Renewable Energy Sector 'Best Bets' Project

Global Foresight Review

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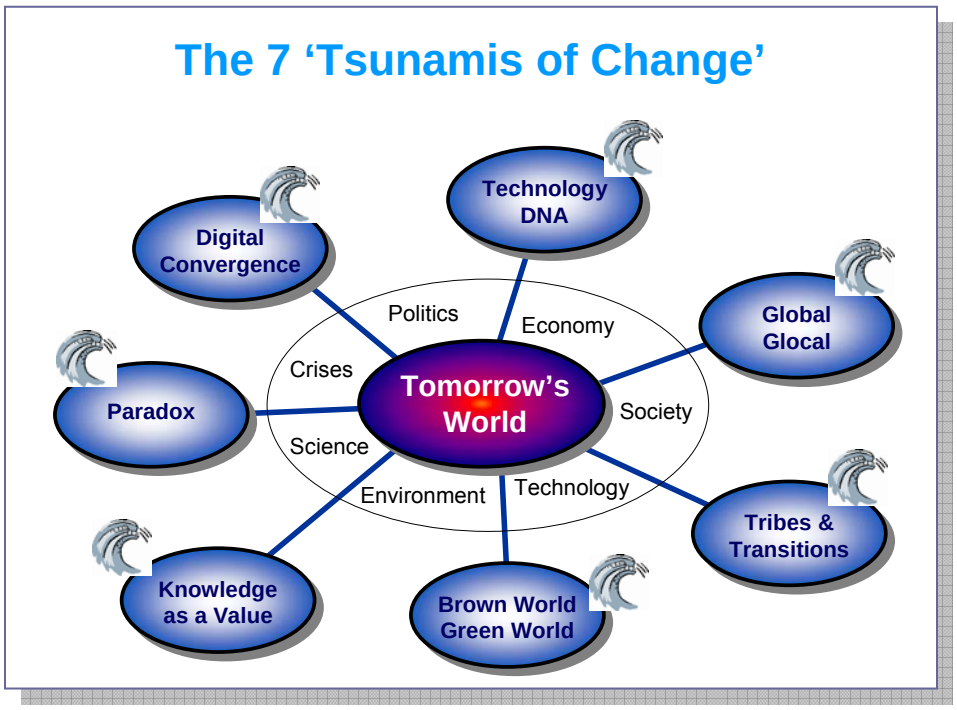
Contents

1 Introduction

This Global Renewable Energy Sector Foresight Report provides an overview of what is happening at the leading edge internationally.

Energy impacts upon just about every aspect of our lives and how the world we live in is evolving. It impacts across sectors, within sectors, in our private lives, in our business lives, on governments – everywhere. The global energy scene is now reaching a 'tipping point' that has never been seen in history – the changing balance between 'old energy' and 'new energy'. In order to understand the widespread impacts that the changing energy scene is having on economies and societies, it is useful to view it within the context of seven major 'Tsunamis of Change' that are re-shaping the world.

Figure 1: The NEXT 7 Tsunamis of Change ([1])



Within each of these '7 Tsunamis' there are numerous trends, discontinuities, and uncertainties (TDUs) evolving at any one point in time.

- **Trends** are things that are changing along a relatively predictable pathway – such as an increasing world demand for energy.
- **Discontinuities** are things that are likely to change the shape of the future in a way that is quite different to how things have been in the past – like the supply of finite fossil fuel resources not being able to meet increasing energy demand.
- **Uncertainties** are areas where we can see that changes are likely to happen but we have no clear idea how and to what extent – such as the potential impacts of climate change.

[1] NEXT Archives

In the context of this report, the seven Tsunamis can be linked to changes in the energy sector in the following way:

- **Tsunami 1: Digital Convergence** – digitalisation is driving the convergence of almost everything around the world and becoming a fundamental driver of changes in the shape of the global energy sector.
- **Tsunami 2: Technology DNA** – the blurring of boundaries between synthetic industrial systems and biological systems is opening up a whole new range of energy opportunity areas.
- **Tsunami 3: Global Glocal** – The changing global energy scene is leading to the development of local energy solutions – so called 'distributed energy'.
- **Tsunami 4: Tribes & Transitions** – new 'tribes' and personal relationships are complementing and sometimes substituting for traditional tribal, familial, and individual relationships and changing the way we do things.
- **Tsunami 5: Brown World Green World** – a sustainable energy future depends upon achieving a balance with the environment humans live in. If the environment suffers because of increasing energy demands, the human race is also likely to suffer as both are intimately interlinked.
- **Tsunami 6: Knowledge as a Value** – Knowledge is now the world's most valuable asset and people are increasingly focusing on using such knowledge to develop innovative more sustainable energy solutions for the future.
- **Tsunami 7: Paradox** – Humans often do things that don't make sense – like driving to buy organic food in a gas-guzzling SUV. Trying to understand such paradoxes is becoming a growing part of every sector – including energy.

The world's energy demand is forecast to increase by a staggering 50% between 2005 and 2030 unless the current pattern of use and ways of thinking change ([2]).

The global energy sector embraces many components including:

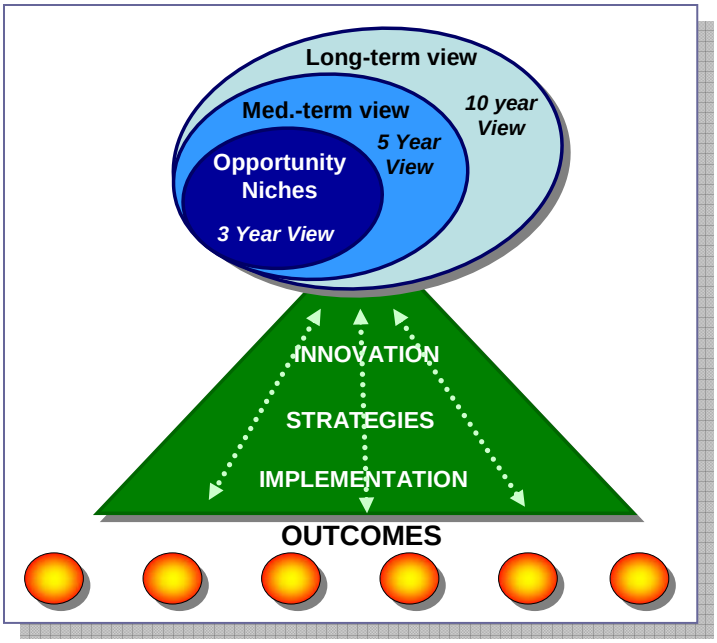
- Fossil fuels such as oil, gas and coal.
- Established renewable energy sources such as wood, hydro, and geothermal.
- Rapidly evolving renewable energy sources such as wind, solar, sea, biofuel and advanced biomass systems.
- Hydrogen and fuel cells.
- Micro-energy systems.
- Hi-technology developments.
- Centralised versus distributed energy systems.
- Energy use efficiency.

This report is not intended to provide a view of everything that is happening or likely to happen in the global, regional, or local energy sector. It has been complied to stimulate thinking about how the global sector is likely to evolve over the next ten years or so and to help identify some of the associated threats and opportunities for Trinidad and Tobago (T&T) within a long-term context such as that shown in Figure 2.

[2] http://www.eia.doe.gov/oiaf/ieo/highlights.html

It is important to develop a view of what the world and our environment looks like some ten years or so into the future so that we can make better decisions today about sector opportunities and threats. In essence the context shown in Figure 2 requires us to develop a set of alternative futures (scenarios) based around how the energy sector may look about ten years into the future, and extend that back to what we are doing today so we can identify potential opportunity areas by aligning minds and resources in a focussed strategic direction.

Figure 2: A context framework for thinking about the future of the energy sector ([3])



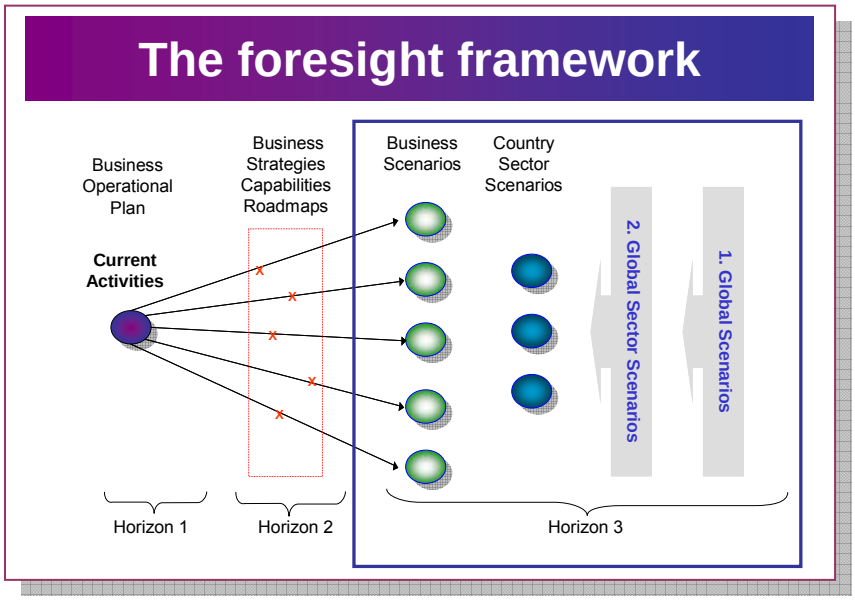
Once those opportunity areas have been identified the focus is then on combining innovation with business strategies and implementation roadmaps to commercialise particular 'best bets'. The total process can be illustrated in the way shown in Figure 3.

In Figure 3:

- **The Horizon 3 component** is the long term view 5 – 10 years into the future which provides a tool to picture the emerging opportunity areas within a global and regional context.
- **The Horizon 2 component** is the business strategic component normally with a 2 to 3 year timeframe.
- **The Horizon 1 component** is the annual operational and business planning component that enables implementation.

[3] NEXT Archives

Figure 3: The 3 horizons framework for using foresight to develop business opportunity scenarios ([4])



The following review of the global energy sector draws upon a wide range of sources and provides examples of key trends in the sector which are shaping the ten year Horizon 3 space, as well as an overview of some of the key players.

At the end of this report a number of potential 'best bet' opportunity areas have been identified which could provide the basis of a significant new energy sector focus in T&T.

4 NEXT Archives

2 Definitions

The following two definitions provide a clear view of the areas embraced within the renewable energy terminology:

'Renewable energy is energy generated from natural resources—such as sunlight, wind, rain, tides and geothermal heat—which are renewable (naturally replenished). Renewable energy technologies range from solar power, wind power, hydroelectricity/micro-hydro, biomass and biofuels for transportation' ([5]).

'The term renewable energy generally refers to electricity supplied from renewable energy sources, such as wind and solar power, geothermal, hydropower, and various forms of biomass. These energy sources are considered renewable sources because they are continuously replenished on the Earth' ([6]).

5 http://en.wikipedia.org/wiki/Renewable_energy

6 http://www.launch3energy.com/?p=31

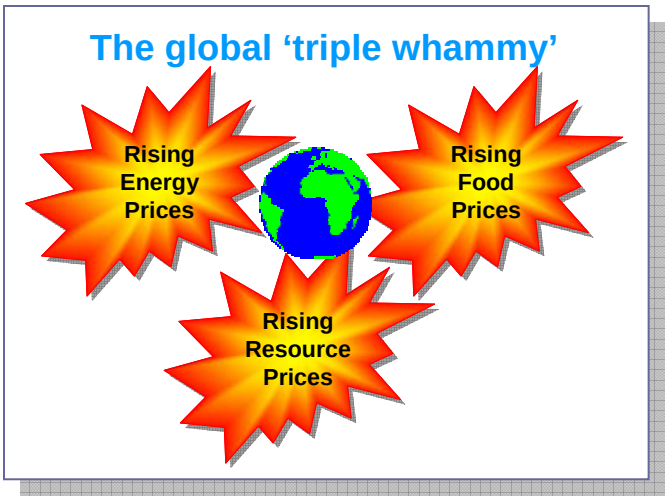
3 Global Trends

In this section examples of a number of key trends shaping the global energy sector are presented.

3.1 The Big Meta-Trends Shaping the Future of Energy

The energy sector does not operate in isolation to other sectors. What is shaping its 'big picture' future are three meta-trends which are coming together to create a 'Triple Whammy' effect as shown in Figure 4.

Figure 4: The 'Triple Whammy'

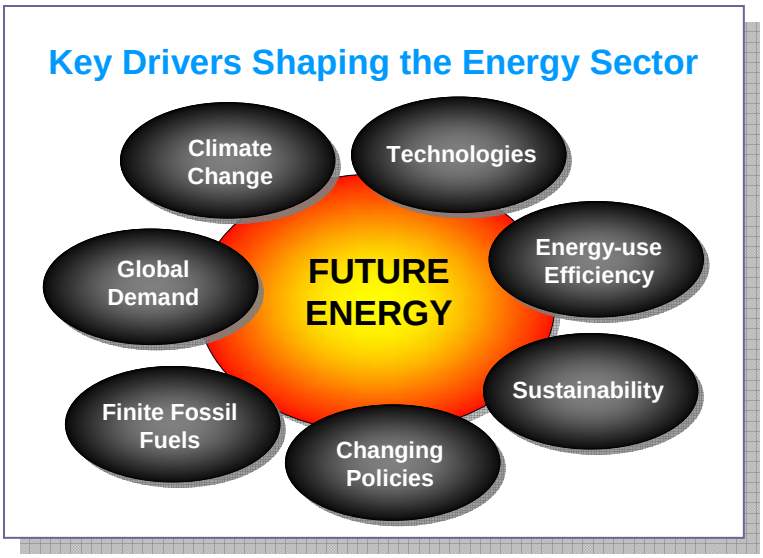


- **Rising Energy Prices** – The general consensus is that global demand for energy is now beginning to exceed the current capabilities to supply. There are numerous reasons for this including the levels of investment, finite resources, the time lag to introduce and gear up new technologies, and rapid economic growth in China and India. It is unlikely that energy will ever be cheap again in future years.
- **Rising Food Prices** – The world's population is continuing to grow and a combination of factors is leading to significant increases in global food prices. Those factors include a lack of investment in agriculture, the competition for arable land driven by the growing of food crops for biofuel production and urbanisation, increasing energy and input costs, and environmental extremes such as drought, floods, and land degradation.
- **Rising Resource Costs** – The rapid growth in China and India is putting a huge strain on the world's resources. The prices for copper, aluminium, steel, and rubber are at all time highs. The same applies for oil, gas and coal. The people living in these two countries want to have the same material possessions and quality of life as the Americans. But there is a growing doubt that this can realistically be achieved.

How the balance between these three competing meta-trends plays out will have a major impact upon the future of the energy sector.

In terms of the energy sector itself, the major drivers of change are shown in Figure 5.

Figure 5: Major drivers shaping the future of the global energy sector

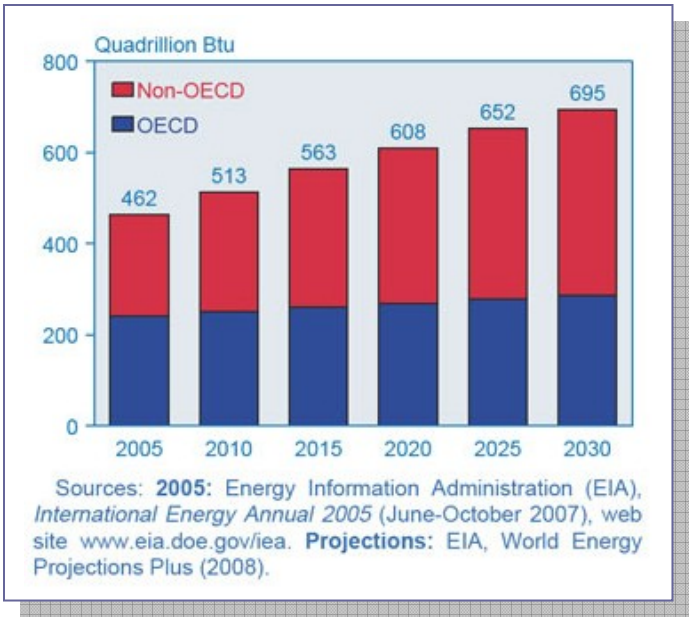


- The potential impacts of these major drivers will become clearer as the reader progresses through this report.

3.2 Energy Demand Trends

- The global demand for energy is growing strongly. Figure 6 illustrates that the global energy sector equated to 462 quadrillion British Thermal Unites (BTUs) in 2005.

Figure 6: Global energy use trends 2005 – 2030 ([7])



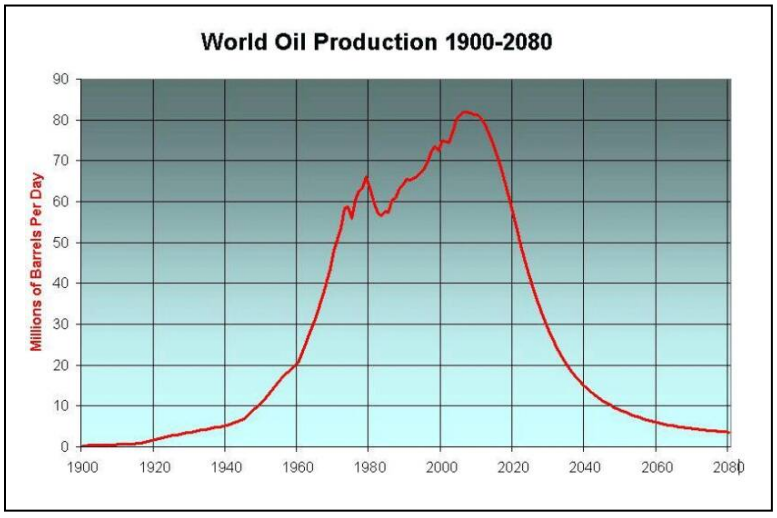
[7] http://www.eia.doe.gov/oiaf/ieo/highlights.html

- Based upon a 'business as usual' forward scenario, where the sector doesn't undergo any dramatic reshaping over the next several decades, global energy consumption is projected to increase by a staggering 50%!
- The Annual Energy Outlook 2008 Report (AEO 2008) presented trends and issues impacting on the US energy markets between now and 2030. Key changes include:
  - Higher prices for crude oil and natural gas.
  - Higher delivered energy prices, reflecting both higher wellhead and mine mouth prices and higher costs to transport, distribute and refine fuels (per unit supplied).
  - Slower projected growth in energy demand (particularly for natural gas but also for liquid fuels and coal).
  - Faster projected growth in the use of non-hydroelectric renewable energy.
  - Higher domestic oil production, particularly in the shorter term.
  - Slower projected growth in energy imports, both natural gas and liquid fuels.
  - Slower projected growth in energy related emissions of carbon dioxide (CO_2)
- This report presents fairly much a 'business as usual' scenario out to 2030. For instance, coal, liquid fuels derived from fossil sources, and natural gas met 85% of total US primary energy supply requirements in 2006. This is projected to remain at a high 83% in 2030.
- If China consumes oil at the same rate per capita as the US, they would need 4.5 billion tonnes of oil a year - but the global supply is just 4 billion tonnes a year ([8]).
- This makes it clear that a 'business as usual' scenario is most unlikely, not only because of supply factors but also climate change related issues.

3.3 Resource Limitations

- The world's fossil fuel resources are finite. 'Peak Oil' is the time when the rate at which oil can be extracted peaks and thereafter cannot meet global demand – as shown in Figure 7.

Figure 7: Have we already reached 'Peak Oil'? ([9])



8 http://news.yahoo.com/s/afp/20070415/bs_afp/chinaenvironmentenergy_070415031913&printer=1;_ylt=AgQQRs_XG1f55UodBAU_3mWoOrgF

9 http://www.lifeaftertheoilcrash.net/

- Currently global oil production is approximately 85 million barrels per day - including oil extracted from tar sands and from gas to liquid processes.
- In 2007 global oil consumption increased by 1 million barrels per day driven largely by increasing demand from China and India.
- By July 2008, oil prices reached a global high of US$ 147 a barrel.
- The high global dependency on oil as a major source of energy is threatening the rate of global economic growth and adding to inflationary concerns.
- There are many who say we have already reached 'Peak Oil' and the high prices on global markets reflect a fundamental shift in the supply and demand balance.
- For years the global oil and gas giants have said that 'Peak Oil' is still years away and that global customers should not be concerned as there is plenty to go around.
- However the release of two reports in July 2007 from conservative sector changed the playing field.
- **The 'Medium Term Oil Market Report'** put out by the International Energy Agency ([10]) says that the demand for oil is likely to match or exceed supply by 2012, possibly even by 2010. They add that the world's gas supplies are already at a plateau level and are more likely to decline than increase and so they are not going to provide an alternative to shortfalls in the global oil supply. The demand-supply problem is being exacerbated short-term by infrastructural constraints and longer-term by oil-field access and production limitations.
- **The 'Facing the Hard Truths About Energy Report'** produced by the National Petroleum Council ([11]), which represents major global oil companies, also concedes that the global supply of oil and natural gas is unlikely to be able to supply the growth in demand foreseen over the next 25 years. They go further by saying that matching oil production with demand could be a real challenge within 7 years.
- The whole world is built around systems that are highly dependent upon fossil fuels - think of cities with their sprawling suburbs where fossil-fuelled vehicles are the lifeblood of their existence, gas-fired power stations, the plastics industry, the mining industry, and the global shipping and logistics sector.
- An increasing number of industry observers believe the global oil price could reach US$ 200 / barrel soon. A Goldman Sachs analyst, Arjun Murti, predicts an oil price spike of over US$ 200 a barrel, possibly before the end of 2008 ([12]). He says that it is unlikely oil will drop below US$ 100 a barrel well into 2011 (although oil prices had dropped back to around US$ 64 a barrel in October 2008).
- Many political leaders are calling for increased global oil production but, even with the high global prices, production levels are staying relatively static. That suggests there will be real issues supplying growing global demand in the foreseeable future.
- There are also growing concerns about the sector having a high level of dependency on oil supplies from areas in the world characterised by unstable regimes.
- Coal prices are also forecast to increase by as much as another 45% in the period up to 2010 - after rising by several hundred percent in the past year, e.g. coking coal moving from US$ 85-98/tonne to US$285-300 ([13]).
- The costs of 'clean coal' technologies could add another 10-15% to the costs of producing power compared to conventional coal fired power stations.

10 http://www.evworld.com/library/iea_midtermreport07.pdf
11 http://www.npc.org/
12 http://www.nytimes.com/2008/05/21/business/21oil.html
13 http://www.mineweb.com/mineweb/view/mineweb/en/page38?oid=53328&sn=Detail

- Rio Tinto and BP have abandoned a carbon capture and storage project that was going to be built at Kwinana in Australia. The project that was going to produce hydrogen as a fuel from coal. However, there have been problems with storing the CO_2 produced ([14]).
- Producing biofuels, such as ethanol, from food crops is contributing to rising global food prices. Because of this the United Nations (UN) is asking countries to revisit their biofuel policies.
- Based upon the resource availability factor alone, the global energy sector will need to be built around a quite different model to that being used today. And that model is likely to be built more around sustainable and renewable resources.

3.4 Climate Change

- Vaclev Havel, the former president of the Czech Republic, says we should be thinking of our time on earth as a loan. He adds that many developed countries have been running up a debt and that nature is 'issuing warnings that we must not only stop the debt from growing but start to pay it back'.
- Havel says the world's climate has evolved 'turbulently over billions of years into a gigantic complex of networks, and networks within networks, where everything is interlinked in diverse ways'. He contends that the impact of human activities on such complex systems could in fact change these complex relationships into a new state - and that this new state could easily be one which might not be favourable for continued human existence on the planet ([15]).
- A report released by the Intergovernmental Panel on Climate Change (IPCC) in 2007 presented a consensus view of 2500 scientists working in the field around the world, and states that this group is '90% certain that humans are overheating the earth' ([16]).
- Yvo de Boer is head of the UN's Climate Change Secretariat in Europe. He says that studies undertaken by the UN Climate Change panel indicate that greenhouse gas emissions had to peak within 10 - 15 years and then reduce by half by 2050 if the worst effects of global warming were to be avoided ([17]).
- In the wake of the Stern Report on climate change, the UK government is introducing a law to make reductions in CO_2 emissions of 20% by 2010 and 60% by 2050 legally binding ([18]).
- European leaders hope to introduce new legislation in 2009 that will lead to the adoption of binding targets for cutting greenhouse gas emissions and raising renewable energy use levels. This is in addition to the EU's current commitment to reduce greenhouse gas emissions by 20% and use 20% renewable energy by the year 2020. A number of EU countries, including the UK and Germany, are already close to achieving the 20% reduction in emissions ([19]).
- The Energy Independence and Security Act was passed by the US Congress in December 19, 2007. This law aims to promote improved vehicle fuel use efficiency, a

14 http://www.environmentalmanagementnews.net/storyview.asp?storyid=242340
15 http://www.nytimes.com/2007/09/27/opinion/27havel.html
16 http://www.ipcc.ch/SPM2feb07.pdf
17 http://www.alertnet.org/thenews/newsdesk/L28528423.htm
18 http://www.economist.com/research/articlesBySubject/displayStory.cfm?
19 http://www.energysavingtrust.org.uk/resources/daily_news/climate_change/binding_eu_emissions_targets

500% increase in the production of renewable fuels from non-food crops by 2022, higher building insulation standards, and the banning of sales of incandescent light bulbs ([20]).

- High greenhouse gas emission levels are a sign of excessive and inefficient resource use. Dr Mark Diesendorf from the University of NSW says Australia could reduce such emissions to 30% less than 1990 levels by 2020. ([21]).
- Just three years ago it was thought that China would not overtake the USA as the world's biggest polluter until around 2025. During 2008 emission levels in China are expected to reach 6020 million tonnes compared to America's 5910 million tonnes. They will rise further as new coal-fired power stations come on line ([22]).
- The average annual per capita CO_2 emissions in China are 3.6 tonnes and in the USA and Australia 20.2 and 19.4 tonnes respectively.
- Whilst the Chinese are building many new coal-fired power plants they also have more solar water heating systems than the rest of the world combined, are planting 133.3 billion square metres of forest for biomass production by 2020, building the world's first eco-cities, and making rapid advances in green technologies.
- California passed a law last year that aims to cut greenhouse gases 25% by 2020. Vehicle exhaust emissions must be reduced by 10% over the same time frame.
- Currently 98% of all vehicles in the world run on fossil fuel derived products - petrol and diesel. GM has decided that the high reliance on fossil fuels is not sustainable and so the group is changing its future focus to alternatives.
- Ethanol is an interim solution but not the whole answer. It tends to be more expensive and produces less power per litre. Biobutanol may be a more interesting prospect. But the big interest is in new generation electric vehicles that also use hydrogen fuel cells to provide the source of power.
- The biggest challenge is to overcome the resistance to change created by the owners of fossil fuel distribution and retail operations - the big global oil companies.
- The French Prime Minister, Dominique de Villepin, recently threatened to impose a carbon tax on the USA and Australia for all goods and services supplied by them to the EU because the two countries had failed to ratify the Kyoto Protocol ([23]).

3.5 Sustainability

- Moving towards long-term sustainability is a growing global trend. This means shifting away from using finite non-replaceable resource sources to those which are totally renewable.
- However, because the world is currently consuming resources at approximately 125% of the rate that they are being renewed, improved resource use efficiency is becoming a key focus ([24]).
- The town of Woodstock in the US has committed to becoming the first town in the US that is carbon neutral. This includes a shift to renewable energy through retrofitting buildings and sourcing from 'green' suppliers, alterations in mobility habits, and changing lifestyles. The town's population strongly backs the initiative.

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20 http://www.nytimes.com/2007/12/19/washington/19energy.html?

21 http://www.environmentalmanagementnews.net/storyview.asp?storyid=119884&sectionsource=s149

22 http://news.yahoo.com/s/afp/20070415/bs_afp/chinaenvironmentenergy_070415031913&printer=1;_ylt=AgQQRs_XG1f55UodBAU_3mWoOrgF

23 http://www.abc.net.au/pm/content/2006/s1791645.htm

24 http://www.panda.org/news_facts/publications/living_planet_report/index.cfm

- The Jubilee Wharf building development in the Cornish town of Penryn in the UK is claimed to have zero carbon emissions. It uses only renewable clean energy generated on site and is designed to optimise natural light and heating ([25]).
- The giant Dell computer group now uses 100% renewable energy supply in its global headquarters in the USA. Half that energy comes from a landfill gas-to-energy project. It plans to make all its facilities carbon neutral during 2008 ([26])
- HP aims to cut its energy consumption and greenhouse gas emission levels to 25% below 2005 levels by the year 2010. To do this HP also audits its suppliers and expects them to achieve similar levels of energy use and emission reductions ([27]).

3.6 Energy Use Efficiency

- A move towards a sustainable energy future will also require a greater focus on energy use efficiency as the practicalities of supplying the forecasted increases in demand will be a challenge to both the traditional and renewable energy sectors.
- How countries are dealing with greenhouse gas emission levels provides an indication of such increases in energy use efficiency.
- For example, greenhouse gas emissions in Germany are now 20.4% lower than the 1990 level (under the Kyoto Protocol the country's target was 21% by 2012). In the past year the renewable energy contribution from wind, water, biomass, and solar energy increased by 15% ([28]).
- Germany could easily achieve a 30% reduction in energy use without damaging economic growth. This has significant ramifications for the future cost-competitiveness of German industry.
- The McKinsey Group says there is substantial room to cut the global demand for energy by 50% or more over the next 15 years without impacting upon end-user enjoyment and economic growth ([29]). By 2020 the following could be achieved:
  - Residences account for about 25% of total end-use demand. Adopting the use of high efficiency building shells, compact fluorescent lighting, and high efficiency water heating would reduce demand by 21%.
  - Offices, retail outlets, hotels and restaurants, schools, and hospitals use about 10% of global end use demand. Improved insulation measures and more energy efficient appliances and equipment could save 20%.
  - Road transport accounts for 16% of global energy demand and 46% of global petroleum product demand. Global fuel usage could be reduced by 9% overall through the removal of subsidies and the use of more fuel efficient vehicles. Government fuel tax policies also play a significant role e.g. Europe's vehicles are 37% more fuel efficient than American vehicles because of such measures.
  - Industry is the big use sector - 47% of global end use demand. A 16 - 22% reduction in demand that could be achieved mainly in areas such as heat recovery systems and the optimisation of motor driven systems.
- The areas of savings McKinsey have identified are not particularly radical. The technologies to achieve them are available today.

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25 http://arts.guardian.co.uk/art/architecture/story/0,,1987678,00.html

26 http://www.greenstudentu.com/eco_lifestyle/renewable_energy_for_dell_headquarters.aspx

27 http://www.environmentalmanagementnews.net/storyview.asp?storyid=171336

28 http://www.bmu.de/files/pdfs/allgemein/application/pdf/hintergrund_meseberg_en.pdf

29 http://www.mckinsey.com/mgi/reports/pdfs/Curbing_Global_Energy/Curbing_Global_Energy_executive_summary.pdf

- About 60% of the energy used in traditional power generation is wasted. A researcher at Michigan State University is developing a new type of thermo-electric converter that has the potential to recover 20% of energy currently lost.
- Green buildings, such as the Swiss Re Tower in London, use technology and design to reduce energy consumption by 50% compared to conventional office buildings ([30]).
- A migration away from incandescent light bulbs to light emitting diodes (LEDs) could provide an energy savings of up to 99%.
- If 20 million UK households replaced just one incandescent light bulb in each house with a compact fluorescent bulb, one average power station could be taken out of service. If all the incandescent light bulbs in UK households were replaced, 14 power stations would no longer be required ([31]).
- LED technology offers light conversion efficiency ratios that are 7 to 10 times better and is likely to impact within the next five years. If this technology replaced all the current incandescent light bulbs, 28 power stations could be shut down in the UK.
- Fibre optics, coupled with solar capture technologies, could result in even greater savings. This type of technology could reduce power use needs by up to 99%.
- In 2007 the Australian government announced that incandescent light bulbs would be phased out in three years and replaced with energy efficient alternatives saving more than 70% of the energy used for illumination.
- New Zealand is implementing a ban on the sales of incandescent light bulbs to reduce light related energy consumption 20% by 2015 ([32]).
- Smart sensor based systems that control the use of power when persons enter or leave a room are already available and will become more mainstream ([33]).
- The Berlin Energy Partnership Project in Germany has achieved 30%+ energy use savings by using innovative public private partnerships to upgrade the energy efficiency of older public buildings and apartment blocks ([34]).
- Organic Rankine Cycle and BHKW gas turbine technologies convert biomass and other fuel sources into electricity and heat energy with a 70 - 95% efficiency level, far higher than the 45% typical for gas and coal fired power stations.

30 http://www.economist.com/PrinterFriendly.cfm?story_id=3422965
31 http://www.shapingtomorrow.com/newsletter.cfm
32 http://www.nbr.co.nz/article/govt-plans-ban-old-style-light-bulbs
33 http://www.businessgreen.com/business-green/news/2219660/intelligent-buildings-hampered
34 http://energy-pro.net/php/download/files/Energy%20Saving%20Partnership.doc

4 Renewable Energy

Renewable energy is seen as being a critical component of a long-term sustainable future for both the planet and the people who live on it. Prior to the industrial revolution in the 19th century, renewable energy was virtually all that everyone used. But that changed and fossil fuels became the big driver behind global industrialisation. Now the world is approaching a point where this era is no longer sustainable. This is driving rapid growth in interest and investment into renewable energy.

However, any transition away from traditional non-renewable energy sources - so-called 'old energy' - to a greater proportion of renewable energy sources – so-called 'new energy' - is not only going require many years but is likely to need to be accompanied by considerable improvements in energy use efficiency.

4.1 Overview

- The proportion of the world's energy that is produced from renewable energy is shown in Figure 8 and the proportion of the world's electricity generated from renewable sources is shown in Figure 9.

Figure 8: Renewable energy share of global end energy consumption, 2006 ([35])

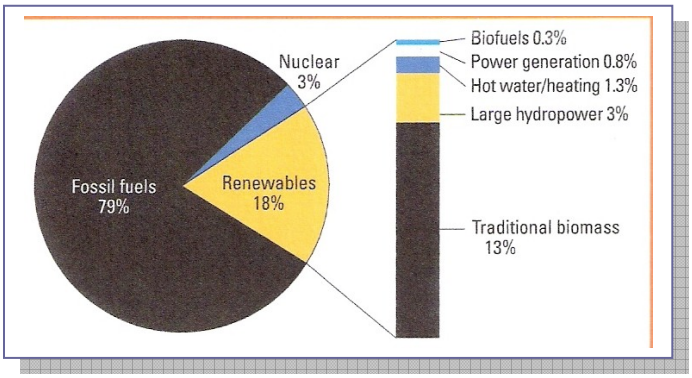
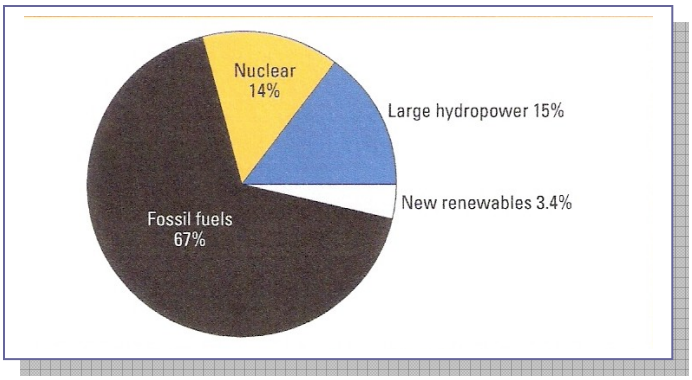


Figure 9: Share of global electricity from renewable energy, 2006 ([36])

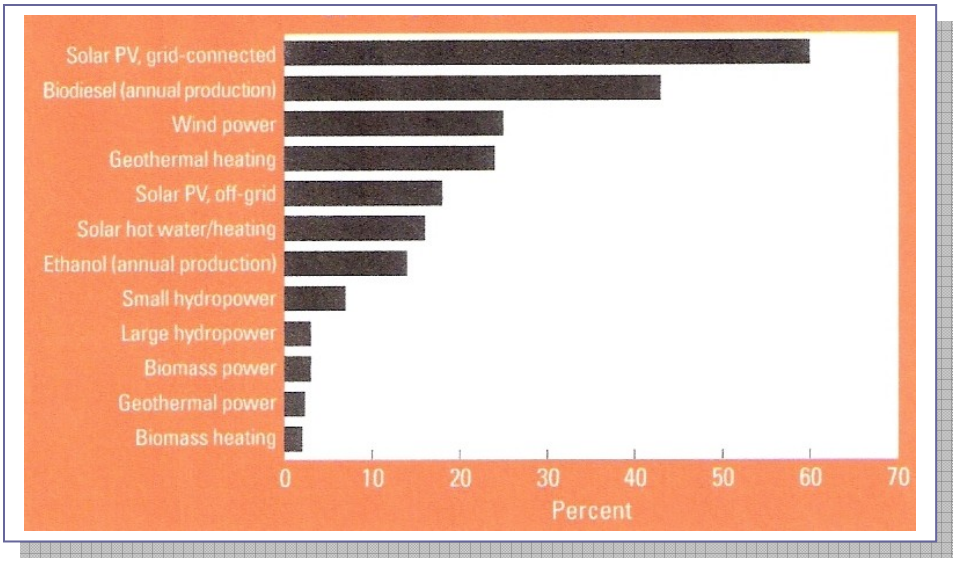


35 http://www.ren21.net/pdf/RE2007_Global_Status_Report.pdf

36 http://www.ren21.net/pdf/RE2007_Global_Status_Report.pdf

- Even before oil reached US$ 140+ a barrel in July, 2008, the growth rates for various renewable energy sub-sectors were high. For example, solar PV achieved an average annual growth rate in capacity of more than 60% between 2002 and 2006. Details for other renewable sectors are shown in Figure 10.

Figure 10: The annual average growth rates of renewable energy capacity between 2002 and 2006 ([37])



- Jim Kingsdale, a leading analyst with Energy Investment Strategies ([38]), says that future energy demand is not expected to slacken but continue to grow. Because non-renewable energy sources are becoming depleted, he puts forward two basic strategies:
  - The development of *alternative fuels* - usually from renewable sources in nature and includes biofuels, biomass wind solar and wave.
  - A greater emphasis on *technological efficiency* for maximizing energy yield - this includes development of new engine turbines for air travel, innovations in fuel use, new transmission lines.
- Both will require a major transition over the coming decades.
- It is not clear though how developing countries will handle a transition towards a greater use of renewable energy. India and China are likely to expand their car fleets based on highly fuel efficient small cars. However, this is likely to be transitional and combustion engine powered vehicles may only last 25 years at best.
- As a result of the changing global energy situation, research into energy sources has focused on three main areas:
  - Increasing the efficiency (measured in megawatts) or energy potential from traditional fuel sources. This approach includes improving the efficiency of internal combustion engines and improved vehicle emissions. In the case of buildings,

37 http://www.ren21.net/pdf/RE2007_Global_Status_Report.pdf

38 http://www.energyinvestmentstrategies.com

emphasis is on better insulation and design to optimize internal comfort but with greater efficiency and lower emissions.
  - Replacing or blending of traditional sources of fuels with other new fuels (usually liquid fuels). An instance of this is the commercialization of ethanol production in recent times in response to high global oil prices. Ethanol extracted from corn and sugarcane can be successfully blended with traditional fuels up to 10% without reduced engine performance.
  - Developing alternative energies which are from renewable sources and which have very little or no adverse impact on the environment. These include efforts to develop wind farms, wave motion and flow based turbines, and solar technology.
- Table 1 provides an overview of how renewable energy may roll out in future years from both the urban and rural perspectives.

Table 1: The rural and urban potential for various renewable energies ([39])

Time	Urban application	Rural suitability
Short-term potential	• Biofuels • Natural gas	• Solar • Biofuel (small scale) • Biogas • Biomass
Medium-term potential	• Wind, • Biofuels (non-traditional crop sourced) • Solar	• Solar • Integrated eco communities • Biofuel (small scale) • Geothermal
Long-term potential	• Hydrogen fuel cell • Solar (large scale) • Wind (large scale)	• Solar (small scale) • Wind (small scale) • Geothermal • Integrated eco-villages (larger and in clusters) • Wave energy

- In the following sections a brief overview of the current status and trends associated with a range of evolving renewable energy fields are presented.

4.2 Wind

4.2.1 Current status

- Growth in the wind sector is currently over 30% a year.
- The costs of wind power generation per unit of electricity produced dropped by 80% between 1980 and 2006 to less than US 4 cents a unit ([40]).
- A current challenge is in the material supply chain for manufacturing wind generation units. The turbines used require a large number of components and there is a major constraint in this area. New plants are being built by large turbine producers such as Vestas but they take several years to come on stream. In the meantime suppliers can't keep up with global demand ([41]).

39 http://www.ren21.net/pdf/RE2007_Global_Status_Report.pdf
40 http://www.patp3.webbler.co.uk/doc.php?id=2791
41 http://news.economist.com/cgi-bin1/DM/y/h6kS0E75Bw0Mo0Dr2g0EK

- The German group, Siemens, ([42]) is rapidly expanding its manufacturing capabilities in wind power. They have provided more than 6300 wind turbines around the world, which are estimated to be saving 10 million tons of CO_2 emissions per year.
- The NIMBY (not in my back-yard) syndrome has stalled major wind farm projects in many countries - especially in Europe and Australia. Not everyone is happy to have gigantic wind generating units in the neighbourhood.
- This is leading to major wind farm developments offshore in Denmark and the UK.

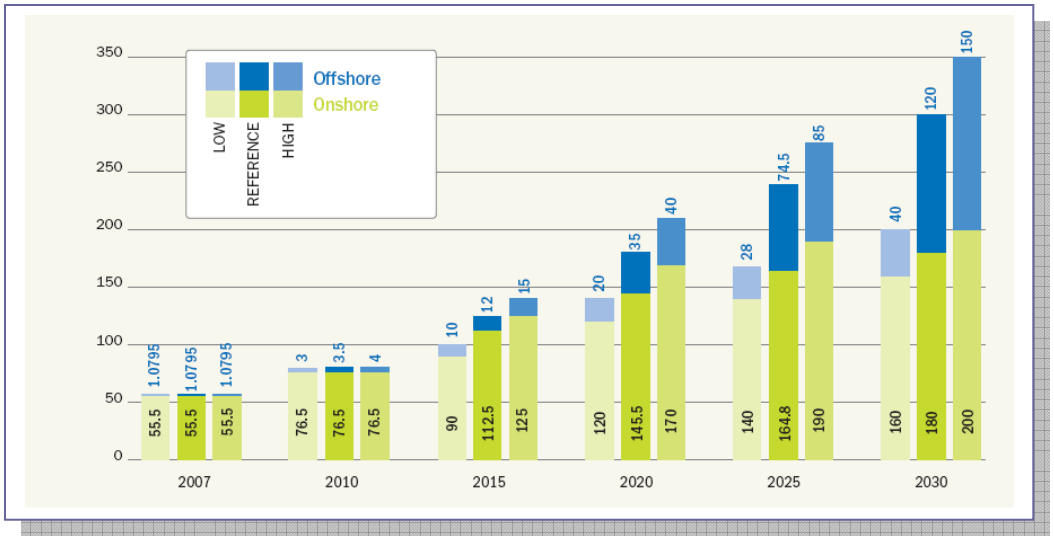
Figure 11: A commercial offshore wind farm in the UK ([43])

4.2.2 Future Trends

- There are a number of innovative approaches being pursued in the wind energy sector.
  - o One is wind turbines that rotate horizontally around a vertical axis that are being developed by TMA in the US. The system is claimed to convert 43 - 45% of the wind's energy to electricity compared to 25 - 40% for conventional wind turbines. It is also claimed to withstand much stronger wind speeds ([44]).
  - o Another US company, Sky WindPower, is developing a prototype that is literally a 'flying wind power generating' unit that operates high in the atmosphere at jet stream level where the potential for generating energy is up to a hundred times greater than that at ground level ([45]).
- Offshore wind energy generation is likely to grow in importance but will depend upon policy moves. The potential for land-based generation is now becoming limited due to the high impact factor on urban and rural environments and the availability of suitable land-based sites.
- Three scenarios for the future of wind generation in Europe are shown in Figure 12. The low scenario represents a case where there are many hindrances to offshore development and the high scenario case represents where moves favour offshore generation.

42 http://www.usa.siemens.com
43 http://www.kentishflats.co.uk/index.dsp?area=1374
44 http://www.economist.com/research/articlesBySubject/displayStory.cfm?
45 http://www.economist.com/research/articlesBySubject/displayStory.cfm

Figure 12: Future wind power scenarios for Europe are likely to depend heavily on offshore developments ([46])



- In July 2008, plans to build Europe's largest onshore wind farm in Scotland were announced. It will produce 452 MW of electricity – enough to power 250,000 homes. It is planned to begin operations in 2011 ([47]).
- In Germany, the government says that offshore wind farms with a total generation capacity of 10,000 MW should be operational by 2020 ([48]).

4.3 Solar

4.3.1 Current Status

- The solar energy sector is also growing rapidly – 60% a year. Up until recently much of that growth was driven by subsidies and proactive policies because the payback periods for the relatively high capital costs have been long. However this is changing fast as fossil fuel prices rise and the costs of manufacturing solar panels decline.
- Another trend favouring solar power is that it offers predictable (and declining) costs, something which fossil fuels do not offer.
- It is estimated solar energy could eventually supply as much as 20% of the US market needs.
- According to the US Energy Department, a coal-fired power station now has a capital cost of US$ 2.10 per watt of output. This cost does not include the cost of carbon credits to cover the emissions produced or the ongoing cost of fuel.
- Nanosolar is a company that has developed a low-cost manufacturing system for producing solar panels by 'printing' the photovoltaic component onto aluminium backing sheets. As a result the cost of producing finished solar panels has been reduced by 80%.

46 http://www.ewea.org/index.php?id=178
47 http://www.guardian.co.uk/environment/2008/jul/22/windpower.renweableenergy
48 http://www.spiegel.de/wirtschaft/0,1518,druck-566749,00.html

- This has led to a huge reduction in the capital costs for solar panels which can now be produced and sold for just $1.00 per watt of output. Add in the costs of the rest of the system required it still cost only around $2.00 a watt for a fully operational solar power producing plant - less than coal-fired. There are no ongoing fuel costs or carbon credit costs.
- Their first 18 months of production capacity has been fully booked out. They now have two production plants - one in the US and the other in Germany, a country that has been highly proactive in encouraging greater use of solar energy ([49]).

4.3.2 Future Trends

- The Thin Film Photo Voltaic (TFPV) process developed by companies such as Nanosolar means that energy capture surfaces can be manufactured using simple printing machines and this has the potential to lower capital costs by 75% or more, reducing waste, and increasing throughput. It is expected to be a rapid growth area.
- TFPV is also low weight and can be applied to flexible substrates. This means solar power generating capabilities can be embedded into walls, roofs, and windows. Unlike more conventional photovoltaic (PV) cells that use crystalline silicon, TFPV also has an ability to operate under low light conditions.
- A number of manufacturers are building production capacity in this field. First Solar, Fuji Electric, Nanosolar, Sanyo, and G24i are all building plants with more than 100MW in annual production capacity.
- The world TFPV market is forecast to reach US$$7.2 billion by 2015 ([50]).
- Researchers at Australian National University have developed a prototype 'Silver Cell Technology' that has the potential to reduce photovoltaic manufacturing costs by 60% ([51]).
- Australian and Chinese researchers at the University of Queensland's Australian Institute for Bioengineering and Nanotechnology have grown titanium oxide crystals with large amounts of reactive surfaces that hold promise for the development of cost effective solar cells and producing hydrogen by splitting water.
- Professor Max Lu at the University expects that the first commercial applications in the solar energy area will be seen within 5 – 10 years ([52]).
- There is renewed interest in the US in CSP (concentrating solar power) systems. The world's largest solar farm in the Mojave Desert was established in the 1980's and covers 10.3 square kilometres of desert. The sun's rays are focused by mirrors to heat a carrier liquid which is then used to drive turbines.
- Advances in CSP technology are likely to reduce the cost of power from such systems by over 40% in the near future. Government incentives and legislation requiring more 'green power' are favouring new large solar projects ([53]).
- A new solar energy plant in Almeria, Spain, jointly developed by the Fraunhofer Institute and MAN Ferrostal AG, uses a radically different approach to traditional parabolic reflectors that focus sunlight onto a central absorber tube – a very expensive option. They are using flat linear Fresnel reflectors to heat water in a tube

49 http://www.nytimes.com/2007/12/18/technology/18solar.html
50 http://www.renewableenergyworld.com
51 http://www.environmentalmanagementnews.net/storyview.asp?storyid=242377
52 http://news.xinhuanet.com/english/2008-05/29/content_8275909.htm
53 http://www.economist.com/world/na/displaystory.cfm?story_id=9804148

to 450 °C at high pressure and this is used to drive a turbine. It costs far less to manufacture and set up ([54]).

- One of the biggest challenges for solar power is how to supply energy at night when there is no radiation. Batteries are an expensive and in efficient option - retaining only about 65% of the generated energy. One alternative being used is based around solar thermal units which focus the solar energy onto a liquid medium which can then be used to produce steam and drive a turbine. The efficiency of conversion of such systems is now around 95%. These types of plants are becoming popular in the US, Germany and Spain.
- A Swedish entrepreneur, Per Olofsson, has developed a solar powered air-conditioning unit that promises to heat and cool buildings and eliminate the high energy costs associated with traditional systems. The current capital cost is high at $25,000 fully installed, but savings are estimated to be at least $130 a month at current energy prices. The system would also reduce the average household output of CO_2 by 13 tonnes a year ([55]).

4.4 Biomass

4.4.1 Current Status

- Biomass was a major source of energy in old societies. It involves the direct conversion of biological materials such as wood, crop residues, or animal waste into energy or for the generation of biogas that can be used also to produce energy.
- In Laos, biomass still provides 89% of all the country's energy needs.
- In Nepal biogas is produced in an airtight underground container where livestock manure or household toilet waste is stirred with water. Anaerobic bacteria convert the waste into a gas containing up to 70% methane which is then used for cooking.
- This technology has been used in Nepal for thirty five years. The government aims to have 200,000 such plants installed by 2009.
- The benefits to Nepal to date include a reduction in CO_2 emissions by an estimated 890,000 tonnes and the provision of over 20,000 jobs. It has also improved rural sanitation by utilising the waste from 95,000 household toilets.
- Veolia has commissioned a power generator built on a 'bioreactor' landfill near Goulburn in Australia. It generates methane which is collected and fed into a small power generation unit. Some 92% of the methane produced on the site is captured compared to the 70-75% on best-practice landfill gas capture sites.
- By 2034, 24 small generation units with a 25 MW capacity (enough to power 20,000 houses) will be operating on the site. A wind farm is also being constructed on the site and will produce enough electricity to power another 17,000 houses ([56]).

4.4.2 Future Trends

The following examples illustrate the beginnings of what is likely to be a strong future growth trend. It is the development of community based decentralised energy systems and total energy independence built around modern biomass utilisation technologies.

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54 http://www.teknikogviden.dk/artikler/visArtikel.asp?id=9508

55 http://www.time.com/time/globalbusiness/article/0,9171,1565559,00.html

56 http://www.environmentalmanagementnews.net/storyview.asp?storyid=171387&sectionsource=s0

The Jühnde example – Germany ([57])

- 750 people live in this small north German village. It is the country's first village to become 100% self-sufficient in energy. The decision to go this way was made by the community in 2001.
- They built a bio-gas production plant, essentially a large fermentation unit that is fuelled by a combination of animal waste streams, maize and tricale. They also built a wood chip fuelled plant to provide the village's additional winter heating needs.
- This new infrastructure is village owned and operated and has created over a hundred new jobs. It even feeds excess electricity generated into the national grid. The cost of heating is 50% that of using fossil fuels.

The Güssing example - Austria ([58])

- Güssing in Austria is much larger than Jühnde with a population of 27,000. In 1990 the town depended largely on agriculture and was struggling to pay its annual energy bill. A decision was made to shift totally away from a dependence on fossil fuels.
- Today the town has fifty energy businesses that produce energy from sustainable sources - sun, sawdust, corn and cooking oil. A thousand jobs have been created and boosted the local economy.
- The town uses 22 megawatts of power a year from these sustainable sources and also produces an excess of 8 megawatts that is sold to the national grid.
- One of the key pillars of Güssing's sustainable energy infrastructure is an innovative wood biomass gasification unit that was installed in 2004. It has an 81.3% operating efficiency rating.
- Blue Chip Energy is a local company that has developed an alliance with Linde Nippon Sanso in Japan to expand a solar panel manufacturing operation in the town. The town is becoming an international centre for the installation and manufacture of innovative new sustainable energy infrastructure ([59]).
- Jühnde and Güssing are just two examples of communities that are relegating fossil fuels to the history books. Other examples with advanced programmes include the German communities of Morbach (11,000 people), Dardesheim, Ostritz (3000 people), and Freiamt. Many other towns and cities are moving in the same direction.
- Such communities are proving that oil, natural gas and coal will not be needed in tomorrow's energy future.

4.5 Biofuel

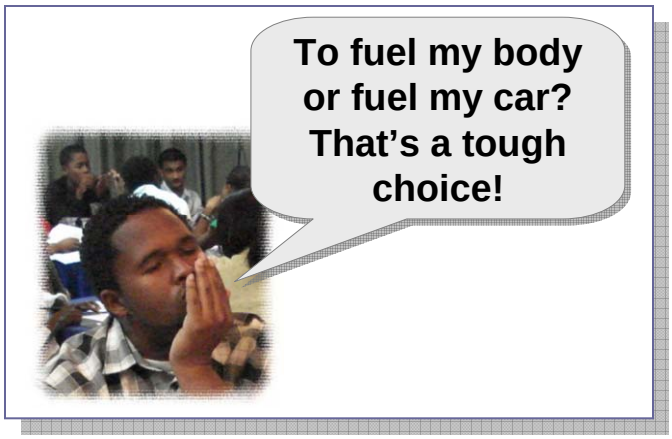
4.5.1 Current Status

- There is a great deal of interest and investment being focused towards biofuels. In the short term they provide an alternative source of liquid fuels that can be used in combustion engines and industrial units that have traditionally relied on fossil fuels.

57 http://www.finfacts.com/irelandbusinessnews/publish/article_10008702.shtml
58 http://www.iht.com/articles/2007/08/28/business/carbon.php
59 http://www.opet-chp.net/download/wp3/g%C3%BCssingaustria.pdf

- However, the long-term future is less clear as the clash between producing crops for biofuels or food has intensified.

Figure 13: The big question!



- Biofuels are produced from a range of plant crops including soy, corn, sugarcane, palm oil, coconut, and jatropha.
- The fuels extracted can be used in a pure form or blended with conventional fuels – such as 10% ethanol / 90% petrol blends.
- Brazil is a world leader in producing ethanol from sugar cane. The retail price is significantly less than gasoline and economic, even though ethanol generates about 24% less energy per litre in standard engines.
- Brazil has developed a whole range of technologies based around ethanol including the 'flexi-fuel' car which can efficiently use either 100% gasoline or 100% ethanol – and a range of blends in between.
- The US and EU have introduced policies over recent years to promote biofuel production.
- Research has shown that, when compared to gasoline and diesel, ethanol and biodiesel produced from corn and soybean crop cycles reduce greenhouse gas emissions by almost 40%, reed canary grass by 85%, and switch grass and hybrid poplar by approximately 115%.
- Both switch grass and hybrid poplar produce the greatest contribution towards reducing emissions compared to other biofuel crops and offset twice as much, compared to fossil fuels, if used for electricity generation via biomass gasification ([60]).
- Recent research suggests that biofuels may lead to negative climate change outcomes. Growing crops to make biofuels results in vast amounts of carbon dioxide being released into the atmosphere and does nothing to mitigate climate change or global warming, especially if land is cleared to grow crops for biofuel, for example:
  - Converting undisturbed peat lands in Indonesia to palm oil plantations would take 423 years to pay off the carbon debt caused by such clearance.
  - Forested land in the Amazon cut down to establish soybean fields would take 319 years to repay the carbon debt caused by felling the trees in the first place.

[60] One such study used the Daycent biogeochemistry model developed by Parton and Del Grosso.

  - Converting land to grow crops such as maize, sugar cane, palm oil trees or soybeans to produce biodiesel or bioethanol releases between 17 and 420 times more carbon than the annual savings achieved by replacing fossil fuel altogether.
  - In addition grasslands, peat lands, and forests store greater amounts of carbon than these agricultural crops.
- Other unintended effects occur when farmers focus on growing crops for biofuel rather than food. This is contributing to a decline in the global stocks of key food grain commodities and resulting in higher costs to consumers.
- Biofuel production is causing habitat destruction both directly or indirectly. Global agriculture is producing food for nearly 6.5 billion people. Producing biofuel from food crops means that more land will need to be converted from forests to agriculture.
- Between 1990 and 2005 global grain consumption was driven largely by population growth and increased levels of grain fed animal production. The increase in demand equated to an average of an additional 21 million tonnes of grain per year. Then came the explosion in demand for grain used by ethanol distilleries which jumped from 54 million tonnes in 2006 to 81 million tons in 2007 ([61]).
- Historically the food and energy economies have been largely separate. Now that so many ethanol distilleries have been built the two are merging. The result is that if the food value of grain is less than its fuel value the market will move the grain into the energy economy. As the price of oil rises, the price of grain rises.
- As a consequence of the growing impact on food prices, the EU is revising its biofuel policy ([62]). In future, it is expected that biofuels entering the global market will need carbon certification and have to comply with sustainability criteria.
- Examples of several crops being used for fuel include:
  - **Sweet sorghum** – which possesses a number of qualities which make it ideal for biofuel. It is high yielding, tolerant to drought, water logging and soil salinity. Sweet sorghum is increasingly attractive for ethanol production and can still meet food feed and fodder needs, and is increasingly attractive to countries such as China and India.
  - In China petroleum reserves are expected to run out by 2016 and ethanol is already being used either alone or combined with petrol or diesel, to fuel cars. In the Northeast and Northwest arid regions of China, saline or alkaline land and drought cause low crop yields and failed harvests of traditional summer crops such as maize and cotton. Sweet sorghum is well suited to these conditions. Alternative crop sources of ethanol are not as well adapted to these harsh environmental conditions.
  - Sweet sorghum production in the Asia region is expected to reach 500,000 hectares by 2010 ([63]).
  - **Coconut derived biodiesel –** The use of coconut oil as fuel in diesel engines started during the Second World War due to oil shortages and was used as fuel in the Philippines. In Vanuatu today coconut oil is used to fuel cars and minibuses, thanks largely to the vision of a local entrepreneur and engineer, Tony Deamer. He developed an innovative gravity feed filtration system and heat exchange unit which warms the coconut oil to improve the viscosity of diesel before it enters the engine.

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61 http://www.earthpolicy.org/updates/2008

62 http://www.europarl.europa.eu/news/expert/infopress_page/064-19610-023-01-04-911-20080124IPR19608-23-01-2008-2008-false/default_en.htm

63 http://www.new-ag.info

- Coconut oil also powers the generator of COPV Santo, Vanuatu's only industrial copra mill.
- On the Fijian isle of Taveuni the village of Welagi has an electrificity system which is based on a dual fuel generator which can run on either diesel or coconut oil.

- The hardy Jatropha tree produces a fruit that can be used to produce biofuel. It grows in harsh environments and is being planted alongside railway tracks in India. There is a great deal of interest in this tree crop which has no food value.

4.5.2 Future Trends

- The decentralisation of fuel production systems is an interesting area of development. One example is the Carlstein Technique for small scale bio-diesel production ([64]).
- Ricardo Carlstein is an engineer from Argentina who developed a miniature biodiesel refinery which allows poor farmers to make their own fuel. The agriculture industry consumes over three quarters of diesel used in Argentina.
- Enabling farmers to grow, refine and consume their own fuel eliminates transport costs to centralized plants, stimulate rural economies, reduce oil dependence and benefit the environment.
- The Carlstein units can handle almost any oil-based plant and refines the oil with 98% efficiency producing little waste. At a cost of US$ 3,800 per mini-refinery unit, this technology has particular potential in developing countries.
- Virent Energy Systems Inc has developed a 'bioforming' technology that catalyses plant sugars into hydrocarbon molecules the same as those produced by the petroleum industry. These new biogasoline molecules have a higher energy content than ethanol or butanol and deliver better fuel efficiency ([65]). Such plant sugars can be derived from non-food crops and crop components.
- Virgin Atlantic recently flew a jumbo jet between the UK and USA using biofuel made from a mixture of Brazilian babassu nuts and coconuts ([66]). It shows that alternative fuels for large aircraft are perhaps a lot closer than many think.
- GS GreenTech has developed a bioreactor using algae to convert the CO_2 in flue gases into bio-fuel and solid fuels - the 'ultimate in recycling'. Initial tests have shown 75% of the CO_2 in flue gases can be removed by such a system. The bioreactor is currently undergoing commercial testing at a power plant in Arizona, USA ([67]).
- A joint venture between Global Green Solutions Inc. in El Paso, Texas, and Valcent Products, has developed the innovative Vertigro system for producing biofuel using algae ([68],[69]).
- It is a continuous flow system that promotes the growth of algal species that contain as much as 50% of their weight as oils. This can be used to make biofuel.
- A special feature of the system is the vertical growing panels which are made of clear plastic and contain tubes through which the algae circulates in a water stream exposed to sunlight. As it circulates the algae grow and the increased growth is extracted from the circulating stream on a continuous sustainable basis.

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64 http://www.new-ag.info

65 http://www.virent.com

66 http://newsvote.bbc.co.uk/mpapps/pagetools/print/news.bbc.co.uk/2/hi/uk_news/7261214.stm

67 http://www.economist.com/displaystory.cfm?story_id=9431233

68 http://www.globalgreensolutionsinc.com/s/Vertigro.asp

69 http://www.youtube.com/watch?v=ODHjg9l-hQA

- The system is computer controlled to compensate for variable growing conditions.
- The extracted algal component is processed to remove the oil. The non-oil residues have potential to be used in other sectors such as for heath and beauty products, pharmaceutical products and animal feeds.
- The system can be established in arid areas where sunlight levels are high and alternative land uses are low. The circulating water stream is closed cycle and so only a minimal amount of re-charging is required.
- The system offers a high biofuel yield off small areas of land. One hectare of corn typically produces about 200 - 300 litres of biofuel. One hectare of the Vertigro system produces 100 - 200 times as much biofuel.
- The whole process is now patent protected. Currently one small scale commercial development unit is operational in the USA with large commercial units planned to come on stream during 2009.
- It is a real opportunity area in the biofuels field because it does not impact upon global food supplies and is fully sustainable because it only uses CO_2 and sunlight as the basis for its ongoing productivity.

Figure 14: The 'Vertigro' system ([70])

4.6 Sea and Hydro

4.6.1 Current Status

- Hydro-power does not produce greenhouse gas emissions and is a well-established contributor to renewable energy.
- New Zealand produces 70% of its electricity from hydro-power, Iceland 80%, and Laos 97%. It is a well-proven technology.
- However, it does have its downsides. Blocking a river with a dam has negative environmental consequences including:
  - The vegetation flooded by the rising waters decays to form methane gas – a far worse greenhouse gas than carbon dioxide.
  - Fish are unable to go upstream to spawn.

70 http://xavianet.files.wordpress.com/2007/10/vertigro_algae.JPG?w=394&h=249

  - They impair wetland and farming activities downstream which rely on seasonal flows.
  - They have high capital costs.
  - They lead to the relocation and resettlement of people in affected communities.
- In spite of that, hydropower offers big opportunities for developing countries such as Laos. In 2003 peak domestic power demand was 250 MW. The potential hydro-electric generation capacity is estimated to be between 18,000 and 23,000 MW ([71]).
- Over the next 25 years Laos will earn US$ 1.9 billion from the Nam Theun 2 dam project, which will be completed in 2009, through electricity exports to Thailand.
- 10 dams are currently under construction and 70 more are in the planning stage.
- Some 14 countries now produce energy from offshore tidal and wave plants. However, most of these plants are small scale and relatively high cost. But the interest is growing rapidly.

4.6.2 Future Trends

- Advances in computer technology are driving the development of free-standing turbines that eliminate the need for hydro dams and overcome historical low levels of efficiency ([72]). They can also be used in the sea. Three examples of developments in this field are:
  - **The Gorlov Helical Turbine** – which extracts 35% of the energy from a water stream, whatever the flow direction. The electric generator can be installed above the water due to its vertical shaft. The turbine design has been patented and is now being commercialized by Lucid Energy Technologies. Pilot projects are underway in both South Korea and North America.
  - **The Philippe Vauthier designed turbines** - manufactured by UEK. These turbines are anchored on a submerged platform. They are designed to align themselves with a water current, in the same way as windsocks at an airport, so that they find the best position for power generation. They are easy to install and maintain and are now being utilized in remote areas in developing countries.
  - **The OpenHydro designed turbine** - is a new design of underwater generator. Magnets are attached directly to the external rotating parts of the turbine then enclosed within an outer rim of rotating blades. There is also a circular gap at the centre of the blades which makes them safer for marine life.
- According to New Energy Finance, investments in companies planning to build or deploy free standing turbines increased from US$13 million in 2004 to US$ 156 million in 2007. Projects currently underway include the installation of a tidal turbine in the East River in New York, and UEK, OpenHydro, and the Canadian company, Clean Current, are operating pilot projects in Nova Scotia.
- Australian scientists estimate that all that country's energy needs could be satisfied by harvesting wave energy along the country's Southern Coast.
- The British Carbon Trust reckons that 20% of the UK's needs could be generated from tidal and wave sources ([73]).
- The world's first commercial wave farm is being set up of the coast of Portugal. The farm uses a series of tubes linked together in chains which are laid in the same direction as waves travel. The tubes bob up and down as the waves pass by. The

71 http://news.bbc.co.uk/1/hi/business/7104254.stm

72 http://www.economist.com/research/articlesBySubject/PrinterFriendly.cfm?story_id=10789262

73 http://www.economist.com/research/articlesBySubject/PrinterFriendly.cfm?story_id=9086536

energy generated is harnessed by a hydraulic system which converts it to electricity. It is hoped that 500 MW of power will be generated using such systems in the near future. The Portuguese government has set electricity tariffs at levels that ensure its future viability.

Figure 15: Portugal's 'wave snakes' ([74])

- In the state of California**,** utility companies PG&E and Chevron are in the initial stages of developing wave farms off the Northern California coast. Two new plants will produce a combined 80 MW of energy ([75]).
- The Chevron project is intended to generate power for commercial and industrial purposes that currently use natural gas, coal or other fossil fuels. It is also expected to remove 308,000 metric tonnes of CO_2 emissions that would otherwise be produced by coal fired plants.

4.7 Hydrogen

4.7.1 Current Status

- There is a considerable international investment going towards developing the hydrogen economy. Almost all vehicle manufacturers in the world have developed prototype vehicles that run on hydrogen fuel cells. Hundreds of hydrogen fuel cell powered buses are already on the roads in Europe and the USA.
- Battery manufacturers are developing hydrogen based fuel cell batteries for laptops and similar devices.
- There are already gas stations that supply hydrogen to commercial and private users in countries such as Germany.
- However, there are still some technological hurdles to be overcome. These include:
  - How to deliver the hydrogen – it is not an easy gas to compress.
  - The need for a substantial infrastructure investment.
  - The current cost of hydrogen fuel cell technology – although it is declining rapidly.
  - How to produce hydrogen sustainably and efficiently.
- Swiss researcher, Ulf Bossell, believes that a hydrogen economy is not a sustainable future option because no matter how the hydrogen is produced - be it by electrolysis

74 http://www.guardian.co.uk/environment/2007/oct/01/waveandtidalpower.renewableenergy

75 http://blogs.business2.com/greenwombat/2007/07/chevron-joins-c.html

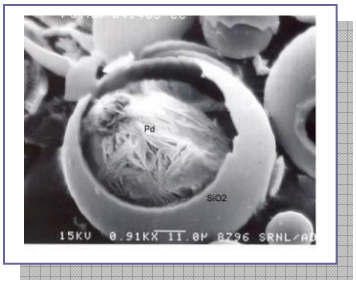
of water or other means - the energy required to produce hydrogen will be substantially more than the energy hydrogen produces when combusted.

- Bossell argues that the electricity generated by sustainable technologies can be delivered with 90% efficiency over 'modest' distances through standard transmission grids. Using that same energy to produce hydrogen as a fuel is only about 20 - 25% efficient. Bossell argues it makes more sense to use electrical energy directly as it is far more efficient ([76]).

4.7.2 Future Trends

- In spite of Bossell's reservations, it seems likely that hydrogen will play a significant role in future. The fact that it produces only water when combusted overcomes the major factor behind climate change – greenhouse gas emissions.
- Japan's Honda Motor company has commenced production of its newest fuel cell car. Toyota and BMW have already commenced production of fully hydrogen powered vehicles.
- Hydrogen fuel cells are likely to be available to power laptop computers by the end of 2009. The fuel cell batteries have been developed by a group of Russian researchers ([77]).
- A 100% hydrogen fuel cell powered prototype plane has been developed and tested by Boeing in Spain. It paves the way for rapid innovation in this sector ([78]).
- One of the big issues with hydrogen is how to deliver it to vehicles and other end users. Scientists at the Savannah River National laboratory in the USA have developed new nanospheres out of a composite material that can be filled with gas absorbent materials and made to flow like a liquid.
- The big excitement is that hydrogen could be delivered to fuel cell vehicles through traditional gasoline retailing and infrastructure channels using such as system. This would accelerate the change to a hydrogen future.

Figure 16: New glass nanospheres that could accelerate the hydrogen economy ([79])



- Iceland has a plan to become the world's first 'hydrogen economy' and be 100% free of fossil fuels by 2030. The country has vast resources of geothermal energy (only 5% tapped at this stage) and hydropower that would support the production of hydrogen ([80]).

76 http://www.efcf.com/reports
77 http://www.nanowerk.com/news/newsid=5488.php
78 http://www.boeing.com/news/releases/2008/q2/080403a_pr.html
79 http://www.sciencedaily.com/releases/2008/06/080606135330.htm
80 http://news.bbc.co.uk/1/hi/programmes/newsnight/archive/2208013.stm

- The country already has a number of hydrogen powered buses, hire cars, and the world's first partially hydrogen fuel cell powered ship, the 'Elding' ([81]).

4.8 Geothermal

4.8.1 Current Status

- Whilst geothermal energy has been used for a long time, it is only in recent years that the potential associated with this sustainable resource has been recognised. Geothermal power causes no emissions and is sustainable ([82]).
- There are two types of geothermal energy that are being developed:
  - Geothermal sources associated with volcanic zones
  - So-called 'hot rock' geothermal energy.
- Countries that have developed significant geothermal energy production sectors based around volcanic zones include The Philippines, Indonesia, New Zealand, and Iceland.
- Currently The Philippines generate about 25% of their energy from geothermal sources. Their geothermal sources are associated with the volcanic instability that impacts severely on the country from time to time. ([83]).
- There is a lot of action in Australia's Cooper Basin which has some of the world's hottest non-volcanic 'hot rocks'. Seven companies are prospecting the area. Geodynamics is one of those companies and recently claimed to have completed the first commercial scale well which could be used to produce electricity. In France a non-commercial project at Soultz will soon produce electricity from a 'hot rock' source.

4.8.2 Future Trends

- More funding is being directed towards researching and developing Australia's hot rock resources and 23 companies have applied for 237 geothermal licences and are expected to invest almost AU$ 700 million by 2013. Big finds have also been made in Tasmania ([84]).
- Indonesia and The Philippines have enough potential geothermal resources to more than adequately supply their internal electricity needs. Indonesia currently produces only 4% of its electricity from geothermal sources but could potentially produce 200% of its needs from such sources.
- The US could produce 10% of its current needs from 'hot rock' sources by 2050.
- The community of Unterhaching in Bavaria, Germany, has the world's most modern geothermal plant. It uses 'hot rock' geothermal energy to power a plant that supplies this community of 10,000 people with all its electricity and heating needs.
- It is built around the Kalina Process which uses an ammonia based mixture as the gas medium to drive the turbines. The advantage is that it becomes a gas at much lower temperatures than water and so converts ground heat into energy more efficiently. The Unterhaching plant is just the second commercial plant in the world to

81 http://www.reuters.com/article/environmentNews/idUSL1465235520080123
82 http://www.economist.com/research/articlesBySubject/displayStory.cfm?
83 http://www.economist.com/surveys/displaystory.cfm?story_id=11565660&fsrc=RSS
84 http://www.environmentalmanagementnews.net/storyviewprint.asp

use this process and is far more efficient than steam driven systems being used to exploit 'hot rock' ([85]).

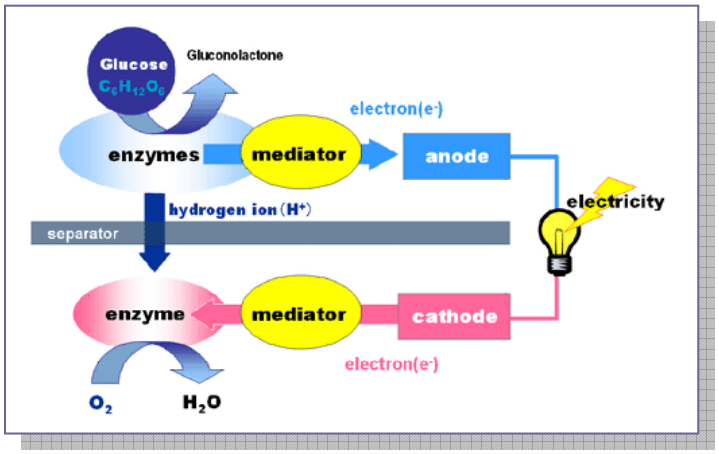
4.9 Other Developments

In this section a selection of innovative developments associated with the renewable energy sector are presented.

4.9.1 Technological Developments

- **Sugar powered bio-batteries** - This is a fascinating example of a revolutionary new bio-battery being developed by Sony. Energy is produced by enzymes that release it from carbohydrate sources such as sugar. The energy output is sufficient to power music playback from a memory type Walkman.

Figure 17: Sony's bio-battery design ([86])



- **CO_2 recycling** - British scientists as Newcastle University have developed a new highly efficient technology that converts waste CO_2 into chemical compounds called cyclic carbonates. These are used as a raw material for the manufacture of solvents, paint strippers, biodegradable packaging, as well as for applications in the chemical sector and anti-knocking agents in petrol. They estimate such uses would require the conversion of 48 million tonnes of CO_2 a year and reduce the UK's emissions by 4% ([87]).
- **99% less energy lighting** - Researchers at the Fraunhofer Institute for Production Technology in Germany have developed a way of increasing the light emission distribution efficiency of LED units. It's an important development in today's world of rising energy costs because a 1 Watt LED unit can provide about the same optical light output as a 100 Watt incandescent light bulb - a huge efficiency improvement ([88]).

85 http://www.spiegel.de/wirtschaft/0,1518,555875,00.html
86 http://www.sony.net/SonyInfo/News/Press/200708/07-074E/index.html
87 http://www.sciencedaily.com/releases/2008/04/080424103217.htm
88 http://www.fraunhofer.de/EN/press/pi/2008/05/ResearchNews52008Topic4.jsp

- **E-Fuel Corporation** - is a Silicon Valley start up company and has developed a miniature ethanol refinery package for home use. It makes alcohol by fermenting sugar with yeast and water and can produce over 100 litres of ethanol a week. However, it doesn't come cheap at just under US$ 10,000 for the package ([89]).
- **Charge up anywhere** - A Delaware based company, WildCharge, has developed a unique pad that charges a range of electronic devices merely by placing them on a pad. It may mean no more adaptors and cables ([90]).
- **Bremer Reederei Beluga Shipping GmbH** - is a German shipping group that is experimenting with using giant 'paraglider' attachments on large freighters that help pull a ship along using wind. These 'skysails' are said to be able to achieve a fuel use saving of 10 - 35% ([91]).
- **Nanotechnology as a solution** - The UK Department for Environment, Food and Rural Affairs has released study that explores ways of using nanotechnology to cut greenhouse emissions. The technology offers a unique contribution in areas such as fuel additives to reduce diesel use, enhancing solar cell conversion efficiency, for hydrogen production, more efficient batteries, and high efficiency building insulation ([92]).
- **Biojoule** is a New Zealand company that's has developed a process to produce ethanol as a biofuel from willow trees - a non-food crop that can be grown on a lot of marginal locations. They also discovered that they could convert the residual lignin into polyurethane. The cost is competitive with polyurethane produced from traditional fossil fuel sources. ([93]).

4.9.2 Eco-cities and Green Buildings

- Abu Dhabi, one of the world's largest oil producers, is currently developing the world's first carbon neutral city - Masdar. All its energy will come from wind, solar and geothermal sources. Cars will be banned. Construction started in January 2007 with completion planned for 2009 ([94]).
- The City of Brisbane in Australia has signed a deal with Origin Energy for the supply of 25% of the city's electricity needs from renewable sources (up from 5% in 2007) which will rise to 50% in future years. The city aims to become carbon neutral within 30 years ([95]).
- **Helene Tower** - A 38 storey apartment block in New York has been built incorporating a number of interesting features including photo-voltaic systems on the roof, in the building's cladding, and the entrance canopy ([96]).
- **Burj Al Taqa** - German architect, Eckhard Gerber, has designed this 322 metre high 68-storey tower for construction in the Middle East. It will be largely self-sufficient in energy and water. The glass facades will be constructed using double glazing with a vacuum between the inner and outer layers and a special mineral coating to reduce heat transfer and build up inside the tower. Wind will be used to cool the building as will seawater. All the building's energy needs will be from solar and wind. A back up

89 http://www.popularmechanics.com/blogs/science_news/4262690.html
90 http://www.technologyreview.com/Infotech/19894/
91 http://www.skysails.info/index.php?L=1
92 http://www.infomaticsonline.co.uk/articles/print/2190219
93 http://news.biotech.org.nz/2007/07/Biojoule-produce-green-plastic/
94 http://money.cnn.com/magazines/business2/business2_archive/2007/08/01/100138819/index.htm
95 http://www.environmentalmanagementnews.net/storyview.asp?storyid=115289
96 http://www.thestar.com/comment/article/239467

system will use excess energy from the solar and wind sources to produce hydrogen that can be used in fuel cells, if the other two sources fail to keep up with demand ([97]).

- **The Main Tower** – is a skyscraper in the German city of Frankfurt and has 2,550 windows. Within five years all these windows will be coated with a new thin layer photovoltaic system. The building will produce 400 megawatts of electricity a year. The cost of these new photovoltaic coating systems is about € 100 per m² compared to € 350 per m² for traditional silicon based modules ([98]).
- **The 'Lighthouse Tower'** - will be the tallest commercial building constructed in Paris since the Eiffel Tower in 1889. The building is designed to be eco-friendly and will include wind turbines to generate electricity on the roof ([99]).
- **BedZed** - This award- winning development in the UK aims to develop a community living environment that is 'zero-carbon'. It is UK government policy to try and achieve such an objective - possibly by 2016 - for all new buildings ([100]).
- **Human power** - Researchers at the Georgia Institute of Technology have developed novel new nano-fibres that generate electricity from movement and could form the basis for designing clothes that generate enough electricity from the wearer to power small electronic devices ([101]). Konarka is a group that has formed a strategic alliance with Textronics to create prototype garments that generate electricity ([102]).
- **Vibration power** - Many industrial activities generate large amounts of waste heat. Orest Symko leads a team at Utah State University who have developed a device that converts waste heat into an air vibration which in turn generates electricity. It may also turn out to be an even cheaper method for harnessing solar energy than the options available today ([103]).
- **The 'Energy Orb'** - is one of a number of smart energy monitoring devices that alert people to the energy usage they are creating. It emits different colours of light that represent pricing information i.e. if power use is being optimised ([104]).

97 http://www.arabianbusiness.com/505812-a-green-gulf?start=0

98 http://www.faz.net/s/Rub560251485DC24AF181BBEF83E12CA16E/Doc~E416C2EB17C034549807C4344D3A3B472~ATpl~Ecommon~Scontent.html

99 http://www.able2know.com/forums/about87086.html

100 http://www.peabody.org.uk/pages/GetPage.aspx?id=179

101 http://news.bbc.co.uk/2/hi/technology/7241040.stm

102 http://www.gizmag.com/go/5097/

103 http://www.msnbc.msn.com/id/19034341/

104 http://www.ambientdevices.com/

5 Sector Evolution

5.1 Changing Delivery Models

- One of the biggest trends is the shift away from highly centralised energy systems that often extend around the world (in the case of fossil fuels) towards localised solutions which are centred largely on using renewable and sustainable energy. Following are some examples of what is happening:
  - **Home produced energy** - One future option is to move towards smaller scale local-based community energy projects. Neighbourhood energy projects are likely to be a serious future alternative. Wind, solar, and fuel cell technologies may be installed in every household. Power will be generated and consumed off grid. In the long run, the costs of such schemes may be a less, both economically and environmentally than the existing highly centralised systems ([105]). .
  - **Dongtan eco-city** - is one of China's new eco-cities and will be built around a 'three villages' concept in phases. Phase 1 is due to be completed by 2010 and will provide living space for 25,000 people. By 2040 it is envisaged the eco-city will accommodate half a million residents. It will generate most of its own energy from renewable sources, have virtually zero waste, be compact so it is easy to cycle and walk around, have hydrogen fuel cell powered public and private vehicles, and will ban access to conventionally fuelled vehicles ([106]).
  - **Leasing options** - Solar Dynamics, based in Barbados, has recently started offering a solar system lease package to the developers of large building projects, in particular hotels. Solar Dynamics will supply, install, and maintain all the equipment required as a lease package. The power savings achieved in a country that has high generation costs make such a lease package very attractive ([107]).
  - **The ultimate model?** - Neil Gaught is a Brand Strategist with the global group, DesignWorks Enterprise IG, who works with large corporate clients such as BP. He says we are seeing a more radical example of a business model emerging in energy area - the personal energy supply. It's already possible to buy solar powered backpacks and electricity generating clothing that will power a computer or a cell-phone - and support the needs of an independent mobile lifestyle ([108]). Such personally generated supplies are far more secure than centralised grid systems that sometimes fail and leave large areas blacked out - often for hours - and fail to satisfy the need to always be 'energised and connected 24/7/365'.
  - **The traditional utility model threat** - Gaught says the traditional centralised utility model faces an extremely challenging future because they have less to offer in the consumer needs area. The global trend is away from large-scale infrastructure towards individual personal needs infrastructure - a radical shift!
  - **The fossil fuel sector** - faces increasing challenges which seriously threaten its future. It is not a sector that is currently 'built to last'. Here are a few examples threatening that sector's business model:

105 http://www.toolbase.org/ToolbaseResources/level3.aspx?BucketID=2&CategoryID=58
106 http://www.epa.vic.gov.au/projects/eco-footprint/australia.asp
107 http://www.solardynamicsltd.com/
108 http://www.scottevest.com/

- **The finiteness of resources** - which people are now starting to realise. 'Peak oil' is just a few years away, if not already here. This is accelerating the move to alternatives with a far greater urgency.
- **Transport and logistics constraints** - the volumes of oil and coal that need to be shifted around the world are huge and the strain is starting to tell.
- **Carbon credits** - when Kyoto comes up for review in 2012 the cost is likely to rise.
- **The rapid growth in renewables** - and advances in hydrogen energy technologies.
- **Changing consumer attitudes**.

o **Changing priorities** - In late August 2007, the US government slapped an extra US$ 16 billion of taxes on oil companies. At the same time they pledged to provide billions of dollars in tax breaks and incentives for renewable energy and energy conservation. A line has been drawn in the sand and it is clear the direction that policy will take in the future ([109]).

o **Tomorrow's 'Smart Grids'** ([110]) - The electricity grid systems of tomorrow will accommodate a multiplicity of diverse power sources and end-users including:
- Micro-generation combined with local storage components will enhance local supply security and provide buffering.
- Automated remote metering will provide 24/7/365 real time information to both suppliers and customers.
- Micro-grids will provide security of supply to small clusters of end-users and eliminate the risk of large-scale blackouts.
- Smart grids will be self-healing, interactive, optimised, predictive, distributed, integrated, and more highly secure.

o Participants in a recent EurEnDel energy Delphi survey predicted that decentralised energy systems of less than 10 MW would contribute more than 30% of Europe's electricity supply by 2020 ([111]). Other predictions include:
- Large international grids built around centres of renewables (e.g. solar in North Africa) may play a significant role around 2030.
- Advanced energy storage technologies will become widely used in renewable energy systems by 2023.
- 50% less energy use per unit of manufactured product by 2028.
- Biofuels may have a 25%+ share of the road transport sector by 2026.

5.2 Key Players

5.2.1 Country Players

- The number and spread of countries now using renewable energy has grown significantly in recent years.
- Many developing countries have now joined the trend toward the use of wind power. Over 70 countries now use this source to add to their national power generation capacity including Brazil, China, Egypt, Morocco and South Africa.

109 http://news.yahoo.com/s/nm/20070805/pl_nm/usa_energy_house_dc
110 http://ec.europa.eu/research/energy/pdf/gp/gp_events/smartgrids/2-vision/smartgrids_vision_sasse_en.pdf
111 http://www.risoe.dk/rispubl/SYS/syspdf/energconf05/session7_holst_pre.pdf#search=%22eurendel%22

- Countries leading the way in investments into increasing wind energy generation capacity include the United States, Germany, India, and Spain.
- Small hydro-power generation plants are sited primarily in China. The number grew by 19% in 2006.
- Biomass power generation is expanding as an option in over 40 countries.
- Solar PV growth is most prolific in Germany, Japan, Spain, Italy, South Korea and the US states of California and New Jersey.
- China accounted for 80% of the global market for solar hot water systems in 2007.
- Ethanol production is dominated by the US and Brazil. Biodiesel production is led by Germany followed by other EU member states, African and Southeast Asian countries are also establishing biofuel production plants.
- Small scale renewable energy systems are being incorporated into rural development programmes in many countries e.g. Argentina, Bangladesh, Bolivia, Brazil, Cambodia, Chile, China, Ethiopia, India, Kenya, Mexico, Pakistan, Peru, The Philippines, Thailand, Uganda and Vietnam.
- Scandinavian countries are leading the way in developing more secure and sustainable energy futures. The Denmark story is a model likely to be followed by many other countries as energy costs rise ([112]). Selected key points are:
  - In the 1970's Denmark was totally dependent upon imported fuel and 94% of the country's fuel consumption was oil.
  - In the 1990's it became a net exporter of oil.
  - In 1997 the import of energy equalled its exports of energy – the country had become self-sufficient in energy.
  - Coal replaced oil as the main electricity generating source using new technologies to reduce pollution.
  - District heating used waste heat from power generation and industry instead of it being wasted – in 2002 59% of homes were heated in this way.
  - Heating planning was used to develop the best local solutions to heating needs from a combination of district heating, natural gas or decentralised systems.
  - In 2004 20% of the country's energy was generated from wind.
  - Biomass makes up over 40% of the renewable energy supplies.
  - Waste makes up 34% of renewable energy supplies.
  - In total renewable energy now supplies 12% of the country's total energy needs and this is expected to double over the next decade.
  - Energy use efficiency has increased due to high energy taxes e.g. space heating energy consumption reduced by 12.5% nationally between 1980 and 1998.

5.2.2 Policy Players

- Increasing concerns about climate change and environmental destruction are driving new policy initiatives that promote the development and use of renewable energy.
- At least fifty eight countries now have targets to increase the share renewable energy contributes to their total energy generation needs. These countries include all the EU member countries, thirteen developing countries including China, and many states and provinces in the United States and Canada.
- At least fifty such countries worldwide now have some type of renewable energy policy, including twenty developing countries.

[112] http://www.denmark.dk/portal/page?_pageid=374,520560&_dad=portal&_schema=PORTAL

- At least forty four countries, states and provinces have enacted policies promoting renewable electricity, more than half of which have been enacted since 2002.
- Mandates for blending biofuels with conventional vehicle fuels have been enacted in countries in Latin America and Asia and in various states and provinces in the United States, India and Canada.
- Major cities have also set future targets for renewable energy and CO_2 emissions.
- The use of renewable energy varies from country to country due to natural physical and climatic differences. It is also significantly influenced by state policies and fiscal incentives.
- For example, Germany is looking to introduce more subsidies to accelerate a shift into renewable energies and further remove the country's dependence on traditionally high emission creating energy generation systems.
- The central German city of Marburg has become the first in the country to require all newly built or renovated buildings to have solar panels installed. The city says the new law will take effect October 1, 2008.
- The Bavarian state Government exceeded a target set for 5% of the state's total energy supply to be produced from biomass in 2007.
- The state of Texas has committed to generating 5880 MW of wind energy by 2015 and 10,000 MW by 2025 ([113]).
- The City of Sydney in Australia unveiled a vision for becoming a sustainable city. It was put forward in its City of Sydney's Sustainable Sydney 2030 draft plan. The City will facilitate this through commercial partnerships for the development of 'green transformers' - infrastructure hubs which include plants that produce low-carbon energy, recycle water and convert waste to energy ([114]).
- The Caribbean island of Dominica plans to develop a geothermal power plant which will greatly reduce its dependency on oil and gas imports. It will tap the volcanic activity around Mt. Soufriere and is expected to commence operations in 2010 ([115]).
- In Brazil 40% of vehicles are estimated to run on ethanol or ethanol/petrol mix. The country's National Biodiesel Production and Utilisation Programme made it compulsory to add 2% biodiesel to diesel fuel in 2008. This will rise to 5% in 2013.
- In 2006 Argentina passed a biofuel law requiring 5% of all liquid fuels to be derived from a renewable resource by 2009. Financial incentives are being offered to farmers and businesses entering the biofuel market.
- Argentina is the third largest soybean producer globally and, because most of its biodiesel is made from soybean, the acreage under cultivation will need to increase by 10% to meet both food and fuel targets.
- About US$284.5 million has been invested into biofuel projects in Argentina over the last 20 months. It is estimated to reach US$1 billion over the next four years.
- Other South American countries are developing their own solutions in an attempt to reduce expenditure on traditional oil imports ([116], [117]). Examples include:
  - **Chile** currently imports 72% of its energy. It has announced schemes to develop its own biofuel industry.

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113 http://featured.matternetwork.com/2008/5/texas-builds-pipeline-wind-energy.cfm

114 http://www.cityofsydney.nsw.gov.au/2030/

115 http://geology.com/news/2008/geothermal-in-dominica.shtml

116 http://www.biofuels-sa.com

117 http://wwwbiodiesel.gov.br/programa

- **Colombia** has just backed a US$180 million biodiesel investment to develop a lucrative export industry to Europe.
- **Venezuela** is developing a biodiesel production strategy that links with small farmers as a means of reducing rural poverty.

5.2.3 Private Sector Players

- 'Green-tech' is considered to be the next big thing. There are huge amounts of money being invested into solar power, wind power, fuel cells, biofuels and emerging innovative energies.
- More than two thirds of the US$ 1.2 billion clean technology investments made internationally in 2007 was made by US investors - US$ 884 million. US$ 500 million of that came from Silicon Valley entrepreneurs. 'Green-tech' energy investments still only account for 3.7% of the total venture capital market in the world - but the interest is growing rapidly.
- There has been a trend for leading executives to leave ICT companies and become involved in others focussing on environmentally friendly technologies. Examples include the resignation of Shai Agassi, next in line to be CEO at software giant SAP who has set up a venture called 'Better Place'. Its first investment is into developing electric cars in conjunction with Renault. Elon Musk was co-founder of PayPal and now chairs Tesla Motors, also involved with building electric cars. Mitch Madich moved from Apple to a company called 'Range Fuels', which is developing biofuels from non-food crops and crop residues ([118]).
- General Electric (GE) one of the leading US blue chip companies has been diversifying its portfolio mix into renewable energy technologies.
- Virgin Group founder, Richard Branson, is aiming to produce clean biofuel by the start of 2010 through a subsidiary, Virgin Fuels, which is investing $400 million over thee years in renewable energy initiatives.[119]. This fuel will be utilized in planes buses, trains and cars within three to four years. Virgin is developing biofuels in association with Boeing, and GE Aviation, a division of General Electric.
- Japanese company, Linde Nippon Sanso (LNS), is has won a contract to supply Austria's first solar cell manufacturing plant. They will work with local company, Blue Chip Energy, which is investing 50 million euros in the first phase of the plant. The plant is expected to manufacture 800,000 square meters of solar cells a year, enough to provide power to 16,000 households ([120]).
- Approximately 77% of Australian architects, engineers, contractors and building owners surveyed for the 2008 Green Building Market Report said rising energy prices were a key reason for incorporating sustainability into their building designs. 85% of the 1200 respondents have been involved in green projects to date ([121]).

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118 http://www.economist.com/business/displaystory.cfm?story_id=10766460

119 Excepted from Technology News- Story copyrighted to Reuters Limited 2007

120 http://www.linde.com

121 http://www.gbca.org.au

5.2.4 Consumers

- Consumers are becoming more concerned about their environment showing an increasing preference for environmentally friendly products ([122]).
- Increasing numbers of traditional companies are repositioning themselves. The global energy giant, BP, is a good example. 'British Petroleum' is becoming 'Beyond Petroleum' and focusing more on renewable energy.
- Electricity providers in many US states now offer green power to their customers. The power is fed directly into the power grid. Green power is also sold in the form of renewable energy certificates.
- The state of Michigan has been expanding renewable energy as part of its consumer 'Balanced Energy Initiative'. At present approximately 5% of the electricity consumed in the state is from renewable resources. By 2015, it is planned to increase the supply of renewable energy to 10%. Since 2001 this initiative has offered customers an opportunity to support the development of renewable energy in Michigan through a program known as 'green generation'. In 2007 in excess of 10,000 people enrolled.

5.3 Economics & Market Trends

- This section presents a number of renewable energy indicators relating to market size and growth trends that complement those quoted elsewhere in this report.
- Table 2 illustrates the contributions made by different types of renewable energy sources in 2006.

Table 2: Contributing sectors to renewable energy – 2006 figures ([123])

	Contributing Sectors to Renewable Energy	Energy Contribution
1	Wind power	74 GW
2	Small hydro power	73 GW
3	Biomass – power generation	45 GW
	Biomass - heating	235 GW
4	Geothermal power	9.5 GW
	Geothermal heating	33 GW
5	Solar power generation	8.2 GW
	Solar hot water heating	105 GW
6	Biofuels - Ethanol production	39 billion litres
7	Biofuels – Biodiesel production	6 billion litres
8	Large hydropower	770GW
9	Wave and tidal power	0.3 GW
10	Total power generated from renewable energy	1000GW
11	Global power generating capacity	4300GW

122 http://www.consumerenergy.com

123 http://www.ren21.net/pdf/RE2007_Global_Status_Report.pdf

- In 2007 the global investment into renewable energy was estimated to exceed US$100 billion ([124]). This was made up as follows:
  - US$ 66 billion in added capacity for new types of renewable energy investments.
  - US$ 15-20 billion for large hydropower.
  - US$ 10-12 billion in new manufacturing plants for solar PV and biofuels.
  - US$ 16 billion in public and private research and development.
- An indication of the growth potential for players in the renewable energy sector is shown in Table 3. This Table lists the current contribution renewable energy makes to the total primary and final energy levels as well as future targets set in a range of developed and developing countries.

Table 3: The share of primary and final energy from renewables – existing levels in 2006 and future targets ([125])

	Primary energy (IEA method)		Final energy (EC method)	
Country/region	**Existing share (2006)**	**Future target**	**Existing share (2005–06)**	**Future target**
World	13%	—	18%	—
EU-25/EU-27	6.5%	12% by 2010	8.5%	20% by 2020
Selected EU Countries				
Austria	20%	—	23%	34% by 2020
Czech Republic	4.1%	8–10% by 2020	6.1%	13% by 2020
Denmark	15%	30% by 2025	17%	30% by 2020
France	6.0%	7% by 2010	10%	23% by 2020
Germany	5.6%	4% by 2010	5.8%	18% by 2020
Italy	6.5%	—	5.2%	17% by 2020
Latvia	36%	6% by 2010	35%	42% by 2020
Lithuania	8.8%	12% by 2010	15%	23% by 2020
Netherlands	2.7%	—	2.4%	14% by 2020
Poland	4.6%	14% by 2020	7.2%	15% by 2020
Spain	6.5%	12.1% by 2010	8.7%	20% by 2020
Sweden	28%	—	40%	49% by 2020
United Kingdom	1.7%	—	1.3%	15% by 2020
Other Developed/OECD Countries				
Canada	16%	—	20%	—
Japan	3.2%	—	3.2%	—
Korea	0.5%	5% by 2011	0.6%	—
Mexico	9.4%	—	9.3%	—
United States	4.8%	—	5.3%	—
Developing Countries				
Argentina	8.2%	—	—	—
Brazil	43%	—	—	—
China*	8%	15% by 2020	—	—
Egypt	4.2%	14% by 2020	—	—
India	31%	—	—	—
Indonesia	3%	15% by 2025	—	—
Jordan	1.1%	10% by 2020	—	—
Kenya	81%	—	—	—
Mali	—	15% by 2020	—	—
Morocco*	4.3%	10% by 2010	—	—
Senegal	40%	15% by 2025	—	—
South Africa	11%	—	—	—
Thailand*	4%	8% by 2011	—	—

Note: Not all countries with primary energy targets are included in table; see Endnote 43 for countries not shown. Targets for final energy by 2020 for EU countries were proposed in January 2008 by the European Commission and were subject to review and confirmation by the member countries. Final energy existing share is 2005 for EU countries and 2006 for world and other countries. EU primary energy target by 2010 applies to EU-25; final energy target by 2020 applies to EU-27. (*) Existing share and targets for China, Morocco, and Thailand exclude traditional biomass. Some countries shown also have other types of targets; see Tables R8 and R9. *Source:* See Endnote 43.

124 http://www.ren21.net/globalstatusreport/

125 http://www.ren21.net/pdf/RE2007_Global_Status_Report.pdf

- Table 4 provides an overview of the investment trends and capacity growth for the renewable energy sector.

Table 4: Trends in investments and capacity building associated with renewable energy ([126])

Selected Indicators	2005	2006	2007 (estimated)
Investment in new renewable capacity (annual)	$40	55	71 billion
Renewables power capacity (existing, excl. large hydro)	182	207	240 GW
Renewables power capacity (existing, incl. large hydro)	930	970	1,010 GW
Wind power capacity (existing)	59	74	95 GW
Grid-connected solar PV capacity (existing)	3.5	5.1	7.8 GW
Solar PV production (annual)	1.8	2.5	3.8 GW
Solar hot water capacity (existing)	88	105	128 GWth
Ethanol production (annual)	33	39	46 billion liters
Biodiesel production (annual)	3.9	6	8 billion liters
Countries with policy targets	52		66
States/provinces/countries with feed-in policies	41		46
States/provinces/countries with RPS policies	38		44
States/provinces/countries with biofuels mandates	38		53

Top Five Countries	#1	#2	#3	#4	#5
Annual amounts for 2006					
New capacity investment	Germany	China	United States	Spain	Japan
Wind power added	United States	Germany	India	Spain	China
Solar PV added (grid-tied)	Germany	Japan	United States	Spain	South Korea
Solar hot water added	China	Germany	Turkey	India	Austria
Ethanol production	United States	Brazil	China	Germany	Spain
Biodiesel production	Germany	United States	France	Italy	Czech Republic
Existing capacity as of 2006					
Renewables power capacity	China	Germany	United States	Spain	India
Small hydro	China	Japan	United States	Italy	Brazil
Wind power	Germany	Spain/United States		India	Denmark
Biomass power	United States	Brazil	Philippines	Germany/Sweden/Finland	
Geothermal power	United States	Philippines	Mexico	Indonesia/Italy	
Solar PV (grid-connected)	Germany	Japan	United States	Spain	Netherlands/Italy
Solar hot water	China	Turkey	Germany	Japan	Israel

126 http://www.ren21.net/pdf/RE2007_Global_Status_Report.pdf

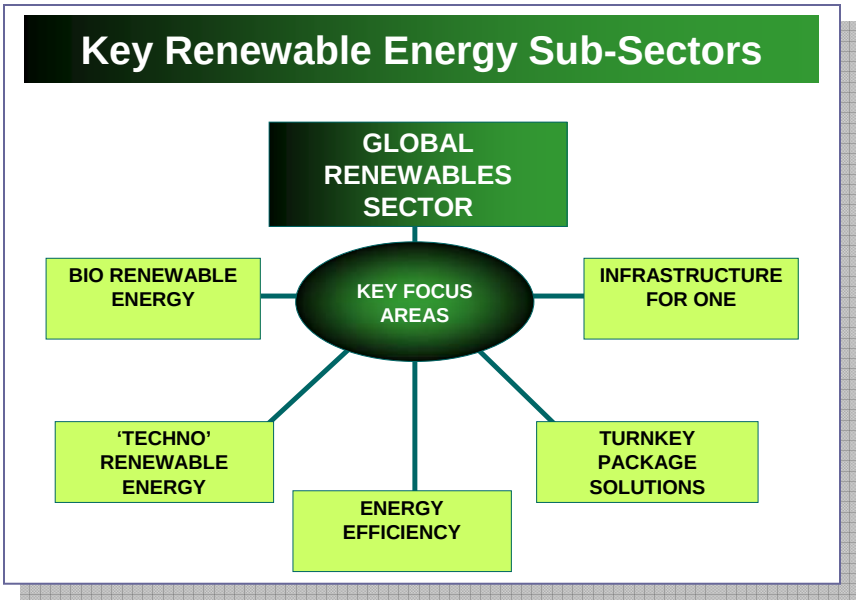
6 Renewable Energy Sub-sectors

In this section the focus is on identifying key renewable energy sub-sectors that have strong growth potential and identifying areas that may provide opportunities for investment in T&T.

6.1 An Overview

- Energy is a fundamental requirement for every sector and human life. In Figure 18 an overview of what are likely to be the most important renewable energy sub-sectors over the next decade or so is presented.

Figure 18: Key renewable energy global sub-sector opportunity areas ([127])



- A breakdown of potential niche opportunity areas within each of those sub-sectors is as follows:

6.1.1 Bio Renewable Energy Niche Areas

- Biomass.
- Biofuel – food crop sourced.
- Biofuel – non-food crop sourced.
- Bio-generation systems.
- Waste to energy systems

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6.1.2 'Techno' Renewable Energy Niche Areas

- Wind generation.
- Solar PV generation.
- Solar water heating.
- Other solar (air conditioning, etc.).
- Small hydro.
- Large hydro.
- Wave and tidal power generation.
- Geothermal.
- Hydrogen.
- Other.

6.1.3 Energy Efficiency Niche Areas

- Smart sensor based control systems.
- Design focuses.
- Energy saving products.
- Software-based energy management packages.

6.1.4 Turnkey Package Solutions Niche Areas

- Decentralised community-based 100% renewable energy systems.
- Decentralised commercial 100% renewable energy systems.
- Decentralised household 100% renewable energy systems.
- Smart local grids.

6.1.5 Infrastructure For One Niche Areas

- Consumer applications.
- Energy generating clothes/fashion.
- Portable tech-based micro-generation systems.
- Micro-energy devices for mobile living.

6.2 Appropriate Technologies

An important part of the foresight process is to determine which niche areas offer the greatest opportunities for a small country such as T&T when the capabilities and enablers available locally are taken into account.

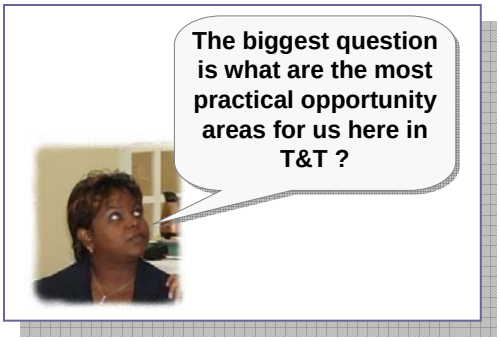


Figure 19: The big question for T&T

In Table 5 each of the sub-sector niche areas has been ranked in terms of the potential opportunities they may offer to T&T based on the author's experience in the country and region.

Table 5: A ranking of the potential appropriateness of various renewable energy opportunity areas for T&T

Bio Renewable Energy			
Biomass	♦♦♦	Bio-fuel – non-food crop sourced	♦♦
Bio-fuel – food crop sourced	♦	Bio-generation systems	♦♦♦
Waste to energy systems	♦♦		
'Techno' Renewable Energy			
Wind generation	♦♦♦	Large hydro	♦
Solar PV generation	♦♦	Wave and tidal power	♦♦♦
Solar water heating	♦♦♦	Geothermal	♦♦
Other solar (air-conditioning etc)	♦♦	Hydrogen	♦
Small hydro	♦♦	Other	♦
Energy Efficiency			
Smart sensor-based control systems	♦♦	Energy saving products	♦
Design focuses	♦	Software based energy management packages	♦♦♦
Turnkey Package Solutions			
Decentralised community-based 100% renewable energy systems	♦♦♦	Decentralised household 100% renewable energy systems	♦♦♦
Decentralised commercial 100% renewable energy systems	♦	Smart local grids	♦
Infrastructure For One			
Consumer applications	♦	Portable tech-based micro-generation systems	♦♦
Energy generating clothes/fashion	♦♦	Micro-energy devices for mobile living	♦

♦ Unlikely to be appropriate.
♦♦ Appropriate for limited niche application areas.
♦♦♦ Appropriate for a number of niche application areas.

6.3 Potential Best Bets Opportunities for T&T

- Based upon the research undertaken to produce this Global Sector Foresight Report, the following potential 'best bet' investment areas have been identified as offering opportunities for T&T.
- This list of potential 'best bets' will be ranked using a scorecard based system by key stakeholders in T&T and the top three or four ranking 'best bets' will be developed into full investment opportunity business cases.

6.3.1 Potential Best Bet 1: Turnkey Package Community Systems

- The model for this 'best bet' is based upon community systems that have been developed in Europe to provide 100% fossil fuel free energy supplies to communities ranging in size from 750 people (e.g. Jühnde in Germany) up to up to 27,000 (Güssing, Austria).
- Such turnkey community renewable energy packages can embrace a range of energy sources including biomass, biogas, solar, wind, and waste to energy systems.
- A whole range of technologies from both the developing and developed parts of the world can be integrated into such turnkey packages to provide a customised community system.
- It provides long-term sustainable energy supplies and substantial employment for smaller communities and will continue to provide a solution long after the country's oil and gas resources are exhausted, and for countries without such resources.
- It provides a solution for areas with poor access to national infrastructure systems.
- The design, construction and management of such systems could form the basis of a business that can expand throughout the region and even worldwide.

6.3.2 Potential Best Bet 2: Wave energy

- T&T is surrounded by a restless sea. The country has considerable potential for harnessing wave energy.
- Professor Prakash Persad and his team in the Mechatronics group at the University of Trinidad and Tobago are currently working on a project to harness wave energy to power desalination plants.
- Large wave farms are now being developed off the coast of Portugal. The economics of wave energy use are becoming more competitive now that global fossil fuel prices have risen so high.
- There is considerable potential to develop innovative wave energy harvesting solutions not only for T&T but also for other countries with huge potential such as Australia.

6.3.3 Potential Best Bet 3: Solar TFPV systems

- Because of T&T's artificially low energy costs, solar PV systems are currently not a feature of the country's energy scene.

- However, following recent breakthroughs in TFPV systems by companies such as Nanosolar, a whole new opportunity area has opened up.
- Being able to apply thin film PV systems to construction components and other surfaces offers a whole new range of interesting options.
- There is already at least one company in T&T in the electronic component manufacturing area that has expressed an interest in entering this field.
- It may be as simple as securing a regional license from a smart solar technology development company offshore.

6.3.4 Potential Best Bet 4: Solar air-conditioning systems

- Air-conditioning is used extensively in the Caribbean and other tropical and sub-tropical areas around the world.
- There have been some prototype solar powered air conditioning systems developed in several parts of the world – including Sweden
- There is a real opportunity to come up with a solar powered air-conditioning system that operates on a stand alone basis and does not have any requirement for standard electricity inputs.

6.3.5 Potential Best Bet 5: Biogas systems for household use

- The government of Nepal is funding the development of hundreds of thousands of household sized biogas generation systems which utilise human and animal waste.
- Not only do such systems provide a reliable and cheap source of gas for cooking and other household purposes but they also provide a means of safely dealing with human waste streams and improving the sanitary environment in small communities.
- It is a highly decentralised solution that does not require major infrastructure investments for either gas reticulation or sewage system installation.
- This 'best bet' is also unlikely to require large investments for setting up a business.

6.3.6 Potential Best Bet 6: Free standing turbine systems

- This is a unique evolving field with three technologies currently being developed that show a high level of promise.
- A potential opportunity exists to use such systems off the coast in areas where there are strong tidal flows to generate electricity in a totally sustainable way.
- Once again the opportunity may simply be the securing a regional license for one or more of these technologies from a high technology manufacturer offshore.

6.3.7 Potential Best Bet 7: Hot rock geothermal systems

- The Caribbean region is known for its high level of volcanic activity, geothermal zones, and hot rocks.
- Geothermal energy is one of the most under-exploited renewable energy areas in the world and yet it has vast potential and can provide total energy independence to many countries which possess this natural and sustainable resource.

- New technological developments such as the Kalina based process that is being used in the village of Unterhaching in Germany offer highly cost efficient ways of using even lower temperature hot rocks and geothermal zones.
- There is a great deal of expertise in the whole area of geothermal power in The Philippines, New Zealand, and Iceland.
- It is becoming a cost competitive option that could offer a lot of opportunities for the region. T&T companies could lead the way in this field by creating the right offshore alliances.

6.3.8 Potential Best Bet 8: Software-based energy management

- Achieving energy use savings of 30 – 50%, compared to current use levels, is becoming an integral part of future energy strategies.
- T&T has a well developed energy sector and within that a number of highly regarded energy specialists such as Mr Tony Paul who are involved in the development of renewable energy and software related solutions for the energy sector.
- This 'best bet' would focus on developing smart ICT based energy use efficiency management systems for which specialist software applications are an integral part.
- There are a number of ICT companies in T&T that have a history of being innovative and, if strong public private partnerships are built, could drive developments in this opportunity area.

6.3.9 Potential Best Bet 9: Micro-electricity generation systems

- This is a real 'wild card best bet' and is based upon the sugar battery development being pursued by Sony in Japan. They have already developed prototype batteries that use sugar and enzymes and can power a Walkman music player.
- This is a totally sustainable battery concept that suits people on the move.
- It also gets over many of the current problems associated with the use of heavy metals e.g. Nickel and Cadmium, in most traditional batteries. These create a toxic waste problem.
- T&T has considerable expertise in both the fields of sugar production and microbiology. There is no reason why T&T could not become a global leader in the development of bio-battery type micro-energy generation units.
- They may even power evolving fibre optic illumination systems which require 1% or less of the power of traditional incandescent bulbs.
- There is also the illuminating capability of the local firefly that could also form the basis of some interesting developmental project work in the renewable energy field. The field of 'biomimicry' is a rapid growth area internationally.

7 What Comes Next?

In this report a global foresight view of the renewable energy sector and key sub-sectors has been developed. It provides a context for looking at potential 'best bet' investment opportunities for T&T.

The challenge is to identify areas that are going to be of the greatest relevance for T&T to focus on so that new energy sector businesses become well positioned in markets that that offer strong growth prospects over at least the next 5 - 10 years. The whole sector is changing rapidly and many things that are relevant today will become outdated and irrelevant tomorrow.

T&T needs to become far more focused on the opportunities associated with the entire renewable energy sector because it has invested heavily in the development of considerable expertise in the energy field. However, once the country's oil and gas fields enter into a decline phase – which may be little more than a decade away – that investment will have little long-term value to the country unless it is redirected towards future rapid growth opportunity areas in the 'new energy' scene.

These nine initial possible renewable energy sector 'best bets' will now be subjected to a peer review and the top three to four will be developed into full business opportunity investment cases over the coming months.

8 Appendix 1: Sector Foresight – The Long Term View

In this section we look at some 'big picture' views of factors shaping the renewable energy sector over the next decade or so.

8.1 Consumer Trends

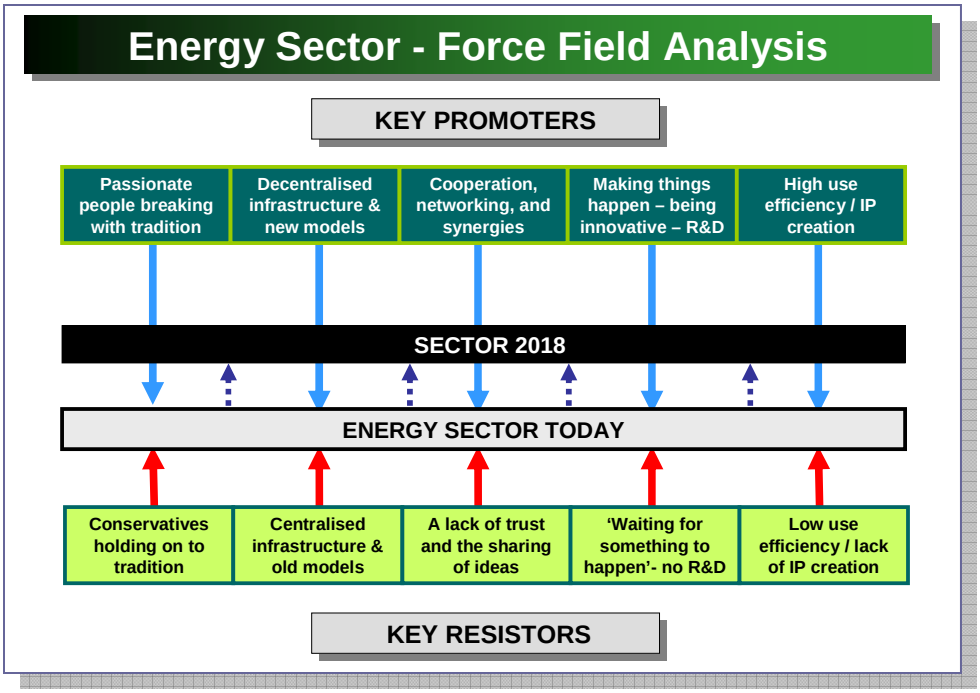
We have identified a number of consumer trends likely to impact significantly on energy related market sectors over the next decade. These include:

- Pursuit of pleasure, quality of life, and happiness.
- Self-enhancement – including technological gadgets, heightening the senses, and high risk experiences.
- Comparative material well-being.
- 'Give me a gift of time – so I have more time to do the things I love.'
- Longevity and 'Age Defiance' – people want to defy aging and will pay for it – particularly amongst the over 45s but also increasingly a focus of the young – so anything that makes people feel young is a growth area.
- Individualism – markets of one - more singles, the egoistic society.
- Fascination – people are looking for '5 minute fascination' – instant gratification.
- A move from the 'technology immigrants' to the 'technology natives' – those who have been born and brought up in a technology driven world and accept major advances as being an expectation and normal.
- Global living – being able to move freely around the world with the minimum of hassles and enjoy ethnicity and culture as part of that lifestyle – in both the real and virtual worlds.
- Health and wellness – particularly as the over 45s begin to realize half their lives are behind them and looking after their health and wellness is essential is they want to maximize what they get out of life.
- Being 'out' is 'in' – the death of the mass market – an aspect of growing individualism – 'I am unique' – and a move to extremes.
- Changing spending priorities – the high priorities are now smart technology, experiences and entertainment, and personal enhancement.
- Mobile living and being connected 24/7/365.
- The blurring of boundaries between real and virtual worlds.
- Sustainability is becoming a concern of greater numbers of consumers, especially the large and influential 'Cultural Creative' group.

8.2 Force Field Analysis

A number of factors that are either promoters or resistors and which are shaping the future development of the energy sector are summarised in Figure 20.

Figure 20: Energy Sector force field analysis ([128])



The 'Promoters' favouring growth of the renewable energy sector include:

- Advances in technology and applications.
- The development of more creative and innovative solutions.
- Growing investment into green and sustainable futures.
- New and highly innovative players.
- The greening of consumers.
- Decentralisation and new business models.
- Markets are becoming more open globally and allow a greater range of new and innovative products to be accessed and supplied from a wider range of sources to satisfy a need for customised solutions for markets of one.

The 'Resistors' holding back advances in the renewable energy sector include:

- Traditional attitudes that hinder the transition to a more sustainable future.
- Concerns that can restrict information sharing and innovative expression.
- The market can change quickly and alter the whole proposition for an individual sector player within a very short timeframe.
- A lack of investment into new and innovative opportunities.
- Market distortions such as subsidies.
- Individualism that restricts collaborative developments.
- A lack of 'big picture' visions and an understanding that what used to the case will not necessarily be the case in the future.

The future usually arrives faster than most expect!

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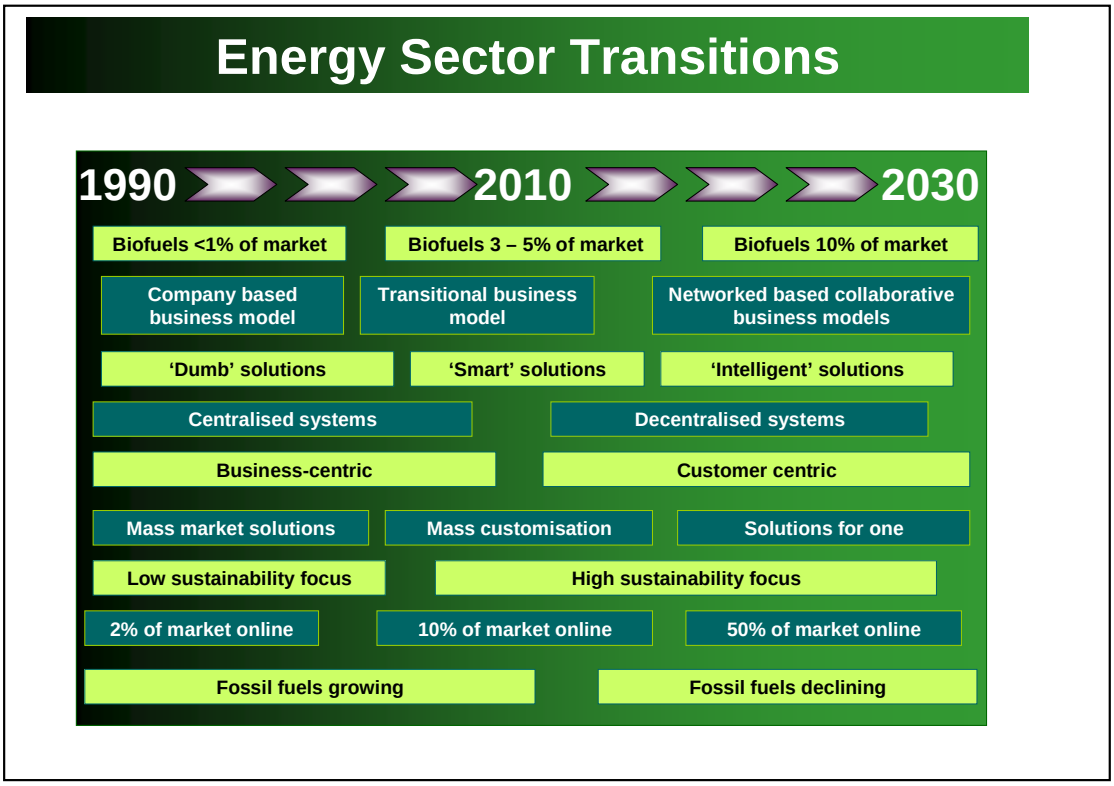
8.3 Sector Transitions

A simple way of mapping sector change from the past to the future is shown in Figure 21. Such change does not necessarily happen in a linear fashion. It can be the result of a trend (a gradual change), a discontinuity (a change that alters a traditional space often quite quickly) or a critical uncertainty (something that happens in a less predictable way – often suddenly).

Figure 21: Energy sector transition roadmap showing selected examples of change ([129])



8.4 Sector Scenarios

In this section we present an excellent example of how to develop a set of alternative futures for a sector. This set was released by one of the world's leading scenario development groups, the Global Business Network, during 2007 ([130]). The most important thing about developing such scenarios is that they are tools used to develop a picture of how the future may play out from different perspectives as a basis for developing strategies and strategic responses. It is rare for any single scenario within a set to play out in its entirety. Normally the future outcome includes parts of several different scenarios.

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130 http://www.energystar.gov/ia/business/GBN_Energy_Strategy.pdf

Scenario 1 'The Same Road'

This scenario assumes that the world continues fairly much in the same direction it is heading today with regard to energy and environmental concerns. This is fairly much a 'reactive' pathway where most change occurs because of increasing costs and responses to imposed legislative changes. This is essentially a business as usual scenario and typifies what is happening in most economies today.

'No worries mate!'

Scenario 2: 'The Long Road'

This scenario assumes that the world sees a significant shift in the economic, geopolitical and energy centres of gravity. This is a scenario characterised by disruption and more ups and downs in the industrialised economies. It is a largely negative scenario and would lead to a generally less stable world - politically and economically.

'Who has the power now?'

Scenario 3: 'The Broken Road'

This scenario sees the world continuing fairly much as it is today until a major event occurs that leads to the overturning of established systems and rules within a very short space in time. This could be a serious supply shock or a dramatic climate change related event that leads to a rapid change in policies. This is a middle of the road scenario that could play out at any time - as we saw with the oil shock of the early 1970s.

'Oops! I didn't see that coming!'

Scenario 4: 'The Fast Road'

This scenario sees a world within which reasoned decisions and investments in energy and climate risk are made early enough to make a difference. It is a forward looking proactive scenario where businesses make a move before they 'hit the wall'. It is a positive and largely logical scenario based upon where the world's energy markets are heading today.

'Nothing like a bit of foresight!'