

The energy scenario mapped-out by Ecofys in the second part of this report is ambitious and radical – but it is grounded firmly in what exists today. Only technologies and processes that are already proven have been included. These are sure to be refined and improved in the years ahead, but the report is cautious in estimating their growth potential. This means we have an opportunity to further advance on the Ecofys scenario – to increase the proportion of renewable energy from 95 per cent to 100 per cent by 2050, and to reduce the need for biofuels and the pressure this puts on food and water supplies and the natural world.

R&D INVESTMENT

But to get there, we will need to substantially step-up our research and development (R&D) into renewable energy production and energy efficiency. At the moment, we spend around €65 billion a year globally on R&D in these areas, out of a total global expenditure of around €900 billion on R&D in all sectors[31]. We'll need to double this over the next decade. Under the Ecofys scenario, annual R&D expenditure rises to a high of €170 billion in 2040. Until 2025, the focus is on reducing energy demand – the most pressing requirement. This will come chiefly through developing more efficient materials, industrial processes and vehicle technology, particularly electric cars.

The supply side – particularly renewable power and fuels – becomes increasingly important. As we have seen, smart energy grids that are capable of managing demand and accommodating a much larger proportion of variable electricity have a vital role to play, and will be an important area for R&D. Smart appliances that respond to varying electricity supplies will complement this.

We must also focus on improving storage of electricity generated by wind and solar. Several solutions are already in use. Solar power can be stored as heat. Wind power can be used to turn a flywheel, whose spinning motion then generates electricity when it is needed – a method of storing energy that goes back many centuries. Compressed air storage, which has been around since the 19th century, is another possibility: wind farms pump air underground, then release the compressed air to generate electricity on demand.

Electricity can also be stored in batteries, and battery technology will be a crucial area for development. We have yet to develop batteries that can store enough energy to power trucks over long distances.

Using renewable hydrogen, fuel cells, and electrifying trucking will slash the demand for biofuels – but this is a long way in the future. In the meantime, we need research into efficient biofuels, to find out which crops can produce the most energy for the least amount of land and water. Algae has the potential to provide a truly sustainable source of bioenergy – we need to research ways to produce fuels from algae with the least environmental impact. As a precaution, though, we should avoid locking ourselves into needlessly high levels of demand for liquid fuels.

Hydrogen could also have a major role to play in industry, aviation and shipping, although it provides only a small fraction of energy in 2050 under the Ecofys scenario. Hydrogen is the ultimate renewable fuel: the raw material is water, and water vapour is the only emission. It produces energy either through direct combustion or in fuel cells, and is easily produced through electrolysis, which can be powered by renewable electricity at times of high supply or low demand. However, major challenges remain in storing and transporting it. Intensive R&D into hydrogen could have a major impact on the future energy balance. The British Royal Mail is using hydrogen to fuel postal vans on the Scottish island of Lewis in a pilot project that is being watched with interest.

According to the Ecofys scenario, the world will still need to burn a small amount of coal in 2050 (less than 5 per cent of total energy supply). This is because some industrial processes, such as steel manufacturing, depend on specific chemical properties, as well as the very high temperature heat that it can produce. Research is needed into alternative production processes or materials that will allow us to phase-out fossil fuels altogether.

Technology moves fast. Just 50 years after the Wright Brothers made their first flight, jet planes were carrying passengers from London to Johannesburg. Tim Berners-Lee wrote the first World Wide Web page in 1991, and there are now two billion web users and an immeasurable number of web pages. Given the right political and economic support, human ingenuity will allow us to realize our vision of a 100 per cent renewable energy supply by 2050.

31. Estimated global spending on R&D for 2009 was US$1,140 billion – see http://www.battelle.org/news/pdfs/2009RDFundingfinalreport.pdf

WHAT NOW?

"CURRENTLY, RENEWABLE SOURCES ACCOUNT FOR ONLY 13% OF THE WORLD'S ENERGY PROVISION"*

We need to radically increase investments in researching, developing and commercializing technologies that will enable the world to move toward a 100 per cent renewable energy supply. These include energy-efficient materials, design and production processes, electric transport, renewable energy generation, smart grids and alternative fuels.

At the same time, we should stop pursuing ideas that will lock the world into an unsustainable energy supply, particularly techniques for extracting unconventional fossil fuels. We need to limit the damage from existing power stations, some of which will be with us for decades. One

Figure 7: Collage-image into what the future could be made of.
Everything changes but nothing changes. Invisible revolution.

** IPCC 2007: Working Group III: Mitigation of Climate Change*

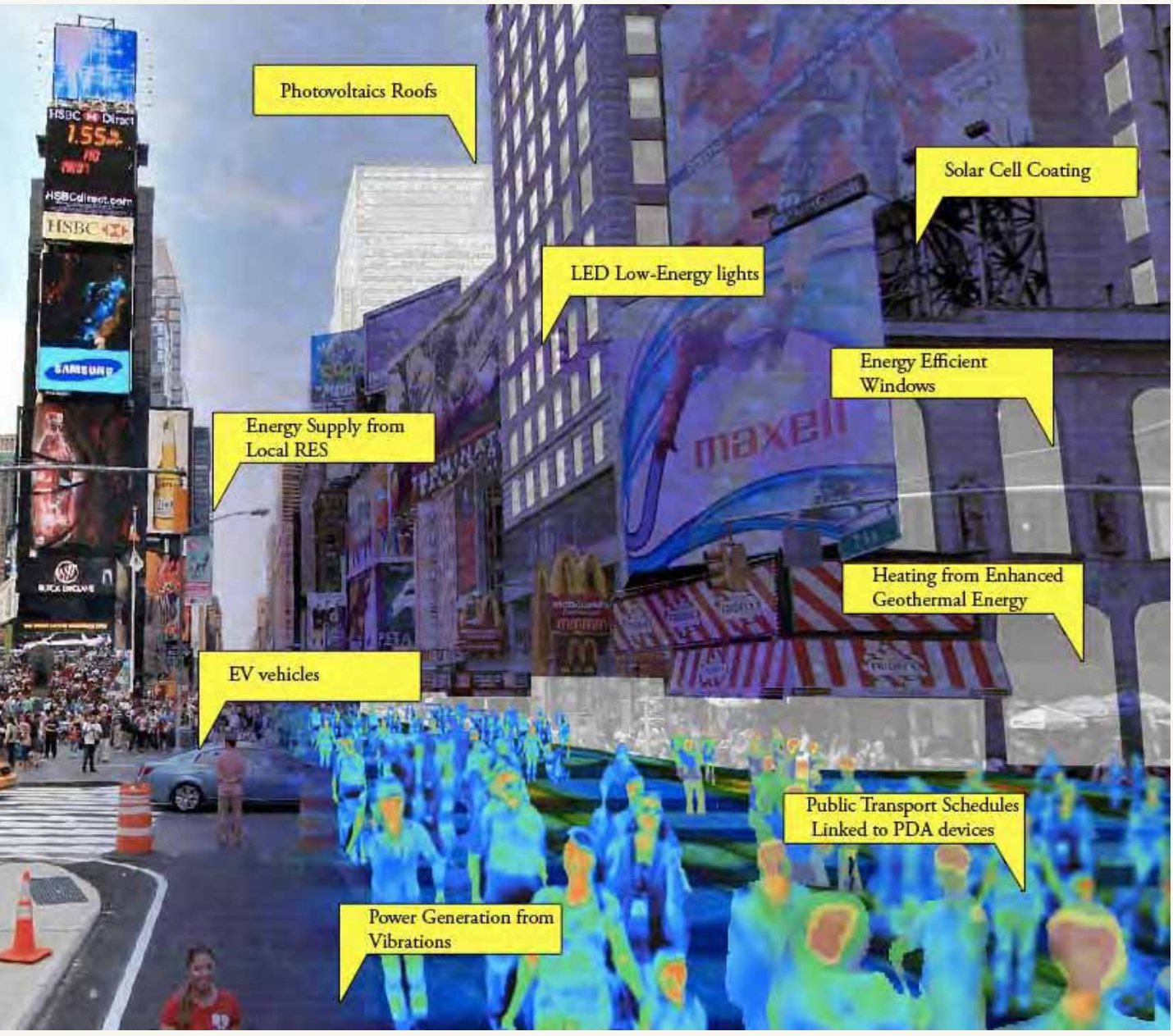
way to do this is through carbon capture and storage (CCS), which we should continue to develop for existing power stations, industrial processes with high carbon emissions (such as cement and steel manufacture), and biomass plants.

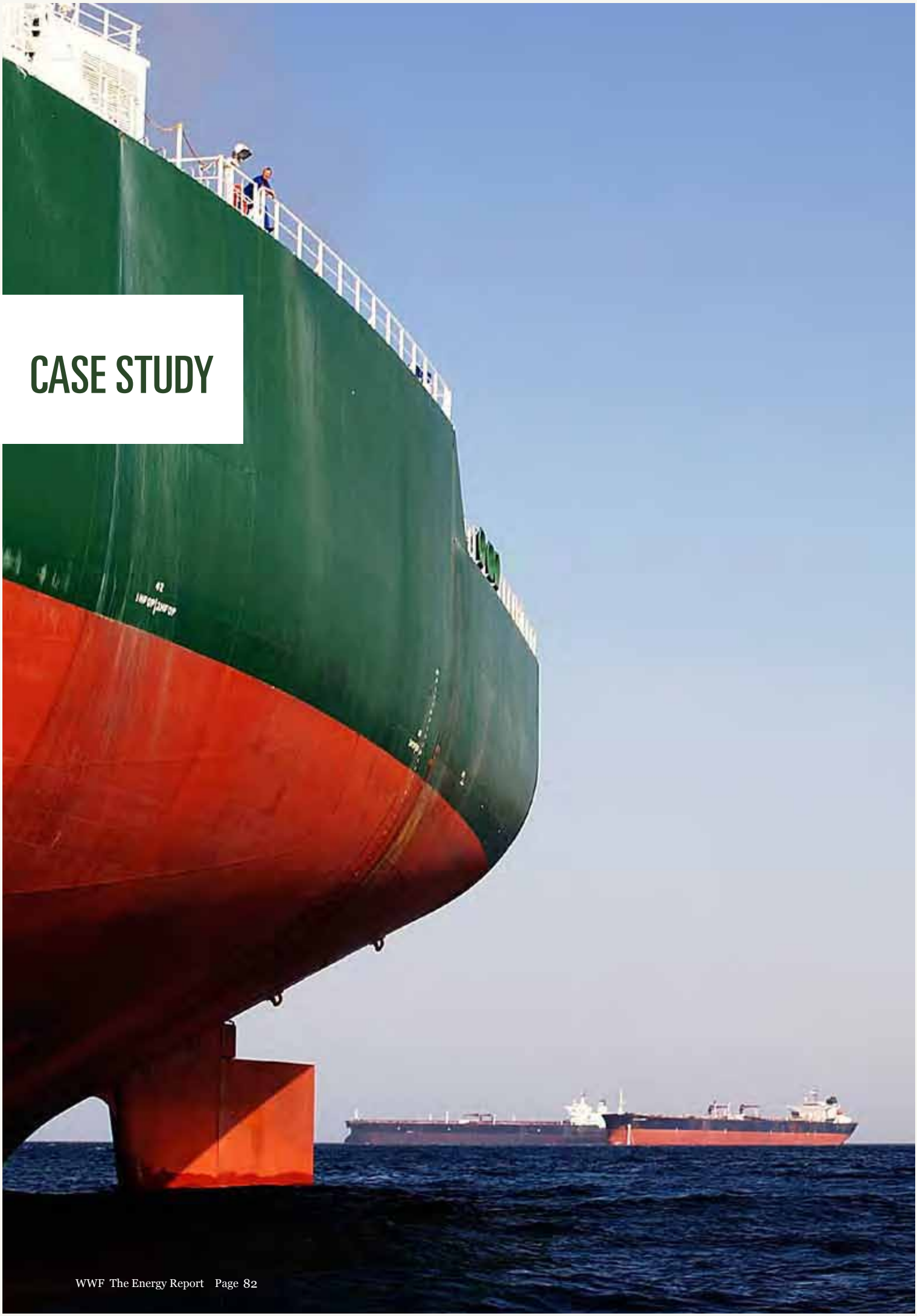
Global and national policies for renewable energy innovations are often fragmented or simply non-existent. Governments need to introduce supportive policies, in close collaboration with representatives from industry and finance.

We need to educate, train and support the scientists, engineers and other skilled workers who will dream-up, design, build and maintain our new energy infrastructure. We also need to support entrepreneurs and innovative companies with ideas to help us realize a renewable energy future.

Developing countries need support in building their own capacity for innovation. All of us will benefit from sharing knowledge within and across borders.

Because of the potential environmental and social impact of biofuels, research into alternative fuels – such as algae and hydrogen – should be a priority.





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CASE STUDY

"THE USE OF MODERN FUEL CELLS IN THE SHIPPING INDUSTRY CAN REDUCE TRANSPORT GHG EMISSION BY 20–40%"*

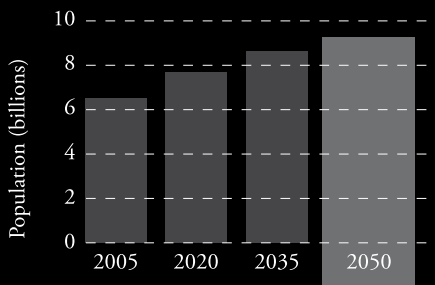
** IPCC 2007: Working Group III: Mitigation of Climate Change*

BACK TO THE FUTURE

Sometimes, innovation can mean going back to the past. Ships have always harnessed the power of the wind – and a new generation of sailing ships could help reduce the amount of fuel needed in the shipping sector. Hybrid cargo ships like the Ecoliner, made by Netherlands-based Fairtransport Shipbrokers, combine sails with back-up engines. German company Beluga SkySails has completed trans-Atlantic cargo voyages partly powered by a giant kite, which it claims can reduce fuel use by 10-35 per cent.[32]

32. http://www.skysails.info/english/information-center/background-information/skysails-performance-calculation/

Global Population
Growth Projections



Population

Growth Projections

THE FUTURE IS IN YOUR HANDS

That the world faces an energy crisis is beyond doubt. There's a pressing need to secure a sustainable energy supply as demand for fossil fuels outstrips environmentally and economically sustainable supplies. A lack of access to energy is one of the main causes of poverty. On top of this, the world needs to start drastically reducing CO_2 emissions within the next few years if we're to have the best chance of avoiding catastrophic climate change.

We – individuals, communities, businesses, investors, politicians – must act immediately, and boldly. Half-hearted solutions are not enough. We must aim for a fully renewable energy supply by the earliest possible date.

It is possible. The second part of this report lays out, in unprecedented detail, one way that we can do this. It isn't the definitive solution, and it isn't perfect. As we've seen, it raises many challenges and difficult questions. But it shows that solutions are at hand. We are putting it forward to catalyze debate and to spur action.

We now need to respond to the issues it raises. We need to take it further. But most of all, we need to act on it – each and every one of us. Starting today.

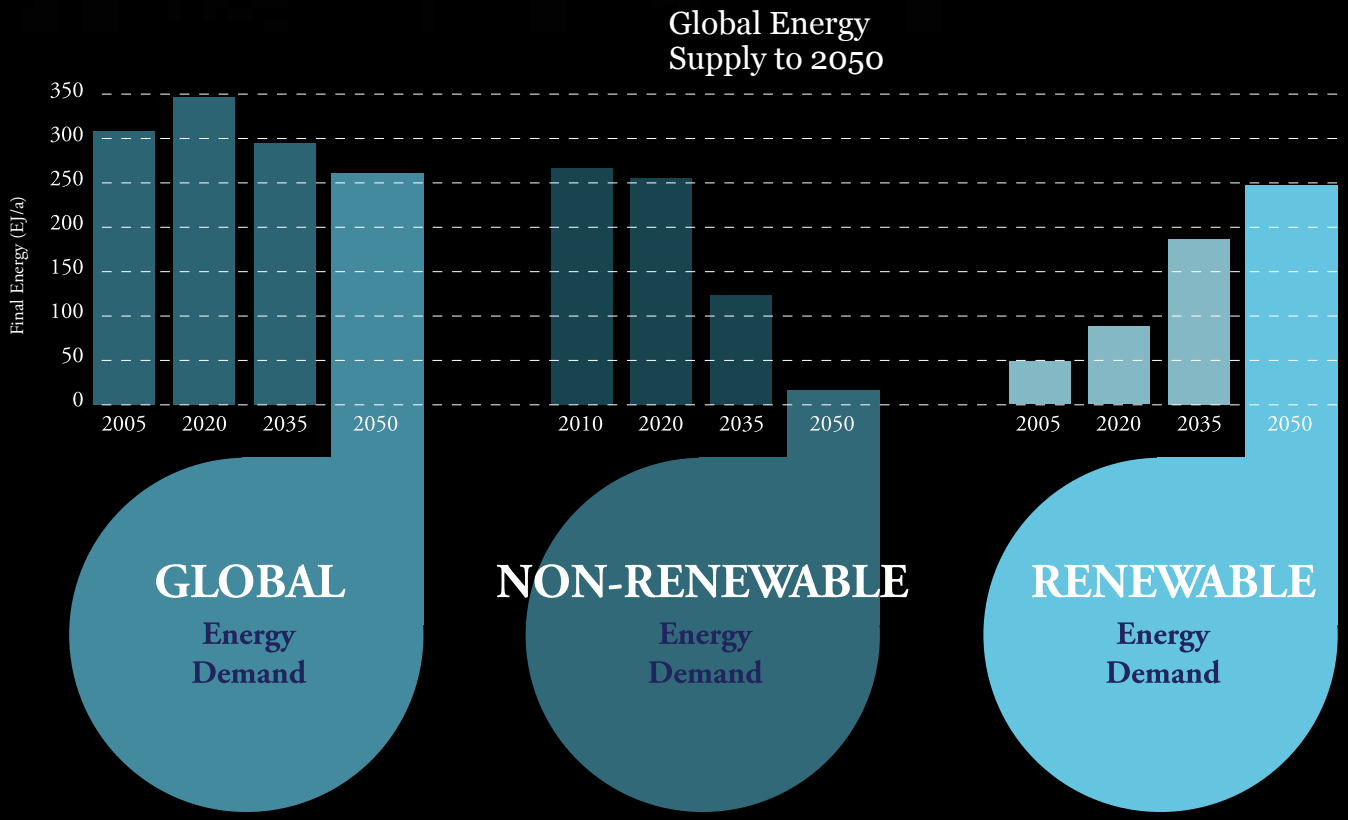


Figure 8: **World Renewable & Fossil Fuel Use Projection**