STUDY I

STUDY ON MID-TERM AND LONG-TERM TRENDS OF GLOBAL PHOTOVOLTAIC INDUSTRY DEVELOPMENT

THE CIRCA GROUP EUROPE

January 2013

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1 INTRODUCTION

1.1 Study I: Mid-term and long-term trends of global photovoltaic industry development

1.1.1 Study goals and objectives

The aim of this study is to provide an analysis of the mid-term and long-term challenges and trends of the global photovoltaic (PV) industry in the context of the policy issues, long-term strategies, action plans and market development perspectives of the global energy sector and its applicability to a potential Lithuanian PV industry.

This is Study number 1.

This study provides the context and background for a series of related photovoltaic studies that critically assess other aspects of the photovoltaic industry and the opportunities for the evolving Lithuanian PV industry.

The other studies are:

- State of art and next generation photovoltaic (Study II)
- Present and prospective PV applications and challenges for the PV industry (Study III)
- The dynamics of PV industry: integration and competitiveness in the energy sector (Study IV)
- State of the art analysis of Lithuanian PV technology cluster and potential for its development (Study V)

Thus, this study is by its nature broad and extensive, rather than detailed and in depth. It is aimed at a broad audience of policymakers, energy specialists, energy suppliers (including fuel suppliers, other materials suppliers, power companies, distributors and energy related manufacturers and infrastructural providers), energy commentators, researchers and other interested stakeholders including politicians and consumers. Energy is a highly political area where price and supply are crucial elements of a modern economy and any disruption can cause political turmoil.

The study covers the current economic and social context of the global energy industry, its main components, policies and trends, as well its challenges, barriers and future prospects. Its value is in the comprehensive nature of the study and the wide perspective and opportunities it examines in relation to the future of Lithuania's energy sector.

Over the last 20 years the global energy sector has matured and consolidated, particularly following the collapse of communism, the expansion of the European Union and the emergence of China and India as significant trading countries. The challenges of limited fossil fuel and the dangers of excessive carbon dioxide emissions have focused much effort on how global energy will evolve over the next 40 years. The availability, reliability and timeliness of pertinent data has greatly improved and provides a key input for this study.

1.1.2 Reasons for the doing this study

Lithuania has an active photovoltaic technology cluster (PTC). It has 26 members, which include both commercial companies and research institutes. It was founded in 2008 with the aim to establish systematic background for international competitiveness and development of PTC members and a Lithuanian PV industry. The main PTC objective is to increase the added value produced by PTC members and Lithuanian PV technology and enhance companies' competitiveness by integrating RTD into the business model. The main PTC activity areas are (i) photovoltaic RTD and industry development and (ii) development of interface between photovoltaic and other areas of research and industry, where the achieved results in PV technology could be deployed.

PTC became a member of the European Photovoltaic Industry Association (EPIA) in 2009, and is the representative of Lithuania in European Photovoltaic Technology platform "Mirror" and "Research and Technology" working groups.

But the Lithuanian PV industry is currently only at an early stage of development and evolution. This study and its related studies are important contributions to the PTC's further development and the sustainable development of the Lithuanian PV industry by preparing the long-term development strategy and optimising the synergy of business and research and technological innovation (RTI) from both Lithuanian research centres and the research area of the European Union.

1.1.3 Scope

The scope of this report is on the global and regional energy sector. All components of the energy mix are covered and the key focus is on renewables, and within renewables on photovoltaic cells. The period covered is generally the last five years, although a longer period is used to illustrate trends, usually ten years.

Scenarios developed by international, regional and national bodies are used to look at likely and potential future developments. These are usually described in the following time horizons: 2020, 2030 and 2050.

1.1.4 Methodology and information sources

The core method of research for Study 1 is the use of a wide and extensive range of secondary sources, including:

- Reports and data from international bodies such as the United Nations, the World Bank and International Energy Agency, Intergovernmental Panel on Climate Change (IPCC),European Environment Agency www.eea.europa.eu; OECD

- Reports and data from national and regional bodies such as the European Commission, the United States Department of Energy, 12th Five Year Plan of the Republic of China
- Company information such as annual reports, energy forecasts and scenarios, articles, press releases, R&D reports etc. from energy companies (such as BP, Shell, Statoil to global PV manufacturers (from China, Germany etc.) such as Sunpower, Trina solar, Yingli, etc.
- Reports and information from research institutions and research centres, Technology Platforms, national and EU research programmes etc.
- Information and data from international and national solar energy representative industry bodies and trade associations such as the Global Wind Energy Council, Renewable Energy Association (UK), Solar Electric Power Association (SEPA), California Solar Energy Industries Association (CAL SEIA), and German Solar Industry Association (BSW)
- Information and data (such as manufacturing prices) from PV representative industry bodies and trade associations such as European Photovoltaic Industry Association (EPIA), U.S. Solar Energy Industries Association (SEIA), Spanish PV Union (Unión Española Fotovoltaica or UNEF), Asian Pacific PV Industry Council (APPIC), Japan Photovoltaic Energy Association (JPEA),
- Information extracted from reports, investigations and debates at national, regional and local political levels
- Non-governmental bodies' data, information and opinions such as Greenpeace, Intergovernmental Panel on Climate Change (IPCC), www.forumforthefuture.org; www.greenenergyforearth.com www.innovateus.ne;
- Trade and business magazines such as http://www.pv-magazine.com/; The Economist www.economist.com; www.solarthermalmagazine.com; www.chinadaily.com.cn;
- Specialised market information from stockbrokers, investment advisors, leading consultancy companies and banks such as Reuters, www.ft.com; www.greenworldinvestor.com; Bloomburg, www.greentechmedia.com; www.solarbuzz.com; www.solarpvinvestor.com; www.businessweek.com;
- Relevant websites such as www.pvmarketresearch.com; www.solarbuzz.com; www.solarpraxis.de; www.forbes.com; www.oilprice.com; www.globalchange.gov; www.renewableenergyworld.com; www.co2science.org;

Further information on the references quoted or used for background information are listed in the References in the annexes.

The report was prepared by three very experienced senior consultants. The team leader was Circa Group's Managing Director. The process used to prepare this report was that:

- An outline of the report was prepared by the team working together and initial research was undertaken. This formed the basis of the two monthly progress report submitted to VsI "Perspektyviniu technologiju taikomųju tyrimų institutas".
- The research was divided between the team members which allowed for a degree of overlap thus ensuring at least two of the team would cover the same ground.
- More detailed research was undertaken, then the team met to review the layout and develop a more detailed format. The writing was allocated to the team members.
- Detailed research was then undertaken and initial draft chapters were written.
- These drafts were circulated and reviewed by the team.
- The chapters were redrafted and a final content and presentation agreed.
- The whole report was formally proofed and the final edits undertaken.

It was submitted to VsI "Perspektyviniu technologiju taikomųju tyrimų institutas" in January 2013.

1.2 Summary Layout

The layout of the report is outlined in the following paragraphs.

Chapter 1 includes the following sections:

- Introduction – which includes the study goals and objectives, reasons for the study, scope and format, methodology and information sources
- Summary layout of the study
- An overview of the content of the study

Chapter 2 covers the overview of short-term, mid-term and long-term trends and development perspectives of the global energy. It includes the following sections:

- Key drivers in the global energy markets, such as, recent developments with potential long term effects; globalisation, geopolitics and trade; key uncertainties; and key variables driving global demand
- Consideration of the global economy starts from a historic context, discusses a medium term outlook and considers the long term prospects
- The overall energy sector outlook assessed energy demand and intensities, global and regional energy mix and carbon dioxide emissions

- The global energy market covered an overview of the global market, and more detailed assessment of the global oil, gas, coal, nuclear power and the power sector. It also considered renewables in power generation and bio-fuels production

Chapter 3 covers the overview of short-term, mid-term and long-term trends and development perspectives of global renewable energy sectors. Each section is presented under three headings: a general introduction, global and regional forecasts until 2020; and global and regional forecasts beyond 2020. The renewables discussed are:

- Wind
- Geothermic resources
- Water-power
- Energy from biomass
- Photovoltaics

Chapter 4 presents an overview and analysis of the main factors influencing the PV market. Its main sections are:

- Political-economic environment – including national and regional policies stimulating PV demand
- PV's generation cost and competitiveness
- The main factors influencing PV market
- Impact assessment of recent and planned policy changes on the market

Chapter 5 analyses the strategic documents shaping the future for PV. It includes:

- Description of scenarios for development of energy sector
- Targets of roadmaps related to energy sector
- Comparative analysis of the main strategic tends

Chapter 6 provides the context for Lithuania and assesses global energy policies and trends in relation to Lithuania, particularly renewables and photovoltaic energy. In includes the following:

- Lithuanian energy policy and context
- Impact of trends of global energy sector to the short-, mid- and long-term development perspectives of Lithuania energy sector
- Impact of trends of global renewable energy sector to short-, mid- and long-term development perspectives of Lithuanian renewable energy sector
- Impact of the main factors influencing global PV market to Lithuanian PV sector
- Impact of strategic documents shaping the future for PV to Lithuanian PV sector and political-economic environment

Chapter 7 provides the conclusions to the study.

Finally, the annexes include a glossary and a list of references.

1.3 Overview of the report

1.3.1 Context

Global economies are so tightly interconnected that companies, governments and industries will soon be forced to cooperate in ways unimaginable just a few years ago. There are currently three key drivers of global change that could affect the energy market:

- **Demographic shifts:** population growth, increased urbanisation, a widening divide between countries with youthful and quickly aging populations and a rapidly growing middle class are reshaping not only the business world, but also society as a whole.
- **Reshaped global power structures:** as the world recovers from the worst recession in decades, the rise of relationships between the public and private sectors has shifted the balance of global power faster than most could have imagined just a few years ago.
- **Disruptive innovations:** continue to have massive effects on business and society. Emerging markets are becoming hotbeds of innovation, especially in efforts to reach the growing middle class and low-income consumers around the globe.

In 2012, the global financial system remains fragile, but economies around the world began moving toward recovery. Some, especially those in emerging markets, continued their rapid growth but at a lower level.

The global market for energy can be very uncertain. For example, there have been a number of major changes over the last decade that has severely affected the current global environment for energy including:

- **Economic** – the credit crisis, followed by a global recession leading to austerity budgets in many OECD countries, negative for very low growth in GDP, and a significant reduction in GDP growth in non-OECD countries such as China and India
- **Political** – the major political event was the 'Arab Spring' who's repercussions are still being felt in many Arab countries such as Egypt and Libya. Other political events that are creating uncertainty include the recent Israel – Palestine dispute, the differences between Iran and the United States which have resulted in United Nations sanctions, and the more recent civil war in Syria. Unfortunately negative political events tend to have a greater impact on uncertainty than many of the positive political events that happened in the same period.

- **Environmental –** on 11th March 2011, an earthquake occurred off the Pacific coast of Tōhoku, Japan that resulted in a very destructive tsunami which caused nuclear accidents at three reactors in the Fukushima Daiichi Nuclear Power Plant complex, leading to a complete shutdown of Japan's nuclear power stations and a change in attitude towards the use of nuclear power future in Japan and in a number of other countries in Europe
- **Social** - the major social change of the last decade is the successful emergence of a new middle class in a large number of countries such as China and India in many African countries. In China alone over 60 million people joined the middle-class, equivalent to the population of France, and this is set to continue with increases in Chinese GDP.

Some of these changes or events can be predicted, others cannot. Thus, forecasting can be both difficult and uncertain. Indeed, from a national or regional perspective additional concerns include security of supply, availability of investment from both public and private sources, and environmental deterioration, particularly greenhouse gas emissions that affect global warming.

These events have had a major impact on the global supply and demand for energy. Other factors that affect the energy market are:

- The level of globalisation which has been increasing continuously over the last decade stimulates the demand for energy, particularly in rapidly growing economies.
- Geopolitics particularly as practiced by the leading world countries (United States, China, and Russia and other countries such as Japan, Brazil, and the Middle East), international terrorism, trade protection and disputes
- Increased international trade and trade liberalisation increases the demand for energy which can in turn be affected by trade disputes, barriers to trade and anti-dumping policies.

1.3.2 Current environment

The main driving forces influencing energy supply and demand are shown in Figure 1 (see also Chapter2).

Figure 1: Key drivers impacting on energy supply and demand

The main driving forces in energy supply and demand scenarios are:

- Global economic growth – the rate of GDP growth is closely related to energy demand and coupled with population growth they can provide a reliable demand growth factor. Over 70% of future world growth for the foreseeable future will come from Asia, particularly China and India. Some Africa countries and some South American countries will also continue to grow at above average world rates. The OECD countries will only grow marginally with the United States growing at a slightly higher rate.
- Population growth and demographic change – population will increase from 7 billion to 9.2 billion by 2050 and the middle class will continue to expand rapidly. There are over 1.4 billion people without electricity and 2. 6 billion without clean cooking facilities requiring additional electricity supply.
- Energy intensity - according to the McKinsey Global Institute, "$170 billion a year invested in efforts to boost energy efficiency from now until 2020 could halve the projected growth in global energy demand".
- Price of primary energy can influence the level of substitution, e.g., cheap shale gas in the United States has replaced local coal which was then exported to Europe replacing more expensive European coal. The growing LNG is likely to compete with more expensive regional gas sources.
- Investment requirements – energy investments are by their nature long term (investments planned today will probably still be in use in 2050) and the sector requires considerable investment in replacement plant, new infrastructure to enhance security and integrate renewables as well as investment to reduce intensity.

- Greenhouse gas emissions, particularly CO_2 emissions, influence the choice of energy sources and are stimulating the drive to renewables and low emissions choices such as natural gas instead of coal or oil. Until the Fukushima Nuclear disaster, nuclear was seen as a good choice by many countries, many European countries are now less sure or even against the nuclear option.
- Alternative energy sources will depend on their technical/cost availability and the investment necessary to make them significant. Wind, hydro and geothermal are technically available today; PV and bio-fuels require further development, primarily improved cost-efficiency before they make major contributions; and wave technologies are only at the development stage. All require major investment to become significant suppliers of global energy.

Other factors such as the availability of energy supply locally or regionally will also influence choice, e.g., the import of natural gas in Europe from Russia, or oil from the Middle-East.

Thus, appreciating the impact of these factors adequately and developing forecasts or scenarios for the future is a very complex and challenging task facing all countries and international bodies with an interest in the global and regional energy market.

1.3.3 Structure of energy sector

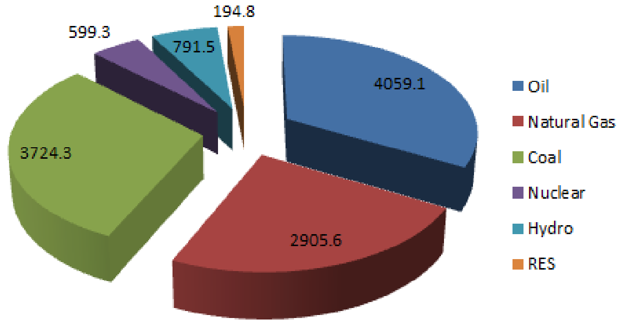
The world's Primary Energy Consumption by fuel in 2012 was as follows: Oil 33.1 percent, Coal 30.3 percent, Natural Gas 23.7 percent, Nuclear Energy 4.9 percent, Hydro Energy 6.4 percent and Renewables (RES) 1.6 percent (see Figure 2).

All of the net growth took place in emerging economies. China alone accounted for 71 percent of global energy consumption growth. OECD consumption declined, led by a sharp decline in Japan (in volume terms), the world's largest decline. The data suggests that growth in global CO_2 emissions from energy use continued in 2011, but at a slower rate than in 2010.

World primary energy consumption is projected to grow by 1.6% p.a. over the period 2010 to 2030, adding 39% to global consumption by 2030. The growth rate declines, from 2.5% p.a. over the past decade, to 2.0% p.a. over the next decade, and 1.3% p.a. from 2020 to 2030[1].

Figure 2: Primary Energy Consumption by fuel in 2012

[1] BP, (2012), Energy Outlook 2030.



The global energy map is changing radically for the following reasons: the increase in oil and gas production in the United States from unconventional sources, the retreat from nuclear power in some countries, continued rapid growth in the use of wind and solar technologies, and Iraq rejoining the oil producers of the Middle East. The energy market is truly a global market and no country can be an energy 'island' isolated from the global market. At the same time the interactions between different fuels, markets and prices are intensifying as energy products become substitutes for each other. Two future scenarios are shown in Figure 3.

Figure 3: International Energy Agency and industry scenarios to 2030

	2012[1]	2030 (IEA)[2]	2030 (Shell)[3]
Oil	33.1%	30.0%	26.9%
Natural gas	23.7%	20.5%	26.3%
Coal	30.3%	16.6%	23.0%
Nuclear energy	4.9%	9.5%	7.6%
Renewable energy	8.0%	23.4%	16.2%
Total	**100.0%**	**100.0%**	**100.0%**

Notes:
(i) BP Statistical Review of World Energy June 2012.
(ii) IEA highly ambitious scenario with a maximum target of 2° temperature rise with a CO_2 content of 450 ppm by 2100
(iii) Shell International, projections under current and expected policies
(iv) *Renewables include: biomass, solar, wind, hydro-electric, geothermal, wave/tidal and waste.*

Two scenarios differ radically with the IEA and industry scenarios. These scenarios were developed by Greenpeace and WWF and both argue that a considerably higher proportion of renewables can be used in the overall energy mix and provide plans for achieving this. These scenarios project that in 2050 renewables can be 95 percent of the total energy mix (WWF) or under Greenpeace (r)evolution scenario renewables could provide 96 percent of electricity produced in OECD European countries (see also Chapter 5).

Key points emerging from the scenarios are:

- All fossil fuels are finite. Current proven reserves of oil are 50 years, coal 118 years and gas 59 years. This may change with unconventional (shale) oil and gas, and other new discoveries
- According to successive reports by the IEA the climate goal of limiting warming to 2° C is becoming more difficult and more costly with each year that passes – no more than one third of proven reserves of fossil fuels can be consumed prior

to 2050 if the world is to achieve the 2° goal unless carbon capture and storage (CCS) is widely deployed

- Under all scenarios the only fossil fuel that grows is natural gas.
- The global demand for electricity will grow at almost twice as fast as did total energy consumption. Currently the power industry needs to replace a significant portion of its plant as it is reaching the end of its life cycle
- The largest single fuel contribution comes from gas, which will meet 31% of the projected growth in global energy
- Growth in the use of renewables - a steady increase in hydropower and the rapid expansion of wind and solar power will ensure that renewables become a key part of the global energy mix; by 2035, renewables account for almost one-third of total electricity output.
- Water is essential to energy production: in power generation; in the extraction, transport and processing of oil, gas and coal; and, increasingly, in irrigation for crops used to produce biofuels - Water needs for energy production are set to grow at twice the rate of energy demand.
- Notwithstanding practical challenges of RES, such as variability and location of RES, all the scenarios assume that the large scale integration of RES is technologically feasible but that policy makers and industry will have to contribute in overcoming these challenges if the scenario targets. The cultural, organisational and economic challenges are even greater in maximizing the use of RES

This report then assessed the current state and future prospects for the different components of the global energy mix: the oil market, the global gas market, nuclear power and the power sector (Chapter 2).

All the scenarios and global energy sectoral analysis predict a very bright future for renewables.

1.3.4 Status of the renewable energy sources (RES)

The report also assessed the current status, and future predictions for a number of specific renewable energy sources (RES) including, RES for the power industry and bio-fuels (Chapter 2). Wind, geothermal, water-power, and biomass are assessed in Chapter 3; and Chapter 4 assesses the photovoltaic industry.

Biofuels: They are renewables targeted at the transport sector. Transportation accounts for approximately 25% of world energy demand and for about 61.5% of all the oil used each year. Biofuels accounted for 2 percent of the transportation fuel in 2011. The United States accounted for 46 percent of the global use of biofuels, Brazil accounted for a further 22.4 percent, and Europe and Eurasia a further 16.7 percent - a total of 85.1 percent. The production of biofuels in 2012 was estimated at 140,000 million litres

The barriers to biofuels are very challenging. They include: competition with food and fibre production (for use of arable land); cost; the regional market structure and lack of distribution networks. Yet it remains a key part of the reduction of CO_2 in the transport sector and biofuels are projected to grow by over 10 percent per annum for 2015-2020.

Low biodiesel-diesel blends (5%-10%) can fuel diesel vehicles with no engine change. Synthetic biodiesel (BTL) is fully compatible with diesel fuel and engines. Estimates of global potential for industrial biomass production by 2050 vary considerably. Estimates of 100-200 EJ per year (roughly 10%-20% of 2050 primary energy supply) are based on the assumption of no water shortage and increased food agriculture yields in the coming decades, partly due to genetically modified crops.

Power industry: Renewable power will become an indispensable part of the global energy mix by 2035, generating almost one-third of global electricity, the International Energy Agency projected in its 2012 World Energy Outlook. There will be almost as much electricity generated from renewables as from coal by 2035. About half of all renewable electricity will come from hydro power, while a quarter will come from wind, and solar photovoltaics will represent about 7.5 per cent, according to the IEA.

This scenario – which is based on the current policies and commitments set out by global governments – would mark a tripling of renewable electrical generation. But much more aggressive moves by policy makers would be needed if the world is to limit global warming to two degrees above preindustrial levels, the IEA says. For that to happen, fossil fuel subsidies would have to be reduced, huge investments would be needed in carbon capture and storage, and far more support would have to be given to energy-efficiency programmes.

A majority of global power leaders, based on 12th Annual PwC Global Power and Utilities Survey[2], believe:

- While it is tough to secure **investment**, regulatory risk and the ability to recover costs are a bigger barrier
- Time is running out to be able to limit **global warming** to an average 2^oC
- **Gas** is not a game changer - many questions still remain about its accessibility in some locations and its environmental safety
- **Renewables** onshore wind, biomass and all forms of solar will not need **subsidies** to compete by 2030
- Potential for a break through in **storage technologies**

[2] The 12th Annual PwC Global Power & Utilities Survey is based on research conducted between October 2011 and April 2012 with senior executives from 72 utility companies in 43 countries across Europe, the Americas, Asia Pacific, Middle East and Africa. http://www.pwc.com/gx/en/utilities/global-power-and-utilities-survey/index.jhtml

- **Electric cars** will form a significant porportion of the world fleet by 2030
- **Smart grids and smart metering** are high on the list of company investment priorities

Figure 4 shows the relative growth potential of each RES. Both hydro and biomass have a well-established base and a predicted low growth over the next 40 or so years. But in the short term, hydro will have the largest absolute growth up to 2017. While wind and photovoltaic (PV) are predicted, in all scenarios, to have very rapid growth potential to 2030 and 2050.

Figure 4: Estimated growth in electricity production from RES 2010, 2030 and 2050

Renewable energy sources	2010	2030	2050
Wind	197 GW / 440 TWh (2.2%)	1,000 GW / 2,600 TWh[2]	2,000 GW (12%)[2]
Geothermal	67.2 TWh[3]	180-200TWh	1,400TWh
Water-power	3,500 TWh (16.3%)	4,740 TWh[4]	7,100 TWh[5]
Bioenergy / biomass	50EJ (10%)[3]	52EJ	100 EJ[6]
Photovoltaic cells	40 GW / 49 TWh[2]	900 GW	3,000 GW / 4,500 TWh

Notes:
(1) The percentage in the brackets gives its share of global electricity produced Energy Technology Perspective (ETP) study 2009
(2) 2017, not 2030
(3) Roughly 50% of the theoretical potential (1GW=3.647TWh)
(4) Plus 60 EJ for the production of transport fuel

An important message of the Energy Technology Perspective (ETP) study is that there is no single energy technology solution that can solve the combined challenges of climate change, energy security and access to energy

1.3.5 The photovoltaic industry

The installation of photovoltaic (PV) has been most rapid in the following countries: Japan, Germany, United States, Spain, Italy

The development of the photovoltaic industry has been supported to date by subsidies and/or feed-in-tariffs (FiT) in the following countries:

- **Germany** had 24.82 GW of PV installed by the end of 2011. The main driving force behind the robust PV market in Germany is the long-standing Renewable Energy Sources Act (EEG). German PV electricity prices are now around parity with retail electricity prices. Germany has a wide range of policy and promotional initiatives
- **Spain** had 4.21 GW of PV installed by the end of 2011. Currently 99 percent of PV installations in Spain are grid-connected systems. The Spanish feed in tariff differs from the German model in that it offers the option of incentives for sales into the wholesale electricity spot market as well as fixed incentives. Following the 2008 financial crisis, Spain cut its subsidies and capped its installallations at 500 MW per year. In 2012 all incentives were suspended for new installations due to austerity budgets

- **Italy** had 9.3 GW of PV installed by the end of 2011, over 60 percent of all new electricity generation capacity. It now provides 3 percent of the national electricity consumption
- **United States** has 3.97 GW installed by the end of 2011. They were supported at both the Federal and State level (30 percent tax credit and five year accelerated depreciation)
- **Japan** has 4.9 GW, 2.1 percent of installed of total national electricity generation capacity (2011). They are mainly residential, grid-connected distributed PV systems. The PV market was led by a subsidy programme for residential PV systems and a programme to purchase surplus PV power at a preferential price from systems of less than 500 kW capacity

Other European countries with PV installations include the Netherlands, France, United Kingdom, and Sweden. Outside Europe Korea and Canada have installation programmes in place. Both China and India have made commitments in recent years to install PV as part of their increased investment in renewables. Obviously countries that lie near the equator are better places for installing PV as they receive more intense sunlight and benefit from a longer day. In Europe, the Mediterranean countries are better locations for large PV installations. Notwithstanding that Northern countries can also benefit from using PV as well.

There are still a number of technical challenges in making a PV module more competitive with conventional sources of electricity. These challenges are being addressed by research and development programmes both within the private sector, and PV companies, and in the public sector in many of the research institutes specialising in energy related research. According to reported information, in IEA reports, European research reports, technology platform reports and research centres and institutes from many countries, the most significant spenders on research and development are in the United States, Germany, Korea, Japan, Australia and France. China also reports various ongoing programs. Several of these programs are described in Chapter 4. Many of these programs are targeted at reducing the cost of producing a PV module or increasing the efficiency of the PV cell itself. Further research is essential to bring the cost down to be competitive with conventional electricity.

Factors influencing the PV market

Global energy mix: The global energy map is changing with potentially far-reaching consequences for energy markets, trade and the global energy mix. For example, unconventional gas and oil in the United States is turning that country into a leading global producer of oil, providing gas for electricity generation and thus freeing up coal for export to Europe, which in turn is replacing more expensive gas in Europe. The growth in LPG trade and the exploitation of similar discoveries all around the world could lead to a dramatic change in trade patterns in the global energy markets. Also because the price of substitutes is a significant factor in determining the energy mix at the regional and national level, giving rise to the possibility that power generating companies would want to retain a range of plant flexibility to allow for such substitution in the future. This could have a detrimental effect on the investment levels and the nature of investments given that a high proportion of obsolete plant needs to be replaced in the next few decades. The reduction in the use of nuclear power following the nuclear disaster in Japan will also influence the energy mix in the future.

The cost of a PV module: is measured in price-per-peak-watt (€/Wp or US$/Wp for example). The cost has been declining steadily for the last 20 years. Currently it is more expensive than traditional electricity power generation. It is likely that it will become price competitive within the next 10 years, certainly that is the expectation by 2030, at the latest. Until it is competitive subsidies are necessary. This is a key objective of the research currently being undertaken. A PV module is a collection of PV cells set in a frame ready for fixing in a roof or open space and connecting it to a electrical system

The cost of an installation: but an installation involves more than that, it includes the balance of the system such as the PV array support structure, electric cabling equipment and an inverter plus installation. In addition the PV system would also include a cost for site preparation system design and engineering, installation labour, permits and operation and maintenance costs. Thus it is complex and costly task to install a successful PV system in a green field site. Many of the manufacturers simply sell PV modules and allow installation/finance companies to put together the rest of the requirements. But all these costs must be minimised if PV is to become price competitive.

Current manufacturing competition

In 2008, the top fifteen companies produced 58 percent of the world's PV cell production. Two companies were European, three were Japanese, six were Chinese, two were American, and two were Taiwanese. Three Asian companies became top fifteen cell producers in 2008 (Trina Solar, Solarfun and Gintech). Two European companies (BP Solar, Isofoton), and one Japanese company (Mitsubishi) dropped out of the top-fifteen. By 2011, there were no European companies in the top ten manufacturers.

In 2009, the German photovoltaic industry had manufacturers of silicon, wafers, solar cells, and modules (~70 PV manufacturers), PV equipment manufacturers (~100). Together they employed more than 57,000 people. German PV manufacturers' sales exceeded €9.5 billion in 2008 and PV equipment manufacturers' sales added a further l €2.4 billion (GTAI 2009c). The companies developed their skills in supporting the semiconductors, chemicals, optics and glass industries, and transferred these skills to PV manufacturing. The successful German industry has been built from the skills base.

Chinese manufacturers initially imported their equipment, later they developed their own capacity, since wafer manufacture is not as difficult a process as that of polysilicon manufacturing. After several years' R&D, the Chinese successfully developed appropriate polysilicon production. Accordingly, the wafer market is very competitive. Now, big cell and polysilicon manufacturers are starting to integrate wafer production[3].

Most cell manufacturing is integrated with module manufacturing. Integration allows these manufacturers to export at lower cost, compared to other non-integrated module manufacturers; moreover, their market demand is not limited by the capacity of module manufacturers. And since the process technology and equipment are easy to buy, many large cell producers have established their own module production line.

The most notable contrast between the German and Chinese PV industries is that production capacities for PV manufacturing are higher in China, while more of the manufacturing equipment is supplied by Germany. To some extent the relative size may reflect the specific expertise of Germany and China in these two related industries, but it may also reflect the outcome of the policies in place in each country.

In both Germany and China there is a mix of vertically integrated companies and value chain segment specialists. Such a mix of strategies - where some companies seek to maintain a competitive advantage in specific technologies or processes and others seek an advantage through risk management or economies of scale and scope – this is not uncommon strategy for maturing industries.

In 2011 solar photovoltaic grade silicon feedstock supply was dominated by China, the Unites States, Korea, Germany and Japan, with smaller levels of production in Canada and Norway. Of the main movers in 2011, China increased production by 87 percent, and also increased imports by 36 percent from the previous year. Korea increased polysilicon production capacity by 60 percent.

China, Germany, Korea, Malaysia, Japan and the Unites States are the dominant producers in the ingot and wafer section of the PV industry value chain with additional manufacturing capacity in Italy, Switzerland, France and the Unites States. Crystalline silicon wafer prices dropped by over 40 percent during 2011 causing some companies to re-evaluate their business models.

The total value of PV business in 2011 amongst the IEA PVPS countries (now including China) was approximately €85 billion. Total direct employment is reported to be around 900,000 persons across research, manufacturing, development and installation.

1.3.6 Analysis of Strategic documents shaping the future of PV

Future energy scenarios have been developed by the International Energy Agency (IEA) and a number of oil companies including BP, Statoil and Shell. Greenpeace International and the WWF are two of the private bodies that also develop energy scenarios. They are described and compared in Chapter 5. This is useful analysis as it allows one appreciate the potential differences in the variables used and also reinforces common ideas and variables. It confirms the key drivers discussed in Chapter 2, reaffirms some critical obstacles and derives some agreed conclusions:

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[3] Grau Thilo, Huo Molin and Neuhoff Karsten (2011), Survey photovoltaic industry and policy in Germany and China, Berlin

- **Fossil fuel:** supply will run out, it is finite.
- **Uncertainties:** particularly in supply are impossible to predict
- **Climate change:** the 2011 IEA outlook noted in its executive summary that there were "few signs that the urgently needed change in direction in global energy trends is underway"
- **Renewables:** the demand will grow dramatically in the next 40 or so years from a very low base. They could make a bigger contribution in 2050, but few scenarios suggest this
- **Security issues:** will continue to provide challenges

European Technology Platforms and Roadmaps for are also discussed in this chapter, including those for PV. CO_2 emissions targets and possible global fuel mixes are also discussed.

1.3.7 Implications for Lithuania

So what are the implications of future global and European policy and trends for Lithuania? The role and very rapid expansion of renewables in both the European and global energy markets, offers immense commercial potential for those entrepreneurial and skilled enough to seize the opportunity. This is challenge for many countries.

Chapter 6 initially examines the national energy policy of Lithuania and then presents the key reports that it should examine to assess its attitude and policies towards the PV sector. Finally it outlines the components of how to develop a plan to move forward from this stage incorporating the other related studies as part of this programme.

Lithuanian's major energy strategies are based on three key principles:

- Energy independence
- Competitiveness
- Sustainability

The main goal of this strategy is to ensure Lithuania's energy independence before the year 2020 by strengthening Lithuanian's energy security and competitiveness. The building blocks of energy independence are:

- A floating LNG terminal to allow gas imports from countries other than Russia (end of 2014)
- Synchronisation of the country's transmission six system with that of the EU's ENTSO-E system
- A new nuclear power plants at Visaginas (2020-2022)

Commentators believe the LNG terminal is a definite possibility, but there is some doubt over the nuclear power plant as its capital and operating costs may be higher than anticipated. The cost of LNG terminal is affordable for Lithuania - the only challenge is to find available (and guaranteed) LNG supplies at reasonable price. Whereas the Visaginas plant is expected to cost €7 billion and that cost is likely to rise during the construction, especially taking into account new safety requirements of the post-Fukushima 'nuclear era'. Furthermore, Visaginas is likely to face competition from the Baltic Nuclear Power Plant (NPP) in Russia which could have direct access to consumers in Estonia, Latvia and Lithuania (Russia's electricity grid is synchronously interconnected with the Baltic countries).

Furthermore, the National Strategy stated a move from fossil fuels to RES wherever possible, i.e., in heating a shift to RES, from coal to RES, and from oil to RES.

A review of the impact of international energy trends on Lithuanian energy supply and demand indicates that the price and security of primary fuel is a major concern and this makes national RES even more important for Lithuania. Improved energy intensity and lower CO_2 are of medium importance and will be influenced by European trends and developments.

Examining the impact of trends of global renewable energy sector to short-term, mid-term and long-term development perspectives of Lithuanian renewable energy sector revealed that investment is the key factor in the adoption of RES. Other factors of high importance are the availability of technology and expertise in the key RES areas of wood and hydro, wind and PV. Wood and hydro are well developed, wind technology is fairly well established, but PV is still in a transition phase – its technology is evolving, manufacturing efficiency continues to improve, costs are dropping, and supply chains and sales will undergo rapid expansion over the next thirty years. The industry is currently undergoing a 'shake out' and this will be followed by a rationalisation. Then it will expand. It is volatile enough to allow new entrants.

Finally this section assesses key influences of international PV trends on a potential Lithuanian PV industry in Lithuania.

The conclusions of the overall report are in Chapter 7 and, in brief, they are:

Conclusion 1	**The global demand for energy will continue to increase in the foreseeable future**
Conclusion 2	**The proportion of renewables in the future global energy mix will increase dramatically between 2013 - 2050**
Conclusion 3	**PV offers the best manufacturing opportunity within the renewables sector**
Conclusion 4	**PV is the most suitable sector of RES to develop a new manufacturing industry**
Conclusion 5	**PV is the most suitable sector of RES to develop a new manufacturing industry**

But this study has only examined the PV market potential from the energy market perspective, other studies are necessary to complete the evaluation. The other studies are:

- State of art and next generation photovoltaic (Study II)
- Present and prospective PV applications and challenges for the PV industry (Study III)
- The dynamics of PV industry: integration and competitiveness in the energy sector (Study IV)
- State of the art analysis of Lithuanian PV technology cluster and potential for its development (Study V)

Finally, Chapter 6 restates a small number of key reports that would be useful references in developing any national Lithuanian PV manufacturing plan and programme and provides an outline planning approach derived from 'best practice' German planning. The next steps to develop and implement an agreed plan would include:

- Agree a long term vision for the Lithuanian PV industry
- Establish key targets on use of PV in Lithuania, such as, support the establishment of a PV sector, create a realistic jobs target, improver manufacturing efficiency, establish a Lithuanian brand, target and secure specific market shares, generate a targeted contribution to the Lithuanian economy, and invest at least 5 percent of sales on R&D.
- Involve all the stakeholders in the implementation programme.
- Identify and schedule all implementation activities under the following timescales
    - Short-term measures to be undertaken in 2013 and 2014
    - Medium-term measures to be taken between 2015 and 2018
    - Long-term measures to be taken in the period after 2019 and over the following five years

The Annexes contain a Glossary and a list of References.

2 Overview of Short-term, mid-term and long-term trends and development perspectives of the global energy Sector

2.1 Key drivers in global energy markets

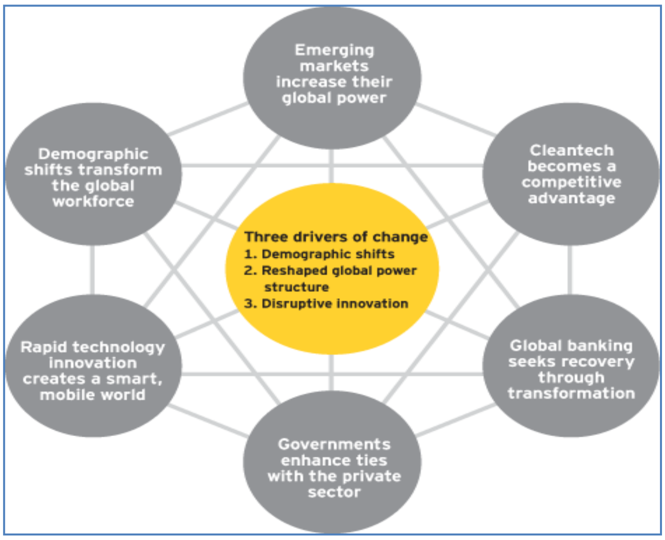
In 2012, the global financial system remains fragile, but economies around the world began moving toward recovery. Some, especially those in emerging markets, continued their rapid growth but at a lower level.

Ernst and Young's report, Tracking global trends[4], identified six broad, long-term developments that are shaping our world:

- Emerging markets increase their global power
- Cleantech becomes a competitive advantage
- Global banking seeks recovery through transformation
- Governments enhance ties with the private sector
- Rapid technology innovation creates a smart, mobile world
- Demographic shifts transform the global workforce

Global economies are so tightly interconnected that companies, governments and industries will soon be forced to cooperate in ways unimaginable just a few years ago. In fact, Ernst and Young believes that the six trends are themselves connected by three underlying drivers that have helped establish each trend and perpetuate it (see Figure 5).

Figure 5: Six global trends, interconnected by three key drivers of change



Source: Ernst & Young, 2010

- **Demographic shifts.** Population growth, increased urbanization, a widening divide between countries with youthful and quickly aging populations and a

[4] Ernst & Young, (2010), Tracking Global Trends, http://www.ey.com/GL/en/Issues/Business-environment/Six-global-trends-shaping-the-business-world

rapidly growing middle class are reshaping not only the business world, but also society as a whole.

- **Reshaped global power structure.** As the world recovers from the worst recession in decades, the rise of relationships between the public and private sectors has shifted the balance of global power faster than most could have imagined just a few years ago.
- **Disruptive innovation.** Innovations in technology continue to have massive effects on business and society. Emerging markets are becoming hotbeds of innovation, especially in efforts to reach the growing middle class and low-income consumers around the globe.

2.1.1 Recent developments with potential long-term effects

This section looks at recent developments over the last five years that have potential long-term effects on global energy supply and demand. The main factors are grouped under the following headings:

- Economic – global credit crisis, global recession, problems in the Eurozone,
- Political - Arab Spring, territorial disputes between countries, war, or international disputes, e.g., related to Iran and North Korea
- Natural disasters – earthquakes, tsunamis, storms
- Social - world population growth, social media, protest movements, such as, 'occupy wall street'
- Energy related – new fossil fuel discoveries, new technology, energy related spills or threats

These events are not discussed in any great detail, rather they are described briefly to remind us of their occurrence. Their impact on global and regional energy supply and demand is also outlined.

2.1.1.1 Economic

Over the last five years the major economic events have included a global credit crisis in 2007, followed by a worldwide recession and major financial difficulties were encountered in the Eurozone countries. The global credit crisis is described in more detail in Section 2.2.2. As a consequence of the credit crisis, a number of countries including the United States, Spain, Ireland and the UK had a housing bubble and a complete collapse in housing prices, putting a further strain on their already stretched banking systems. Greece Ireland and Portugal had to be rescued by the IMF and the EU, while Spain and Italy only just avoided a similar fate, and many banks had to be supported by the European Central bank to the tune of €1 trillion through 'quantitative easing', i.e., printing more euros.

The immediate consequence was a global recession. This recession was more keenly felt in the United States and Europe (OECD countries), and in some of the Middle Eastern countries, such as Dubai. The effect was less dramatic in the BRIC and other non-OECD and African countries and Australia. Many of the OECD countries suffered a drop in GDP growth, a rapid increase in unemployment, a drop in investment, imports and, in many cases, reduced exports also. In the non-OECD countries the effect was less dramatic but it did result in a decline in GDP growth to what is probably more sustainable levels in the longer-term. A final factor worth mentioning is the fiscal consolidation that many OECD countries face, i.e., bringing their budget deficits and national debts down to more sustainable levels for the longer-term

The impact on energy supply and demand was immediate. The recession led to a decline in demand for energy and a consequential decline in global oil prices, demonstrating the close relationship between rates of GDP growth and the price of oil. The fiscal consolidation identified as necessary in many OECD countries, including the United States and Japan, could lead to a reduction in available investment essential to support the expansion of renewable sources of energy and their related infrastructural needs.

2.1.1.2 Political

There are many political events that could impact on the energy market, some of which are difficult to foresee while others will likely have a more direct impact. Political changes in countries and regions that contain the majority of the oil and gas reserves have the greatest potential to cause new problems. The major political change that occurred recently is the 'Arab Spring', resulting in many changes across North Africa and the Middle East. To date, rulers have been forced from power in Tunisia, Egypt, Libya, and Yemen; civil uprisings have erupted in Bahrain and Syria; major protests have broken out in Algeria, Iraq, Jordan, Kuwait, Morocco, and Sudan, and minor protests have occurred in Lebanon, Mauritania, Oman, Saudi Arabia, Djibouti, and Western Sahara. The major oil rich nations (Saudi Arabia, UAE, Qatar, Kuwait and Oman) have been able to keep their ruling families in power. The disruption to the global oil supplies has been low, due primarily to the civil war in Libya which led to a temporary rise in prices. Other oil producing countries were able to increase their supply and make up the difference.

Other political situations have caused potential problems recently, such as,

- Internal unpopularity of a leader can result in civil war, demonstrations or civil disobedience and possible supply disruption (e.g., Libya in the past or maybe Russia in the future)
- Countries in international disputes, e.g., Iran where the United States is currently attempting to block Iran's oil exports to curb Iran's 'going nuclear' ambitions
- War, whether internal such as in Libya, or involving external forces, such as Iraq, has caused disruption in the recent past. There are other potential flashpoints that could also affect oil or gas pipelines that supply Europe.

Other types of disputes can also cause problems that could disrupt supplies, such as, territorial disputes like the dispute between Japan and China over uninhabited islands in the East China Sea.

2.1.1.3 Natural disasters

On 11th March 2011, an earthquake occurred off the Pacific coast of Tōhoku, Japan. It had a magnitude 9.03 (M_w) with an epicentre approximately 70 kilometres off the coast at an underwater depth of approximately 32 km. It was the most powerful known earthquake ever to have hit Japan and one of the five most powerful earthquakes in the world since modern record-keeping began in 1900. The earthquake triggered powerful tsunami waves that reached heights of up to 40.5 metres (133 ft) in Miyako in Tōhoku's Iwate Prefecture, and which, in the Sendai area, travelled up to 10 km inland (see Figure 6).

Figure 6: An aerial view of damage in the Sendai region with black smoke coming from the Nippon Oil Sendai oil refinery

The cost of the earthquake was very high – 15,870 people died, 6,114 were injured, and 2,814 people are missing, as well as 129,225 buildings totally collapsed, and a further 254,204 buildings 'half collapsed', and another 691,766 buildings were partially damaged[5]. The earthquake and tsunami also caused extensive and severe structural damage in north-eastern Japan, including heavy damage to roads and railways as well as fires in many areas, and a dam collapse. The World Bank's estimated economic cost was €94-180 billion (US$122-235[6] bn), making it the most expensive natural disaster in world history.

The tsunami caused nuclear accidents, primarily the level 7 meltdowns at three reactors in the Fukushima Daiichi Nuclear Power Plant complex, and the associated evacuation zones affecting hundreds of thousands of residents. Many electrical generators were taken down, and at least three nuclear reactors suffered explosions due to hydrogen gas

[5] Report by The National Police Agency on 12th September 2012.
[6] Prices are in euros (€) or $ (U.S. dollars/USD) unless otherwise stated. Billions=bn; millions=m. The conversion rate used in this report is €1 = $1.3

that built up within their outer containment buildings after cooling system failure. Residents within a 20 km radius of the Fukushima Daiichi Nuclear Power Plant and a 10 km radius of the Fukushima Daini Nuclear Power Plant were evacuated. In addition, the U.S. recommended that its citizens evacuate up to 80 km (50 miles) of the plant.

As a consequence many of Japan's nuclear plants have been closed, or their operation has been suspended for safety inspections. Its nuclear plants generated 30 percent of its electrical power and they had planned to increase that share to 40 percent. Germany and Switzerland subsequently decided to close their nuclear programmes and even France may cut its nuclear capacity by one-third.

2.1.1.4 Social

The key social factor affecting energy demand is the growing middle-class, particularly in non-OECD countries and regions such as China, India, Indonesia, South America and Africa. The middle class have a much higher demand for energy than the working class, particularly where this also involves moving from a largely agrarian society to an urban society. On the other hand, many middle-class people in OECD countries tend to have a greater appreciation of the need to reduce energy demand and organise their lives according. Social acceptance and widespread adoption is core to lowering energy usage, e.g., the adoption of the Toyota Prius by many leading Hollywood actors has led to a quicker acceptance by many of the population that one should be using more fuel effective vehicles every day. This has already led to a reduction in fuel demand in Europe and has encouraged the manufacturers to invest in more fuel efficient vehicles.

The widespread application of existing technology could lead to a reduction in half of the fuel/power used in everyday activities.

2.1.1.5 Energy related

Finally, there are energy related developments that influence future supply and demand. The major factor is the expression of unconventional oil and gas in the United States. Natural gas extracted from dense shale rock formations has become the fastest-growing source of gas in the United States and could become a significant new global energy source. Although the energy industry has long known about huge gas resources trapped in shale rock formations in the United States, it is over the past decade that energy companies have combined two established technologies—hydraulic fracturing and horizontal drilling—to successfully unlock this resource. Consequently, natural gas prices in these United States are one fifth of the European prices. Thus natural gas is being used instead of coal and has helped reduce CO_2 emissions. A knock-on effect is that coal is now being exported from the United States to Europe and is causing a drop in the price of coal in Europe. This is likely to continue in the future and there is a possibility that natural gas could also be exported to Europe in time.

2.1.2 Globalisation, geopolitics, and trade

Globalisation: In its most general usage, globalisation refers to the idea of a world increasingly shrunk, connected, interwoven, integrated, interdependent, or less territorially divided economically and culturally than heretofore. Globalisation is a product of an Anglo-American maritime trading practice that seeks "the free flow of goods, capital, and ideas"[7].

Geopolitics: On the other hand, geopolitics is about territorial control of space, resources, and capacities. It concerns the relationship between geography and politics a government's legitimate activities in domestic and foreign territories. But from an operational standpoint of certain governments' geopolitics, its primary purpose is to safeguard or advance their economic, security and foreign policy interests. It doubles as a code word for political muscling, coddling, and/or finessing of particular nations that have strategic value or pose threats, based on factors including location, resources, intelligence, terrorism and military implications.

In short, regardless of norms or ideals, no government or society has escaped the gravitational pull of geopolitics and globalisation, which are opposing forces that configure today's "balance of power" to the advantage of select nations while inadvertently or consequently giving rise to related terrorism. Twentieth-century history, according to Brian Blouet was grounded by the struggle between these competing systems of social organization[8].

United States' Geopolitics: Within the necessary interdependency of globalisation however, colonial-like political and corporate arrangements are maintained whereby power and wealth remain largely concentrated within the grip of Western nations and their institutions. This grew out of the following major influences: The rapid expansion of the United States post the American Civil War and the creation of a large integrated modern economy that was increasingly dominated by large firms, which as they developed overseas interests were able to help shape the American international agenda. Their 'development role' in the United States economy prior to the first World War grew into using 'a development' approach to international geopolitics, out of which emerged the Marshall Plan post World War II (WWII). In the 1960's it further morphed into a liberal economic agenda as a counter force to communism during the cold war that then evolved into the modernisation of the "Third World". This policy was most actively pursued by the Kennedy and Regan administrations and was promoted as part of the United States international geopolitical agenda. After WWII, rather than follow a colonial path, the United States instead sought to 'influence' international trading mechanisms. This is reflected in the 68-year-old Bretton Woods outcome whereby only Americans could head the World Bank, while Europeans would head the IMF. Hence, the EU's demand that the former-IMF chief Dominique Strauss-Kahn was replaced by another European.

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[7] Blouet Brian W. (2001) Geopolitics and Globalization in the Twentieth Century. London: Reaktion Books
[8] Ibid.

The Future: In many ways globalisation could be considered a strategic effort by the United States and Europe to maintain their geopolitical position is a rapidly changing world, given that most of the future global growth in GDP over the next 40 years will occur in the BRIC and Asian counties, with China becoming the largest economy in the world and India the most populous. BRIC multinational corporations will probably dominate the world's top companies, and alternative commercial structures other than Western capitalism will become dominant (e.g., State owned or family cabals are more typical in the non-OECD countries). Already over 50 percent of United States innovation is generated by non-Americans and the level of spend on innovation and R&D is rising rapidly in the new growing economies, particularly China.

The Middle-East: The United States has no permanent enemies or permanent friends in the Middle-East, except for Israel, and it has vacillated based on oil interests and the degree to which Arab governments are amenable to United States policies. Iran for example received billions in support after a CIA-engineered coup installed Shah Pahlavi (1967-1979). But once Ayatollah Khomeini ruled Iran, America propped up and supplied Saddam Hussein in Iraqi's war against Iran (1980-1988). The world is now locked into a rotational axis where geopolitics, globalisation, and terrorism are fixed realities. And since America's globalised-edge is dependent on strategic resources like oil, the United States cannot stop trying to convert Arab allies who are just as diametrically opposed to Americanisation as Americans are to them. So irrespective of which president is in power, America will continue to support regimes that it may afterwards seek to dismantle – under the pretext of supporting those who are "fighting for freedom." Europe to a greater or lesser degree suffers from its association with the United States in the eyes of many people in the middle-east.

New World Order: The world order has already changed and now the key question is where will it find a new balance? The BRIC countries have proved very adept at using a combination of different commercial structures, adopting the west's technology advances (while largely retaining both ownership and cultural identity), and using Direct Foreign Investment (FDI), and low labour costs to grow rapidly and evolve internationally competitive enterprises. As labour costs are now beginning to rise significantly the BRIC countries, especially China (which is losing production to other lower cost countries such as Bangladesh, Laos, Vietnam and Cambodia) more sophisticated production for the United States market is moving from China to Mexico and Mexico exports to the United States are beginning to surpass China's.

Trade Liberalisation: International trade has been a major influence on the reduction of international disputes throughout the world. The World Bank and the WTO have had a major impact on assisting the growth of peaceful trade between countries and in providing a more equitable base for trade. However, trade liberalisation has recently taken a major blow in the failure of the financial services to develop global enterprises. They failed on two counts – firstly to develop durable, reliable new financial instruments and secondly, to expand across borders (trans-nationally) successfully. Now both Europe's and the United States' citizens, governments and their economies have suffered major losses, compounded by property bubbles, credit squeezes, the need to rescue failing private banks, government budget deficits, increasing national debts, recession and high unemployment and the rising cost of international loans.

This in turn has resulted in a withdrawal of many banks from the international market, a rapid increase in banking and financial services' regulations, increased oversight and monitoring and the need to maintain larger asset to loan ratios than heretofore.

United States Policy: These changes and the demise of communism have severely dinted the United States geopolitical policy, and if the experience of European former colonial powers is any indicator it will take a number of decades to formulate a sustainable successful alternative policy. Lack of such a policy means that the shifts and reversals in United States policy that are likely to occur in the meantime, will create unpredictable impacts on any scenarios attempting to predict or analyse future energy options.

Other Flashpoints: From a geopolitical point of view there are a number of potential flashpoints around the world that could explode at short notice including the dispute between China and Japan (over a number of small Islands); the Arab Spring that could result in the rise of extreme fundamentalism in any or all involved countries; the civil war in Syria; the long term Jewish-Palestine dispute; potential nuclear dangers from North Korea or Iran; Afghanistan, and Mali, which was recently invaded by an Al Qaeda group. Individually, any of these potential flashpoints do not of themselves have the possibility of creating major world disruption, but they could escalate into regional problems relatively easily and some could result in serious oil shortages.

2.1.3 Key uncertainties

2.1.3.1 Security of Supply

The primary uncertainty is the supply of oil. The main negative potential of the global reliance on oil is that it is located in unsettled regions where there are a number of potential flashpoints that could adversely affect the supply of oil. A number of papers and articles have already being published on the challenges in the middle-east. Most focus on the on-going difficulties between Iran and the west and the United States If the situation were to deteriorate and the Gulf of Hormuz closed, 18 percent of global supply would be unavailable. It is highly likely that such an occurrence would lead to severe global oil shortages. This is the major concern in relation to oil supply.

In 2011, the pace of demand growth fell sharply driven by warm weather, high oil prices and a normalisation of the Chinese energy markets. However, the 'Arab Spring' uprising in Tunisia raised fears that it would spread to other oil producing countries in the MENA region and created uncertainty in the oil market. When the uprisings reached Libya in February oil prices rose further to $110-120 USD/bbl. During summer, social disruption occurred in many other countries, e.g. in the Yemen, Syria and Nigeria, and nearly all of Libyan's production was locked in (1.6 mbd). For 2011 as a whole, the production losses outside OPEC amounted to 0.6 mbd, implying that non-Opec production hardly grew at all in 2011. To prevent prices from spiralling and destroying oil demand, Saudi Arabia increased its production by more than 1.0 mbd from the start of 2011 to almost 10 mbd in December– the highest level since 1980. Consequently, at the same time its spare capacity was reduced to only 1.5 mbd.

Also at the beginning of 2011 the conflict between Iran and the West about the development of nuclear bombs in Iran escalated. The broadening of United States economic sanctions and EU's decision to embargo Iranian oil, formally starting 1 July, has led to a reduction in Iranian oil production by about 0.5 mbd. Furthermore the conflict between Sudan and South Sudan has led to supply loss of about 0.3 mbd. In aggregate, low OPEC spare capacity and a high risk premium has kept oil prices above USD 115/bbl until April.

A number of factors can improve the security of supply and these include:

- The development of alternative sources of energy, located in more stable countries, such as shale gas or new sources of oil (e.g., in the Artic)
- Programmes that aim to reduce greenhouse gas emissions, such as in the European Union
- Growth in renewables
- Reduction in energy intensity

The availability of shale gas has improved the cost and security of energy supply in the United States for without shale gas that country would have a growing dependency on imported LNG and at least double the current gas price. But almost all of the 150 billion cubic meters of worldwide shale gas production – equivalent to about 1 percent of global primary energy demand or five months of growth in Chinese coal mining – is in the United States. Growth elsewhere is less certain. Some of the best potential sources of shale gas, like Algeria and Russia, still have impressive conventional resources. And elsewhere, such as Ukraine, there may be plenty of gas underground, but not the investment framework to access it.

The EU is committed to reducing greenhouse gas emissions to 80–95 percent below 1990 levels by 2050 in the context of necessary reductions by developed countries as a group[9]. The Commission analysed the implications of this in its 'Roadmap for moving to a competitive low-carbon economy in 2050'[10]. The 'Roadmap to a single European transport area'[11] focused on solutions for the transport sector and on creating a Single European Transport Area.

Most countries in the world are planning to increase their use of renewables as part of their strategic approach to national energy planning, e.g., the European Union, China and the United States This in turn will reduce their reliance on oil and should improve their security and sustainability.

[9] European Council, October 2009.
[10] COM(2011) 112 of 8 March 2011.
[11] COM(2011) 144 of 28 March 2011.

2.1.3.2 Willingness to invest

Another uncertainty is whether the energy sector can attract the high levels of investment needed to change the composition of energy supply from coal and nuclear energy to renewables and gas, while still satisfying the continuing growth in demand?

The IEA has stressed the importance of investments in energy infrastructure over the next 25 years, as OECD countries need to retire significant amounts of ageing infrastructure and non-OECD countries have to provide for new energy demand[12]. According to the IEA, €25 trillion ($33 trillion) will need to be invested in energy-supply infrastructure between now and 2035. Half of these investments are required in power generation and around 42 percent for transmission and distribution of energy. Non-OECD countries account for 64 percent of the total investment needs, with China alone representing 16 percent of the investment needed.

Over half of this investment is for the oil supply chain ($8.1 trillion) and natural gas ($7.1 trillion)[13]. In comparison, investments needed in the coal sector are relatively low ($721bn) for mining activities and transport infrastructure. The transport proportion is about 10 percent and is necessary to avoid bottlenecks and queues at international ports and on domestic transport routes.

In 2010, over 10,000 coal trucks transporting coal to the Western part of China from Inner Mongolia were blocked in a 120km traffic jam for around nine days. Although road transport for coal is twice as expensive as rail transport, Chinese freight capacity is

already overloaded and coal producers also need to use trucks. Authorities in China are aware of the need to invest in energy infrastructure and transport infrastructure is being built at a record pace - Chinese freight capacity grew by 17 percent in 2009. However, infrastructure expansion is still not happening fast enough to match the country's growing coal demand.

Given the position of coal as a key energy resource for the economic development of China and its role as a central pillar of national energy security, investments in domestic transport infrastructure for coal are of great importance.

The following sections outline a few examples on the type of investment needed.

Gas liquefaction: One example is the investment needed to create a world market using gas liquefaction so that supply can be moved from its production location to where it is needed. Many commentators are predicting a major shift to gas as a fuel of choice and an increase in the import dependence of regions facing declining domestic reserves[14]. The volume of global liquefaction capacity is set to double over the next decade, requiring an estimated $1 trillion of new investment.

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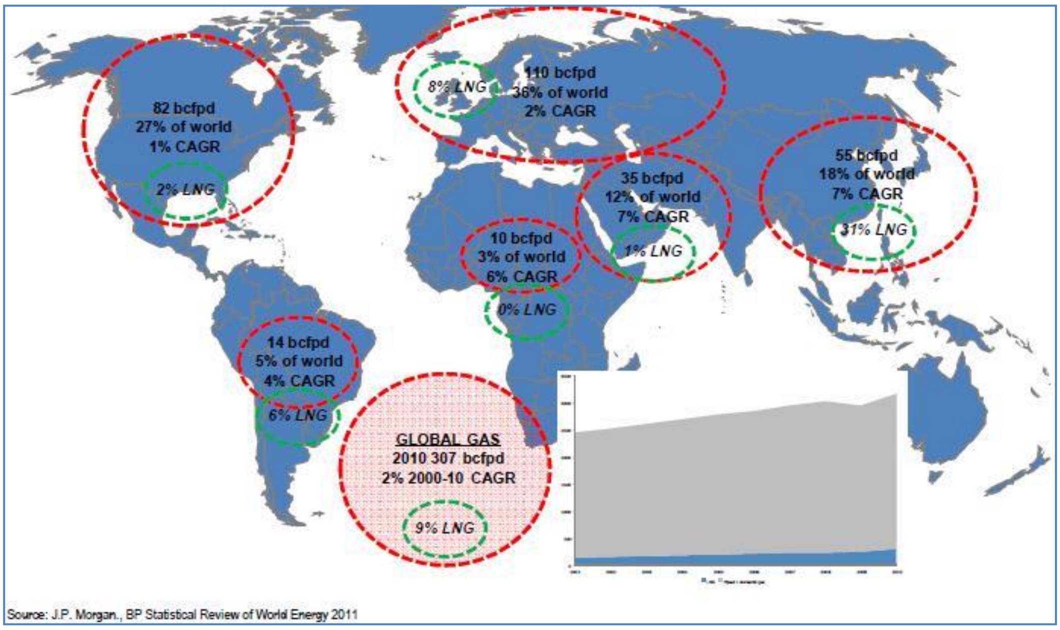
[12] IEA, (2010), World Energy Outlook

[13] The World Coal Institute, (Jan. 2011), Investing in Energy Infrastructure, Ecoal, Vol. 73

[14] Some relevant articles:

However, only a small portion of global gas consumption is currently satisfied by LNG (around 9 percent as illustrated in Figure 7)[15]. This lack of global LNG cargo flexibility is currently reflected in the regional price divergence across Asia (tight market post Fukushima), Europe (broadly tracking oil-indexed contract supply) and the US (flooded with cheaper domestic shale gas). Expansion of LNG transportation should result in price convergence across regional hubs, however there is considerable uncertainty around the evolution of the LNG market or what will will follow over the next decade[16].

Figure 7: A geographical summary of the global gas market



This uncertainty arises from four major influences:

- **Australian liquefaction capacity:** Australia is set to overtake Qatar as the world's largest exporter of LNG by the end of this decade. But its costs are high and competition particularly from the United States could constrain investment.
- **United States exports:** Uncertainty remains as to whether the government will approve large volumes of US exports and the sustainability of the United States shale gas revolution given significant environmental concerns.
- **Fukushima fallout:** High level of Japanese demand following closure of its 50 nuclear power plants may now be reduced given its decision to re-open 'some' plants given the high cost of imported alternatives and the likelihood of significant shortfalls in electricity supply.

[15] Five key drivers of global LNG market evolution: http://www.timera-energy.com/commodity-prices/five-key-drivers-of-global-lng-market-evolution/

[16] Other reports:

The influence of new LNG importers on the global market
China's influence on global LNG demand
Will US LNG exports revolutionise the global gas market?
European gas pricing dynamics in the global context

- **Chinese LNG demand:** Continuing economic growth is driving increased demand for electricity in China and a decision to use more 'clean technologies' such as gas will result in increased demand, but some of that could be supplied by pipeline imports from neighbouring countries (Turkmenistan, Kazakhstan, Burma and Russia) and by domestic shale gas resource. It is difficult to predict Chinese demand for LNG gas.

There can be little doubt that the rapid development of the LNG market will increase the influence of global pricing on regional gas markets this decade. The complexity and uncertainty around the interaction of global gas market drivers presents an interesting challenge from an analytical perspective.

Other major investments required include:

Infrastructure and renewables: Europe requires a greatly improved electricity infrastructure to accommodate the increased use of renewables and greater inter-country trade where wind is likely to predominate in Northern Europe and photovoltaic

cells in Southern Europe. For example, the Global investment in renewable power and fuels was $257bn in 2011 (an increase of 17 percent over 2010). Developing economies made up 35 percent of this total investment, compared to 65 percent for developed economies[17].

Renewables can provide more of a continent's energy needs than previously thought. For example, it is technically feasible for the United States to get 80 percent of its electricity from renewable sources by 2050, according to a new report[18] from the National Renewable Energy Laboratory (NREL). And no major breakthroughs are needed to do it as the report considered only currently commercially available technologies.

The massive, 850-page, four-volume, NREL report is not a prediction of how much renewable energy will actually be used—that depends on lots of variables. Instead, it assesses technical feasibility and its conclusions are positive. The main reason that the United States can depend on renewables that are intermittent and difficult to predict is that the United States is a large country, with large and varied sources of renewable energy. The report assumed that 50 percent of the country's power would come from wind and solar. The rest would come from sources such as biomass and hydroelectric and conventional geothermal, which are not as variable.

Many countries need to expand their basic energy infrastructure to meet their growing needs. For example, the Middle East and North Africa (MENA) region needs to pump $250bn into their power sectors in the next five years to meet regional electricity

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[17] UNEP, (2012), Global Trends in Renewable Energy Investment 2012, UNEP Collaborating Centre for Climate & Sustainable Energy Finance, Frankfort School. http://fs-unep-centre.org/publications/global-trends-renewable-energy-investment-2012

[18] Mai, T.; Wiser, R.; Sandor, D.; Brinkman, G.; Heath, G.; Denholm, P.; Hostick, D.J.; Darghouth, N.; Schlosser, A.; Strzepek, K. (2012). Exploration of High-Penetration Renewable Electricity Futures. Vol. 1 of Renewable Electricity Futures Study. NREL/TP-6A20-52409-1. Golden, CO: National Renewable Energy Laboratory (Volume 1)

demand growth, according to a new report by the Arab Petroleum Investment Corporation[19]. "Over the next five years, power capacity in the MENA region will increase by 7.8 percent annually, creating a capacity increment of 124 gigawatts". The total amount of required capital investment includes power generation, transmission and distribution (GTD) and accounts for more than 200 planned and announced energy-related projects in the MENA region valued between $100m and $20bn. The report stated that countries in the Gulf Cooperation Council hold the lion's share of investment growth, accounting for 42 percent ($105bn) of total required expenditure, while Iran alone will require $49bn (20 percent of total value) worth of investment for power GTD by 2017.

Energy efficiency: According to the McKinsey Global Institute, in 2008[20], "$170 billion a year invested in efforts to boost energy efficiency from now until 2020 could halve the projected growth in global energy demand". Furthermore, these investments could also deliver up to half of the emission abatement required to cap the long-term concentration of atmospheric greenhouse gases at 450 parts per million. This is the level experts suggest will be needed to prevent the global mean temperature from rising by more than two degrees centigrade.

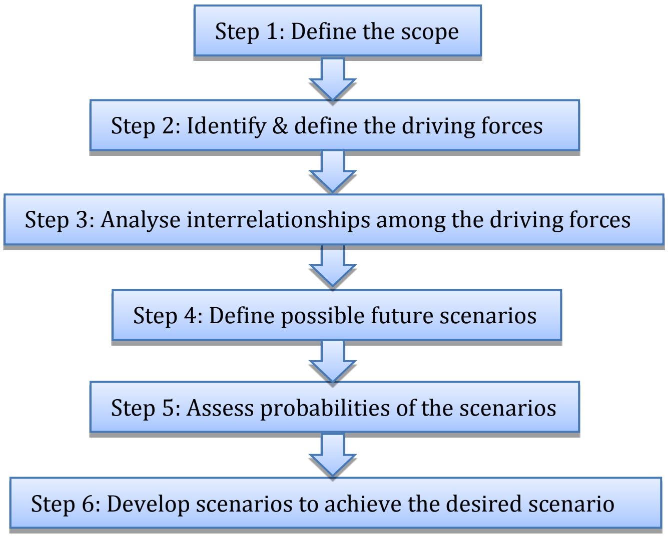
These results could be achieved by carefully targeting cost-effective opportunities to boost the level of output achieved from the energy consumed, such as, improving the efficiency of lighting, cooling, and heating systems, and of other technologies like vehicles and factory machinery (see previous reference[21]). Concerted action could reduce global energy consumption in 2020 by 135 quadrillion British thermal units (QBTU) a year, the equivalent of roughly 64 million barrels of petroleum a day.

2.1.4 Key variables driving global energy demand

The timescales for looking at energy supply and demand are very long, typically 25 to 50 years into the future. Normal forecasting techniques based on techniques that require some extension of current activities into the foreseeable future are unsuited. The scenario approach has been adopted widely by international oil companies, government agencies and international bodies to assess likely future supply and demand issues. Nezhard[22] identified the sequence of steps in such a scenario approach in 2007 (see Figure 8).

[19] ArabianBusiness.Com, (Nov 2012), $250bn energy investment needed in MidEast
http://www.arabianbusiness.com/-250bn-energy-investment-needed-in-mideast-478277.html
[20] http://www.mckinseyquarterly.com/How_the_world_should_invest_in_energy_efficiency_2165
[21] http://www.mckinseyquarterly.com/How_the_world_should_invest_in_energy_efficiency_2165#footnote1
[22] Nezhad, H. (2007), Software Tools for Managing Project Risk Vienna, VA: Management Concepts.

Figure 8: The main steps in using scenario methodologies



The main driving forces in energy supply and demand scenarios are:

- Global economic growth
- Population growth and demographic change
- Energy intensity - technology development and change
- Price of primary energy
- Investment requirements – cost and availability
- Greenhouse gas emissions including CO_2 emissions
- Alternative energy sources

These driving forces are discussed in the following paragraphs

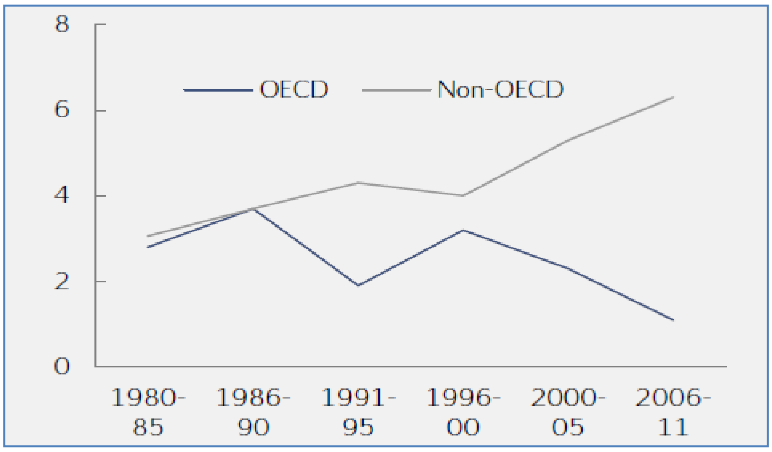
2.1.4.1 Global economic growth

Global energy demand has been growing in parallel to economic growth over the last three decades, with the world economy growing by an annual average of 2.9 percent. There are wide differences between the growth rates of the OECD and non-OECD countries. Annual OECD growth averaged 1.1 percent over the period 2006-2011 whereas a 6.3 percent average growth rate was recorded for the non-OECD countries. These differences arise through different demographic growth rates and the resultant variations in nations' relative labour market strength in addition to regional variation in productivity growth. The recent growth gap reflects the fact that the 2008 financial crisis hit hardest in the Western OECD countries.

The global rate of growth is predicted to be largely similar, maybe marginally lower. There is a long-term impetus for convergence of income levels and productivity between less industrialised and advanced economies. This convergence is still at a nascent stage while inhabited by only around 20 percent of the global population, the OECD economies generate nearly 70 percent of global GDP (see Figure 9).

Despite significant contributions from the Middle East and South America, the bulk of non-OECD growth has come from emerging Asia, whose share in global GDP increased from 3.5 percent in 1980 to beyond 15 percent in 2011. This increase was led by China, whose real GDP grew 17-fold over the past 30 years, making it the world's second largest economy by 2010. It will become the largest economy in the world in either 2018 (the Economist's estimate) or in 2019 (according to Mr Pettis, a finance professor at Peking University)[23].

Figure 9: Global economic growth showing diverging trends (GDP percent)



Source: Statoil, Energy Perspectives, Long-term macro and market outlook, June 2012

China owes its rapid ascent to a fortuitous combination of massive rural-to-urban labour migration, a state-directed export-oriented growth model and heavy investment inflows. Although its growth has recently slowed, it will still outpace the growth of Western economies.

2.1.4.2 Population growth

The last one hundred years have seen a rapid increase in global population due to medical advances and massive increase in agricultural productivity made possible by the Green Revolution. World population peaked in 1962/1963 at an annual growth rate of 2.2 percent and has been declining since then. In 2009, the estimated annual growth rate was 1.1 percent. The actual annual growth fell from its peak of 88.0 million people in 1989, to a low of 73.9 million in 2003, after which it rose again to 75.2 million in 2006. Since then, annual growth has declined. In 2009, the human population increased by 74.6 million, which is projected to fall steadily to about

[23] The Economist (March 2012): http://www.economist.com/blogs/freeexchange/2012/03/china-will-overtake-america-within-decade-want-bet

41 million per annum in 2050, at which time the population will have increased to about 9.2 billion.

Each region of the globe has seen great reductions in growth rate in recent decades, though growth rates remain above 2 percent in some countries of the Middle East and Sub-Saharan Africa, and also in South Asia, Southeast Asia, and Latin America. Some countries experience negative population growth, especially in Eastern Europe mainly due to low fertility rates, high death rates and emigration, as well as abortion. Some Western Europe countries might also encounter negative population growth. Japan's population began decreasing in 2005.

According to the UN's 2010 revision to its population projections, world population will peak at 10.1bn in 2100 compared to 7bn in 2011.[24] However, some experts dispute the UN's forecast and have argued that birth rates will fall below replacement rate in the 2020s. According to these forecasters, population growth will only be sustained till the 2040s by rising longevity but will peak below 9bn by 2050, but some well-known scholars have been arguing that global fertility will fall below replacement rates in the 2020s and that world population will peak below 9 billion by 2050 followed by a long decline.

Two or three more billion people will be using the world's energy resources in 2050, and that is an increase of 29 - 42 percent.

A global trend towards urbanization is also taking place. The world's urban population is growing by 60 million a year, about three times the increase in the rural population. The movement of people towards cities has accelerated in the past 40 years, particularly in the less-developed regions, and the share of the global population living in urban areas has increased from one third in 1960 to 47 percent (2.8 billion people) in 1999.

2.1.4.3 Cost and availability of investment

The adequacy, quality and reliability of grid-based electricity supply are of crucial importance to economic development and growth. Large amounts of investment will be needed in the coming decades to meet the increase in demand for both the quantity and quality of electricity services, as well as to maintain and replace existing infrastructure that will be retired. Just how much investment will be needed and how much will actually be forthcoming will depend on a range of factors, including macroeconomic and population trends, prices, government policies, technology, and availability of capital.

In a Reference Scenario, in which no new government policies are assumed, global electricity demand is projected to grow at an average annual rate of 2.5 percent through to 2030. The world will consume twice as much electricity in 2030, than it does today. Developing countries account for much of the increase in global demand, their electricity use more than tripling by 2030. OECD electricity consumption grows less rapidly. Even

[24] United Nations, 2010 Revision of World Population Prospects

so, in 2030 the 1.3 billion people in the OECD area still consume more electricity than the 6.5 billion people in the developing world.

Moreover, some 1.4 billion in the developing regions still lack any access to electricity – according to the World Bank[25]. Total cumulative electricity investment needs worldwide in the Reference Scenario amount to close to USD $10 trillion dollars over 2003-2030 (based on year 2000 values), equal to about USD 350 billion per year. More than half of this investment goes to transmission and distribution, with distribution taking the lion's share of overall network investment. Developing countries account for more than half of world electricity investment needs. China's needs will be the largest, exceeding USD 2 trillion. New investment is also substantial in North America and Europe.

Attracting all this investment in a timely manner – especially in developing countries – may not be easy. In an IEA Alternative Policy Scenario, which considers the impact of new government policies to curb demand growth and promote switching to cleaner fuels, world electricity demand and investment needs grow less rapidly in almost every region. World demand grows by 0.5 percentage points more slowly than in the Reference Scenario as a result of end-use energy-efficiency improvements.

Total cumulative investment needs over 2003-30, at USD 8.3 trillion, are USD 1.5 trillion – or 16 percent – lower. Lower supply capacity requirements more than outweigh the higher capital costs in power generation that result from switching to nuclear power, renewables and distributed generation.

2.1.4.4 Greenhouse gas emissions

The EU is committed to reducing greenhouse gas emissions to 80–95 percent below 1990 levels by 2050 in the context of necessary reductions by developed countries as a group. The Commission analysed the implications of this in its 'Roadmap for moving to a competitive low-carbon economy in 2050'. The 'Roadmap to a single European transport area' focused on solutions for the transport sector and on creating a Single European Transport Area.

Greenhouse gas emissions are discussed in more detail in Section 2.3.3.

2.1.4.5 Economic growth rates and demographic change drives energy demand and composition

Estimates show that 70 percent of world growth over the next few years will come from emerging markets (called the non-OECD countries), with China and India accounting for 40 percent of that growth. The forecasts suggest that investors will continue to invest in emerging markets for some time to come. The emerging markets already attract almost 50 percent of foreign direct investment (FDI) global inflows and account for 25 percent of FDI outflows.

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25 World Bank: http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTENERGY2/0,,contentMDK:22855502~pagePK:210058~piPK:210062~theSitePK:4114200,00.html

The major regions for FDI continue to be Africa, the Middle East, and Brazil, Russia, India and China (the BRICs), with Asian markets of particular interest at the moment. By 2020, the BRICs are expected to account for nearly 50 percent of all global GDP growth.

The rapid pace of economic growth in China has raised concerns about the country's large consumption of energy and its environmental impact. The transition from an agricultural - to an industrial-based economy has meant that growth is extremely energy-intensive. At the same time, industrialisation raised working wages, helping spur the growth of the Chinese middle class as the population continued to urbanize. These demographic changes have created an additional boost in energy demand. Consequently, energy use increased by more than 150 percent during the past ten years and China became the world's largest consumer of energy in 2010, surpassing the United States. The country's energy demand is expected to continue on an upward trajectory, but at a slower rate.

This growth is fuelling an increase in household income in places like China and India where nearly 60 million people - the same population of either France or the United Kingdom - are joining the ranks of the middle class each year. Middle class have a greater demand for energy than lower classes. This in turn implies an increase in cost structures in these economies, with higher labour costs, increased demand for, and provision of social programmes such as increased education, medical and welfare provision and national costs. Population growth and demographic change are the key factors that influence the growth in energy demand over the next 40 years. Global population will increase from 7,000,000 to 9,000,000 people. Population trends will also identify the regions and countries where energy demand will increase.

2.1.4.6 Technology development and change also drives energy demand

A range of technologies, including both disruptive and incremental advances are driving change in industry, services, social conditions and national planning. These include the convergence of ICT, Web 2 and 3, smart technologies impacting on city design and infrastructure, energy use and conservation, to mention but a few. Many of these new technologies have an energy focus, either reducing intensity (which is expected to reduce future energy needs significantly), improving energy conservation or facilitating better performance.

These technologies are significantly influencing government and private sector planning, in ways such as: 'Clean energy as a national competitive advantage'. Many governments are aggressively implementing clean energy policies, setting emissions targets and providing incentives for cleantech investment. China, Germany, India and Brazil are gaining leadership positions in solar, wind and biofuels. The United States remains a cleantech leader because of its entrepreneurial culture and vibrant venture capital environment. Policy-makers are betting that cleantech investments will yield other benefits such as job creation and innovation-led economic growth. Notably, private investment is flowing to countries with comprehensive, clear and long-term energy policies aimed at incentivising renewable energy use, promoting efficiency and reducing carbon emissions.

In addition, new technology developments have assisted the extraction of oil and gas, such as the extraction of gas from shale through the fracking process or the extraction of more oil from existing wells. Hydraulic fracturing was first used in 1947 but the modern fracking technique, called horizontal slickwater fracking, made the extraction of shale gas economical in Texas in 1998. Proponents of fracking point to the economic benefits from vast amounts of formerly inaccessible hydrocarbons the process can extract. Opponents point to potential environmental impacts, including contamination of ground water, risks to air quality, the migration of gases and hydraulic fracturing chemicals to the surface, surface contamination from spills and flowback and the health effects of these[26]. For these reasons hydraulic fracturing has come under scrutiny internationally, with some countries suspending or even banning it. However, it has made enormous volumes of gas available in the United States and is likely to changes the regional market for gas into a more competitive global market. It is also going to make additional reserves of gas available in many countries.

Other drivers that affect energy supply and demand include:

Prices: Energy prices normally respond to changes in demand and supply. However, oil prices are affected not only by global demand for oil, but also the uncertain future of oil supply, the relative value of the U.S. dollar, as well as political factors which could lead to short-term supply disruptions. Reducing dependency on oil, a major primary source of energy worldwide, has become a political objective of many governments. Some energy products, such as natural gas, have a regional market rather than a global market, and prices can vary by region. For example, the price of natural gas in Europe is nearly five times the price of natural gas in the United States currently and nearly seven times in Japan. Extraction cost and cost of delivery can be significant factors in the price of any energy product. New discoveries can obviously affect the price of existing energy products, such as unconventional oil and gas exploitation in the United States, but they usually take a long period to come fully on stream. Some renewable energy sources, such as wind and solar energy, are best delivered within a reasonable distance from their generation due to the high losses incurred in transmission, whereas coal and oil are easily and efficiently transported to their place of use. Finally, one primary energy product can be used to replace another provided the conversion facilities exist. Thus, predicting prices can be both difficult and fraught with potential error, and past trends are frequently a poor indicator of future prices.

Investment requirements: To meet global energy needs by 2050, IEA estimates total cumulative investment in the order of 6-7 percent of global GDP over the period. Most of this investment arises from the increase in demand. However some of the investment is necessary to replace existing obsolete plant. Furthermore, new plant and new

[26] Brown, Valerie J. (February 2007). "Industry Issues: Putting the Heat on Gas", Environmental Health Perspectives (US National Institute of Environmental Health Sciences)

distribution systems will be required for distributing power derived from alternative energy sources, primarily renewables, such as wind and solar energy. In terms of sectors, the transportation sector dominates the investment needs in all future scenarios developed by both public and private organisations. This is because of the high unit cost of cars, trucks, ships and planes and the huge increase in their use in non-OECD countries. Transportation is also an area where considerable R&D is being undertaken.

CO_2 emissions: One of the major global challenges in the coming decades is how to maintain the availability of energy supply with minimum damage to the environment. According to a report by the intergovernmental panel on climate change (IPCC, 2007)[27], about 69 percent of all CO_2 emissions are energy related and about 60 percent of all greenhouse emissions can be attributed to energy production and consumption. The IPCC report warns that if current trends in CO_2 emissions continue global temperature could rise by an average of 6 degrees centigrade. The consequences would be traumatic and there would be significant change in many aspects of life and irreversible change in the natural environment. Thus, there is an urgent need to reduce greenhouse gas emissions in order to minimise global warming to between 2 and 2.4 degrees centigrade.

Alternative energy sources: The future will be radically different to the past, in that the pace of development of alternative energy sources and clean technologies will have a significant impact on the world's energy supply and demand and consequently on global climate change. The traditional use of solar energy is directly for cooking and heating, more recently it is converted into liquid biofuels and used as an additive with oil or as a replacement fuel for transport or power generation. Approximately 2.5 billion people in the developing countries rely on biomass for cooking and heating.

The global market for wind power has grown tremendously since its early development in the 1980s. Denmark has been the pioneering country in this technology. Over 1 percent of global electricity supply is currently provided by wind. Early large adopters of this technology were Germany, the United States and Spain, and together they accounted for 56 percent of global installed capacity in 2007. India (8 percent) and China (6 percent) were the next largest users of wind power. Wind turbines need no fuel and have zero CO_2 emissions (except for production, delivery and installation of equipment) and they can be installed relatively quickly. The cost of wind energy has decreased as wind turbines have become larger in size, turbine efficiency has increased significantly, and the capital cost per kilowatt has declined significantly as well.

Solar energy is the most abundant energy source but currently it provides less than 1 percent of the world's total commercial energy. Its potential is enormous and will be equally significant in both the OECD and the non-OECD countries.

[27] IPCC, (2007), Fourth Assessment Report: Climate Change 2007 (AR4) at http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml

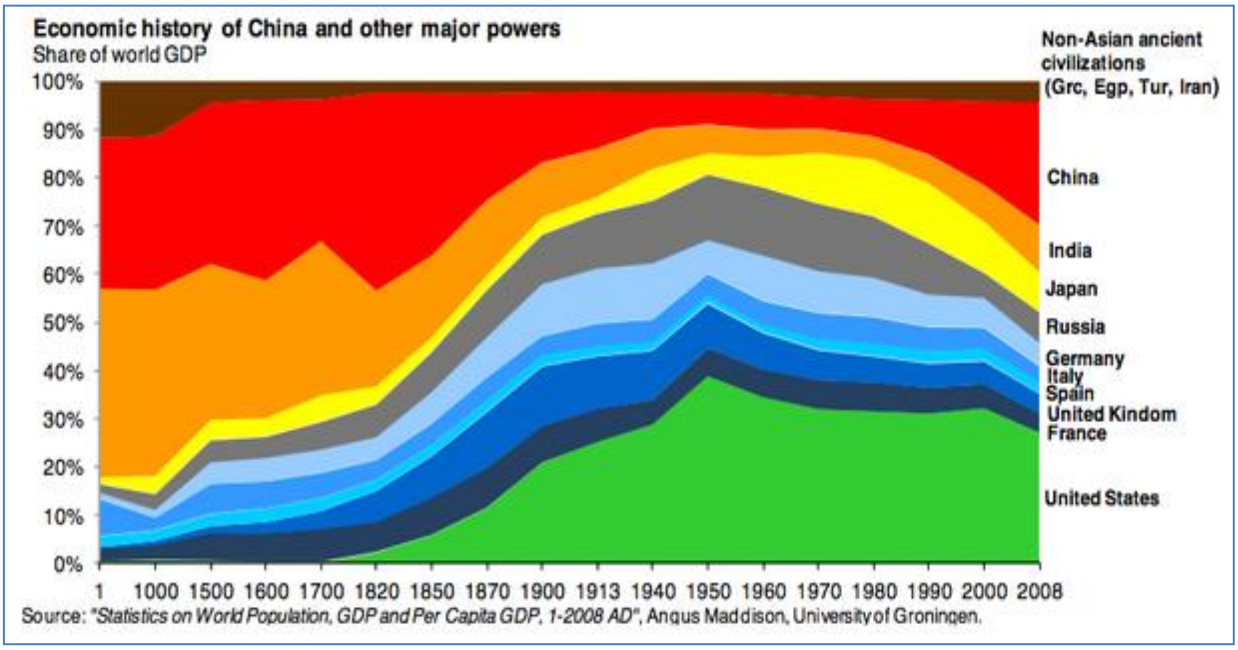
2.2 The global economy

2.2.1 Historical context

The economic history has nearly completed one full cycle. In Year 1 the major powers' share of world GDP is shown in Figure 10 (based on research by Michael Cembalest, chairman of market and investment strategy at JP Morgan[28]).

In Year 1, India and China's population consisted of one-third and one-quarter of the world's total population, respectively. Consequently, they also commanded one-third and one-quarter of the world's economy, respectively.

Figure 10: Share of the World Economy, Year 1 – 2008



Up to the Industrial Revolution population approximated to GDP around the world, but after the Industrial Revolution, labour productivity became the important driver of GDP, i.e., the mastering of means of manufacturing, production and supply chains by steam, electricity, and ultimately software that concentrated, first in the West, and then spread to Japan, Russia, China, India, Brazil, and beyond.

Europe and the United States developed faster than other countries out of the Industrial Revolution, such that today, the United States accounts for 5 percent of the world population and 21 percent of its GDP. While Asia (minus Japan) accounts for 60 percent of the world's population and 30 percent of its GDP. This is due largely to an increase in labour productivity driven by innovation, capital investment and industry re-structuring. The very long-term trend, already visible in the case of China and Brazil, is that many countries are aspiring to similar structures, productivity and capital investment levels as the OECD countries and the GDP percentage per country will again tend to approximate to population levels.

[28] http://www.theatlantic.com/business/archive/2012/06/the-economic-history-of-the-last-2000-years-part-iii/258877/

Much of the political and economic shape of today's world emerged from the ashes of World War II, the rise in nationalism that eliminated colonisation, and the collapse of communism in Europe and Asia.

When it became clear that World War II was in its final stages, the Western Allied powers in 1944 set out to create three international institutions that would reduce the possibility of future conflict. The objective was to assist development, financial stability and trade.

These were:

- The International Bank for Reconstruction and Development (IBRD), now known as the World Bank).
- The International Monetary Fund (IMF) which has become the world's overseer of the international financial system.
- The third institution proposed was the International Trade Organization (ITO), which later emerged as the General Agreement on Tariffs and Trade (GATT) in 1948 and was replaced by the World Trade Organisation (WTO) in 1995.

The post-World War II period (1950s - 1990s) is marked by a number of major geopolitical events, mainly, decolonisation, the establishment of the European Union, the Cold War and a number of major disruptions to oil supplies.

Decolonisation: In a vast political reshaping of the world, more than 80 former colonies comprising some 750 million people gained independence since the creation of the United Nations. At present, 16 Non-Self-Governing Territories (NSGTs) across the globe remain to be decolonized, home to nearly 2 million people. Many of these countries adopted socialist policies giving government a very large role in their economies. Their choices, by and large, were the result of wanting to distance themselves from their former colonial masters.

The **European Union:** In 1957 six countries[29] signed the Treaty of Rome, which extended the earlier cooperation within the European Coal and Steel Community (ECSC) and created the European Economic Community, (EEC) establishing a customs union. Since then other countries have joined and the European Union (renamed under the Maastricht Treaty in 1993) and it now has 27 members. It is a political and economic union. The Eurozone, a monetary union, was established in 1999 and is composed of 17 member states. In 2011, the EU had a population of over 500 million inhabitants, or 7.3 percent of the world population, it generated the largest nominal world gross domestic product (GDP) of 17.6 trillion US dollars, representing approximately 20 percent of the global GDP when measured in terms of purchasing power parity.

The Cold War (1947–1991): During this period there was a sustained state of political and military tension between the powers of the Western world (United States and its

[29] The founding members of the Community were Belgium, France, Italy, Luxembourg, the Netherlands, and West Germany

NATO allies), and the communist world, led by the Soviet Union, including its satellite states and allies. Following a period of economic stagnation and liberalisation reforms from within the Soviet Union and increased United States diplomatic, military, and economic pressure during the 1980s, the U.S.S.R., opened the country and its satellite states to a mainly peaceful wave of revolutions which culminated in the collapse of the Soviet Union in 1991, creating of a large number of independent states in Eastern Europe, many of which have subsequently joined the European Union.

2.2.1.1 Major Economic Changes

Oil price shocks of the1970s: These massive price hikes forced many people to realise that their economy was not independent from the rest of the world and everybody learned their real dependency on oil, particularly middle-east oil. The recessions following the oil crises of 1973 and 1979 led to both recession and inflation simultaneously in the early 1980s.

The United States and Japan exited recession relatively early, but high unemployment continued to affect other OECD nations through at least 1985. Long-term effects of the recession contributed to the Latin American debt crisis, the savings and loan crisis in the United States, and the adoption of neoliberal economic policies throughout the 1980s and 1990s. This price increase in oil also led to high investment in many oil companies and the availability of petro dollars banked in the West in turn led to increased borrowings by many countries.

New Developments have changed the old world economic order, such as:

- The emergence of **globalisation** which can be largely accounted for by developed economies integrating with less developed economies, by means of foreign direct investment, the reduction of trade barriers, other economic reforms and, in many cases, immigration. Economic globalization can be viewed as either a positive or a negative phenomenon, depending on the perspective chosen. Advances in transportation and telecommunications infrastructure, including the rise of the Internet, are major factors in globalization and precipitate further interdependence of economic and cultural activities.
- The rise of the **BRIC countries** (Brazil, Russia, India and China) as international competitive economies. Chinese economic reform began to open China to the globalization in the 1980s and foreign investment helped to greatly increase quality, knowledge and standards, especially in heavy industry. China and India's experience supports the claim that globalization greatly increases wealth for poor countries. By 2009, about 300 million people—equivalent to the entire population of the United States—have escaped out of extreme poverty in India.
- The growth in the Internet and in telecommunications led to the **dot-com bubble** during the late 1990s and its collapse in 2000/2001. Western nations

saw an increase in their total value, and a very rapid growth of GDP resulting from technology companies growing at speculative rates. Dozens of companies filed for bankruptcy, hundreds of dot-com companies simply disappeared, and there was widespread collapse in the ICT industry.

- The development of computer technology allowed the **Financial Services sector** expand and develop many new products and subsectors in the late 1990s and early 2000s.

Recent Period of Rapid Growth: Between 2000 and 2007 world growth was high. World gross domestic product (GDP) grew by 3.2 percent a year, exceeding annual growth of 2.5 percent during the 1990s. Emerging market economies, which include China, India, and Russia, expanded at a very high 6.5 percent a year, in part because of the economic reforms enacted over the previous two decades. Growth in Africa was generally high as well, in those countries without local wars or tribal conflicts.

2.2.1.2 Global economic crisis 2007–2012

Since 2007, countries around the world experienced a series of major economic and financial problems. The collapse of the United States housing bubble, which peaked in 2006, caused the values of securities tied to United States real estate prices to plummet, damaging financial institutions globally. It resulted in the threat of a total collapse of a number of large financial institutions, the bailout of banks by national governments in the United States and Europe, downturns in world stock markets and worldwide recession which was deeper in OECD countries. The crisis played a significant role in the failure of key businesses, declines in consumer wealth estimated in trillions of U.S. dollars, and a downturn in economic activity leading to the 2008–2012 global recession and contributing to the European sovereign-debt crisis. In many countries, the housing market also suffered, resulting in evictions and foreclosures (Spain, Ireland, U.K.) and high, prolonged unemployment. The United States and European governments, as well as Japan, have pumped liquidity into the system and taken on direct capital investments in these financial behemoths, in an effort to stabilize credit markets and prevent a global economic meltdown.

The world-wide recession that began with the United States financial crisis of 2007–2008, is considered by many economists to be the worst financial crisis since the Great Depression of the 1930s. By December 2012, the economic side effects of the European sovereign debt crisis and limited prospects for global growth in 2013 and 2014 continue to provide obstacles to full recovery from this recession.

The world has never has been so closely linked as it seems today. The credit crunch in the United States has taken its toll on the economy of the whole world. The economies of most countries, whether big or small, were affected. Asia and Europe being more closely linked with the United States have suffered the greatest impact.

2.2.1.3 Regional impacts – the United States

Housing prices in the United States started to decline in 2006 and 2007, and continued dropping until they reached new lows by 2012 causing the subprime collapse. Recognising the severity of the collapse, the United States government initially supported the mortgage providers including Fannie Mae and Freddie Mac (both of which are government backed mortgage providers) and later provided a $787bn economic stimulus package aimed at helping the economy recover from the deepening worldwide recession[30]. The package included increased federal spending on health care, infrastructure, education, tax breaks and incentives, and direct assistance to individuals. It was distributed over a number of years. In addition, up to $2 trillion was provided to purchase depreciated real estate assets[31]. The administration also assisted in rescuing the troubled automotive industry, even taking a temporary 60 percent equity in General Motors and assisting the sale of Chrysler to Italian automaker Fiat.

As a consequence unemployment increased, peaking at 10 percent in 2009. However, growth resumed in late 2009 and unemployment steadily decreased thereafter and stabilised at 8 percent by the election in 2012. Despite these trends poor economic performance was an important issue in the 2012 Presidential election, which Obama won.

Total retirement assets, Americans' second-largest household asset, dropped by 22 percent, from $10.3 trillion in 2006 to $8 trillion in mid-2008. During the same period, savings and investment assets (apart from retirement savings) lost $1.2 trillion and pension assets lost $1.3 trillion. Taken together, these losses total a staggering $8.3 trillion[32].

2.2.1.4 Regional impacts – Europe

The credit crisis has had a major impact on EU politics, leading to power shifts in several European countries, most notably in Greece, Ireland, Italy, Portugal, Spain, and France. In Europe, causes of the crisis varied by country. In several countries, private debts arising from a property bubble were transferred to sovereign debt as a result of banking system bailouts and government responses to slowing economies post-bubble. Greece, Ireland, U.K. and Spain were particularly affected by their own property collapse and the scarcity of credit with a virtual collapse in the Greek, Irish and UK banking systems which had to be significantly bailed-out by their governments and over 400,000 homeowners losing their homes in Spain. Inability to either repay or re-finance their government debts has resulted in Greece, Portugal and Ireland having to be bailed-out by the International Monetary Fund (IMF). Other European counties, such as Italy and Spain are having or are likely to have difficulties in meeting their international debts. Many banks in most European counties have had difficulties in securing credit and had

[30] The American Recovery and Reinvestment Act of 2009
[31] Public-Private Investment Program for Legacy Assets
[32] Altman. Roger C., (2009), "The Great Crash, 2008 – Roger C. Altman". Foreign Affairs.

to be supported initially by their own governments (such as, France and Germany) and more recently by the European Central Bank through quantitative easing.

The official response at EU level has been slow and primarily in reaction to, rather than in anticipation of new difficulties. In 2010, Europe's Finance Ministers approved a rescue package worth €750 billion aimed at ensuring financial stability across Europe by creating the European Financial Stability Facility (EFSF)[33]. In October 2011 and February 2012, the Eurozone leaders agreed on more measures designed to prevent the collapse of member economies. This included an agreement whereby banks would accept a 53.5 percent write-off of Greek debt owed to private creditors, increasing the EFSF to €1 trillion, and requiring European banks to achieve a higher capitalisation (9 percent). As a confidence boosting measure the EU leaders also agreed to create a European Fiscal Compact which included the commitment to introduce a balanced budget each year and increased centralised control over banking operations. The ECB (European Central Bank) has supported these activities with lower interest rates and cheap loans of more than one trillion Euros for weaker banks. In addition, to address the deeper roots of economic imbalances most EU countries agreed on adopting the Euro Plus Pact, consisting of political reforms to improve fiscal strength and competitiveness. This has forced weaker countries to draw up ever more austerity measures to bring down national deficits and debt levels. However, while sovereign debt has risen substantially in only a few Eurozone countries, it has become a perceived problem for the area as a whole, leading to continuous speculation. The weaker counties have already adopted austerity budgets for a number of years and even the U.K., the Netherlands and France are planning austerity budgets.

2.2.1.5 Regional impacts – Asia and Africa

Asia: The Asian countries are a big market for United States outsourcing, the technological products being manufactured in Asian companies find their way largely into the United States market and the financial needs of Asians have been more or less satisfied by United States' banks. Economies worldwide slowed during this period, as credit tightened and international trade declined. Numbers of companies in China, India, Singapore and other Asian countries were forced to cut production due to cancellation of outsourcing orders across the Pacific, for example, in China the low-end contract manufacturers are scrambling for survival and large numbers of engineers have been or may be laid off. This does not mean that these countries fell into recession like their European counterparts, but in virtually all cases their GDP growth was significantly reduced relative to their average GDP in the previous decade.

Africa: Initially Africa suffered as a direct result of the crisis. Sectors such as mining, tourism and manufacturing experienced decline as did flows of foreign direct investment. However, the continent's banking system was insulated due to strict exchange control regulations and the existence of very few off-balance-sheet assets. Unlike the IMF, the African Development Bank (AFDB) recommended that African

[33] BBC News, (10 May 2010), EU ministers offer 750bn-euro plan to support currency".

countries pursue growth rather than austerity responses and undertake financial market reform and rebalance the ratio of international and local income. Thus, the average 6 percent GDP growth experienced since the year 2000 is likely to be largely maintained following a rebound in 2009 in many of the more successful African countries.

2.2.1.6 Some important issues

Some important issues arise from recent economic events:

- While international enterprises have emerged in all corners of the globe, regulatory organisations and institutions essential to ensure corporate accountability and protection of the environment have lagged behind.
- Over the past 50 years, there has been a steady increase in the importance of international trade in the global economy and simultaneously, the world has seen substantial environmental degradation and currently faces the global challenge of climate change influenced in part by the rate of development.
- According to KPMG[34], China is losing its edge as the world's cheapest place to manufacture goods. Minimum wage levels in China are now four times greater than other places in South and South East Asia. Production of clothing and footwear is now more widely dispersed across Asia, with Indonesia, Bangladesh and Vietnam specialising in the production of footwear and India in hand-stitched fabrics and metal ware as rising costs in China force firms to switch production. But China is still dominant in the production of goods such as consumer electronics and furniture. China is battling its highest rate of inflation in three years although the latest consumer prices data from August suggests that the rate is beginning to ease. While much of China's manufacturing has begun to migrate westwards from the south and east of the country to cheaper provinces such as Sichuan, the report says the cost advantages from such moves inland may be short-lived. KPMG says that China's increasing manufacturing costs are primarily to do with the country's demographics. China's one-child policy has resulted in a "sudden and serious" shortage of the labour that gives workers in both the richer coastal provinces and poorer inland areas the leverage to demand higher wages. "Sourcing goods in China purely because of ultra-low costs is a thing of the past," said Nick Debnam, KPMG's Asia-Pacific chair. With demand is still soft in many Western consumer markets, it is also proving difficult for companies to pass on higher costs to consumers. This changing environment is forcing companies to reassess sourcing strategies.

[34] The report was based on interviews with 12 major multinational companies including Ikea, B&Q-owner Kingfisher and Hong Kong's Li & Fung, which sources goods for big-name clients including Wal-Mart. http://www.kpmg.com/global/en/issuesandinsights/articlespublications/press-releases/pages/china-beyond-sourcing.apex

2.2.2 Medium-term outlook

2.2.2.1 Short-term Predictions - 2012

In October 2012, IMF unveiled its latest set of global forecasts. The world economy is weakening, not alone is the weakness and very low growth of the euro-area likely to continue, the emerging–market growth is also slowing. Both India and Brazil have had their forecasts reduced by one percentage point or more.

However, emerging markets are still the strongest part of the global economy. Their growth rates are still significantly higher than the advanced economies. In addition, their overall public policies seem to be supportive, their interest rates are low and there is a gradual process of lowering their deficits. Growth in the developed world is more anaemic and its policymakers are responding badly, especially when it comes to fiscal policies.

In the United States, while the volume of retail sales and apartment rentals are increasing, and unemployment has decreased, the signs are still ominous, particularly the decline in international trade (growth has decreased to an estimated 2.5 percent in 2012 according to WTO) which is adversely affecting exports in China, the Eurozone and the United States. In addition, the United States is facing a 'fiscal cliff' at the end of February 2013 where it will have to raise taxes and make spending cuts to meet agreed deficit reductions, cutting about 4 percent out of GDP.

Many European countries and the United States are either undertaking or planning an austerity budget (or series of budgets) to achieve fiscal consolidation. However, to compound this situation, new research from IMP recently revealed that the multiplier effect of deficit reduction to be nearly twice to three times that previously thought, i.e, a budget reduction of 1 percent was thought to have an negative impact on GDP of 0.5 percent, it is now believed to vary from 0.9 percent to 1.7 percent. Thus, the impact of austerity budgets is much more severe than previously realised.

These impacts are already visible in the case of Spain, Portugal, Ireland and Greece where severe austerity budgets have become the norm. Except for Spain these countries are receiving support from the IMF and operating under its control. In addition, the U.K., France and the Netherlands are also planning to front-load their budget reductions. The only bright spot is that these latter three countries have room to manoeuvre as borrowing costs are historically low and they could spread their reductions over a longer time. Also euro financial markets are no longer in a state of emergency over Europe's high government debts and weak banks and this gives politicians from the 17 countries in the Eurozone breathing room to fix their remaining problems.

The overall conclusion is that a rebound of the global economy is looking less and less likely. Low growth is likely to continue. Olivier Blanchard, Chief Economist of IMF now says that "it will surely take at least a decade from the beginning of the crisis for the world economy to get back in shape". This implies the world economy will not recover fully until 2018.

The latest outlook for Africa and Asia is good. The IMF says Africa's GDP will grow by 5 percent in 2012, much faster than almost anywhere else, while growth in China, India and Indonesia will continue at higher levels that the United States or Europe, although at a lower rate than heretofore.

2.2.2.2 Prospects for 2013–2014

According to the results of latest polls conducted by Reuters and recently released, hundreds of economists worldwide have predicted that after reaching 3.1 percent in 2012, world economic growth is expected to hit 3.4 percent in 2013 -- a minor cut from July's poll and slower than the International Monetary Fund's (IMF) latest forecasts of 3.3 percent and 3.6 percent.

"The surveyed economists also said that at least part of the economic weakness will unavoidably spill over into next year while debt-wracked Europe, with its growing sovereign debt crisis, is expected to remain the biggest drag on the world economy in 2013"[35].

A majority of those surveyed also predicted a slow recovery in the United States, as even the IMF had earlier warned that the global economy could get worse due to the Eurozone crisis and the United States fiscal cliff in the future.

The polls further revealed that five worst performing economies in 2013, out of the 19 covered in the surveys, are all European, as few analysts polled expected anything other than slight growth in the quarters ahead.

Additional data from a December 2012 report is shown in Figure 11[36].

Figure 11: World Economic prospects for 2013–2014 (annual percentage change)

Selected Regional/country data	2006-2009	2010	2011	2012	2013	2014
World	1.1	4.0	2.7	2.2	2.4	3.2
Eurozone	-0.4	2.1	1.5	-0.5	0.3	1.4
Other European countries	0.9	1.9	1.7	1.7	1.5	1.9
Other developed countries	1.2	2.8	2.3	2.3	2.0	3.0
Africa	4.7	4.7	1.1	5.0	4.8	5.1
East & South Asia	7.1	9.0	6.8	5.5	6.0	6.3
- of which China's GDP growth is	11.0	10.3	9.2	7.7	7.9	8.0

Source: United Nations, Global Outlook, 10 December 2012.

It is important for this study to bear in mind the long-term economic and social drivers of change that could impact on the supply and demand for energy. The key drivers are population growth, rise in middle class numbers, growth in GDP and the increase in employment.

2.2.3 Long-term prospects

The principal effects of the current credit crisis, such as high unemployment, large fiscal imbalances and uncompetitive costs and excess capacity will take a long time to be

[35] http://www.presstv.ir/detail/2012/10/12/266226/2013-world-economy-not-to-improve-much/
[36] United Nations, (Dec 2912), World Economic Situation and Prospects 2013, New York.

redressed. Further ahead, demographic changes, including ageing, and the fundamental forces of economic convergence between Asia and South America with Europe and North America will bring about massive shifts in the composition of global GDP and the competitiveness of international trade.

The main trends identified for the next 40 years are based primarily on a recent OECD report[37]. The model used by OECD uses two blocks of countries – OECD countries and Other G20 countries (Argentina, Brazil, China, India, Indonesia, the Russian Federation, Saudi Arabia and South Africa), equivalent to about 90 percent of world GDP.

Growth Rates	**Economic growth of the Other G20 countries will continue to outpace that of the OECD countries**, driven primarily by catch-up in multi-factor productivity, but the difference will likely narrow substantially over coming decades. OECD growth is estimated at 2.75 percent per annum from 2018-2030 and 2 percent from 2031-2050. Over the last decade the Other G20 countries grew at over 7 percent per year on average, their growth may decline to around 5 percent in the 2020s and to about half that by the 2040s. China will have the highest growth rate among major countries until 2020. After 2020, the growth rates of both India and Indonesia could be higher than China's. These continuing high growth rates mean that China's and India's r combined GDP will move from less than half of the total output of the major seven OECD economies in 2010 to exceeding it by around 2025 (measured at 2005 purchasing power parities). China's GDP is projected to surpass that of the United States in 2017.
Standards of Living	**Large gaps in standards of living will persist**, e.g., by 2050 GDP per capita in China and Russia will be half that of the leading countries. While Brazil will be 40 percent and India and Indonesia will be 33 percent of GDP of the leading countries. Among the OECD countries, initially the most rapid catch-up countries will likely be the lowest income countries such as Turkey, Mexico Chile and eastern European countries.
Fiscal and current accounts	**Fiscal and current account imbalances are likely to worsen**, unless more ambitious policy initiatives are undertaken to stabilise public debt than currently planned. The imbalances are likely to reoccur in the next cycle in the late 2020s. In addition, in many OECD countries government indebtedness will exceed thresholds at which there is evidence of adverse effects on interest rates, growth and the ability to stabilise the economy.
Countries needing Consolidation	Fiscal consolidation requirements are substantial in many countries, particularly in the two largest, the United States (6.5 percent points of GDP) and Japan (13 percent points from 2011), and the euro countries currently being supported by the ECB and the IMF (between 4 and 7 percent points improvement of GDP). United States and Japan stand out also because they have no plans as yet. In addition, for a typical OECD country, additional offsets of 3 to 4 percent of GDP will have to be found over the coming 20 years to meet spending pressures due to increasing pension and health care costs. These countries are already front loading their improvements.
Reduction of Debt levels to 60 percent of GDP	Consolidation requirements would be more demanding if the aim were to lower debt-to-GDP ratios to 60 percent, which for most countries could be achieved before 2030 – this would require 6 percent points for OECD as a whole

The baseline long-term economic scenario includes the following structural and policy assumptions:

[37] OECD, (2012), OECD Economic Outlook, Medium and Long-Term Growth, Volume 2012/1, Chapter 4.

- The gap between actual and potential output in both OECD and Other G20 countries that arose during the current recession is gradually eliminated from 2013, for most countries within four to five years.
- The upward pressure on oil prices is assumed to continue for the remainder of the decade, but is thereafter assumed to be mitigated by a supply response. Hence, an increase in real oil prices by about 5 percent per annum is assumed from 2013 to 2020, 2 percent per annum from 2020 to 2030 and 1 percent per annum thereafter.
- Bilateral exchange rates between most OECD countries remain unchanged in real terms. The real dollar exchange rate for Other G20 countries appreciates in line with convergence in living standards.
- The availability of private-sector credit in the economy (relative to GDP) is assumed to gradually equal the situation in the United States – where private credit is assumed to remain constant at around 200 percent of GDP – with the gap assumed to close at 2 percent per annum.

Assumptions regarding monetary and fiscal policy are as follows:

- Policy interest rates continue to normalise as output gaps close and beyond that are directed to converge on a neutral real short-term rate, which in turn follows the potential growth rate of the economy.
- The target for inflation is generally taken to be 2 percent, with exceptions
- For those countries where the debt-to-GDP ratio is currently rising, there is a gradual increase in the underlying fiscal primary balance of 0.5 percentage point of GDP per year from 2013 onwards until the ratio of government debt to GDP is stable given long-term trend growth and long-term interest rates.
- There are no further losses to government balance sheets as a result of asset purchases or guarantees made in dealing with the financial crisis. No contribution to deficit or debt reduction is assumed from government asset sales.
- Effects on public budgets from population ageing and continued upward pressures on health spending are implicitly assumed to be alleviated through reforms of relevant spending programmes or offset by other budgetary measures.
- The share of active life in life expectancy is assumed to remain constant, hence the legal pensionable age is implicitly assumed to be indexed to longevity. On average, these reforms raise total labour force participation in 2050 by 0.7 percentage points.
- Structural unemployment in OECD countries gradually returns to the lowest value estimated between 2007 and 2013. Unemployment in Other G20

countries is assumed to gradually converge to the average level of unemployment in OECD countries; it remains unchanged in countries currently below the OECD average.

- The long-term trend increase in average years of schooling per worker (i.e., human capital) is assumed to continue in all countries. It will only moderately raise labour force participation – on average by 0.5 percent points in 2050.
- Countries with relatively stringent product market and trade regulations are assumed to gradually converge towards the average regulatory stance observed in OECD countries in 2011.
- For Other G20 countries, a gradual increase in public spending on social protection is assumed, amounting on average to an increase of 4 percent points of GDP to a level of provision similar to the average OECD country. It is further assumed that this is financed in a way in which there is no effect on public saving.

The outcomes of the model tend to be optimistic in that policies are generally assumed to be positive, the credit crisis had no permanent adverse impacts on output, and demographic impacts still allow moderate GDP growth. Further information on these assumptions are referenced below.[38]

[38] OECD Economic Outlook, op cit, Chapter 4, pages195-99.

Table 2.1: Growth in total economy potential output and its components Annual averages, percentage change

	Output Gap	Potential real GDP growth				Potential labour productivity growth (output per employee)				Potential employment growth				Real GDP growth
	2012	2001-2007	2012-2017	2018-2030	2031-2050	2001-2007	2012-2017	2018-2030	2031-2050	2001-2007	2012-2017	2018-2030	2031-2050	2012-2017
Australia	-2.0	3.2	3.3	3.0	2.3	1.1	2.0	2.1	1.6	2.1	1.3	0.9	0.7	3.6
Austria	-2.2	2.1	1.8	1.5	1.4	1.2	1.2	1.6	1.4	0.9	0.6	-0.1	0.0	1.9
Belgium	-1.1	1.8	1.9	2.2	1.9	0.8	1.1	1.8	1.6	1.0	0.7	0.3	0.3	1.8
Canada	-1.0	2.6	2.2	2.2	2.3	0.9	1.4	1.8	1.8	1.7	0.8	0.4	0.5	2.3
Chile	-0.2	3.9	4.9	3.6	2.3	1.6	2.5	2.5	2.0	2.3	2.4	1.1	0.3	4.8
Czech Republic	-3.4	3.7	2.6	3.0	1.8	3.5	2.3	2.8	1.9	0.3	0.3	0.1	-0.1	2.7
Denmark	-3.3	1.5	0.9	1.7	2.2	1.0	0.7	1.5	1.9	0.5	0.2	0.2	0.3	1.4
Estonia	-3.0	5.0	3.0	2.8	2.2	4.2	2.7	3.0	2.4	0.8	0.3	-0.2	-0.1	3.5
Finland	-1.1	2.6	2.1	2.3	1.7	1.8	2.0	2.1	1.4	0.8	0.1	0.1	0.2	2.2
France	-3.3	1.8	1.8	2.1	1.5	0.9	1.4	2.0	1.3	0.9	0.4	0.1	0.1	2.2
Germany	-0.8	1.3	1.6	1.2	1.0	0.9	1.4	1.8	1.5	0.3	0.2	-0.6	-0.4	1.7
Greece	-12.0	3.0	0.6	2.4	1.1	1.8	0.3	2.2	1.6	1.1	0.3	0.2	-0.4	1.7
Hungary	-5.3	2.7	1.9	2.9	1.8	2.6	1.4	2.8	2.3	0.2	0.6	0.2	-0.5	2.3
Iceland	-3.6	3.7	1.4	2.4	2.3	2.2	0.8	1.4	1.8	1.4	0.6	0.9	0.6	2.3
Ireland	-9.5	5.0	1.4	2.6	1.8	2.3	1.0	1.5	1.1	2.7	0.4	1.1	0.7	2.8
Israel	1.6	3.5	3.2	2.4	2.6	0.6	1.1	0.9	1.2	2.8	2.1	1.5	1.3	2.8
Italy	-4.5	1.2	0.2	0.7	1.2	0.2	-0.3	0.7	1.3	0.9	0.5	0.1	-0.1	0.5
Japan	-0.9	0.6	0.9	1.4	1.3	0.9	1.2	1.7	2.0	-0.3	-0.3	-0.3	-0.7	1.3
Korea	-0.3	4.4	3.4	2.4	1.0	3.1	2.7	2.4	1.7	1.2	0.7	0.0	-0.6	3.4
Luxembourg	-4.0	3.9	2.4	1.6	0.6	1.8	0.5	0.7	0.4	2.1	1.9	0.9	0.2	2.8
Mexico	-0.8	2.4	3.2	3.5	3.0	0.6	1.1	1.9	2.3	1.8	2.1	1.6	0.6	3.5
Netherlands	-3.1	1.9	1.7	2.0	1.6	1.0	1.3	2.1	1.8	0.9	0.4	0.0	-0.2	1.8
New Zealand	-1.0	3.1	2.4	2.8	2.7	0.9	1.2	2.0	2.0	2.2	1.1	0.8	0.6	2.5
Norway[1]	-1.8	2.9	3.1	2.8	2.0	1.8	1.8	2.0	1.4	1.1	1.2	0.7	0.6	3.6
Poland	0.2	4.2	3.5	2.3	1.1	3.4	3.1	2.8	1.9	0.7	0.4	-0.4	-0.8	3.3
Portugal	-6.4	1.6	0.7	1.9	1.6	1.1	0.6	1.8	2.0	0.5	0.1	0.1	-0.4	1.0
Slovak Republic	-0.9	4.7	3.5	2.8	1.6	3.7	3.3	2.7	1.8	0.9	0.3	0.2	-0.3	3.5
Slovenia	-4.6	3.2	1.6	2.3	1.8	2.3	1.5	2.4	2.0	0.9	0.1	-0.2	-0.3	1.8
Spain	-8.7	3.4	1.5	2.2	1.5	0.3	0.7	1.6	1.7	3.1	0.8	0.6	-0.2	2.3
Sweden	-2.2	2.6	2.7	2.4	1.9	1.9	1.9	2.0	1.4	0.7	0.8	0.4	0.4	2.7
Switzerland	-1.3	1.8	2.2	2.3	2.1	0.9	1.2	2.0	1.9	0.9	1.0	0.3	0.2	2.2
United Kingdom	-3.5	2.4	1.6	2.2	2.3	1.5	0.9	1.7	1.7	0.9	0.8	0.5	0.6	2.1
United States	-3.6	2.5	2.1	2.4	2.1	1.5	1.3	1.5	1.3	1.0	0.8	0.9	0.8	2.7
Turkey	-2.2	4.0	5.2	4.1	2.3	2.7	2.7	2.4	1.8	1.3	2.5	1.6	0.5	5.2
Argentina	5.4	4.0	4.5	3.2	2.3	0.9	2.9	1.9	1.9	3.0	1.6	1.3	0.4	3.7
Brazil	-1.4	3.2	4.4	3.9	2.5	0.9	2.9	3.1	2.6	2.2	1.4	0.8	-0.1	4.4
China	-0.8	10.2	8.9	5.5	2.8	9.2	8.4	5.9	3.6	0.9	0.5	-0.3	-0.8	8.8
Indonesia	0.9	4.0	5.9	5.1	3.7	2.1	4.0	4.0	3.7	1.9	1.8	1.0	0.0	5.7
India	-0.3	7.4	7.2	6.5	4.5	5.5	5.3	4.6	3.6	1.8	1.8	1.8	0.8	7.2
Russian Federation	-3.9	5.3	3.6	2.7	0.9	4.6	4.8	3.4	2.0	0.7	-1.1	-0.7	-1.2	4.2
South Africa	-2.4	3.5	4.0	3.8	2.7	0.7	1.5	2.0	2.1	2.7	2.5	1.8	0.6	4.3
Euro area	-3.6	1.8	1.4	1.7	1.4	0.7	1.0	1.7	1.5	1.1	0.4	0.0	-0.2	1.7
Total OECD	-2.8	2.1	2.0	2.2	1.9	1.2	1.2	1.7	1.6	1.0	0.8	0.5	0.3	2.3
Total non-OECD	-0.9	6.9	6.9	5.1	3.0	5.5	5.8	4.4	3.0	1.3	1.0	0.6	0.0	6.9
World		2.7	3.4	3.3	2.4	1.5	2.4	2.7	2.3	1.2	0.9	0.6	0.1	3.6

Source: OECD Economic Outlook 91 long-term database.

Key economic risks to the above scenario are:

- Rising government debt poses a risk to the growth outlook
- Higher interest rates and lower growth aggravate debt dynamics
- Reducing debt ratios to 60 percent would require greater fiscal consolidation

Note the model does not take into consideration any major natural disaster, severe social unrest or war that could impact on economic trends.

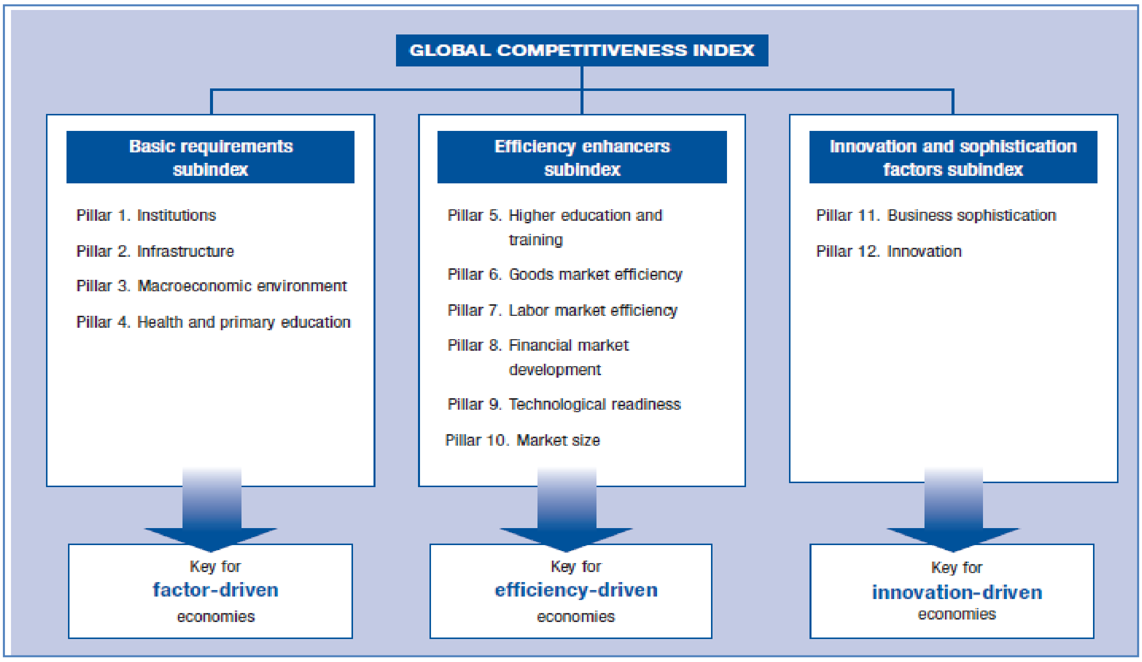
2.2.3.1 Different Perspectives on the Future

Competitiveness considerations: A different perspective is to use the model applied in the Global Competitiveness Report[39]. This model allows for three different variations of the dominant factor in the economy, e.g., factor driven economies or efficiency driven

[39]Schwab, Klaus Prof, (2012), Global competitiveness report, 2012-2013, World Economic Forum, Geneva.

economies or innovation driven economies (see Figure 12). However, the components of the three variations are also interrelated, e.g., to be successful at high-tech innovation a country needs a high level of third level education as well.

Figure 12: The global competitiveness index framework



Source: Global Competitiveness Report, 2012-2013

It uses a benchmarking system to compare and rank country performance based on the factors listed in the model. These are critical factors of performance and will help determine the success of a country or region and will influence its rate of GDP growth.

2.2.3.2 A different perspective

The only certainty is that we cannot foresee or forecast the future with any level of dependability. So we present a few different views for consideration.

The sixth Kondratiev wave bringing change: Australian engineer and philosopher Dr. Moody[40] believes that the economy of the future will not look like the economy of present times. According to the scientist, production and business will have to adapt to the growing shortage of natural resources on the planet. To put it in a nutshell, the world will have to learn to develop in a different way.

According to Moody, the economic crisis of 2008 triggered the sixth Kondratiev wave. Such waves, named after Russian economist Nikolai Kondratiev, are sinusoidal-like cycles in the modern capitalist world economy. A Kondratiev wave, or K-wave, lasts from 40 to 60 years and comprise two phases. During the first phase, as Kondratiev calculated, the technological progress pushes the development of production, and creates economic growth.

[40] Moody, James (2011), Economy of the future to make the world unrecognizable http://english.pravda.ru/science/tech/08-06-2011/118149-economy-0/

However, such transformations inevitably take the society towards changes. The ability of the society to change lags behind the requirements of the economy. The development thus enters another phase - a phase of decline. Crisis and depression make the world reform economic and other relations, which creates conditions for a new wave of technological progress and starts another stage of the economic growth. Thus, the world economy will be in decline by 2050.

A Chinese perspective: Andy XIE[41], a West-trained economist based in Shanghai, has just published an article on the future of WTO (http://bit.ly/W9K1NX). His main line is that globalization's benefits from trade have not reached the "losers" from the same process in the West; as a result structural problems have arisen in the form of higher unemployment and lower wages. At the global level growth is unlikely to accelerate from the current lacklustre performance – stagnation is likely to become the norm. This also applies to China, where he estimated productive overcapacity to be 50 percent of total exports. WTO's future may at best remain one of dealing with trade disputes. Further liberalization rounds are unlikely. Sliding back on overt or covert ways cannot be excluded. In addition, conflict flash-points seem to be increasing in many areas, such as, Afghanistan, the Middle East (Iran, Syria etc.), China and Russia.

Rise and fall of the world's economies in the next 40 years: The global research department of HSBC has released a report[42] predicting the rise and fall of the world's economies in the next 40 years. As expected the world's top economy in 2050 will be China, followed by the United States.

Less predictable changes suggested include: By 2050, the Philippines will leapfrog 27 places to become the world's 16th largest economy. Peru's economy, growing by 5.5 percent each year, will jump 20 places to 26th place – ahead of Iran, Colombia and Switzerland. Other strong performers will be Egypt (up 15 places to 20th), Nigeria (up nine places to 37th), Turkey (up six places to 12th), Malaysia (up 17 to 21st) and the Ukraine (up 19 to 45th). While Japan's working population will contract by 37 percent in 2050 – yet HSBC economists predict it will still be toward the top performing economies, dropping only one place to the 4th largest economy. India will jump ahead of Japan to 3rd on the list.

The big loser in the next 40 years will be the advanced economies in Europe. HSBC predicts, who will see their place in the economic pecking order erode as their working population dwindles and developing economies climb. Only five European nations will be in the top 20, compared to eight today. Biggest falls will be felt in northern Europe: Denmark to 56th (-29), Norway to 48th (-22), Sweden to 38th (-20) and Finland to 57th (-19).

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41 Xie, Andy, (2012), A Chinese economist's view of the future of the world economy http://www.diplomacy.edu/blog/chinese-economist%E2%80%99s-view-future-world-economy

42 Voight, Kevin, (2011), World's top economies in 2050 will be... CNN http://business.blogs.cnn.com/2012/01/12/worlds-top-economies-in-2050-will-be/

"If we step away from the cyclicality, there are two ways economies can grow; either add more people to the production line via growth in the working population, or make each individual more productive," the report says.

The Top 30 positions are predicted to be (their change is shown in brackets):

1) China (+2)	11) Italy (-4)	21) Malaysia (+17)
2) United States (-1)	12) Turkey (+6)	22) Saudi Arabia (+1)
3) India (+5)	13) S. Korea (-2)	23) Thailand (+6)
4) Japan (-2)	14) Spain (-2)	24) Netherlands (-9)
5) Germany (-1)	15) Russia (+2)	25) Poland (-1)
6) UK (-1)	16) Philippines (+27)	26) Peru (+20)
7) Brazil (+2)	17) Indonesia (+4)	27) Iran (+7)
8) Mexico (+5)	18) Australia (-2)	28) Colombia (+12)
9) France (-3)	19) Argentina (2)	29) Switzerland (-9)
10) Canada (same)	20) Egypt (+15)	30) Pakistan (+14)

In other words, demographics – the size of a country's working population – along with the opportunities to flex that muscle help determine long-term economic trends. Big factors on the back half of that equation are: education opportunities, democratic governments or strong rule of law (a caveat that explains China and Saudi Arabia's high placement).

"We openly admit that behind these projections we assume governments build on their recent progress and remain solely focused on increasing the living standards for their populations," the report says. "Of course, this maybe an overly glossy way of viewing the world."

Chief factors that may derail economies moving forward, the report suggests are: War, energy consumption constraints, climate change, and growing barriers to population movement across borders.

Finally a word of warning, only time will tell whether any predictions are realised. Patterns of change are simply too unpredictable yet, to place any strong reliance on future scenarios. For example OECD predicted a long-term boom in 1999[43] for the early part of the 21st century – a prediction that quickly proved to be untrue.

2.3 Overall energy sector outlook

The economic progress of past decades has seen hundreds of millions of people enjoy major improvements in their material well-being, and these changes have been particularly noteworthy in the emerging economies. The availability of energy has played a crucial enabling role in raising standards of living in many countries. Without heat, light and power one cannot build or run the factories and cities that provide goods, jobs and homes, nor enjoy the amenities that make life more comfortable and enjoyable. Energy is the 'oxygen' of the economy and the life-blood of growth, particularly in the mass industrialisation phase that emerging economic giants are facing today.

This section reviews the overall energy sector outlook from the following perspectives:

- Energy demand and energy intensities

[43] OECD (1999), The Future of the Global Economy: Towards a Long Boom?

- Global and regional energy mix
- CO_2 emissions
- Energy demand in different sectors

Energy can be analysed from two perspectives – energy demand and energy intensity. Energy demand increases as societies develop and evolve; they need and will continue to need energy to power homes, businesses, industry, transportation, electricity generation and other vital and leisure services.

Whereas energy intensity is defined as the total energy consumption divided by gross world domestic product (GWDP), energy intensity is influenced by a number of factors including the standard of living, new technologies, and the price of energy.

This section should be appreciated in the context that all fossil fuels are finite and the world energy supply is currently highly dependent on fossil fuels (see Figure 13).

The major producers of oil are typically geographically remote from the major consumers of oil. For example, the United States consumes about 19 million barrels per day, produces about 7 million per day and imports a further 5 million barrels per day from its neighbours, Mexico and Canada. Major suppliers are Venezuela, Nigeria, Angola and Saudi Arabia. The import position of Europe is similar to that of the United States. Europe produces about 2 million barrels per day and consumes about 14 million barrels per day.

Figure 13: Proven Reserves of Fossil Fuels, 2010

Fuel Source	Reserve (in years)	Comment
Oil	50	Canadian oil from shale and sand accounts for 20-40 years supply. But all 'easy oil' has been found. Reserves in the OECD countries are concentrated in more difficult locations such as in deep water offshore, the Artic or in unconventional resources. About 60 percent of oil reserves are concentrated in five countries: Saudi Arabia, Iran, Iraq, Kuwait and Abu Dhabi. Canada's unconventional supplies are the second largest source after Saudi Arabia.
Coal	118	By far the largest reserves to production (R/P) ratio of all fossil fuels
Gas	58.6	R/P ratios declined for each region, driven by rising production. The Middle east had the highest R/P, while the Middle East and the former Soviet Union regions jointly hold 72 percent of the world's gas reserves. U.S's shale gas will change this picture.

Renewable energy sources for transport are crucial for energy security and for meaningful diversification away from oil. In this context work should continue on the development of advanced biofuels and electric mobility, including hydrogen fuel cell vehicles. However, realistically it will be 10 to 20 years before these technologies can make a material difference. Therefore attention needs to be focused on improving the efficiency of existing internal combustion engine technology.

2.3.1 Energy demand and energy intensities

2.3.1.1 Global Energy Demand

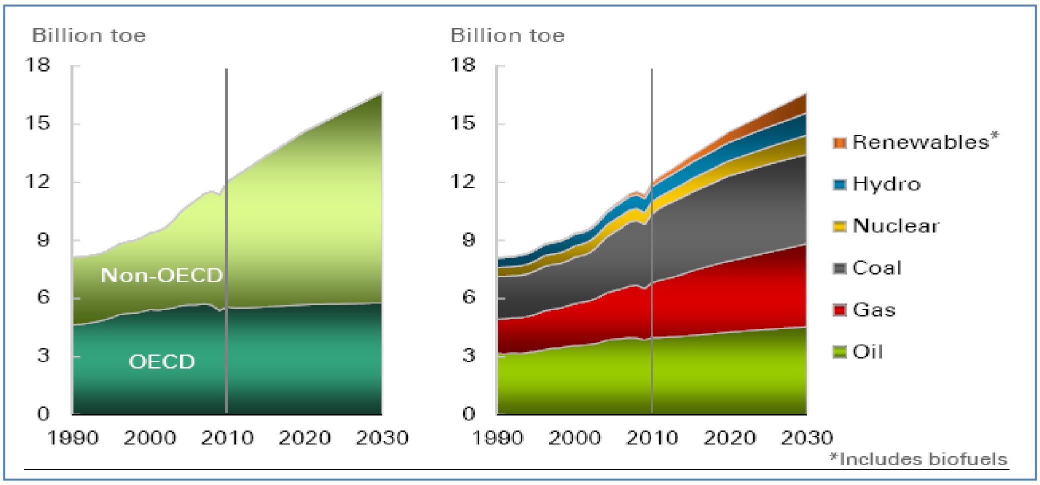
A number of organisations have made predictions and scenarios about the future. Two different sources of scenarios are discussed here – a BP scenario and a number of IEA scenarios.

The 2030 picture presented by BP here is based on the following assumptions and shown in Figures 14 and 15:

- World primary energy consumption is projected to grow by 1.6 percent p.a. over the period 2010 to 2030, adding 39 percent to global consumption by 2030. The growth rate declines, from 2.5 percent p.a. over the past decade, to 2.0 percent p.a. over the next decade, and 1.3 percent p.a. from 2020 to 2030
- Almost all (96 percent) of the growth is in non-OECD countries. By 2030 non-OECD energy consumption is 69 percent above the 2010 level, with growth averaging 2.7 percent p.a. (or 1.6 percent p.a. per capita), and it accounts for 65 percent of world consumption (compared to 54 percent in 2010) OECD energy consumption in 2030 is just 4 percent higher than in 2010, with growth averaging 0.2 percent p.a. to 2030. OECD energy consumption per capita is on a declining trend (-0.2 percent p.a. 2010-30)
- The fuel mix changes slowly, due to long gestation periods and asset lifetimes. Gas and non-fossil fuels gain share at the expense of coal and oil. The fastest growing fuels are renewables (including biofuels) which are expected to grow at 8.2 percent p.a. 2010-30; among fossil fuels, gas grows the fastest (2.1 percent p.a.), oil the slowest (0.7 percent p.a.)

The above picture is presented in a BP report, Energy Outlook 2030[44].

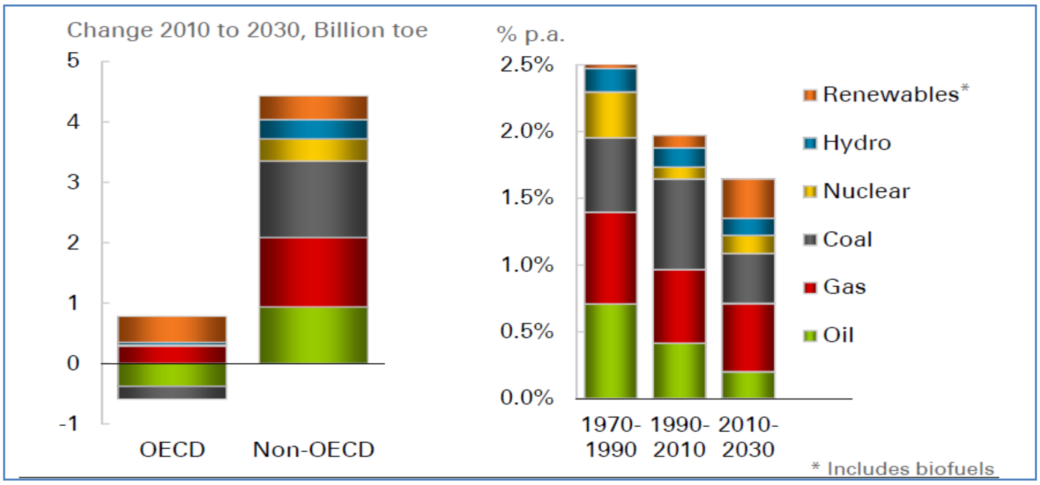
Figure 14: Growth in Energy Demand and its Composition, 1990-2030



Source: BP, (2012), Energy Outlook 2030

[44] BP, (2012), Energy Outlook 2030

Figure 15: Contributions to Global Growth, 2030



Source: BP, (2012), Energy Outlook 2030

A number of conclusions arise from BP's analysis, that are generally agreed by other commentators, including:

- The economic development of non-OECD countries will stimulate an expansion of all fuels. For many developing countries the imperative remains securing affordable energy to underpin economic development.
- Renewables, nuclear and hydro together account for 34 percent of the growth; this aggregate non-fossil contribution is, for the first time, larger than the contribution of any single fossil fuel. The largest single fuel contribution comes from gas, which meets 31 percent of the projected growth in global energy.
- World electricity demand (2.6 percent p.a.) is projected to grow more rapidly than total energy over the next 20 years, although not as rapidly as GDP (3.7 percent p.a.) due to increased efficiencies.
- Over the next decade coal will still be the largest contributor to the growth of power fuels, accounting for 39 percent, but non-fossil fuels are rapidly catching up. In aggregate nuclear, hydro and other renewables contribute as much as coal. The contribution of non-fossil fuels is considerably greater in the period 2020-2030, accounting for most of the growth.

According to the IEA a new global energy landscape is emerging[45]. The global energy map is changing, with potentially far-reaching consequences for energy markets and trade. As already noted it is being redrawn by the resurgence in oil and gas production in the United States and could be further reshaped by a retreat from nuclear power in some countries (such as, Japan, Germany and France), continued rapid growth in the use of wind and solar technologies and by the global spread of shale gas production. If new policy initiatives are broadened and implemented in a concerted effort to improve global energy efficiency, this could likewise be a game-changer.

[45] IEA (2012), World Energy Outlook 2012, Paris.

The assessment of how these new developments might affect global energy and climate trends over the coming decades can only be based on a series of global scenarios and multiple case studies. Otherwise the impact and interaction of the many variables cannot be adequately weighed and evaluated. The scenarios and case studies examine their impact on the critical challenges facing the energy system to meet the world's ever-growing energy needs; to provide energy access to the world's poorest, and to bring the world towards meeting its climate change objectives.

New Policies Scenario: This IEA's central scenario is based on global energy demand growing by more than one-third over the period to 2035, with China, India and the Middle East accounting for 60 percent of the increase. Energy demand barely rises in OECD countries, but in these countries considerable restructuring, already begun or planned, will take place. This is primarily based on a pronounced shift away from oil, coal (and, in some countries, nuclear) towards natural gas and renewables (wind and solar). Despite the growth in low carbon sources of energy, fossil fuels remain dominant in the global energy mix and the main growth in demand is in non-OECD countries.

United States: Energy developments in the United States are game changing and their impact will be felt globally. The recent increase in United States oil and gas production, enabled by new technologies that are allowing light oil and shale gas resources to be extracted are changing the role of the United States in the global energy trade. By around 2020, the United States is projected to become the largest global oil producer (overtaking Saudi Arabia) and the impact of new fuel-efficiency measures in transport will kick in about that time. This will result in the United States becoming a net oil exporter around 2030.

But the law of unintended effects can play a part. For example, low-priced natural gas is reducing coal use in the United States, freeing up coal for export to Europe (where, in turn, it has displaced higher priced gas). At its lowest level in 2012, natural gas in the United States traded at around one-fifth of import prices in Europe and one-eighth of those in Japan. The availability of LNP will strengthen the development of a global market and will probably reduce price differences in regional markets.

Competitive power markets within countries and regions, are creating stronger links between gas and coal markets. These markets are also adapting to the increasing role of renewables and in some countries to the reduced role of nuclear power. Policy makers looking for simultaneous progress towards energy security and economic and environmental objectives are facing increasingly complex – and sometimes contradictory – choices.

Energy efficiency is widely recognised as a key option in the hands of policy makers but current efforts fall well short of tapping its full economic potential. But even with these and other new policies in place, a significant share of the potential to improve energy efficiency still remains untapped. In the case in the buildings sector this can be up to 80 percent and more than 50 percent in manufacturing industry.

Efficient World Scenario: The IEA Efficient World Scenario shows how tackling the barriers to energy efficiency investment can realise very considerable gains for energy security, economic growth and the environment. These gains are not dependent on achieving any major or unexpected technological breakthroughs, but on taking positive actions to remove the barriers obstructing the implementation of proven energy efficiency measures that are economically viable. If successful, these actions would have a major impact on global energy and climate trends, compared with the New Policies Scenario.

The IEA estimate that if this happened the growth in global primary energy demand to 2035 would be halved. Oil demand would peak just before 2020 and would be almost 13 mb/d lower by 2035, a reduction equal to the current production of Russia and Norway combined. This would ease the pressure for new discoveries and development. Furthermore, the additional investment in more energy-efficient technologies would be more than offset by reduced fuel expenditures. This expenditure would be in the order of $11.8 trillion (in year-2011 dollars). The expenditure would also increase global GDP with the biggest gross domestic product (GDP) gains being in India, China, the United States and Europe. Also air quality would be improved as emissions of local pollutants would fall sharply. Consequently, energy related carbon-dioxide (CO2) emissions would peak before 2020, with a decline thereafter consistent with a long-term temperature increase of 3 °C. The IEA report also proposed policy principles that can ensure that the Efficient World Scenario will be implemented and the targets suggested above realised.

In addition to the two IEA scenarios, the IEA has also developed the following scenarios:

- **450 Scenario**: A scenario presented in the World Energy Outlook, which sets out an energy pathway consistent with the goal of limiting the global increase in temperature to 2°C by limiting concentration of greenhouse gases in the atmosphere to around 450 parts per million of CO_2.
- **Current Policies Scenario**: A scenario in the World Energy Outlook that assumes no changes in policies from the mid-point of the year of publication (previously called the Reference Scenario).
- **Deferred Investment Case**: A scenario created in World Energy Outlook 2011 to analyse how global markets might evolve if investment in the upstream industry in Middle East and North Africa countries were to fall short of that required in the New Policies Scenario over the next few years.
- **Low Nuclear Case**: A scenario created in World Energy Outlook 2011 to examine the implications for global energy balances of a much smaller role of nuclear power than that projected in any of the three scenarios presented in the WEO-2011.

These scenarios provide insights into potential challenges in the years ahead and assist countries to formulate better energy policies and related programmes.

2.3.1.1 Global Energy Intensity

Global energy intensity increased 1.35 percent in 2010, according to a Worldwatch Institute article[46]. This is the second year global intensity has increased at a faster rate than expected in that it is a reversal of a broader trend of decline over the last 30 years. The article highlighted reasons for these changes in both emerging economies (non-OECD) and industrialized countries (OECD), including China and the United States, and predicts that global energy intensity will return to an overall decline over the long-term as economies opt for, and in many cases achieve more sustainable development.

Between 1981 and 2010, global energy intensity decreased by about 20.5 percent, or 0.8 percent annually. During this period of decline, most developed countries underwent a period of restructuring their economies, and energy-intensive heavy industries accounted for a shrinking share of production and low cost labour businesses moved to the developing countries such as China. According to Haibing Ma, Manager of Worldwatch's China Program, who conducted the research, "New technologies applied to energy production and consumption significantly improved efficiency in almost every aspect of the economy." Particularly during the surge of the so-called "knowledge-based economy" from 1991 to 2000, global economic productivity increased without equivalent increases in energy use.

The article notes that worldwide energy efficiency had been increasing steadily until recently. The trend in global energy intensity was as follows:

- Declined at an average annual rate of 0.98 percent in the 1980s
- Declined at an average annual rate of 1.40 percent in the 1990s, and
- Declined at an average annual rate of 0.3 percent between 2001 to 2010

For a short period between 2004 and 2008, global energy intensity experienced its sharpest decline in 30 years, with an average annual decrease rate of 1.87 percent. However, starting in 2008-09, energy intensity again increased, experiencing the first rise in three decades.

Price developments can also play a major role in determining overall energy usage, sharp increases in price have been seen to dramatically reduce energy intensity when people monitor and control their use of energy. For example, when world crude oil prices more than tripled between 2004 and 2008 - the fastest rise since the oil crisis of the late 1970s – it contributed to a sharp decline in energy intensity during that period. But after the second half of 2008, when international oil prices dropped 75 percent, global energy intensity started rising.

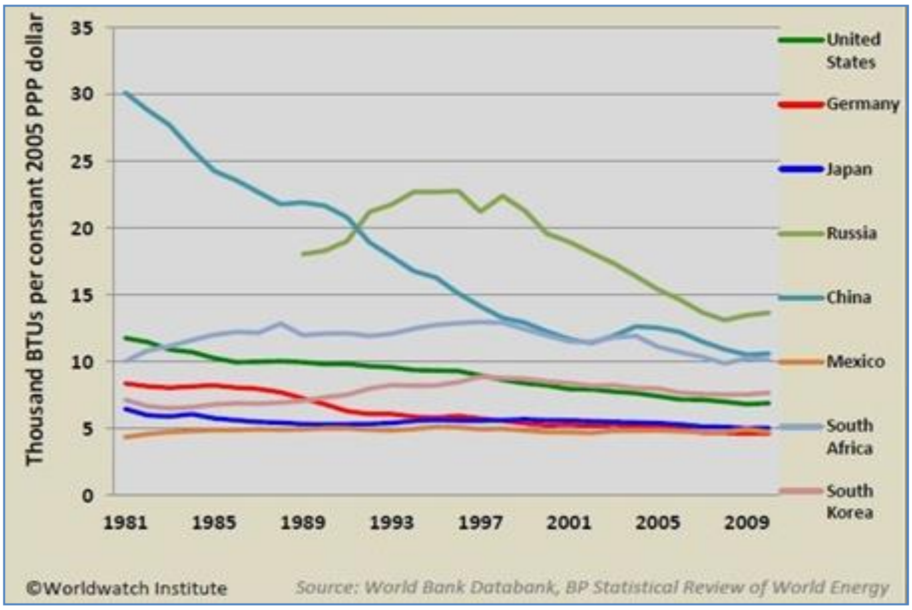
Energy intensity is declining in many advanced economies, including the United States, Germany, and Japan. The most dramatic declines in industrial countries have occurred in the United States and Germany. Overall, China may have made the most progress

[46] Sheldon Yoder, (December 2012), Energy Intensity of Global Economy Rises, Reversing Longtime Trend, Worldwatch Institute.

worldwide with a 65 percent decline in energy intensity in the past 30 years despite a large growth in a middle class and a large migration by millions of people from the land to urban conurbations driving a huge increase in the demand for energy (see Figure 16).

Between 1981 and 2002, China's energy intensity declined 4.52 percent annually. Between 2005 and 2010, it declined a staggering 15.37 percent, although this fell short of the government's goal of 20 percent. One reason for this shortfall is that more than half of China's 4 trillion RMB (630 billion USD) stimulus plan was invested in infrastructure development, which drove up energy consumption. China now has very ambitious plans to use renewables sources of energy (12^{th} 5 Year Plan).

Figure 16: Energy intensity trends by country, 1981 - 2010



Newly industrialized and transitional countries have experienced more turbulent energy intensity trends. For example, South Korea's energy intensity increased during the country's rapid growth period of the 1980s and 1990s, but then declined sharply following the 1997 Asian Financial Crisis. Since the early 2000s, the Korean government and industry have sought actively to shift the country's energy use patterns by focusing more on advanced technology R&D and clean energy initiatives.

Global energy intensity is likely to keep rising in the next few years as the world continues to rely on large-scale infrastructure development as a means to create jobs and bring the global economy out of recession. In the long-term, a green transition could boost new industries, including clean technology and renewable energy, and cause global energy intensity to continue its decline. Countries need more proactive energy plans and strategies. The two major elements of a sustainable energy strategy are more efficient use of energy and more renewable energy production.

Worldwatch's research has shown that "50 percent or more of global electricity demands can be delivered by renewable energy if - but only if - renewable energy is implemented in tandem with energy efficiency."

2.3.1.2 Countries and Regions

Many factors influence an economy's overall energy intensity, such as the general standard of living and/or weather conditions in an economy. It is not atypical for particularly cold or hot climates to require greater energy consumption in homes and workplaces for heating (oil, gas or electric heating systems) or cooling (air conditioning, fans, or refrigeration). A country with an advanced standard of living is more likely to have a wider prevalence of such consumer goods and thereby be impacted in its energy intensity than one with a lower standard of living.

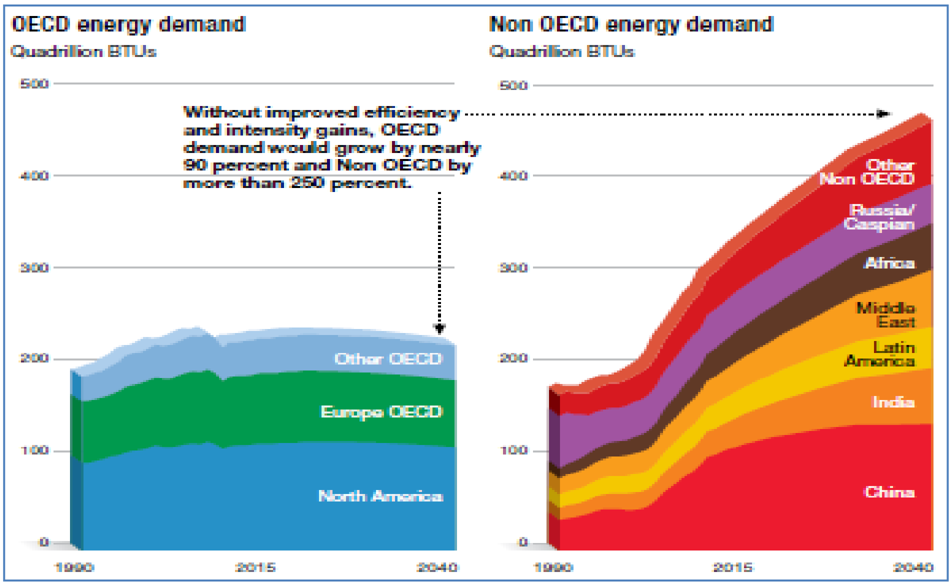
Energy efficiency is a vital part of the nation's energy strategy and has been since the first oil crisis in 1973. As part of a national priority for improving energy efficiency, the United States Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) established a new national system of indicators to track changes in the energy intensity of its economy and economic sectors over time.

In the last year, major energy-consuming countries have announced new measures. China is targeting a 16 percent reduction in energy intensity by 2015; the United States has adopted new fuel economy standards; the European Union has committed to a cut of 20 percent in its 2020 energy demand, and Japan aims to cut 10 percent from electricity consumption by 2030. In the New Policies Scenario, these help to speed up the slow progress in global energy efficiency seen over the last decade

2.3.2 Global and regional energy mix

Today, the global energy mix is an aggregate of different regional mixes that have been shaped by local resource availability, security of supply concerns, economic development, and technology. Examples of this range from coal dependence in South Africa to high hydro-electricity and biomass use in Brazil and nuclear in France. The picture is very clear, the bulk of the growth will occur in the Non-OECD countries (see Figure 17).

Figure 17: Predicted Trends in Energy Demand by Region, 1990-2040



Source: Exxon Mobile, (2012), The Outlook for Energy: A View to 2040

The following figure is based on the Exxon Mobile report[47].

Figure 18: Changes in the Energy Mix by 2040

Oil	Will remain the world's top energy source, led by 70 percent growth in liquid petroleum demand in Non OECD nations
Gas	By 2025, natural gas will have become the second most widely used source of energy worldwide. It will also be the fastest-growing major energy source, with global demand rising by about 60 percent between 2010 - 2040.
Coal	Demand for coal will peak around 2025 and then decline, due to improved efficiency coupled with a shift to less carbon-intensive energies. Even China's demand which is currently 50 percent of the world total, will decline to 10 percent by 2040.
Nuclear power	Nuclear power will grow on average at about 2.2 percent a year – a substantial increase, but lower than projections prior to the 2011 tsunami damage to the Fukushima plant in Japan.
Wind, solar and biofuels	Wind, solar and biofuels will see strong growth. By 2040, they will account for about 4 percent of global demand. Wind is the fastest-growing energy source in the Outlook period, rising at about 8 percent a year – or more than 900 percent – over the period.
	Source: Exxon Mobile, (2012), The Outlook for Energy: A View to 2040

Nonetheless, oil, gas and coal combined will still account for about four-fifths of the fuel mix throughout 2012 – 2040.

The investment gap: According to the 2011 IEA World Energy Outlook, $38 trillion of cumulative investment is needed in energy supply infrastructure to meet demand between 2011 and 2035. This is the equivalent of 1.6 percent of global annual GDP. Almost half is in the power sector. A large part will be in Asia, with China and India accounting for $5.8 trillion and $2.2 trillion respectively. To achieve the 450 ppm scenario, $15.2 trillion additional spending will be required in that period: power-sector ($3.1 trillion), transport ($6.3 trillion), and buildings ($4.1 trillion). Financing the 450 ppm scenario will be a significant challenge.

Regional and national decline rates varied strongly with

- China's energy use per unit of GDP produced falling by an average of 4 percent per year
- The Middle East's energy intensity increased by an annual 1.6 percent
- North America had declines of 1.7 percent per year
- The European OECD countries saw declines of 1.4 percent per year[48]

The overall decline rate decelerated in the 2000s mainly because of China and a few other emerging economies' rapid, energy intensive industry based economic growth. Different intensity rates can result in very different results over the next 30 years. For example, if regional energy intensities remain at their current levels, economic growth rates in line with this outlook's assumptions then this would result in global primary energy demand by 2040 of more than 29 bn toe per year. If history repeats itself – i.e., if regional energy intensities remain on their current trends so that the ratio of world primary energy demand to world GDP continues to decline at 1 percent a year – the

[47] Exxon Mobile, (2012), The Outlook for Energy: A View to 2040
[48] Statoil, (2012), Energy Perspectives Long-term macro and market outlook

result would be a global primary energy demand in 2040 slightly above 22 bn toe per year – a difference of 26 percent in demand.

However, the outcome depends on how willing countries and people are to commit to tough energy efficiency targets and to act on them.

Europe: Five years ago, the EU agreed to lower member countries' energy consumption in 2020 by one fifth relative to the EU's 2007 baseline energy demand scenario – an ambitious target. In 2011 the Commission found that members were likely to accomplish only half of the agreed target in spite of the 2008-09 recession. The target was not legally binding. The Commission then proposed an Energy Efficiency Directive to accelerate the renovation of buildings and oblige energy retailers to lower annual sales by a certain percentage each year. However, one year after the draft directive was released member country governments and EU bodies are still haggling over amendments, exemptions and milestones. Governments are reluctant to yield authority in this area to Brussels. Meanwhile the Commission published an Energy Roadmap for the entire period to 2050. This is a scenario study with five different versions of a greener future. Energy efficiency is important across all scenarios with energy use per unit of GDP produced declining by 2.5-2.9 percent a year. This is roughly twice that achieved in the past. The roadmap does not propose any policies, so it is not clear how the green scenarios may be achieved. Also there is concern that implementing tough energy efficiency measures would further unsettle the EU's already struggling carbon emission allowance trading system.

OECD North America: In 2010, it was the largest energy consuming region globally, accounting for 21 percent of TPED. The annual growth to 2040 is low (0.16 percent or 150 mtoe). Approximately 70 percent of the increase is expected to be consumed by the manufacturing and power sectors. North America is likely to reduce its reliance on oil, like all OECD economies (1 percent p.a.) and coal is expected to decline in importance even more (3.4 percent p.a.) significantly dampening the overall growth in demand for coal globally. These trends are partly driven by the remarkable increase in the United States domestic gas resources and reduced prices with a consequent increase in demand of 40 percent (1.1 percent p.a.). Thus, fossil fuel use will decrease from 84 to 67 percent between 2010 and 2040. Nuclear power is growing gradually at 1.2 percent per year, causing its share in the energy mix to increase from 9 to 13 percent in the outlook period. Renewables are expected to be three times higher by 2040. Thus, their share in the energy mix will increase from 11 to 21 percent between 2010 and 2040; of this 8 percent refers to new renewables.

In the United States, the Environmental Protection Agency (EPA) has been instrumental in formulating rules to raise the efficiency of cars. Two years ago car manufacturers who had already been instructed to raise the average fuel economy of their passenger vehicle fleets from 27.5 miles per gallon (mpg) in 2011 to 35.5 mpg by 2016, were presented with a 54.4 mpg target for 2025.

China: China's 11th Five Year Plan which covered the period 2006-10 targeted a 20 percent decline in energy consumption per unit of GDP produced. The result was that the provinces managed a 19 percent reduction, although in some cases this was achieved by shutting down energy inefficient factories and power plants just before reporting time. The 12th Five Year Plan stipulates a further 16 percent drop in the energy intensity of the national economy and indicates a partial shift from command-and-control measures to price incentives.

Finally, while policies are very important in reducing consumption and energy intensities, they do not account for all reductions or changes. Policies such as taxing fuel use or obliging builders, car makers, appliance manufacturers and others to meet progressively tougher efficiency standards will have an impact on future energy intensities. It is important not to expect policies to provide all the answers. Because energy intensity changes at aggregate levels reflect not alone deliberate policies, but also other factors such as the unintended effects of policies, current supply of capital investment and some uncontrollable factors as well. For example:

- Unintended effects include energy efficiency measures that may result in reducing product prices and this in turn could give rise to increased demand for those same products. There are many examples of this in practice.
- Capital investment in energy infrastructure tends to be in long-life plant and equipment, thus it may prove more cost effective to maximise the use of that equipment over its full lifetime (or near lifetime) rather than replace it with more cost effective equipment.
- Uncontrollable factors may occur such as freak weather, fuel price spikes or business cycles interfering with the availability of capital (short-term), or underlying structural trends such as more gas less coal (longer-term).

Overlooking these other factors may lead to overly optimistic assessments of the manageability of energy intensities.

2.3.3 CO_2 emissions

The change in the global energy mix over the next few decades is linked to many factors, such as, growing demographics, increasing country GDP, government policies to reduce energy intensity, the use of more renewables and changing patterns in consumer use of energy.

The mix is also influenced by new discoveries (such as shale gas and light oil in the United States). But one must bear in mind that new sources of energy such as wind and solar take time to be commercialised and grow adequately to have an impact of the current energy mix. New discoveries require investment, supply options to get to the market and adequate prices to accept the risk. Where new technology is involved it can take up to twenty years to become profitable and widespread, for example, new technology in the construction and automobile industries.

Although a global agreement on CO_2 emissions seems difficult still, regional and national policies and targets on CO_2 are being put in place. Examples include

- EU's Large Combustion Plant Directive, 20-20-20 targets and Emission Trading System
- The US Environmental Protection Agency's recent New Source Performance Standard and Mercury and Air Toxics standard proposal, and California's and other western North American states' emission reduction and carbon trading schemes

Although these climate policies will only have a marginal effect in the current decade, a long-term decline in coal-based power generation is expected. One possible solution is carbon capture and storage (CCS) but only a few demonstration projects have so far been implemented. However, successful large scale CCS faces formidable challenges: financing of relatively high investments, higher operating costs and reduced efficiency of plants with CCS, development and financing of CO_2 transport infrastructure and safe and permanent CO_2 storage.

CCS is assumed to be gradually implemented in the power sector from 2030 in all regions, except Africa and the Middle East. However, the implementation will be slow, some 20-30 years once the technology is better established, so only a minority of fossil fuel power plants and a small proportion of industrial facilities will be equipped with CCS in 2040.

IPCC[49] and IEA experts take all these factors into account when building possible future scenarios for the changing energy mix. Apart from the distribution of different energy sources, these scenarios account for the amount of CO_2 emissions and resulting rising temperatures (because of the accelerating greenhouse effect).

For example, the IEA has drawn up a highly ambitious scenario for the global energy mix in 2030, according to which the international community would set a maximum target of 2° temperature rise with a CO_2 content of 450 ppm by 2100. This energy mix would be broken down as follows:

- **Oil** would provide 30 percent of primary energy consumed worldwide, compared to 33 percent in 2012
- **Natural gas** would provide 20.5 percent - it had already achieved 24 percent in 2012
- **Coal** would provide 16.6 percent compared to 30 percent in 2012
- **Nuclear energy** would provide 9.5 percent compared to 4.9 percent in 2012

[49] IPCC stands for the Intergovernmental Panel on Climate Change. It was set up by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988. Its mission is to objectively, methodically and clearly review and assess the scientific, technical and socio-economic information needed to better understand scientific reasoning behind the risks of human-induced climate change.

- **Renewable energy** would provide 23.4 percent compared to 2 percent in 2012

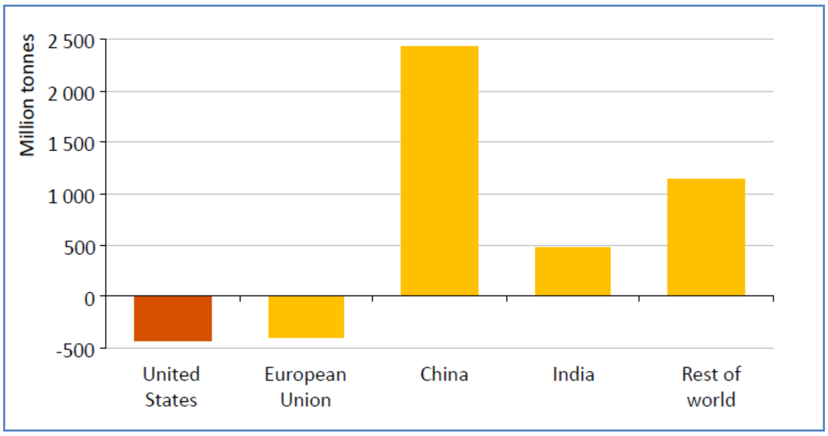
In this scenario, consumers would use less oil and coal in favour of nuclear and renewable energy, which emit fewer greenhouse gases. This is known as decarbonizing the energy mix.

Coal-fired electric power generation emits around 2,000 pounds of carbon dioxide for every megawatt-hour generated, which is almost double the CO_2 released by a natural gas-fired electric plant per megawatt-hour generated. This accounts for the unexpected drop in emissions in the United States as they move from coal to cheaper shale natural gas. CO_2 emissions in the first quarter of 2012 were the lowest of any recorded for the first quarter of any year since 1992 (see Figure 19).

CO_2 emissions in the United States have now fallen by 430 Mt (7.7 percent) since 2006, the largest reduction of all countries or regions.

Transitioning from a carbon-intensive economy to a low-carbon future presents challenges and opportunities for developing countries. Worldwatch Sustainable Energy Roadmaps[50] help countries successfully navigate the change to an infrastructure capable of meeting the energy challenges of the 21st century.

Figure 19: Global CO2 emissions growth, 2006-2011



Source: OECD/IEA, (2012), World Energy Outlook

Its roadmaps include technical assessment (efficiency, renewables and grid considerations), socio-economic analysis (costs, scenarios and macroeconomic effects) and finance and policy assessment. These analyses lead to recommendations that cover visions and long–term goals, policy mechanisms and governance and administration processes.

Worldwatch strengthens government and civil society capacity, enhances stakeholder engagement and advances policies that combat climate change. By collaborating with local stakeholders in each country, Worldwatch produces concrete Low-Carbon Energy Roadmaps that empower them to reduce dependence on fossil fuel imports, local pollution, greenhouse gases, and long-term energy costs. At the same time, the roadmaps lead to new business opportunities and high quality jobs.

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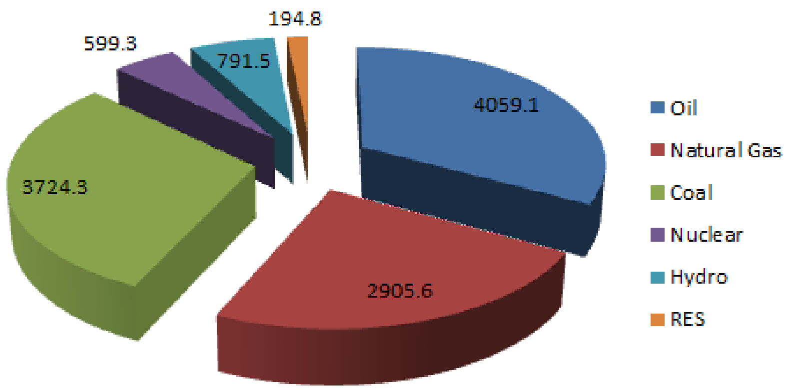
[50] http://www.worldwatch.org/sustainable-energy-roadmaps

2.4 The Global Energy Market

The world's Primary Energy Consumption by fuel in 2012 was as follows: Oil 33.1 percent, Coal 30.3 percent, Natural Gas 23.7 percent, Nuclear Energy 4.9 percent, Hydro Energy 6.4 percent and Renewables (RES) 1.6 percent (see Figure 20).

Figure 20: Primary Energy Consumption by fuel in 2012



Source: BP Statistical Review of World Energy, 2012

All of the net growth took place in emerging economies. China alone accounted for 71 percent of global energy consumption growth. OECD consumption declined, led by a sharp decline in Japan (in volume terms), the world's largest decline. The data suggests that growth in global CO_2 emissions from energy use continued in 2011, but at a slower rate than in 2010.

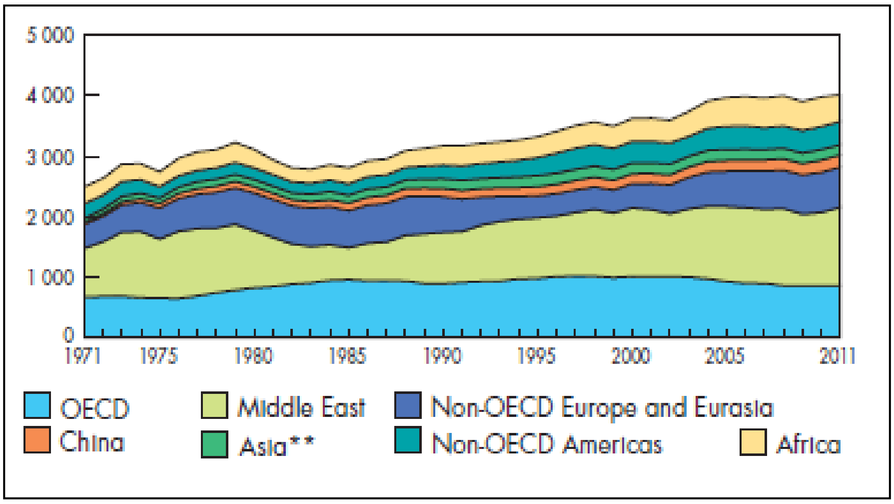
Energy developments: World primary energy consumption grew by 2.5 percent in 2011, roughly in line with the 10-year average. Consumption in OECD countries fell by 0.8 percent, the third decline in the past four years. Non-OECD consumption grew by 5.3 percent, in line with the 10-year average. Global consumption growth decelerated in 2011 for all fuels, as did total energy consumption for all regions. Oil remains the world's leading fuel, at 33.1 percent of global energy consumption, but oil continued to lose market share for the twelfth consecutive year and its current market share is the lowest in the data set, which began in 1965.

2.4.1 The Oil Market

2.4.1.1 Trends in Crude Oil Production

Figure 21 shows the growth in crude oil production from 1971 to 2011 by region.

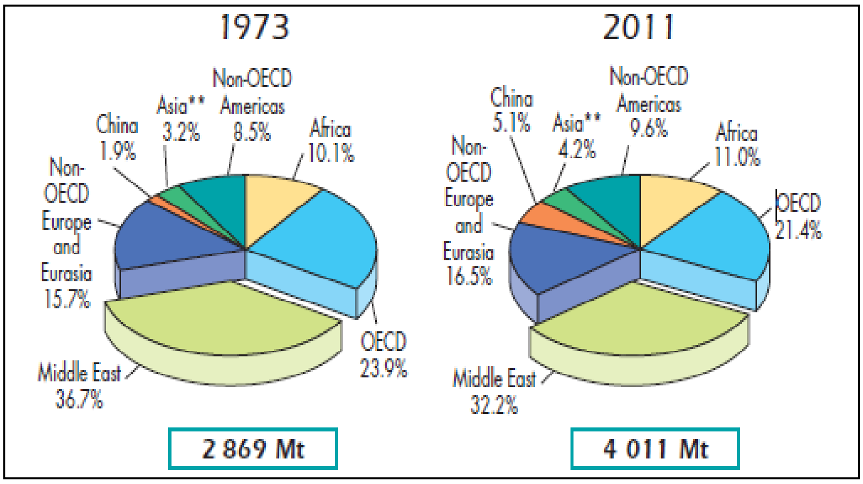
Figure 21: Growth in crude oil production, 1971-2011



Source: IEA, Key World Energy Statistics 2012

The growth in oil production between 1973 and 2011 was 40 percent or 1,142 million tonnes (Mt) – see Figure 22. Every region has increased its output, but some regions have increased their share of the total output, e.g., the largest increase was China, but from a very low level. There were relatively small increases in Asia, Non-OECD Americans and Africa, while both OECD and the Middle East decreased their share of production.

Figure 22: Growth in crude oil production, 1973-2011 (Mt)



**Includes crude oil, NGL, feed stocks, additives and other hydrocarbons.*

***Asia excludes China.*

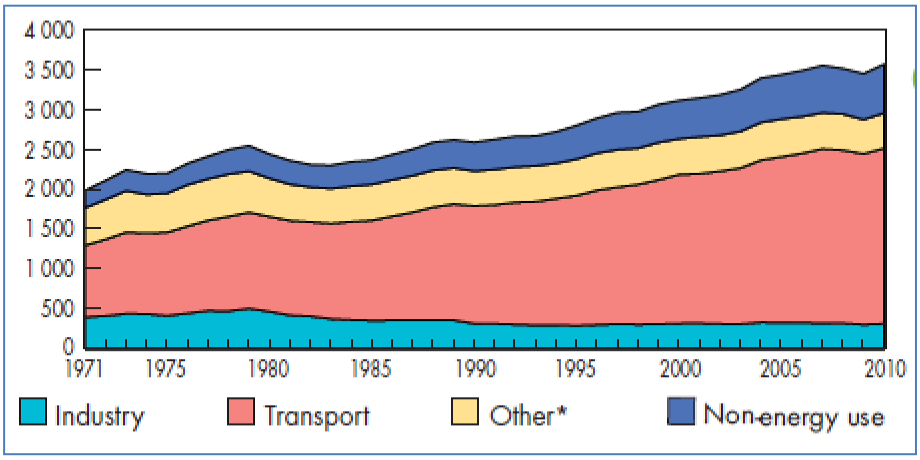
Source: IEA, Key World Energy Statistics 2012

The top five producers accounted for 45 percent of world production. The largest producer is Saudi Arabia (517Mt – 12.9 percent of world production in 2011), Russian Federation (510 Mt or 12.7 percent), United States (346 Mt or 8.6 percent), Islamic Republic of Iran (215 Mt or 5.4 percent), and the People's Republic of China (203 or 5.1 percent).

2.4.1.2 *Trends in Crude Oil Demand*

Figure 23 shows the total consumption of oil from 1971 to 2010 by sector in million tonnes, transport and industry accounting for most of the growth. All sectors grew in the period from 1973 to 2010 in volume terms but the relative shares changed significantly also – transport increased its share from 45.5 to 61.5 percent and industry declined from 19.9 to 9.0 percent.

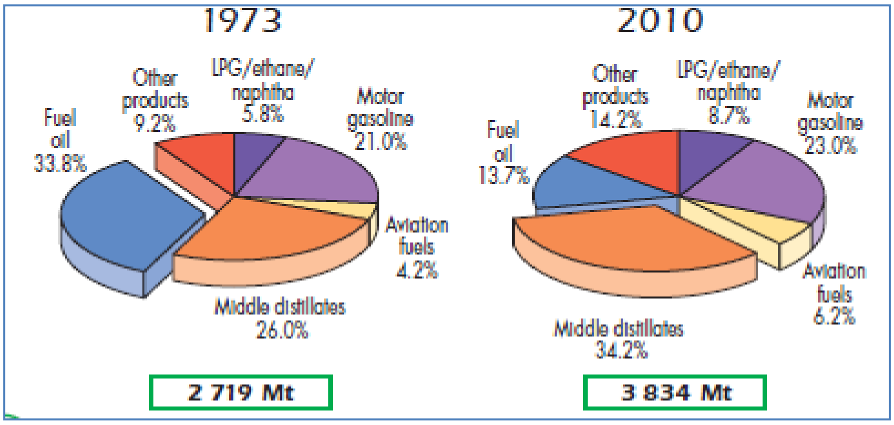
Figure 23: Total final consumption of oil by sector, 1971-2010 (Mt)



Source: IEA, Key World Energy Statistics 2012

All products grew in the period from 1973 to 2010 in volume terms and the relative shares changed significantly – fuel oil fell from 33.8 percent to 13.7 percent, and aviation fuel and LPG/ethane/naphtha increased significantly (see Figure 24).

Figure 24: Global refinery production by product, 1973 and 2010 (Mt)



Source: IEA, Key World Energy Statistics 2012

2.4.1.3 *Current Prices, Consumption and Production*

Energy price developments were mixed. Oil prices for the year 2011 exceeded $100 per barrel for the first time ever (in current money terms) and inflation-adjusted prices were the second-highest on record. Dated Brent averaged $111.26 per barrel in 2011, an increase of 40 percent from the 2010 level. Crude oil prices peaked in April following the loss of Libyan supplies, combined with smaller disruptions in a number of other countries, pushing prices sharply higher despite a large increase in production among other OPEC members and a release of strategic stocks from International Energy Agency member countries.

The differential between Brent and West Texas Intermediate (WTI) reached a record premium (in $/bbl) due to infrastructure bottlenecks (limited pipeline capacity) driven by rapidly increasing United States and Canadian production. Global oil consumption grew by a below-average 0.6 million barrels per day (b/d), or 0.7 percent, to reach 88 million b/d. This was once again the weakest global growth rate among fossil fuels.

OECD consumption declined by 1.2 percent (600,000 b/d), the fifth decrease in the past six years, reaching the lowest level since 1995. Non-OECD consumption grew by 1.2 million b/d, or 2.8 percent. Despite strong oil prices, oil consumption growth was below average in producing regions of the Middle East and Africa due to regional unrest. China again recorded the largest increment to global consumption growth (+505,000 b/d, +5.5 percent) although the growth rate was below the 10-year average.

Annual global oil production increased by 1.1 million b/d, or 1.3 percent. Virtually all of the net growth was in OPEC, with large increases in Saudi Arabia (+1.2 million b/d), the UAE, Kuwait and Iraq more than offsetting a loss of Libyan supply (-1.2 million b/d). Output reached record levels in Saudi Arabia, the UAE and Qatar. Non-OPEC output was broadly flat, with increases in the United States, Canada, Russia and Colombia offsetting continued declines in mature provinces such as the UK and Norway, as well as unexpected outages in a number of other countries. The United States (+285,000 b/d) had the largest increase among non-OPEC producers for the third consecutive year. Driven by continued strong growth in onshore production of shale liquids, United States output reached the highest level since 1998.

2.4.1.4 Future Prospects

What the demand and supply for oil will look like in the future is the subject of much speculation and uncertainty. To improve its understanding of these issues and broaden its evidence base, the Department of Energy and Climate Change - DECC (U.K.) collected the views of a range of experts including academics, advisory bodies and private business.

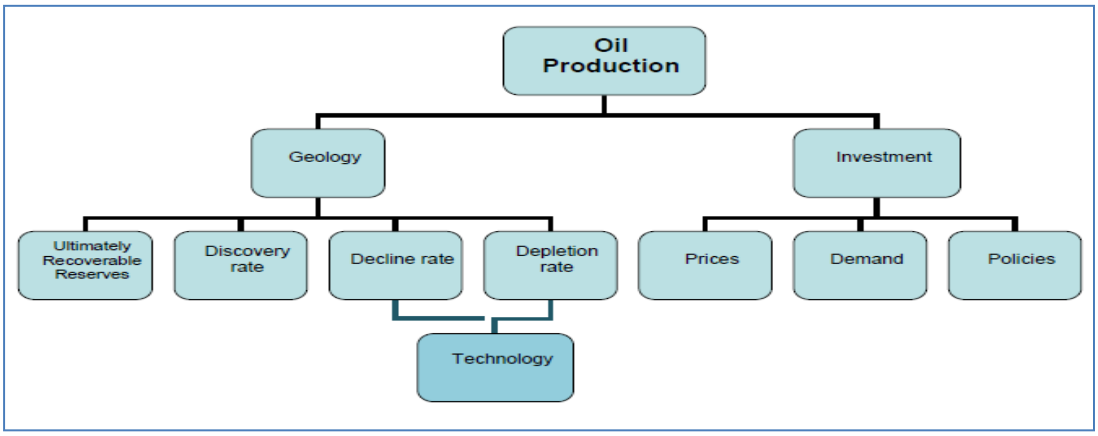
These views are expressed in a series of document at: ttp://www.decc.gov.uk/en/content/cms/meeting_energy/int_energy/global_oil/cfe_crude_oil/cfe_crude_oil.aspx

The International Energy Agency's (IEA) World Energy Outlook 2008 (WEO 08) projects that production from yet-to-find fields would reach 19 mb/d in 2030 from the discovery of 114 billion barrels of reserves worldwide, and World Energy Outlook 2010 (WEO 10) predicts that about 20 mb/d of 2030 production will come from fields yet to be found, increasing further to 2035. Total oil production continues to expand through to 2035 in the Current Policies Scenario, reaching 107.4 mb/d by 2035 while the 450 Scenario sees production peaking before 2020 and then declining to 2035[51]. The majority of respondents to DECC believe that production will peak before 2030.

A majority of respondents to DECC from a variety of backgrounds believe that total oil production will be less than 100 mb/d at its maximum. Following the peak, production will decline slowly. The majority also expect production to reach a plateau which could last for up to 20 years.

The main drivers are geology and investment, prices and demand (See Figure 25). The most significant above ground factor is investment. The main influences on investment in oil production are argued to be prices, demand and policies. If prices are volatile or low relative to investment, the available investment decreases. Other respondents believe that demand drives supply.

Figure 25: Key Drivers related to Future Oil Supply



Source: DECC, (June A), DECC Call for evidence - Summary of responses Prospects for crude oil supply and demand, U.K. Government.

Other factors that could affect oil supply are the impact of the 2010 Gulf of Mexico oil spill and competition from coal and unconventional gas (shale gas).

The game changer is that "fracking" underground shale formations — cracking them open with high-pressure jets of water, chemicals and sand — has unlocked new supplies of natural gas and oil in places such as North Dakota and Pennsylvania. What is surprising is how big those supplies are, and how much they might change the world. In its latest annual forecast released last week, the Paris-based agency, IAE, says fracking means the United States will overtake Russia to become the world's largest natural gas producer by 2015 and pass Saudi Arabia as the world's largest oil producer by 2017[52].

The majority of respondents to DECC believe that prices are likely to increase to over $100 per barrel over the medium-term but many argue that the long-term price will be set by the marginal cost of production at $60-90 per barrel. Others argue that there could be a possible spike to $200 resulting from a supply crunch and that a low of $40 could be achieved when hybrid and electric transport reduce the demand for oil.

[51] DECC, (June A), DECC Call for evidence - Summary of responses Prospects for crude oil supply and demand, U.K. Government.

[52] IEA, (November 2012), World Energy Outlook 2012, Paris

2.4.2 The Global Gas market

2.4.2.1 Current Position

The share of natural gas in world primary energy consumption has increased steadily from 16 percent in the early 1970's to 24 percent at the end of 2006. This growth is expected to continue as a result of the increased use of natural gas in electricity generation and as increased emphasis on cleaner fuels results in a move away from oil and particularly coal.

Key reasons for the increase in demand for gas:

- Environmental pressure for cleaner fuels
- Wholesale electricity market competition raised the demand for smaller scale electricity plants, which CCGT (an improved technology relative to older gas turbines) satisfied
- Falling LNG production and transport costs facilitate global markets and price competition thus reducing regional markets and related price differentials
- Available gas supplies from unconventional sources, e.g., gas in the United States

Possible constraints:

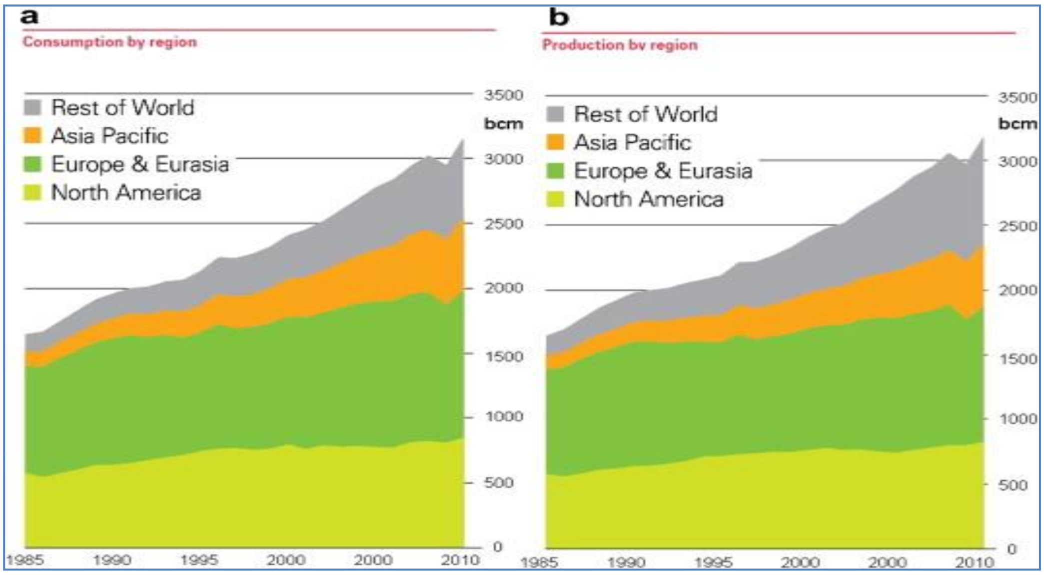
- Lack of investor confidence in investing in many gas-rich nations
- Resource curse – might the growing rents from gas provoke political instability?
- Slowdown to electricity reforms – could disadvantage gas relative to other fuels
- Alternative energy technologies – coal gasification, solar, hydro and/or nuclear power, perhaps assisted by falling costs, could displace gas in electricity generation

2.4.2.2 Gas Consumption and Production

World natural gas consumption grew by 7.4 percent in 2010 (See Figure 26), with above-average growth in all regions but the Middle East[53]. Consumption growth was the most rapid increase since 1984 in all regions – except the Middle East. The United States had the world's largest 2010 increase in consumption (in volume terms), rising by 5.6 percent to a new record high. Russia and China also registered large increases – the largest volume increases in the country's history in each case. Consumption in other Asian countries also grew rapidly in 2010 (+10.7 percent), led by a 21.5 percent increase in India.

[53] Weijermars, Ruud, (March 2012), Strategy implications of world gas market dynamics, Elserier, Energy Strategy Reviews, Volume 1, Issue 1, Pages 66–70

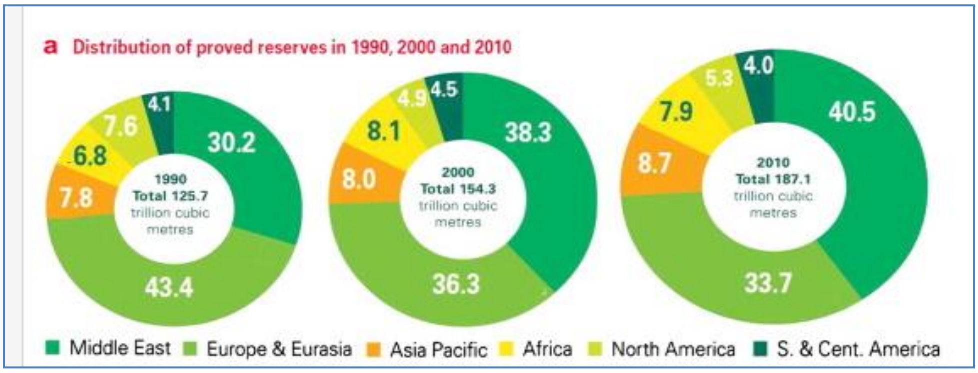
Figure 26: Growth in gas consumption and production, 1985-2010



Source: http://www.sciencedirect.com/science/article/pii/S2211467X11000058#bib2

World conventional gas reserves have expanded between 1990 and 2010 by 50 percent (Figure 27). This expansion occurred unevenly across the regions, led mostly by the growth of gas reserves in Middle East. The Middle East and the former Soviet Union jointly hold 72 percent of the world's remaining conventional gas reserves.

Figure 27: Distribution of Proven Reserves, 1990, 2000 and 2010



Source: BP Statistical Review of World Energy, 2012

Globally, natural gas is the fastest growing fossil fuel in power generation and grows its share in power generation from fossil fuels grows from 30 percent today to 37 percent in 2030[54]. Its share in total electricity generation increases from 20.5 percent to 22 percent.

2.4.1.1 Future Trends

Natural gas is well on its way to a bright future, according to a new report from the International Energy Agency (IEA)[55] that projects **China will more than double consumption** over the next five years while **lower prices** from the unconventional gas revolution will continue to benefit the United States.

[54] BP Statistical Review of World Energy, June 2011. www.bp.com/statisticalreview.
[55] IEA, (2012), Medium-Term Gas Market Report 2012, Paris.

The report identifies other future sources of supply, with most incremental gas production coming from the Former Soviet Union (FSU) and North America. Further growth in unconventional gas will come mostly from shale gas in North America plus tight gas and coalbed methane (CBM) production elsewhere. Shale gas developments in other regions are likely to be concentrated in China and Poland.

Other key findings of the report include:

- A quarter of new gas demand will come from China, another quarter from the Middle East and other Asian countries together, and a fifth from North America.
- Low gas prices will result in gas generating almost as much electricity as coal in the United States by 2017.
- Global gas trade will expand by 35 percent, driven by LNG and pipeline gas exports from the Former Soviet Union region; most of this expansion will occur from 2015 onwards, following a period of further tightening of global gas markets.
- Natural gas is the most important commodity with no global market price yet. Divergence among regional gas prices will decline but remain a feature of global gas markets. The emergence of a spot price in Asia would aid regional producers and buyers.

The global gas market has changed radically in recent years due to the development of extraction technology and the opening up of new sources of gas, particularly in the United States. This has been called 'unconventional supply' in North America.

Many other countries are lining up to emulate this success, notably in China, Australia, Europe and Latin America. But concerns remain that production might involve unacceptable environmental and social damage, such as:

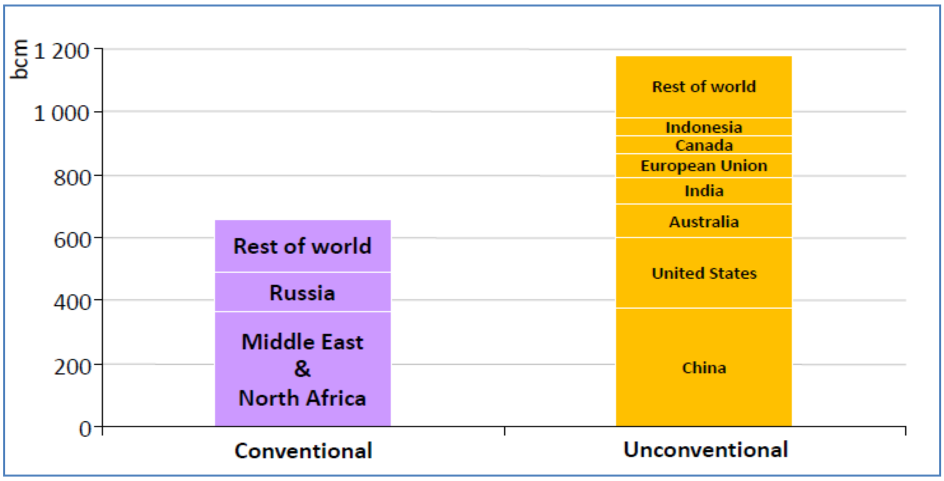
- Major implications for local communities, land use and water resources
- Serious hazards include the potential for air and water pollution

Improperly addressed, these concerns threaten to hold back and perhaps halt the unconventional gas revolution.

Combined unconventional gas output growth from the United States, China and Australia surpasses that of all conventional producers - mainly the MENA region and Russia[56] (see Figure 28).

[56] OECD/IEA presentation on World Energy Outlook 2012 at: http://www.worldenergyoutlook.org/pressmedia/recentpresentations/Developmentinglobalgasmarketsandimplicationsfor Europe.pdf

Figure 28: Natural gas supply growth potential, 2010-2035

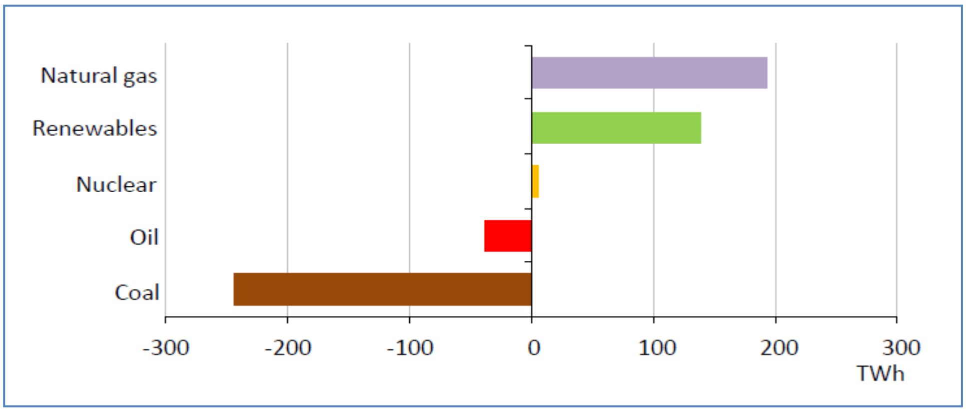


Source: OECD/IEA, World Energy Outlook, 2012

As an indicator of how supply could evolve in the future it is interesting to note that over the past 5 years, natural gas and renewables were the leading sources of incremental electricity generation in the United States (see Figure 29).

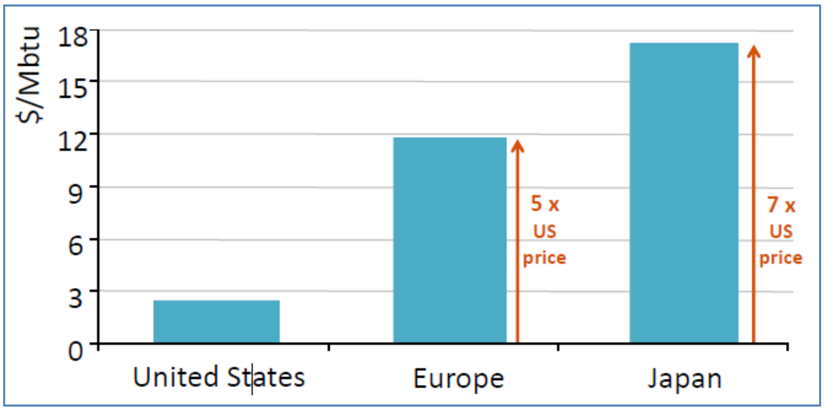
How will the unconventional gas boom affect prices in other markets? Natural gas prices are significantly higher in Europe and Japan compared to United States gas prices (see Figure 30). The unconventional gas boom will spur a degree of convergence in global prices by putting pressure on oil-price indexation of gas contracts in Europe and Asia.

Figure 29: United States electricity generation growth, 2006-2011



Source: OECD/IEA, World Energy Outlook 2012

Figure 30: Average natural gas prices by region, May 2012



Source: OECD/IEA, World Energy Outlook 2012

The IEA has developed a set of "Golden Rules" that can address the environmental and social impacts of unconventional gas – making the golden age of gas a reality. "The technology and the know-how already exist for unconventional gas to be produced in an environmentally acceptable way," said IEA Executive Director, Maria van der Hoeven[57]. "But if the social and environmental impacts are not addressed properly, there is a very real possibility that public opposition to drilling for shale gas and other types of unconventional gas will halt the unconventional gas revolution in its tracks. The industry must win public confidence by demonstrating exemplary performance; governments must ensure that appropriate policies and regulatory regimes are in place."

The Golden Rules underline the importance of full transparency, measuring and monitoring of environmental impacts and engagement with local communities, careful choice of drilling sites and measures to prevent any leaks from wells into nearby aquifers, rigorous assessment and monitoring of water requirements and of waste water, measures to target zero venting and minimal flaring of gas, and improved project planning and regulatory control.

Unconventional gas can transform energy markets by:

- putting downward pressure on prices
- broadening diversity and security of gas supply

However, Europe's unconventional gas prospects remain uncertain, but in any case it gains as global markets become more liquid and competitive. Natural gas has a role to play in a low-carbon energy economy, but increased use in itself is *not* sufficient to reach the 2°C goal. For a truly sustainable energy system, radical changes to energy efficiency and more renewables and greater deployment of new technologies are needed.

In a Golden Rules scenario case, the application of these rules helps to underpin a brisk expansion of unconventional gas supply, which has far-reaching consequences:

[57] IEA, (2012), 'Golden Rules' Press Release by IEA on 29 May 2012 http://www.iea.org/newsroomandevents/pressreleases/2012/may/name,27266,en.html

- World production of unconventional gas, primarily shale gas, more than triples between 2010 and 2035 to 1.6 trillion cubic metres
- The United States becomes a significant player in international gas markets, and China emerges as a major producer
- New sources of supply help to keep prices down, stimulate investment and job creation in unconventional resource-rich countries, and generate faster growth in global gas demand, which rises by more than 50 percent between 2010 and 2035

By contrast, in a Low Unconventional Case where no Golden Rules are in place, a lack of public acceptance means that unconventional gas production rises only slightly above current levels by 2035.

Ultimately, there appears to be substantial gas available to satisfy demand at a reasonable price until the second half of the century when alternative backstop technologies should become competitive. The global supply curve for natural gas is reasonably elastic. But substantial known gas reserves may not be exploited since they are likely to be more expensive than the feasible alternatives.

2.4.3 The Coal Market

Coal is a global industry, with coal mined commercially in over 50 countries and used in over 70 (see Figure 31). Coal is readily available from a wide variety of sources in a well-supplied worldwide market. Coal can be transported to demand centres quickly, safely and easily by ship and rail. A large number of suppliers are active in the international coal market, ensuring a competitive and efficient market.

Coal has many important uses worldwide. The most significant uses are in electricity generation, steel production, cement manufacturing and as a liquid fuel. Around 6.6 billion tonnes of hard coal were used worldwide last year and 1 billion tonnes of brown coal. Since 2000, global coal consumption has grown faster than any other fuel. The five largest coal users - China, United States, India, Russia and Japan - account for 76 percent of total global coal use.

Coal prices have historically been lower and more stable than oil and gas prices. Coal is likely to remain the most affordable fuel for power generation in many developing and industrialised countries for decades.

World proved reserves of coal in 2011 were sufficient to meet 112 years of global production, by far the largest R/P ratio[58] for any fossil fuel. Europe and Eurasia hold the largest regional reserves and have the highest R/P ratios. The Asia Pacific region holds the second-largest reserves, while North America has the second-highest R/P ratio.

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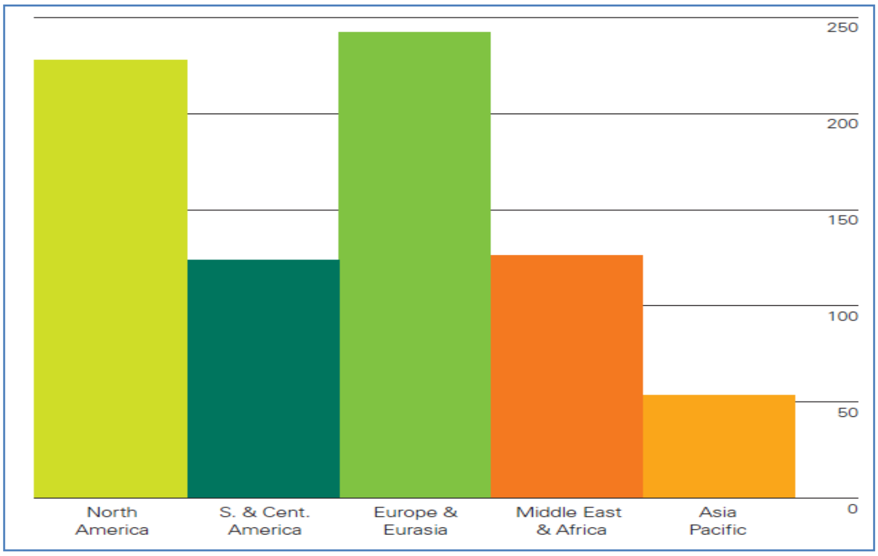
[58] R/P ratios represent the length of time that those remaining reserves would last if production were to continue at the previous year's rate. It is calculated by dividing remaining reserves at the end of the year by the production in that year.

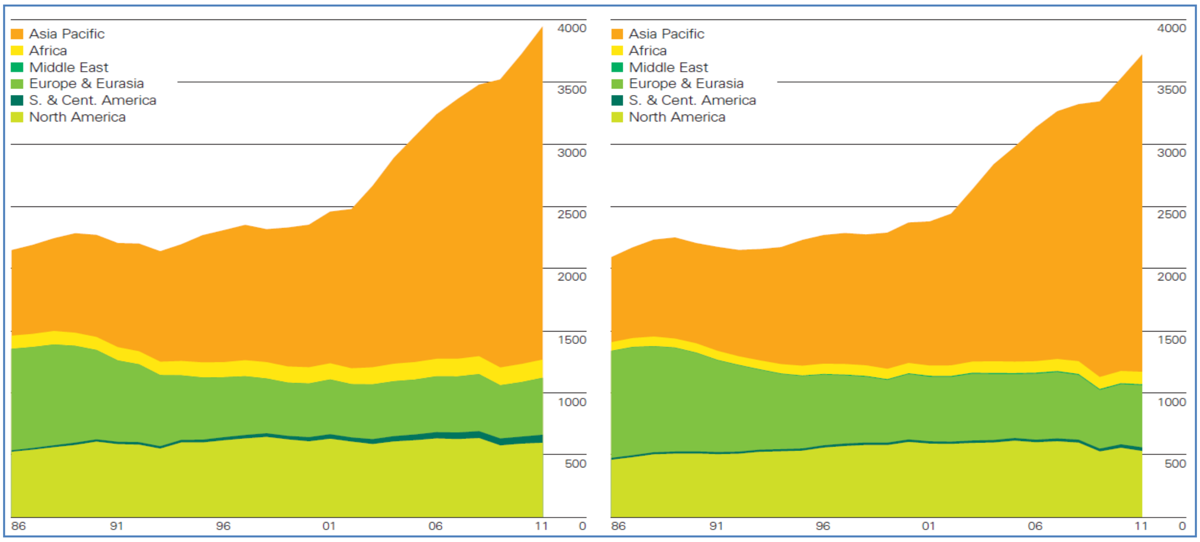
Figure 31: World Coal Reserves by Region, 2011



Source: bp.com/statisticalreview

Coal was again the fastest-growing fossil fuel. Global production grew by 6.1 percent. The Asia Pacific region accounted for 85 percent of global production growth, led by an 8.8 percent increase in China, the world's largest supplier. Global coal consumption increased by 5.4 percent, with the Asia Pacific region accounting for all of the net growth. Elsewhere, large declines in North American consumption were offset by growth in all other regions (see Figure 32).

Figure 32: Production and Consumption by Region, 2011 (mt. oil equivalent)



Source: bp.com/statisticalreview

According to Barclay Capital (BarCap), global coal supply was balanced or in slight surplus during 2012 and will remain so in 2013 as weak demand is met by healthy supplies[59] (see Figure 33). In global coal trading, BarCap said that 2012's import demands of 837 million tonnes would be met by available exports of 843 million tonnes,

[59] Reported by Reuters, on 30 August 2012
http://in.reuters.com/article/2012/08/30/energy-coal-gas-idINL6E8JU2PZ20120830

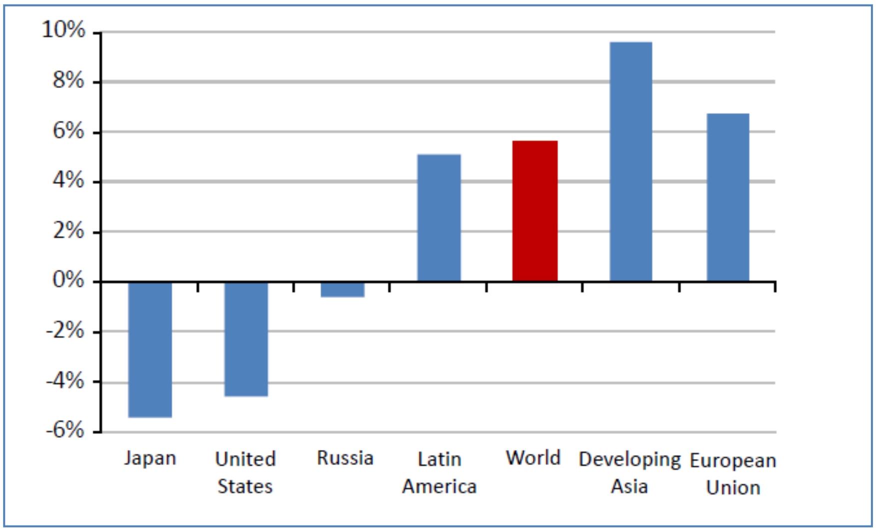
while 2013 would see import needs of 849 million tonnes met by 850 million tonnes ready for export.

Coal pricing remains subdued, with weaker demand growth from Chinese steel and power producers, coupled with healthy supply increments from traditional exporters and the United States, leaving the seaborne market well supplied."

The healthy coal exports mean that BarCap expects prices to drop, with API2[60] (European) prices to average $94 per tonne in 2012, and $92 a tonne in 2013. South African API4 prices were expected to fall from an average of $95 to $94 a tonne between 2012 and 2013, while Australian Newcastle coal prices would see a an annual average decline from $99 a tonne to $97 per tonne.

European Union coal demand rose by a historical 7 percent in 2011, driven by cheap US imports

Figure 33: Growth in world coal demand, 2011



Source: OECD/IEA, World Energy Outlook 2012

2.4.4 Nuclear Power

2.4.4.1 Current position

Nuclear power first generated electricity on December 20, 1951, at the Experimental Breeder Reactor in Arco, Idaho, United States. There was a slow adoption of the technology since then. By 2011, nuclear power provided about 5.7 percent of its energy and 13 percent of its electricity. There are 435 nuclear plants in operation and 62 new nuclear plants are under construction in 30 countries now. The leading countries are the United States (104 nuclear plants), France (58), Japan (50), Russia (33), Republic of Korea (23), India (20) and Canada (18). Also more than 115 nuclear powered naval vessels have been built. China, Russia and India are building the largest number of new nuclear plants with 26, 11 and 7 plants respectively currently under construction. China plans to build more nuclear plants.

[60] The Argus/McCloskey Coal Price Index service is the source of the API prices, which are the key indexes used for international physical and derivatives coal business.

The United States currently produces the highest absolute output of electricity from nuclear power in the world (i.e., which only provides 19 percent of its electricity consumption), while France produces the highest percentage of its electrical consumption from nuclear power – currently in the order of 75 percent of its consumption.

2.4.4.2 The nuclear debate

There is an ongoing debate about the use of nuclear energy. Proponents such as the World Nuclear Association, the IAEA and Environmentalists for Nuclear Energy contend that nuclear energy is a sustainable energy source that reduces carbon emissions. Opponents such as Greenpeace international and NIRS, believe that nuclear power poses many threats to people and the environment. Following three major accidents - the Chernobyl disaster (1986), Fukushima Daiichi nuclear disaster (2011), and the Three Mile Island accident (1979), and some nuclear-powered submarine mishaps the argument currently favours those who are against nuclear power.

In the aftermath of the Fukushima disaster, the fate of nuclear power appeared to hang in the balance as generating states scrambled to conduct safety checks on their existing nuclear reactors and newly-restarted nuclear programmes. A number of these states have since elected to phase out their nuclear power plants. Japan, Switzerland, Belgium and Germany have decided to effectively reduce/close its nuclear programme as quickly as possible. Others have decided to reduce their dependency on nuclear power including countries such as France (to 50 percent of its electricity needs). The potential loss of worldwide nuclear power generating capacity is therefore considerable.

In marked contrast to these countries, all non-OECD countries with operating nuclear power plants (NPPs) or nuclear programmes underway have thus far given no indication that they are likely to abandon them. India has not announced any material change to its nuclear energy plans to boost generating capacity to 63 GW by 2032. Likewise, Russia's nuclear energy policy was endorsed by PM Vladimir Putin in April 2011 as part of a balanced energy mix. The nuclear status quo for many of these developing countries thus remains despite the impacts of the Fukushima nuclear disaster. Many developing economies were unable to provide the investment and/or expertise necessary to build a nuclear power plant. But GDP growth and education development has made this more possible for many countries in the future. However, the key question is whether these countries will follow China's or Japan's example.

2.4.4.3 China's nuclear plans

Prior to Fukushima, China had been pursuing the world's most ambitious nuclear power program. Following Fukushima, this is still the case. Its nuclear expansion goals are primarily driven by closely related energy security and carbon emission concerns and, relative to its other power generating options, the fact that it is arguably a relatively environmentally friendly and efficient source of electricity. This underscores the significance of China's decision to forge ahead with its 12th Five Year Plan target to install 40 additional gigawatts of nuclear capacity by 2015.

Most of the electricity produced in China has thus far been supplied by coal, which provided 2,940,525 GWh of electricity in 2009 and constituted almost 80 percent of the total electricity generation mix and gives rise to high levels of greenhouse gas emissions. China's need to quickly reduce carbon emissions in power generation is highlighted by the government's objective to reduce the ratio of GDP to carbon dioxide emissions by 40-45 percent between 2005 and 2020. Furthermore, the heavy reliance upon coal fired power generation causes immediate local health and environmental problems. Pollutants released from coal combustion have been identified as causing the rise of respiratory illnesses and has precipitated increased occurrences of acid rain and a consequent degradation in soil quality. These factors enhance nuclear power's appeal as a means to reduce greenhouse gas emissions and improve environmental quality.

Furthermore, amongst China's energy security issues is the pressing need to ensure that domestic power demands are met. China's power generation capacity has increased rapidly, as has its electricity infrastructure, but this growth in supply has only unevenly met the growing demands for electricity. This growth is predicted to continue in coming decades – the International Energy Agency has projected that China's total electricity generation will increase by a compound annual growth rate (CAGR) of 3.9 percent from 2009 to 2035. Of this total, coal is projected to increase by a CAGR of 2.5 percent while nuclear power, which has a much smaller base, is projected to increase by a CAGR of 10.6 percent in the same period.

While China does possess substantial fossil fuel reserves, and indeed used to export oil and coal, it has become a net importer of fossil fuels and has extended its geopolitical reach in part to feed its growing power demands. The government's decision to continue its nuclear power programme can thus be seen as a combination of realism about the growing requirements of its electricity grid and belief that the viability and safety of nuclear power technology has not been seriously compromised by the Fukushima nuclear disaster which, unlike Chernobyl or Three Mile Island, was triggered by natural disaster rather than human error.

Perhaps the most vexing environmental issue associated with China's nuclear power programme is the issue of spent fuel disposal. The World Nuclear Association (WNA) estimates that China's nuclear power industry produced about 600 tonnes of used fuel in 2010 and will produce 1000 tonnes in 2020. Since the inception of the nuclear power program, the government has envisioned a closed fuel cycle as the program's long-term plan for its nuclear program. A number of facilities and projects have been created towards that end. The permanent disposal of nuclear power waste has long been the bugbear of the nuclear power industry worldwide and no nuclear power producing state has yet found a solution to it.

While China has announced ambitious targets for renewable power deployment, it cannot presently rely exclusively upon renewable power to fulfil rapidly growing energy demands. One reason for this is the substantial distances between the urban centres of electricity demand and the rural sites of renewable power potential. For example, wind power potential is concentrated mainly in China's north and west, while the primary centres of electricity demand are located in the eastern coastal areas. Electricity demand in Chinese cities has been increasing exponentially due to high rates of rural-urban migration.

2.4.4.4 Europe's nuclear programme

There are 165 nuclear reactors producing power in Europe (excluding Russia), with six under construction and others planned (see Figure 34, next page). There is a wide divergence of approaches to nuclear power. Some countries, like Germany and Spain, are committed to phasing out nuclear power; others, like the UK and Italy, have recently committed themselves to building new power plants, while some, including Ukraine and Finland, already are.

The key countries with nuclear programmes are:

- In 2011 17 German nuclear plants generated 107.9 billion kWh of electricity. However, less than a week following the Fukushima Japanese nuclear disaster, the German Chancellor stunned the nation by withdrawing the licensing extensions and temporarily closing seven of Germany's oldest nuclear plants. The restart of an eighth plant, which was offline for refuelling, was delayed. As of July 2012, Germany still had 9 operating nuclear power plants with a gross output of 12,696 MW. On May 30, the Chancellor announced that she was making the temporary closures permanent. Furthermore, she decided to permanently close all nine of its remaining nuclear power plants by 2022.

Figure 34: Nuclear power plants in operation in Europe, July 2012

Source: http://www.euronuclear.org/info/encyclopedia/n/nuclear-power-plant-europe.htm

- France has been Europe's most enthusiastic supporter of nuclear power, constructing dozens of reactors since the 1970s oil crises spurred on its desire for energy independence. It has become the world's biggest net exporter of electricity, and is also a major exporter of nuclear technology. France recently decided to reduce its nuclear plants to 50 percent of its electricity consumption (a one third reduction).

- The UK was the first country to use nuclear energy to generate power for large-scale civilian use, opening its first plant in 1956. The last new reactor was opened in 1995, and the country has been steadily decommissioning its old plants, with many set to close by 2023. In 2008, the government gave the go-ahead for a new generation of nuclear power stations. The latest projections from the Department of Energy and Climate Change have reduced the amount of nuclear power expected in future, with only Hinkley expected to be up and running by 2025. The troubled French nuclear giant EDF has postponed its decision on whether to build a new power station at Hinkley Point in Somerset. But the decision to plough billions of pounds into the project is now unlikely to be taken before April 2013, according to sources close to the project.
- Sweden decided in the 1960s and 70s to increase nuclear capacity to reduce dependence on oil. In 1980, Swedes voted in a referendum to phase out nuclear power amid heightened fears over safety. Since then, however, only two of 12 reactors have been closed. Sweden formerly had a nuclear phase-out policy aiming to end nuclear power generation in Sweden by 2010. On 5 February 2009, the Swedish Government announced an agreement allowing for the replacement of existing reactors, effectively ending the phase-out policy. The Fukushima accident sparked an intense flurry of debate which then died out after about six months.

In October 2012, the European Commission published its assessment of stress tests carried out by European nuclear plant operators and regulators following the Fukushima nuclear disaster in Japan. Those tests revealed Europe's nuclear plants have serious safety problems.

2.4.5 Power sector outlook

Electricity is most often generated at a power station by electromechanical generators, primarily driven by heat engines fuelled by chemical combustion (coal or gas) or nuclear fission but also by other means such as the kinetic energy of flowing water and wind. There are many other technologies that can be and are used to generate electricity such as solar photovoltaics and geothermal power.

The challenge is that despite good progress in the recent past, nearly 1.4 billion people remain without access to electricity and 2.6 billion do not have access to clean cooking facilities which would require more electricity supply. Ten countries – four in developing Asia and six in sub-Saharan Africa – account for two-thirds of those people without electricity and just three countries – India, China and Bangladesh – account for more than half of those without clean cooking facilities.

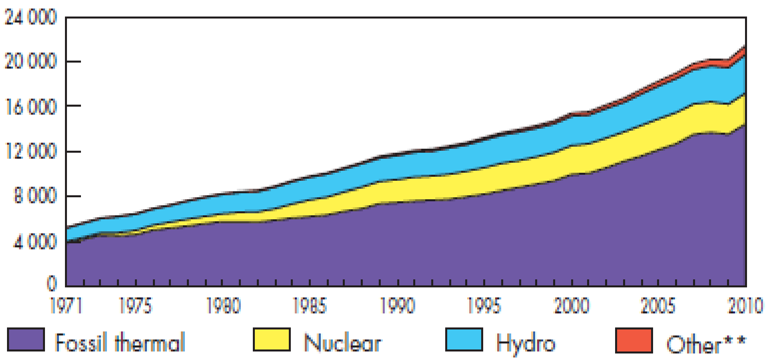
Population and income remain the key drivers of electricity demand.

2.4.5.1 Current Position

Between 1990 and 2009 world electricity consumption increased by an average of 2.9 percent a year. In comparison, world total final energy consumption increased by 1.5 percent per year. Consumers have switched from coal, oil, gas and biomass to electricity for convenience reasons, because higher incomes generally and more service jobs have supported more energy intensive services such as air-conditioning and other quality of life enhancing equipment. The IT revolution has also contributed with an explosive growth in the range of electrical and electronic appliances on the market.

The overall generation of electricity in 1973 was 6,115 TWh and this grew to 21,431 TWh in 2010, an increase of 350 percent (see Figures 35 and 36).

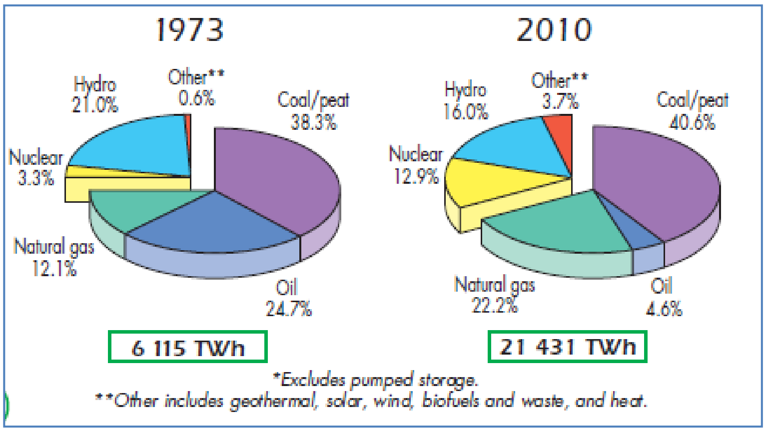
Figure 35: World electricity generation by fuel (TWh), 1971-2010



Source: IEA Key World Energy Statistics 2012

Industry accounted for 53.5 percent of electricity consumed in 1973 but this had dropped to 41.5 percent by 2010. Transport also declined from 2.4 percent to 1.6 percent, while 'other' increased from 44.1 percent to 56.9 percent ('other' includes agriculture, commercial and public services, residential and non-specific other). The growth here is largely due to the increase in the service sector and the growth in population (and its additional households/homes).

Figure 36: Fuel shares of electricity generation, 1973 and 2010



Source: IEA Key World Energy Statistics 2012

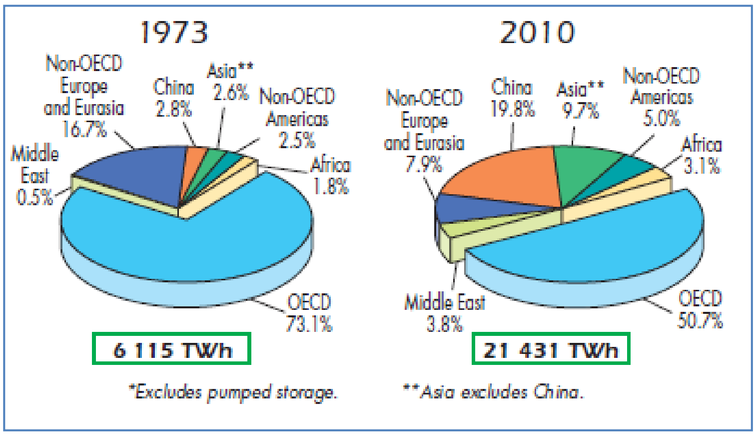
The main producers of electricity from fossil fuels, based on 2010 data, are:

- **Coal/peat:** People's Republic of China, United States and India

- **Oil:** Saudi Arabia, Japan and the United States
- **Natural gas:** United States, the Russian Federation and Japan

The change in share of electricity generation between 1973 and 2010 is very significant. OECD's share has shrunk from over 73 percent to just over 50 percent, while China has grown from 2.8 percent to 19.8 percent and the rest of Asia has grown from 2.6 percent to 9.7 percent (see Figure 37). While the overall growth in electricity generated has increased by a factor of 3.5 times or 350 per cent. It demonstrates the real growth in the non-OECD countries. The two largest producers of electricity in 2010 were the United States with 20.3 per cent and China with 19.6 percent of the total electricity produced.

Figure 37: Electricity generation by region, 1973 and 2010



Source: IEA Key World Energy Statistics 2012

The power sector's fuel mix varies across countries and regions and also changes over time. In the OECD regions the gas share has increased considerably. Coal has lost ground in Europe and North America, but still accounts for a higher share of North American power generation than any other single fuel. In Asia, the coal share has increased since 1990. It may seem paradoxical that two decades of attention to global warming have seen further growth in these countries' already heavy reliance on coal, but rapid economic growth, domestic resource endowments skewed towards solid fuels and major cost advantages associated with exploiting these fuels are powerful drivers.

Oil is on its way out of the power sector in most regions, but remains important in the Middle East, Latin America and parts of Asia. The nuclear share was down in Europe and parts of non-OECD Asia between 1990 and 2009, but it was stable in North America and up in most other regions. The Fukushima Daiichi nuclear disaster in Japan has led to further declines in Europe and Japan, but is unlikely to affect China's nuclear expansion plans or America's current supply. Renewable energy in power generation grew by an above-average 17.7 percent. Wind generation (+25.8 percent) accounted for more than half of renewable power generation for the first time. Renewables accounted for 3.9 percent of global power generation, with the highest share in Europe and Eurasia (7.1 percent).

Renewables are generally more costly than other energy sources, although in some cases they are competitive already (e.g. Brazilian biofuels, United States onshore wind in the best locations). Policy support is assumed to remain in place to help the industry deploy new technologies and drive down costs. A key constraint on the pace of renewables penetration is the willingness and ability to meet the rapidly expanding cost of policy support as renewables scale up.

In March 2009, Chief Executives of power companies representing over 70 percent of EU electricity production signed a declaration in which they committed to become carbon neutral by 2050. As a consequence EURELECTRIC *Power Choices* study was set up to examine how this vision can be made a reality. Generally, the key outcomes of the study endorse the recommendations, policy initiatives, energy mix (more gas and renewables) and energy efficiency proposals, the investments and technology choices (such as CCS) identified in other reports by IEA, the oil companies and national energy planning organisations.

2.4.5.2 Future Projections

World electricity consumption is expected to increase by an average of 2.4 percent per year between 2010 and 2040. OECD consumption is assumed to increase by 1.4 percent per year and Non-OECD consumption by 3.2 percent per year[61]. There may well be upsides to these projections since most global warming risk mitigation scenarios require accelerated electrification combined with accelerated growth in renewables based power generation. These features of almost any conceivable solution to the climate change problem reflect both the high share of CO_2 emissions stemming from fossil fuel based power generation, and the concentrated nature of power sector emissions.

The global electricity demand is projected to increase from 17, 200 TWh in 2009 to over 31,700 TWh in 2035[62].

Energy used to generate electricity remains the fastest growing sector, accounting for 57 percent of the projected growth in primary energy consumption to 2030 (compared to 54 percent for 1990-2010). The power sector is also the main driver of diversification of the fuel mix; non-fossil fuels, led by renewables, account for more than half of the growth.

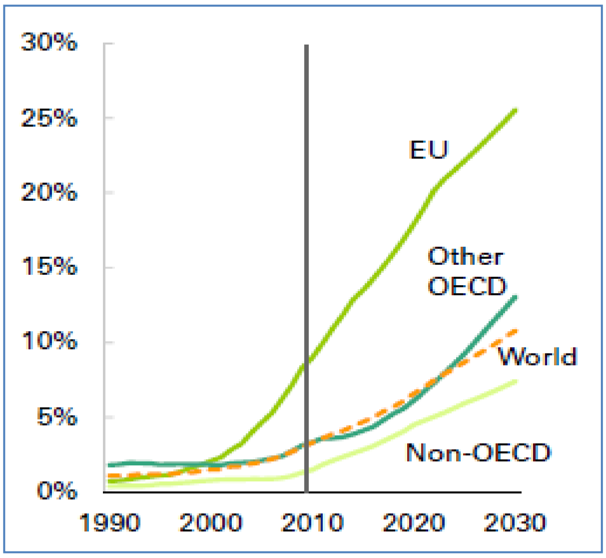
Industry leads the growth of final energy consumption, particularly in rapidly developing economies. The industrial sector accounts for 60 percent of the projected growth of final energy demand to 2030.

Renewable power will become an indispensable part of the global energy mix by 2035, generating almost one-third of global electricity, the International Energy Agency projected in its 2012 World Energy Outlook. There will be almost as much electricity generated from renewables as from coal by 2035. About half of all renewable electricity will come from hydro power, while a quarter will come from wind, and solar photovoltaics will represent about 7.5 per cent, according to the IEA.

[61] Statoil, (2012), Energy Perspectives
[62] International Energy Agency, World Energy Outlook 2011

This scenario – which is based on the current policies and commitments set out by global governments – would mark a tripling of renewable electrical generation (see Figure 38 and 39). But much more aggressive moves by policy makers would be needed if the world is to limit global warming to two degrees above preindustrial levels, the IEA says. For that to happen, fossil fuel subsidies would have to be reduced, huge investments would be needed in carbon capture and storage, and far more support would have to be given to energy-efficiency programmes.

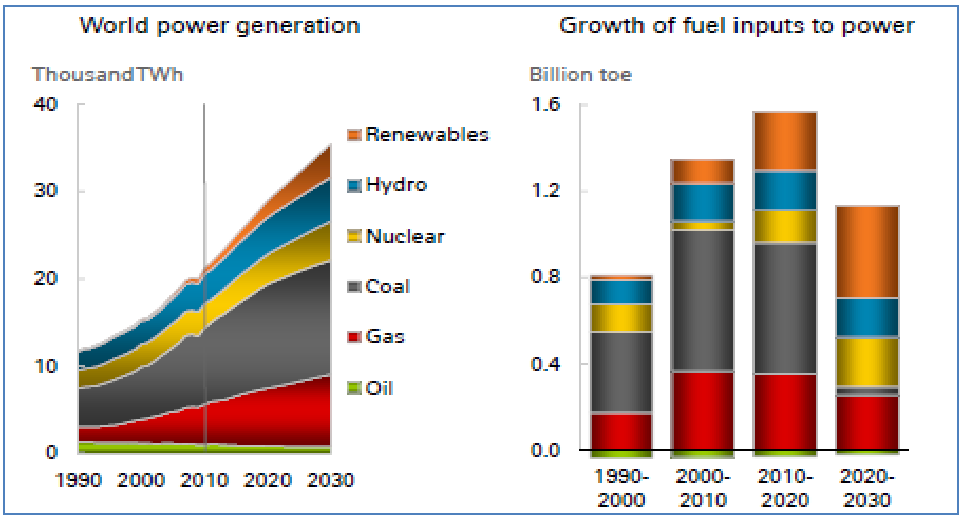
Figure 38: Increasing share of renewables in power



Source: BP, (2012), Energy Outlook 2030

That will help cut carbon emissions, but it will also do much more, the IEA says. Bringing more renewables on-stream will also help countries to diversify their energy mix and cut down on imports, reduce the use of water resources, and curtail air pollution.

Figure 39: Strong growth in power generation continues



Source: BP, (2012), Energy Outlook 2030

Other thoughts on the future can be highlighted from the main conclusions of the 12th Annual PwC Global Power and Utilities Survey[63]:

- **Investment:** Attracting investment is key to meeting the future electricity demand challenge. But more than twice as many survey participants say obtaining finance for generation and transmission is tough compared to those who are finding it relatively easy. Tough as it is, financing is actually not the biggest challenge for power and utilities businesses as a whole. Investment is running up against regulatory risk, price and affordability worries. Worries about energy affordability are emerging. Sixty six percent of the respondents see the ability to recover costs fully from customers as a barrier to meeting demand growth. Half see a medium to high probability that the number of customers in fuel poverty will increase significantly over the next 20 years.
- **Emissions:** Time is running out in the race to decarbonise and achieve the goal of limiting global warming to an average 2°C increase. Looking ahead, the survey participants anticipate a significant increase in the share of non-fossil fuels. But it won't be enough for the 2°C target. Instead, it is closer to a 3.5°C degree warming trajectory.
- **Gas:** More gas generation certainly has a role to play but it is not a game-changer. Overall, producers see the gas share of their companies' fuel mix rising from 29 percent now to 33 percent in 2030. Despite the large quantities of shale gas, many questions still remain about its accessibility in some locations and its environmental safety.
- **Renewables:** The PwC Global Power and Utilities Survey also lends strong support to a 2030 outlook where onshore wind and a range of solar generation facilities, including utility-scale concentrating solar power, compete and play a major role in the energy mix without the need for subsidy – 80 percent plus think onshore wind, biomass and all forms of solar will not need subsidies to compete by 2030. Major barriers remain in the way of renewables in the next decade. Seventy five percent of the survey participants point to the high cost compared with other generation options as an important or very important barrier. Sixty six percent highlight the unwillingness of consumers to pay and sixty two percent stress the cost and difficulty of grid connections.
- **Storage technologies:** Respondents indicated that there is the potential for a 'power to gas' breakthrough in electricity storage. One in five in the survey even go so far as to say it will be the most common form of electric storage by 2030. But they are outnumbered three to one by those saying that current pumped storage technologies will be the main answer to storing electricity.

[63] The 12th Annual PwC Global Power & Utilities Survey is based on research conducted between October 2011 and April 2012 with senior executives from 72 utility companies in 43 countries across Europe, the Americas, Asia Pacific, Middle East and Africa.
http://www.pwc.com/gx/en/utilities/global-power-and-utilities-survey/index.jhtml

- **Electric cars:** Three-fifths of the respondents think there is a medium to high probability that electric cars will form a significant proportion of the world vehicle fleet by 2030. But two thirds (67 percent) express frustration that regulatory agreement on standards for electric vehicle infrastructure is evolving too slowly.
- **Smart grids and smart metering:** These are high on the list of company investment priorities. The opportunity to get closer to customers and help them manage peak demand tops the list of reasons for such investment, however, companies would be wise to be cautious about the customer opportunity. Two-thirds say there is a medium to high probability that the future technology will get installed but shortcomings in customer engagement will limit its potential.

Member countries of the European Union are committed to achieving a minimum target of 20 percent renewables as part of their energy mix by 2020. Figure 40 shows the targets for renewable energy in electricity (percent) for both 2015 and 2020. This was extracted from individual national plans in 2010. Only time will tell whether these targets will be met or not.

The power sector's future technology and fuel choices will reflect the availability and cost development of different options. These variables will in turn depend on available resources, technology developments and the legal and regulatory framework.

2.4.6 High Growth in Renewable Power Generation

Renewable energy sources (RES) are derived from natural processes (e.g. sunlight and wind) that are replenished at a faster rate than they are consumed. Solar, wind, geothermal, hydro, and some forms of biomass are common sources of renewable energy. Solar photovoltaic (PV) directly converts solar energy into electricity using a PV cell. There are three main considerations in relation to RES - variability, cost and subsidies. Figure 41 shows where the recent growth in RES has been – Europe has had the largest increase.

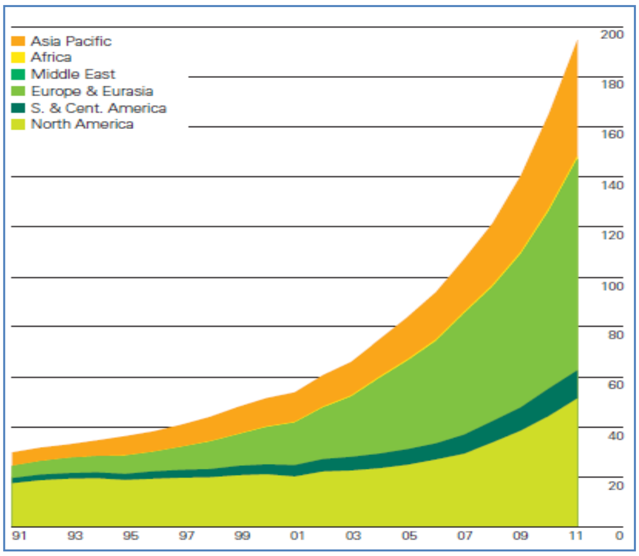
Figure 40: EU member states' renewable energy goals in electricity (percent)

Country	2010	2015	2020
: Austria	: 69.3	: 71.2	: 70.6
: Bulgaria	: 10.6	: 16.6	: 20.6
: Cyprus	: 4.3	: 8.4	: 16
: Czech Republic	: 7.4	: 12.9	: 14.3
: Denmark	: 34.3	: 45.7	: 51.9
: Finland	: 26	: 27	: 33
: France	: 15.5	: 20.5	: 27
: Germany	: 17.4	: 26.8	: 38.6
: Greece	: 13.3	: 27.6	: 39.8
: Ireland	: 20.4	: 32.4	: 42.5
: Italy	: 18.7	: 22.4	: 26.4
: Lithuania	: 8	: 17	: 21
: Luxembourg	: 4	: 8.9	: 11.8
: Malta	: 0.6	: 7	: 13.8
: Netherlands	: 8.6	: 21	: 37
: Poland	: 6.2	: 11.5	: 19.4
: Portugal	: 41.4	: 50.5	: 55.3
: Slovakia	: 19.1	: 22.4	: 24
: Slovenia	: 32.4	: 35.4	: 39.3
: Spain	: 28.8	: 33.8	: 40
: Sweden	: 54.9	: 58.9	: 62.9
: UK	: 9	: 16	: 31

Source: ENDS from NREAPs data

Source: Ends Europe, 2010 Renewable Energy Europe A special report on the National Renewable Energy Action Plans outlining goals and measures to boost renewable energy use

Figure 41: Other renewables (except hydroelectric) consumption by region (Mtoe)



Source: BP Statistical Review of World Energy June 2012 bp.com/statisticalreview

Variability: RES provides variable supply due to fluctuations of wind or sun during the course of any given day or season. Thus, power systems with large shares of variable RES require more flexibility than those that are more dependent on fossil fuel. Typically, flexibility comes from interconnections with other countries, use of storage systems (e.g. with pumped-hydro plants), and/or load-management empowered by smart grids. These solutions can be combined to provide the required flexibility.

Cost: Over the last two decades the renewable energy sector has demonstrated its capacity to deliver cost reductions due to technical and efficiency advances, as well as cost efficiencies in manufacturing. Established technologies such as hydro and geothermal are often fully competitive already. However, further reductions in cost or increased efficiency are necessary before wind and PV are competitive in many cases. If fossil fuel subsidies and the cost of carbon emissions are considered then wind and PV are nearly cost competitive. Regardless of whether subsidies are fully considered or not, wind and PV are likely to be become fully competitive within the next 10 years as their level of use dramatically increases.

Subsidies: The IEA believes that further growth of RES is essential for a secure and sustainable energy system and that transitional economic incentives that decrease over time are justified. Incentives were necessary to stimulate cost reductions through technology learning (e.g., improvements in manufacturing, increased technical efficiency, economies of scale through larger deployment). Incentives may also be justified to secure additional energy security and environmental benefits. Current policies have started to deliver in this respect. Nevertheless, in several countries, the design of support policies has not been ideal, and this has led to higher than anticipated levels of deployment and excessive policy costs (e.g., as occurred in Spain).

Investment: Overall global investment in RES has grown rapidly in recent years. This expansion was primarily driven by concerns about climate change and the increasing cost of fossil fuels. In the United States individual states saw it as a way to create jobs whereas in Europe it was driven by public policy at EU level and national targets were agreed by all member states. Global investment in renewable energy projects will rise from $195bn in 2010 to $395bn in 2020 and to $460bn by 2030, according to a Bloomberg New Energy Finance analysis[64]. Over the next 20 years this growth will require in the order of $7 trillion of new capital.

2.4.6.1 Current Position

In 2011, renewable energy sources (not including biofuels) used in power generation grew by an above-average 17.7 percent, driven by continued robust growth in wind energy (+25.8 percent), which accounted for more than half of renewable power generation for the first time. This was up from 13.1 percent in 2009. The United States and China once again accounted for the largest increments in wind generation. Solar power generation grew even more rapidly (+86.3 percent), but from a smaller base.

[64] Bloomberg New Energy Finance, (2011), Global Renewable Energy Market Outlook, UK.

Renewable forms of energy accounted for 2.1 percent of global energy consumption, up from 0.7 percent in 2001.

The recent growth rates have been:

- Global **wind power** capacity was 238 Gigawatts (GW) at the end of 2011, up from just 18 GW at the end of 2000, with an average growth rate of over 25 percent over the past five years
- The global total of **solar PV** was roughly 67 GW at the end of 2011, to be compared with just 1.5 GW in 2000. Over the past five years, solar PV has averaged an annual growth rate of over 50 percent. Growth has been mostly concentrated in a few countries, where PV currently generates a few percent of total yearly electricity production.

2.4.6.2 Future

Global hydroelectric output grew by a below-average 1.6 percent. Strong growth in North America (+13.9 percent) was offset by drought-related declines in Europe and Eurasia and Asia Pacific.

Renewables increase their penetration significantly in all long-term scenarios. For example, in the central scenario of the World Energy Outlook 2012, the New Policies Scenario – which takes account of broad policy commitments and plans that have been announced by countries – renewable electricity generation will grow threefold from 2009 to 2035. In the 450 Scenario – which is in line with limiting global warming to about 2°C – renewables grow even more, by a factor of almost four. As a carbon dioxide emissions reduction option, renewables and biofuels come in second only to energy efficiency improvements in IEA scenarios.

In July 2012, the IEA acknowledged the coming of age of the renewable energy sector by publishing, for the first time, an annual medium-term report that analyses that market[65]. The report, the Medium-Term Renewable Energy Market Report 2012, examined in detail 15 key markets for renewable energy, which currently represent about 80 percent of renewable generation, while identifying and characterising developments that may emerge in other important markets. It presents a forecast of global developments and detailed country projections over the next five years.

The report presents detailed forecasts for renewable energy generation and capacity for eight technologies – hydropower, bioenergy for power, onshore wind, offshore wind, solar photovoltaics (PV), concentrating solar power (CSP), geothermal and ocean power**.** This first edition focuses on renewable energy in the electricity sector, and it also examines solar thermal heating.

The forecasted supply of renewables is:

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[65] IEA, (2012), Medium-Term Renewable Energy Market Report 2012, Paris.

- Renewable electricity generation should expand by 1,840 TWh between 2011 and 2017, almost 60 percent above the 1,160 TWh growth registered between 2005 and 2011.
- Renewable generation will increasingly shift from the OECD to new markets, with non-OECD countries accounting for two-thirds of this growth.
- Of the 710 GW of new global renewable electricity capacity expected, China accounts for almost 40 percent. Significant deployment is also expected in the United States, India, Germany and Brazil.

Other key findings of the report include:

- **Hydropower** continues to account for the majority of renewable generation and it registers the largest absolute growth (+730 TWh) of any single renewable technology over 2011-17, largely driven by non-OECD countries.
- Non-hydropower renewable technologies continue to scale up quickly. Between 2011 and 2017, generation from these technologies will increase by over 1,100 TWh, with growth equally split between OECD and non-OECD countries.
- **Onshore wind, bioenergy and solar PV** see the largest increases, respectively, in generation after hydropower. Offshore wind and CSP grow quickly from low bases. Geothermal continues to develop in areas with good resources. Ocean technologies take important steps towards commercialisation.

The report is released amid significant policy developments and the uncertainties associated with an uncertain macroeconomic outlook. First, governments in several key markets are deliberating significant changes to renewable policies and deeper electricity market reforms as renewable deployment scales up. Second, the cost and availability of financing will act as a key variable, with a need for more investment in structures. Finally, some parts of the renewable industry are going through a period of difficult trading, with supply chains restructuring and shifting geographically while delivering cost reductions. Ultimately, such a consolidation should lead to a more mature and robust renewable sector. Despite these conditions, the future for RES for generating electricity is very bright.

Furthermore, energy security and diversification of the energy mix is a major policy driver for renewables. Growth of renewables generally contributes to energy diversification, in terms of the technology portfolio and also in terms of geographical sources. Use of renewables can also reduce fuel imports and insulate the economy to some extent from fossil fuel price rises and swings. This certainly increases energy security. However, concentrated growth of variable renewables can make it harder to balance power systems, which must be duly addressed.

2.4.7 Outlook for global bio-fuels production

Bioethanol production is the conversion of starch or sugar-rich biomass (corn/maize, other cereals, sugar cane, etc.) into sugar, fermentation, and distillation.

It is difficult to determine energy inputs and emissions because of the variety of feedstocks and processes, figures vary widely and make it difficult to be precise or predictive (see Figure 2.35). There is growing interest in advanced biofuels in China. Both biotechnology and new energy are listed as 'strategic emerging industries' in China's 12th Five-Year Plan, which sets a target of renewable energy consumption of 11.4 percent by 2015.

Figure 42: Bio-fuels their energy contribution, C02 emissions and potential

Process	Contribution to final energy	CO_2 reduction	Potential
Sugar-cane ethanol	Fossil fuel input some 10%-12% of final energy	Up to 90% CO_2 reduction compared with gasoline.	Low ethanol-gasoline blends (5%-10%) can fuel gasoline vehicles with little if any engine modification. New flexi-fuel vehicles run on up to 85% blends.
Corn ethanol	High energy input	Much smaller CO_2 reduction (15-25%).	
Ligno-cellulosic ethanol	Total energy input may be higher than for corn ethanol, but most of such energy could be provided from biomass itself	CO_2 reduction up to 70% (100% with power co-generation).	May greatly increase feedstock variety and quantity, but requires further R&D (from all kinds of biomass). Potential market: 45 EJ by 2050.
Biodiesel	About 30% energy input	Up to 60% CO_2 reduction - low sulphur and particulate emissions.	Low biodiesel-diesel blends (5%-10%) can fuel diesel vehicles with no engine change; Synthetic biodiesel (BTL) is fully compatible with diesel fuel and engines. Potential market: 20 EJ by 2050. Global biomass potential is some 100-200 EJ per year by 2050 (10%-20% of total energy supply).

Costs are related to the feedstock, the process, the land type and the crop yield. The following figures are only indicative:

- *Sugar-cane ethanol* (Brazil): $0.25-$0.35/litre of gasoline equivalent (lge), competitive with gasoline at $40-$50/bbl oil prices. Higher cost in other regions
- *Ethanol from corn (US) and sugar-beet (EU)*: $0.6- $0.8/lge
- *Ligno-cellulosic ethanol*: at present over $1.0/lge (feedstock price $3.6/GJ), with potential reduction to $0.50/lge in the next decade
- *Biodiesel from animal fat*: $0.4-$0.5/lde
- *Biodiesel from vegetable oil*: $0.6-$0.8/lde
- *Biodiesel from BTL*: > $0.9/lde

Barriers: The main barriers to wider adoption of biofuels are the competition with food and fibre production (for use of arable land), its cost, the regional market structure, biomass transport, lack of well managed agricultural practices in emerging economies, high water and fertiliser requirements, conservation of bio-diversity, and logistics and distribution networks.

2.4.7.1 Current Position

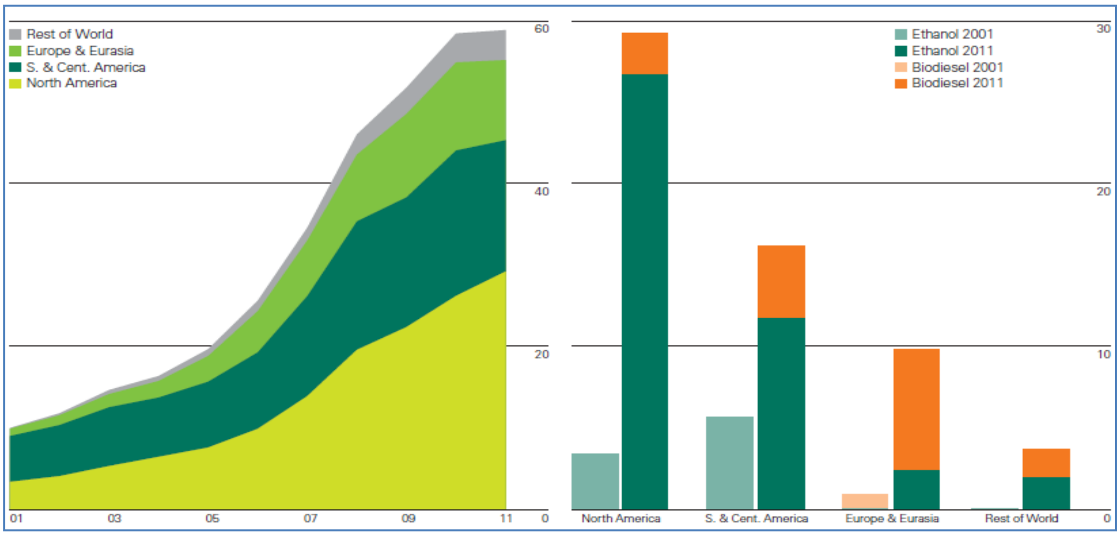
Global biofuel production grew from 16 billion litres in 2000, to more than 100 billion litres in 2010. This biofuel provides around 3 percent of the world's fuel for transport. In Brazil, biofuel provided 23 percent of all transport fuel, compared with 4 percent in the United States and 3 percent in the European Union.

In 2011, global biofuels production stagnated:

- Rising by just 0.7 percent or 10,000 barrels per day oil equivalent (barrels per day oil equivalent - b/doe), the weakest annual growth since 2000
- Growth in the United States (+55,000 b/doe, or 10.9 percent) slowed as the share of ethanol in gasoline approached the 'blendwall'
- Brazilian output had the largest decline in IEA's data set (-50,000 b/doe, or -15.3 percent) due to a poor sugar harvest

Increased output in North America was offset by declines in South and Central America, and Europe (see Figure 43). Biodiesel accounts for just 27.5 percent of global biofuels output, but accounted for all of the growth in global biofuels output. Global ethanol output declined by 1.4 percent[66]. In 2011, the United States accounted for 46 percent of the global use of biofuels, Brazil accounted for a further 22.4 percent, and Europe and Eurasia a further 16.7 percent - a total of 85.1 percent.

Figure 43: World biofuels production (Mtoe)



Source: BP Statistical Review of World Energy, June 2012

[66] Source: BP Statistical Review of World Energy, June 2012. bp.com/statisticalreview

Outside of Brazil, biofuels generally cost much more to produce than conventional gasoline and diesel. By using existing technologies, through upscaling and improving logistics, further cost reductions are achievable. Advanced biofuels, like BTL biodiesel or ligno-cellulosic ethanol, are currently not competitive with conventional fuels and are mostly in the demonstration phase, but are expected to be commercialised by 2020.

World ethanol prices increased strongly in 2011 well above the levels of the 2007/08 highs in the context of strong energy prices, although the commodity prices of ethanol feedstock, mainly sugar and maize, decreased from their peaks in 2010. The two major factors behind this increase were the stagnating ethanol supply in the United States and a drop in Brazilian sugar cane production. Additionally, ethanol production was also significantly below expectations in developing countries having implemented mandates or ambitious targets for the use of biofuels.

World biodiesel prices also increased in 2011. In contrast with the global ethanol market, production did not stagnate in 2011; the four major biodiesel producing regions (the European Union, the United States, Argentina, and Brazil) increased their supply compared to 2010. This increase was moderated by a decreasing biodiesel production in Malaysia (from about 1 Bnl in 2010 to almost nothing in 2011).

2.4.7.2 Future Expectations

Three different forecasts on the future of biofuels are discussed below.

Firstly, according to the OECD – FAO[67] biofuel trade is expected to expand in the decade to 2011-2021, with cross trade likely to occur. Changes in the implementation of biofuel policies can strongly affect biofuel markets. The projection highlights are:

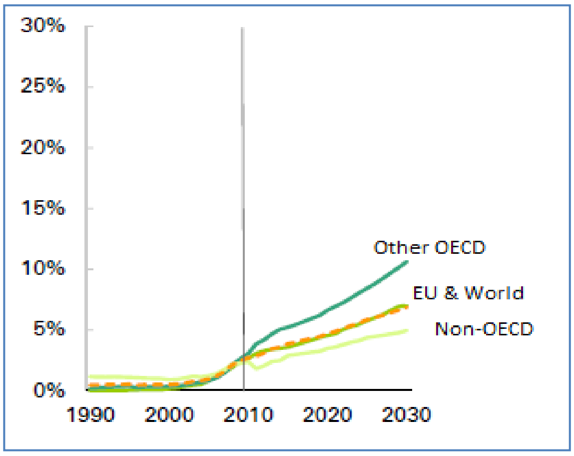
- Ethanol and biodiesel prices are expected to remain supported by high crude oil prices and by the implementation and continuation of policies promoting biofuel use.
- Global ethanol and biodiesel production are projected to expand but at a slower pace than in the past. Ethanol markets are dominated by the United States, Brazil and to a smaller extent the European Union. Biodiesel markets will likely remain dominated by the European Union and followed by the United States, Argentina and Brazil.
- Biofuel trade is anticipated to grow significantly, driven by differential policies among major producing and consuming countries. The United States, Brazil and the European Union policies all "score" fuels differently for meeting their respective policies. This differentiation is likely to lead to additional renewable fuel trade as product is moved to its highest value market, resulting in potential cross trade of ethanol and biodiesel.

[67] OECD-FAO, (2012), Agricultural Outlook 2012-2021 http://www.oecd.org/site/oecd-faoagriculturaloutlook/biofuels-oecd-faoagriculturaloutlook2012-2021.htm

Secondly, biofuels will be used far more widely in transportation, including aviation, by 2035. Ethanol will be the most commonly used biofuel, although biodiesel will gain growth in freight transport. The United States will be the biggest market, while Brazil will have the highest proportion of biofuels – about one-third of all transport fuel. According to the IEA's 2 degree Celsius rise scenario, biofuel use will increase to approximately 240 billion litres in 2020, which, when produced sustainably, will lead to a reduction of approximately 0.1 Gt of CO_2 emissions in the transport sector (see Figure 44).

Thirdly, in its report on Global Biofuel Production Forecast 2015-2020, Market Research Media[68] forecasts that global biofuel production is estimated to reach 1,900 million barrels in 2020, at a compound annual growth rate (CAGR) of 10 percent over the forecast period 2015 – 2020.

Figure 44: Increasing Share of Renewables in Transport, 2010-2030



Source: BP Energy Outlook 2030

What does this estimate mean?

- It is about 6 percent of the world's estimated liquid fuel production in 2020
- It is about half of the current Saudi oil production
- It is about half of the current United States oil imports
- It is a game changer in geopolitical and economic sense, a mighty leverage against the petroleum cartel, a balancing force in national wealth transfer and once-in-a-lifetime market opportunity along the entire biofuel supply chain.

The past decade has seen soaring oil prices, Middle East turmoil, government biofuel incentives, cleantech venture investments and maturing technologies, all these factors contributing to the critical mass necessary to launch a sustainable biofuel market.

Inadequate progress: Despite the above forecast according to the IEA, biofuels for transport are not on track to meet their share of CO_2 reduction that is needed to achieve the IEA's goal of an average 2 degree Celsius rise in global temperature by 2020[69]. To do

[68] http://www.marketresearchmedia.com/?p=630
[69] IEA, (2012), Tracking Clean Energy Progress, Paris, France

so the IEA has stated that total biofuel production needs to double, with advanced biofuel production to expand four-fold over currently announced capacity. Along with the warning about the need for more biofuels production, the IEA also cited a key policy priority that will achieve their 2 degree Celsius rise scenario objective. The IEA has recommended that governments establish policies to support the development of the advanced biofuels industry.

3 Overview of short-term, mid-term and long-term trends and development perspectivesof global renewabnle energy sectors

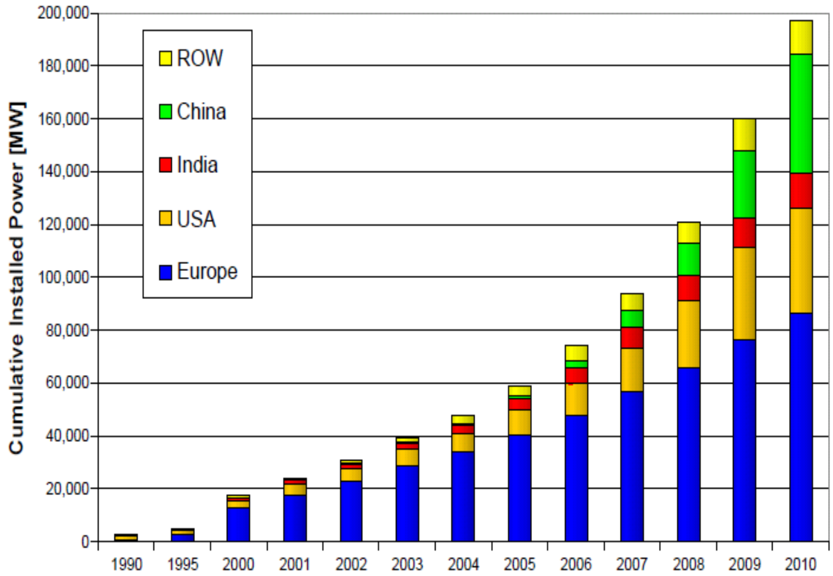
3.1 Wind: the global market in 2012 and the forecasts

3.1.1 General presentation

Wind turbines of all sizes have become a familiar sight around the world for a variety of reasons, including their economic, environmental, and social benefits. Wind energy is a low carbon (LC) renewable energy source (RES) which has the ability to supply a significant proportion of global electricity and improve the security of supply. In 2010, 38.7 GW of new wind turbine capacity were installed bringing the world wide total installed wind capacity to almost 197 GW[70] (see Figure 45).

In 2010 the European Union installed 84 GW capacity, China 44.7 GW and the United States installed 40.2 GW capacity[71]. The total value of new generation equipment installed in 2010 was about €40 billion[72]. The total installed wind capacity at the end of 2010 can produce about 440 TWh of electricity or about 2.2 percent of the global electricity demand. Although annual capacity is a good indication of economic activity, manufacturing job creation and investments, capacity is a poor indicator for electricity production because, for example, 1 GW wind power capacity does not produce the same amount of electricity as 1 GW of nuclear capacity due to the difference between load factors of wind turbines and nuclear reactors.

Figure 45: Cumulative world-wide installed Wind Power capacity, 1990-2010



Source: Renewable Energy Snapshots, September 2011, JRC Scientific & Technical Reports.

[70] BTM Consult, (Sept. 2011), World Market Update 2010 cited by Renewable Energy Snapshots, Sep JRC Scientific & Technical Reports

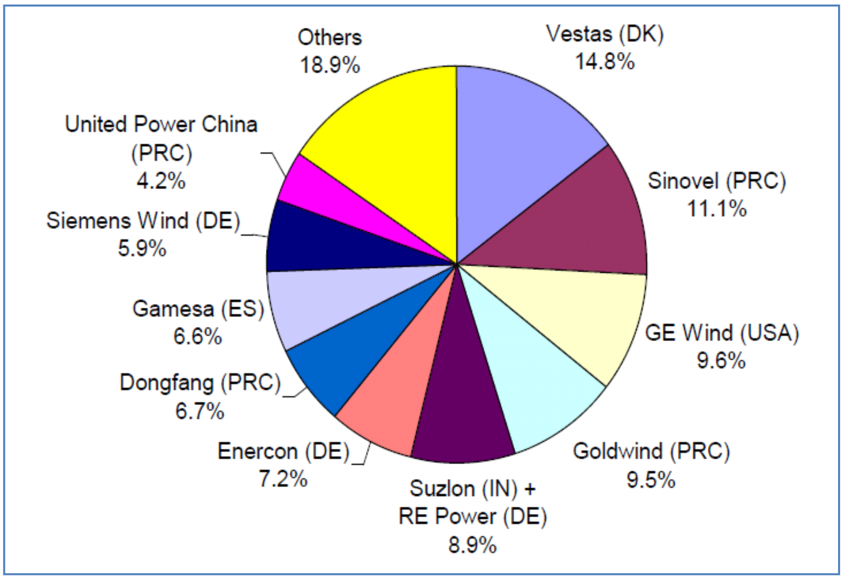
[71] Renewable Energy Snapshots, (Sept. 2011), JRC Scientific & Technical Reports

[72] World Wind Energy Association, (2011), World Wind Energy Report 2010

The general trend shows that the wind energy sector is broadening its market base and more and more countries are increasing the installation of wind energy capacity. In 2010 a total of 83 countries used wind energy on a commercial basis and 50 of them increased their installations in that year. The European market accounted for about 25 percent of the total new capacity, a significant percentage decrease from 75 percent in 2004. Offshore wind capacity increased more than twice the rate of onshore installations at 59.4 per cent although starting from a low base. The added offshore capacity for 2010 was 1.16 GW which brought the total offshore capacity to 3.1 GW or 1.6 per cent of the total wind capacity worldwide. Within the EU there was 2.9 GW installed at the end of 2010 which was 3.5 per cent of installed wind capacity. The UK overtook Denmark in 2010 when they became the first EU country to exceed the 1 GW installed offshore capacity.

The wind turbine manufactures continue to expand but the industry is still dominated by a few larger players. Figure 46 shows that Vestas of Denmark continues to defend its top manufacturing position, followed by Sinoval and Goldwind from China and GE Wind from the United States. Four of the top ten wind turbine companies are from the People's Republic of China and there are more than 100 companies involved in wind equipment manufacture. Currently most of the Chinese wind turbines are sold in China but a number of players plan to expand outside China. For example, Sinoval has established an office in Madrid and this move is seen as a first step in the Chinese locating significant manufacturing capability in the larger global markets.

Figure 46: Market shares of manufactures 2010 (39.4 GW installations)



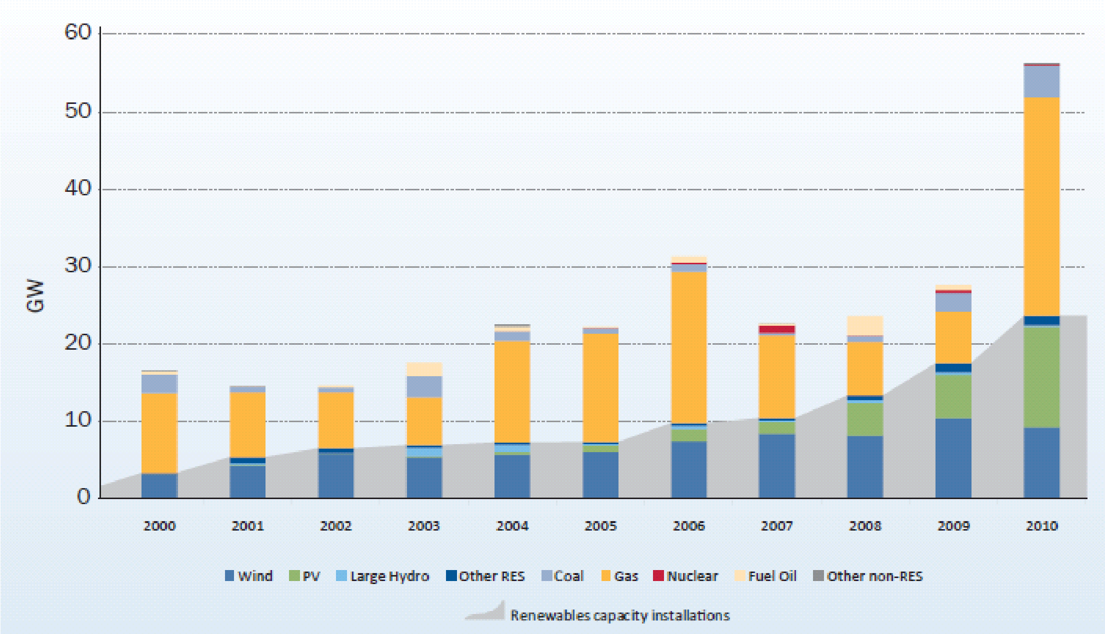
NB: The total is more than 100 percent due to the difference between installed and delivered installations

Source: Renewable Energy Snapshots, (Sept. 2011), JRC Scientific & Technical Reports.

The wind energy industry creates a significant number of jobs and according to the World Wind Energy Association (WWEA) at the end of 2010 the industry had provided 670,000 direct and indirect jobs and has more than tripled its employment figures within the last five years.

Wind energy increased its share of total power capacity in the EU to 9.6 percent in 2010. However, it is wind's energy contribution to new generation capacity that is even more striking; 27.7 percent of all power capacity installed since 2000 has been wind energy, making it the second largest contributor to new EU capacity over the last ten years after natural gas which accounted for 48.3 percent (see Figure 47).

Figure 47: New EU Power Generating Capacity (2000-2010) Total 272GW



Share of RES in new power capacity additions:

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
21%	38%	45%	40%	34%	34%	30%	47%	58%	64%	42%

Source: EWEA, EPIA, Estela, EU-OEA and Platts Powervision

Achieving the ambitious EU energy and climate policy objectives, in particular the decarbonisation of the energy system by 2050 requires the deployment of low carbon technologies. The increased share of wind power helped significantly in this regard with the CO_2 avoided by wind energy, accounting for 28 percent of the EU's Kyoto commitment in 2010. However, notwithstanding these benefits to the EU low carbon drive the EWEA[73] is concerned that whilst wind power is capable of supplying a share of European electricity demand comparable to the levels currently being met by conventional technologies such as fossil fuels, the current regulatory frameworks for wind power integration are not conducive to facilitate its cost efficient integration into the market. Integration costs are not a consequence of the technology capability itself, but due to existing rigid market rules and institutional frameworks that were never designed with wind power, or other variable generation technologies, in mind. This prevents the full and cost-efficient exploitation of their capabilities.

A functional, mature and competitive market should be seen as a pre-condition to exposing wind generators and other producers to market risks, included carbon and fuel

[73] European Wind Energy Association, (2012), Creating the internal energy market in Europe.

price risks. Where this is the case, exposure to balancing risks could be considered as a first step as long as a functional regional wholesale market and application of advanced forecast tools and operational routines by the Transmission System Operators (TSOs) are in place.

In these cases, regulators should also ensure that costs are transparent and represent only the real cost of balancing. Specific market design and rules for wind integration require provisions and products that fully exploit wind energy capabilities. These include large control zones (for smoother output variability) and shorter trading time horizons (for improved forecast accuracy and reduced balancing needs). Functional intraday and balancing markets at Member State level are imperative as a first step to achieving this with interconnectivity of short term markets between Member States being encouraged for efficient trading of wind-generated electricity[74].

As wind power steadily increases its market share then its distinctive characteristics of varying output over short periods of time and its unpredictability become an issue.

Consequently, an increasing wind market share puts pressure on electricity systems and increases the need for system flexibility. Tools that can deliver flexibility include energy storage, demand-side response, increasing interconnection and supply-side response (*i.e.* other forms of generation capacity which can be ramped up or down in response to changing demand). Much of the flexibility in electricity systems is currently delivered by supply-side response; this instrument is likely to play an important role in supporting an increasing wind market share. An analysis of the effect of an increasing wind market share on residual power demand patterns shows that wind does indeed affect residual power demand, albeit to a limited degree. As there is no significant correlation between wind output and electricity demand, an increasing wind market share neither amplifies nor dampens existing power demand patterns and does not strongly increase demand variability or the size of demand changes. The variability of residual demand increases only when variations in wind become larger than the existing variation in demand. Exactly at which market share this happens differs by country and depends on both national wind output and electricity demand patterns. An increasing wind market share increases the spread in residual power demand – that is, the difference between minimum and maximum demand observed in a time period (hourly, daily or annually). A higher spread in residual demand leads to a larger spread in the amount of fuel needed to fill this demand. The effect of an increasing demand spread is enhanced by the limited predictability of wind compared to demand, especially on the longer term (year-ahead). Thus a conventional power generation source is required to support wind power generation.

At this time natural gas technologies seem to be best suited to support wind power in the future, due to their relatively low investment costs and technical capabilities to deliver flexibility. This makes it likely that, as the market share of wind increases, the role of natural gas as a flexible fuel supporting wind output increases. As a result, wind

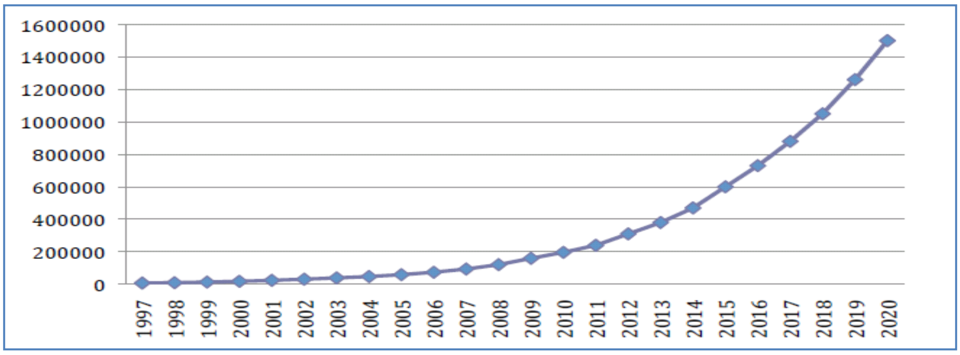
[74] Ibid.

will also have a growing impact on natural gas demand in the power sector. But as natural gas is often contracted significantly in advance, a higher demand spread and decreasing demand predictability increases the need for flexibility in gas supplies. A growing wind output also changes the way in which existing flexibility instruments are used. Natural gas storage facilities are currently mostly single-cycle – *i.e.* switching from injecting to sending out or vice versa twice per year – and have a relatively predictable output pattern. A higher wind market share changes this pattern, with storages having to become multi-cycle. It also increases the required send-out capacity due to the increasing spread in fuel demand. Thus the increasing inroads of wind power has significant effects on how other power generating sources are utilised, regulated and costed. These additional balancing costs to the power system need to be considered when assessing the efficacy of wind power.

3.1.2 Global and regional forecasts until 2020

In spite of the need to reinforce national and international policies and to accelerate the deployment of wind power, it can be observed that the appetite for investment in wind power is strong and many projects are in the pipeline. Further substantial growth can especially be expected in China, India, Europe and North America. High growth rates can be expected in several Latin American as well as new Asian and Eastern European markets. In the mid-term, also some of the African countries will see major investment, after all in Northern Africa, but also in South Africa. Based on the current growth rates, World Wind Energy Association (WWEA) revised its expectations for the future growth of the global wind capacity. In 2015, a global capacity of 600,000 MW is possible. By the end of year 2020, at least 1,500,000 MW can be expected to be installed globally[75] (see Figure 48).

Figure 48: Projected Installed Global Wind Capacity to 2020 (MW)

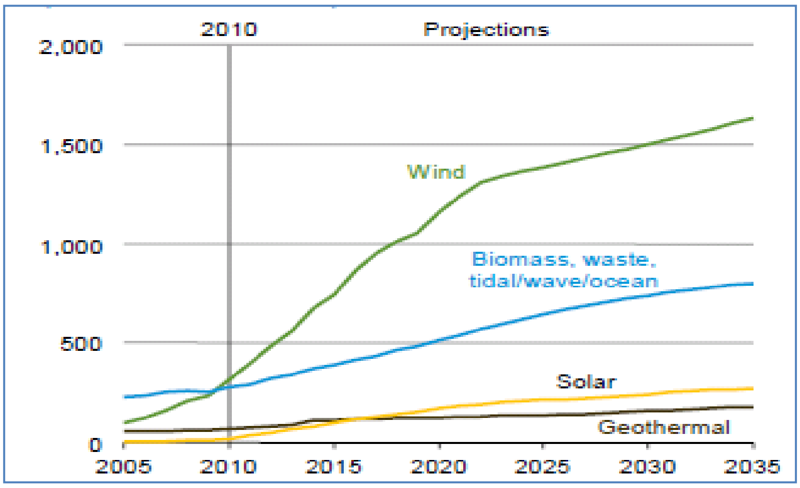


Source: World Wind Energy Association

Wind power leads the rise in world renewable generation (see Figure 49). Wind generation accounts for the largest increment in non-hydropower renewable generation, about 60 percent of the total increase[76]. According to the Annual Energy Outlook of 2012 published by the United States Energy Administration, the expected installed wind capacity will be 1,300GW by 2020.

[75] World Wind Energy Association, (2010), World Wind Energy Report
[76] United States Energy Administration, (2012), Annual Energy Outlook, 2012

Figure 49: World Renewable Electricity Generation by Source, Excluding Hydropower, 2010-2035 (Billion Kilowatt Hours)

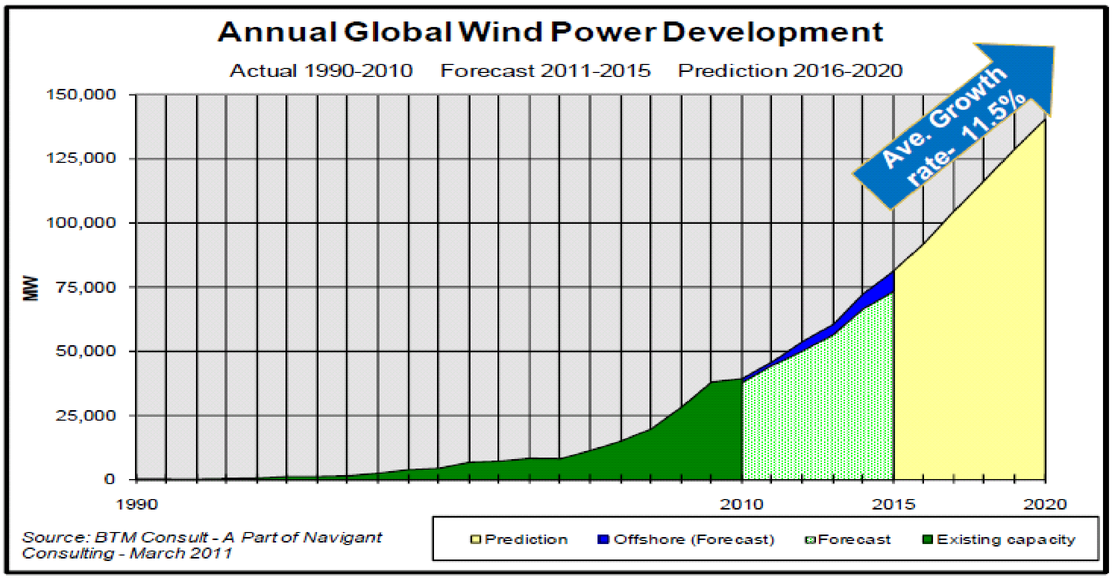


Source: United States Energy Administration, Annual Energy Outlook 2012.

According to BTM[77] annual new installations will grow from today's levels of 39,500MW to 81,350MW by 2015. The average growth rate for annual new installations up to 2015 is 15.5 percent per annum. China will maintain the leading installation position followed by the United States with India continuing at high level of up to five MW per year. Europe on the other hand will be seen as a stable market with France and the UK growing to the current German and Spanish levels. The emerging markets of Europe are Romania, Poland, Bulgaria and Turkey.

Between 2015 and 2020, the total predicted installation rate will be about 11.5 percent per annum (see Figure 50). This equates to an installation level of 1,100 GW which is about five times the current installation level.

Figure 50: Actual 1990-2012; Forecast 2011-2015; Prediction 2016-2020



[77] BTM, International, (2010), Wind Power market update

3.1.2.1 United States

This growth is not uniformly spread across the regions due to various local factors. In May 2008[78], the U.S. Department of Energy, in collaboration with its national laboratories, the wind power industry, and others, published a report that analysed the technical and economic feasibility of achieving 20 percent wind energy penetration by 2030 (DOE, 2008).

In addition to finding no insurmountable barriers to reaching 20 percent wind energy penetration, the report also laid out a potential wind power deployment path that started at 3.3 GW/year in 2007, increasing to 4.2 GW/year by 2009, 6.4 GW/year by 2011, 9.6 GW/year by 2013, 13.4 GW/year by 2015, and roughly 16 GW/year by 2017 and thereafter, yielding cumulative wind power capacity of 305 GW by 2030.

Historical growth over the last six years puts the United States on a trajectory exceeding this deployment path, a trend that is anticipated to continue in 2012. Nonetheless, all of the projections for annual capacity additions in 2013 and 2014 – even those that assume that the Production Tax Credit (PTC) extension (as denoted by the green, rather than red, circles in Figure 51) – fall short of the annual growth envisioned in the 20 percent wind energy report for those years, suggesting that there is a very-real risk that the market will not grow rapidly enough to maintain a long-term trajectory consistent with a 20 percent wind energy penetration level by 2030.[79]

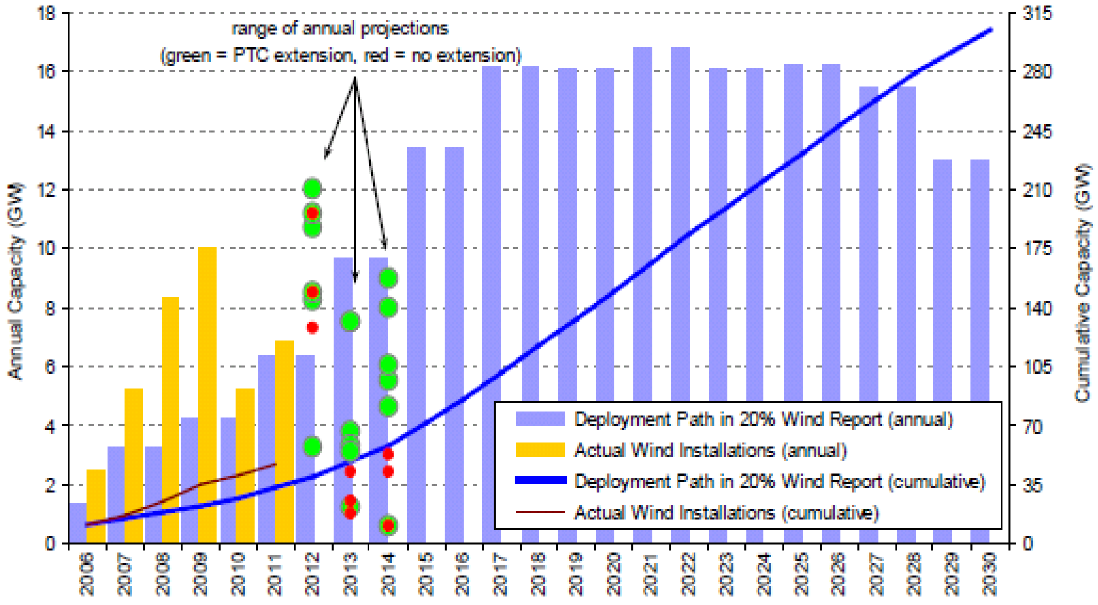
Ramping up to the annual installation rate of roughly 16 GW per year needed for wind power to contribute 20 percent of the nation's electricity by 2030, and maintaining that rate for a decade, would be a challenging task. This rate of deployment has not yet been witnessed in the United States market, and is not expected to be achieved in the near term, due to uncertainty in federal policy towards wind energy after 2012, market expectations for continued low natural gas prices, slow growth in electricity demand, and uncertainty surrounding future environmental regulations to limit carbon emissions.

In addition to stable long-term promotional policies, the DOE (2008) report suggests four other areas where supportive actions may be needed in order to reach such annual installation rates. First, the nation will need to invest in significant amounts of new transmission infrastructure designed to access remote wind resources. Second, to more-effectively integrate wind power into electricity markets, larger power control regions, better wind forecasting, and increased investment in fast-responding generating plants will be required. Third, siting and permitting procedures will need to be designed to allow wind power developers to identify appropriate project locations and move from wind resource prospecting to construction quickly.

[78] U.S. DOE, (2011), Wind Technologies Market Report, U.S. Department of Energy, Washington, D.C

[79] U.S. DOE. (2008). 20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply. DOE/GO-102008-2567, U.S. Department of Energy, Washington, D.C

Figure 51: Wind power capacity growth, actual installations and projected growth



Source: DOE (20% wind scenario); AWEA (historical additions): Table 6 (projected additions)

Finally, enhanced research and development efforts in both the public and private sector will be required to lower the cost of offshore wind power, and incrementally improve conventional land-based wind energy technology. Thus, whilst the potential for wind energy development in the United States is significant there is much uncertainty whether they can reach their potential.

3.1.2.2 China

The Chinese government, on the other hand, has proposed a low-carbon development strategy, with wind power being a key energy technology which will be used to realise low carbon targets. The government has produced a road map that foresees wind power capacity reaching 200 GW by 2020[80] (see Figure 52).

Figure 52: China Wind Power Targets to 2020

Regions	***2010***	***2020***
West Inner Mongolia	6.50	40
East Inner Mongolia	3.62	20
Northeastern China provinces	7.31	30
Hebei Base	3.78	15
Gansu Base	1.44	20
Xinjiang Base	1.13	20
Distributed land-based wind in Eastern and Central China and other areas	7.43	25
Near offshore wind	0.10	30
Far offshore wind	0	0
Total	**31.31**	**200**

Source: Technology Roadmap, China Wind Energy Development 2050, OECD/ International Energy Agency 2011.

80 OECD/IEA, (2011), Technology Roadmap, China Wind Energy Development 2050

Leading up to 2020, China's wind power development will focus on land-based and near offshore resources. Without considering transmission costs, when wind power development reaches 200 GW in 2020, the estimated tariff level will be CNY 0.36/kWh. This roadmap finds that in 2020, capacity that could be installed at this tariff level would be located in five areas: Jiuquan (85 GW), Hami (60 GW), East Inner Mongolia (9 GW), West Inner Mongolia (30 GW) and Hebei (8 GW).

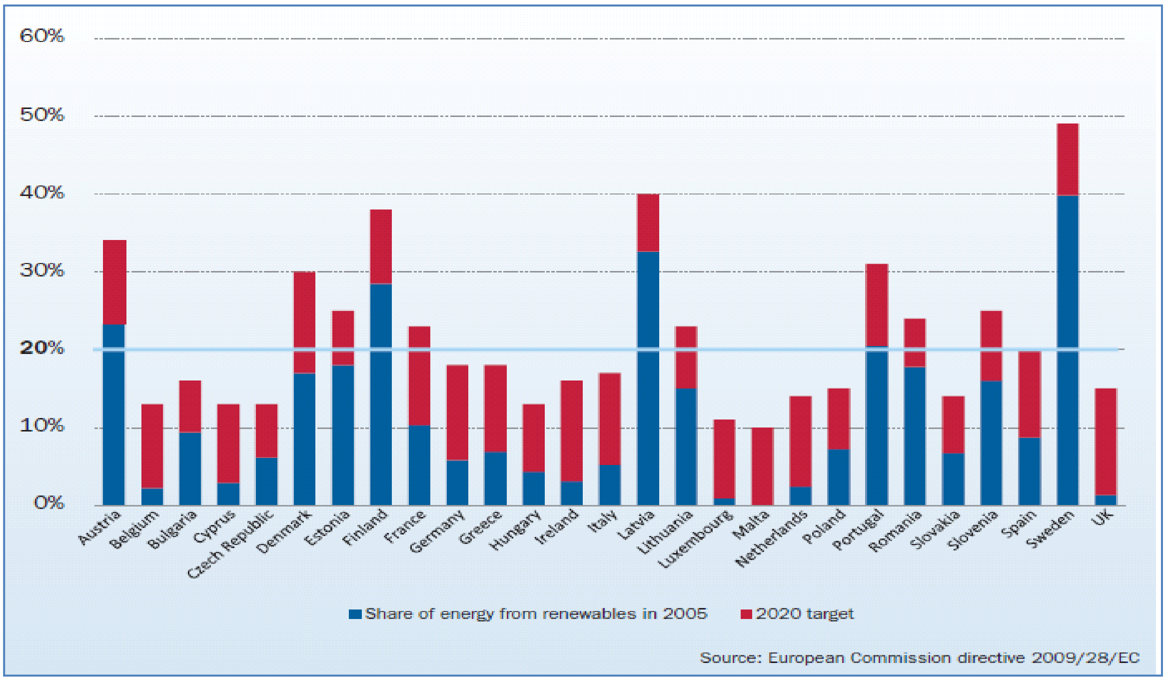
When transmission costs are taken into account, the top-end grid-connected tariff would be CNY 0.49/ kWh. Capacity installed at this tariff level could include: Jiuquan (3 GW), East Inner Mongolia (41 GW), West Inner Mongolia (100 GW), Hebei (51 GW) and Jilin (5 GW). Finally, when the extent of the existing grid is taken into account, as well as plans to develop it over the next ten years and predictions of electricity demand growth, this roadmap finds that by 2020 China will see capacity development as follows: West Inner Mongolia (40 GW), East Inner Mongolia (20 GW), Northeast China (30 GW), Hebei (15 GW), Gansu (20 GW), Xinjiang (20 GW), and more than 10 GW will be developed in each of the Jiangsu and Shandong bases. Of the total wind power capacity of 200 GW, near offshore wind will contribute 30 GW. By 2020, land-based wind power will dominate, with offshore wind power at the demonstration stage; from 2020 and onwards both land and offshore wind power will be developed, and far offshore wind power will be in demonstration mode. By addressing grid infrastructure conditions and other possible constraints, the wind power market can be developed on a large scale before 2020. Establishment of a wind power industry with advanced technologies and standards will be a major goal. More than 15 GW of new capacity will be installed each year, with land-based wind power supplemented by offshore demonstration projects. By 2020, total installed capacity could be as much as 200 GW. Without taking into account transmission cost, wind power costs will fall to levels similar to those of coal power. At the end of 2020, wind power will contribute significantly to the energy system, representing 11 percent of total installed generation capacity and 5 percent of total electricity production.

3.1.2.3 European Union

The EU's wind energy policy is driven by the 2009 EU Renewable Energy Directive which aims to increase the share of renewable energy in the EU from 8.6 percent in 2005 to 20 percent in 2020. The directive sets binding national targets for the share of renewable energy in each of the 27 EU Member States in 2020[81] (see Figure 53). It is by far the most significant legislative effort to promote renewable energy, including wind power, anywhere in the world.

[81] EWEA, (2012), Pure Power Wind Energy targets for 2020 and 2030, A report by the European Wind Energy Association

Figure 53: National overall Targets for the share of renewables in final consumption in 2020



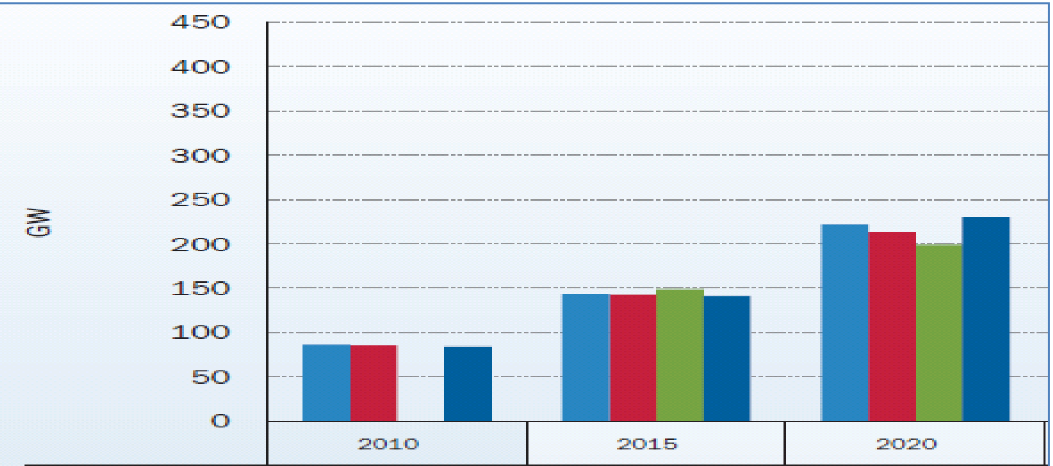
The latest wind energy scenarios from the IEA, European Commission and EWEA are compared in Figure 54. As can be seen there is good convergence of the forecasts and it is likely that these projects will be met and exceeded based on past performance.

Assuming the European Commission's "EU Energy Trends to 2030"[82] projections for electricity demand in 2020, EWEA's 2020 target of 230 GW of wind power would meet 15.7 percent of EU electricity demand, including 4 percent of overall demand being met by offshore wind. If the electricity consumption scenario from the NREAPs is assumed, 230 GW of wind power would meet 19.3 percent of electricity demand (4.2 percent from offshore).

Figure 54 shows the annual market for wind power up to 2020 according to EWEA's targets[83]. In 2011, the annual market for offshore wind is expected to reach 1 GW for the first time and exceed it in subsequent years. During the second half of this decade, an increasing amount of existing onshore wind power capacity will be decommissioned. The market for replacement is expected to increase from 1 GW in 2015 to 4.2 GW in 2020. By 2020, 28 percent of the annual market for new wind power capacity will be offshore. Annual investment in wind power will increase from €12.7bn in 2010 to €26.6bn in 2020. Annual investment in offshore wind will increase from €2.6bn in 2010 to €10.4bn in 2020, equal to 39.1 percent of total investment.

[82] European Commission, (2010), "EU energy trends to 2030 – 2009 update"
[83] Ibid.

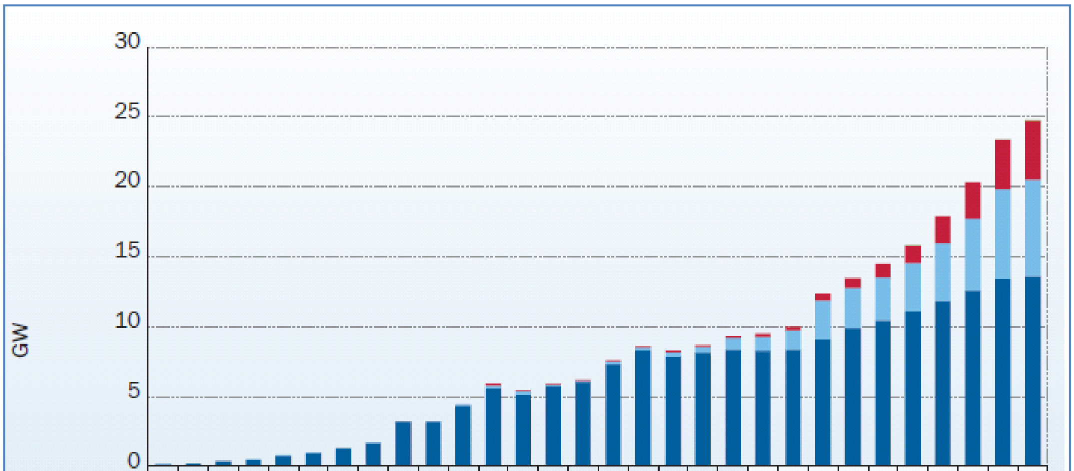
Figure 54: Latest Wind Forecasts from the European Commission, the Member States, The IEA and EWEA (GW Total Installed capacity)



	2010	2015	2020
EC 2009	86	144	222
NREAPs	85	143	213
IEA 2010		149	199
EWEA 2011	84	141	230

The wind energy capacity installed at end 2010 will, in a normal wind year, produce 181.7 TWh of electricity. If EWEA's scenarios are met, wind energy will produce 330 TWh in 2015 and 581 TWh in 2020 – meeting, respectively 9.4 and 15.7 percent of the EU's total electricity consumption. Offshore wind energy's share of EU wind energy production will increase from 5.8 percent in 2010 to 25.5 percent in 2020[84] (see Figure 55).

Figure 55: New Annual EU wind Power Capacity Additions (1991-2020)



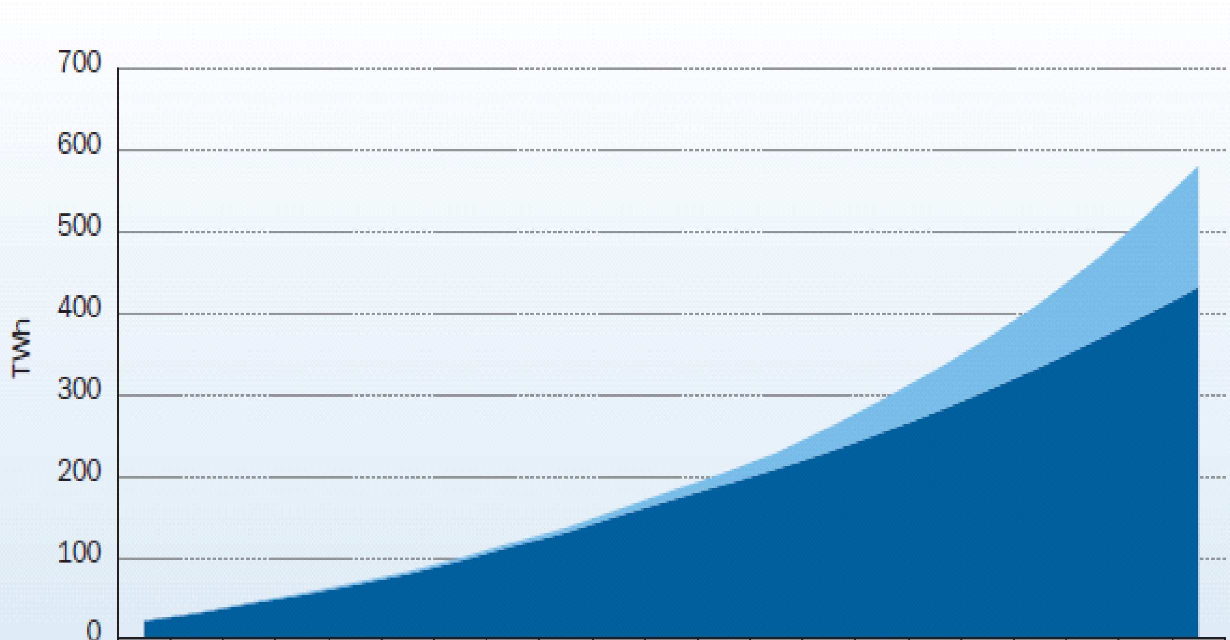
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Offshore repowering	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Onshore repowering	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
New offshore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.1	0.1
New onshore	0.2	0.2	0.4	0.5	0.8	1.0	1.3	1.7	3.2	3.2	4.4	5.6	5.1	5.8	6.0
Total	0.2	0.2	0.4	0.5	0.8	1.0	1.3	1.7	3.2	3.2	4.4	5.9	5.5	5.9	6.2

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Offshore repowering	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Onshore repowering	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.5	0.7	1.0	1.3	1.9	2.6	3.5	4.2
New offshore	0.2	0.2	0.4	0.4	0.9	1.0	1.4	2.8	2.9	3.1	3.4	4.1	5.1	6.4	6.9
New onshore	7.3	8.3	7.8	8.1	8.3	8.3	8.4	9.1	9.9	10.5	11.1	11.8	12.6	13.4	13.6
Total	7.6	8.6	8.3	8.7	9.3	9.5	10.0	12.3	13.5	14.5	15.8	17.9	20.3	23.4	24.8

[84] EWEA, (2012), Pure Power Wind Energy targets for 2020 and 2030, A report by the European Wind Energy Association

EWEA's 40 GW target for offshore wind energy by 2020 requires an annual average market growth of 21 percent – from 883 MW in 2010 to 6,902 MW in 2020 – over the next 10 years. For comparison, the onshore market grew by an annual average of 22 percent – from 809 MW in 1995 to 5,749 MW in 2004 (see Figure 56). EWEA is confident that the development of onshore can be replicated at sea, but it requires increased efforts, not least in terms of R&D and the construction of a European offshore power grid.

Figure 56: Wind Energy in the EU (2000-2020)



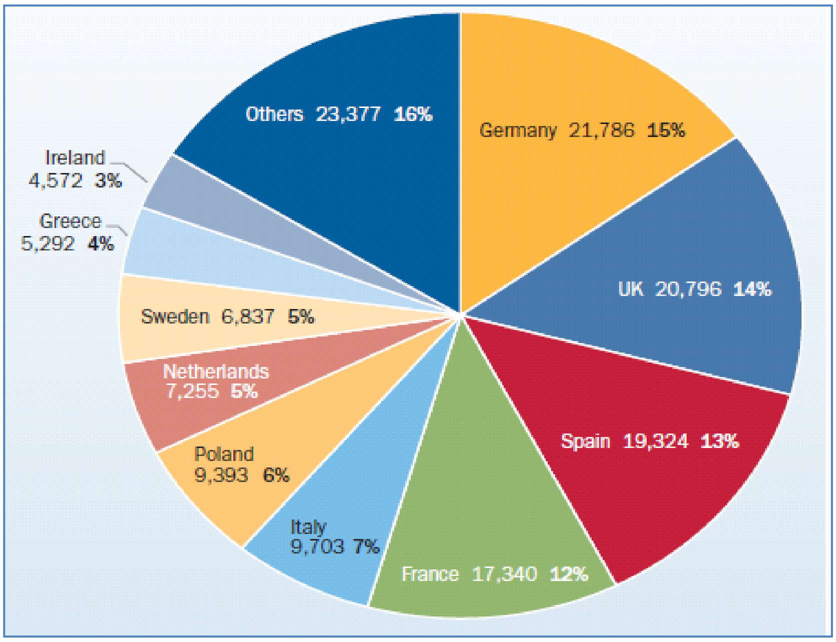
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Offshore	0.1	0.3	0.9	1.8	2.1	2.5	3.2	3.9	5.3	7.4	10.6	14.2	19.1	29.1	39.5	50.6	63.2	78.3	97.1	120.5	148.2
Onshore	22.5	31.7	43.5	54.8	67.3	80.3	96.4	114.5	131.2	151.6	171.1	190.0	209.5	230.8	254.2	279.2	305.9	334.7	365.6	398.8	432.7
Total	22.6	32.0	44.4	56.6	69.4	82.8	99.6	118.5	136.4	159.0	181.7	204.2	228.6	259.9	293.7	329.8	369.1	412.9	462.6	519.3	581.0

Figure 57 shows the national breakdown of the increase in wind power capacity according to EWEA's 230 GW scenario85. In total, wind energy capacity in the EU will increase by 146 GW by 2020. Germany will continue to be in the lead over the next 10 years, increasing its installed capacity by 21.8 GW. Spain, with a 19.3 GW increase would be overtaken by France (adding 20.8 GW) and the UK would come in fourth adding 17.3 GW. They are followed by Italy (9.7 GW), Poland (9.4 GW) and the Netherlands (7.3 GW). The group labelled "others" has 16 percent of the total increase in capacity (23.4 GW). All 27 Member States are expected to have operating wind farms by 2020. Nevertheless, Germany and Spain together would still make up 28 percent of the total EU increase.

The European Commission's 2009 reference scenario takes into account the European Union's "climate and energy package" – including decreased CO_2 emissions (impacting on the price of carbon), increased energy efficiency and increased penetration of renewables through the policy framework of the Renewable Energy Directive 28/2009/EC.

[85] Ibid

Figure 57: Top Ten countries for increased wind power capacity in GW (2011-2020)



In contrast to its 2008 scenario forecasting a reduction in investments in wind energy, in the Commission's 2009 scenario wind energy capacity is expected to increase to 222 GW by 2020 – 85 percent more than the 120 GW predicted in 2008. This forecast is above the sum of the 27 NREAPs (213 GW) and just short of EWEA's 230 GW target.

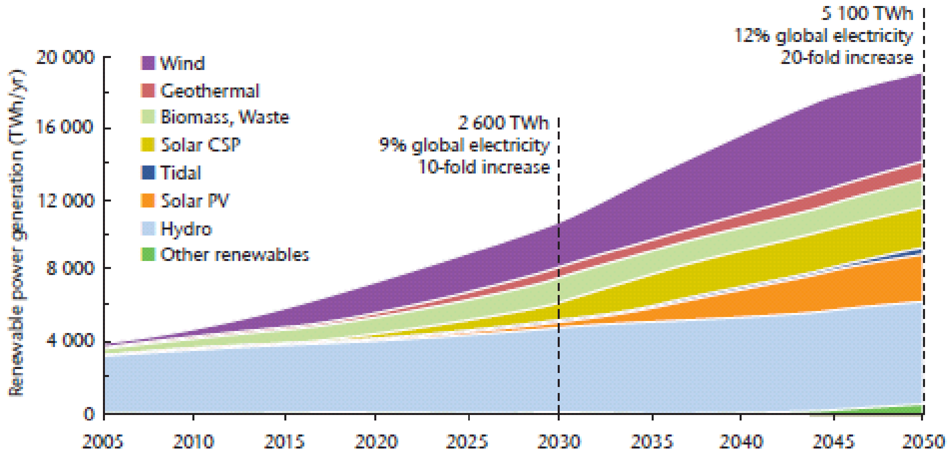
Figure 58: Increase in Wind Capacity for the remaining 17 EU States

Others		
	Increase in wind power capacity 2011-2020 (MW)	% of EU-27 increase in wind power capacity 2011-2020
Portugal	3,602	2.5%
Belgium	2,986	2.1%
Bulgaria	2,625	1.8%
Romania	2,538	1.7%
Austria	2,489	1.7%
Denmark	2,202	1.5%
Finland	1,703	1.2%
Czech Republic	1,385	1%
Lithuania	846	0.6%
Slovakia	797	0.5%
Hungary	605	0.4%
Slovenia	500	0.3%
Estonia	351	0.2%
Luxembourg	258	0.2%
Cyprus	218	0.1%
Latvia	169	0.1%
Malta	100	0.1%

3.1.3 Global and regional forecasts beyond 2020

By 2030, approximately 2,600 terawatt hours (TWh) of wind electricity is estimated to be produced annually from over 1,000 GW of wind capacity, corresponding to 9 percent of global electricity production[86]. This rises to 5,100 TWh (12 percent, over 2 000 GW) in 2050. An essential message of the Energy Technology Perspective (ETP) study is that there is no single energy technology solution that can solve the combined challenges of climate change, energy security and access to energy. The ETP model is based on competition among a range of technology options, and the resulting technology portfolio reflects a least cost option to reduce CO_2 emissions, rather than the maximum possible wind deployment. Figure 59 illustrates the role of renewable energy in the global power portfolio to 2050.

Figure 59: Electricity from renewable sources up to 2050 in ETP Blue Map Scenario



Source: IEA (2008a).

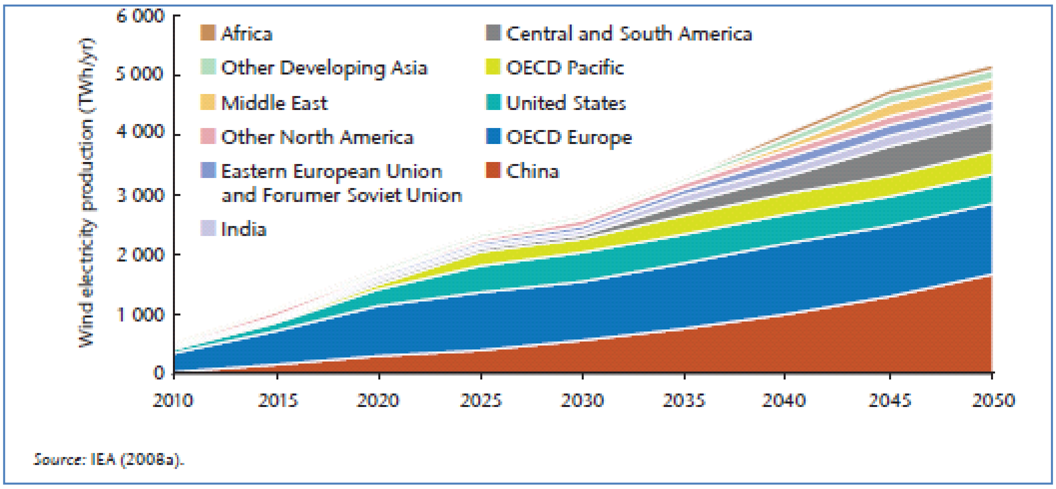
While offshore wind power remains more expensive, deployment is expected to take place mainly on land. The present offshore industry is located almost entirely in Northern Europe where land resources with good wind conditions are scarcer than in regions like North America and China. Moreover, water depth is a principal cost factor in offshore development, and the majority of offshore deployment is taking place in the North, Baltic and Irish Seas, which are areas of continental shelf (shallower seas) and so are currently less costly for wind development than in deeper oceans. It will be critical to place greater emphasis on offshore technology R&D to achieve roadmap targets for cost effective wind energy

According to the BLUE Map scenario, in 2020 OECD Europe remains the leading market for wind power, followed by the United States and then China. By 2030 China overtakes the United States (557 TWh and 489 TWh respectively), and OECD Pacific countries emerge as an important market at 233 TWh. By 2050, China leads with 1,660 TWh, followed by OECD Europe and the United States, which are shown to remain steady from 2030, and then by OECD Pacific countries and Central and South America. The remaining

[86] OECD/IEA (2009), Technology Roadmap Wind Energy, International Energy Agency, Paris, France

regions, including India, Africa and the Middle East, provide nearly one-fifth of wind electricity in 2050 (see Figure 60).

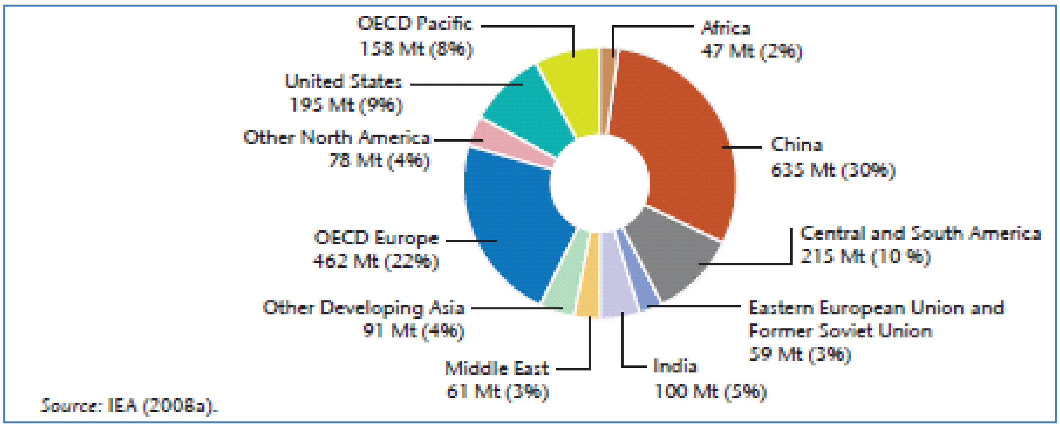
Figure 60: Regional Production of Wind Electricity in ETP Blue Map Scenario



CO_2 reduction from wind energy under the BLUE Map scenario reaches a total of 2,100 Mt per year in 2050. China makes the largest contribution with 635 million tonnes (Mt) avoided, followed by OECD Europe at 462 Mt, and Central and South America with 215 Mt (see Figure 61).

Approximately USD $3.2 trillion of investment (EUR 2.2 trillion) will be required to reach the BLUE Map finding of 12 percent global electricity produced from wind energy in 2050[87]. While this number seems large, it is just 1 percent of the additional investment needs required to achieve the BLUE Map goal of reducing CO_2 emissions 50 percent by 2050. Current investment in wind power deployment is considerable, but not sufficient.

Figure 61: CO2 emissions reductions by wind



Wind power saw nearly $52 (€40bn) of new investment in 2008, of which asset finance, investment in new generation assets, made up 92 percent (UNEP, 2009). The BLUE Map scenario projects over 2,000 GW of installed capacity in 2050, up from 120 GW in 2008. This would require an average annual installation of 47 GW for the next 40 years, up

87 Ibid

from 27 GW in 2008. This is equal to an additional 75 percent over present investment, to around $81bn per year (€62bn).

In China from 2020 to 2030, without considering the cost of inter-provincial transmission, wind power is expected to be less expensive than coal power[88]. If transmission costs are included, the full cost of wind power will still be higher than that of coal power, but if the environment and resource costs of coal power are considered, the full cost of wind power will be lower than that of coal power. The wind power market will be further expanded. Land-based and offshore wind power will both be developed, with new capacity of more than 20 GW added annually. Of the total installed power capacity added annually in China, 30 percent will come from wind.

By 2030, cumulative installed capacity could be over 400 GW. Wind power will meet 8.4 percent of the total electric power consumption and account for 15 percent of total electric power capacity. Wind power will play an increasing part in meeting China's electricity demand, improving its energy structure and supporting its economic and social development.

From 2020 to 2030, both land-based and offshore wind power will be developed. Far offshore wind demonstration projects should also start. The same analysis is used for 2030 investment costs and feed-in tariffs. When total installed capacity reaches 400 GW, the top-end feed-in tariff (not including transmission costs) will be about CNY 0.39/kWh. Capacities installed at this tariff level would be: Jiuquan (130 GW), Hami (97 GW), East Inner Mongolia (36 GW), West Inner Mongolia (89 GW), Hebei (30 GW) and Jilin (18 GW).

If transmission costs are accounted for, the feed-in tariff would be CNY 0.542/kWh. At this tariff level, planned wind power bases and installed capacities would be: Jiuquan (40 GW), East Inner Mongolia (93 GW), West Inner Mongolia (186 GW), Hebei (58 GW), Xinjiang Hami (2 GW), Jilin (20 GW) and Jiangsu (1 GW).

Assuming significant improvement to grid infrastructure, as well as multiple additional energy storage facilities, and sufficient land resources, capacities could be as follows in 2030: West Inner Mongolia (100 GW), East Inner Mongolia (40 GW), Northeast China (38 GW), Hebei (27 GW), Gansu (10 GW), Xinjiang (40 GW) and 40 GW will be developed in the Jiangsu and Shandong bases together. Of the total capacity of 400 GW, near offshore wind will contribute 60 GW and far offshore 5 GW

Between 2030 and 2050, wind power, power systems and energy storage technologies will continue to progress. Wind power will be better integrated in the national power system. China will further expand the scale of wind power, with co-ordinated development of land-based, near offshore and far offshore projects. About 30 GW of capacity will be added annually, accounting for about half of newly installed capacity. By 2050, installed capacity could reach 1 TW, about 26 percent of total power capacity. Wind power will meet 17 percent of national electricity consumption and become a

[88] OECD/IEA (2009), Technology Roadmap Wind Energy, International Energy Agency, Paris France

major power supply, with a wide range of industrial applications. This roadmap assumes that development up to 2050 will also centre on these key geographical areas. The assessment is based on current investment and O&M costs, existing wind resource data, and transmission costs. However, with continuing deployment, wind turbine and component manufacturing technologies will improve significantly, and offshore wind R&D will advance. These factors could greatly improve wind power technology and reduce deployment costs. Grid and system integration issues will gradually be resolved. Improved grid planning practices, extension and reinforcement will maximise local consumption of wind power, and transmission costs over long distances will decline.

By 2050, when total installed capacity will reach 1 TW, the wind power development strategy will need to be adjusted: wind farms will be developed in several additional areas[89]. Inner Mongolia will have installed some 400 GW, based in several interconnected key areas. In Xinjiang and Gansu, more than 200 GW of capacity will be constructed. About 100 GW of capacity will be developed in Hebei and Northeastern China. With improved road access it will be possible to harvest the majority of the best resource.

Offshore capacity will reach 200 GW, including 150 GW in near offshore areas. Several far offshore wind farms will be developed. Wind power applications will be expanded towards remote and desert areas and to far offshore. Technologies will be further improved, with power system upgrades and technology breakthroughs. Wind power development targets and distributions have been calculated for 2020, 2030 and 2050 (see Figure 62).

Figure 62: Wind power development targets and distribution (GW)

Regions	2010	2020	2030	2050
West Inner Mongolia	6.50	40	100	300
East Inner Mongolia	3.62	20	40	90
Northeastern China provinces	7.31	30	38	60
Hebei Base	3.78	15	27	60
Gansu Base	1.44	20	40	120
Xinjiang Base	1.13	20	40	100
Distributed land-based wind in Eastern and Central China and other areas	7.43	25	50	70
Near offshore wind	0.10	30	60	150
Far offshore wind	0	0	5	50
Total	**31.31**	**200**	**400**	**1 000**

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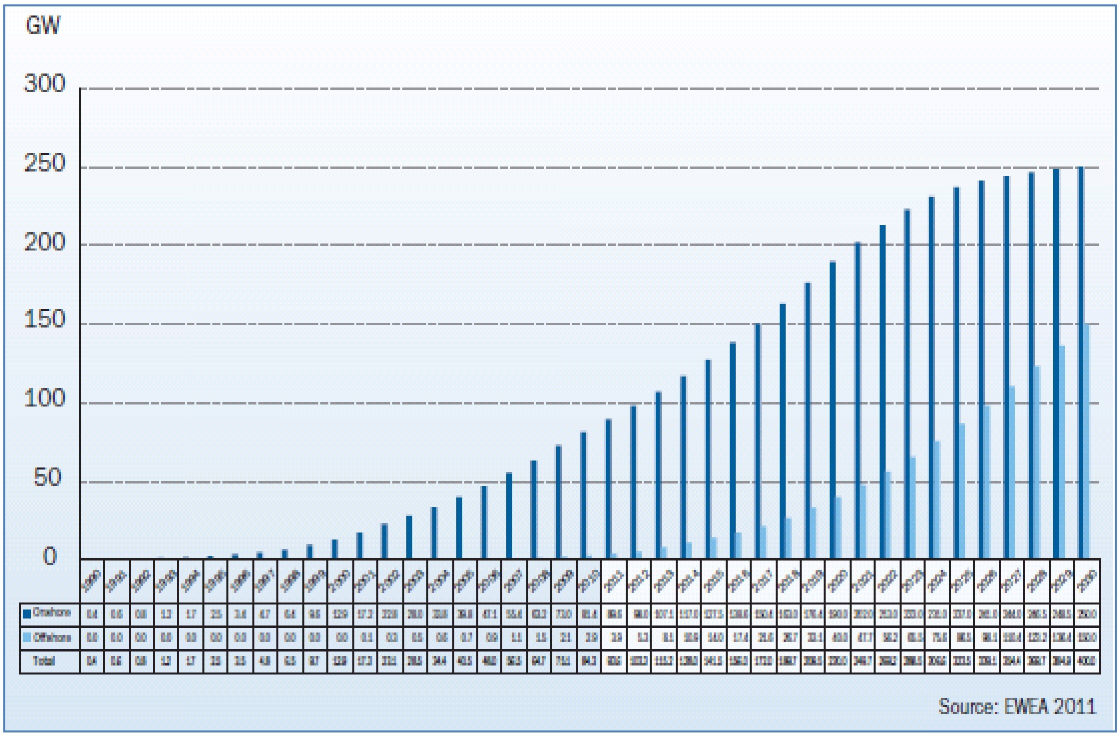
By 2030, EWEA expects 400 GW of wind energy capacity to be operating in the EU – 250 GW on land and 150 GW offshore. Figure 63 shows the development in cumulative wind energy capacity according to this target. The onshore development forms a classic S-curve of early exponential growth being replaced by saturation towards 2030. In terms of total capacity, offshore is currently (end 2010) at the level of onshore wind in 1995.

[89] Ibid

By 2025, offshore capacity is expected to exceed the 84.3 GW of wind that was operating onshore at the end of 2010. According to the target, offshore wind is following onshore wind in Europe with a 15 year time-lag. Given its larger potential, it can be expected that total offshore wind capacity will exceed onshore capacity at some point beyond 2030.

Figure 63 shows that the market for onshore wind power will increase up to 2020, then decline steadily in the decade up to 2030, while an increasing share of the onshore market will come from the replacement of existing capacity. No significant decommissioning of offshore wind turbines is envisaged until after 2030. Wind energy development after 2020 will to a large degree be determined by the price and availability of fuel and the price of emitting CO_2. In total, EWEA's targets suggest that 162 GW of new capacity will be built in the 10 years from 2011 to 2020, and that an additional 241 GW will be constructed in the decade from 2021 to 2030.

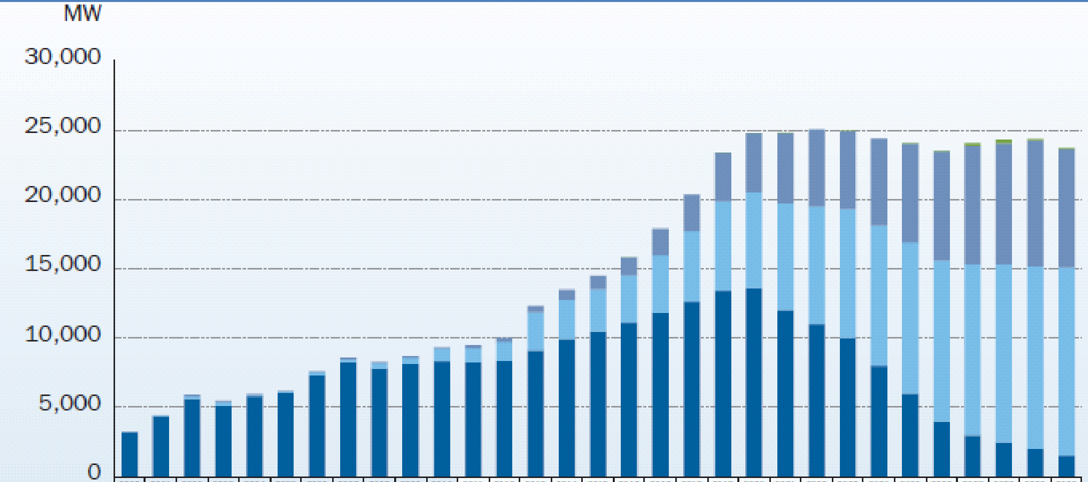
Figure 63: Cumulative onshore and offshore wind power in the EU (1990-20)



The annual market for offshore wind reached 0.9 GW in 2010 which translates into an average annual growth rate for offshore of 33 percent this decade – similar to the annual growth rate in onshore in the ten years from 1991 to 2000 (33 percent). To meet the 230 GW target in 2020 would require an average growth in annual installations of 10 percent from 2011 to 2020, 8 percent growth in the onshore market and 21 percent growth in the offshore market.

In total, average annual installations are assumed to more than double from 7.2 GW in the past decade (2001 to 2010) to 16.2 GW between 2011 and 2020 (see Figure 64). Between (2021 to 2030) average annual installations will be some 40 percent higher (24.2 GW) than the decade before.

Figure 64: Annual wind power installations in the EU 2000-2030



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Offshore repowering															
Onshore repowering			130	69	65	76	61	67	67	109	111	241	271	469	694
Offshore	4	51	170	259	90	90	201	210	374	430	883	1,000	1,370	2,768	2,859
Onshore	3,205	4,377	5,613	5,134	5,791	6,038	7,330	8,277	7,822	8,129	8,338	8,259	8,359	9,100	9,913
Total	3,209	4,428	5,913	5,462	5,946	6,204	7,592	8,574	8,263	8,668	9,332	9,500	10,000	12,337	13,466

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Offshore repowering		5	0	0	2	5	17	0	3	0	4	51	170	259	90	90
Onshore repowering	980	1,256	1,911	2,609	3,506	4,250	5,062	5,555	5,622	6,287	7,114	7,842	8,570	8,739	9,049	8,512
Offshore	3,054	3,429	4,145	5,116	6,418	6,897	7,700	8,500	9,300	10,100	10,900	11,600	12,300	12,800	13,200	13,600
Onshore	10,466	11,106	11,822	12,602	13,436	13,600	12,000	11,000	10,000	8,000	6,000	4,000	3,000	2,500	2,000	1,500
Total	14,500	15,796	17,878	20,326	23,362	24,752	24,779	25,055	24,924	24,387	24,017	23,493	24,040	24,296	24,339	23,702

Source: EWEA 2011

3.2 Geothermic Resources

3.2.1 General Presentation

Geothermal resources consist of thermal energy from the Earth's interior stored in both rock and trapped steam or liquid water. Geothermal systems as they are currently exploited occur in a number of geological environments where the temperatures and depths of the reservoirs vary accordingly. Many high-temperature (>180°C) hydrothermal systems are associated with recent volcanic activity and are found near plate tectonic boundaries (subduction, rifting, spreading or transform faulting), or at crustal and mantle hot spot anomalies. Intermediate- (100 to 180°C) and low-temperature (<100°C) systems are also found in continental settings, where above-normal heat production through radioactive isotope decay increases terrestrial heat flow or where aquifers are charged by water heated through circulation along deeply penetrating fault zones. Under appropriate conditions, high-, intermediate- and low-temperature geothermal fields can be utilized for both power generation and the direct use of heat[90].

Geothermal resources can be classified as convective (hydrothermal) systems, conductive systems and deep aquifers. Hydrothermal systems include liquid and vapour-dominated types. Conductive systems include hot rock and magma over a wide range of temperatures[91]. Deep aquifers contain circulating fluids in porous media or fracture zones at depths typically greater than 3 km, but lack a localized magmatic heat source. They are further subdivided into systems at hydrostatic pressure and systems at

[90] Tester, J.W., E.M. Drake, M.W. Golay, M.J. Driscoll, and W.A. Peters (2005) Sustainable Energy – Choosing Among Options. MIT Press, Cambridge, Massachusetts, United States, 850 pp (ISBN 0-262-20153-4).

[91] Mock, J.E., J.W. Tester, and P.M. Wright (1997). Geothermal energy from the Earth: Its potential impact as an environmentally sustainable resource. Annual Review of Energy and the Environment, 22, pp. 305-356 (ISBN: 978-0-8243-2322-6).

pressure higher than hydrostatic (geo-pressured). Enhanced or engineered geothermal system (EGS) technologies enable the utilization of low permeability and low porosity conductive (hot dry rock) and low productivity convective and aquifer systems by creating fluid connectivity through hydraulic stimulation and advanced well configurations. In general, the main types of geothermal systems are hydrothermal and EGS.

Resource utilization technologies for geothermal energy can be grouped under types for electrical power generation, for direct use of the heat, or for combined heat and power in cogeneration applications. Geothermal heat pump (GHP) technologies are a subset of direct use. Currently, the only commercially exploited geothermal systems for power generation and direct use are hydrothermal (of continental subtype). Hydrothermal, convective systems are typically found in areas of magmatic intrusions, where temperatures above 1,000°C can occur at less than 10 km depth. Magma typically emits mineralized liquids and gases, which then mix with deeply circulating groundwater. Such systems can last hundreds of thousands of years, and the gradually cooling magmatiche at sources can be replenished periodically with fresh intrusions from a deeper magma chamber. Heat energy is also transferred by conduction, but convection is the most important process in magmatic systems.

Subsurface temperatures increase with depth and if hot rocks within drillable depth can be stimulated to improve permeability, using hydraulic fracturing, chemical or thermal stimulation methods, they form a potential EGS resource that can be used for power generation and direct heat applications. EGS resources include hot dry rock (HDR), hot fractured rock (HFR) and hot wet rock (HWR), among other terms. They occur in all geothermal environments, but are likely to be economic in geological settings where the thermal gradient is high enough to permit exploitation at depths of less than 5 km. In the future, given average geothermal gradients of 25 to 30°C/km, EGS resources at relatively high temperature (≥180°C) may be exploitable in broad areas at depths as shallow as 7 km, which is well within the range of existing drilling technology (~10 km depth). Geothermal resources of different types may occur at different depths below the same surface location. For example, fractured and water-saturated hot-rock EGS resources lie below deep-aquifer resources in the Australian Cooper Basin[92].

Geothermal energy is classified as a renewable resource because the tapped heat from an active reservoir is continuously restored by natural heat production, conduction and convection from surrounding hotter regions, and the extracted geothermal fluids are replenished by natural recharge and by injection of the depleted (cooled) fluids. Geothermal fields are typically operated at production rates that cause local declines in pressure and/or in temperature within the reservoir over the economic lifetime of the installed facilities. These cooler and lower-pressure zones are subsequently recharged from surrounding regions when extraction ceases.

92 Goldstein, B.A., A.J. Hill, A. Long, A.R. Budd, B. Ayling, and M. Malavazos (2009). Hot rocks down under – Evolution of a new energy industry. Transactions of the Geothermal Resources Council, 33, pp. 185-198.

Global technical potential for geothermal electricity has been estimated at 45 EJ/yr to 12,500 TWhe, *i.e.* about 62 percent of 2008 global electricity generation[93]. The same study estimated resources suitable for direct use at 1,040 EJ/yr to 289,000 TWht; worldwide final energy use for heat in 2008 was estimated at 159.8 EJ/44 392 TWht. The estimated technical potential for geothermal electricity and geothermal heat excludes advanced geothermal technologies that could exploit hot rock or off-shore hydrothermal, magma and geo-pressured resources. Although geothermal energy has great technical potential, its exploitation is hampered by costs and distances of resource from energy demand centres. Geothermal typically provides base-load generation, since it is generally immune from weather effects and does not show seasonal variation. Capacity factors of new geothermal power plants can reach 95 percent. The base-load characteristic of geothermal power distinguishes it from several other renewable technologies that produce variable power. Increased deployment of geothermal energy does not impose load balancing requirements on the electricity system. Geothermal power could be used for meeting peak demand through the use of submersible pumps tuned to reduce fluid extraction when demand falls. However, procedures and methods that allow for a truly load-following system have yet to be developed. Geothermal energy is compatible with both centralised and distributed energy generation and can produce both electricity and heat in combined heat and power (CHP) plants.

In 2009, global geothermal power capacity was 10.7 GWe and generated approximately 67.2 TWhe/yr of electricity, at an average efficiency rate of 6.3 GWh/MWe[94] (Figure 65). A remarkable growth rate from 1980 to 1985 was largely driven by the temporary interest of the hydrocarbon industry – mainly Unocal (now merged with Chevron) – in geothermal energy, demonstrating the considerable influence on the geothermal market of attention from the hydrocarbon sector, which has expertise similar to that needed for geothermal development.

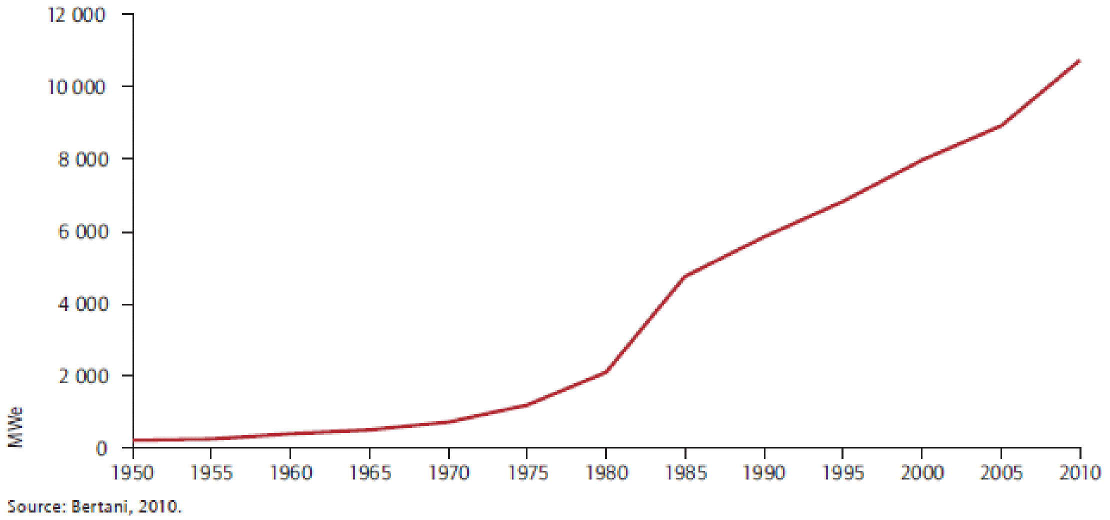
Geothermal electricity provides a significant share of total electricity demand in Iceland (25 percent), El Salvador (22 percent), Kenya and the Philippines (17 percent) each, and Costa Rica (13 percent). In absolute figures, the United States produced the most geothermal electricity in 2009, 16,603 GWh/yr from an installed capacity of 3,093 MWe. Total installed capacity of geothermal heat (excluding heat pumps) equalled 15,347 MWt in 2009, with a yearly heat production of 223 petajoules (PJ). China shows the highest use of geothermal heat (excluding heat pumps), totaling 46.3 PJ/yr geothermal heat use in 2009[95] .

[93] Krewitt, W., K. Nienhaus, C. Klessmann, C. Capone, E. Stricker, W. Graus, M. Hoogwijk, N. Supersberger, U. von Winterfeld and S. Samadi (2009), Role and Potential of Renewable Energy and Energy Efficiency for Global Energy Supply, Federal Environment Agency

[94] Bertani, R. (2010), Geothermal Power Generation in the World 2005–2010 Update Report, proceedings at World Geothermal Congress 2010, Bali, Indonesia, 25-29 April 2010.

[95] Lund, J.W., D.H. Freeston and T. L. Boyd (2010), Direct Utilization of Geothermal Energy 2010 Worldwide Review, proceedings at World Geothermal Congress 2010, Bali, Indonesia, 25-29 April 2010

Figure 65: Global development installed capacity geothermal power (MW)



Until recently, utilisation of geothermal energy was concentrated in areas where geological conditions permit a high-temperature circulating fluid to transfer heat from within the Earth to the surface through wells that discharge without any artificial lift. The fluid in convective hydrothermal resources can be vapour (steam), or water-dominated, with temperatures ranging from 100ºC to over 300ºC. High-temperature geothermal fields are most common near tectonic plate boundaries, and are often associated with volcanoes and seismic activity, as the crust is highly fractured and thus permeable to fluids, resulting in heat sources being readily accessible.

Geothermal energy can be used for a wide range of applications from standard 12 kW heat pump systems in residential buildings up to geothermal power plants with an electric capacity of 100 MW and more. The application depends mainly on the system's heat content (enthalpy) and on the designated use of the geothermal source. For geothermal power generation usually a minimum fluid temperature of 100°C is required. With the signing of the IEA Geothermal Implementing Agreement, the presently 13 GIA member countries have declared their intention to promote the sustainable utilization of geothermal energy worldwide. Accounting for 60 percent of the world's geothermal power generation and about half of the geothermal heat produced worldwide, GIA members contribute a considerable share of the geothermal energy use worldwide[96].

The designed output of a power plant is indicated by its installed capacity which is denoted in Watts [W]. How much energy is actually produced is given by the plant's capacity factor (cf). In 2010, nine of 13 GIA countries had available units for geothermal power generation with eight countries actually producing electricity. The total installed capacity in GIA countries accounted for 6,870 MW of the nearly 11,000 MW installed capacity worldwide (see Figure 66)[97].

96 IEA, (2012), Trends in Geothermal Applications, Survey Report on Geothermal Utilization and Development in IEA-GIA Member Countries in 2010.

97 Ibid

Figure 66: Geothermal power generation in GIA countries and worldwide in 2010

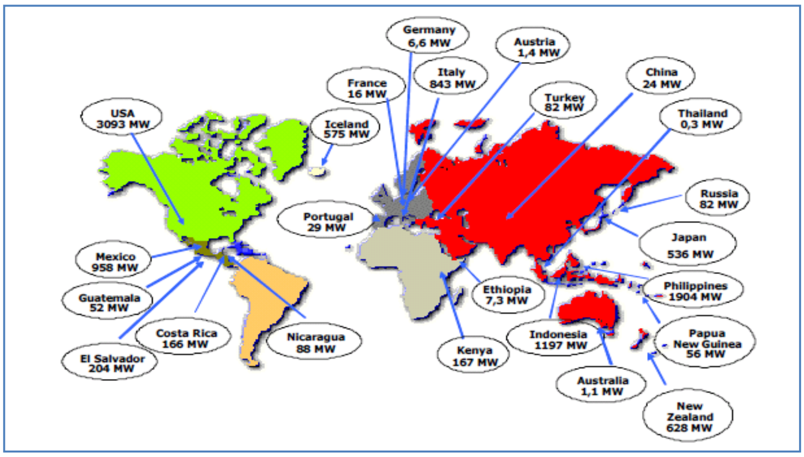
Country	Installed capacity MW	Energy produced GWh/a	cf
AUS	0.1	0.0	0.0
DEU	7.3	27.5	0.4
FRA	18.3	14.9	0.1
ISL	575.0	4,465.0	0.9
ITA	882.5	5,376.0	0.7
JPN	537.7	2,908.0	0.6
MEX	958.0	6,618.0	0.8
NZL	792.0	5,551.0	0.8
USA	3,101.6	15,009.0	0.6
total GIA	6,872.5	39,969.4	0.7
World	10,898.0	67,246.0	0.7

Source: IEA, 2012

The United States contributes the largest share of geothermal capacities in GIA countries with 3,100 MWe installed, followed by Mexico, Italy, New Zealand, Iceland, and Japan. The electricity produced worldwide exceeded 67,000 GWh in 2010[98], with GIA countries contributing about 40,000 GWh/a. The average capacity factor is 0.7 worldwide and similar in GIA countries, indicating that average geothermal plants are being operated about 6,000 full load hours per year.

The capacity factor varies widely among GIA countries, with a maximum of 0.9 or nearly 8,000 full load hours in Iceland followed by New Zealand and Mexico each with a capacity factor of about 0.8. Low capacity factors indicate that units were not in operation during part of the year. Downtimes can be due to maintenance, repair work, or the commissioning of a new plant part way through the respective year. The global map indicating installed capacity in 2010 is shown in Figure 67[99].

Figure 67: Global installed capacity in 2010 (10.8GW)



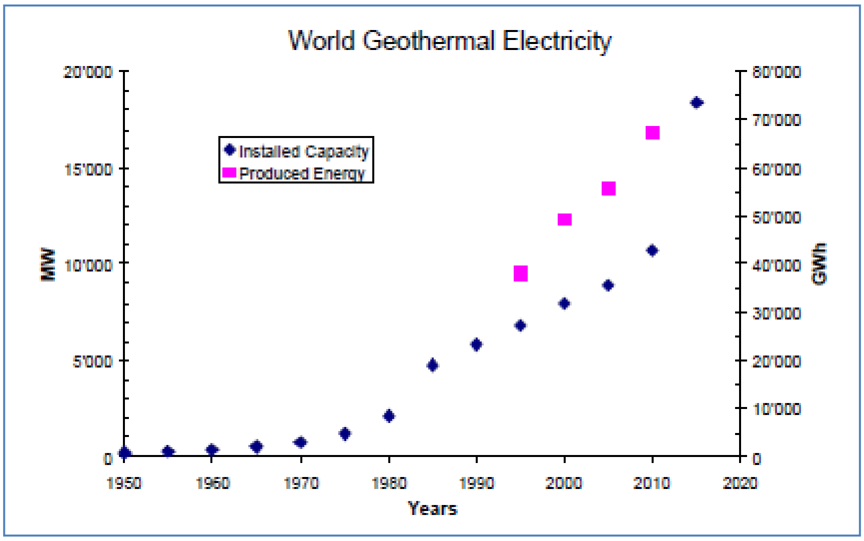
Source: IEA, 2012

98 Bertani, R. (2011): Geothermal Power Generation in the World: 2005 – 2010 update report.
99 Ibid

3.2.2 Global and regional forecasts to 2020

The expected total installed capacity from worldwide geothermal power plant is shown in Figure 68[100]. The short-term forecasting for 2015 is ambitious with the expected 18 GW on the exponential curve as opposed to a linear forecast. It would be important to transform the 7 GW of paper projects to real plants by 2015 to demonstrate that the future forecasts can be attained. This would give the entire geothermal community a clear signal of the possibility and the willingness of being one of the most important renewable energy players in the future electricity market.

Figure 68: Projected Geothermal installed capacity (left) with electricity generation (right) to 2020.



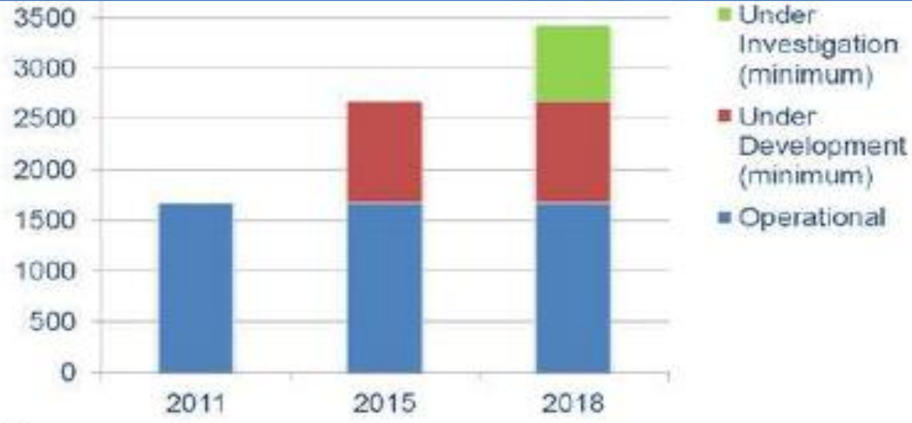
Significant geothermal energy capacity is now being developed across Europe. As of 2011 Europe had a total installed capacity of 1,600 MW for geothermal energy, producing 10,900,000 MWh of electric power through 59 geothermal power plants, 47 of which were in European Union (EU) member states. Europe currently has 109 new power plants under construction or under investigation in EU member states.

By 2015, Europe is expected to have about 1,600 MW of installed geothermal energy capacity, with an additional 1,800 MW to be under development or investigation by 2018 (see Figure 69)[101]. As far as conventional geothermal electricity is concerned, the vast majority of eligible resources, in Continental Europe at large, are concentrated in Italy, Iceland and Turkey; the presently exploited potential represents so far 0.3 percent of the whole renewable energy market.

[100] Ibid

[101] European Geothermal Energy Council, (April 2001), "Energy Roadmap 2050. EGEC policy paper on the European Commission

Figure 69: Installed capacity of geothermal electricity in Europe (MWe)



Source: EGEC

3.2.2.1 Europe

It is even more difficult to appraise the impact of new frontier technologies as well as the contribution of Enhanced Geothermal System (EGS) issues in the European geothermal scenario. Geothermal sources, suitable for electricity production, are fairly limited and not equally shared throughout Europe, whereas direct use prospects shape much more favourably. However, to date, only a small part of the whole geothermal potential has been explored and exploited. Prospects, in this respect, are very promising and opportunities for extracting heat in non-hydrothermal, artificially fractured, systems, via a closed loop circulation can be quite significant in a long run, far sighted, perspective. Summing up, geothermal electricity development in Europe stands at 1,500 to 2,000 MWe in year 2010, while for 2020 it can be estimated to match the 4,000 to 6,000 MWe targets.

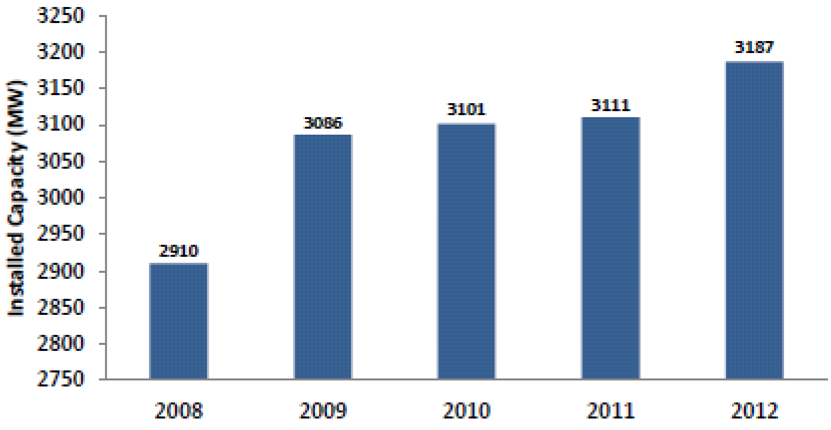
3.2.2.2 United States of America

The development of geothermal energy resources for utility-scale electricity production in the United States began in the 1960’s. Since that time, the continual development of geothermal resources and technology has positioned the United States as a leader in the global geothermal industry. The United States currently has approximately 3,187 MW of installed geothermal capacity, more than any other country in the world[102].

Figure 70 shows geothermal companies continue to increase the development of geothermal resources in the United States. In 2010 geothermal energy accounted for 3 percent of renewable energy-based electricity consumption in the United States[103].

[102] Geothermal Energy Association, (2012), Geothermal International Market Overview Report 2012 209 Pennsylvania Avenue SE, Washington, D.C. 20003 United States.
[103] Renewable Energy Consumption and Electricity Statistics 2010. US Energy Information Administration.

Figure 70: Annual US installed capacity growth 2008-2012



Source: GEA

While the majority of geothermal installed capacity in the United States is concentrated in California and Nevada, geothermal power plants are also operating in Alaska, Hawaii, Idaho, Oregon, Utah, and Wyoming. Five additional geothermal projects with gross capacity of approximately 91 MW came on line in 2011 and early 2012. Additional geothermal resources are under development in the United States. As of April 2012, there were 147 projects identified under development, with over 5,000 MW of power potential. These projects were found in over 15 states, comprising over one-third of the land area of the United States.

3.2.2.3 Asia and the Pacific

Countries in Asia and the Pacific Islands are poised to make a significant contribution to the growth of the global geothermal industry. High-grade resources and friendly policy environments have resulted in an emergence of advanced-stage geothermal projects that are beginning to attract the expertise of geothermal developers as well as the interest of project financiers. The potential for the development of geothermal resources throughout the region is immense.

3.2.2.4 China

China's geothermal resource has not received the same focus or development as other renewable sources, such as hydro and wind. China has rich geothermal resources throughout the country, and leads the world in overall usage of geothermal resources. However, most of China's geothermal resource is utilised as direct heat due to low source temperature. High temperature resources exist in the regions of Tibet and Yunnan, which hold the greatest potential for geothermal power generation. While geothermal electricity is unlikely to play a major role in China's nation-wide electricity supply in the near future, it could be an important provider of local electricity in remote regions.

The potential of overall geothermal resources in China is significant. According to Guan Fengjun, Head of the Geological Environment Department at the Ministry of Land and Resources (MLR), China's twelve major geothermal basins have energy resources amounting to an equivalent of 853 billion tons of common coal, which could generate around 7 billion GWh of electricity[104]. Geothermal energy is still small-scale in China (compared to hydro, wind and even solar), but the potential of this sector is significant. By 2015, the Ministry expects that China will be using geothermal energy equivalent to 68.8 million tons of standard coal (560,000 GWh of electricity), representing 1.7 percent of the country's energy consumption.[105]

3.2.2.5 Indonesia

A rapidly growing economy and increasingly urbanised population are contributing to increased electricity demand in Indonesia. Indonesia has abundant geothermal resources which it can use to help meet rising electricity demand and increase electrification. With 27,510 MW of potential resources, Indonesia's estimated conventional hydrothermal geothermal resource base is among the largest in the world. Moreover, most geothermal systems in Indonesia are considered to be high temperature (i.e. >250°C), and ideal for electricity generation. Indonesia is eager to develop its geothermal resources and has set a goal to increase the amount of its installed geothermal capacity to 5,000 MW by 2025.

3.2.2.6 Japan

Over the past decade, efforts to develop additional geothermal power plants in Japan had been minimal as the national policy favoured production of electricity from nuclear power. However, in the wake of the Fukushima disaster Japan's government reassessed its energy policy and is shifting its focus from nuclear energy to power production from renewable energy resources such as solar, wind, and geothermal power. In order to drive the development of renewable resources, the Japanese Ministry of Economy, Trade and Industry (METI) is considering a plan to implement feed-in tariffs for renewable technologies. Under the current proposal, the feed-in tariff for geothermal energy generation in Japan would be set at approximately 0.53 $/kWh[106].

Geothermal is responsible for approximately 0.2 percent of electricity generation in Japan, but with an estimated 23,000 MW of geothermal energy, opportunities to further develop Japan's geothermal resources abound. Until recently, access to Japan's geothermal resources was restricted due to the fact that a significant portion is located within national park land. However, in March 2012 Japan's Ministry of the Environment stated that, under certain conditions, it would allow vertical drilling for geothermal resources in its national parks. Easing the restrictions on geothermal drilling in national parks alone could open up 1,000 MW of geothermal resources to development according to one estimate with potential for 2 GW by 2020[107].

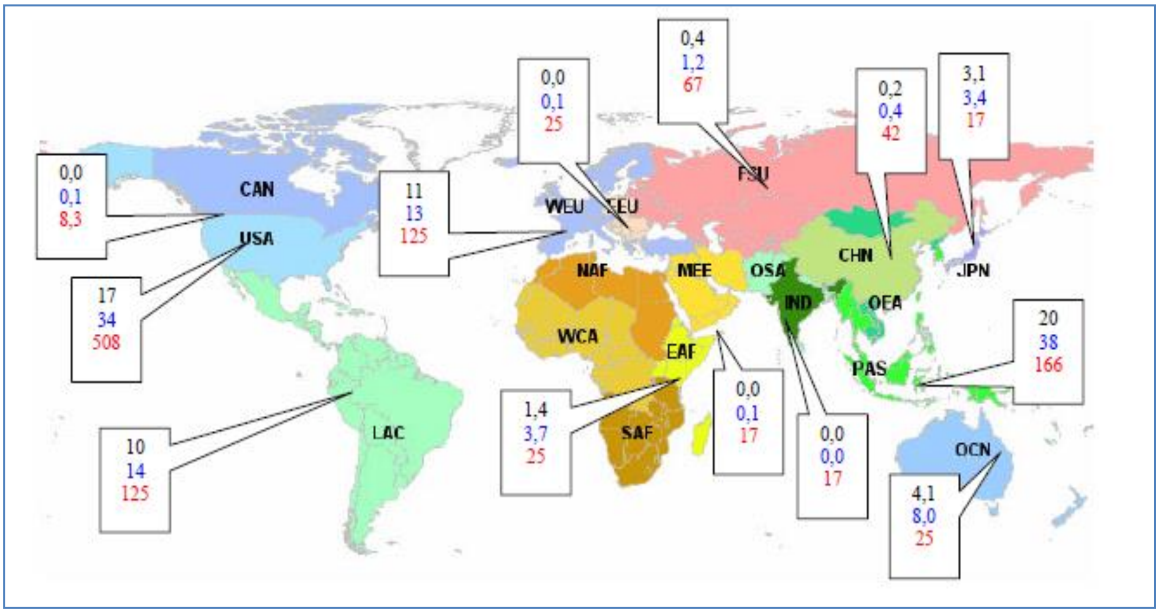
[104] Worldview, (June 2012), Geothermal Potential of China, A fresh Perspective on Global Issues, A Worldview Report, New Zealand.
[105] Ibid
[106] Geothermal Energy Association, (2012), Geothermal International Market Overview Report 2012, Washington, D.C. 20003 United States.
[107] Watanabe, Chris, (April 2012), Japan Geothermal Could Grow to 2 Gigawatts by 2020s.

3.2.3 Global and regional forecasts beyond 2020

The growth of developing countries will result in a two fold increase of the global electricity with demand increasing from 15,000 TWh in 2005 to 30,000 TWh in 2030 (see Figure 71). Geothermal Energy provides approximately 0.4 percent of the world global power generation, with a stable long-term growth rate of 5 percent. Estimating the overall worldwide potential is a delicate exercise due to the many uncertainties involved. Nevertheless, it is possible to try estimation, taking into consideration the economically exploitable zones, making an intense development in the low-medium temperature range, which is the most abundant geothermal resource. The expected value of 70 GW[108] is a realistic target for year 2050. Moreover, including new technologies (permeability enhancements, Enhanced Geothermal System EGS, Supercritical fluids and magmatic resources), it is possible to have an additional contribution for minimum doubling the total world electrical geothermal production by 2050, with 40 countries (mostly in Africa, Central/South America and the Pacific) that can be wholly geothermal powered[109].

The IEA Roadmap foresees geothermal electricity producing 1,400 TWh annually by 2050, see Figure 72[110]. This will amount to around 3.5 percent of global electricity production by that time on the basis of a projected 37,500 TWh/yr in 2050. This assumes that conventional high-temperature resources as well as deep aquifers with low and medium temperature resources will play an important role in geothermal development. Advanced hot rock geothermal technologies are assumed to become commercially viable soon after 2030.

Figure 71: World forecasting for the 18 GEA regions (2015 in blue) and (2050 in Red) TWh/year



Source: IEA Roadmap

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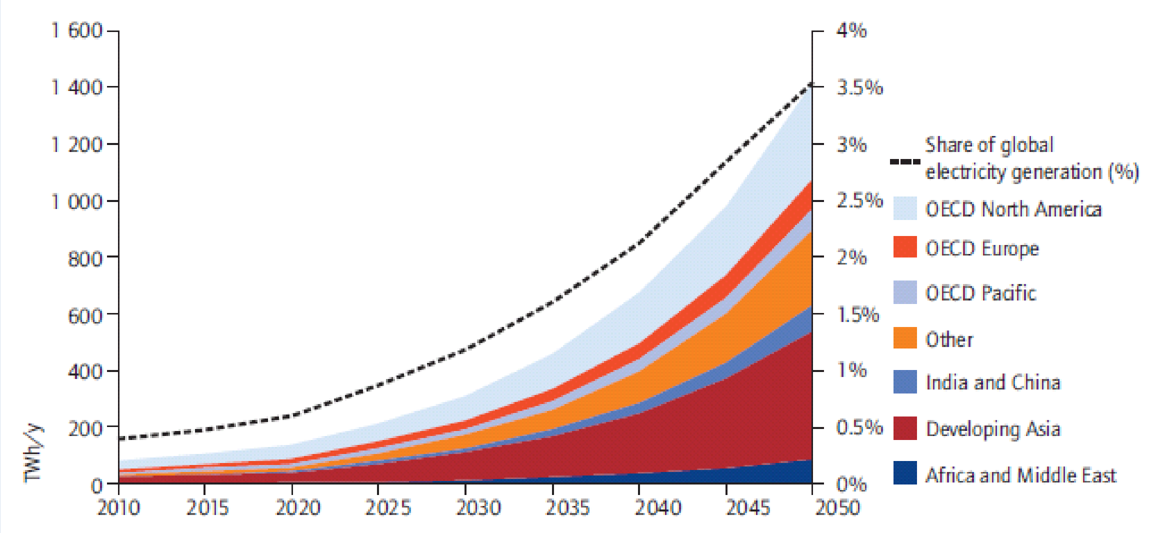
108 Bertani, R. (2011): Geothermal Power Generation in the World: 2005 – 2010 update report
109 Ibid
110 OECD/IEA, (2011), IEA Technology Roadmap, Geothermal Heat and Power

Figure 72: Roadmap vision of geothermal power production by region (TWh/y)



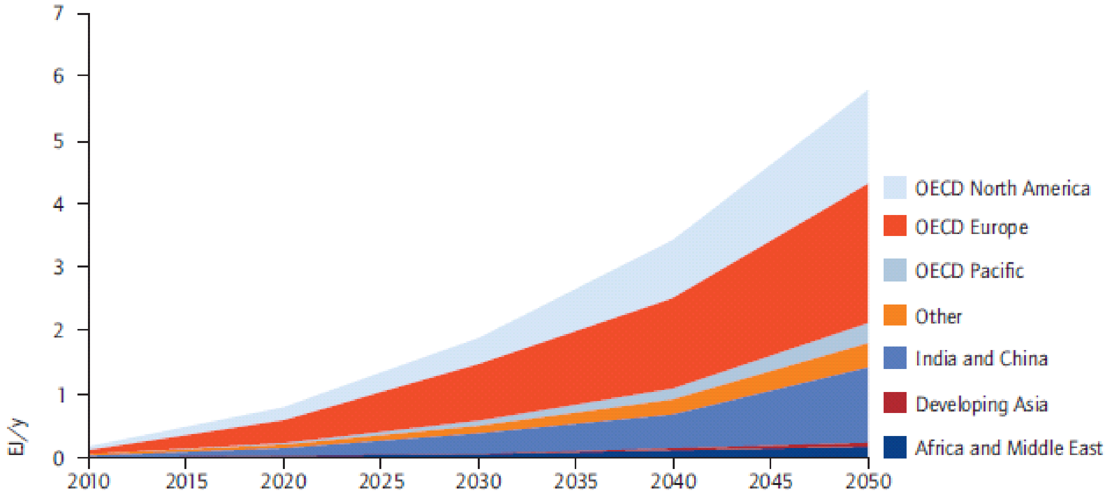
Geothermal heat use may be most relevant in colder countries. Recent rapid increases in the numbers of geothermal heat-only plants and in geothermal CHP binary plants in northern Europe confirm that interest in the direct use of geothermal heat is growing. Several East European countries face the need to renovate ageing district heating systems, while realising that they are located above or close to deep geothermal aquifers such as the Pannonian Basin. Projections for geothermal heat use are related to the development of advanced technologies, which will benefit from the combined use of heat and power as this can increase economic viability of more expensive technology.

The largest potential for geothermal heat can be found in regions with high heat demand, Europe, China and North America. However, there is great potential for geothermal power in developing countries in Asia, where abundant high-temperature hydrothermal resources have yet to be exploited. OECD North America also shows considerable growth expectations, not only from high-temperature hydrothermal resources in the western United States but also from development of EGS. Geothermal development in OECD Europe is expected to come from a combination of high temperature hydrothermal, deep aquifers with low and medium-temperature resources and EGS.

Figure 73 shows the IEA Roadmap for the growth, on a regional basis, of geothermal heat use to 2050 , when the global sum of annual direct use amounts to 5.8 EJ (about 1,600 TWh thermal energy)[111]. This scenario assumes that hot rock technology becomes commercially viable soon after 2030. Under this condition, the utilisation of heat from deep rock formations should theoretically become possible wherever rock temperatures and the properties of the underground allow the economic sale of energy

[111] Ibid

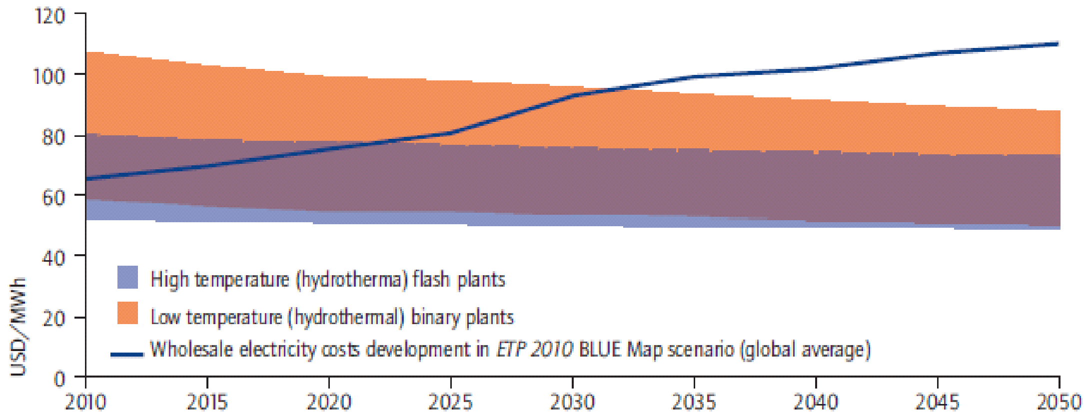
Figure 73: Roadmap vision of direct use of geothermal heat by region excluding ground source heat pumps (EJ/y)



The production costs of geothermal energy vary considerably. Flash plants in high-temperature resources are considered proven technology with an average learning rate of 5 percent[112], this implies a 5 percent reduction in investment per kW when installed capacities double. Costs of electricity production in flash plants, in many situations are already competitive and are estimated to continue to fall at a moderate rate towards 2050 (Figure 74).

Binary (hydrothermal) plants, working with lower temperature resources, are also considered to be a relatively mature technology. For binary plants, which currently have small capacities, costs will decrease to competitive levels as capacities increase. With wholesale electricity prices expected to rise over time, hydrothermal flash plants are expected to be fully competitive between 2020 and 2030. Hydrothermal binary plants should be fully competitive after 2030.

Figure 74: Range of reduction of average levelised costs of electricity production in hydrothermal flash plants and binary plants



Note: Assumptions: interest rate 10%, technical lifetime 35 years, O&M costs 2.5%
Source: IEA analysis.

[112] IEA, (2010), Energy Technology Perspectives 2010

3.3 Water-power

3.3.1 General presentation

Water power is a key renewable source of clean energy. Harnessing energy from rivers, man-made waterways and oceans to generate power fall into two broad categories, conventional hydropower and marine and hydrokinetic technologies. Conventional hydropower is a well-established mature industry while the marine and hydrokinetic energy industry is an emerging field with only a small number of demonstration projects operating around the globe.

Hydroelectric power is energy derived from flowing water. This can be from rivers or from man-made installations, where water flows from a high-level reservoir down through a tunnel and away from a dam. Turbines placed within the flow of water extract its kinetic energy and convert it to mechanical energy. This causes the turbines to rotate at high speed, driving a generator that converts the mechanical energy into electrical energy. The amount of hydroelectric power generated depends on the water flow and the vertical distance (known as "head") the water falls through.

There are three main types of hydroelectric projects, storage, run-of-river, and pumped systems. In storage schemes, a dam impounds water in a reservoir that feeds the turbine and generator, which is usually located within the dam itself. Run-of-river schemes use the natural flow of a river, where a weir can enhance the continuity of the flow. Both storage and run-of-river schemes can be diversion schemes, where water is channelled from a river, lake or dammed reservoir to a remote powerhouse, containing the turbine and generator. Pumped storage incorporates two reservoirs. At times of low demand, generally at night, electricity helps pump water from the lower to the upper basin. This water is then released to create power at a time when demand, and therefore price, is high. Although not strictly a renewable energy (because of its reliance on electricity), pumped storage is very good for improving overall energy efficiency. While hydropower is a well proven and mature technology, it is still advancing and expanding its scope of application, for example by developing cheaper technologies for small-capacity and low-head applications so as to enable the exploitation of smaller rivers and shallower reservoirs.

Ocean wave energy is mostly derived from a transfer of wind energy to the surface of the ocean[113]. Due to the difference of properties in the energy carrier media (water), wave energy is less intermittent and more predictable than other renewable technologies such as wind, although forecasting techniques need improvement. Thus, the oceans represent a huge, predictable resource for renewable energy. The main forms of ocean energy are waves, tides, marine currents, salinity gradient and temperature gradient. Wave and tidal energy are currently the most mature technologies. The energy is

[113] Ocean Wave Energy, SETIS. Strategic energy technology information service, EU Commission http://setis.ec.europa.eu/about-setis/technology-roadmap/technology-roadmaps

measured in terms of kilowatts per metre of wave front (kW/m) and can be converted to electricity in a number of ways.

However, capturing energy from waves is complex and very location specific. In general, the main types of wave energy systems are:

- Shoreline devices, either fixed to or embedded in the shoreline, do not require deep-water moorings or long underwater electricity cables and are easier to install and maintain. Their disadvantage is the less powerful wave resource available.
- Near-shore devices are deployed at moderate water depths (20-25m), at distances of up to 500m from the shore. With many of the advantages of shore-line devices, they exploit higher power wave resources. They include several point absorber systems.

The global wave energy resource exploitable with today's technology is estimated to be in the order of 1,400 TWh/year[114] with around 150-240 TWh per year of this total in Europe and around 400 TWh per year in the United States[115]. Various wave energy systems have been deployed at sea in several countries and these technologies are making the transition from research to demonstration to market penetration. Though wave energy is not yet competitive with more mature technologies such as wind, in the medium term it will contribute significantly to energy markets close to the sea.

In the longer term, wave energy could become a much more important part of the world's energy portfolio. Some of the best resources are found between 40-60° latitude, which takes in most of the European Atlantic coast, where the available resource is 30-70 kW/m with peaks to100 kW/m.

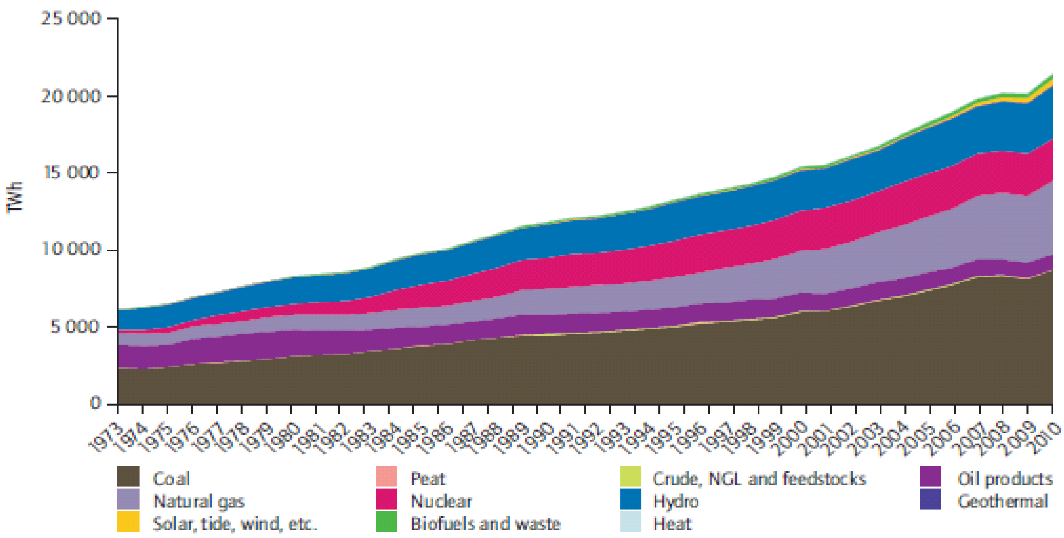
Conventional hydropower on the other hand is a fully mature technology in use in 159 countries. It provides 16.3 percent of the world's electricity (about 3,500 TWh in 2010), more than nuclear power (12.8 percent), much more than wind, solar, geothermal and other sources combined (3.6 percent), but much less than fossil fuel plants (67.2 percent)[116]. In OECD countries, hydropower's contribution is 13 percent (about 1,400 TWh in 2008). This is smaller than in non-OECD countries (19.8 percent, about 2,100 TWh in 2008), where it has increased by an annual average 4.8 percent growth rate since 1973 (see Figure 75).

[114] Ibid

[115] US DOE, (June 2011), Wind and Water Power Programme, US Department of Energy DOE/GO-102011-3287, Washington..

[116] IEA, (2012a), Electricity Information 2012, OECD/IEA. Paris, France.

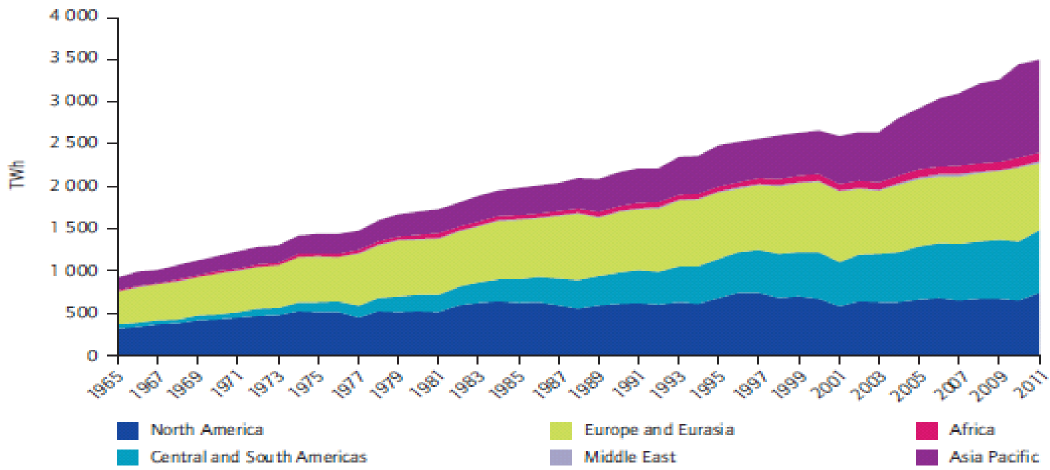
Figure 75: Global electricity generation by fuel, 1973-2010



Source: Unless otherwise indicated, material in all figures, tables and boxes derives from IEA data and analysis.

The long-term output trend reflects the growth of hydropower capacities worldwide, with an increase of 52 percent from 1990 to 2009 (see Figure 76)[117], with a particularly rapid growth in China. A slowdown between the late 1990s and the early 2000s resulted from escalating local and international controversies over large dams, among other factors.

Figure 76: Hydroelectricity generation, 1965-2011

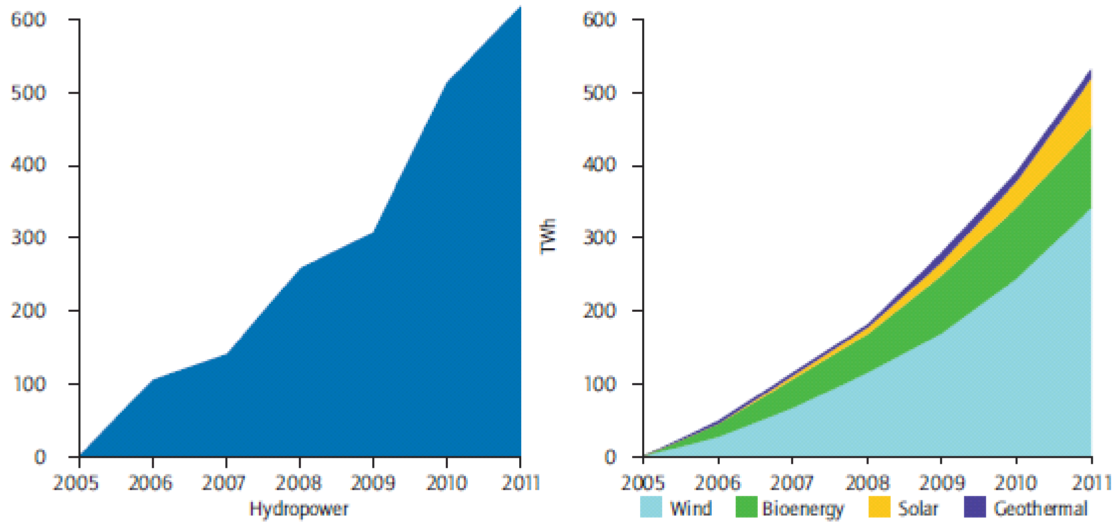


Sources: BP, 2012 and IEA analysis.

Hydropower capacity is on the rise, reaching 1,000 GW worldwide at the end of 2010. Its average annual growth rate of about 2.5 percent looks small, especially when compared to growth rates of wind and solar – but this ignores its large existing base. In the last decade, electricity generation from additional hydro capacities has kept pace with generation from all other renewables together (see Figure 77).

[117] IEA, (2012), Technology Roadmap Hydropower, OECD/IEA.

Figure 77: Electricity generation from recent additions to hydropower (left) and other renewables (right)



Source: IEA, 2012b.

3.3.2 Global and regional forecasts to 2020

The technical potential for hydropower is usually estimated at around 15,000 TWh/yr, or about 35 percent of a theoretical potential derived from the total annual runoff of precipitation.[118] Total capacity is expected to reach 1,300 GW in 2017[119] (see Figure 78). Given the long lead times of Hydropower development, these figures represent capacities in construction virtually certain to come on line.

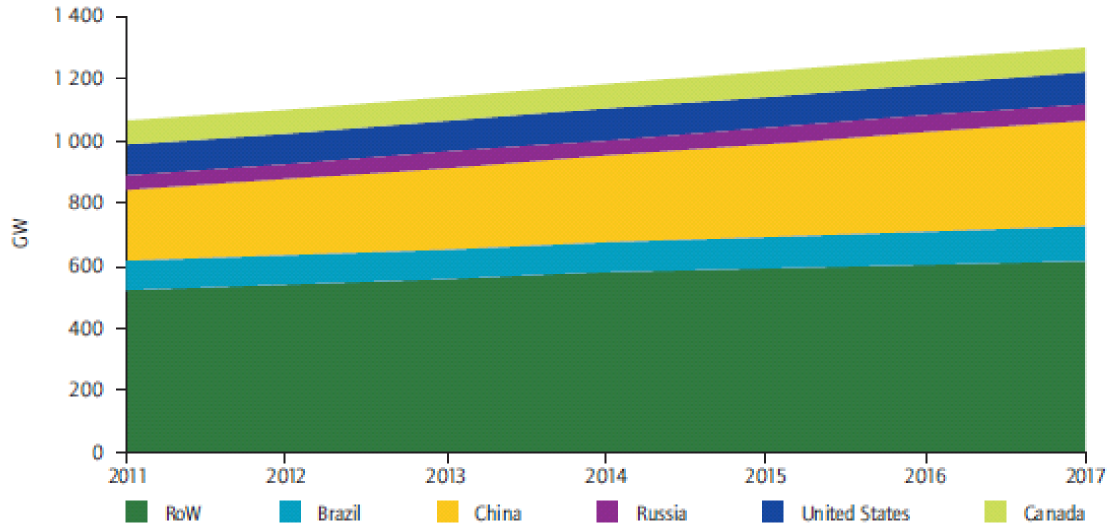
3.3.2.1 Europe

According to Eurelectric, Hydro is the current major technology in Europe, accounting for 69 percent of all renewable electricity generation. Beyond electricity, hydro facilities deliver storage capacity and other services to the grid system. Thus, hydropower is crucial for a secure supply of electricity and as a back-up for intermittent renewables. However, its growth prospects within Europe are limited and where hydropower sits in terms of the EU meeting its renewables target of 20 percent by 2020 is not clear.

The "EU Energy Trends 2030[120]," report predicts significant increases in all forms of renewables except Hydro. By 2020, the report indicates onshore wind will overtake Hydro with 348 TWh compared to hydro's 341 TWh. With flat growth predicted, hydro share of the renewable power market will decline.

[118] Ibid
[119] IEA (2012b), Medium-Term Renewable Energy Market Report, OECD/IEA.
[120] P. Capros, L. Mantzos, N.Tasios, A. DeVita and N.Kouvaritakis, (2010), EU Energy Trends 2030 – update 2009. European Commission, Brussels, Belgium.
http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2030_update_2009.pdf

Figure 78: Expected mid-term evolution of hydropower installed capacity (GW)



Source: IEA, 2012b.

However, according to the IEA Technology Roadmap 2012, only about half the technically feasible potential for hydropower in Europe (which does not include Russia and Eurasia) has been developed. The additional potential could be 660 TWh a year, of which 276 TWh would be in EU member states and more than 200 TWh in Turkey. A significant barrier for future development of hydropower in Europe is the lack of harmonisation between EU energy policy and various EU water management policies. This creates substantial regulatory uncertainties, which are amplified by highly variable national implementation of these conflicting EU legislations.

The future for hydro may lie in the development of reservoir Hydropower Plant (HPP) and Pumped Storage Plant (PSP) which could be used to facilitate the expansion of renewables. Already several EU countries are cooperating and Norway's Statnett and UK's National Grid, for example, are jointly developing a project to construct a High Voltage Direct Current (HVDC) cable between Norway and the UK. The North Sea Offshore Grid Initiative aims to provide energy security, foster competition and connect offshore wind power. It will benefit from Norway's Hydropower capacity to help with the uncertainty associated with the wind power.

Europe is at the forefront of the development of new PSP, either open-loop or pump-back. PSPs, previously used for night pumping and diurnal generation, are now used for frequent pumping and generation during either day or night, as a result of the expansion of variable renewables.

Germany, for example, which has very little conventional hydropower, already has about 7 GW of PSP and will add 2.5 GW by 2020. According to the National Renewable Energy Plans, EU countries will increase their PSP capacities from 16 GW in 2005 to 35 GW by 2020. Within this time frame the maximum potential forecast for wave energy predicts a capacity in the EU-27 of up to 10 GW by 2020.

3.3.2.2 North America

The United States' Department of Energy (US DOE) aims to double hydropower capacity through upgrades to, and optimisation of, the existing facilities, powering non-powered dams and developing small hydropower facilities. Some regions of the United States are increasing variable renewable penetration by more than 30 percent, typically through wind power and increasing amounts of solar photovoltaics. Under aggressive clean energy deployment scenarios – such as the 15 to 18 percent solar penetration targets of the Department of Energy's "Sunshot"[121] and "20 percent Wind by 2030" goals – installation of PSP and modernisation of the existing reservoir hydropower will be critical for integrating growing amounts of variable renewable energy.

Canada is already producing about 60 percent of its electricity through hydropower. The country currently exports around 40 TWh per year to the United States, about 1 percent of its electricity supply. Canada is entering a significant period of new hydropower development. A Canadian Hydropower Association study estimates that there remains 163 GW of undeveloped hydropower potential, more than twice the current capacity of about 74 GW. This potential is distributed evenly across the country. At present, 14.5 GW of new hydropower facilities are under construction or in advanced planning states and expected to come online over the next 10 to 15 year[122].

3.3.2.3 Asia

According to the Deutsche Bank Group Report[123] China is experiencing an impressive deployment of new hydropower capacities. Its hydropower generation jumped from less than 400 TWh in 2005 to an estimated 735 TWh by 2011, and is expected to increase to almost 1,100 TWh by 2017. By 2020, China will have installed around 384GW of hydropower with the potential of producing 15 percent of their annual electricity needs. This level of hydropower will reflect the use of about 86 percent of the economically feasible hydropower resources in China

In India, the Central Electricity Authority has mapped out hydropower resources by river basin, ranking the attractiveness of potential hydropower sites (CEA, 2001), for a total of 148.7 GW in 399 hydro schemes – plus 94 GW in 56 possible pumped storage projects. Three other nations bordering India have rich hydropower potential far in excess of their domestic needs, Nepal (potential of 84 GW), Bhutan (24 GW) and Burma (100 GW). India, with its large gap between demand and supply, offers a ready market.

3.3.2.4 Central and South America

Hydropower developments in Central and South America has been remarkable, especially since the 1970s, reaching 150 GW of installed capacity. About half the electricity produced in the region is water generated. This strongly contributes to the

[121] US Department of Energy, (February 2012), SunShot Vision Study,
[122] IEA, (2012), Hydropower Roadmap.
[123] Deutsche Bank Climate Change Advisors (DBCCA) (2011), Hydropower in China: Opportunities and risks, October, London.

region having the cleanest energy mix in the world (26 percent of primary energy supply from renewable sources), particularly with respect to electricity production. The available but unexploited hydropower potential is approximately 540 GW, distributed among almost all countries of the region

Historically, the Brazilian electric generation system was developed largely based on hydropower due to the large potential and favourable economics. The current hydropower generation system comprises large reservoirs, capable of multi-year regulation, arranged in complex cascades distributed over several river basins. The interconnected transmission system was developed to take advantage of the hydrological synergies, and a complementary thermal system mitigates possible unfavourable hydrological conditions. Brazil's 10-year Energy Plan 2020[124] predicts hydropower capacity increasing to about 115 GW. Although the contribution of hydropower to the electricity generation will fall from 80.2 to 73 percent, the share of renewable resources will be kept roughly constant. There is around another 20 GW coming on stream in other parts of the region by 2020.

3.3.2.5 Africa

Regional instability remains one of the main impediments to development in Africa, especially for large projects requiring extensive cross-border transmission. Grand Inga on the Congo River, potentially the largest hydro development in the world has suffered many false starts. The necessary infrastructure to generate and transfer power is immense and will affect a major part of the continent. Regulatory challenges to this and other large projects include the prevalence of state monopolies, lack of integration of water and power policies, and grid access. Thus there is unlikely to be any significant hydropower developments up to 2020.

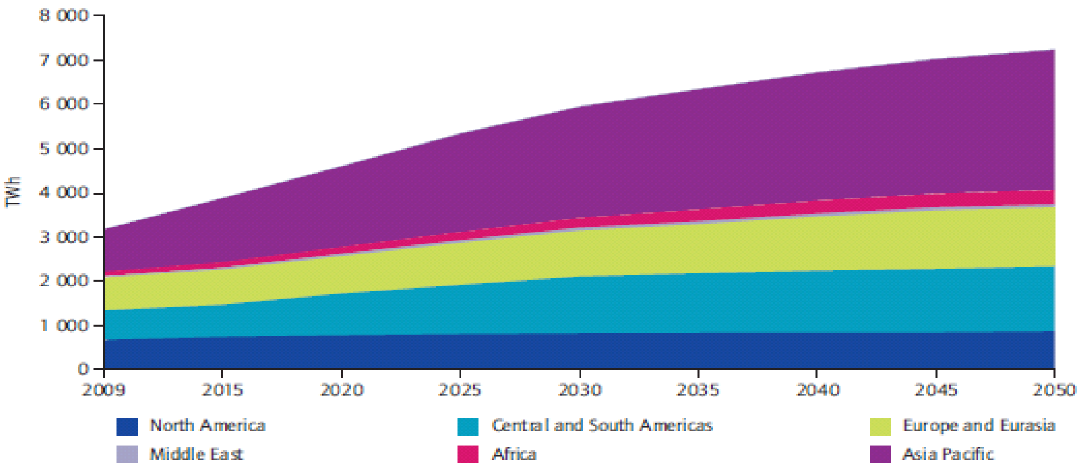
3.3.3 Global and regional forecasts beyond 2020

The growth of hydropower beyond 2020 is shown in Figure 79. This growth generation is largely focused in emerging economies and it is based on the 2°C Scenario of the IEA Energy Technology Perspectives 2012[125]. This describes how energy technologies across all energy sectors may collectively achieve the goal of reducing annual CO_2 emissions to half that of the 2009 value.

The two degree centigrade rise in global temperature (2DS) estimates a global installed hydropower capacity by 2050 of 1,947 GW, nearly twice the current level. Generation of hydro-electricity would near 7,100 TWh, a doubling of current generation leaving hydro's share of total electricity generation approximately constant.

[124] MME/EPE (2011), Brazil's 10-year Energy Plan 2020 - PDE 2020". www.mme.gov.br
[125] IEA (2012), Energy Technology Perspectives 2012, OECD/IEA

Figure 79: Hydroelectricity generation to 2050 (TWh)



Sources: IEA, 2012c and MME data.

The IEA Technology roadmap anticipates a doubling of hydropower by 2050, mostly in Asia, Africa and South America, driven by the search for energy security, environmental sustainability and promotion of social and economic development, especially for local communities. Actions necessary to achieve this target relate to the policy framework, sustainability and public acceptance, and economic and financial challenge

3.3.3.1 Europe and Eurasia

Within Europe the IEA Technology Roadmap predicts that Europe's hydropower capacity will grow to 310 GW by 2050 with hydroelectricity reaching 915TWh. In Eurasia the expected capacity by 2050 is 145GW with hydropower reaching 510TWh of which almost 75 percent will be in Russia.

3.3.3.2 North America

The IEA Technology roadmap foresees very little growth in North America with a total hydropower capacity in of 215 GW by 2050, with hydroelectricity reaching 830 TWh.

3.3.3.3 Asia

Chinese hydropower generation will likely pass the 1 500 TWh mark by 2035[126] or before. In the next 20 to 30 years, hydropower will remain second after coal within the Chinese energy mix. PSP is also developing quickly in China, with targets of 30 GW by 2015 and 70 GW by 2020[127]. Five state-owned companies are responsible for most investment in electricity generating capacities. They are usually given responsibility for all dams on a single river basin, thus allowing for harmonised management of the resource.

[126] IEA (2012c), Energy Technology Perspectives 2012, OECD/IEA
[127] Gao, H. (2012), Personal communication. Centre for Renewable Energy Development, Energy Research Institute, Beijing.

In India, the Central Electricity Authority has mapped out hydropower resources by river basin, ranking the attractiveness of potential hydropower sites[128], for a total of 148.7 GW in 399 hydro schemes – plus 94 GW in 56 possible pumped storage projects. Their development faces several constraints such as delays in environmental approvals, forest clearance, lack of infrastructure (roads, power and reliable telecommunication systems), and other issues. However, taking these delays into consideration the IEA Technology Roadmap foresees a total hydropower capacity in Asia of 852 GW by 2050, half in China and one quarter in India, with hydroelectricity reaching 2930 TWh. This region shows the largest growth projection to 2050.

3.3.3.4 Central and South America

Hydropower projects play a major part in the expansion plans of many countries in the South American region. In addition to economic, environmental and technical factors this is due most importantly to the countries' advanced energy planning. Generally, the conditions of hydropower development are favourable in Latin America and the Caribbean. Many countries have established legislation in this area, with guidelines for negotiation and consultation with affected communities.

On the basis of the 2DS, the IEA Technology Roadmap foresees a total capacity in central and South America of 240 GW by 2050, of which 130 GW will be in Brazil alone. Hydroelectricity generation would reach 1 190 TWh, again more than half in Brazil.

3.3.3.5 Africa

The African continent has the largest proportion of untapped hydropower potential, with only 8 percent currently developed. Most of this potential lies in Africa's many regional and cross-boundary river basins, including the Congo, Nile, Niger and Zambezi rivers. The necessary infrastructure to generate and transfer power is immense and will affect a major part of the continent. Regulatory challenges to this and other large projects include the prevalence of state monopolies, lack of integration of water and power policies, and grid access.

While the development of large projects will remain a challenge for Africa in the foreseeable future, smaller hydropower projects are easier to fund, have smaller social impacts and shorter project development cycles. In conjunction with increased investment in the strengthening and maintenance of regional distribution and transmission networks, these initiatives will have significant impact on the short- to medium-term energy shortages on the continent.

The IEA Technology roadmap foresees a total hydropower capacity in Africa of 88 GW by 2050, with hydroelectricity generation reaching 350 TWh.

It is interesting to relate the projections given above to the more general projections of the fuel mix in power generation under the various scenarios of Energy Technology

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[128] CEA (Central electricity Authority) (2001), Preliminary Ranking Study of Hydro Electric Schemes I to III & V to VII Volumes), CEA, Government of India, New Delhi, October.

Perspectives[129], as this clarifies the twin roles of hydropower providing clean, renewable electricity and enabling the grid integration of variable renewables. The 2DS shows a strong trend toward diversification with the most variable renewable sources such as wind, solar photovoltaics and marine increasing the most, contributing to 22 percent of the total supply. These variable inputs to the grid will need to be balanced and PSP is seen as a means of achieving this goal.

Thus the timing of investment in complementary technologies also needs attention. While policy makers plan to further deploy renewable electricity-generating technologies, they should be aware that onshore wind power or photovoltaic power plants have significantly shorter lead times than the reservoir HPP or PSP that could be necessary to balance the additional variability on electric grids. Most importantly, the short-term market effects of renewables might be to depress electricity prices on spot markets and reduce the gap between peak and base-load prices, thereby undermining the business model of PSP and, to a lesser extent, of reservoir HPP projects. Thus market design reforms and renewable energy planning must be implemented in parallel and consistent manner. This implies that the need for storage to accommodate variable renewables is still not fully understood at present and that the markets do not fully value this requirement. In the longer-term, market designs need to evolve to ensure that storage and reservoir hydropower, as well as other means, are given the appropriate market value for their flexibility and develop fast enough to balance the rise of variable renewables while preserving energy security for all.

3.4 Energy from biomass

3.4.1 General Presentation

Since the beginning of civilization, biomass has been a major source of energy throughout the world. Biomass is the primary source of energy for nearly 50 percent of the world's population (e.g., Karekezi & Kithyoma, 2006)[130] and wood biomass is a major renewable energy source in the developing world, representing a significant proportion of the rural energy supply (Hashiramoto, 2007)[131]. Most of this is traditional biomass, which plays an important role in providing energy for cooking and heating, in particular to poor households in developing countries. In the past decade, the number of countries exploiting biomass opportunities for the provision of energy has increased rapidly, and has helped make biomass an attractive and promising option in comparison to other renewable energy sources.

Biomass is the largest single renewable energy source today, providing 10 percent of global primary energy supply[132]. It plays a crucial role in many developing countries,

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[129] IEA (2012), Energy Technology Perspectives 2012, OECD/IEA

[130] Karekezi S., Kithyoma W. 2006. Bioenergy and Agriculture: Promises and Challenges. Bioenergy and the Poor. In: 2020 Vision for Food, Agriculture, and the Environment.

[131] Hashiramoto O. 2007. Wood-product trade and policy issue. Cross-sectoral policy developments in forestry, pp.24-35.

[132] IEA, (2012), Technology Roadmap, Bioenergy for Heat and Power.

where it provides basic energy for cooking and space heating, but often at the price of severe health and environmental impacts. The deployment of advanced biomass cooking stoves and clean fuels, and additional off-grid biomass electricity supply in developing countries, are key measures to improve the current situation and achieve universal access to clean energy facilities by 2030.

Biomass is capable of providing all the energy services required in a modern society, both locally and in most parts of the world. Renewability and versatility are, among the important advantages of biomass as an energy source. Moreover, compared to other renewables, biomass resources are common and widespread across the globe. Thus biomass is a sustainable energy supply and with increasing prices for fossil fuels and the availability of stocks of wood raw material which has had a major influence on the promotion of wood energy policies (e.g., Hashiramoto, 2007; Sims, 2003)[133].

Biomass is any organic, *i.e.* decomposing, matter derived from plants or animals available on a renewable basis. Biomass includes wood and agricultural crops, herbaceous and woody energy crops, municipal organic wastes as well as manure. Bioenergy **i**s energy derived from the conversion of biomass where biomass may be used directly as fuel, or processed into liquids and gases. The biomass resources currently available come from a wide range of sources (Figure 80)[134]. These can be classified into woody biomass, agricultural sources and wastes. Biomass can be used in several fields (heat, power, liquid biofuels and biobased products),

Biomass is a unique source of renewable energy as it can be provided as solid, gaseous or liquid fuel and can be used for generating electricity, transport fuels, as well as heat – in particular, high temperature heat for industry purposes. Bioenergy can be stored at times of low demand and provide energy when needed. Depending on the type of conversion plant, bioenergy can thus play a role in balancing the rising share of variable renewable electricity from wind and solar in the power system. In addition, the possibility to store biomass allows for generation of biomass-derived heat to meet seasonal demand, as is commonly done for instance in Nordic countries.

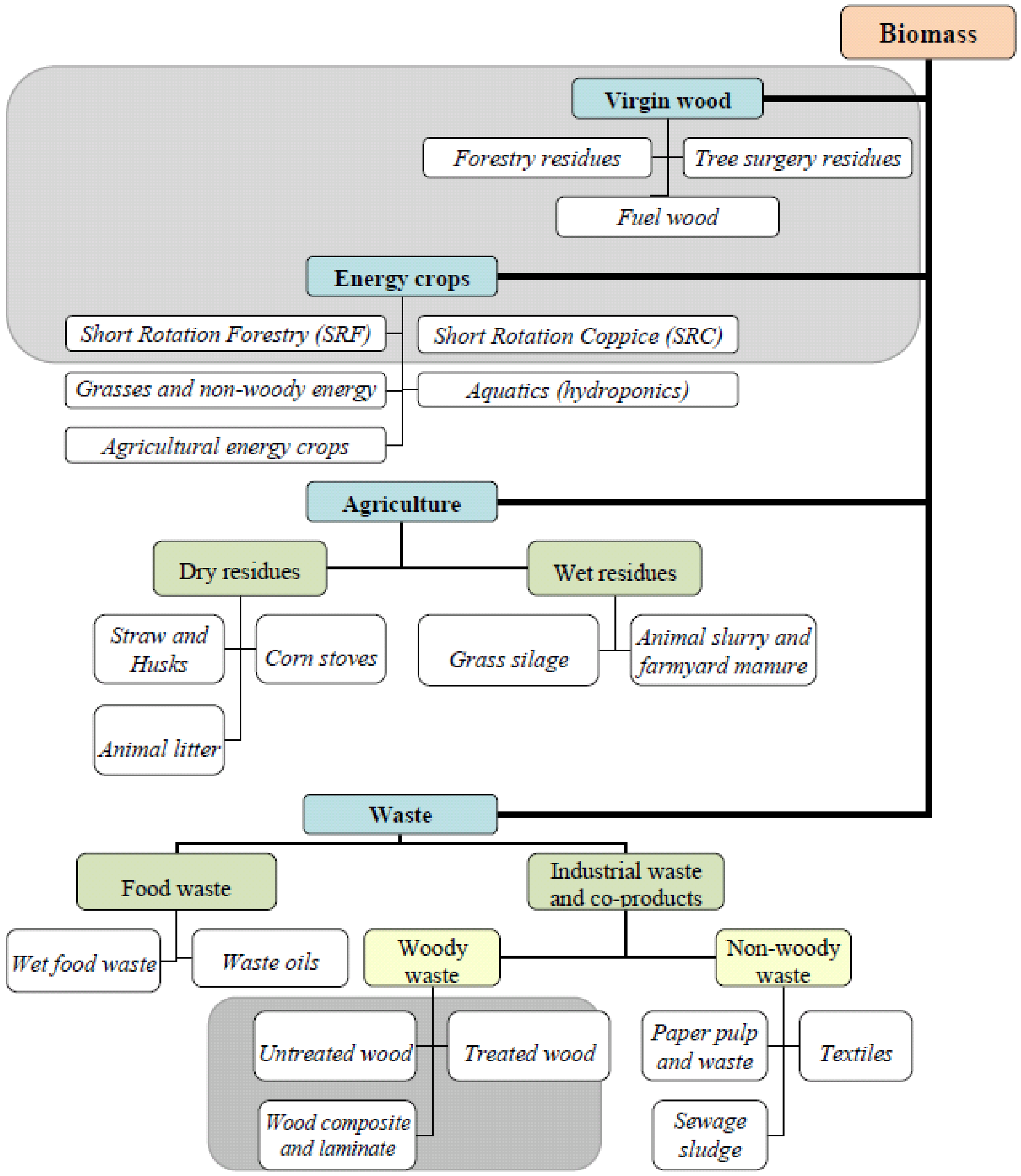
Since bioenergy can be generated from energy crops and biomass residues, as well as organic wastes, there is considerable potential for new sources of income along the whole value chain, from cultivation to harvest, processing and conversion into energy. This can potentially benefit farmers and forest owners and support rural development[135]. Biomass feedstock's in the form of wood chips, pellets, pyrolysis oil corn biomethane, etc., can be traded globally. Regions with good biomass supply and those with insufficient supply of cost-competitive biomass can be connected within an international market to meet supply and demand patterns.

[133] Ibid & Sims R.H. 2003. Bioenergy to mitigate for climate change and meet the needs of society, the economy and the environment. Mitigation and Adaptation Strategies for Global Change 8(4), 349-370

[134] Svetlana Ladanai & Johan Vinterbäck, SLU, Global Potential for Sustainable Biomass for Energy, Institutionen för energi och teknik, Swedish University of Agricultural Sciences, Department of Energy and Technology.

[135] IEA, (2012), Technology Roadmap, Bioenergy for Heat and Power.

Figure 80: Sources of biomass for production of energy. Biomass from woody materials are in the shaded area.



However, there are some sensitive aspects to be considered in the sustainable development of bioenergy for heat and power. The large-scale deployment of bioenergy can create competition with existing uses of biomass such as for food and feed, or forest products, or can compete for land used for their production. This competition can create upward pressure on agricultural and forestry commodity prices and thus affect food security. In some cases bioenergy may also lead to direct and indirect land-use changes resulting in release of GHG emissions, more intensive land use, pressure on water resources and loss of biodiversity.

Not all of the mentioned aspects are necessarily negative, however. Production of bioenergy feedstock's can create additional income sources and help stabilize prices for agricultural and forestry products, creating new opportunities for farmers to invest in more efficient production and related socioeconomic benefits for rural communities

A sound policy framework will be vital to minimise the potential negative aspects and maximise social, environmental and economic benefits of bioenergy production and use. Only then can bioenergy contribute to meeting energy demand and reducing GHG emissions in a sustainable way, as envisioned in this roadmap.[136]

Bioenergy accounted for roughly 10 percent (50 EJ[137]) of world total primary energy supply (TPES) in 2009[138], with most of this being traditional biomass in non-OECD countries. In OECD countries, bioenergy supply mainly uses modern technologies and overall plays a considerably smaller role than in developing regions (see Figure 81). Although bioenergy can be competitive with fossil fuels today under favourable circumstances (with high fossil fuel prices and/or very low feedstock costs) in most cases of commercial use, support policies are needed to offset cost differences with fossil fuels

Most bioenergy is currently consumed in the buildings sector. The major part of this occurs in developing countries in Asia and Africa (Figure 82)[139], where the traditional use of biomass in basic cooking-stoves or three-stone fires is still the main source of energy in the residential sector. Traditional biomass, including wood, charcoal, agricultural residues and animal dung, is mostly used for cooking and water heating; in colder climates biomass stoves also provide space heating. The traditional use of biomass is associated with very low efficiencies (10 to 20 percent) and significant health impairment through smoke pollution. In addition, the biomass often comes from unsustainable sources, leading to deforestation and soil degradation. Nonetheless, population growth in developing countries means that traditional biomass use is expected to continue to grow in the next decades, potentially creating considerable environmental and health problems unless more efficient stoves and fuels (biogas, ethanol) are deployed to reduce pollutants and improve efficiency.

In most OECD countries bioenergy plays only a minor role in buildings and has been growing slowly. Pellet stoves are gaining some momentum in certain countries, where government support is available and/or direct cost benefits compared to fossil fuels make such stoves profitable.

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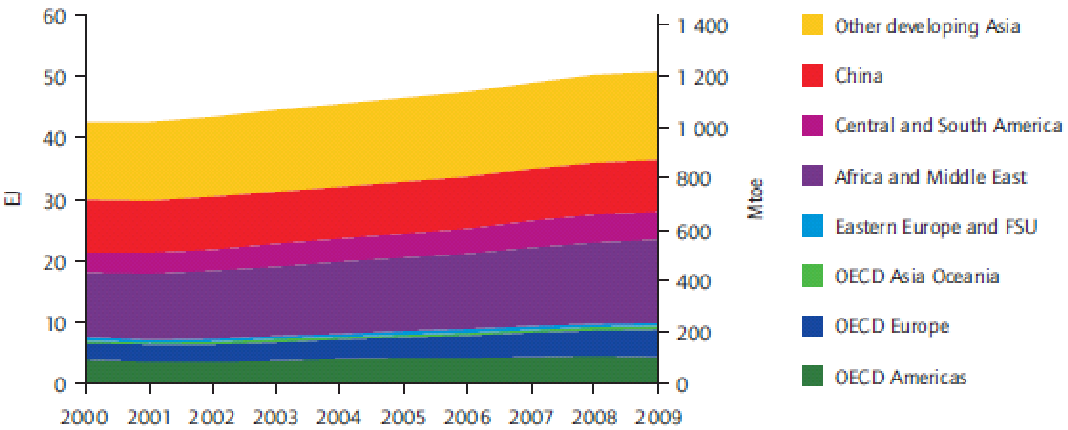
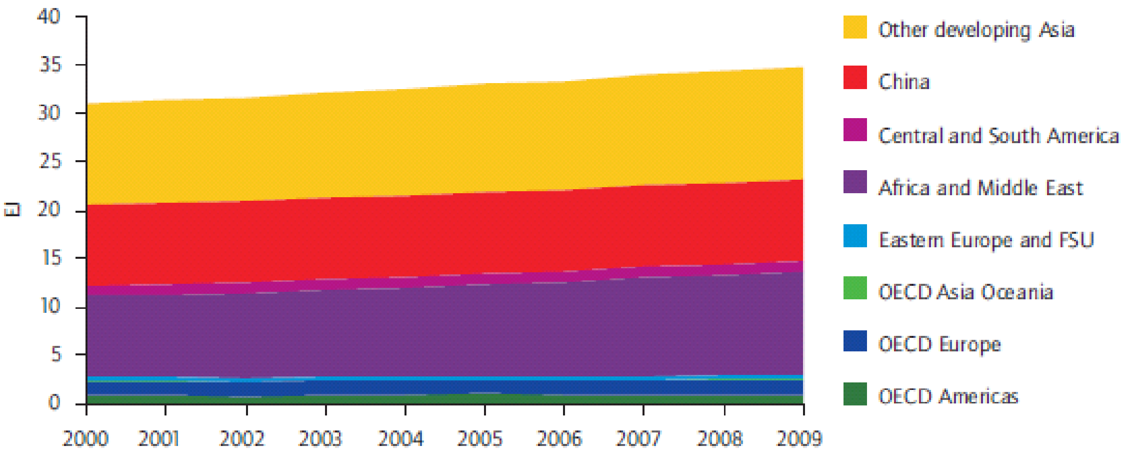
[136] Ibid
[137] 1 EJ = 1018 J
[138] Ibid
[139] Ibid

Figure 81: Global primary energy supply



Source: IEA, 2012

Figure 82: Total final bioenergy consumption in buildings



Source: IEA, 2012

Commercial bioenergy heat production, on the other hand, has been growing more rapidly. It has doubled over the last decade as a result of increased co-firing in coal plants and installation of dedicated biomass co-generation power plants. Use of biomass for district heating is particularly advanced in Sweden, Finland, and Austria, but other countries are now following this path.

Electricity supply from bioenergy has been rising steadily since 2000; in 2010 bioenergy provided some 280 TWh of electricity globally, equivalent to 1.5 percent of world electricity production. Power generation from biomass is still concentrated in OECD countries, but China and Brazil are also becoming increasingly important producers thanks to support programmes for biomass electricity generation, in particular from agricultural residues[140] (see Figure 83).

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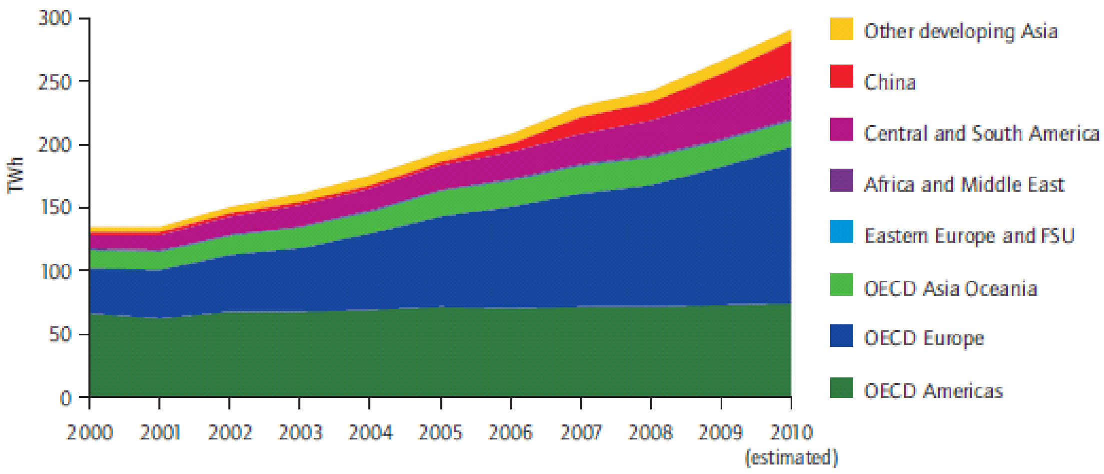
[140] IEA, (2012), Technology Roadmap, Bioenergy for Heat and Power

Figure 83: Global bioenergy electricity generation 200-2010



Source: EIA, Roadmap, 2012

Models established in China and Brazil could also become a viable way to promote bioenergy electricity generation in other non-OECD countries with high energy demand growth rates and high availability of biomass residues in agro-processing industries such as sugar or rice. Currently, bioenergy electricity is principally derived through combustion and power generation via steam turbines, including through co-firing of biomass with coal. In several emerging and industrialised countries (including Brazil, Canada, China, the European Union, South Africa, and the United States), support policies are an important driver for the development of modern bioenergy supply (IEA, 2012b). Some regions have experienced strong growth rates for bioenergy electricity and commercial heat over the last decade. In some countries this growth has recently slowed, due to constrained government support in combination with rising feedstock costs and resulting lack of competitiveness of bioenergy with other energy sources. Concerns over the sustainability of bioenergy – mainly related to biofuels for transport – have also had an impact. Addressing these economic and non-economic barriers will be vital to ensure sustained growth of bioenergy.

A wide range of biomass feedstocks can be used for heat and/or power production. These include wet organic wastes such as sewage sludge, animal wastes and organic liquid effluents, the organic fraction of municipal solid waste, residues from agriculture and forestry, and purpose grown energy crops, including perennial lignocellulosic plants. As a feedstock for producing electricity or heat, biomass has a number of advantages over fossil fuels. It is widely distributed, relatively easy to collect and use and can produce less net CO_2 emissions than fossil fuels per unit of useful energy delivered, if sourced sustainably (see sustainability section for further discussion). In addition, biomass usually contains less sulphur than coal or oil. On the other hand the combustion characteristics of biomass feedstocks differ markedly from those of fossil fuels like oil, coal and gas, posing some technical and economic challenges:

- The bulk density and calorific value are lower, which means that transporting untreated feedstocks can be more difficult and costly. This can limit the area

- within which it is possible to source biomass and limit the economic scale of operation. Some biomass resources are generated seasonally, *e.g.* during a specific harvesting period, so storage is needed to provide energy all year round.

- Systems for storing and handling and for feeding raw biomass into combustion or conversion systems have to be bigger and therefore more expensive than the fossil fuel equivalents.

- Untreated biomass often contains high levels of moisture, which reduces the net calorific value and affects handling and storage properties. Dry biomass also absorbs water and undercover storage is often necessary to keep the fuels dry and avoid degradation.

- The thermo-chemical characteristics and chemical composition of biomass feedstocks differ markedly from solid fossil fuels due to typically higher oxygen, chlorine and alkaline content. Combustion systems (including the feed systems, furnace, particle and emission abatement systems, and ash management) have to be designed specifically with the feedstock in mind, to ensure clean and efficient combustion and to avoid fouling, and corrosion problems.

This means that systems for using biomass have to be specifically designed to match the feedstock properties, and that pre-treatment of biomass before conversion to energy is often necessary. Further efforts to introduce international technical standards for different types of (pre-treated) biomass feedstocks would help to reduce technical challenges and costs related to conversion of biomass to energy.

The most common form of bioenergy still used as the principal source of heat and for cooking and space heating in many less developed countries, involves the use of an open fire or a simple stove – commonly referred to as traditional biomass use. The key problem of this type of bioenergy is that the biomass is often sourced unsustainably, leading to forest degradation. In addition, open fires or simple stoves show very low conversion efficiency – often in the range of 10 percent to 20 percent – and can cause severe problems of smoke pollution, as well as black carbon emissions with considerable global warming potential

With comparatively small investments in new, more efficient biomass stoves for cooking or heating, in the cost range of a few dollars up to $100, can lead to significantly improved efficiencies. They reduce fuel use and improve indoor air quality, while providing employment in the stoves supply chain. Initiatives such as The Global Alliance for 'Clean Cook stoves', which aims for 100 million homes to adopt clean and efficient stoves and fuels by 2020 (Global Alliance for Clean Cookstoves, 2012) will be critical to achieve the envisaged level of energy access, and reduce the environmental and health problems associated with traditional biomass use.

Large-scale biomass combustion plants to produce heat are a mature technology; in many cases the heat generated is competitive with that produced from fossil fuels. Modern on-site biomass technologies include efficient wood log, chips, and pellet burning stoves, municipal solid waste (MSW) incineration, and use of biogas. Bioenergy heat can also be produced in co-generation power plants, when there is a steady heat demand, for instance from industry or a district heating network. In such cases overall efficiencies of around 70 to 90 percent are possible.

Commercially available systems range from very large boilers with a capacity between 1 MW and 10 MW commonly used in the paper and timber industry, to small installations that provide heat for individual houses from logs, wood chips or wood pellets. Heat can also be provided from biogas or biomethane, and small-scale (10 kWth to 500 kWth) biomass gasifier systems for heating purposes are entering the market in China, India and South-East Asia, although their reliability of operation still needs to be improved[141].

In biomass-based power plants, the heat produced by direct biomass combustion in a boiler can be used to generate electricity via a steam turbine. This technology is currently the most established route to produce power from biomass in stand-alone applications. The efficiency of power generation depends on the scale of the plant. At a scale compatible with the availability of local biomass feedstocks (10 MW to 50 MW), power generation efficiencies using steam turbines tend to be in the range of 18 to 33 percent, somewhat lower than those of conventional fossil-fuelled plants of similar scale.

Gasification is a thermo-chemical process in which biomass is transformed into fuel gas, a mixture of several combustible gases. Gasification is a highly versatile process, because virtually any (dry) biomass feedstock can be efficiently converted to fuel gas. The produced gas can, in principle, be used to produce electricity directly via engines or by using gas turbines at higher efficiency than via a steam cycle, particularly in small-scale plants (<5 MWe to 10 MWe).

Figure 84 shows an overview of conversion technologies and their current development status.

At larger scales (>30 MWe), gasification-based systems can be coupled with combined gas and steam turbines, again providing efficiency advantages compared to combustion. The efficiency and reliability of such plants still need to be fully established. Although several projects based on advanced concepts such as biomass integrated gasification combined cycle (BIGCC) are in the pipeline in northern Europe, United States, Japan, and India, it is not yet clear what the future holds for large-scale biomass gasification for power generation[142]. Developments and pilots in IGCC, for instance in China, will likely also contribute to key technology learning that may help development of BIGCC technologies, including in developing countries where related pilot projects and R&D are underway.

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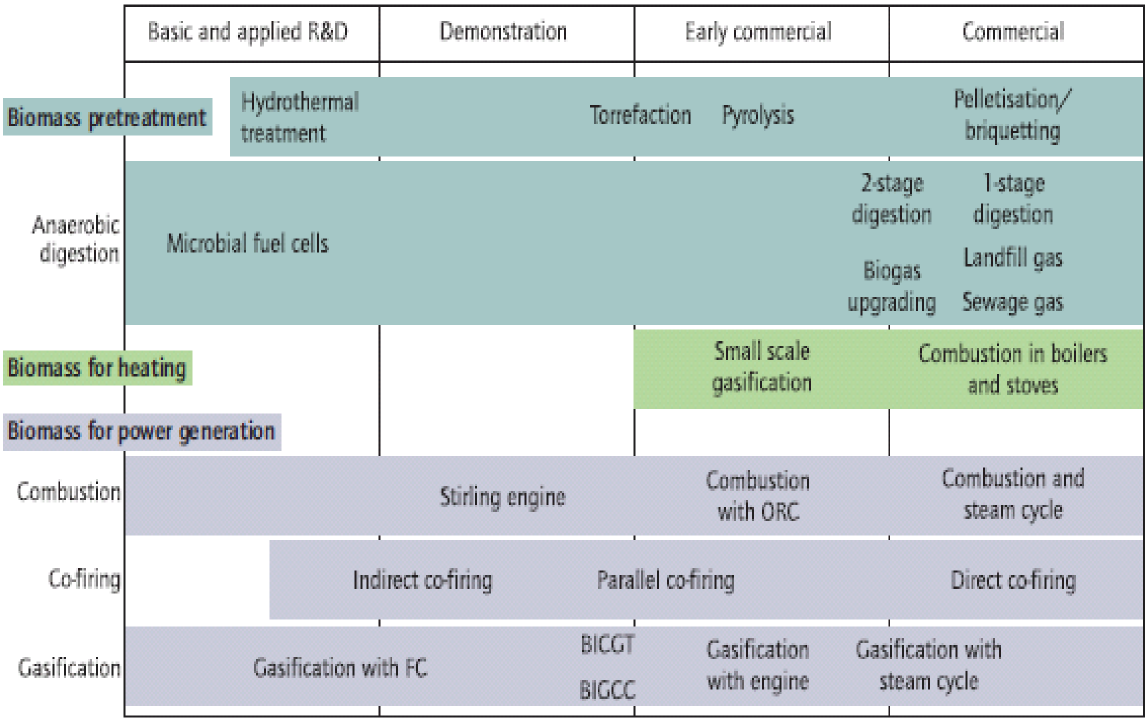
[141] Bauen et al. (2009), Biomass - A Sustainable and Reliable Source of Energy
[142] Ibid.

Figure 84: Overview of conversion technologies and their current development status



Note: ORC = Organic Rankine Cycle; FC = fuel cell; BICGT = biomass internal combustion gas turbine; BIGCC = biomass internal gasification combined cycle

Source: Modified from Bauen *et al.*, 2009

The economic viability of bioenergy derived electricity and/or heat depends on which of the wide variety of feedstocks and technologies are deployed, and critically on the scale of operation and availability of heat sinks (district heating network, demand in industry). This is particularly important as far as electricity generation is concerned, as with increasing scale efficiency increases and the capital costs per unit of generation decline sharply. Electricity generation can in some cases be competitive today where low-cost fuels such as wastes or process residues are used, the scale of generation is high or there is also a good heat load enabling effective co-generation operation. However in most cases generation currently requires some level of financial support, particularly where the external costs of fossil fuel based generation are not fully taken into account. Heat generated from biomass can also be a cost competitive option today, again depending on feedstock and scale of operation, and on the fuel source being replaced

A variety of different environmental, social and economic issues need to be addressed to ensure the overall impact of bioenergy is positive compared to that of fossil fuels. The debate about potential negative environmental, social, and economic impacts of bioenergy has been principally associated with biofuels for transport, where the main feedstocks today (starch, sugar and oil crops) are also used as feed and food. However the same sustainability issues are also relevant for heat and power generated from biomass, and the whole lifecycle impact of bioenergy production needs to be carefully considered.

One of the key issues for heat and power generated from biomass is the reduction of lifecycle Greenhouse Gas (GHG) emissions compared to the use of fossil fuels, as this is one of the key drivers to promote bioenergy use. GHG benefits of bioenergy systems can be evaluated by comparing them with the energy system they replace through a lifecycle assessment (LCA)[143]. In most LCA and emission accounting guidelines, the CO_2 released during the conversion of biomass is considered "neutral" as it has been absorbed from the atmosphere during its growth, and will be absorbed again by plant regrowth (provided the biomass is sourced sustainably). This assumption is recently being questioned, however by Cherubini [144].

While GHG life-cycle emission savings are an important environmental aspect of bioenergy use, there are several other issues to be considered: biodiversity, impact on soil fertility and soil degradation, the use of water and impact on water quality, employment, and potential health impacts, among others. Key environmental concerns include the overuse of natural resources through deforestation or increased extraction rates of forest biomass, with negative impact on soil quality, carbon stocks and biodiversity. For agricultural biomass, the issues include unsustainable intensification associated with excessive residue removal, excessive use of fertiliser and pesticides, and overuse of irrigation water. Most of these issues can be addressed by sound land-use planning, strict application of good management practices, and the use of well-adapted indigenous energy crops[145] (*e.g.* use of perennial instead of annual species)

3.4.2 Global and regional forecasts until 2020

The global demand for biomass is increasing and biomass consumption is expected to increase to 52EJ by 2020 (see Figure 85).

3.4.2.1 European Union Region

The European Commission foresees biomass playing a vital role in reaching Europe's 2020 targets for sustainability. This is probably because heat and power from biomass today accounts for almost two thirds of the consumption of renewable energy in the EU, and because biomass has a number of well-known advantages as an energy source. It reduces carbon emissions substantially if sustainability aspects are carefully managed, it is a proven technology, it can function as reliable base-load capacity, and it is in many applications relatively capital-light.

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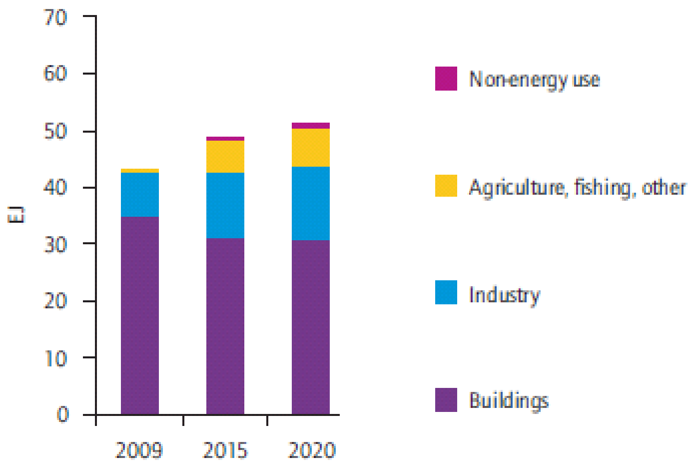
143 Bird, N., A. Cowie, F. Cherubini and G. Jungmeier (2011), Using a life-cycle assessment approach to estimate the net greenhouse-gas emissions of bioenergy, IEA Bioenergy: ExCo:2011:03.

144 Cherubini, F., N.D. Bird, A. Cowie, G. Jungmeier, B. Schlamadinger and S. Woess-Gallasch (2009), "Energy- and greenhouse gas-based LCA of biofuels and bioenergy systems: Key issues, ranges and recommendations", Resources, Conservation and Recycling, Vol. 53, No. 8, pp. 434-447.

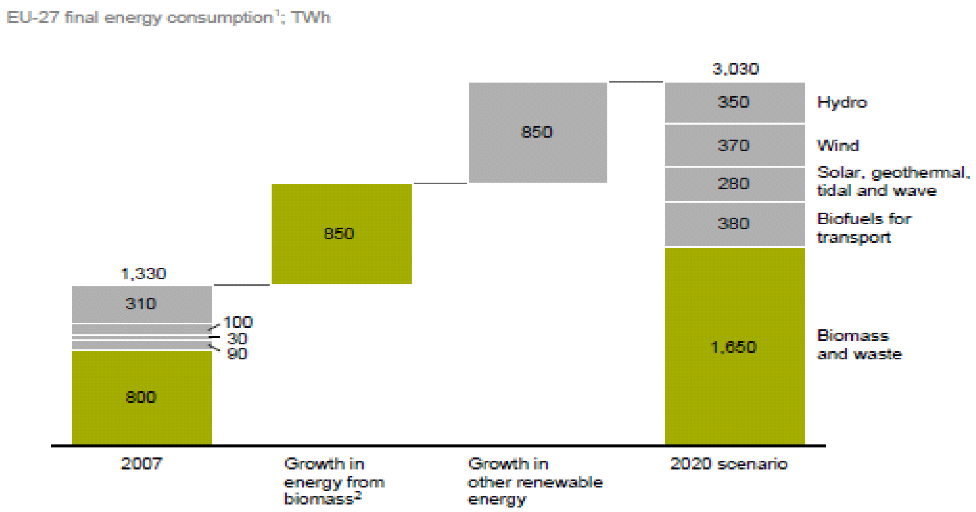
145 IEA, (2012), Technology Roadmap, Bioenergy for Heat and Power.

Figure 85: Road map of biomass energy consumption to 2020 in different sectors (excluding transport fuels)



In the scenarios published by the European Commission for how Europe could meet its targets, as shown in Figure 86, annual biomass heat and power consumption is predicted to grow by a full 850 terawatt hours (TWh) by 2020 to a total of 1,650 TWh, i.e., a doubling of today's level and a growth equal to the combined growth of all other renewable energy sources. As points of reference, 850 TWh corresponds to roughly half of today's energy consumption sourced from coal and lignite in the EU countries. In terms of primary energy supply, the consumption is roughly equal to the annual harvest of roundwood in the EU[146].

Figure 86: Role of biomass in meeting Europe's renewable energy targets-European Commission scenario



1 Average of the "EC proposal with RES trading" and the "EC proposal with CDM and RES trading" scenarios
2 Varies between 839 and 886 TWh depending on scenario
SOURCE: Capros et al (2008):Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables; IEA

Current trends suggest biomass energy is not on track to play the important role envisioned by the European Commission. Between 2000 and 2007, biomass energy consumption grew by roughly 25 TWh per year. Some 10 TWh of this came from direct

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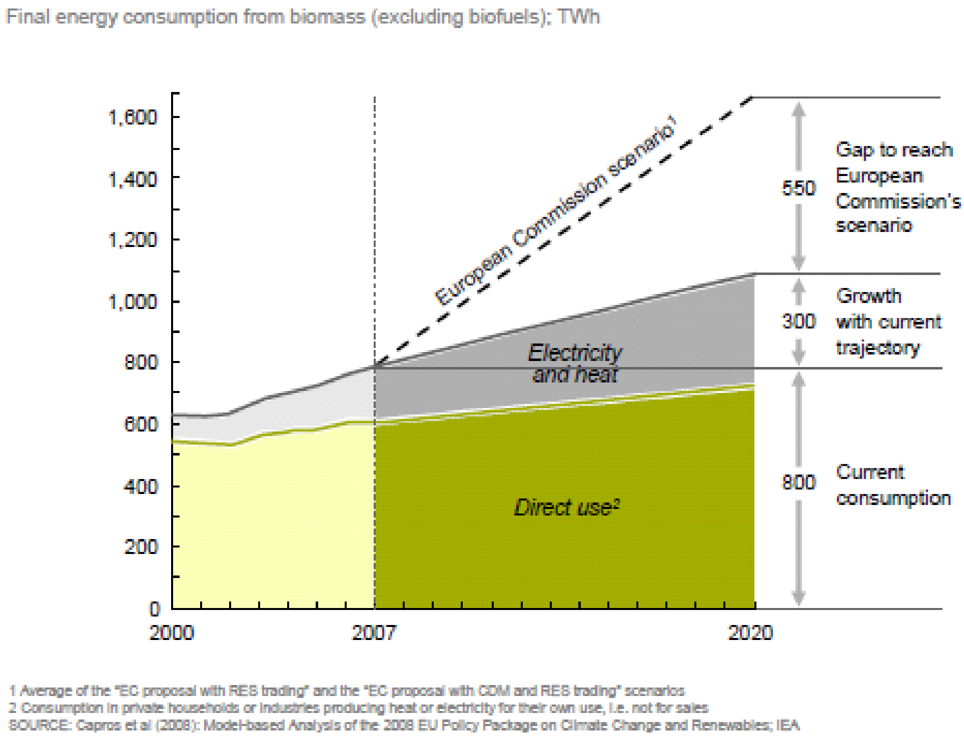
146 Hogan Michael, Otterstedt Jens, Roine Morin Roine, & Wilde Jonas, (2010), Biomass for Heat & Power – Opportunity & Economics 2010, the European Climate Foundation, Sveaskog, Södra, and Vattenfall, presented to the European Commission.

use – i.e., companies operating their own plants, or households using biomass for domestic heating, and 15 TWh from commercial electricity and heat generation.

If growth continues at this rate, the annual consumption of biomass energy will rise with a total of 300 TWh to around 1,100 TWh by 2020. This is a significant growth which is approximately equivalent, for instance, to the combined electricity consumption of Sweden, Norway, and Finland. It will, however, still leave a major gap of some 550 TWh towards the European Commission's scenarios, as illustrated in Figure 87. This is problematic, as the other renewable energy sources also grow significantly in the scenarios, and it is hard to see that they could compensate for a biomass short-fall in this order of magnitude

Figure 87: Current biomass energy growth compared to the growth required to reach the European Commission scenario



One of the main reasons why biomass growth is much slower than expected is that there is a considerable amount of uncertainty around several important aspects of the attractiveness of biomass as a renewable energy source, an uncertainty that creates hesitation towards biomass on the parts of companies and policy makers. Examples of important areas of uncertainty include:

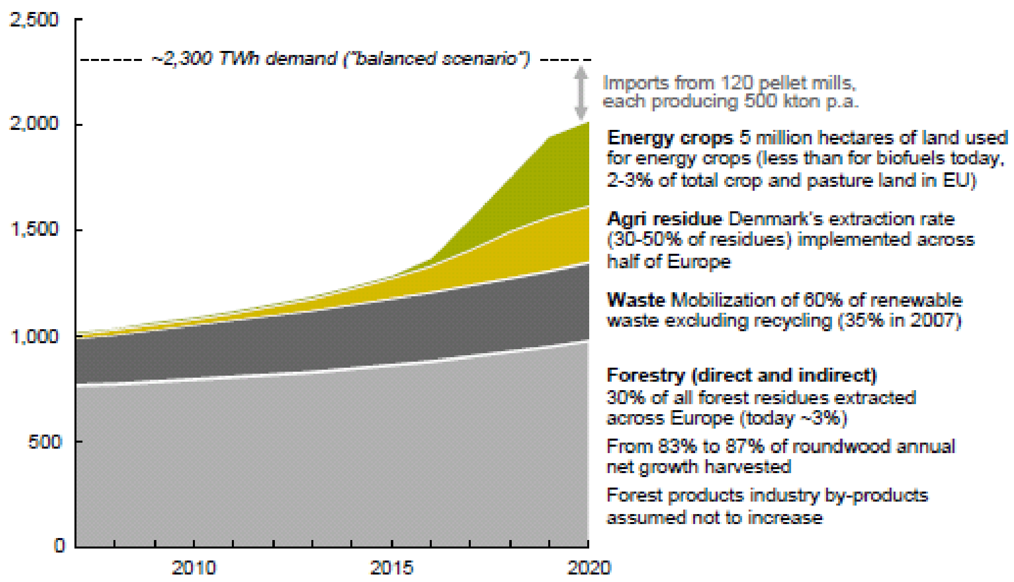
- **The supply of biomass**. Will there will be an adequate, reliable supply of biomass for heat and power generation, given the need for food and feed production, the forest industry's needs, and potential future uses of biomass, such as in the production of biochemicals?
- **The economic competitiveness of biomass energy**. Will it be able to compete with other energy sources over time without significant subsidies? In other words, would transitional government support for biomass as an energy source "pay off"?

- **The eco-credentials of biomass energy**. What are its advantages and disadvantages relative to other renewable energy sources and fossil fuels?
- **Sustainability frameworks.** Which types of frameworks are necessary to ensure sustainability?

To meet the EU Commission's scenario of 1,650 TWh final energy consumption from biomass heat and power in 2020, supply of primary energy from biomass needs to be between 1,850 and 3,400 TWh, depending on how the biomass is being used. This will be a considerable challenge for the EU as about 75 percent of this energy in 2007 originated from forestry either directly from fuel wood or forest residues or indirectly from industry by-products such as sawdust and black liquor. The remainder is mostly waste (recovered wood, municipal solid waste, manure, and sewage). Agricultural residues and energy crops are other supply sources, but represent less than 2 percent of the potential supply. Thus with the domestic supply growth rate of 35-40 percent then extrapolating this growth yields about 1,500 TWh of primary energy per year in 2020, well below the 2,300 TWh needed in the balanced generation scenario.

The EU has developed an aggressive EU supply scenario as a method of investigating the domestic potential of biomass which could be provided by 2020 if Europe chose to focus on implementing this resource. The scenario considers the land available, the types of feedstock available, the appropriate sustainability level and the associated time line. The result is that 1,000 TWh of additional renewable energy supply is available domestically to supply about 2,000 TWh annually by 2020 (see Figure 88).

Figure 88: Aggressive EU supply mobilization scenario



SOURCE: AEBIOM; EEA (2006); IEA; Capros et al (2008): Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables; McKinsey biomass model (2009)

Two thirds of these additional resources are in energy crops and agricultural residues which are hardly used to day. In addition there are opportunities to extract more forest residue and to use additional waste for energy purposes.

3.4.2.2 China Region

The Chinese government on the other hand in 2009 announced the importance of biomass in meeting its objectives of controlling greenhouse gases by determining that by 2020 China's per GDP emission would be reduced by 40 to 45 percent based on the level in 2005.

According to its long-term renewable energy development plan, China expects to reduce 15 to 20 percent of greenhouse gas emission by using Renewable Energy sources by 2020. China is a biomass resource rich country with variety of biomass applications for electricity, biogas, liquid biofuels, and solid fuels. By 2015, produced biomass for energy shall total 51.79 million tons coal equivalent (Mtce) and 119 Mtce by 2020, which include installed biomass power capacity of 3450GW, biogas of 112.7 billion cubic metres (m^3), biomass, pellet fuel of 30 million tons, and liquid biofuel of 12 million tons[147] (see Figure 89).

Figure 89: Chinese Biomass Targets 2015 and 2020

Technologies	2015		2020	
	Capacity	Energy equivalent (10^4tce)	Capacity	Energy equivalent (10^4tce)
Biomass power (10^4kW)	1449	3192	3450	7494
From crop straws	675	1445	1618	3405
From biogas	407	882	1025	2193
From municipal solid waste	367	865	807	1896
Biofuel gas (10^8m3)	163	1127	288	1635
Straw gasification	37	137	150	549
Biogas	126	990	138	1087
Biomass pellet fuel (10^4tons)	600	300	3000	1500
Liquid biofuel (10^4tons)	500	560	1200	1304
Fuel ethanol	350	365	1000	1043
biodiesel	150	195	200	261
Total		5179		11933

Source: Energy Research Institute, 2010

To fulfil these targets, 78.36 million tce biomass resources will be consumed by 2015 and 17.901 billion tonnes coal equivalent by 2020, of which crop and forest residues will contribute to 50 percent of the total biomass resources see Figure 90[148].

Base on the above, the Chinese 2020 Biomass plan envisages a prioritised focus on livestock waste and municipal solid waste for power generation. During this time line

[147] Energy Research Institute, (2010), Study on China Biomass Energy Technology Development Roadmap, National Development and Reform Commission, China
[148] Ibid

energy plantation is not expected to be commercialised because of immature technologies. These energy crop breeds will be optimised to cultivate high yield trees with developing plantation bases.

Figure 90: Chinese development objectives for biomass resources

Resources	2015		2020	
	Biomass (10^4t)	Coal equivalent (10^4tce)	Biomass (10^4t)	Coal equivalent (10^4tce)
Agro-forestry residues	7299	3337	21313	9743
Livestock waste	63000	1980	115200	3621
Municipal solid waste	13760	1966	22816	3259
Feedstock for fuel ethanol		355		1012
Aged grain	525	156	525	156
Cassava	770	115	980	146
Sweet sorghum	1280	83	10880	709
Biodiesel		198		266
From waste oil and grease	180	154	225	193
From woody oil plant	120	44	200	73
Total		7836		17901

Source: Energy Research Institute, 2010

3.4.2.3 United States Region

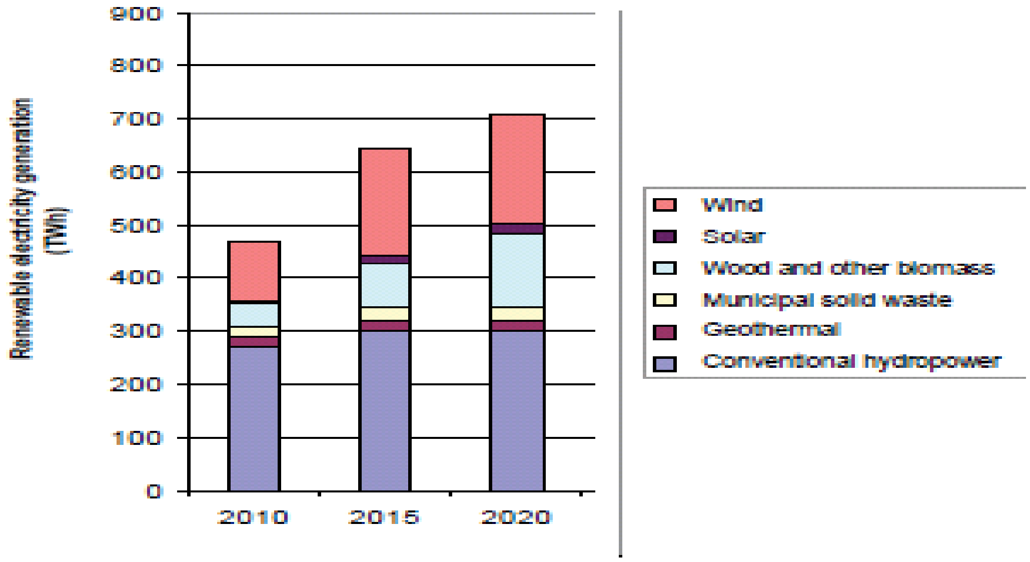
In the United States, forests are expected to play an important role in climate change mitigation under future climate change policy. About 2 percent of the energy consumed annually in the United States is generated from wood and wood-derived fuels[149]. Of the renewable energy consumed (including that from hydroelectric dams), 27 percent is generated from wood and wood-derived fuels. The majority of bioenergy produced from woody biomass is consumed by the industrial sector -mostly at pulp and paper mills using heat or electricity produced onsite from mill residues.

The United States DOE estimates that electricity generation from wood and other biomass will increase to 81 billion kWh by 2015 and 218 billion kWh by 2020 (see Figure 91). These projected figures include expected expansion of the biomass supply from energy crops—including perennial grasses and energy cane—grown on agriculture lands. Assuming the share of woody biomass contribution to renewable electricity and electricity generation efficiency from woody biomass remains constant, approximately 57 million oven dry ton (ODT) of woody biomass will be demanded in 2015 and 154 million ODT of woody material in 2020 for electricity generation.

[149] White, Eric M. (July 2010), Woody Biomass for Bioenergy and Biofuels in the United States, A Briefing Paper, United States Department of Agriculture

These projections from the DOE indicate a general increase in the use of energy created from biomass in the years ahead. Policies aimed at reducing carbon emissions are expected to increase the use of woody biomass for energy generation because it results in less carbon emissions than using coal.

Figure 91: Projected baseline electricity generation from RES to 2020



Source: White, Eric M., July 2010.

3.4.3 Global and regional forecasts beyond 2020

A number of different environmental, social and economic issues need to be looked at to determine the overall impact of bioenergy and to ensure that there is a net positive improvement compared to that of fossil fuels.

The discussion about potential negative environmental, social, and economic impacts of bioenergy has been mainly associated with biofuels for transport, where the main feedstocks today (starch, sugar and oil crops) are also used as feed and food. However the same issues are also relevant for heat and power generated from biomass, and the complete lifecycle impact of bioenergy production needs to be considered in a careful and rational manner.

The contribution of bioenergy to global primary energy supply increases from around 50 EJ in 2009 to roughly 160 EJ in 2050. Bioenergy would then provide around 24 percent of Total Primary Energy Supply (TPES) in 2050 compared to 10 percent today. About 60 EJ of this primary bioenergy supply is needed for production of transport fuels. A total of 100 EJ, *i.e.* 5 billion to 7 billion dry tonnes of biomass, will be needed to provide electricity and heat for the residential sector, industry and other sectors.

Figure 92 shows the worldwide investment in power generation to meet requirements to 2050[150]. Much of this investment will be used primarily to refit coal-fired plants and

[150] IEA, (2012), Technology Roadmap, Bioenergy for Heat & Power, International Energy Agency

build dedicated biomass power plants. The highest absolute investments during this period will be required in China.

Figure 92: Investment needs (billion USD) in bioenergy electricity generation capacity, including co-firing, in different world regions in this roadmap

Region	2010-20	2021-30	2031-50
OECD Europe	21	8	22
OECD Americas	13	11	20
OECD Asia Oceania	4	6	6
Africa and Middle East	7	3	7
China	39	99	54
India	14	8	10
Central and South America	16	5	17
Other developing Asia	12	15	52
Eastern Europe and FSU	3	6	15
World	130	160	202

Note: Numbers might not add up due to rounding.

Source: IEA, 2012

3.4.3.1 European Union Region

It is often argued that biomass will be a short-term solution to meet Europe's 2020 renewable energy targets, and will later be replaced by wind and solar power that do not depend on costly fuel supply chains.

However according to the authors of the Biomass for Heat and Power report[151]Biomass will continue to be an important renewable energy source because of its importance in Carbon Capture and Storage (CCS), its ability to reduce the share of intermittent power production capacity in the total production mix and it will be required to meet the challenging growth trajectory for other renewable energy sources.

There has been much discussion and debate about the ability of the EU to deliver the sustainable volume of biomass to meet the ever increasing requirements. However, according to research[152] the indication is that total biomass supply could be two to four times higher in 2050 than in 2020 while the global biomass supply could be five times higher than the full 2020 potential[153]. This major increase could be brought about by

[151] Hogan Michael, Otterstedt Jens, Roine Morin Roine, & Wilde Jonas, (2010), Biomass for Heat & Power – Opportunity & Economics 2010, the European Climate Foundation, Sveaskog, Södra, and Vattenfall, presented to the European Commission.

[152] Ericsson Karin, & Nilsson Lars J. (2006), Assessment of the potential biomass supply in Europe using a resource-focused approach, Biomass and Bioenergy, Vol. 30, No. 1, pp. 1-15.

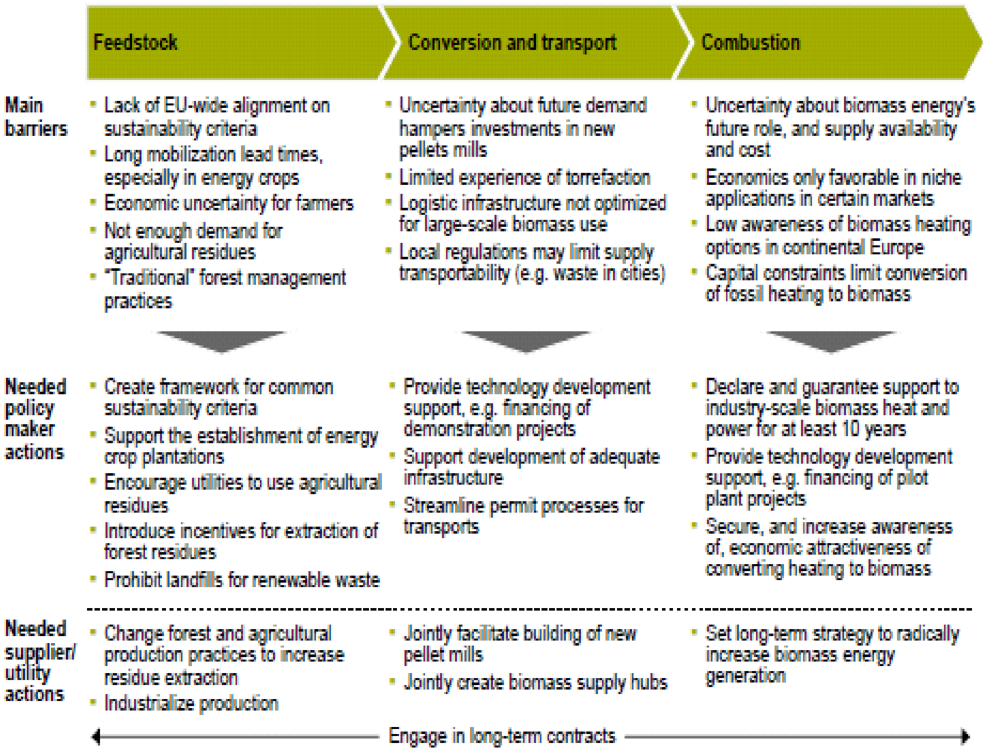
[153] Faaij et al (2005), 2005. Opportunities and barriers for Sustainable International *bio*-energy Trade; Strategic advice of IEA Bioenergy Task 40. 14th European Biomass Conference and Exhibition, October, Paris, France

improved agricultural yields, intensified forest management and utilisation of degraded land.

Besides food, heat and power, there are other competing uses for biomass. The largest consumers of forest biomass today are the pulp and paper industry and sawmills. The former is not expected to grow significantly in Europe, while the latter may show moderate growth. Other uses of biomass include 2nd generation biofuels which are seen as the key clean fuels for air and sea transport. Additionally, efforts are being made to use biochemicals to replace the oil used in industry for non-energy purposes, such as, in the production of plastics and chemicals.

Figure 93 shows the major barriers to increasing the supply of biomass within the EU. Thus, it can be seen that there are challenging objectives which need to be acted upon to mobilise the additional biomass supply required for biomass energy applications and to avoid the negative side effects on food and feed production and on the forest products industry that could otherwise follow.

Figure 93: Barriers and actions required to expand biomass for heat and power.



Source: Faaij et al (2005)

3.4.3.2 United States Region

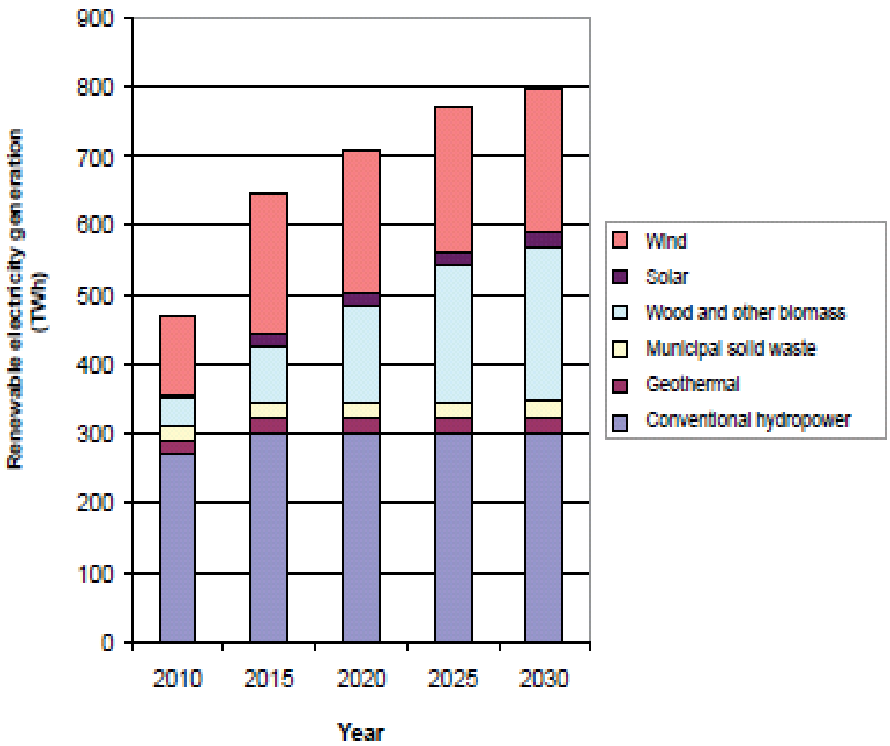
According to Johansson and Azar (2007)[154] biomass is expected to be the source of about 16 percent of the energy generated in the United States in 2030 which is approximately a fourfold increase over modelled use in the current period. By 2050, the projected biomass would be the source of about 30 percent of the energy generated

154 Johansson, D.J.A. & Azar, C. 2007. A scenario based analysis of land competition between food and bioenergy production in the U.S. Climatic Change. 82: 267–291.

which is approximately a sevenfold increase from the modelled use in the current period. It is important to note that Johansson and Azar did not include carbon offsets, which are likely to be an important tool for coal power plants to meet carbon caps under the legislation currently being considered in the U.S. Congress.

The DOE projects that electricity generation from wood and other biomass will increase to 81 billion kWh by 2105 and 218 billion kWh by 2030 (Figure 94)[155]. These projected figures include expected expansion of the biomass supply from crops including perennial grasses and energy cane grown on agriculture lands

Figure 94: Projected baseline electricity generation from renewable fuel sources, 2010 to 2030



Source: US DOE 2009

3.5 Photovoltaics - the global market in 2012 and the forecasts

3.5.1 General presentation

Photovoltaic (PV) systems contain cells that convert solar energy into electricity. Since there is an abundant amount of free power from the sun, PV technology has the potential to meet most of mankind's energy needs. The basic building block of a PV system is the PV cell, which is a semiconductor device that converts solar energy into direct-current (DC) electricity. PV cells are interconnected to form a PV module, typically up to 50-200 Watts (W). The PV modules combined with a set of additional application dependent system components (*e.g.* inverters, batteries, electrical components, and mounting

[155] White, Eric M. (July 2010), Woody Biomass for Bioenergy and Biofuels in the United States, A Briefing Paper, United States Department of Agriculture

systems), form a PV system. PV systems are highly modular, *i.e.* modules can be linked together to provide power ranging from a few watts to tens of megawatts (MW).

The key issue for the PV industry is how to utilise this free source of energy in the most cost and effective manner to satisfy user needs. PV technology has many advantages over some of the other conventional and renewable energy sources. In particular, it has a negligible environmental footprint and it is very versatile so it can be deployed almost anywhere. It utilises existing technologies and manufacturing processes which makes it cheap and efficient to implement and it has significant potential for cost reduction.

The growth of PV technology over the last decade has been impressive and it is now seen as a major key world energy source. In fact it is now the third most important renewable energy source after hydro and wind power in terms of installed capacity. At the end of 2009, the world's PV cumulative installed capacity was about 23 GW see Figure 95[156]. One year later it was 40 GW. In 2011, there was more than 69 GW installed globally which could produce 85 TWh of electricity annually.

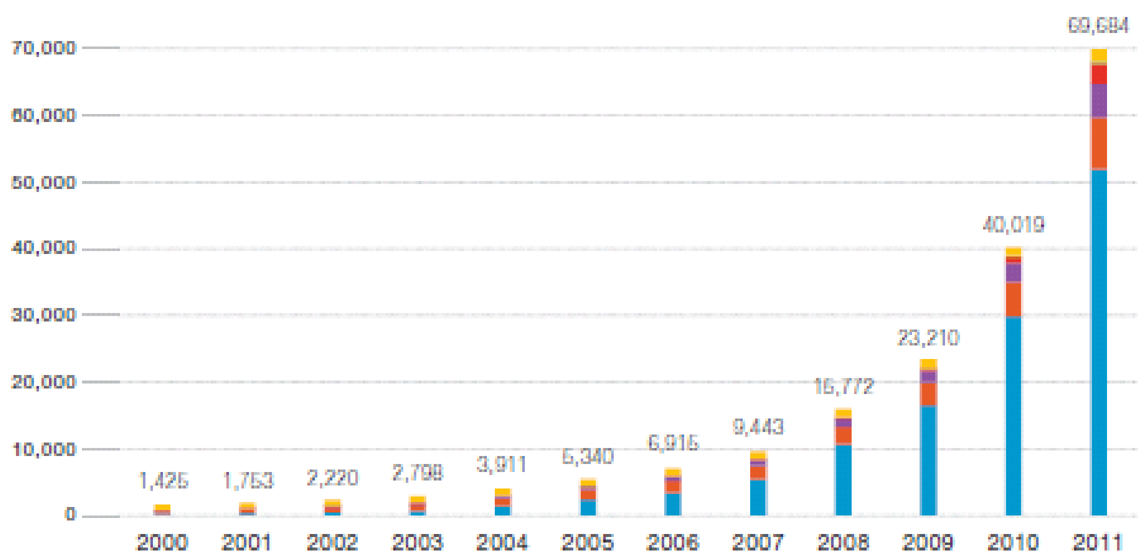
In terms of global cumulative installed capacity, Europe still leads the way with more than 51 GW installed in 2011. This represents about 75 percent of the world's total PV cumulative capacity. Next in the ranking are Japan (5 GW) and the United States (4.4 GW), followed by China (3.1 GW) which reached its first GW in 2011. Many of the markets outside Europe, in particular China, the United States and Japan, but also Australia (1.3 GW) and India (0.46 GW), have addressed only a very small part of their enormous potential. Several countries from large sunbelt regions like Africa, the Middle East, South East Asia and Latin America are on the brink of starting their development.

Even so, the cumulative installed capacity outside Europe almost doubled between 2010 and 2011[157], demonstrating the ongoing rebalancing between Europe and the rest of the world and reflecting more closely the patterns in electricity consumption.

[156] EPIA, (May 2012), Global Market Outlook for Photovoltaics until 2016, European Photovoltaic Industry Association, Brussels, Belgium

[157] Ibid

Figure 95: Evolution of global cumulative capacity 2000-2011 (MW)



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
ROW	761	807	887	964	993	1,003	1,108	1,150	1,226	1,306	1,209	1,717
MEA	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	21	205	336
China	19	30	45	55	64	68	80	100	145	373	893	3,093
America	146	177	222	287	379	496	645	856	1,205	1,744	2,820	5,063
APAC	355	491	677	902	1,178	1,475	1,797	2,080	2,643	3,409	5,116	7,769
Europe	154	248	389	690	1,297	2,299	3,285	5,257	10,554	16,357	29,777	51,716
Total	1,425	1,753	2,220	2,798	3,911	5,340	6,915	9,443	15,772	23,210	40,019	69,684

Notes: ROW: Rest of the World; MEA: Middle East & Africa; APAC: Asia Pacific
Source: EPIA, May 2012.

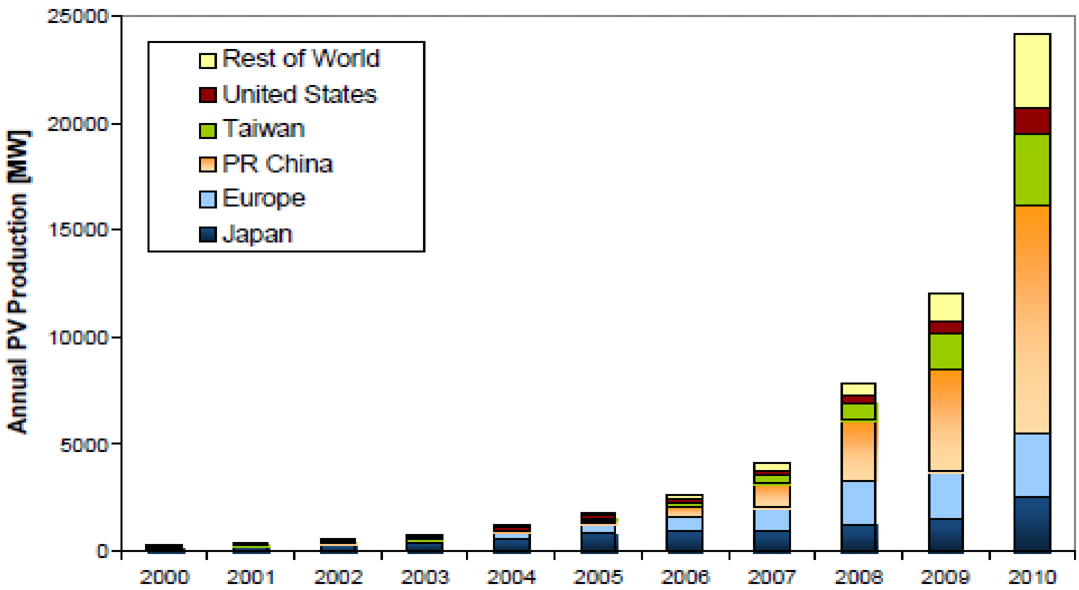
While the production data shows variances with the capacity data, not all shipped cells and modules end up in the market the year they are produced or in the country in which they were first sold, but the data are useful in showing where PV production is currently taking place. Thus the world wide PV production from 2000 to 2010 is shown in Figure 96[158].

Since 2000, total PV production increased almost by two orders of magnitude, with annual growth rates between 40 percent and 90 percent. The most rapid growth in annual production over the last five years was observed in Asia, where China and Taiwan together now account for almost 60 percent of world-wide production.

Wafer-based silicon solar cells are still the preferred technology with more than 80 percent market share in 2010. Of these, polycrystalline solar cells still dominate the market (45 to 50 percent) even if their share has been slowly decreasing since 2003. The previous tight silicon supply situation reversed due to massive production expansions, as well as the economic situation. This led to a price decrease from the 2008 peak of around $500/kg to about $50–55/kg at the end of 2009, with a slight upwards tendency throughout 2010 and early 2011.

[158] EC JRC (2011), Renewable Energy Snapshots. EUR 24954EN-2011
ec.europa.eu/energy/publications/.../2011_renewable_energy_snapshots.pdf

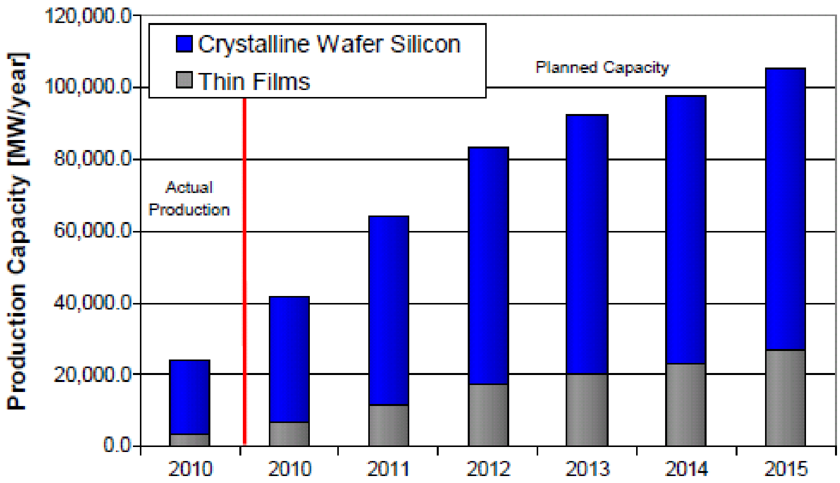
Figure 96: Global PV production 2000 to 2010



Source: EC JRC, Renewable Energy Snapshots 2011.

There are more than 200 companies involved in thin-film solar cell activities, ranging from basic R&D activities to major manufacturing activities and over 120 of them have announced either the start or an increase in production. The first 100 MW thin-film factories became operational in 2007, followed by the first 1 GW factory in 2010. If all expansion plans are realised in time, thin-film production capacity could be 17 GW, or 21 percent of the total 83 GW, in 2012 and 27 GW, or 26 percent, in 2015 of a total of 105 GW (Figure 97)[159].

Figure 97: 2010 Production and Planned PV production capacities of Thin-Film and Crystalline Silicon based solar modules



Source: JRC RES Snapshots 2011.

It is interesting to note that of the 120 companies with announced production plans only about one third of them have produced thin-film modules of 10 MW or more in 2010. Another 70 companies are silicon based and use either amorphous silicon or an amorphous/microcrystalline silicon structure and another 36 companies were using Cu

159 EC JRC (2011), Renewable Energy Snapshots. EUR 24954EN-2011 ec.europa.eu/energy/publications/.../2011_renewable_energy_snapshots.pdf

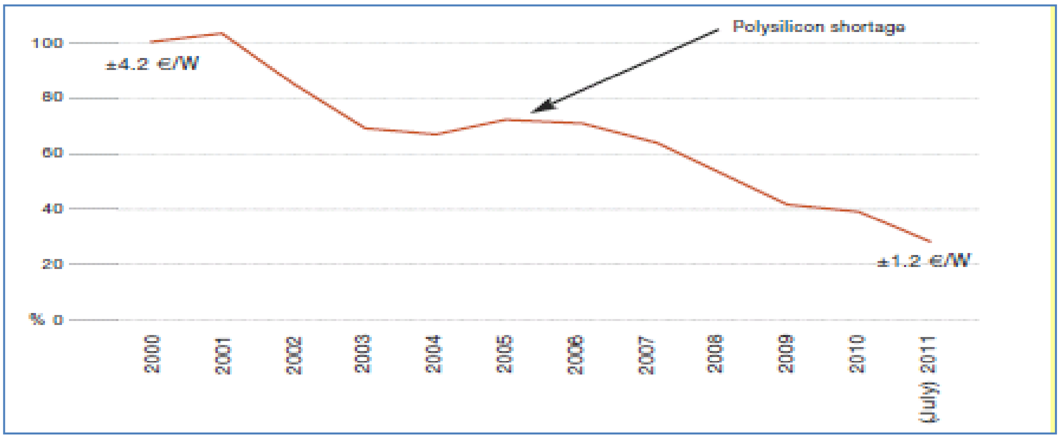
(In, Ga) (Se, S) 2 as absorber material for their thin-film solar modules whereas 9 companies use cadmium telluride (CdTe) and eight companies go for dye and other materials.

The emerging Concentrator Photovoltaics (CPV) technology is growing at a very high rate although from a low starting point. There are about 50 companies active in this field and almost 60 percent of them were founded in the last five years. Over half of the companies are located either in the United States (primarily in California) and Europe (primarily in Spain).

The market share of CPV is still small, but analysts forecast an increase to more than 1,000 MW globally by 2015 with market estimates for 2010 in the 5 to 10 MW range. Currently the pipeline is dominated by just three system manufacturers, Concentrix Solar, Amonix, and SolFocus[160].

A key driver in the market penetration of PV is the cost of the PV system. PV system costs have been reducing significantly over the last decade see Figure 98[161]. In fact the module price reduced by 20 percent with every doubling in volume.

Figure 98: Reduction in the average module price in Europe



Source: EPIA, 2011

The average (or levelised) PV module price in Europe in July 2011 reached about €1.2 per watt which is about 70 percent lower than 10 years ago[162]. These price reductions are set to continue with predicted price reductions ranging from €0.83 to €1.59 per watt over the next decade[163]. This continuation of price reductions will further enhance the attractiveness of PV technology as a viable renewable energy source.

However, European pricing is impacted by external market forces since 80 percent of the global PV market is in Europe, but 80 percent of modules are assembled outside the

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[160] EC JRC, (2011), Renewable Energy Snapshots 2011. ec.europa.eu/energy/publications/.../2011_renewable_energy_snapshots.pdf

[161] EPIA, (Sept. 2011), Solar Photovoltaics, Competing in the energy sector

[162] PV installations include the following range of typical installations with very different prices:

- Residential households: 3 kW
- Commercial buildings: 100 kW
- Industrial plants: 500 kW
- Utility-scale plants (ground-mounted): 2.5 MW

[163] Ibid

EU. This means that international trade dynamics will have an impact on the price of PV systems. The relationship between the Euro, the US Dollar and the Chinese Renminbi will affect PV prices in Europe and will cause local price fluctuations but this will not affect the long-term price reduction trend.

The high investment costs, or total system costs, represent the most important barrier to PV deployment today[164]. Total system costs are composed of the sum of module costs plus the expenses for other system components, including mounting structures, inverters, cabling and power management devices. While the costs of different technology module types vary on a per watt basis, these differences are less significant at the system level, which also takes into account the efficiency and land-use needs of the technology. Total system costs are sensitive to economies of scale and can vary substantially depending on the type of application.

In general though, the growth in PV technology for power generation is assured since it will be required to satisfy the growing demand for electricity generation. Renewables are seen as an indispensable part of the global energy mix by 2035, with renewables accounting for almost one-third of the total electricity output and according to the International Energy Agency[165] (IEA) solar grows more rapidly than any other renewable technology. The rapid increase in renewable energy is underpinned by falling technology costs, rising fossil-fuel prices and carbon pricing, but mainly by continued subsidies. From $88bn globally in 2011, they rise to nearly $240bn in 2035. Subsidy measures to support new renewable energy projects will need to be adjusted over time as capacity increases and as the costs of renewable technologies fall, to avoid excessive burdens on governments and consumers[166].

Feed-in Tariffs (FiT) are widely acknowledged to be the best suited support scheme for successful PV deployment. The German FiT is an example of a well functioning system which, after its latest revision, is evolving with the growing market, balancing the interests of the PV industry and final consumers. The FiT is granted for 20 years, guaranteeing sustainable returns on investment (in 2008, IRR ranged from 6 percent to 9 percent depending on the system size and respective tariff level). The recent revision of tariffs for 2009 provided a measured reduction in tariffs that has shown to maintain sustainable IRRs for investors while keeping the financial burden to electricity consumers in check. A functioning FiT by itself, however, is not a guarantee of effective PV deployment. In the mid to long-term, support schemes have to evolve with the growing share of PV at different levels of competitiveness. During the competitive phase, policy support for PV will also be needed, as investment parity alone does not automatically provide a sufficient incentive to invest in PV.

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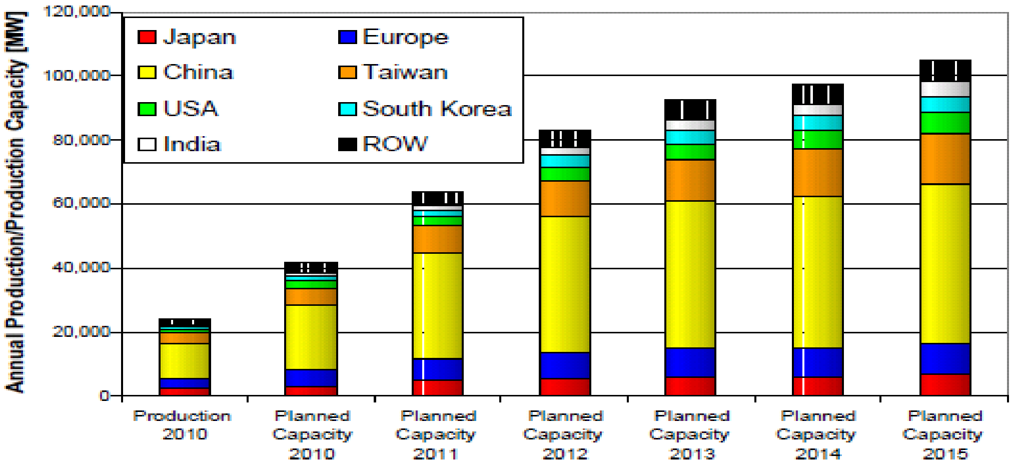
[164] IEA, (2010), Technology Roadmap, Solar Photovoltaics Roadmap
[165] IEA, (2012), World Energy Outlook 2012, International Energy Agency
[166] Ibid

3.5.2 Global and regional forecasts until 2020

As of 2011, the expected PV production capacities to 2015 are shown in Figure 99[167]. This figure shows that the greatest growth rates are seen in China which will have about 47.3 percent of the world-wide production capacity of 105 GW, followed by Taiwan (15.2 percent), Europe (9.0 percent) and Japan (6.7 percent).

The IEA roadmap to 2050 envisages an accelerated growth outlook which is based on the recent PV market growth and associated cost reductions between 2007 and 2009. During this period the global PV market more than doubled and system prices fell by 40 percent[168]. This acceleration in the deployment of PV has been triggered by the adoption of PV incentive schemes in an increasing number of countries.

Figure 99: World-wide PV planned capacity with future planned increases



As a result of this sort of policy support, the IEA roadmap predicts that PV will achieve grid parity (*i.e.* competitiveness with electricity grid retail prices) in many countries by 2020. Initially parity is expected to be achieved in those countries having a high solar irradiation level and high retail electricity costs. The roadmap also assumes the continuation of a continuing favourable and balanced policy framework for market deployment and technology development. As grid parity is achieved, the policy framework should evolve towards fostering self-sustained markets, with the progressive phase-out of economic incentives, but maintaining grid access guarantees and sustained R&D support.

To accommodate renewable production locally, the distribution grid needs to become smarter to deal with variable generation from many distributed sources such as, solar photovoltaic. By 2020 interconnection capacity needs to expand at least in line with current development plans. An overall increase of interconnection capacity by 40 percent up to 2020 will be needed, with further integration after this point[169].

Europe: Solar photovoltaic electricity generation has again increased its cumulative installed capacity by more than 80 percent to 29 GW in 2010. The European

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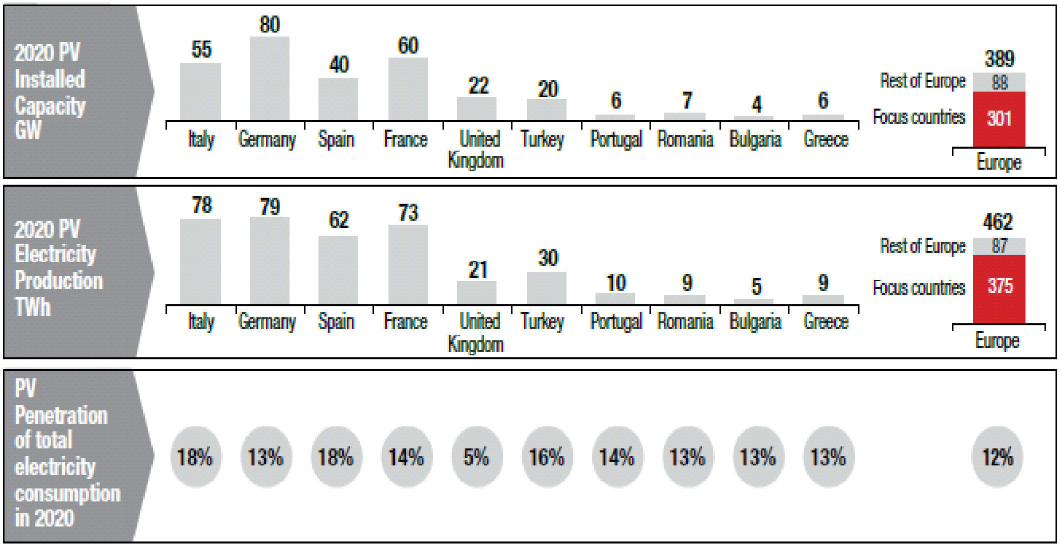
[167] EC JRC (2011), Renewable Energy Snapshots. EUR 24954EN-2011
[168] IEA Roadmap 2050
[169] EU Energy Roadmap 2050

Photovoltaic Industry Association published a new plan envisioning a target of 12 percent of the European electricity generated with solar photovoltaic electricity generation, or from 380 to 420 TWh by 2020. The necessary growth rate would be 36 percent annually, which is much lower than what the industry has seen in the last 8 years. From an industry point of view the target is ambitious, but achievable, however it will need accompanying measures to ensure that the electricity grid will be able to absorb and distribute the generated solar electricity. This is especially important, because 12 percent of total electricity from solar Photovoltaics translates to a cumulative installed PV capacity of circa 350 GW or close to 60 percent of the total European thermal electricity generation capacity (590 GW in 2008) or more than 40 percent of the total European electricity generation capacity (800 GW in 2008). Therefore, efficient transmission and storage systems, as well as modern supply and demand management, have to be available to fulfil this vision.

The deployment of PV can happen much quicker in Europe but it is likely to occur at different speeds in different countries. Figure 100[170] provides a snapshot of the possible deployment in the focus countries under the ambitious Paradigm Shift Scenario, based on an estimate of the deployment factors mentioned above.

Figure 100: Photovoltaic deployment in focus countries under the Paradigm shift Scenario



Sources: EPIA - EU DG TREN "European Energy and Transport: trends to 2030, update 2007"- EU Joint Research Centre Photovoltaic Geographical Information System - LBBW "PV Sector, Valuing the invaluable", 2008 - A.T. Kearney analysis.

China: The goal of solar power generation for China under the energy stimulus plan is much more conservative compared to that of other sources, reaching only 20GW by year 2020 (Source: National Development and Reform Commission - NDRC). However, China has abundant solar energy resources and the world's largest rooftop areas, which offer tremendous opportunity for PV installations. Thus PV should be an important part of the energy mix for China to meet its emission reduction and renewable energy goals. A Preliminary Report on a Recommended China PV Policy Roadmap, by the SEMI PV Group and SEMI China PV Advisory Committee urged the Chinese government to

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[170] SET for 2020, Solar Photovoltaic Electricity, a mainstream power source in Europe by 2020, EPIA

expedite the development of a domestic PV market and recommended a PV installation roadmap with annual installation targets to the year 2020, reaching global average PV penetration level by year 2016, and 1.3 percent electricity from PV by year 2020[171] (see Figures 101 and 102).

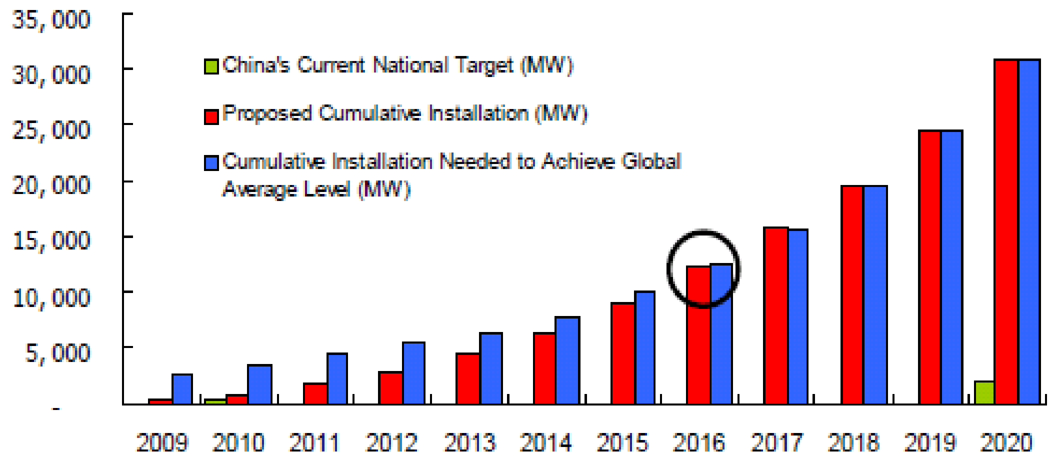
India has a large and diversified PV industry consisting of ten fully vertically integrated manufacturers making solar cells, solar panels and complete PV systems, and around 50 assemblers of various kinds. Together, these companies supply around 200 MW per year of 30 different types of PV systems in three categories namely, rural, remote area and industrial. However, despite this strong industrial base, PV constitutes a small part of India's installed power generation capacity, with 2.7 MW grid connected systems.

Figure 101: Recommended China PV policy Roadmap

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Electricity Demand (Billion kWh)	2,652	2,783	2,914	3,052	3,196	3,346	3,504	3,643	3,787	3,938	4,094	4,256
% of PV Electricity (Global Average)	0.16%	0.20%	0.24%	0.29%	0.35%	0.42%	0.51%	0.61%	0.74%	0.89%	1.08%	1.30%
Cumulative Installation Needed to Achieve Global Average Level (MW)	2,632	3,479	4,393	5,547	6,226	7,861	9,926	12,444	15,600	19,558	24,518	30,738
China's Current National Target (MW)		300										1,800
Proposed Cumulative Installation (MW)	340	840	1,650	2,800	4,300	6,180	8,840	12,280	15,780	19,510	24,485	30,785

The 2008 Action Plan on Climate Change included a "National Solar Mission" that establishes a target of generating 20 GW of electricity from solar energy by 2020; the programme aims to boost annual PV power generation to 1 000 MW by 2017[172].

Figure 102: Current national target, proposed cumulative installation and cumulative installation needed to achieve global



[171] PV Group, SEM and CPIA, (April 2011), China's Solar Future, A recommended China PV policy roadmap 2.0

[172] EPIA, (March 2011), Unlocking the Sunbelt Potential of Photovoltaics, Third Edition

In the United States, the U.S. Department of Energy (DOE) Solar Program focuses on achieving the goals of the SunShot Initiative[173], which seeks to make solar energy cost-competitive with other forms of electricity by the 2020. This initiative aims to reduce the total costs of photovoltaic solar energy systems by about 75 percent so that they are cost competitive at large scale with other forms of energy without subsidies before the end of the decade. This equates to about $1 per watt which corresponds approximately to 6 cents per kilowatt-hour. At this price solar energy systems could be broadly deployed across the United States. Figure 103 provides a breakdown of PV prices for utility scale and commercial and residential rooftop uses. Benchmarked prices in 2010 and projected prices in 2020 for both the SunShot and reference scenarios are included.

Figure 103: Benchmarked 2010 Solar Prices and Projected 2020 solar prices (2010$/Wdc)

Technology/Market	Benchmark 2010 Price	Reference 2020 Price	SunShot 2020 Price
Utility-Scale PV ($/$W_{DC}$)	4.00	2.51	1.00
Commercial Rooftop PV ($/$W_{DC}$)	5.00	3.36	1.25
Residential Rooftop PV ($/$W_{DC}$)	6.00	3.78	1.50

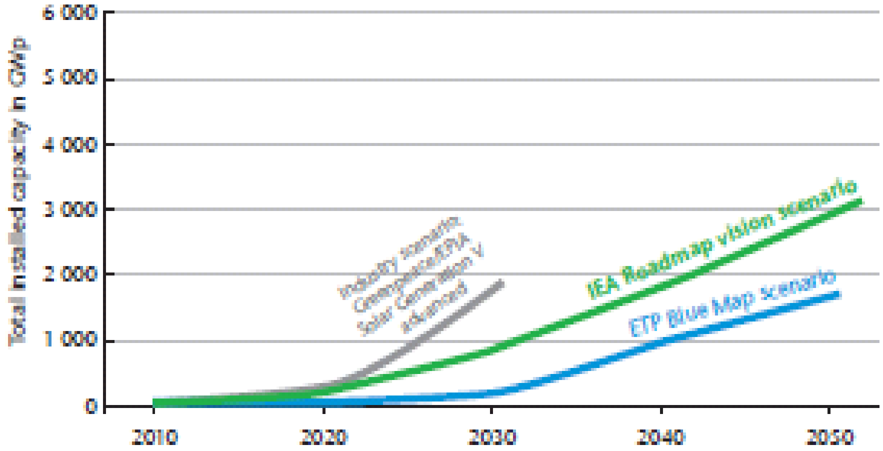
The reference scenario with moderate solar energy price reductions was also modelled to enable comparison of costs. These installed system prices represent a set of very aggressive, but technically possible targets that would translate into solar technology having a similar levelised cost of energy (LCOE) as competing electricity sources in each market segment. In other words, $1/W will be competitive in the wholesale electricity market, while $1.25/W will be competitive in the commercial retail market, and $1.50/W will be competitive in the residential retail market. Based on the above scenario the United States is expected to increase its installed PV capacity to 70 GW by 2020.

3.5.3 Global and regional forecasts beyond 2020

Assuming the policies are successfully implemented and price parity is achieved with conventional power sources then, by 2050 there will be 3,000 GW of installed PV capacity worldwide, generating 4,500 TWh per year which is 11 percent of the expected global electricity supply[174]. From 2020 to 2030, an average annual market growth rate of 11 percent is assumed, bringing global cumulative installed PV capacity to about 900 GW by 2030. At this time, the annual market volume of new installed capacity would be over 100 GW per year. The total cumulative installed PV capacity is predicted to reach 2,000 GW by 2040 and 3,000 GW by 2050, taking into account the replacement of old PV systems (see Figure 104).

173 U.S. DOE, (Feb. 2012), SunShot Vision Study, Department of Energy
174 IEA, (2010), Technology Roadmap 2010, Solar Photovoltaic Energy, International Energy Agency.

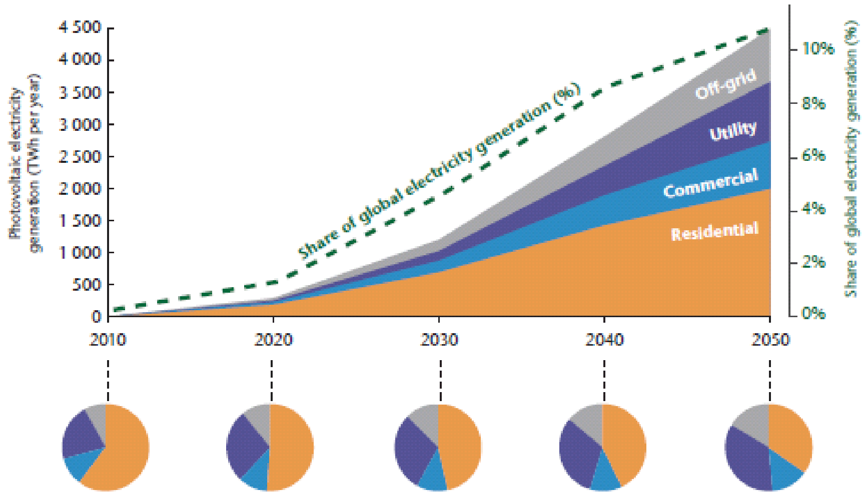
Figure 104: Comparison of IEA roadmap vision of global cumulative installed PV capacity to other scenarios



However, while the production costs for different PV module technologies vary, these module level cost differentials are less significant at the system level, which are expected to converge in the longer term. Therefore, the setting of overall cost targets by application (e.g., residential, commercial or utility-scale) rather than for specific PV technologies (e.g., crystalline silicon, thin films, or emerging and novel devices) makes more sense. Thus overall system prices should drop from current ($4,000 to $6,000) per kW to ($1,200 to $1,800) per kW by 2030.

The application of PV in the four identified market segments namely, residential, commercial, utility-scale and off-grid is shown in Figure 105[175]. In particular it should be noted the relative decrease from almost 60 percent today to less than 40 percent by 2050, in residential usage compared to large scale applications. According to the IEA Roadmap the main PV economic goal is to reduce overall system prices and electricity generation costs by more than two-thirds by 2030.

Figure 105: Evolution of photovoltaic electricity generation by end-use sector



Source: IEA analysis based on survey reports of selected countries between 1992 and 2008, IEA PVPS, and IEA 2008 (ETP).

175 Ibid

This IEA roadmap predicts a rapid growth of PV power across the world in OECD countries as well as in Asia, and at a later stage in Latin America and Africa. Major countries such as China and India have become global solar players in the past decade, and will remain important market influencers in the decades to come. The potential of PV for distributed generation is very substantial in South America and Africa. These world regions may become very important markets in the mid to long-term. Brazil is a leading country in the use of PV for rural electrification and can play a major role in technology collaboration with developing countries.

It is interesting to note that Chinese companies have been rapidly ramping up production capacities, making China the world's top producer of PV cells and modules. In 2010 alone China produced more than 50 percent of global production of PV cells and modules. However, most of this production was for export with very small domestic demand, Thus the SEMI PV Group and SEMI China PV Advisory Committee[176] urged the Chinese Government to expedite the development of a domestic PV market. This committee recommended using the IEA Solar PV Roadmap as a benchmark in order for China to achieve its desired levels of PV penetration. China will need to have 60GW PV installed capacity by year 2020 and 270GW by year 2030[177] to meet its objectives.

The goals presented are seen as challenging; however, the committee believes that the goals are attainable with strong government commitments and the right policies in place. Figure 106 shows China's recommended PV policy Roadmap to 2030 with 404 (TWh) electricity generation from PV accounting for 4.6 percent of China's total requirement.

Figure 106: China's recommended PV policy Roadmap to 2030.

	2010 Actual	2010	2020	2030
Total Electricity Generation (TWh)	4,192	4,192	6,949	8,776
% of PV Electricity	0.025%	0.2%	1.3%	4.6%
Electricity Generation from PV (TWh)	1	8	90	404
Total Installed PV Capacity (GW)	**0.7**	**6**	**60**	**270**

The EU goal to cut greenhouse gas emissions by 80–95 percent by 2050[178] has serious implications for the European energy system. To achieve this goal about two thirds of energy should come from renewable sources. Electricity production will need to be almost emission-free, despite the higher demand. The current energy system has not been designed to deal with the required renewables on such a large scale. Thus by 2050 the system must be transformed with a new energy model which will make the system more secure, competitive and sustainable in the long-run. Thus priority access to the

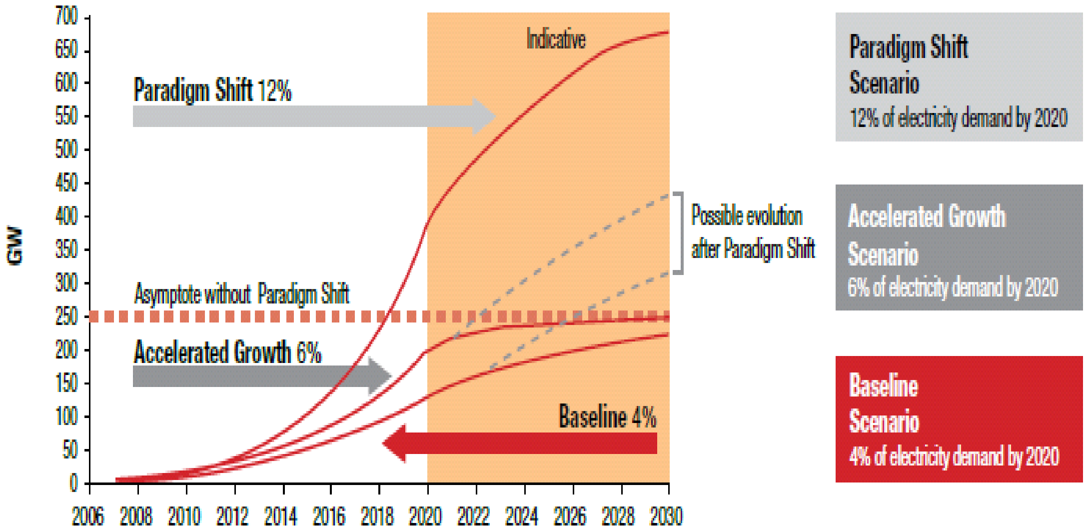
[176] PV Group, SEM and CPIA, (April 2011), China's Solar Future, A recommended China PV policy roadmap 2.0
[177] Ibid
[178] EU Energy Roadmap 2050, 2012

grid for renewable energy sources, the optimal design of support schemes and the reduction of administrative barriers are the key market drivers for sustainable development. This new model must include a Feed-in Tariff (Fit) system which is guaranteed for a significant period of time. According to the EPIA Photovoltaic Observatory Policy Recommendations (2011)[179] this time period should be at least 20 years.

The Solar Europe Industry Initiative Implementation Plan 2010-2012[180] sets out strategies and milestones for 2020 and beyond. For the European PV industry to remain competitive the PV strategy must be implemented, otherwise the strong and increasing competition from China, Taiwan and others will leave Europe behind. Based on this urgency to keep Europe on track the SET for 2020[181] study has identified three possible PV deployment scenarios namely, a Baseline, Accelerated Growth and a Paradigm Shift, which are determined by a series of conditions. Only the more ambitious scenario will yield the 12 percent EU electricity demand 2020 target[182] (see Figure 107).

In the United States, the SunShot Vision Study specifically explores a future in which the price of solar technologies declines by about 75 percent between 2010 and 2020 in line with the U.S. Department of Energy (DOE) targets. As a result of this price reduction, solar technologies are projected to play an increasingly important role in meeting electricity demand over the next 20–40 years, satisfying roughly 11 percent of United States electricity demand by 2030 and 27 percent by 2050. These forecasts assume the federal investment tax credit (ITC) and production tax credit (PTC) run to the end of 2016 and 2012, respectively.

Figure 107: PV deployment Scenarios in Europe 27, Norway and Turkey to 2030



Sources: EPIA - EU DG TREN "European Energy and Transport: trends to 2030 - update 2007" - Eurostat Data Portal - EU Joint Research Centre Photovoltaic Geographical Information System - A.T. Kearney analysis.

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179 EPIA, (2011), Photovoltaic Observatory Policy Recommendations

180 EPIA & Photovoltaic technology Platform, (2010), Solar Europe Industry Initiative Implementation Plan 2010-2012

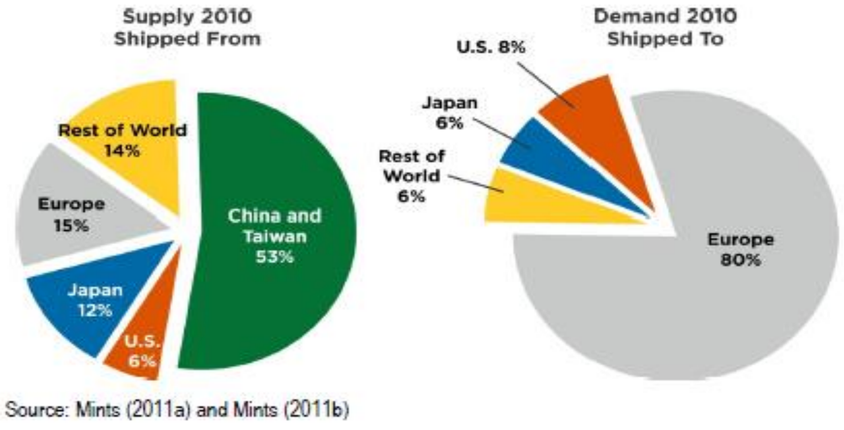
181 EPIA, (2010), SET for 2020, Solar Photovoltaic Electricity, a mainstream power source in Europe by 2020

182 Ibid

If these targets are achieved then it will result in the cumulative installation of about 302 (GW) of PV by 2030 and 632 (GW) of PV by 2050. This would need annual installations of about 25 to 30 (GW) of PV to meet these cumulative installed capacities which would translate into PV generating about 505 (TWh) per year or 11 percent of total US electricity demand in 2030 and 19 percent or 1,036 (TWh) by 2050.

While the SunShot scenario level of solar deployment would result in significant downward pressure on retail electricity prices it would also have the potential to grow the United States domestic solar energy industry which could establish it as a global leader in solar technology innovation, and support a growing number of solar-related jobs. In fact the United States PV workforce is expected to grow, in terms of gross jobs, from about 46,000 in 2010 to 280,000 in 2030 and to 363,000 in 2050[183]. These estimates include direct and indirect jobs throughout the PV supply chain, with about 89 percent and 83 percent designated under manufacturing and installation in 2030 and 2050, and the remainder in O&M. Thus the growth of PV in the United States is aligned to local job growth in the industry. It is interesting to compare the aspiration of the United States in terms of creating jobs in the local PV industry with the European experience. Europe is the largest importer of PV products but China and Taiwan have seen the most benefits from the European PV expansion with only 15 percent of the demand being satisfied by local European suppliers - see Figure 108[184] (the rest of the world region includes Australia, India, the Philippines, and Malaysia).

Figure 108: Global supply and Demand, 2010



Shipments of PV cells and modules by region are a key indicator of market evolution. Shipments attributed to a given region represent PV supplied by that region, as measured at the first point of sale. However, not all shipped cells and modules end up in the market the year they are produced or in the country in which they were first sold.

Already countries are gaining leadership in solar energy supply and demand. China, Germany, India and Brazil are gaining leadership positions in solar, wind and biofuels. The United States remains a cleantech leader because of its entrepreneurial culture and vibrant venture capital environment. Policy-makers are betting that cleantech investments will yield other benefits such as job creation and innovation-led economic

[183] U.S. Department of Energy, (2012), SunShot Vision Study
[184] Ibid.

growth. Notably, private investment is flowing to countries with comprehensive, clear and long-term energy policies aimed at incentivising renewable energy use, promoting efficiency and reducing carbon emissions.

The example of the wind industry is indicative of further potential developments in the PV sector. The global market for wind power has grown tremendously since its early development in the 1980s. Denmark has been the pioneering country in this technology. Over 1 percent of global electricity supply is currently provided by wind. Early large adopters of this technology were Germany, the United States and Spain. India and China were the next largest users of wind power. Like PV, wind turbines need no fuel and have zero CO_2 emissions (except for production, delivery and installation of equipment) and they can be installed relatively quickly. The cost of wind energy has decreased as wind turbines have become larger in size, turbine efficiency has increased significantly, and the capital cost per kilowatt has declined significantly as well. PV industry will develop along a similar path and the sector is discussed in more detail in the next chapter.

4 Overview and analysis of the main factors influencing the PV market

4.1 Political-economic environment

4.1.1 Recent status on local PV funding and programmes[185]

United States of America

Total PV capacity in the US increased by an estimated 1867 MW in 2011 – representing double the growth in the annual market compared to the previous year, for the second year running. Cumulative installed capacity in the US reached 3,966 MW by the end of 2011. More than 60,000 PV systems were connected in 2011 resulting in a 20 percent growth in the number of grid-connected systems installed annually. By the end of 2011, there were approximately 214,000 distributed, grid-connected PV systems installed in the United States; the nation added 770 MW of utility-scale generation capacity that year alone. During 2011, PV capacity reached about 0.4 percent of total national electricity generation capacity, with 9.4 percent of new electricity generation capacity installed during the year being PV.

2011 was marked by a number of large-scale PV projects, with 28 projects over 10 MW being connected to the grid. These include the first 48 MW phase of the 150 MW Mesquite Solar Project in Arizona, the 38 MW San Luis Valley Solar Ranch in Colorado, the 37 MW Long Island Solar Farm in New York, and the 34 MW Webberville Solar Farm in Texas – all completed in 2011. Further, there were an additional 3 GW of utility-scale projects under construction throughout the year.

The US PV market development is supported by financial incentives at both the federal and state levels; policy drivers for renewable energy deployment remain at the state and local levels. Two of the major federal drivers for growth in the PV market included the 30 percent investment tax credit (ITC) and the five-year accelerated depreciation (modified accelerated cost recovery schedule or MACRS). The ITC applies to residential, commercial and utility-scale installations and the MACRS applies only to commercial installations (although it is also indirectly available to the residential systems deployed under a lease or power purchase agreement). For commercial installations, the present value to an investor of the combination of these two incentives (only available to tax-paying entities) amounts to about 56 percent of the installed cost of the PV system.

Of course, local authorities can also exert a positive impact on the market through their role as the permitting body. Vermont has implemented a pre-defined permitting process for PV installations of 10 kW and under, to decrease paperwork processing times and regulatory uncertainty. At the municipal level, the City of Los Angeles has moved towards decreasing permitting barriers by eliminating building height restrictions for

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[185] IEA, (2011), Trends In Photovoltaic Applications, Survey report of selected IEA countries.

roof mounted PV systems, as long as the system under consideration adheres to set-back requirements. The City of Santa Cruz has demonstrated genuine leadership in promoting residential solar by eliminating building permits altogether for PV systems that meet certain criteria[186].

Electricity utility interest continues to increase in the United States, with the key drivers being the 30 percent federal tax credit at the national level and Renewable Portfolio Standards at the state level. Four broad categories of utility PV business models can be seen in the US: utility ownership of assets; utility financing of assets; development of customer programmes and utility purchase of solar output. Ownership of assets allows the utility to take advantage of the tax credit benefits, earn a rate of return on the asset (investor-owned utilities) and provides control over planning, location, operation and maintenance. Financing of Solar Assets is a PV business option for utilities that choose not to own solar assets for tax, cost, regulatory, or competitive considerations. Customer Programmes are designed to increase access to PV electricity by lowering costs for all parties, compared to a traditional customer-located PV system. These may involve a community or centralized PV system and specific classes of participating customers to whom a proportional share of the output can be allocated offsetting their electricity bill directly, or by offering a fixed-rate tariff that is attractive compared with current (and future) retail electricity prices. Utility Purchase of Solar Output is a business model often applied by publicly owned utilities to create value for their communities by supporting local PV development (for example by offering a feed-in tariff to purchase PV electricity).

The up-front capital requirements of PV installations remain a common barrier to deployment. Third-party financing schemes (including leases and power purchase agreements) that address high up-front capital requirements are becoming more common. In 2011 approximately 47 percent of residential PV systems installed through the California Solar Initiative used third-party financing arrangements.

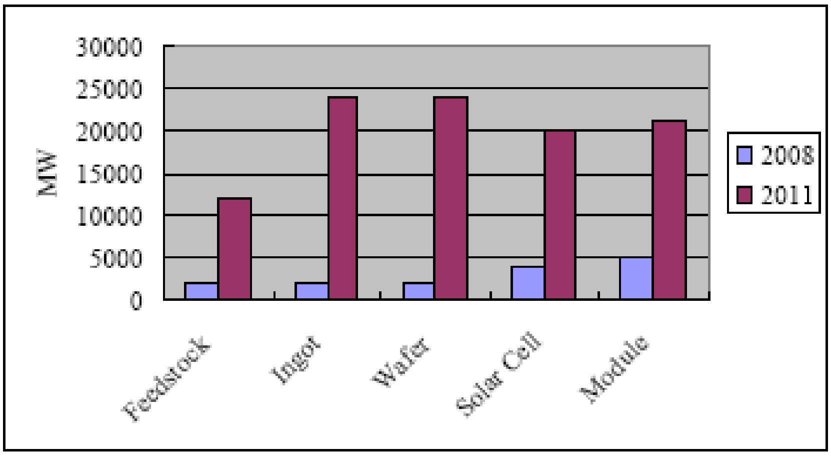
China

About 2,500 MW of PV were installed in China in 2011, a fivefold increase on 2010 levels. Total installed capacity in China reached close to 3,300 MW, up from 100 MW four years ago. Of the PV capacity installed during 2011, some 2,000 MW were large-scale grid-connected power stations, 480 MW were building-integrated or building-attached systems, and about 15 MW were installed for rural electrification and off-grid industrial applications.

Since 2008, large-scale plants have been developed in China and are now clearly the dominant application (see Figure 109). In more recent years building-related PV has been receiving strong support from the government and is playing an increasingly important role in the Chinese PV market. (See also section 4.3).

[186] U.S. Department of Energy, (2008), Solar energies technologies programme

Figure 109: Annual yields of 2011 and its comparison with 2008



Source: Wang Sicheng, Incentive Policies and Market Trends of PV in China, 2012. Solarbuzz China PV Conference.

China, as the world's largest producer, reported production of solar wafers amounting to 24.5 GW, with GCL-Poly Energy and LDK Solar together contributing 17 percent of global production[187].

In 2011, China produced 84,000 tonnes of polysilicon, a 87 percent increase from the previous year and reported 165,000 t/yr of production capacity in 2011. Meanwhile, China imported 64,600 tonnes of polysilicon, a 36 percent increase from the previous year. China reported that its top ten crystalline silicon PV cell producers manufactured 11.5 GW of cells in 2011 and it is noteworthy that nine of these companies have GW-scale production capacity (two have more than 2 GW production capacity – JA Solar with 2.8 GW/yr and Suntech Power with 2.4 GW/yr). 450 MW of thin-film silicon PV modules were produced by Hanergy and Trony Solar in 2011. Hanergy has 1.5 GW/yr of production capacity in total.

Japan

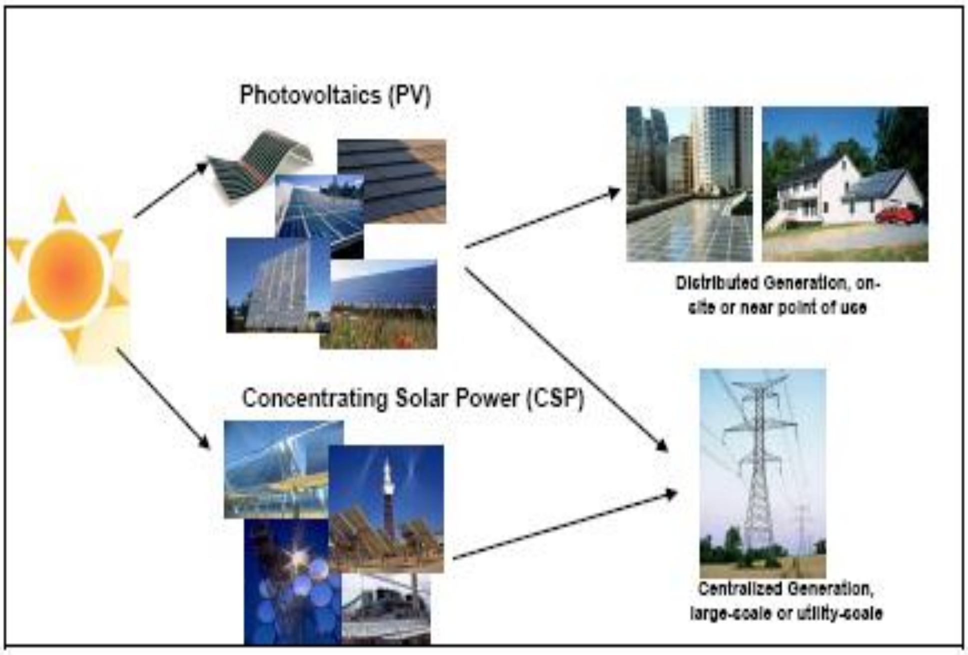
During 2011 a total of 1,295.8 MW of PV were installed in Japan[188], a 31 percent increase above that installed the previous year. Most of these installations (over 1,245 MW) continued to be mainly residential, grid-connected distributed PV systems, with a further 45.9 MW comprising grid-connected centralized plants. The PV market was led by a subsidy programme for residential PV systems and a programme to purchase surplus PV power at a preferential price from systems of less than 500 kW capacity. Cumulative installed capacity of PV systems in Japan in 2011 reached 4.9 GW or 2.1 percent of total national electricity generation capacity.

The Japanese PV market is dominated by grid-connected distributed PV systems, mainly for private housing, collective housing or apartment buildings, public facilities, industrial and commercial facilities (see Figure 110). The 10 MW Komekurayama Solar Power Plant, (Kofu City, Yamanashi Prefecture), Owner: TEPCO (Tokyo Electric Power Company) Residential PV systems accounted for 85.4 percent of the grid-connected

[187] IEA, (2011), National Survey Report of PV Power Applications in China 2011.
[188] US DOE, (2009), Soaking Up the Sun: Solar Power in Germany and Japan

market in Japan in 2011. PV systems for public facilities, supported by the national and local governments, accounted for 2.1 percent of the grid- connected market, while PV systems for industrial and commercial use accounted for 8.6 percent. Grid-connected centralized PV systems accounted for 3.6 percent of the grid-connected market in Japan.

Figure 110: PV in Japan



Source: US DOE Solar Energy Technologies Program 2008

The off-grid domestic PV system market is small in size, and mainly for residences in remote areas. The off-grid non-residential PV system market operates without needing any subsidies.

Germany

The main driving force behind the robust PV market in Germany[189] remains the long-standing Renewable Energy Sources Act (EEG). In terms of achieving expansion targets for renewable energies in the electricity sector, the EEG has proved to be the most effective funding instrument at the German Government's disposal. It determines the procedure for grid access for renewable energies and guarantees favourable feed-in tariffs for them, paid by the electricity utilities. Under the EEG a uniform annual reduction of the PV feed-in tariff was envisaged. To better manage the dynamic PV market that emerged, a mechanism was introduced to adapt the feed-in tariffs to the magnitude of the growth in the market. Under this mechanism, the feed-in tariff reductions are increased or decreased if the market deviates from a pre-defined corridor. For 2010 to 2012, the corridor for the annual market was set between 2,500 MW and 3,500 MW. With around 7,500 MW of PV installed in 2011, the corridor was clearly eclipsed and consequently additional adaptations for the tariffs are under discussion.

[189] IEA, (2011), National Survey Report of PV Power Applications in Germany. Prepared on behalf of BMU – German Federal Ministry July 2012

If Germany builds green technology such as wind turbines and solar panels, its friendly neighbours will be sure to buy them, or so the German government believes. That translates into the things politicians and economists like - jobs, export earnings, trade surpluses and international prestige. As Europe's most influential country, Germany can pretty much guarantee that renewable energies will be a growth machine of the future by insisting on aggressive EU-wide carbon reduction targets.

Germany has a wide range of policy and promotional initiatives. In addition to the EEG, PV in Germany receives support from local fiscal authorities (providing tax credits for PV investments) and the state owned bank, KfW-Bankengruppe (providing loans for individuals and local authorities for measures to reduce energy consumption plus the application of renewable energies in buildings). Some federal states also provide grants for PV plants[190].

The German cumulative capacity has now reached 24.82 GW of PV connected to the electricity grid. German PV electricity prices are now around parity with retail electricity prices. Amendments to the EEG aim to promote consumers' own consumption of PV electricity to a greater degree, with private households not feeding solar electricity into the grid but consuming it themselves to gain up to €0.08/kWh. Businesses will also benefit from the amendment as the provision will apply to PV installations with a capacity of up to 500 kW (100 times the capacity of a typical German single-family home rooftop PV system[191].

Spain

Spain is one of the most advanced countries in the development of solar energy and it is one of the European countries with the most hours of sunshine. In 2008, the Spanish government committed to achieving a target of 12 percent of primary energy from renewable energy by 2010 and by 2020 expects an installed solar generating capacity of 10,000 megawatts (MW). Spain is the fourth largest manufacturer in the world of solar power technology and exports 80 percent of this output to Germany. Spain added a record 2.6 GW of solar power in 2008, increasing capacity to 3.5 GW. Total solar power in Spain was 3.859 GW by the end of 2010 and solar energy produced 6.9 terawatt-hours (TW·h), covering 2.7 percent of the electricity demand in 2010. By the end of 2011, 4,214 GW had been installed, and that year 7,912 TWh of electricity was produced. Building code laws in Spain mandate solar hot water for new and re-modeled private residences, and photovoltaics to offset some power requirements for all new and re-modeled commercial buildings.

In March 2004, the Spanish government removed economic barriers to the connection of renewable energy technologies to the electricity grid, equalizing conditions for large-scale solar thermal and photovoltaic plants and guaranteed feed-in tariffs. In the wake of the 2008 financial crisis, the Spanish government drastically cut its subsidies for solar power and capped future increases in capacity at 500 MW per year, with effects upon

[190] lobeandmail.com: Lessons From Germany's Energy Renaissance 2008
[191] IEA, (2011), Germany National Photovoltaics Status Report 2011

the industry worldwide. [192]The Spanish feed-in tariffs for renewable generators were implemented in 1998, offering the choice to generators between a fixed FiT scheme and a premium FiT scheme. The Spanish feed-in tariff differs from the German model in that it offers the option of incentives for sales into the wholesale electricity spot market as well as fixed incentives. These were changed several times since then, in 2004, 2007, 2008, 2010 and 2012. In the wake of the 2008 financial crisis, the Spanish government drastically cut its subsidies for solar power and capped future increases in capacity at 500 MW per year, with effects upon the industry worldwide. In 2010, the Spanish government went further, retroactively cutting subsidies for existing solar projects, aiming to save several billion euro it owed. During 2011 annual installed PV power in Spain rebounded somewhat to reach 345 MW. Cumulative installed capacity reached 4,260 MW. Currently 99 percent of PV installations in Spain are grid-connected systems, with the total number of PV systems exceeding 57,600. In 2012, the new Spanish government suspended all incentives for photovoltaic systems in response to the current financial situation. They have not made clear when, if ever, any incentives will be reinstated. They did make clear that this will not retroactively affect installations which previously secured feed-in tariffs[193].

Italy

Italy ranks among the world's largest producers of electricity from solar power with an installed photovoltaic capacity of 12,750 MW at the end of 2011. Italy (the south in particular) is very favourably situated for PV installations. More than a fifth of the total production in 2010 came from the southern region of Apulia – see map where red denotes the best locations for PV.

PV power installed in Italy during 2011 reached 9,304.6 MW, over 60 percent of all new electricity generation capacity. Cumulative installed and operating PV power reached 12,803 MW. Italian PV electricity production now provides 10 TWh of electricity or about 3 percent of the national electricity consumption[194].

The grid-connected distributed and grid-connected centralized PV power systems markets continue to grow rapidly and now account for almost 33 percent and 67 percent respectively of the total installed PV capacity in Italy. Almost all off-grid domestic systems have been decommissioned; off-grid non-domestic applications continue to increase slowly.

[192] Couture, Toby D. (February 23, 2011). "Spain's Renewable Energy Odyssey". Greentech Media. http://www.greentechmedia.com/articles/read/spains-renewable-energy-odyssey.
[193] http://www.pv-magazine.com
[194] Italy's total installed photovoltaic (PV) capacity. (Reuters) Sep 26, 2011

The national market stimulation initiative in operation during 2011 was the Conto Energia Programme (second, third and fourth phase). The programme represents a long-standing sustained approach to stimulation of the market. The first phase, Primo Conto Energia, defined through two governmental decrees issued in 2005 and in 2006, was completed toward the end of 2009 with 5,733 PV installations (corresponding to about 165 MW). The second phase, Nuovo Conto Energia, issued in February 2007. This phase saw the issue of the Salva Alcoa decree that extended the validity of the relevant feed-in tariffs until June 2011 and resulted in about 3,650 MW installed capacity. The third phase, (extending from January 2011 until June 2011) saw 1,550 MW installed, while under the fourth phase about 76,150 plants were installed during 2011, corresponding to some 4,100 MW. Around €3bn was provided for market incentive payments throughout 2011.

United Kingdom

During 2011, 899 MW of PV were installed in the UK bringing the cumulative installed capacity to just under 1 GW. Prior to this only 51.6 MW had been installed and this had only started in 2008. Other countries, e.g. Australia, Germany, France, Italy, Japan and the United States of America had commenced their programmes as early as 1995.

The electricity consumption of the UK is around 400 TWh, so even a fraction of this absolute potential would represent a substantial contribution to decarbonising, particularly since electricity is a high grade form of energy and so more carbon-intensive at the point of consumption. The figure for south-facing roofs and facades is 140 TWh, which ties closely to other industry estimates. Costs per watt peak, approaching STG£4 per Wp installed now and below STG£2 per Wp installed by 2020, are falling rapidly today as recent constraints in the upstream PV supply chain unwind. PV has a long-term cost-down prognosis, driven by the nature of the manufacturing process for crystalline silicon PV and also by substitution to thin film. Levelised costs per watt hour, at STG£80-£230/MWh by 2020, will be cost competitive with other energy technologies and lower in absolute, terms, even where levelised cost[195] modelling discounts the future output of the PV[196].

Grid parity will occur in around 2013 for residential customers, and around 2018 for commercial installations, based on current projections. PV grid parity is usually assumed to happen beyond 2020 in the UK. Generally there is a good and ever improving investment case for solar PV, particularly at the residential level. PV is an investment grade technology due to its long life, reliability and predictability, and is seen as a valuable and low risk asset class for investors of many different types.[197]

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[195] Levelized Energy Cost (LEC, also known as Levelised Cost of Energy, abbreviated as LCOE). It is an economic assessment of the cost of the energy-generating system including all the costs over its lifetime: initial investment, operations and maintenance, cost of fuel, cost of capital, and is very useful in calculating the costs of generation from different sources.

[196] UK PV Manufacturers Association. (2009), "2020 A Vision for UK-PV"

[197] Ernst & Young, "Securing the UK's energy future", 2009

France

The grid-connected PV power installed in France during 2011 amounted to 1,634 MW, up from 817 MW in 2010, representing 57 percent of newly installed electricity generation capacity. The 100 percent annual market increase derives mainly from medium-scale systems (36 kW to 250 kW) and large-scale systems (> 250 kW) contributing to 36 percent and 46 percent respectively of the annual installed power. In 2011, 432 MW of ground-mounted centralized systems and 1,232 MW of distributed systems (mainly building applications) were connected to the electricity grid. Also, in 2011 power installations of less than or equal to 3 kW (residential rooftops) represented 12 percent of the installed power but 87 percent of the number of systems installed that year[198].

The majority of French PV installations are located in regions where there is the most sunshine. The most active regions include Provence –Alpes –Côte d'Azur (13 percent of the total cumulative power); Midi-Pyrénées (10 percent); Aquitaine (10 percent); Languedoc-Roussillon (9 percent); Pays de la Loire (7 percent) and Rhône-Alpes (7 percent). Reunion Island accounts for 50 percent of the installed power in the overseas department and 5 percent of the total national photovoltaic power[199].

Netherlands

From 2008, market growth accelerated compared to previous years as a direct consequence of the start of the new subsidy tariff scheme (SDE) and the limited net metering obligation for energy companies. Over three years, an average of 25 MW PV per year was allocated under SDE subsidy conditions. By the end of 2010, 18 MW of a total 69 MW were realized (with the deployment period of the first subsidy rounds remaining open). During 2011, 50 MW of PV subsidies were granted under SDE+ (a total of 111 MW granted within SDE and SDE+ by the end of 2011) and some 20 MW PV were installed. A further 23 MW of PV were installed without subsidy as a result of falling prices and interesting local initiatives. 10 MW of PV were contributed by the 'Wij Willen Zon' (We Want Sun) initiative outside the SDE scheme. Apart from the national feed-in tariff scheme, several provinces and local authorities organized regional support schemes for PV. Most regional activity originated from the provinces of Overijssel and Noord-Brabant.

The province of Noord-Brabant stimulated the development of solar energy with a substantial investment, aimed at positioning this region at the top of solar energy technology and innovation in Europe. Investment is used to attract additional research and knowledge development. The knowledge developed in institutions, laboratories and test facilities is made available to local companies, allowing them to apply new capabilities commercially, with the goal of increasing the solar-related employment opportunities in the region[200].

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[198] IEA, (2012), Trends in photovoltaic applications: Survey report of selected IEA countries
[199] Ibid.
[200] Ibid.

Several banks provide Green Mortgages (ASN, Triodos, ING, Rabobank, Fortis), offering 1 percent to 2 percent discounts on market interest rates.

Sweden

A direct capital subsidy for installation of PV systems has been in operation in Sweden since 2009. This subsidy was planned to end at the close of 2011 but, in October 2011, was extended for one year and a budget was allocated for 2012. The subsidy applies to any type of grid-connected PV system completed by 31 December 2012 and is targeted at companies, public organizations and private individuals. In 2011, the subsidy covered 60 percent (55 percent for big companies) of the installation cost of PV systems, including both material and labour costs. In the new ordinance for 2012 this has been lowered to 45 percent to follow the decreasing system prices in Sweden. The budget for 2012 is 60 MSEK. In 2003, a tradable green electricity certificate system was introduced in Sweden to increase the use of renewable electricity, with the objective of increasing renewable electricity production by 17 TWh from 2002 to 2016. However by the end of 2011 there were only 52 PV installations that have benefited from this measure. With Sweden's PV subsidy only extended one year at a time this has created uncertainty in the market and difficult conditions for the system installers. A proposal for a monthly net-billing scheme is now being investigated by the government.[201].

Canada

Electrical power generation in Canada is under provincial jurisdiction, thus Canada's provinces each have different incentive schemes. Additionally, some provinces without FITs offer either a Net Billing or Net Metering Program. There are two main differences between Net Billing and Net Metering. Net Billing requires more advanced, higher cost metering and it is capable of differentiating between on-peak and off-peak usage. Net Metering is simpler, with less disincentives to feed into the grid[202].

South Korea

South Korea's FIT system expired in 2011. It has now implemented a Renewable Portfolio Standard (RPS) scheme, which requires at least 2 percent of each energy company's supply to come from renewable resources in 2012. This will be ramped up each year. The Korea Electric Power Company (KEPCO) and its six subsidiaries look set to acquire most of their quotas from biomass and waste, as it looks to be the most cost-effective in the short term[203].

4.1.2 R&D programmes

The most significant reporting countries in terms of R&D funding

The most significant reporting countries in terms of R&D funding are the United States of America, Germany, Korea, Japan, Australia and France. China also reports various

[201] Ibid.
[202] http://www.pv-magazne.com
[203] IEA, (2012), Trends in photovoltaic applications: Survey report of selected IEA countries

ongoing programmes. (Note: Unless otherwise stated country R&D information is based on IEA reports, in particular recent annual reports including 2011)[204].

United States of America

The US is a clear leader in terms of R&D public funding for PV. DOE accelerates the research, development, and deployment of all solar energy technologies through its Solar Energy Technologies Programme (SETP). In February 2011, DOE launched the SunShot Initiative, a programme focused on driving innovation to make solar energy systems cost-competitive with other forms of unsubsidized energy. To accomplish this, the DOE is supporting efforts by private companies, academia, and national laboratories to drive down the cost of solar electricity to about $0.06/kWh. This, in turn, would enable solar-generated power to account for 15 percent to 18 percent of America's electricity generation by 2030.

By funding selective R&D concepts, the SunShot Initiative promotes a genuine transformation in the ways the United States generates, stores, and utilizes solar energy. SETP-funded research and development activities include the following: demonstration and validation of new concepts in materials, processes, device designs. The applied scientific research is to provide the technical foundation for significant increases in solar PV cell efficiency, to enable commercial and near-commercial PV technologies to achieve installed system cost targets of $1/W direct current by the end of the decade; and the Rooftop Solar Challenge, an initiative in which cities, states, and regions are awarded funding to develop innovative ways to drive measurable improvements in market conditions for roof-top PV across the United States, with an emphasis on streamlined and standardized approval and interconnection processes[205] (see Figure 111).

Figure 111: From Components to Installed integrated system.

Source: "Advanced Energy Initiative." The White House National Economic Council

The DOE "Solar Program" has initiated a number of activities to engage industry, research institutions and universities. These activities, including the Technology Pathway Partnerships (TPPs), the PV Technology Incubator programs, and the PV Next

[204] IEA Annual Report 2011

[205] The White House National Economic Council, (2006), "Advanced Energy Initiative", Washington, DC.

Generation programs, all are focused on achieving cost parity and domestic production levels necessary for market penetration of advanced PV technologies[206].

The major solar energy program activities include:

- **Photovoltaics Research and Development (R&D)** to achieve impactful improvements in the cost, reliability, and performance of devices, components, and systems.
- **Concentrating Solar Power R&D** to develop and improve utility-scale power systems and to create and demonstrate effective storage technologies.
- **Market Transformation** to reduce market barriers through non-R&D activities, including infrastructure development and deployment assistance.
- **Partnerships with Other Programs** to effectively accelerate the commercialization of solar energy systems and to integrate results of basic research results from other government programs into solar program R&D activities.

The TPPs aim to develop scalable manufacturing processes for commercial (or very near commercial) technologies to be able to meet projected production in the 2010-2015 timeframe.

The PV Technology Incubators explore the commercial potential of new manufacturing processes and products in order to move from pilot or pre-commercial to commercial applications and to meet the 2015 SAI goal.

The PV Next Generation program represents an important early stage investment in exploratory research and development of innovative, revolutionary, and highly disruptive PV technologies, which are expected to produce prototype PV cells and/or processes by 2015, with full commercialization by 2020-2030.

By 2011, the DOE had planned or implemented some 128 projects under the following five headings:[207]

- PV Applied Research – 38 projects
- PV Systems & Component Development – 26 projects
- PV Test & Evaluation – 12 projects
- PV Market Transformation – 29 projects
- Concentrating Solar Power – 23 projects

Germany

In Germany, R&D is conducted under the new 6th Programme on Energy Research ‘Research for an environmental friendly, reliable and economical feasible energy supply’,

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[206] U.S DOE, (2008), Solar Energy Technologies Programme, US Department of Energy, Multi Year Program Plan 2008-2012

[207] U.S. DOE/EIA, (2011), Solar Photovoltaic Cell/Module Manufacturing Activities

which came into force in August 2011. Within this framework, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federal Ministry of Education and Research (BMBF) support R&D ranging from basic research to applied research on almost all aspects of PV. In 2011, PV research funding showed a significant increase, particularly due to the implementation of the Photovoltaics Innovation Alliance, a joint programme of BMU and BMBF, launched in 2010 to promote a significant reduction of PV production costs.

In 2011, a total of 96 new projects were approved (2010: 45 projects), with a total funding volume of around €74M, compared with just under €40M in 2010. In 2011, a total of €39M was allocated to on-going projects, on a par with the previous year. BMU research funding priorities are silicon wafer technology, thin-film technologies, systems engineering, alternative solar cell concepts and new research approaches (such as concentrating PV), as well as general issues such as building-integrated photovoltaics, recycling, and accompanying environmental research projects.

Activities of the BMBF have three focal points: organic solar cells, thin-film solar cells (with the emphasis on topics such as material sciences including nanotechnology, new experimental or analytical methods), and the cluster called 'Solarvalley Mitteldeutschland', in which most of the German PV industry participates[208].

South Korea

Korea Energy Technology Evaluation and Planning (KETEP) has played a leading role in Korea's PV R&D programme since 2008. The R&D budget tripled in 2008 compared with 2007, showed a 20 percent increase in 2009, and increases of 12 percent and 24 percent in 2010 and 2011 respectively.

The government budget in 2010 for PV R&D was 202,551 BKRW, which was a 22.4 percent increase on 2009. Projects were mainly industry oriented, such as:

- Short term commercialization: High efficiency crystalline silicon solar cells
- Long term / innovative goals: Quantum dot, organic and dye-sensitized cells

In 2011, 42 new and continuing projects were organized under four R&D sub-programmes – Commercialization Technology Development; Strategic R&D; Basic & Innovative R&D and Short-term Core Technologies Development for Medium and Small industry. The R&D budget for the 42 new projects amounted to $47.2M. The sub-programme Basic & Innovative R&D is led by research institutes or universities, and the other three sub-programmes are led by industry. An example of Commercialization Technology Development projects funded in 2011 is 'Development of high-efficiency and large-area thin-film PV modules' that focuses on CIGS and silicon-based thin-film technologies.

[208] IEA: Germany National Photovoltaics Status Report 2011 Prepared on behalf of BMU – German Federal Ministry for the Environment, Nature Conservation and Nuclear

Japan

Japan reported various activities concerning PV R&D. The New Energy and Industrial Technology Development Organization (NEDO) conducted national PV R&D programmes, 'R&D on Innovative Solar Cells' and 'R&D for High Performance PV Generation System for the Future' with funding from the Ministry of Economy, Trade and Industry (METI).

The Ministry of Education, Culture, Sports, Science and Technology (MEXT) continued two programmes, Photoenergy Conversion Systems and Materials for the Next Generation Solar Cells, and Creative Research for Clean Energy Generation using Solar Energy. In addition, 'Development of Organic Photovoltaics toward a Low-Carbon Society' continues to be conducted by the University of Tokyo. With the third national supplementary budget for recovery and reconstruction of the damaged regions associated with the Great East Japan Earthquake, the Japanese government allocated a budget for the development of new research facilities in Koriyama, Fukushima Prefecture. The Research AMI PV projects cover research and development of silicon feedstock, crystalline silicon process, thin-films, and concentrator photovoltaic (CPV) and launched the three-year PROGELEC research programme (renewable electricity production and management) in early 2011. The 'Photovoltaic electricity production' theme selected five research projects.

The new three to five-year R&D projects will receive support from ADEME and ANR (refundable advances and subsidies) amounting to around €80M.

China

Currently there are dozens of research institutes, organizations and companies engaged in PV cell R&D, their research scopes cover almost all kind of PV cell technologies. China reported various R&D activities on crystalline silicon solar cells, thin-films, concentrator solar cells and system integration.

While the magnitude of the budget is not reported, China has been conducting PV R&D under the National High-tech R&D Programme (863 Programme) since 1986 and basic research related to PV under the National Basic Research Programme (also called the 973 Programme). The Ministry of Science and Technology (MoST) supports the key technologies in storage, transmission demonstrations of PV and wind power generation.

Under China's 12th Five Year Plan (2011–2015) major R&D projects are planned to facilitate breakthroughs in all areas, to promote significant growth in PV power generation (see Figure 112).

Figure 112: Subsidies (capital and FiT) of National PV projects in China

Project name	Bidding time	Location	Project type	Initial investment or price for winner (RMB 10,000/kWp)	Feed-in Tarrif (FiT)
Solar PV building	Start from 2009	Nationwide	111 projects 91MWp	Subsidy: 15-20% Yuan/kWp	Self-consumption, the rest is feed- in

Project name	Bidding time	Location	Project type	Initial investment or price for winner (RMB 10,000/kWp)	Feed-in Tarrif (FiT)
project					grid based upon the price of eliminating sulfur coal-fire generation units
Golden-sun program	Start from 2009	Nationwide	275projects 632 MWp	Subsidy: 50-70% of initial investment	Self-consumption, the rest is feed- in grid based upon the price of eliminating sulfur coal-fire generation units
Source: Report IEA-PVPS T1-21:2012					

Targets for PV cell development by 2015 are focused on the development of greater than 20 percent and 10 percent conversion efficiencies for crystalline silicon solar cells and silicon-based thin-film solar cells respectively, and also the commercialization of CIGS and CdTe thin-films.

Besides the above investment arranged by the central government, many PV related R&D projects have been planned in 12th FYP and budgeted for by provincial government and enterprises. Other projects are also planned in the areas of polysilicon production, devices, equipment, materials, components and systems.

Demonstration of a 100 MW grid-connected PV power station, 10 MW PV micro-grid and regional 10 MW building-related PV applications are also planned. In addition to these projects, the national Programme will support R&D on the next generation of super-efficiency, new concept PV cells with 40 percent conversion efficiency[209].

EU

The European Commission promotes PV research and development under the European Union's 7th Framework Programme (FP7). 2011 marked the fifth year of the FP7 that will operate until 2013. FP7 has a significantly increased budget compared to the previous framework programme.

Material development for longer-term applications, concentration PV and manufacturing process development have attracted most European funding in FP7. With the first five calls launched under the FP7, more than €172M have already been invested. Furthermore, significant funding has been made available for thin-film technology.

The Centre for Photovoltaic Technologies (RCPVT) at the National Institute of Advanced Industrial Science and Technology (AIST) is leading the preparation work for the new

[209] Trends in photovoltaic applications: Survey report (between 1992 and 2011) : IEA 2012

facilities that will focus on crystalline silicon PV cells and system demonstration research.

4.2 PV's generation cost and competitiveness

4.2.1 Cost factors and cost reduction

PV cost structure [210]

The cost of a PV system is measured in price-per-peak-watt (€/Wp or $/Wp for example). "Peak Watt" is defined as the power at standard test conditions (solar irradiation 1,000 W/m^2, AM of 1.5 and temperature 25°C). Photovoltaic system costs encompass both module and balance of system costs. Module costs typically represent only 40-60 percent of total PV system costs. Typically the cost of installing a photovoltaic system having a power of 1 kW ranges from €3,500 to €5,000/kWp (2009). Approximately half of this investment would be for the PV modules, and the inverter, PV array support structures, electrical cabling, equipment and installation would account for the rest.

The life cycle cost (LCC) of a PV system may also include costs for site preparation, system design and engineering, installation labour, permits and operation and maintenance costs. Photovoltaic systems have an anticipated 25 year life span. Operation and maintenance costs, range between €0.02 to €0.1 cents/kWh. However, these costs can vary significantly, ranging between as low as €0.01/kWh to €0.10/kWh. The higher reported costs included maintenance costs for generators in remote hybrid PV systems, as well as capital replacement costs due to environmental factors such as extreme temperatures and vandalism. The most significant replacement cost will likely be the battery.

A dedicated cost simulation tool: The French company, Yole Développement has developed a solar virtual fab, "PV Cost Simulation Tool", to follow every PV manufacturing step. By using this interface, manufacturers are able to measure the added value generated by an innovative concept (e.g. Inkjet, electroplating, ion implantation, printing)[211].

The most important objective for today's photovoltaic (PV) market is to reduce the ratio of manufacturing cost to power output, and more specifically the manufacturing cost per kWh for solar modules". With this in mind, technical solutions are required to reach grid parity and make PV a competitive energy source. Most PV players, equipment and materials suppliers understand this fact and are partnering with cell manufacturers to bring cost/kWh down. Cost reduction solutions can come from various suppliers, including providers of semiconductor, display, printing and glass components.

This cost/kWh ratio can be reduced through:

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[210] Stanford University, (2011),Solar PV Manufacturing Cost Analysis: U.S. Competitiveness in a Global Industry Precourt Institute for Energy

[211]http://www.solarfeeds.com/pcs-solar-photovoltaics-blog-/7086-impact-of-innovative-solutions-on-pv-manufacturing-cost-.htm

- Optimization and standardization of processes in order to lower production cost down.
- Increase of performances and so produce more kWh with the same amount of money.

New companies, competition and improved performance

The photovoltaic industry landscape has changed considerably over the last five years. For example, a large number of companies invested in polysilicon manufacturing, including established players such as Hemlock, MEMC, Wafer manufacturers, LDK; PV Crystalox, but also, new entrants such as DC Chemical, Hoku, Applied Materials, Oerlikon Solar and Ulva. Applied Materials Company is one of the leading companies in the PECVD (Plasma Enhanced Chemical Vapor Deposition) area, and it has great strength in the field of amorphous silicon thin-film solar cell equipment. It performed quite well in recent years but nonetheless announced a workforce reduction in late 2012 to prosper in a highly competitive market. After several years of development, it is clear that the PV industry is at the maturity level and has its own identity: a PV value chain, specific technologies, high-tech systems and key players[212].

Efficiency – price and cost reductions

In 1998, the efficiency of a crystalline silicon solar cell was 10 percent; now these cells operate at 16 percent for multi-crystalline wafers and at 18 percent for monocrystalline wafers, partly due to the performance offered by the metallisations that DuPont has developed.

To make single crystalline silicon ingots, multicrystalline silicon ingots or multicrystalline silicon ribbons, the basic input material is highly purified polysilicon. The ingots need to be cut into bricks or blocks and then sawn into thin wafers, whereas the ribbons are cut directly to wafers of desirable size. Conventional silicon ingots are of two types: single crystal and multicrystalline.

The first type, although with different specifications regarding purity and specific dopants, is also produced for microelectronics applications, while multicrystalline ingots are only used in the PV industry. In addition, quasi-mono products that have fewer grain boundaries compared to multi-crystalline, are being commercialized by Chinese producers. Ingot producers are in many cases also producers of wafers.

With the exception of polysilicon, costs have been going down as prices for panels rose. The quoted processing costs have been heading down for years. Ingots have gotten much larger, wafers got thinner, handling improved, throughput improved, copper replaced silver, efficiency climbed etc. These things pushed costs down to help profits. Prices went up because there was more demand than supply. Now the situation is reversed and prices have dropped down closer to cost. Average module prices dropped 37.8 percent in 2009[213].

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[212] Solar Cell (Photovoltaic) Equipment Industry Report, 2009 - companiesandmarkets.com
[213] http://www.renewableenergyfocus.com/view/4760/us-report

Reported prices for entire PV systems vary widely and depend on a variety of factors including system size, location, customer type, connection to an electricity grid, technical specification and the extent to which end-user prices reflect the real costs of all the components. On average, system prices for the lowest price off-grid applications are more than double those for the lowest price grid-connected applications. This is attributed to the fact that off-grid systems require storage batteries and associated equipment.

In 2011 the lowest system prices in the off-grid sector, irrespective of the type of application, typically ranged from about $3.7W to $7.2/W. The large range of reported prices is a function of country and project specific factors. The average of these particular system prices is approximately $7.5/W, about 7 percent less than the corresponding average price reported for 2010. The lowest achievable installed price of grid-connected systems in 2011 also varied between countries. The average price of these systems was around $3.6/W, about 17 percent lower than the average 2010 price. Prices as low as around $2/W were reported; typically prices were in the range of $2.6 /W to $4.4/W. Large grid-connected installations can have either lower system prices depending on the economies of scale achieved, or higher system prices where the nature of the building integration and installation, degree of innovation, learning costs in project management and the price of custom-made modules may be significant factors.

In 2011, the average price of modules in the reporting countries was about $1.38/W, a decrease of almost 50 percent compared to the corresponding figure for 2010, following a decrease of 20 percent the previous year. Most, but not all reporting countries recorded lower module prices than in 2010. Two countries reported module prices less than $1/W; half of the lowest achievable prices fell within the range of $1/W to $1.5/W.

Solar Module Price Highlights

As of May 2010, there are now 440 solar module prices below $4.00 per watt (€3.07 per watt) or 31.5 percent of the total survey. This compares with 426 price points below $4.00 per watt (€3.07 per watt) in April. The lowest retail price for a multi-crystalline silicon solar module is $1.74 per watt (€1.31 per watt) from a United States retailer. The lowest retail price for a mono-crystalline silicon module is also $2.07 per watt (€1.55 per watt), from a German retailer. Note, however, that "not all models are equal." In other words, brand, technical attributes and certifications do matter (see also Figure 113). The lowest thin film module price is at $1.50 per watt (€1.12 per watt) from a United States-based retailer. As a general rule, it is typical to expect thin film modules to be at a price discount to crystalline silicon (for like module powers). This thin film price is represented by a 60 watt module.

Price Index Context

The module cost represents around 50–60 percent of the total installed cost of a Solar Energy System. Therefore the solar module price is the key element in the total price of an installed solar system. All prices are exclusive of sales taxes, which depending on the country or region can add 8-20 percent to the prices, with generally highest sales tax rates in Europe.

Figure 113: PV costs per watt, United States and Europe, 2007 and 2010

	USA - $/watt	Europe - €/watt	
Jan 2007	4.88	4.82	
May 2010	4.21	4.11	
May 2010	0.715	0.536	Inverter
May 2010	0.207	0.145	Battery
Source: companiesandmarkets.com/Summary-Market-Report/solar-cell			

The main factors influencing the PV market

4.2.2 The world market is changing

(Note: Unless otherwise stated items in this section are based on recent IEA annual reports).

The International Energy Association's most recent development scenario states that the global energy map is changing[214], with potentially far-reaching consequences for energy markets and trade. It is being redrawn by the resurgence in oil and gas production in the United States and could be further reshaped by a retreat from nuclear power in some countries, continued rapid growth in the use of wind and solar technologies and by the global spread of unconventional gas production. It predicts that renewables will become the world's second-largest source of power generation by 2015 (roughly half that of coal) and, by 2035, they will approach coal as the primary source of global electricity, accounting for almost one-third of total electricity output.

The Energy Development Index (EDI) for 80 countries is a composite index that measures a country's energy development at the household and community level. It reveals a broad improvement in recent years, with China, Thailand, El Salvador, Argentina, Uruguay, Vietnam and Algeria showing the greatest progress. There are also a number of countries whose EDI scores remain low, such as Ethiopia, Liberia, Rwanda, Guinea, Uganda and Burkina Faso. The sub-Saharan Africa region scores least well, dominating the lower half of the rankings. Africa is therefore a potentially important market for PV technology.

Water is growing in importance as a criterion for assessing the viability of energy projects. In some regions, water constraints are already affecting the reliability of existing operations and they will increasingly impose additional costs. In some cases, they could threaten the viability of projects. The vulnerability of the energy sector to water constraints is widely spread geographically, affecting, among others, shale gas development and power generation in parts of China and the United States, the operation of India's highly water-intensive fleet of power plants, Canadian oil sands production and the maintenance of oil-field pressures in Iraq. Managing the energy sector's water vulnerabilities will require deployment of better technology and greater

[214] IEA, (2011), Trends in photovoltaic applications survey report of selected IEA countries

integration of energy and water policies. Wind and solar power have little or no dependency on water and could thus benefit from this factor, especially in the vulnerable regions[215].

Balance of system (BOS) component manufacture and supply 2011

Balance of system (BOS) component manufacture and supply is an important part of the PV system value chain and is accounting for an increasing portion of system costs as PV module prices fall. Accordingly the production of BOS products has become an important sector of the overall PV industry.

Inverter technology is currently the main focus of interest because the demand for grid-connected PV systems is increasing. New grid codes require the active contribution of PV inverters to grid management and grid protection, so new inverters are currently being developed with sophisticated control and interactive communications features. With the help of these functions the PV plants can actively support grid management, for example by providing reactive power or back-up capacity.

4.2.3 Impact assessment of recent and planned changes in the market

In 2011, significant changes were observed in the global PV business environment[216]. The global PV market largely shifted from a seller's market to a buyer's market due to continued excess capital investment in production capacity, larger than the growth of the demand for the products. PV prices declined because of supply and demand gaps rather than the previously experienced effects of mass production and R&D efforts. PV module prices dropped to around $1/W from $2/W or higher in one year. The market share of the world's top ten PV manufacturers decreased to below 50 percent, a large decline from the 70 percent to 80 percent levels of the past. This represents much increased competition in the industry. The business environment for PV manufacturers has changed from a high-profit environment to a low-profit environment, in which the majority of manufacturers are currently incurring losses. However, significant price reductions contributed to an increased competitiveness of PV power and PV is now becoming feasible in the regions where it was previously regarded as too expensive.

Manufacturing capacities are also reported to be growing for the raw materials for thin-film PV cell technologies. Canada reported production of high purity compounds for CdTe thin-film PV cells. Monosilane gas for thin-film silicon PV modules is produced in several countries including the US and Japan.

It is reported that crystalline silicon wafer prices dropped 41 percent during 2011. The competitive business environment for PV cell and module manufacturers also affected many companies in 2011. Additionally, as a consequence of global overcapacity and lower margins within the PV industry, investors and financiers have become increasingly selective.

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215 IEA, (2012), World Energy Outlook 2012

216 companiesandmarkets.com/Summary-Market-Report/solar-cell-(photovoltaic)-equipment-industry-report

Thin-film PV manufacturers are struggling to compete with the costs of crystalline silicon PV products. A number of companies with smaller production capacity and also new entrants trying to raise their production capacity reviewed their plans and restructured their businesses. Some companies announced their withdrawal from the PV business. However, R&D and commercialization of CIGS PV modules are continuing in a number of IEA PVPS member countries, aiming for higher conversion efficiencies and higher throughput.

In 2011, concentrating PV (CPV) cell/modules are reported from several member countries. The technology is mainly based on specific PV cells using group III-V materials, such as GaAs, InP etc.

Production of specialized components, such as PV connectors, DC switchgear and monitoring systems, is an important business for a number of large electric equipment manufacturers. Dedicated products and solutions are now also available in the utility-scale power range. Along with product development of Home Energy Management Systems (HEMS) and Building Energy Management Systems (BEMS), package products consisting of 'storage batteries, new and renewable energy equipment and PV systems' are now on the rise.

Worldwide, electricity utilities are now investing in very large-scale PV plants or asking how they can benefit from meeting their customers' interest in PV plants or PV electricity, often driven by government mandates and increasingly leading to the pursuit of business opportunities. These issues provide benefits, opportunities and challenges for electricity utilities and their industry regulators. Already, on the technical side, concerns have been raised about high penetration of PV in some electricity networks.

It is highly likely that the electricity utilities will have a more significant role to play in PV deployment in coming years, particularly the 'new' electricity network businesses (operating smart grids, with advanced metering and communications, encouraging customers to be more than just a load, electric vehicles becoming significant, storage playing an increasing role in system operations and so on). On the business side, what will be the approach to widespread deployment of PV taken by these utilities and their industry regulators, who is going to pay for some of the network-related issues and how might PV be financed into the future? These are key issues for the coming years.

Key issues identified in 2011 include:

- An increase in the number of GW-scale manufacturers. PV manufacturers with production capacities of between 1 GW and close to 3 GW emerged, mainly in Asia. A number of manufacturers suffered decreased utilization of capacity.
- Supply and demand gaps widened and resulted in price reductions at all levels of the value chain. Due to the widening gap between capacity and demand, manufacturers halted their enhancement plans or downsized their production capacity. Some companies filed for insolvency.

- While manufacturers are suffering from lower margins, price reductions contributed to increased competitiveness of PV power against conventional energy sources.
- Emergence of GW-level supply capabilities for PV in the areas of materials, components and BOS, and emergence of gaps between supply and demand.
- Advancement of a partnership approach to enhance the PV business. In the area of manufacturing equipment, as well as upstream and downstream industries, the following activities were noted:
    - business expansion through acquisitions of companies in the same industry segment, and partnerships
    - securing of raw materials through entries into upstream industries
    - securing of distribution channels through entries into downstream industries
    - establishment of vertically-integrated production frameworks
    - partnerships to accelerate R&D and development of new products.

In most aspects of PV development there are technical barriers to be overcome (see Figure 114)[217].

Figure 114: Technical barriers in Photovoltaics

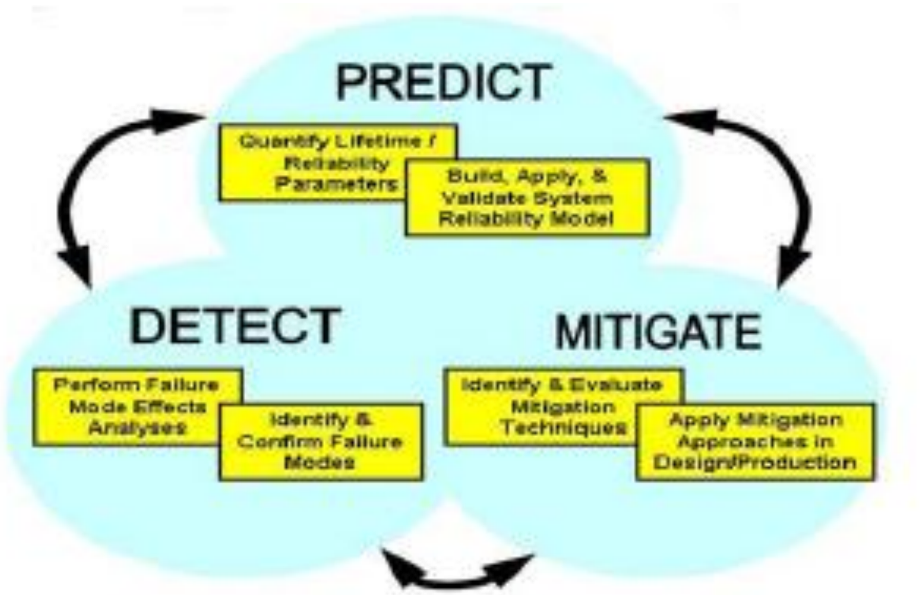
Photovoltaic Technical Barriers
Modules
A. Material Utilization & Cost
B. Design & Packaging
C. Manufacturing Processes
D. Efficiency
Inverters & Other BOS
E. Inverter Reliability & Grid Integration
F. Energy Management Systems
G. BOS Cost & Installation Efficiency
Systems Engineering & Integration
H. Systems Engineering
I. Modularity & Standardization
J. Building-integrated products

Source: US -DOE: Solar Energy Technologies Program – 2008-2012

In all components and stages the concept of reliability is very important and of significance to producers and installers. The United States research programmes have developed an approach to this problem (see Figure 115).

[217] U.S. DOE: Solar Energy Technologies Program – 2008-2012

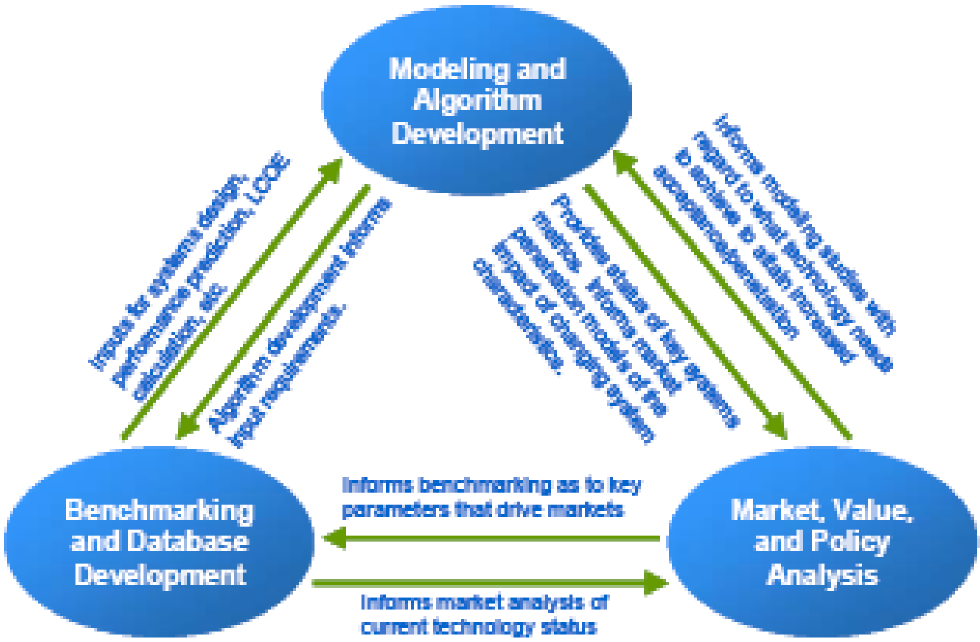
Figure 115: PV reliability program flow chart



Source: US -DOE: Solar Energy Technologies Program, 2008-2012

The formalisation of systems engineering and analysis are fundamental to the overcoming of technical barriers (see Figure 116).

Figure 116: Flowchart of systems analysis project activities



Source: U S-DOE: Solar Energy Technologies Program – 2008-2012

A trade issue concerning PV products emerged during 2011, with ongoing repercussions. In the United States, an industry group filed a petition to instigate anti-dumping procedures against PV modules using PV cells made in China. The United States Department of Commerce investigated and made a preliminary decision to impose duties on PV products using PV cells made in China.

A group of European manufacturers petitioned the European Commission to investigate dumping of Chinese modules on the European markets. The concern is that such retaliatory actions can spiral in such a way as to negatively affect the health of the global PV market.

Chinese solar panel manufacturers control two-thirds of global market share. However their profit levels are declining, exports are declining and they lack sufficient capital investment. American and European (mainly German) policies are moving towards trade protectionism. The United States has introduced a tax on systems using Chinese manufactured components of some 20 percent, which can, in some cases, rise to as high as 250 percent. Germany has, likewise, introduced a similar tax of about 10 percent. However, Britain, Denmark, Ireland, the Netherlands, Sweden and other northern countries do not agree with anti-dumping legislation.

Despite high demand in Europe, there are no European companies in the latest top 10 list of solar photovoltaic (PV) cell manufacturers according to Lux Research[218]. European manufacturers are having trouble remaining cost competitive by producing in Europe, according to Norway's leading solar PV cell manufacturer. Renewable Energy Corporation (REC), as an example, has reduced production at two of its facilities in Norway by about 400 MW in the past two months while it continues its production at full capacity in Singapore. Solar PV module prices are at a record low with major manufacturers selling around $1/W to burn through their inventories. While this price is unsustainable, it makes cost competition cut-throat.

In 2008, the top fifteen companies produced 58 percent of the world's PV cell production. Two companies were European, three were Japanese, six were Chinese, two were American, and two were Taiwanese. Three Asian companies became top fifteen cell producers in 2008 (Trina Solar, Solarfun and Gintech). Two European companies (BP Solar, Isofoton), and one Japanese company (Mitsubishi) dropped out of the top-fifteen. By 2011, there were no European companies in the top ten manufacturers.

The top 10 companies, which make up 44 percent of global solar PV cell production, include some of the Chinese crystalline silicon cell manufacturing giants, such as Suntech, Yingli and Trina (see Figure 117). Neo Solar Power, which is a Taiwanese cell manufacturer, entered the top 10 for the first time with 3 percent of global solar PV cell production. The Asian share in cell manufacturing will continue to rise and go >50percent, even though risks of trade disputes and tariffs loom in the western hemisphere. Moreover, polysilicon production has shifted to Asia during the last quarter while module production had already shifted to Asia in late 2010.

The PV industry supply chain provides many opportunities for economic activity, from feedstock production through to system deployment, as well as other supporting activities. This is highlighted by the variety of business models across the IEA PVPS countries. Significant value of business has been reported by countries with healthy domestic PV market growth and/or large export of production from somewhere along the PV industry supply chain.

[218] Lux Research's Solar Supply Tracker - January 2012

Figure 117: Top ten leading PV manufacturers in the world, 2011.

World Top Ten	Global Cell Production (%)	Cell Production in Q3 2011 (MW)
First Solar	6%	551
Suntech Power	6%	546
Yingli Green Energy	5%	431
Trina Solar	4%	370
SunPower	4%	350
Motech	4%	330
Canadian Solar	4%	325
JA Solar	4%	325
Sharp	4%	316
Neo Solar Power	3%	273
		Source: Lux Research

Export activities continue to play an important role and a number of countries have consolidated their international positions at points along the supply chain. In 2011, the highlights include manufacturing equipment from Switzerland, silicon feedstock from China, Korea, the US and Germany, PV cells from China, Japan, Korea and the US and PV modules from China, Japan and Korea.

In 2009, the German photovoltaic industry had manufacturers of silicon, wafers, solar cells, and modules (~70 PV manufacturers), PV equipment manufacturers (~100). Together they employed more than 57,000 people. German PV manufacturers' sales exceeded €9.5bn in 2008 and PV equipment manufacturers' sales added a further €2.4 bn[219]. The companies developed their skills in supporting the semiconductors, chemicals, optics and glass industries, and transferred these skills to PV manufacturing. The successful German industry has been built from the skills base.

As the demand for polysilicon increased in the early 2000s, supply did not meet demand because it was not possible to find the necessary expertise or technology. After several years' R&D and investment, the Chinese successfully developed appropriate production technologies and with investment, the capacity for polysilicon is higher than that required. Most polysilicon manufacturers were not integrated with other components as they came from R&D. Now big cell manufacturers are starting to integrate polysilicon production so as to assure material supply. The biggest integrator in China, Yingli, has integrated wafer, solar cell and module assembly since 2004, and commissioned a polysilicon facility with a production capacity of 3000 metric tons per year.

Chinese manufacturers initially imported their equipment, later they developed their own capacity, since wafer manufacture is not as difficult a process as that of polysilicon manufacturing. Accordingly, the wafer market is very competitive. Now, big cell and polysilicon manufacturers are starting to integrate wafer production[220].

[219] Kareen El-Beyrouty, Kareen, Meimanaliev, Adilet-Sultan, Lilit Petrosyan, Lilit and Singh D., (2009), Germany's Photovoltaic Cluster, Microeconomics of Competitiveness: Firms, Clusters and Economic Development, Havard University

[220] Grau Thilo, Huo Molin and Neuhoff Karsten (2011), Survey photovoltaic industry and policy in Germany and China, Berlin

Most cell manufacturing is integrated with module manufacturing. Integration allows these manufacturers to export at lower cost, compared to other non-integrated module manufacturers; moreover, their market demand is not limited by the capacity of module manufacturers. And since the process technology and equipment are easy to buy, many large cell producers have established their own module production line.

The most notable contrast between the German and Chinese PV industries is that production capacities for PV manufacturing are higher in China, while more of the manufacturing equipment is supplied by Germany. To some extent the relative size may reflect the specific expertise of Germany and China in these two related industries, but it may also reflect the outcome of the policies in place in each country.

In both Germany and China there is a mix of vertically integrated companies and value chain segment specialists. Such a mix of strategies - where some companies seek to maintain a competitive advantage in specific technologies or processes and others seek an advantage through risk management or economies of scale and scope – is not uncommon for maturing industries. Nevertheless, in an industry where policy support is so important, the mix of segment specialists and vertical integration has important implications for policy. For example, policies that increase transactions costs between segments or increase uncertainty and risk in segments of the value chain are likely to promote the integration plays, while policies that target specific segments may reinforce the segment specialists, particularly in those segments receiving support. Which of these outcomes is desirable will depend on the specific circumstances – for example, whether the sources of future cost reductions are more likely to come from de-risking of the process and growth across the value chain, or from technological advancements focused on a specific segment of the value chain.

The total value of business in 2011 amongst the IEA PVPS countries (now including China) is approximately USD $110 billion, having grown by more than an order of magnitude over the previous five years. In parallel with the business value of PV production and markets, the economic value in the 14 IEA PVPS countries can be characterized by the total direct employment of around 900,000 persons across research, manufacturing, development and installation. The large increase compared to last year's figure is due to the inclusion of the massive Chinese PV sector. Comparing directly with the countries reported in 2010, the number of labour places has remained at roughly the same level in 2011, an encouraging outcome given the prevailing global economic situation. The strong market growth in an increasing number of countries means that the risks to business of relying on single markets have diminished. At the same time, new business risks are clearly emerging with the growth of global manufacturing competition. This can provide a challenge for politicians seeking to boost domestic employment numbers in the renewable energy sector by encouraging strong demand for PV – often met significantly by imports.

New market players and increased production have been reported from non-PVPS countries, particularly Taiwan, supporting the trend towards a further price reduction of the products[221].

These, often conflicting, market developments have worldwide impacts, but on the whole fit into the market scenario of long-term significant growth for PV Inverter technology and business

In a grid-connected system, an inverter is used to convert the DC output of the array to AC power as required by the electric power grid. In Europe, the major PV inverter companies are located in Germany, Spain, Austria, Switzerland, Denmark and Italy. European companies are extending their sales bases in the emerging markets. Outside Europe, activities in this field are reported from Japan, the United States, Korea, Canada and China. In Japan, about 20 manufacturers are producing inverters. The United States produced 1.6 GW of inverters and had 7.3 GW of manufacturing capacity at the end of 2011. In the United States, the share of micro-inverters is increasing and its market share in California for residential installations reached more than 30 percent at the end of 2011. In Korea, more than eight companies are involved in the inverter business. In Canada, a number of inverter manufacturers have established manufacturing bases to address local content requirements implemented by the Province of Ontario. China reported that 53 inverter manufacturers are certified by the China Quality Certification Centre.

The inverter supply shortage that was observed globally in 2010 softened in 2011 with the increase of production capacity. The products dedicated to the residential PV market have typical rated capacities ranging from 1 kW to 10 kW, and single (Europe) or split phase (the United States and Japan) grid-connection. For larger systems, PV inverters are usually installed in a 3-phase configuration with typical sizes of 10 kW to 250 kW. With the increasing number of utility-scale PV systems in the MW range, larger inverters have been developed with rated capacities up to 2.5 MW.

Many advances are needed to transform today's inverter designed for a grid dominated by central generation into one suitable for a grid in which distributed generation (DG) sources provide significant energy to the utility. As distributed generation grows, advanced inverter/controllers and utility rate structures or dispatch signals can be used to manage reverse power flow into a distribution system that is not designed for it. The grid will ultimately need to be redesigned and replaced, at least in areas of high DG penetration. It will also be desirable for the inverter/controllers to enable distributed generation systems to continue to supply power during grid disturbances or to disconnect from the grid while continuing to meet customer needs as a stand-alone micro-grid.

[221] *Solar Supply Tracker - Lux Research January 2012*

Off-grid PV systems

For off-grid systems[222] a *storage battery* is required to provide energy during low-light periods. Nearly all batteries used for PV systems are of the deep discharge lead-acid type. Other types of batteries (e. g. NiCad, NiMH, LiO) are also suitable and have the advantage that they cannot be overcharged or deep-discharged, but are considerably more expensive. The lifetime of a battery varies depending on the operating regime and conditions but is typically between 5 and 10 years.

A *charge controller* (or regulator) is used to maintain the battery at the highest possible state of charge (SOC) and provide the user with the required quantity of electricity while protecting the battery from deep discharge or overcharging. Some charge controllers also have integrated MPP trackers to maximize the PV electricity generated. If there is the requirement for AC electricity, a *'stand-alone inverter'* can supply conventional AC appliances.

United States of America

In 2011, two federal programmes that supported PV expired[223]. A short-term programme allowed owners of non-residential PV properties to receive an up-front 30 percent cash grant in lieu of the 30 percent federal ITC. As of October 31 2011, the programme had provided 22,060 awards to 870 MW of PV projects. A temporary loan guarantee programme through the Department of Energy (DOE) guaranteed loans for seven PV generating assets, totalling 6.1 BUSD, and four PV manufacturing facilities, totalling $1.3bn.

Over the course of 2011 the federal government outlined the potential for a federal-level clean energy standard that would mandate a certain percentage of the nation's energy portfolio be derived from 'clean' sources. However, to date, a federal level mandate has yet to be implemented. Despite this lack of a national renewable energy policy framework, PV continues to grow rapidly in the US as a result of local and state initiatives.

The diversity of state markets is a source of strength, making it less likely for the US to experience the boom-bust cycles seen in many other national PV markets. California represented 29 percent of new capacity installed during 2011 compared to 32 percent in 2010, indicating stronger growth in other states. State incentives in the US have been driven in large part by the passage of renewable portfolio standards (RPS), also called renewable electricity standards (RES). As of December 31 2011, 16 states and Washington D. C. had RPS policies with specific PV provisions. Several other emergent policy and financing mechanisms have the potential to drive PV market expansion through the establishment of widespread local and utility programmes. Such policies include state-level feed-in tariffs and time-of-use electricity tariff structures. Innovative financing programmes have also been a feature of the US PV market.

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[222] Report IEA-PVPS T1-21:2012 ISBN 978-3-906042-09-1
[223] IEA, (2012), IEA world energy outlook 2012, OECD/IEA

Electricity utility interest in PV continues to increase in the US. The key drivers are the 30 percent ITC at the national level and renewable portfolio standards at the state level. To date, four broad categories of utility PV business models have emerged in the US: utility ownership of assets, utility financing of assets, development of customer programmes, and utility purchase of PV electricity.

Much of the growth in installed PV capacity, especially in the second half of 2011, came from non-residential and utility-scale installations. PV capacity continues to be concentrated in a small number of states, which include California and New Jersey. With 2.4 GW of PV projects under construction at the end of 2011, installations in 2012 are expected to increase yet again.

Concentrating Solar Power

Concentrating solar power (CSP) technologies are one of the most attractive renewable energy options for large-scale power generation in the U.S. Southwest, which is home to 15 of the 20 fastest-growing metro areas in the country. CSP plants produce power by first converting the sun's energy into heat, next into mechanical power, and lastly, into electricity using a conventional generator.

Number of installed systems

Until 2006, no commercial solar thermal electric systems had been installed in the U.S. since 1991. Two parabolic trough systems were completed in 2006-2007. No commercial dish-engine or power tower systems have ever been built in the U.S., although an 11 MW power tower began operation in Spain in 2006 and another 20 MW power tower is under construction (see Figures 118, 119 and 120).

Figure 118: Trough Plant

The 2007 parabolic trough technology baseline is a 100-MW trough plant with 6 hours of thermal storage. Since 2011, the CSP subprogram assists technology development and to validate the performance of a 150-MW trough plant.

Figure 119: Dish/Stirling System

The 2007 dish/Stirling technology baseline is a unique, hand-built prototype 25-kW dish/Stirling system that is part of a 1-MW (40-dish system) power plant. During 2011, the CSP subprogram assisted technology development and validating the performance of a 25-kW commercial dish/Stirling system.

Figure 120: Advanced Power Towers

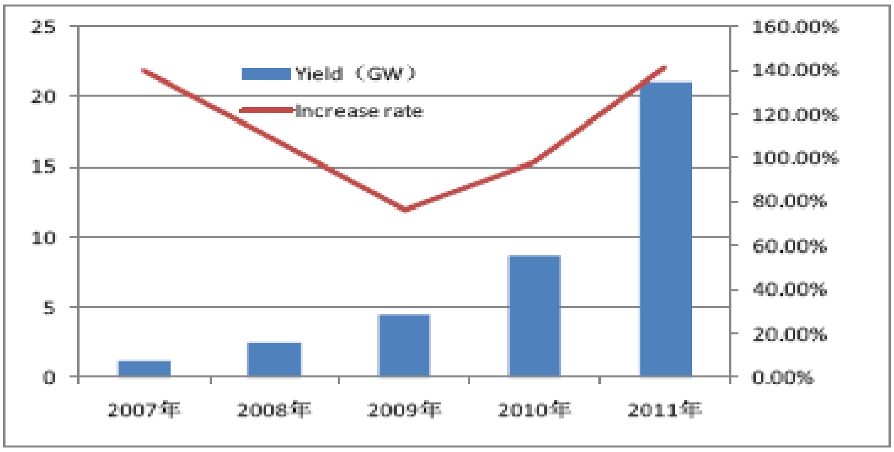
China

The Chinese Government[224] is now providing strong support via incentive policies and financial measures to expand the domestic Chinese PV market in an attempt to better balance domestic industrial production of PV and local PV market demand. Until recently most of the Chinese production was exported mainly to Spain and the United States. Both markets have significantly reduced due to the recession and anti-dumping actions, including taxation.

The recent major market support demonstration programmes in China are the Solar PV Building Project and the Golden Sun Programme, both of which commenced in 2009. Both programmes offer capital subsidies to support a variety of PV applications. The government also operates a concession programme for development of utility-scale PV power stations, with kWh payments allocated as a result of a bidding process. In China this is referred to as the nationwide feed-in tariff (announced in July 2011), with 1.15 CNY/ kWh allocated for projects finished before end 2011 and 1.0 CNY/kWh allocated for those completed thereafter.

The annual increasing rate of yields of solar PV modules in China was more than 100 percent in 2005-2008, 70 percent in 2008-2010. In 2011, it grew by more than 100 percent again (see Figure 121).

Figure 121: Solar PV modules manufacturing and growth in China



[224] Report on Chinese solar PV equipment industry, 2010-2011 - acquire-media-newsedge-dublin-2012

Source: CPIA

The total delivered PV modules were 21GW, a 141 percent increase compared with last year and contributed 60 percent of global outputs. The revenue of the industry was more than 300 billion Yuan RMB (~€3.75bn).

In November 2011, the surcharge for renewable energy collected via electricity bills was doubled to 0.008 CNY/kWh (about 1.5 percent of a typical household retail electricity price). This will allow 20 to 24 BCNY (or about $3.5bn) to be collected each year to support renewable power generation. Also late in 2011, the Chinese PV installed capacity goal for 2015 was updated from 10 GW to 15 GW, indicating an annual market of some 3 GW to 4 GW of PV each year until 2015. Utility-scale PV power stations and distributed generation will each have their own distinct market frameworks. It is anticipated that the annual market may reach 10 GW per year in the period up to 2020 and will exceed 20 GW per year thereafter. Chinese manufacturers cover a wide range of products from small to large capacity, including 1 MW centralized application inverters. With the growth of the domestic PV system market, Chinese manufacturers reported more than 30 GW/yr of production capacity. In 2011, system prices for installed PV systems in China again dropped compared to the previous years. The reduction was 30 percent. In 2011, average system price for typical on-grid systems is RMB 17.5Yuan/Wp, about €2.15/Wp.

Japan

Over 90 percent of solar panels installed in Japan prior to 2012 were installed in the residential market[225]. That means solar companies operating in Japan must adjust to some very unique operating conditions. Indeed, the Japanese home is typically much smaller than residences elsewhere in the world; the average home solar installation in Japan is only about 4 kW. That means many smaller installations; for example, in a typical month, Suntech Power Japan will service anywhere from 1,000 to 2,000 customers orders and installations. Figure 122 shows a typical home installation.

Figure 122: Rooftops and residential: solar power in Japan, Suntech Japan

Many solar companies in Japan offer not only modules, but also everything from cables and mounting hardware to inverters. The government has always offered more

[225] *International Energy Agency. " Japan: Photovoltaic technology status and prospects." 2008*

incentives in this area than in the commercial and utility markets. Currently, any homeowner who chooses to install a PV system receives a cash incentive of about 48,000 yen, or $620 per kW. There's also a net feed-in tariff for residential PV installations.

As a result of the nuclear disaster Japan will soon see commercial and utility markets heat up; the government announced aggressive new feed-in tariffs in 2012 and the market will shift accordingly. By 2020, the residential share of the total Japanese solar market is expected to drop from 90 to 70 percent, according to the Solar Electric Power Association.

In the aftermath of the Great East Japan Earthquake and the failures at the Fukushima power plant, the Energy and Environment Council of the national government began a review of Japan's energy strategy. The review focuses on reduction of dependence on nuclear power generation and expansion of both energy conservation and the use of renewable energy. Furthermore, in August 2011, the government enacted the Renewable Energy Law, under preparation since 2009, that will see Japan's Feed-in Tariff programme come into force as of July 2012. The Ministry of Economy, Trade and Industry (METI) resumed the Subsidy for Installation of Residential Photovoltaic Systems in 2009 and this was continued through 2011. In addition, with the extension of the scheme to oblige electric utilities to purchase surplus electricity generated by PV systems (below 10 kW) at a preferential price, the market demand for residential PV systems has been steadily increasing. The field test and dissemination programmes underway during 2011 were:

- The Subsidy for measures to support introduction of residential PV systems
- The Programme to purchase surplus PV power
- The Project for Promoting the Local Introduction of New Energy
- The Project for Supporting New Energy Operators
- The Project for development of stable power supply facility for emergency cases
- In addition, support for the dissemination and introduction of model projects for PV systems was provided by the Ministry of the Environment (MoE) as part of projects to reduce CO_2 emissions

As part of the nationwide response to power shortages and disaster prevention after the nuclear power plant accident, local authorities and industries showed an increased willingness to install PV systems. This market segment grew to 140 MW of PV installed during 2011 in public, industrial, commercial and power sector business facilities. Some 875 local governments and municipalities implemented their own subsidy programmes to promote the deployment of residential PV systems. Recipients can take advantage of these subsidies in addition to the national subsidies provided by METI.

Electricity utilities constructed MW-scale PV power plants ahead of schedule and many were completed across the nation in 2011. Hokkaido Electric Power, Tohoku Electric Power, Tokyo Electric Power, Chubu Electric Power, Kansai Electric Power, Hokuriku Electric Power, Shikoku Electric Power, Kyushu Electric Power and Okinawa Electric Power have all commenced operation of large-scale PV power plants. Some utilities started on-site PV power generation businesses through their subsidiaries by installing PV systems on the rooftops of properties owned by their customers.

In the housing industry, during 2011 an increasing number of manufacturers – from major prefabricated housing manufacturers to local house builders – installed PV systems as standard items in newly-built houses for sale. The development of smart houses has been accelerated. These houses are equipped with storage batteries and home energy management systems, and may also be energy self-sufficient. The amount of installations of PV systems in condominiums increased.

EU Member States

France

France's PV development objective is to have 5,400 MW of PV connected by 2020. To reach this objective the Government decided to control the development and financial impact on the CSPE tax (public electricity service contribution financed by electricity consumers through their bills) by setting up a system of feed-in tariffs for projects of capacity up to 100 kW. Revised in March 2011, feed-in tariffs are now indexed every quarter based on the number of projects submitted during the preceding quarter. The tariffs also depend on the degree of integration of the PV modules, the installation power and the type of building. Above 100 kW the support scheme involves a tendering procedure. The annual target is 500 MW for installations wanting to benefit from the support schemes: 100 MW for building-integrated residential installations up to 36 kW, 100 MW for installations between 36 kW and 100 kW, 120 MW for installations between 100 kW and 250 kW, and 180 MW for installations of more than 250 kW. The target can be reconsidered and increased to 800 MW after revision of the multi-year national investment programme for electricity production.

The reduction in feed-in tariffs every three months depends on the number of grid-connection requests made during the previous quarter. For building-integrated installations up to 3 kW, the tariff dropped from €0.58/kWh at the start of 2011 to €0.388/kWh at the start of 2012. For ground-mounted plants, the tariff dropped from about €0.3/kWh at the start of 2011 to €0.11/kWh one year later. PV electricity purchase contracts are managed financially by the EDF Compulsory Purchase Agency and other local electricity distribution subsidiaries. The first phase of the 120 MW Invitation to Tender, concerning the construction of PV installations of 100 kW to 250 kW on buildings, was launched on 17 July 2011. The French Energy Regulation

Commission (CRE)) received applications for 345 projects (68 MW). The CRE launched a second type of invitation to tender on 15 September 2011, concerning PV power applications of greater than 250 kW.

Germany

Market support measures continued to sustain the installation of grid-connected PV systems in Germany during 2011, resulting in 7.5 GW of new grid-connected PV capacity for the year, much the same amount as in 2010. The German cumulative capacity has now reached 24.82 GW of PV connected to the electricity grid. In contrast to previous EEG stipulations, open space installations will continue to be promoted beyond 1 January 2015. The areas allowed for PV installations qualifying for the feed-in tariffs under the EEG can also include land converted from residential building or transport use in addition to land converted from agricultural or military use. Open space installations can now also be developed in a 100 m wide margin alongside motorways and railway tracks. The arable land category no longer applies from 1 July 2010. Transitional arrangements for open space installations already having reached an advanced planning stage are in existence.

These actions will further strengthen the German market and thus its production base and resulting exports, especially to other EU countries. It is anticipated that this provision concerning own-consumption will trigger further important technological progress, for example in the field of storage technology. Consumption of grid electricity will be reduced, easing the demand on the grid (and possibly introducing new financial issues for the electricity industry).

Spain

During 2011, annual installed PV power in Spain rebounded somewhat to reach 345 MW. Cumulative installed capacity reached 4,260 MW. Currently, 99 percent of PV installations in Spain are grid-connected systems, with the total number of PV systems exceeding 57,600. New procedures and technical regulations were published regarding the connection of low-power electrical energy production facilities to the electricity network. This impacts PV facilities of less than 100 kW installed capacity that are directly connected to a low voltage distribution network.

According to the national action plan for renewable energies, by 2020 the share of renewables in final energy consumption should increase to 20 percent, with 3.6 percent of the Spanish electricity energy demand in 2020 to be met by PV electricity.

Italy

Italy ranked among the world's largest producers of electricity from solar power with an installed photovoltaic nameplate capacity of 12,750 MW at the end of 2011 and 263,594 plants in operation as of 18 August 201 (see Figure 123).

Figure 123: PV installed capacity by year

Year	Capacity (MW)	Growth
2007	87	100.4%
2008	432	396.6%
2009	1,144	164.8%
2010	3,470	203.3%
2011	12,750	267.4%

Source: IEA Annual Report 2011

The total energy produced by solar power in 2011 was 10,730 GWh, about 3.2 percent of the total energy demand of 332.3 TWh. The installed photovoltaic capacity, compared to the previous year, has tripled in 2010 and almost quadrupled in 2011.

In 2011 the government introduced a cap on incentives and a registry for big PV installations only, saying such measures would limit speculation on the solar market. Operators say the registry will only increase red tape.

During 2012, due to the adverse economic situation, Italy temporally suspended incentives for PV. Nonetheless, in December 2012, PV in Italy is approaching 17 GW of installed capacity, i.e. more or less the equivalent of 17 nuclear power plants, with a production efficiency so high that now the gas turbine power plants operate at half their potential during the day. The PV sector provides employment to 100,000 people especially in design and installation.

Two main barriers have recently emerged that could adversely affect the booming PV market in Italy:

- The adequacy of the electricity grid in some regions of southern Italy, where the installed power of wind turbines and PV is almost the same order of magnitude as the peak load.
- The annual cost of the incentive tariffs is rapidly approaching the budget limits fixed by the Conto Energia Programme.

Portugal

In 2011, Portugal's annual PV market again fell slightly compared to the previous year. 12.75 MW of PV (99 percent being grid-connected systems) were realized and the cumulative installed capacity rose to almost 144 MW. Grid-connected centralized systems account for about three quarters of the cumulative installed capacity in Portugal and grid-connected distributed systems make up about one quarter.

Sweden

Annual installed PV power in Sweden in 2011 reached 4.3 MW – up from 2.7 MW installed the previous year. Grid-connected installations accounted for close to 84 percent of the market. The off-grid market grew slightly due to lower module prices and a growing interest in PV. The cumulative installed power of PV systems in Sweden increased to 15.75 MW by the end of 2011. There was an increase in electricity utility interest in surplus electricity produced by small-scale renewable systems such as PV. Starting from one company buying surplus electricity in 2010, the following year saw a number of electricity utilities launching compensation schemes and some network businesses introduced net metering in 2011(although there is uncertainty how these relate to current tax laws).

The Netherlands

During 2011, about 43 MW of PV were installed in the Netherlands, bringing the cumulative installed capacity to over 131 MW. This represents a doubling of the annual market compared to the previous year for the second year running. The market in 2011 increased significantly irrespective of the absence of subsidies for small systems (less than 15 kW) during the year. The market for small to medium sized PV installations has taken off, with the declining investment costs of PV leading to near grid parity in numerous cases and a consequent upsurge in public interest.

There has been a growth in initiatives to promote the purchase of PV modules. These include large-scale, combined purchasing actions to decrease the price of the modules and their installation, substantial discounts on PV module offerings by electricity utility companies, and schemes that provide free PV, with ownership of the system remaining with the electricity utility.

Since 2004, net metering of electricity has been legally available in the Netherlands. In February 2011 the law was amended to allow for a 5,000 kWh limit on net metering and the penalty for exceeding the limit was removed. The electricity utilities are obliged by law to deduct the PV electricity from the purchased electricity before billing thereby paying the full retail price for solar electricity, including energy tax and VAT.. While many electricity utilities objected to this in principle some are offering PV to their customers and some offer unlimited net metering.

Denmark

By the end of 2011, Denmark (including Greenland) had about 17 MW of PV installed in total, an increase of more than 9 MW compared to 2010. Grid-connected distributed systems make up the majority (90 percent) of PV systems in Denmark. In Greenland stand-alone PV plays a major role as the power source for remote signalling and for the telecommunication network.

Denmark has no general incentive for reducing the investment cost of PV systems but has a net-metering scheme set by law for private households and institutions. Due to higher taxes on electricity and climbing retail electricity prices, the net-metering scheme is increasingly driving the PV market as illustrated by an annual market increase from

2010 to 2011 of 140 percent. The main PV application during 2011 was PV rooftops on residential houses – a market driven by the net-metering scheme. With electricity retail prices around 2.10 DKK, a typical payback period of around ten years can be achieved. Very healthy growth continues into 2012 and many new commercial actors are becoming active.

The Danish transmission system operator, Energinet dk, has for several years expressed interest in PV, both as a potential contributor to electricity supply and as support for the electricity grid. The distribution utilities have also promoted the use of PV and since 2009 several distribution utilities have included PV technology in their portfolio of products. EnergiMidt used to provide a capital incentive to customers inside its service area but is now marketing PV technology without any special support.

Most distribution utilities simply regard PV as a relevant standard product and some offer finance packets and payment via the electricity bill. Through its national federation, Dansk Energi, the Danish utilities have announced that they will not charge PV system owners for the use of the grid and, in addition, several distribution utilities do not charge for the metering system needed to benefit from the net-metering scheme. However, these free-of-charge services could be expected to change to a fee-for-service scheme when PV penetration levels increase significantly.

United Kingdom

Absolute resource potential for solar PV in the UK is 460 TWh for building-mounted PV[226]. Ground mounted PV would add to this further. Absolute potentials for a given technology are to some extent abstract figures, because it makes much more sense to mix technologies and to use each to their maximum benefit. But this value is a fair comparator to the equivalent metric for other technologies, and is higher than usually stated for PV.

Developing Countries

In all these discussions about policy and business in the wealthy countries of the world it should not be forgotten that PV technology offers the ability, sometimes uniquely, to provide electricity to populations remote from electricity grids and also to enhance the quality of existing electricity supplies. With a steadily decreasing cost of PV technology (plus the deployment experiences gained worldwide), it is timely that PV should begin to play a significant role in meeting the electricity needs of developing countries and in particular the one third of the world's population that still does not (and will not) have access to grid electricity. This is a market that has begun to develop.

Despite progress in the past year, nearly 1.3 billion people remain without access to electricity and 2.6 billion do not have access to clean cooking facilities. Ten countries – four in developing Asia and six in sub-Saharan Africa – account for two-thirds of those people without electricity and just three countries – India, China and Bangladesh – account for more than half of those without clean cooking facilities. While the Rio+20 Summit did not result in a binding commitment towards universal modern energy access by 2030, the UN Year of Sustainable Energy for All has generated welcome new commitments towards this goal. But much more is required. In the absence of further action, it is projected that nearly one billion people will be without electricity and 2.6 billion people will still be without clean cooking facilities in 2030. Nearly $1 trillion in cumulative investment would be needed to achieve universal energy access by 2030.

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[226] UK -Solar Cell (Photovoltaic) Equipment Industry Report, 2009 - a new market research report on companiesandmarkets.com

4.3 Themes

Analysis of the various sections of this chapter indicates key themes that affect the number and type of existing and future PV installations.

Policies and Incentives

- Enhanced feed-in tariff: an explicit monetary reward is provided for producing PV electricity; paid (usually by the electricity utility) at a rate per kWh initially higher than the retail electricity rates being paid by the customer, but now sometimes similar or lower
- Capital subsidies: direct financial subsidies aimed at tackling the up-front cost barrier, either for specific equipment or total installed PV system cost
- Green electricity schemes: allows customers to purchase green electricity based on renewable energy from the electricity utility, usually at a premium price
- PV-specific green electricity schemes: allows customers to purchase green electricity based on PV electricity from the electricity utility, usually at a premium price
- Renewable portfolio standards (RPS): a mandated requirement that the electricity utility (often the electricity retailer) source a portion of their electricity supplies from renewable energies (usually characterized by a broad, least-cost approach favouring hydro, wind and biomass)
- PV requirement in RPS: a mandated requirement that a portion of the RPS be met by PV electricity supplies (often called a set-aside)
- Investment funds for PV: share offerings in private PV investment funds plus other schemes that focus on wealth creation and business success using PV as a vehicle to achieve these ends
- Income tax credits: allows some or all expenses associated with PV installation to be deducted from taxable income streams
- Net metering: in effect the system owner receives retail value for any excess electricity fed into the grid, as recorded by a bi-directional electricity meter and netted over the billing period
- Net billing: the electricity taken from the grid and the electricity fed into the grid are tracked separately, and the electricity fed into the grid is valued at a given price
- Commercial bank activities: includes activities such as preferential home mortgage terms for houses including PV systems and preferential green loans for the installation of PV systems

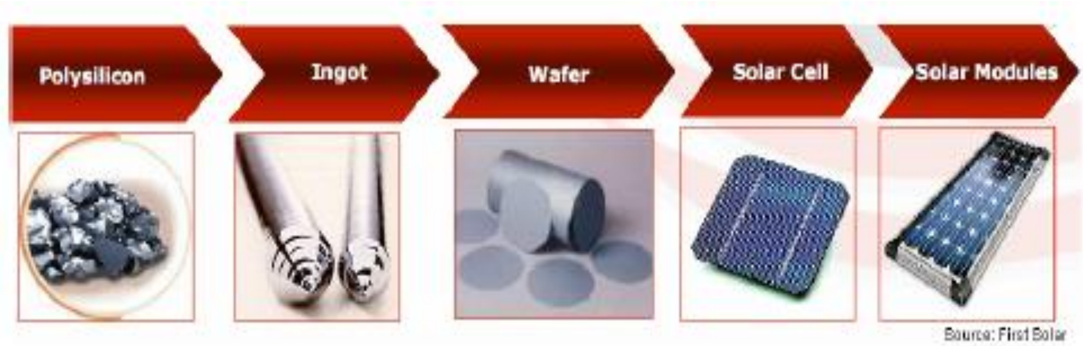
- Electricity utility activities: includes 'green power' schemes allowing customers to purchase green electricity, large-scale utility PV plants, various PV ownership and financing options with select customers and PV electricity power purchase models
- Sustainable building requirements: includes requirements on new building developments (residential and commercial) and also in some cases on properties for sale, where the PV may be included as one option for reducing the building's energy foot print or may be specifically mandated as an inclusion in the building development

Products

PV consists of silicon feedstock, ingots and wafers, solar cells and photovoltaic modules (see Figure 124).

- *Wafer-Based Crystalline Silicon* solar technology is based on the concept of fabricating discrete solar cells from silicon wafers that have been sawn from a silicon ingot, or cut from a thinly grown multi-crystalline sheet. The cells are then electrically interconnected to form a module.

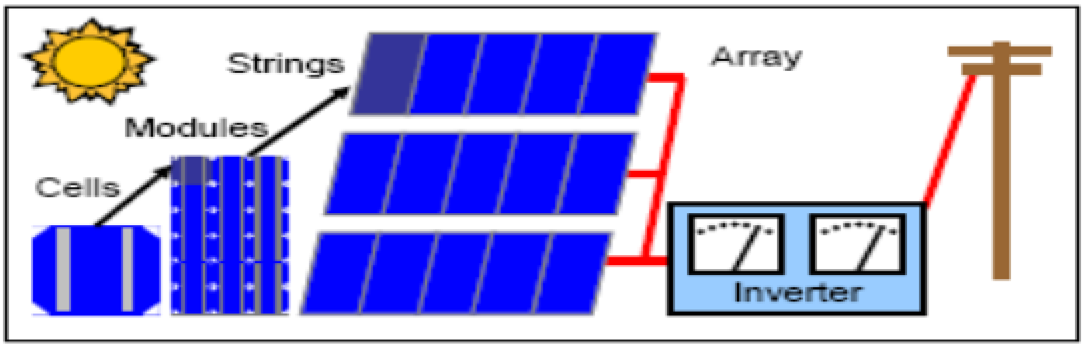
Figure 124: Stages in PV manufacturing process



- A factory-produced package containing multiple cells and composed of glass or other materials to protect the cells is called a module, and typically produces ~10-300 Watts of electricity.
- Balance of system (BOS) component manufacture and supply is an important part of the PV system value chain and is accounting for an increasing portion of system costs as PV module prices fall. Accordingly the production of BOS products has become an important sector of the overall PV industry. Production of specialized components, such as PV connectors, DC switchgear and monitoring systems, is an important business for a number of large electric equipment manufacturers. Dedicated products and solutions are now also available in the utility-scale power range. Along with product development of Home Energy Management Systems (HEMS) and Building Energy Management Systems (BEMS), package products consisting of 'storage batteries, new and renewable energy equipment and PV systems' are now on the rise.

- Photovoltaic Power Systems: For a typical application modules are placed on a ground-mounted framework or on a building and wired in series into strings which are in turn wired in parallel to form an array (see Figure 125). In a grid-connected system, an inverter is used to convert the DC output of the array to AC power as required by the electric power grid.

Figure 125: A simple PV system - suitable for an individual house



- Thin film solar cells use layers of semiconductor materials only a few micrometers thick that are deposited via processes such as vacuum deposition. While thin-films are often deposited on glass, some manufacturers use flexible substrates which are then incorporated into building materials, such as shingles.

- Concentrating PV technologies use lenses or mirrors to concentrate sunlight 25-1,000 times onto a high-efficiency silicon or multi-junction solar cell. The amount of semiconductor material required is reduced by up to 300 times, and cheaper materials, such as glass and steel, are used to capture and concentrate the sunlight.

- Solar Power Towers include a field of tracking mirrors, called heliostats, which reflect the sun's rays to a receiver located on top of a tall, centrally located tower. The solar energy is absorbed by the molten-salt working fluid flowing through the receiver.

- Organic photovoltaics (OPV) includes all forms of solar cells that use organic molecules—including polymers, dendrimers, small molecules, and dyes—as absorbers or transporters, either in fully organic devices or in devices that also contain inorganic nanostructures.

Efficiency, Cost and Price Factors

- Reported prices for entire PV systems vary widely and depend on a variety of factors including system size, location, customer type, connection to an electricity grid, technical specification and the extent to which end-user prices reflect the real costs of all the components.

- Module costs typically represents only 40-60 percent of total PV system costs. Typically the cost of installing a photovoltaic system having a power of 1 kW ranges from €3,500 to €5,000/kWp (2009). Approximately about half of this investment would be for the PV modules, and the inverter, PV array support structures, electrical cabling, equipment and installation would account for the rest.

- The life cycle cost (LCC) of a PV system may also include costs for site preparation, system design and engineering, installation labour, permits and operation and maintenance costs. Photovoltaic systems have an anticipated 25 year lifetime. Operation and maintenance costs are typically 1% - 5% of system lifetime costs. However, these costs can vary significantly, ranging between as low as €0.01/kWh to €0.10/kWh.
- In 1998, the efficiency of a crystalline silicon solar cell was 10 percent; now these cells operate at 16 percent for multi-crystalline wafers and at 18 percent for monocrystalline wafers, partly due to the performance offered by the metallisations that DuPont has developed.
- Improvements have tazken place in the manufacturing process, such as, handling and throughput has improved, copper replaced silver, efficiency climbed etc. These things pushed costs down and improved profitability. Prices increased because there was more demand than supply. Now the situation is reversed and prices have dropped down closer to cost.
- In 2011 the lowest system prices in the off-grid sector, irrespective of the type of application, typically ranged from about $3.7/W to $7.2/W. The large range of reported prices is a function of country and project specific factors.

Place Factors

- The country reports analysed in this chapter show a wide range of PV development, both in the establishment of production facilities and in the application of PV systems.
- Production facility development is largely dependent on the country's level of manufacturing capability, especially of engineering, established R&D and related education.
- The use of PV systems is primarily related to hours of sunshine and competition with other energy sources, including cost relativities (see Figure 126). Other important factors are national policies and incentives (including agreements and reactions to global warming).
- From the European Solar Radiation map it is easy to see why Spain quickly became a leading player in PV development (see Figure 127).

Figure 126: World Solar Radiation

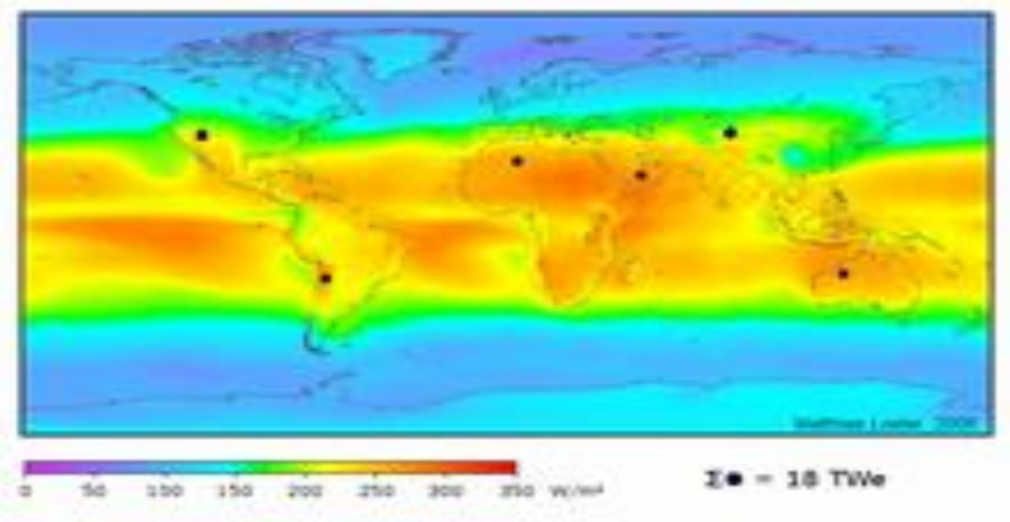


Figure 127: European Solar Radiation

5 Analysis of Strategic Documents Shaping the Future of PV

5.1 Description of scenarios for development of the energy sector

Future energy scenarios have been developed by the International Energy Agency (IEA) and a number of oil companies including BP, Statoil and Shell. Greenpeace International is one of the private bodies that also develop energy scenarios. However, the annual World Energy Outlook is the IEA's flagship publication and it is widely recognised as the most authoritative source for global energy projections and analysis. It includes medium to long-term energy market projections, extensive statistics, analysis and advice for both governments and the energy business. It is produced by the Office of the Chief Economist, IEA.

However, one should be cautious, 30 and 40 year forecasts of the global economy and energy markets are by their nature uncertain. The estimates presented by the organisations undertaking these forecasts represent the most likely trajectory for total primary energy demand and fuel mix, based on initial conditions and the most likely developments in the key energy market drivers. However, "most likely" forecasts over a 30-year horizon are not necessarily the same as "very likely", and the probabilities associated with various alternative paths may be critical. Furthermore, there is no realistic process to predict even major unexpected events, such as, the collapse of communism, the financial crisis or the Arab Spring, that could dramatically alter any forecast or scenario.

Bearing these limitations in mind the alternative scenarios will be examined.

5.1.1 The IEA scenarios

The IEA scenarios evolved over time and have become more sophisticated each year. The key scenario is the Current Policies Scenario. This and other IEA scenarios are described in the following paragraphs.

- **Current Policies Scenario:** A scenario that assumes no changes in policies from the mid-point of the year of publication (previously called the Reference Scenario). It enables policy-makers to evaluate their current path.
- **450 Scenario:** A scenario which sets out an energy pathway consistent with the goal of limiting the global increase in temperature to 2°C by limiting concentration of greenhouse gases in the atmosphere to around 450 parts per million of CO_2.
- **New Policies Scenario:** A scenario which takes account of broad policy commitments and plans that have been announced by countries, including national pledges to reduce greenhouse-gas emissions and plans to phase out fossil-energy subsidies. The measures to implement these commitments may not have been implemented or even identified.

- **Deferred Investment Case:** A scenario to analyse how global markets might evolve if investment in the upstream industry in Middle East and North Africa countries were to fall short of that required in the New Policies Scenario over the next few years.
- **Low Nuclear Case:** A scenario created to examine the implications for global energy balances of a much smaller role of nuclear power than that projected in any of the three scenarios presented in the *WEO-2011.*

In addition, the IEA has undertaken a number of energy technology perspectives that allow different technology scenarios to be explored. They are briefly described below. Those that relate to the technology perspectives are:

- **6°C Scenario (6DS):** largely an extension of current trends where average global temperature rise is projected to be at least 6°C in the long-term
- **4°C Scenario (4DS):** projects a long-term temperature rise of 4°C
- **2°C Scenario (2DS):** describes an energy system consistent with an emissions trajectory that recent climate science research indicates would give an 80 percent chance of limiting average global temperature increase to 2°C
- **BLUE Map Scenario**: is target-oriented; it sets the goal of halving global energy-related CO_2 emissions by 2050 (compared to 2005 levels)

The 4DS scenario is broadly consistent with the New Policies Scenario (to 2035) and the 2DS is broadly consistent with the 450 Scenario (to 2035).

In addition, the IEA launched a new series of medium-term market reports (five year timescales) covering the four main primary energy sources: oil, coal, gas and renewables in 2012 (see Annex 1 for references).

5.1.2 Other scenarios

Shell Scenario: For 40 years, Shell has drawn on its scenarios to enhance business decisions and its ability to respond to change. Its most recent scenarios also contributed positively to the global public debate on energy and the environment[227]. But the financial crash, the deepest economic slump in 70 years, and a patchy and fragile recovery have changed the world dramatically. Despite the economic turbulence, the fundamental drivers and uncertainties explored in its *Shell Energy Scenarios to 2050* remain fully relevant.

Greenpeace Scenario: According to Greenpeace International, its report Energy [R]evolution 2012[228] provides a consistent fundamental pathway on how to protect the world's climate; getting the world from where we are now, to where we need to be by phasing out fossil fuels and cutting CO_2 emissions while ensuring energy security. The Energy [R]evolution Scenario has become a well-known and well respected energy

[227] www.shell.com/scenarios

[228] Greenpeace International, (June 2012), Energy [R]evolution 2012, The Netherlands

analysis since it was first published for Europe in 2005. This is the fourth Global Energy [R]evolution scenario; earlier editions were published in 2007, 2008 and 2010. The evolution of the scenarios has included a detailed employment analysis in 2010, and now this edition expands the research further to incorporate new demand and transport projections, new constraints for the oil and gas pathways and techno-economic aspects of renewable heating systems. While the 2010 edition had two scenarios – a basic and an advanced Energy [R]evolution, this edition puts forward only one, based on the previous 'advanced' case.

5.1.3 Comparability of different scenarios

But are the scenarios consistent or widely different? It can be difficult to compare different scenarios unless they are based on similar type assumptions. Then one can assess if the process seems reasonable and whether they can yield a similar answer.

Five projections of the United States energy demand up to 2035 by INFORUM[229], IHSGI[230], ExxonMobil, IEA, and BP are based on aggregated demand by sectors. They can be made comparable with some minor adjustments. Interestingly, they all use a fairly a similar factor for energy demand growth based on GDP growth. The figures used are generally within 10 percent for the period 2010-2035, i.e., over 25 years.

Total energy consumption is higher in all projected years in both the IHSGI and INFORUM projections than in the *AEO2012* Reference case. ExxonMobil, IEA, and BP show lower total energy consumption in all years. ExxonMobil and BP include a cost for carbon dioxide (CO2) emissions in their outlooks, which helps to explain the lower level of consumption in those outlooks. Total primary energy demand projections for 2030 only vary by 10 percent or so, around an average of 97.8 (quadrillion Btu). For the purposes of this study, any of the reputable forecasts/scenarios give a reasonable vision of the future, subject to assumptions built into the model.

The *Annual Energy Outlook 2012 (AEO2012)*, prepared by the U.S. Energy Information Administration (EIA), presents long-term projections of energy supply, demand, and prices through to 2035, based on results from EIA's National Energy Modelling System (NEMS). EIA published an "early release" version of the *AEO2012* Reference case in January 2012.

The DOE/EIA report[231], for example, with scenarios to 2035 gives a good indication of where the United States energy market is heading and the nature of the changes that are likely to take place:

[229] Inforum, or the Interindustry Forecasting Project at the University of Maryland, was founded 45 years ago. It is dedicated to improving business planning, government policy analysis, and the general understanding of the economic environment.

[230] IHS Global Insight (IHSGI) produces a comprehensive energy projection with a time horizon similar to that of the Annual Energy Outlook 2012 (AEO2012).

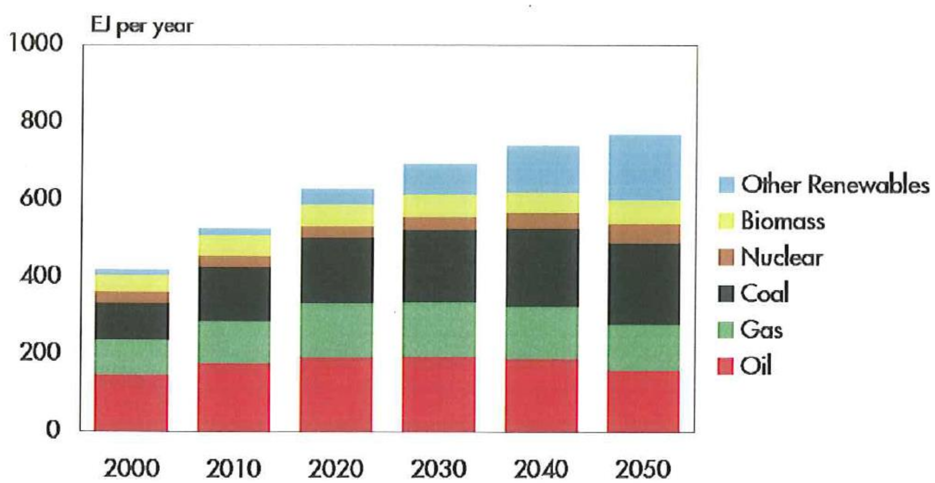
[231] DOE/EIA, (June 2012), Annual Energy Outlook 2012 – forecasts up to 2035, Ref. 0383(2012)

- The United States production of oil will be 5.5–7.8 million barrels per day. Future U.S. crude oil production could vary significantly, depending on the outcomes of key uncertainties related to well placement and recovery rates
- The natural gas share of electric power generation will increase from 24 percent in 2010 to 28 percent in 2035, while the renewables share will grow from 10 percent to 15 percent (Reference case)
- In contrast, the share of generation from coal-fired power plants will decline. The historical reliance on coal-fired power plants in the United States electric power sector has begun to wane in recent years

The data shown in Figure 128 below is based on the Shell 'Blueprints' scenario. This scenario shows that oil demand will peak between the year 2020 and 2030, demand for gas will increase, and coal will initially increase and later decrease.

Shell also predicts that **f**ossil fuels (coal petroleum and natural gas) will meet 60 percent of demand by 2050, down from 80 percent today and that nuclear will only account for 6-8 percent and renewables 30 percent in 2050. Within the renewables group, wind and solar will grow by factors of 40 and 70 times.

Figure 128: Primary energy by source, Shell 'Blueprints' scenario



Sources: Shell International BV and Energy balances of OECD and non-OECD countries.

Figure 129 clearly shows the growth that is projected for renewables over the period 2010 to 2030. Wind is predicted to grow tenfold and solar twentyfold. Other renewables will grow by 65 percent and biomass will grow by 11 percent.

Figure 129: Current projected primary energy demand (EJ per year), 2000-2030

EJ per year	2000	2010	2020	2030
Crude oil	155	168	195	197
Natural gas	87	114	146	169
Coal	96	149	184	193
Nuclear	28	32	41	56
Biomass	42	55	59	61
Solar	0	1	6	20
Wind	0	1	4	10
Other Renewables*	13	17	23	28
Total primary energy	**422**	**536**	**659**	**734**

EJ per year	2000	2010	2020	2030
demand**				
Source: Shell International projections under current and expected policies **Other renewables include hydroelectric, geothermal, tidal and waste* ***Totals may not sum due to rounding*				

AEO2012 generally agrees with this data. Renewable energy is the world's fastest-growing source of marketed energy, in the AEO2012 Reference case, increasing by an average of 3.0 percent per year from 2010 to 2035, compared to an average of 1.6 percent per year for total world energy consumption.

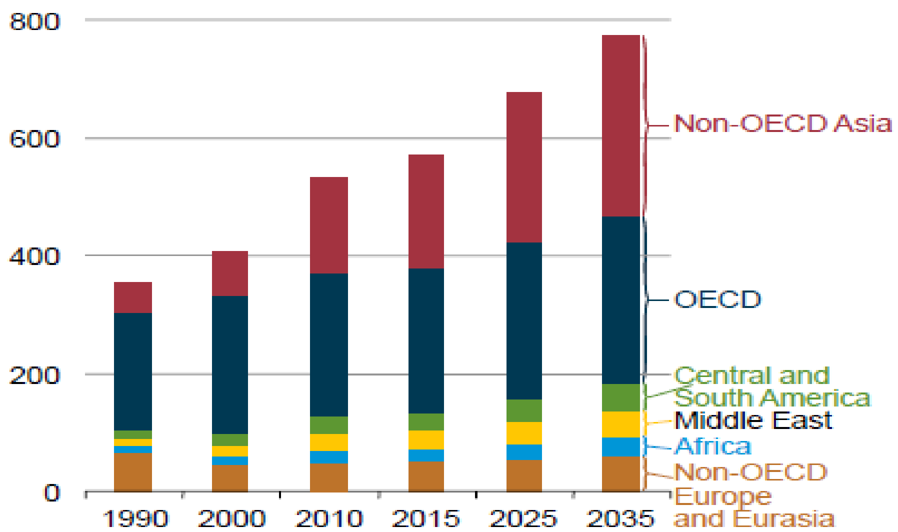
In many parts of the world, concerns about the security of energy supplies and the environmental consequences of greenhouse gas (GHG) emissions have spurred government policies that support rapid growth in renewable energy installations

Solar power is the fastest-growing source of renewable energy in the outlook, with annual growth averaging 11.7 percent. However, because it currently accounts for only 0.4 percent of total renewable generation, solar remains a minor part of the renewable mix even in 2035, when its share reaches 3 percent. Wind generation accounts for the largest increment in non-hydropower renewable generation—60 percent of the total increase, as compared with solar's 12 percent. The rate of wind generation slows markedly after 2020 because most government wind goals are achieved and wind must then compete on the basis of economics with fossil fuels. Wind-powered generating capacity has grown swiftly over the past decade, from 18 GW of installed capacity in 2000 to an estimated 179 GW in 2010.

The key drivers of energy demand and supply that emerge from the scenarios are:

- Population growth and economic development (see also Figure 130).
- Reduction in the level of energy intensity (predicted to be a factor of 2 using current technology)

Figure 130: World energy consumption by region, 1990-2035 (quadrillion Btu)



Source: DOE/EIA, Annual Energy Outlook 2012 (AEO2112)[232]

- Improved transport efficiency (less litres per 100 kilometres), lower emissions, and more electric/hybrid and new hydrogen transport will reduce the demand for petrol
- Investment requirements based on replacing obsolete plant (largely OECD countries); new plant to meet increased demand (largely non-OECD countries) and new infrastructure incorporating smart technology and more renewables
- Technology development and innovation, e.g., lower carbon emissions, improved efficiency and performance etc.
- Alternative energy sources at competitive prices, such as shale gas in the United States

There are a number of generally accepted conclusions from all these scenarios and projections. For example, in the 2011 report (issued 9 November, 2011) the executive summary noted that "The World Energy Outlook (WEO) illustrates the continued dominance of oil for transportation, even as mature economies moderate oil demand through efficiency and biofuels, emerging economies' oil demand for transport grows by almost 50 percent. The bottom line is, like it or not, we should be prepared for price swings at the pump for some time to come."

Some of the agreed conclusions are:

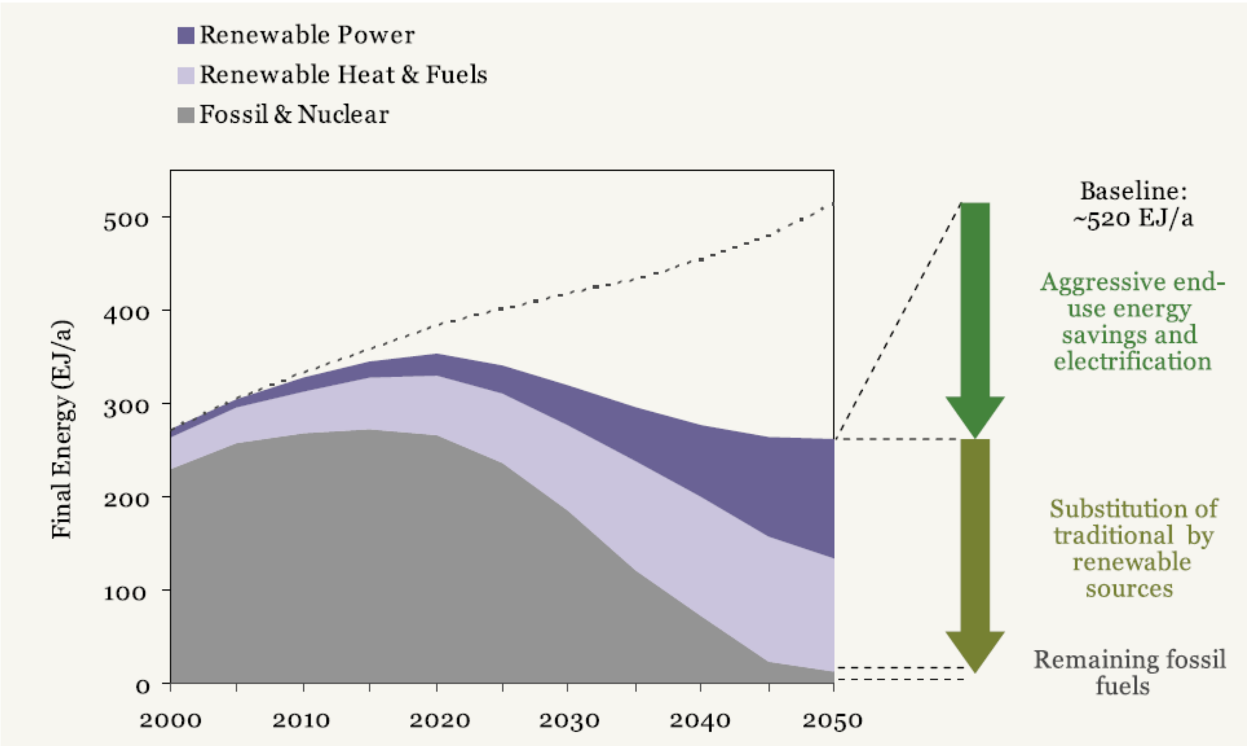
- **Fossil fuel:** supply will run out, it is finite
- **Dominant energy sources:** will remain to be oil, gas and coal up to 2050
- **Uncertainities:** demand is relatively easy to forecast compared to supply, where the impact and reserves of unconventional oil and gas are difficult to estimated and new oil fields are well-nigh impossible to predict
- **Climate change:** the 2011 IEA outlook noted in its executive summary that there were "few signs that the urgently needed change in direction in global energy trends is underway"
- **Renewables:** will grow dramatically as an energy source in the next 40 or so years, from a very low base. But it is only after 2050 they will become a significant contributor to global energy supply
- **Security:** the security of supply is dependent primarily on continuing peace in the middle-east and North African oil countries. However, it is extremely difficult to predict the future in these countries given the recent radical changes driven by the Arab Spring, the Syrian civil war and the periodic outbreaks between Israel and Palestine, and potentially between Israel and Iran

[232] DOE/EIA, (2012), Annual Energy Outlook 2012 with projections to 2035

One forecast in particular does not agree that fossil fuels will remain the dominant portion of the energy mix up to 2050. WWF in collaboration with ECOFYS and OMA produced a report on how to achieve 100% renewals by 2050[233]. *"By 2050, we could get all the energy we need from renewable sources. This report shows that such a transition is not only possible but also cost-effective, providing energy that is affordable for all and producing it in ways that can be sustained by the global economy and the planet."*

But is it possible to achieve 100 per cent renewable energy supplies for everyone on the planet by 2050? WWF called upon the expertise of Ecofys, an energy consultancy to answer this question. In response, Ecofys has produced a bold and ambitious scenario - which demonstrates that it is technically possible to achieve almost 100 per cent renewable energy sources within the next four decades (see Figure 131). The ambitious outcomes of this scenario, along with all of the assumptions, opportunities, detailed data and sources, are presented as Part 2 of this report. Obviously, the scenario raises a number of significant issues and challenges which the report addresses. The Energy Report investigates the most critically important political, economic, environmental and social choices and challenges – and encourages their further debate.

Figure 131: The ECOFYS scenario to achieve 100% renewals by 2050



The biggest challenge is that moving to a fully renewable energy future by 2050 is a radical departure from the world's path. It is an ambitious goal. The report lists 10 objectives that will help achieve its target. It would seem to be a scenario worthwhile investigating. At the very least it supports a much more rapid use of renewables than any other scenario.

EU energy development plans

[233] WWF, (2011), The Energy Report – 100% Renewals by 2050, in association with ECOFYS and OMA

The EU Treaty of Lisbon (2007) legally included solidarity in matters of energy supply and changes to the energy policy within the EU Prior to the treaty of Lisbon EU energy legislation had been based on the EU authority in the area of common market environment. The EU currently imports 82 percent of its oil and 57 percent of its gas, making it the world's leading importer of these fuels, it also imports 97 percent of the uranium used in European nuclear reactors.

The EU supports major research programmes in wind, solar, bioenergy, and CO_2 capture of transport and storage, as well as generation IV nuclear reactors.

In 2009, all member states within the EU agreed to achieve 20 percent of their energy needs from renewable sources by 2020 and to submit a national renewable energy action plan (NREAPs) by June 2010[234]. The 20 percent target is legally binding. The European Commission (E.C.) provided the format required – it included detailed roadmaps of how each Member State expects to reach its 2020 target for its share of renewable energy. They were also required to set out sectoral targets, the technology mix they expect to use, the trajectory they will follow and the measures and reforms they will undertake to overcome the barriers to developing renewable energy. The E.C. evaluated the plans, assessed their completeness and credibility. In addition, the Energy Research Centre of the Netherlands was contracted by the European Environment Agency to create an external database (ECN) and to prepare a quantitative summary of the reports. Individual country reports are available[235].

A project RES4LESS[236] initiated in 2011 under the EU's Intelligent Energy - Europe Programme, is sponsored by the Executive Agency for Competitiveness and Innovation (EACI). Its aim is to develop a Roadmap to a cost effective deployment of RES in the period up to 2020 and 2030. RES4LESS focuses on the identification of surplus potentials and valleys of opportunity for RES, in particular wind energy, biomass and solar energy in EU27+. It will quantify the potential cost-benefits that arise from cross-border cooperation in comparison to a national, fragmented approach for achieving national RES targets.

According to the European Commissioner for Energy the EU goal to cut greenhouse gas emissions by 80–95 percent by 2050 has serious implications for the EU's energy system. It needs to be far more energy efficient and about two thirds of its energy should come from renewable sources. Electricity production needs to be almost emission-free, despite higher demand.

The EU's energy system has not yet been designed to deal with such challenges. By 2050, it must be transformed. Only a new energy model will make the system secure, competitive and sustainable in the long-run. The roadmap will allow Member States to make the required energy choices and create a stable business climate for private investment, especially until 2030.

[234] Article 4 of Directive 2009/28/EC on Renewable Energy
[235] At: http://ec.europa.eu/energy/renewables/action_plan_en.htm
[236] RES4LESS, for more information see: http://www.res4less.eu/

The European Union has produced a number of very important reports including:

- Connecting the Sun: Solar photovoltaics on the road to large-scale grid integration, EPIA report, November 26th, 2012
- The Global Wind Energy Outlook, November 15th, 2012
- European Commission Report "The state of the European carbon market in 2012", November 13th, 2012
- Cost of renewable energy- reports, June 11th, 2012
- 'Green growth' - the impact of wind energy on jobs and the economy, March 6th, 2012
- Public consultation on Ten-Year Network Development Plan 2012, February 13th, 2012
- Half of EU electricity from wind by 2050, June 8th, 2011

5.1.3.1 Cost-benefit analysis of meeting the 20 percent renewables target

As renewable energy produces negligible or zero greenhouse gas emissions, the E.C. estimates that at the 20 percent target it will be possible to cut CO2 emissions by 600-900 million tonnes per year, generating savings of between €150 billion and €200 billion, if the price of CO_2 rises to €25/tonne.

Moreover, developing alternative energy sources to fossil fuels will help guarantee security of energy supply in the EU and reduce the energy bill resulting from increases in the price of fossil fuels. The savings will be over 250 million TOE (tonnes of oil equivalent) per year by 2020, of which 200 million TOE would otherwise be imported.

Furthermore, developing the technologies used in the renewable energy sector will create new business opportunities, particularly for exporting these technologies. It is also expected to have a positive impact on employment and GDP growth.

The cost of renewable energy has been falling steadily for the last 20 years, but remains higher than that of conventional energy sources. The average additional cost of meeting the 20 percent target is estimated at between €10 billion and €18 billion per year, depending on energy prices and the impact of research on lower costs.

On 17 October 2012, the Commission published a proposal to limit global land conversion for biofuel production, and raise the climate benefits of biofuels used in the EU The use of food-based biofuels to meet the 10 percent renewable energy target of the Renewable Energy Directive will be limited to 5 percent.

Roadmap targets related to the energy sector

According to the IEA World Energy Outlook 2012[237] the global energy map is changing due to the resurgence in oil and gas production in the United States; the retreat from

[237]IEA World Energy outlook 2012, (executive summary)

Nuclear Power in some countries; the growth in the use of wind and solar technologies and by the global spread of unconventional gas production. However, taking all new developments and policies into account the IEA report says that the global energy system is still not on a sustainable path. For developments to be sustainable, delivery of energy services needs to be secure and have low environmental impacts with low greenhouse gas (GHG) emissions. The IPCC Fourth Assessment Report (AR4) concluded that[238] "Most of the observed increase in global average temperature since the mid-20th century is very likely due to the observed increase in anthropogenic GHG (greenhouse gas) concentrations." Concentrations have continued to grow since the AR4 to over 390 ppm CO_2 or 39 percent above pre-industrial levels by the end of 2010.

According to the SRREN report this rising GHG concentrations implies an increase in global mean temperature which will have adverse impacts of climate change, on water resources, ecosystems, food security, human health and coastal settlements, with potentially irreversible abrupt changes in the climate system. Thus the Cancun Agreements[239] calls for limiting global average temperature rises to no more than 2°C above pre-industrial values, and to consider limiting this rise to 1.5°C. In order to be confident of achieving an equilibrium temperature increase of only 2°C to 2.4°C, atmospheric GHG concentrations would need to be stabilized in the range of 445 to 490 ppm CO_2. This in turn implies that global emissions of CO_2 will need to decrease by 50 to 85 percent below 2000 levels by 2050 and begin to decrease (instead of continuing their current increase), no later than 2015.

Thus, there are significant challenges ahead to limit the growth of CHG's and the transformation required to reach a low carbon society will need significant planning, coordination and resources. Agreements such as the 'The Kyoto Protocol' demonstrate the importance of setting binding targets as opposed to hoping that targets will be met and this mandatory approach will have to be continuously applied to future agreements and commitments. While the Kyoto agreement was not renewed in Copenhagen in 2009, the Durban meeting on Climate Change agreed to reach a new agreement by 2015. However, the United Nations Environment Program's examination of the climate action pledges for 2020 shows a major gap between what the science requires to curb climate change and what the countries plan to do. The proposed mitigation pledges put forward by governments are likely to allow global warming to at least 2.5 to 5 degrees temperature increase above pre-industrial levels.

The target roadmaps as discussed in this report have their origins in the various reports and agreements that have emanated from the recognition that the global warming and climate change are a direct result of the increase of CHG's arising from the over use of conventional fossil fuels. Thus there has been a significant amount of effort put into

[238] Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN), IPCC, First published 2012, Cambridge University Press

[239] The agreements, reached on December 11 in Cancun, Mexico, at the 2010 United Nations Climate Change Conference represent key steps forward in capturing plans to reduce greenhouse gas emissions and to help developing nations protect themselves from climate impacts and build their own sustainable futures.

generating proposals and scenarios that will not only have the potential to stabilise the level of CHG's but to ensure that it can be achieved by meeting the growing global energy requirements in a cost efficient manner.

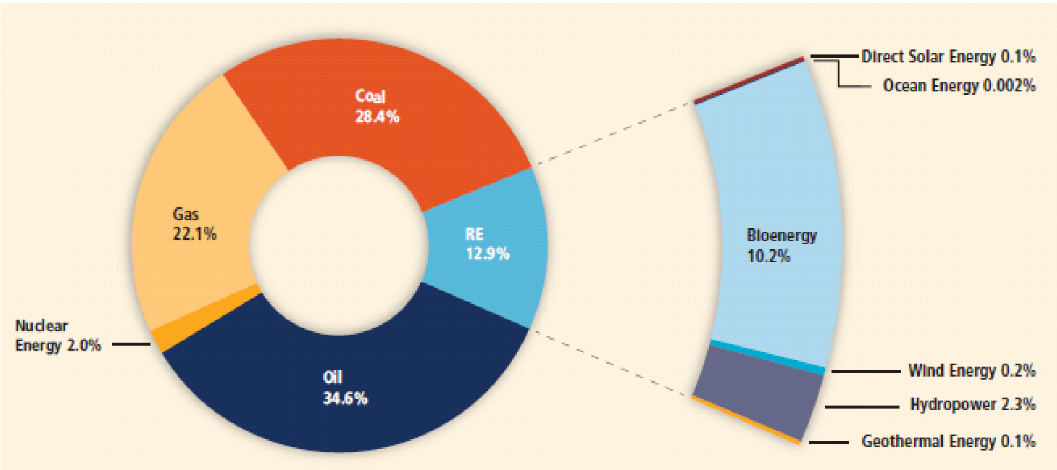
The magnitude of the challenge cannot be underestimated and it is interesting to see the current dependence on fossil fuels.

5.1.4 Renewables sources targets

On a global basis, it is estimated that Renewable Energy Sources (RES) accounted for about 12.9 percent of the 492 EJ of total primary energy supply in 2008. The largest RES contributor was biomass (10.2 percent), with the majority (roughly 60 percent) of the biomass fuel used in traditional cooking and heating applications in developing countries but with rapidly increasing use of modern biomass as well. Hydropower represented 2.3 percent, whereas other RES sources accounted for 0.4 percent (see Figure 132). In 2008, RES contributed approximately 19 percent global electricity supply (16 percent hydropower, 3 percent other RES).

While the RES share is still relatively small, its growth has accelerated in recent years and all the various roadmaps indicate that the proportion of RES in the total primary energy supply will increase between today and 2050.

Figure 132: Shares of energy sources in total global total primary energy supply in 2008 (492EJ).



Note: Modern biomass contributes 38 percent of the total biomass share.
Source: SRREN, 2012

Greenpeace[240], I.I.P.C[241] and the IEA[242] have produced a number of scenarios which attempt to forecast future global energy needs with associated predictions on the mix of energy sources including RES and fossil fuel sources. These scenarios exhibit reasonable correlation in their basic tenets that RES will be an increased contributor to electricity generation by 2050 with Wind and Solar exhibiting significant growth. The scenarios are

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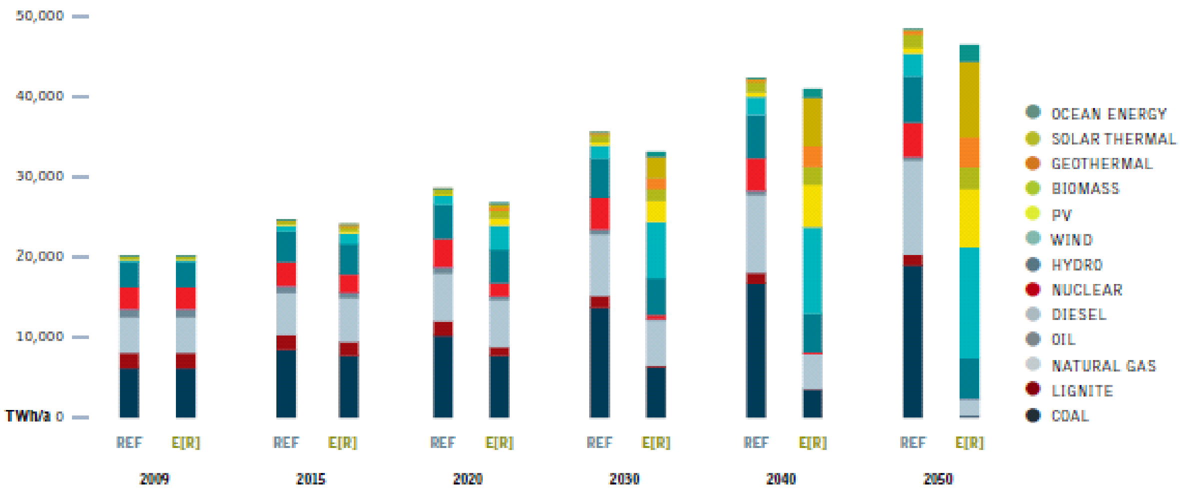
[240] Greenpeace, (2012), Energy [r]evolution, A sustainable world energy outlook, report 4th edition
[241] SRREN, (2012), op. cit
[242] IEA World Energy outlook 2012, (executive summary)

also used by Governments as a basis for setting policies that are needed to meet the various energy demand and climate change targets.

The major RES sources considered in the above reports include Bioenergy, Direct Solar Energy which includes Photovoltaics (PV) and Concentrated Solar Power (CSP), Geothermal Energy, Wind Energy, Ocean energy and Hydropower. However, according to the SRREN report[243] a variety of technology-specific challenges (in addition to cost) may need to be addressed to enable RES to significantly upscale its contribution to reducing GHG emissions. Proper design, implementation and monitoring of sustainability frameworks can minimize negative impacts and maximize benefits with regard to social, economic and environmental issues for the increased and sustainable use of bioenergy. For solar energy, regulatory and institutional barriers can impede deployment, as can integration and transmission issues. For geothermal energy, an important challenge would be to prove that enhanced geothermal systems (EGS) can be deployed economically, sustainably and widely. New hydropower projects can have ecological and social impacts that are very site specific, and increased deployment may require improved sustainability assessment tools, and regional and multi-party collaborations to address energy and water needs. The deployment of ocean energy could benefit from testing centres for demonstration projects, and from dedicated policies and regulations that encourage early deployment. For wind energy, technical and institutional solutions to transmission constraints and operational integration concerns may be especially important, as might public acceptance issues relating primarily to landscape impacts. Figure 133 shows the electricity generation structure under the reference and (R)evolution scenarios[244].

Figure 133: Global electricity generation structure under the reference and (R)evolution scenarios.



Source: Energy [r]evolution, 2012

Figure 134 shows the projected electricity capacity of RES under the Greenpeace reference and (R) evolution scenarios.

[243] SRREN, (2012), op.cit.
[244] Greenpeace, (2012), op. cit

The increased penetration of RES particularly in the power generation area is not without its specific challenges. The characteristics of different RES can influence the scale of the integration challenge. Some RES resources are widely distributed geographically. Others, such as large-scale hydropower, can be more localised but have integration options constrained by geography. Some RES resources are variable with limited predictability. Some have lower physical energy densities and different technical specifications from fossil fuels. Such characteristics can constrain ease of integration and invoke additional system costs particularly when reaching higher shares of RES. Notwithstanding these challenges all the scenarios assume that the large scale integration of RES is technologically feasible but that policy makers and industry will have to contribute in overcoming these challenges if the roadmap targets are to be achieved.

Figure 134: Global renewable electricity capacity under the reference and (R)evolution scenarios (GW)

		2009	2020	2030	2040	2050
Hydro	REF	995	1,250	1,425	1,564	1,695
	E[R]	995	1,246	1,347	1,428	1,484
Biomass	REF	51	98	155	215	272
	E[R]	51	162	265	390	490
Wind	REF	147	525	754	959	1,135
	E[R]	147	1,357	2,908	4,287	5,236
Geothermal	REF	11	18	27	37	47
	E[R]	11	65	219	446	666
PV	REF	19	124	234	351	471
	E[R]	19	674	1,764	3,335	4,548
CSP	REF	0	11	24	40	62
	E[R]	0	166	714	1,362	2,054
Ocean energy	REF	0	1	4	13	18
	E[R]	0	54	176	345	610
Total	**REF**	**1,224**	**2,028**	**2,622**	**3,179**	**3,699**
	E[R]	**1,224**	**3,724**	**7,392**	**11,594**	**15,088**

Source: Greenpeace reference and (r) evolution scenarios[245].

5.1.5 Technical targets – EU Technology Platforms

The EU goal is to cut greenhouse gas emissions by 80–95 percent by 2050[246] is a challenging target which has serious implications for the European Energy Sector. This target is a key driver in terms of energy policy and it sets the scene for various energy developments over the next four decades. During this period the use of energy will have to become more efficient and about two thirds of energy generation will have to come from renewable sources. The target includes the objective of an electricity production system that is almost emission-free despite the increased energy demand. To put the 2050 goal into perspective it is useful to relate it to the EU's 2020 target. The 2020 target if extrapolated to 2050 would still only deliver 40 percent of the 2050 emissions target. This gives an indication of the level of effort and change, both structural and social that will be needed to achieve the necessary emissions reduction, while keeping a competitive and secure energy sector. Currently, the EU energy system is not designed

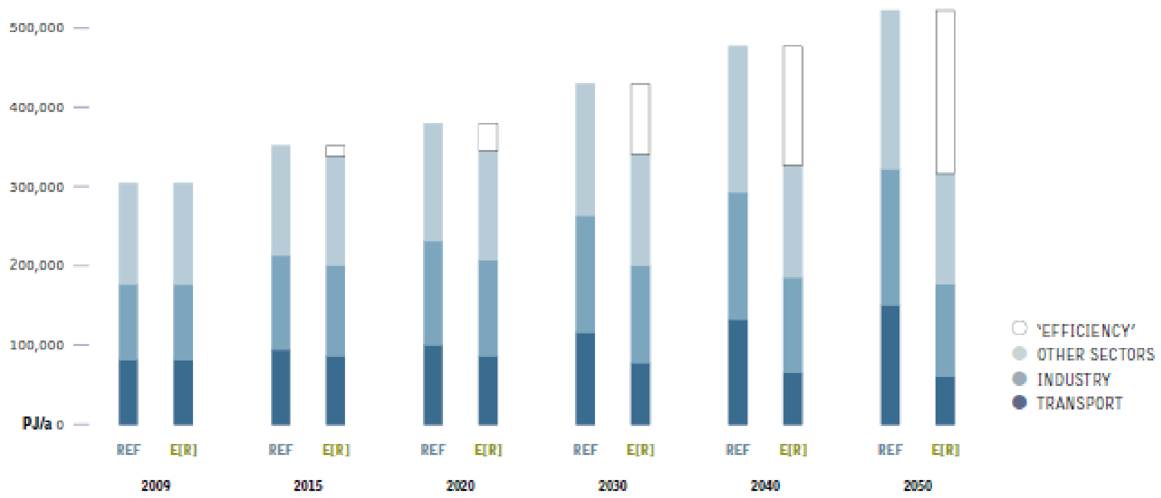
245 Ibid

246 EU, (2011), 'Energy Roadmap 2050' (COM(2011) 885 final of 15 Dec 2011) ISBN 978-92-79-21798-2

to deal with such challenges. By 2050, it must be transformed since only a new energy model will make the system secure, competitive and sustainable. However, it must be borne in mind that decisions taken today are already shaping the energy system of 2050 due to the lifespan of energy generation systems.

The future development pathways for Europe's energy demand are shown in Figure 135 for the Greenpeace Reference and the Energy (R)evolution scenario[247]. Under the Reference scenario, total primary energy demand in OECD Europe increases by 9 percent from the current 75,200 PJ/y to 82,080 PJ/y in 2050. The energy demand in 2050 in the Energy [R]evolution scenario decreases by 36 percent compared to current consumption and it is expected by 2050 to reach 47,800 PJ/y.

Figure 135: OECD Europe total final energy demand by sector under the reference and (R)evolution scenario.

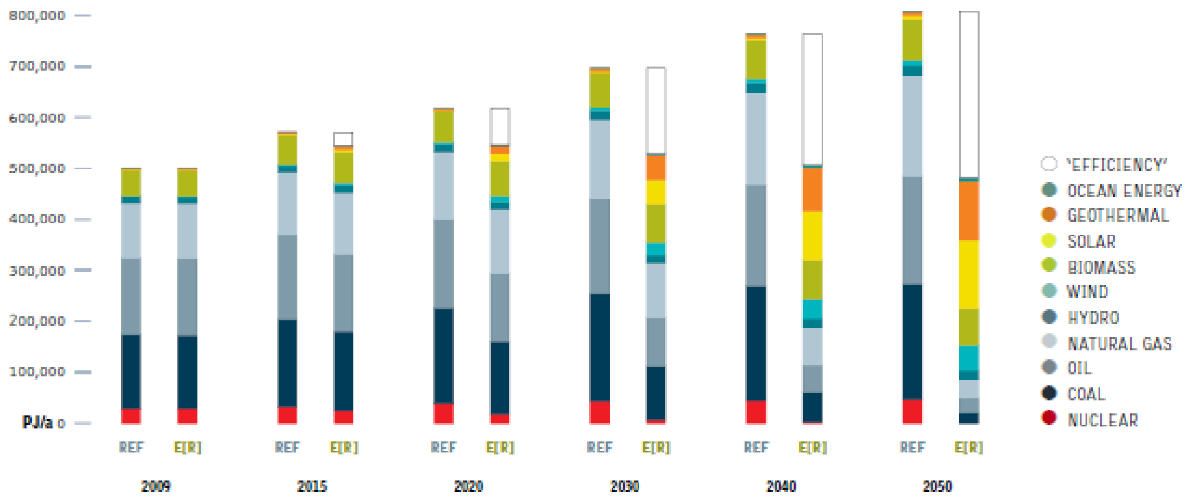


Source: Greenpeace, 2012

Figure 136 shows that by 2050, 96 percent of the electricity produced in OECD Europe will come from renewable energy sources, with wind, solar thermal energy and PV contributing 71 percent of electricity generation. This projection is based on the energy [r]evolution scenario[248].

[247] Greenpeace, (2012), op. cit
[248] Ibid

Figure 136: OECD Europe electricity generation under the reference and (R)evolution Scenario



Source: Greenpeace, 2012

The European Strategic Energy Technology (SET) Plan is intended by the European Commission to help accelerate the deployment of low-carbon energy technologies. It identifies the essential role of renewable energy sources (RES) for heating and cooling as part of the EU's strategy. The SET plan will also help create markets for highly innovative technologies that are useful to society and where European Industry can take global leadership.

The work of developing and updating the Strategic research agendas for the RES sectors is the responsibility of the Energy Technology Platforms (ETP's). These agendas provide valuable input to define European research funding schemes

Since they are developed through dialogue among industrial and public researchers and national government representatives, they also contribute to create consensus and to improve alignment of investment efforts. Avoiding duplication and making the most of centres of excellence and best practices is one of the great challenges of European research, and ETPs are a very good vehicle to improve synergies. Some European Technology Platforms are loose networks that come together in annual meetings, but others are establishing legal structures with membership fees.

Currently there are five established ETP's which are:

- Wind Energy Technology Platform
- Photovoltaics Technology Platform
- Reneable Heating and Cooling Technology Platform
- Biofuels Technology Platform
- Smart Grids Technology Platform

These RES ETP's have each contributed to the setting of targets for the EU Roadmaps which are outlined below.

5.1.6 European Wind Energy Technology Platform (TPWind) from 2008 to 2030

In 2006, the European wind energy sector launched the European Wind Energy Technology Platform (known as TPWind) [249], through the European Wind Energy Association. The main objective of TPWind is to identify areas for increased innovation, new and existing research and development tasks, and to prioritise them. The primary objective is to reduce costs relating to social, environmental and technological aspects.

In addition, TPWind builds collaboration among industry and public sector participants, and is also one of a range of different technology platforms established in partnership with the European Commission with cross-cutting activities. TPWind has developed a research agenda and market deployment strategy up to 2030, which provides a focus for EU and national financing initiatives[250].

TPWind has attempted to identify research, development and demonstration financing needs in Europe. It takes as its basis that investment should be 3 percent of turnover at a minimum in accordance with the objectives of the Barcelona European Council (EC, 2002). The platform also assumes a public/private share of investment of 1:2. In the period 2006 to 2020, the platform suggests a total R&D budget shortfall of some €1 bn in Europe[251].

TPWind have developed a 2030 vision for the industry which is expected to progress through the following phases:

Phase 1: Short-term (2020)

> The market matures in the Western part of Europe and develops in Central and Eastern Europe. Large-scale deployment of offshore wind energy begins. Installed capacity reaches 180 GW, including 40 GW offshore.

Phase 2: Medium-term (2020-2030)

> Wind energy becomes mature in all its applications both onshore and offshore. The main developments are further cost reductions and high technology penetration. Deep offshore technology develops on an industrial scale. Exports from Europe grow. Competition with low labour cost countries increases. The capacity installed reaches 300 GW in 2030, when annual installations reach 20 GW of which half is offshore and 7.5 GW is re-powering.

Phase 3: Long-Term (2030-2050)

> The main markets are in offshore and re-powering, and exports outside Europe remain strong.

To help realise the 2030 vision, TPWind has identified four thematic areas for research; wind conditions, wind turbine technology, wind energy integration and offshore deployment and operation. These thematic areas reflect the overall objective of the

[249] TPWind (European Wind Energy Technology Platform) (2008), Strategic Research Agenda and Market Deployment Strategy, from 2008 to 2030, Brussels, Belgium
[250] Ibid
[251] Ibid

sector, which is to continuously reduce real costs through greater effectiveness and efficiency.

European PV Technology Platform[252]

The European PV Technology Platform[253] recognised the necessity of Photovoltaics (PV) R&D when it produced a Strategic Research Agenda (SRA) to realise the 2005 Vision document of the Photovoltaic Research Advisory Council, set up as a precursor to the Platform. The first edition of the SRA was published in 2007 and was used as input for the definition of the Seventh Framework Programme for Research of the E. U. and also to facilitate a further coordination of research programmes in and between Member States.

Based on the adoption of binding 2020 renewable energy targets in Europe and the establishment of the Solar Europe Industry Initiative as part of Europe's Strategic Energy Technology Plan, the PV Technology Platform decided to update the SRA to address the rapid technological developments required for these new challenges and opportunities. The second edition of the SRA is intended to perform a similar function to its predecessor in terms of informing the research programmes of the EU and the Member States.

The key targets contained in the SRA are summarised in Figure 137[254]. The 2020 targets are in line with the key performance indicators defined for the Solar Europe Industry Initiative and are based on their Case Study 2, a 100 kW commercial roof system in Italy.

Figure 137: Targets for the development of PV that are used to guide research objectives

	1980	TODAY	2020	2030	LONG TERM POTENTIAL
Typical turn-key price for a 100 kW system (2011 €/W, excl. VAT)	>30	2.5	1.5	1	0.5
Typical electricity generation costs in southern Europe (2011 €/kWh)	>2	0.19	0.10	0.06	0.03
Typical system energy payback time Southern Europe (years)	>10	0.5-1.5	<0.5	<0.5	0.25

Source: European PV Technology Platform, 2011.

The study data is based on the following assumptions:

- An average performance ratio of 80 percent[255]

[252] European PV Technology Platform, (2011), A Strategic Research Agenda for Photovoltaic Solar Energy Technology Ed-2

[253] Ibid

[254] European PV Technology Platform, (2011), Strategic Research Agenda for Photovoltaic Solar Energy Technology, Edition 2, Brussels.

[255] A system yield of 800 kWh/kW•yr at a solar irradiation level of 1000 kWh / m^2•yr. A location in southern Europe, with a global solar irradiation at optimum angle of 1800 kWh/m2 is assumed and a performance ratio of 80 percent translates into 1440 kWh/kW•yr

- On average, 1 percent of the system's price is spent each year on operation and maintenance.
- The economic system lifetime is 25 years
- A discount rate of 6.5 percent is used

For the values in 2030 and beyond, longer system lifetimes and improvements in performance ratio are assumed.

The Solar Europe Industry Initiative has been established to promote the short-term R&D required to meet 2020 targets, with projects being predominantly defined and led by European Industry. PV comes, and will come in different formats, suited to different applications. The SRA does not exclude technologies but sets overall targets that any PV format must reach and describes the research priorities for each format in order for it to succeed in meeting those targets. To achieve the required cost reductions, research should address all parts of the value chain, from raw materials to the complete system. As PV provides a growing proportion of Europe's electricity requirements, the integration of PV into the electricity delivery system needs to be fully addressed. The same cost targets are used for all flat-plate PV module technologies considered and these are expressed as installed system level costs: €1.5/W in 2020 and €1/W in 2030. To meet the overall cross technology cost target, lower efficiency modules need to be cheaper than higher efficiency modules

The PV development options, perspectives and R&D needs (short, medium and long-term) aim to focus on the following areas:

- Cell and module technologies for flat-plate systems
- Efficiency, energy yield, stability and lifetime
- High productivity manufacturing, including in-process monitoring and control
- Environmental sustainability
- Integration

5.1.7 European Technology Platform on Renewable Heating & Cooling[256] (HC-Platform)

The European Technology Platform on Renewable Heating & Cooling (HC-Platform) brings together stakeholders from all concerned sources and related industries in cross-cutting technologies such as heat pumps, thermal energy storage and district heating to agree a joint strategy for increasing the use of renewable energy sources for heating and cooling. The RHC-Platform has produced its "Vision Document"[257] which provides a description of the potential deployment of the sector. They now plan to consolidate the

[256] HC-Platform, (2011), 2020 – 2030 – 2050 Common Vision for the Renewable Heating & Cooling sector in Europe, Brussels, 2011.

[257] Ibid

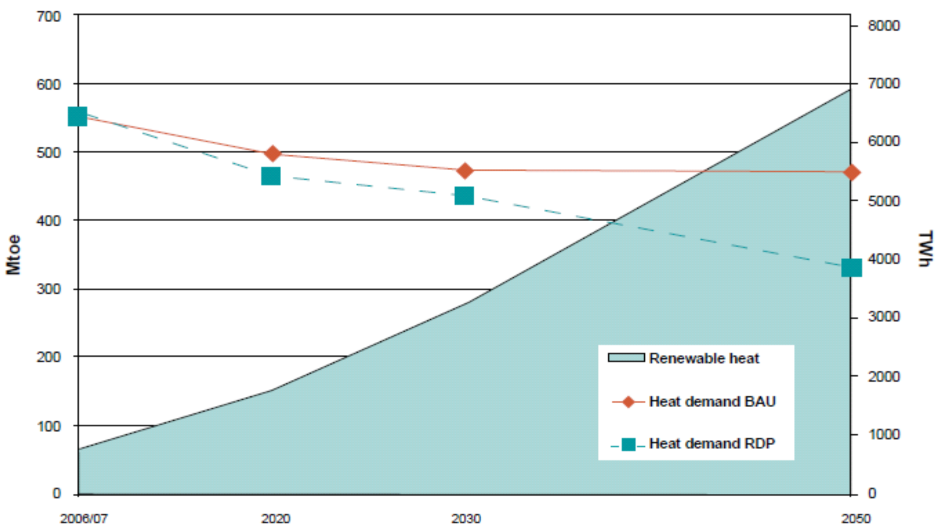
Vision Document with the definition of a Strategic Research Agenda and a dedicated Implementation Plan.

This ETP focuses on direct heating from primary Renewable Heating and Cooling (RHC) and does not consider secondary heating from RES electricity generation. The relevant RHC's that are suitable for direct heating are deemed to be Solar Thermal, Biomass, Geothermal and Hydrothermal. By 2050, the combined potential of RHC exceeds the expected heating demand[258]. Figure 138 shows that the combined potential of RHC exceeds the expected heating demand from both the "Business as Usual Scenario"(BAU) and the "Full Research, Development and Policy" (RDC) Scenario". The long-term scenario with 100 percent renewable heat will result in a dramatic reduction in the emissions of greenhouse gases associated with the consumption of fossil fuels

The HC-Platform potential targets up to 2050 are as follows:

- **By 2020** over 25 percent of heat consumed in the E. U. would be generated with renewable energy technologies.
- **By 2030** renewable heating and cooling technologies could supply over half of the heat used in the European Union.
- **By 2050** biomass could contribute 231Mtoe, while geothermal could account for 150Mtoe and solar thermal could account for 133Mtoe.

Figure 138: Heating Supply from renewable energy sources in the EU

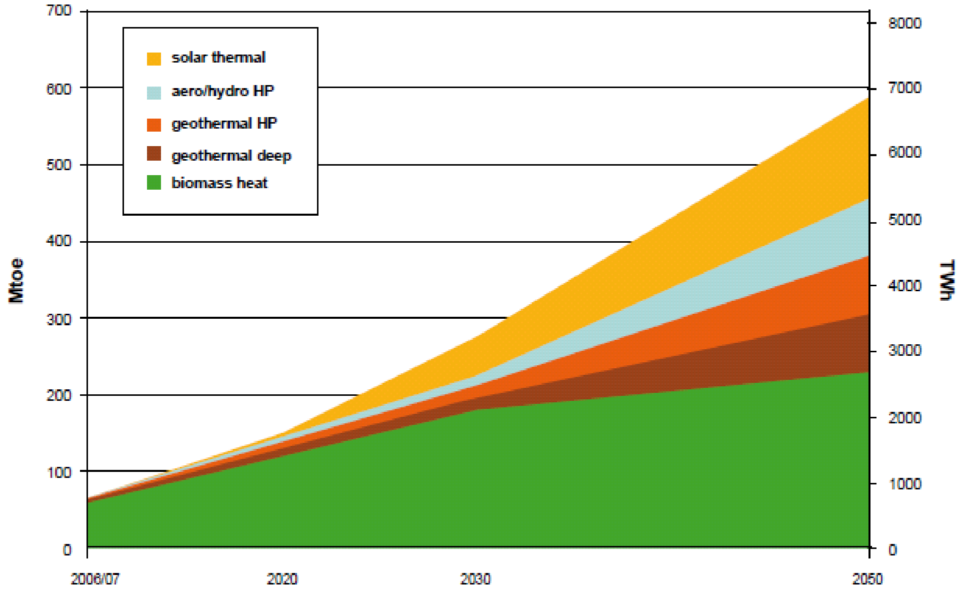


Source: HC-Platform, 2011

The breakdown of RES heat supply into its components is shown in Figure 139. The largest contributor is biomass heat followed by solar thermal.

[258] Ibid

Figure 139: Heating potential by renewable energy source in the EU



Source: HC-Platform, 2011.

The European Biofuels Technology Platform (EBTP)

The European Biofuels Technology Platform (EBTP) was established in 2006 to contribute to the development of cost-competitive, world-class biofuels technologies, and accelerate the deployment of sustainable biofuels in the EU, through a process of guidance, prioritisation and promotion of research, development and demonstration activities (R&D&D)[259].

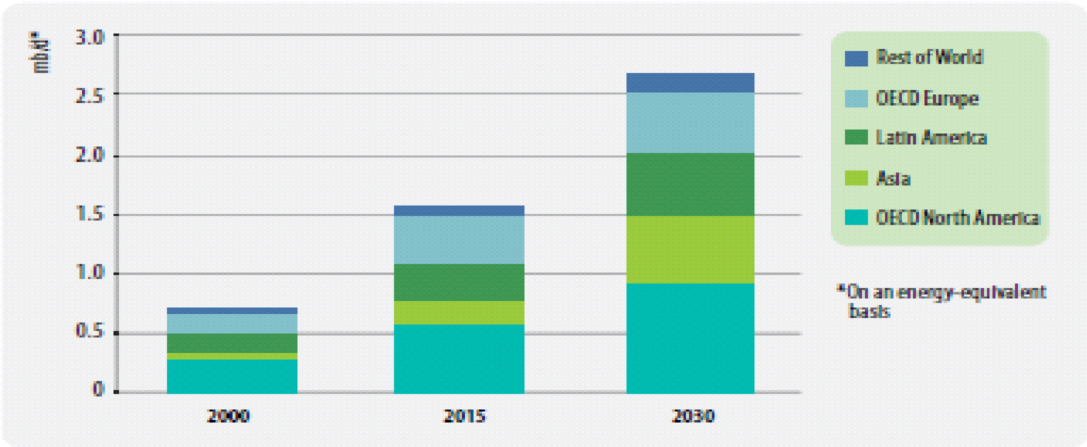
It brings together the knowledge and expertise of stakeholders active in the biofuels value chains: biomass resources provider, biofuels and bioenergy producers, technology vendors and transportation fuels marketers, transport industry, research and technology development organisations and NGOs. It is managed by a Steering Committee and supported by a Secretariat, the European Commission being an active observer. Stakeholders can register and share access to key contacts, internal and external reports, events, opinions and expertise on biofuels R&D. Platform activities are carried out through five working groups (Biomass; Conversion; Logistics and End-use; Sustainability and Markets and Regulations) and Task Forces on specific topics (European Industrial Bioenergy Initiative/EIBI, Algae).

Despite public controversy over biofuels, production and consumption in the EU and worldwide increased sharply over the past years, driven by regulations. The global biofuels supply reached 34.1 Mtoe in 2007, an impressive 37 percent rise compared to 2006. Most of the increase in biofuel usage in 2007 and 2008 occurred in the OECD countries, mainly in North America and Europe. In Europe, 10 Mtoe of biofuels were consumed in 2008. This equals 3.3 percent of all road transport fuel (energy content). Ethanol accounted for two-thirds and biodiesel for one-third of the total biofuel production (see Figure 140). In recent years, prices for both crude oil and agricultural

[259] EBTP, (2010), European Biofuels Technology Platform Strategic Research Agenda 2010 Update, Brussels.

commodities have been highly volatile. This has impacted on the economic profile of biofuels. While rising oil prices tend to increase the competitiveness of biofuels, this was offset by higher prices for agricultural commodities. Thus, even though the first European countries started to introduce biofuels 15–20 years ago, biofuels are not yet ready to compete on the market without adequate regulatory support (except for bioethanol in Brazil).

Figure 140: Biofuel Demand by region



Source: EBTP, (2010)

The *Renewable Energy Directive (RED)* and *Fuel Quality Directive (FQD)* have laid down targets for biofuels that allows for an increase in biofuel output but imposes constraints in terms of land use and the level of Greenhouse Gases (GHG). Increasing the amount of biomass available under sustainable conditions is seen as a critical challenge for the biofuel industry and it has led to a number of R&D recommendations[260].

- Develop a common view on sustainable biomass availability across different sectors, shared with all relevant stakeholders
- Develop cost supply curves for existing and new feedstocks and given timeframes, regions and demand types. Define obstacles to mobilisation
- Develop new plant varieties (crop/tree breeding and physiology); improve cultivation and management practices (propagation, cultivation systems, etc) to optimise water, energy and other inputs and increase productivity
- Optimise associated equipment to minimise logistics chain costs and to meet conversion requirements integrated harvesting, collection and transport solutions for fibre/bio-materials and energy)
- Develop large-scale logistics for new feedstocks or underutilised resources, optimise along the supply chain
- Competition in biomass use. Research should focus on defining the methods and criteria to assess what types of biomass can contribute to a sustainable biofuels market without directly competing with other uses (particularly food)

[260] Ibid

- Use of wastes and residues – maximising efficiency of closed-loop cycles and biorefining

The two Directives set targets for the share of renewable energy and Greenhouse Gas (GHG) emissions reduction for transport fuels.

The Smart Grids Technology Platform

In April 2006, the Advisory Council of the European Technology Platform (ETP) for Europe's Electricity Networks of the Future presented its Vision document for SmartGrids[261]. The Vision, encompassing both transmission and distribution networks, is driven by the combined effects of market liberalisation, the change in generation technologies to meet environmental targets and the future uses of electricity.

Together with the Vision, the Strategic Research Agenda, published in 2007 describes the main areas to be investigated, technical and non-technical, in the short to medium-term in Europe.

With the EU SET-Plan, the current focus is on concrete projects to jump start the deployment of the SmartGrids in Europe. In order to better respond to the needs and requirements for coordination of SmartGrids in Europe, the ETP SmartGrids has restructured its organisation with the result that the recently created SmartGrids ETP Forum replaces the previous Advisory Council, and it now has leadership of the platform structure and the setting of the agenda of activities of the platform.

A SmartGrid is an electricity network that can intelligently integrate the actions of all stakeholders connected to it, generators, suppliers, distributors and consumers, in order to efficiently deliver sustainable, economic and secure electricity supplies.

The SmartGrids Technology Platform produced The SmartGrids Strategic Deployment Document[262] (SDD) which is the third in a series of reports. This report focuses on the deployment of new network technologies and the delivery of the SmartGrids Vision.

The aims of the SDD are to reinforce the need for and benefits of SmartGrids technologies and solutions, to highlight the barriers that are currently constraining deployment and to make recommendations that will address these barriers. SmartGrids will be a major part in the delivery of the energy security policies and sustainability targets mandated by the European Council for 2020 and 2050.

It is vital that Europe's electricity networks are able to integrate all low carbon generation technologies as well as to encourage the demand side to play an active part in the supply chain. This must be done by upgrading and changing the networks efficiently and economically over time. It will involve network development at all voltage levels. For example, substantial offshore and improved onshore transmission infrastructure will be required in the near-term to facilitate the development of wind power across Europe. Distribution networks will need to embrace active network

[261] European Technology Platform SmartGrids, 2010, Strategic Deployment Document for Europe's Electricity Networks of the Future, Brussels. Web: http://www.smartgrids.eu/

[262] Ibid

management technologies to efficiently integrate distributed generation (DG), including residential micro generation, on a large scale. There are many other examples but all will require the connectivity that networks provide to achieve the targets for energy security and environmental sustainability.

Europe's electric power system is one of the largest technical systems in the world serving 430 million people, with 230,000 km of transmission lines at the highest voltage levels of between 220kV and 400 kV and 5,000,000 km of distribution lines at medium and low voltage levels[263]. With all the stations, support systems, etc., the investment in the European electricity grids up to now exceeds €600bn (some €1,500 per citizen).

A significant proportion of the European electricity grids were built over 40 years ago. Renewal is necessary and is already happening and according to the International Energy Agency, approximately €500 billion will be invested by 2030. Without deployment of new "smart" technologies and solutions, this renewal will become a mere replacement programme based on old solutions and extinct technologies, with little utilisation potential for efficiency gains and might eventually lead to stranded assets, lost opportunities and failure to achieve the ambitious energy targets for Europe.

The electricity networks of the future will have to accommodate large-scale distributed generation, enable widespread use of renewable energy sources and facilitate the connection of large-scale centralised generation at suitable locations (e.g. close to the coast to get access to cooling water). Moreover, massive electrification of transportation vehicles (both, public and private), customer-centric and service-oriented electricity supply must be supported and actively enabled.

The SmartGrids Technology Platform has identified ten key challenges that impact on the delivery of the mandated targets for utilisation of renewable energy, efficiency and carbon reductions by 2020 and 2050. They are also interlinked with the targets for one common European electricity market, for reducing European dependency on energy imports and for maintaining security of supply with minimum costs. These challenges are listed below:

- **Strengthening the grid**: ensuring that there is sufficient transmission capacity to interconnect energy resources, especially renewable resources, across Europe
- **Moving offshore**: developing the most efficient connections for offshore wind farms and for other marine technologies
- **Developing decentralised architectures:** enabling smaller scale electricity supply systems to operate harmoniously with the total system
- **Communications**: delivering the communications infrastructure to allow potentially millions of parties to operate and trade in the single market

[263] European Technology Platform, (2010), SmartGrids Strategic Deployment Document for Europe's Electricity Networks of the Future, Brussels.

- **Active demand side**: enabling all consumers, with or without their own generation, to play an active role in the operation of the system
- **Integrating intermittent generation**: finding the best ways of integrating intermittent generation including residential micro generation
- **Enhanced intelligence**: of relevance to generation, demand and most notably in the grid
- **Capturing the benefits of distributed generation and storage**
- **Preparing for electric vehicles:** particularly emphasized due to their mobile and highly dispersed character and possible massive deployment in the years ahead, that would yield a major challenge for the future electricity networks

5.1.8 CO_2 emissions targets

In February 2011[264], The European Council confirmed the European Union (EU) objective to reduce its greenhouse gas (GHG) emissions by 80 percent to 95 percent compared to 1990 levels, by 2050, in order to keep the global average temperatures below 2 deg C [265] provided that the rest of the world also undertake strong emission reducing actions. In March 2011, the European Commission published the "Roadmap for moving to a competitive low-carbon economy in 2050"[266], accompanied by an Impact Assessment study which has used results of modelling analysis based on the PRIMES[267] energy system model and other models.

The emission reduction effort required by the energy demand and supply sectors is thus very substantial and concerns the complete time period to 2050: the targets are 20 percent for 2020 and 40 percent for 2030, relative to 1990 levels. All emission reductions are supposed to take place domestically in the EU, without any use of international carbon credits.

Obviously an emission reduction of that scale will require considerable restructuring in the energy system, since the energy sector produces the lion's share of man-made greenhouse gas emissions. And according to the IEA World Energy Outlook 2012[268], almost four-fifths of the CO_2 emissions allowable by 2035 are already locked-in by existing power plants, factories, and buildings. Therefore, reducing greenhouse gas emissions by 2050 by over 80 percent will put particular pressure on the energy sector. In order to achieve ambitious climate protection goals, energy efficiency improvements alone will not suffice to achieve the required CO_2 reduction targets. But to be environmentally benign, energy services must be supplied with low environmental

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[264] European Council Conclusions, 4th February 2011 (EUCO 2/1/11 REV 1, 8 March 2011).
[265] EC (2007): Limiting Global Climate Change to 2 degrees Celsius e The way ahead for 2020 and beyond, COM (2007) 2 final.
[266] EC, (2011), Roadmap for Moving to a Low-carbon Economy in 2050. http://ec.europa.eu/clima/policies/roadmap/index_en.htm.
[267] E3MLab, PRIMES Model Manual. Available at: (2010) http://www.e3mlab.ntua. gr/e3mlab/PRIMES percent20Manual/The_PRIMES_MODEL_2010.
[268] IEA World Energy Outlook 2012

impacts and low greenhouse gas (GHG) emissions. Renewable Energy Sources (RES) will play a key role in providing energy services in a sustainable manner and, in particular to mitigating climate change. However, the future share of RES applications will depend heavily on climate change mitigation goals, the level of requested energy services and resulting energy needs as well as their relative merit within the portfolio of zero or low-carbon technologies. A comprehensive evaluation of any portfolio of mitigation options would involve an evaluation of their respective mitigation potential as well as all associated risks, costs and their contribution to sustainable development[269].

There are multiple means for lowering GHG emissions from the energy system while still providing desired energy services. The AR4[270] identified a number of ways to lower heat-trapping emissions from energy sources while still providing energy services:

- Improve supply side efficiency of energy conversion, transmission and distribution, including combined heat and power
- Improve demand side efficiency in the respective sectors and applications (e.g., buildings, industrial and agricultural processes, transportation, heating, cooling and lighting)
- Shift from high-GHG energy carriers such as coal and oil to lower GHG energy carriers such as natural gas, nuclear fuels and RES
- Utilize CO_2 capture and storage (CCS) to prevent post-combustion or industrial process CO_2 from entering the atmosphere. CCS has the potential for removing CO_2 from the atmosphere when biomass is processed, e.g., through combustion or fermentation
- Change behaviour to better manage energy use or to use fewer carbon and energy-intensive goods and services

Nonetheless, due in part to the site-specific nature, the diversity of RES and the multiple end-use of these technologies then additional knowledge remains to be gained in a number of broad areas related to RES and CCS to determine fully their role in GHG emissions reductions[271]. According to the Greenpeace Report[272] worldwide CO_2 emissions will increase by 62 percent in the their Reference scenario but under their Energy (R)evolution scenario they will decrease from 27,925 million tonnes in 2009 to 3,076 million tonnes in 2050 (see Figure 141), which is equivalent to 15 percent of the CO_2 emissions compared to 1990. The same report also shows that OECD Europe emissions will decrease by 4 percent in their Reference scenario. Under their Energy [R]evolution scenario they will decrease from around 3,800 million tonnes in 2009 to 192 million tonnes in 2050 (see Figure 142).

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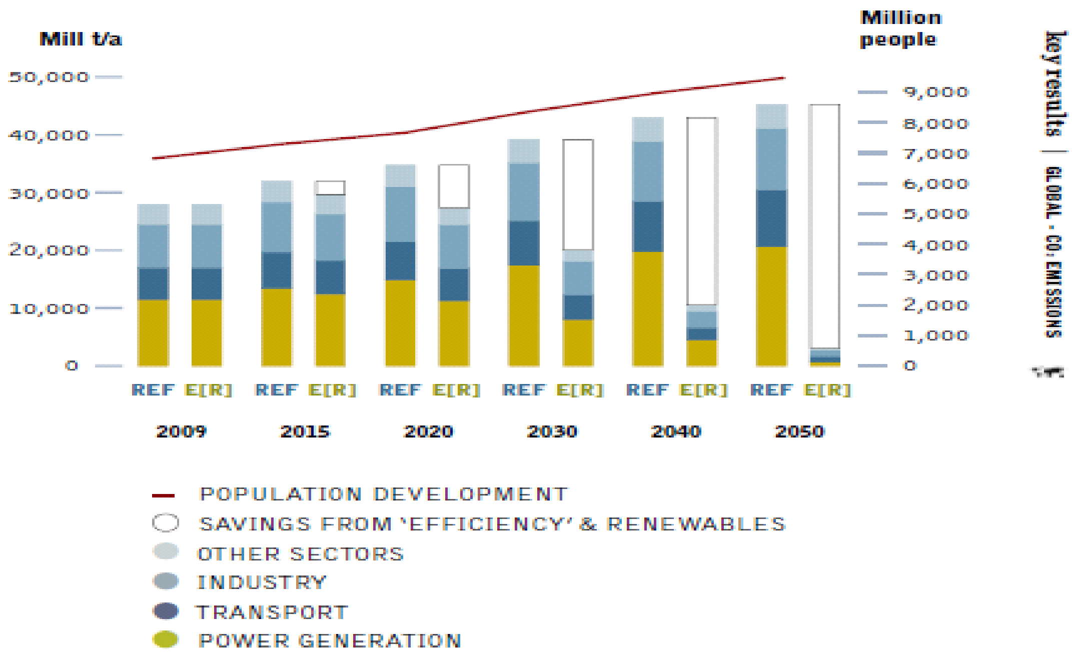
[269] Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN), IPCC, First published 2012, Cambridge University Press

[270] IPCC Fourth Assessment Report (AR4)

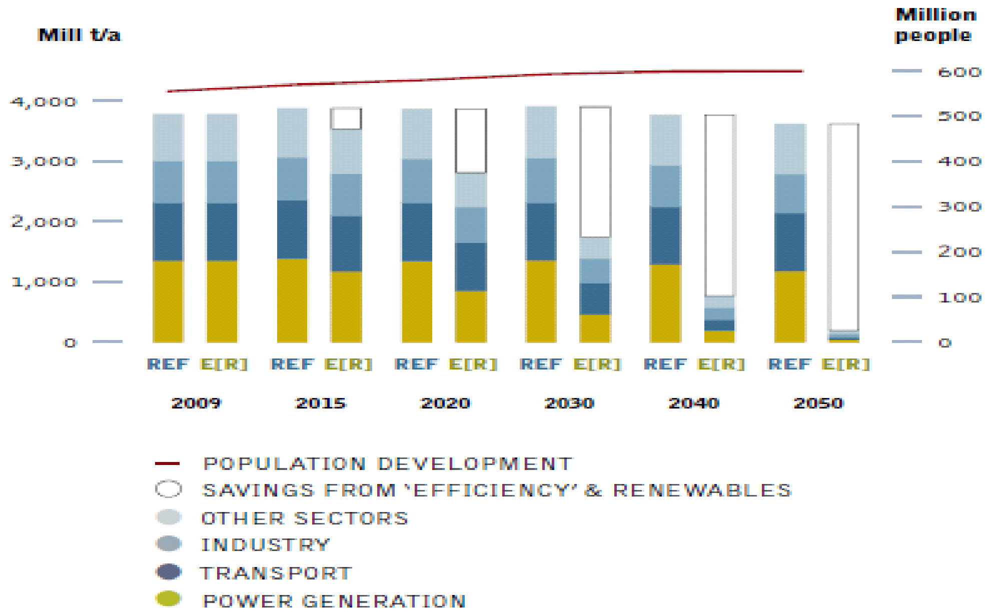
[271] Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN), IPCC, First published 2012, Cambridge University Press, p87

Figure 141: Global Development of CO2 emissions by sector under the energy ®evolution scenario



Source: Greenpeace, 2012

Figure 142: Figure 10: OECD Europe of CO2 emissions by sector under the energy ®evolution scenario



Source: Greenpeace, 2012

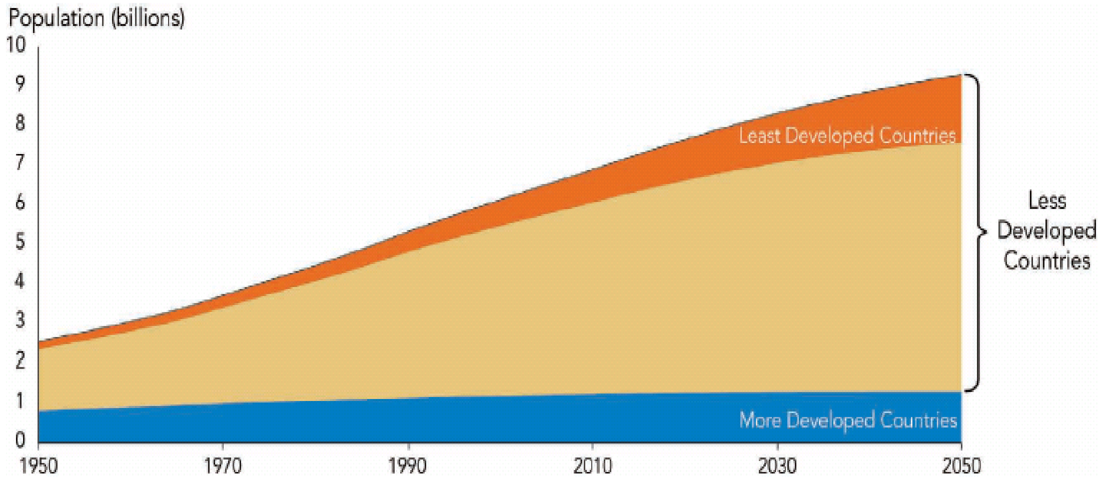
5.2 Comparative analysis of the main strategic trends

5.2.1 Analysis of the main strategic trends

There is no doubt that the global demand for energy will continue to increase into the distant future. This demand is driven by many macroeconomic factors including the key drivers of population and income growth and the desire by all to have the basic essentials for commerce and human comfort. The U.N. Secretary-General, Ban Ki-moon, has recognised these increasing needs as in 2012 he mounted the global initiative called 'Sustainable Energy for All' aimed at mobilising action in support of three interlinked objectives to be achieved by 2030[273]. These objectives were: providing universal access to modern energy services; doubling the global rate of improvement in energy efficiency; and doubling the share of renewable energy in the global energy mix.

The global demographic projections are shown in Figure 143. This figure shows that the more developed countries as a whole will experience little or no population growth up to 2050[274] and much of that growth in developed countries will come from immigration from less developed countries.

Figure 143: Population projection to 2050



SOURCE: United Nations Population Division, *World Population Prospects: The 2010 Revision* (2011), medium variant.

In 1950, 1.7 billion people lived in less developed countries, about two-thirds of the world total. By 2050, the population of less developed countries will number over 8 billion, or 86 percent of world population. In 1950, only about 200 million of the population of the less developed countries resided in countries now defined as "least developed" by the United Nations, but that population is projected to rise to nearly 2 billion by 2050. Those countries have especially low incomes, high economic vulnerability and poor human development indicators.

Alongside the expected global population growth is the increased demand for energy (See Figure 144, below). According to the BP Outlook 2012[275], world primary energy consumption is projected to grow by 1.6 percent per annum over the period 2010 to 2030, adding 39 percent to global consumption by 2030. The growth rate declines, from 2.5 percent p.a. over the past decade, to 2.0 percent p.a. over the next decade, and 1.3 percent p.a. from 2020 to 2030. Almost all (96 percent) of the growth is in non-OECD countries. By 2030, non-OECD energy consumption is 69 percent above the 2010 level, with growth averaging 2.7 percent p.a. (or 1.6 percent p.a. per capita), and it accounts for 65 percent of world consumption (compared to 54 percent in 2010).

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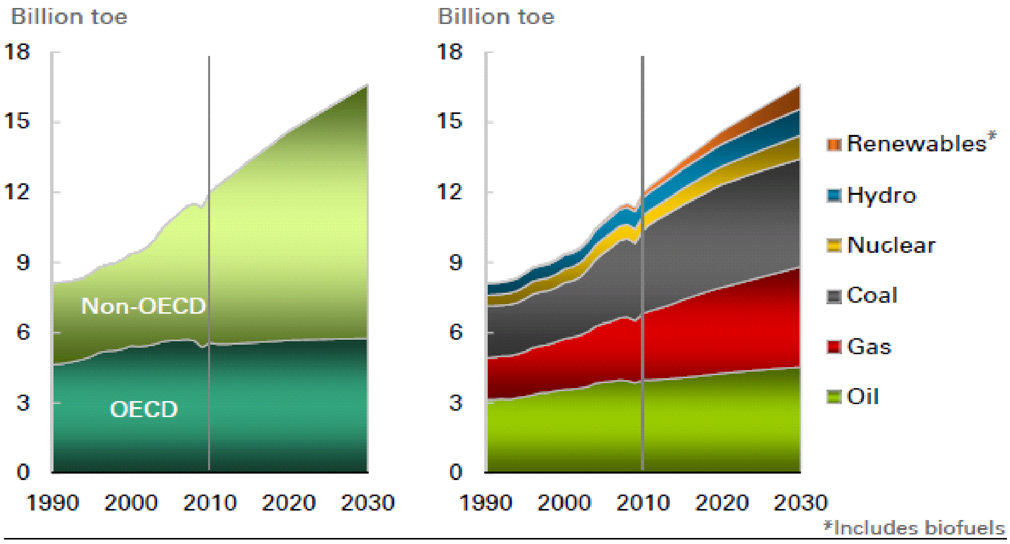
[273] U.N., (2012), *Sustainable energy for all*, United Nations, New York.

[274] Population Reference Bureau, 2012 World Population Data Sheet, 1875 Connecticut Ave., NW, Suite 520, Washington, DC 20009 USA, website: www.prb.org

[275] BP, (2012), BP Energy Outlook 2012, London, UK.

Figure 144: Global energy demand with projected use by energy type

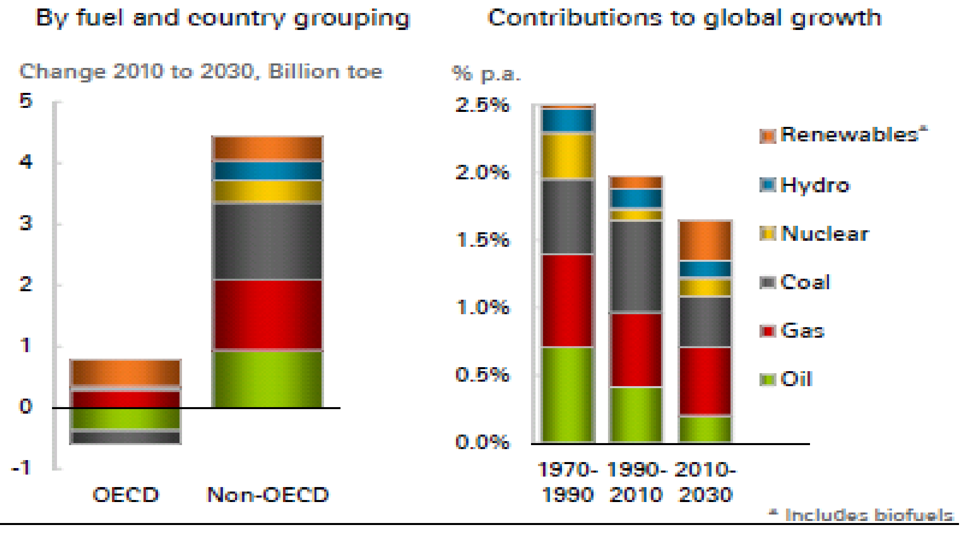


Source: BP Energy Outlook, 2012

The energy consumption in the OECD in 2030 is just 4 percent higher than in 2010, with growth averaging 0.2 percent p.a. to 2030. The OECD energy consumption per capita is on a declining trend (-0.2 percent p.a. 2010-30). The fuel mix changes slowly, due to long asset lifetimes. Gas and renewable energy sources (RES) gain market share at the expense of coal and oil. The fastest growing fuels are from RES (including biofuels) which are expected to grow at 8.2 percent p.a. 2010-30, with gas growing at 2.1 percent p.a. and oil growing at 0.7 percent p.a.

While the OECD total energy consumption is virtually flat, there are significant shifts in the fuel mix. Figure 145 shows that RES displaces oil in transport and coal in power generation; gas gains at the expense of coal in power. These shifts are driven by a combination of relative fuel prices, technological innovation and policy interventions. The economic development of non-OECD countries creates an appetite for energy that can only be met by expanding all fuels. For many developing countries the imperative remains securing affordable energy to underpin economic development. The growth of global energy consumption is increasingly being met by RES, nuclear and hydro which together account for 34 percent of the growth; this aggregate non-fossil contribution is, for the first time, larger than the contribution of any single fossil fuel. RES on its own contributes more to world energy growth than oil. The largest single fuel contribution comes from gas, which meets 31 percent of the projected growth in global energy.

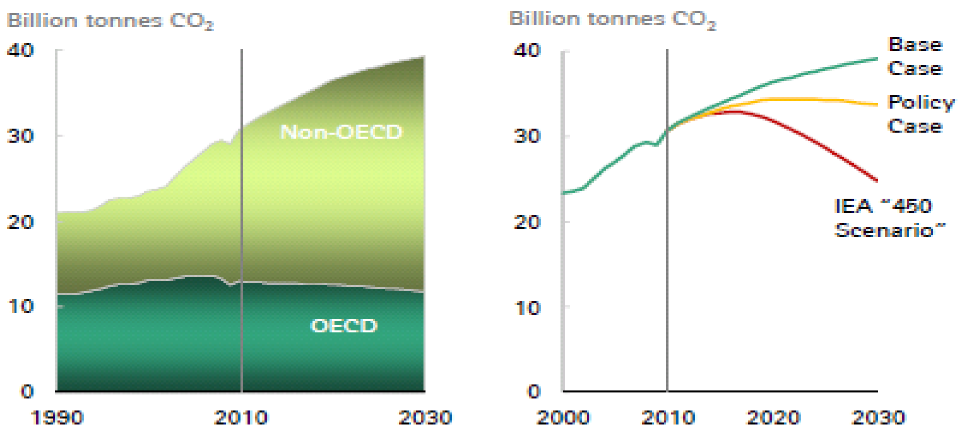
Figure 145: Shifts in the fuel mix to 2030



Source: BP Outlook, 2012

The increased demand for energy also sees an increase in CO_2 emissions. Figure 146 shows CO_2 emissions in the BP Base and Policy cases and the IEA 450 scenarios.

Figure 146: Source: BP Outlook, 2012



Source: BP Energy Outlook, 2012

While non-OECD countries make significant progress in reducing the carbon intensity of their economies this gain is outweighed by carbon increases due to rapid economic growth. The net result is a projected increase in global emissions of 28 percent by 2030. This leaves the world well above the required emissions path to stabilise the concentration of greenhouse gases at the levels recommended by scientists (around 450 ppm). The BP[276] "Policy Case" assumes a step-change in the political commitment to action on carbon emissions. Even in this case, the path to reach 450 ppm remains elusive. The IEA's most ambitious projection, its "450"Scenario, would see the carbon dioxide content of the atmosphere restricted to 450 parts per million and the global temperature increase to two degrees Centigrade. This however would involve CO_2 emissions peaking before 2020 and then falling by 2035 to 1990 levels. It is estimated that 44 percent of this abatement by 2035 would come from efficiency measures, 21 percent from the use of renewable power, 4 percent from the adoption of biofuels, 9

[276] BP Energy Outlook 2012, op sit

percent from the use of nuclear, and 22 percent from the use of carbon capture and storage.

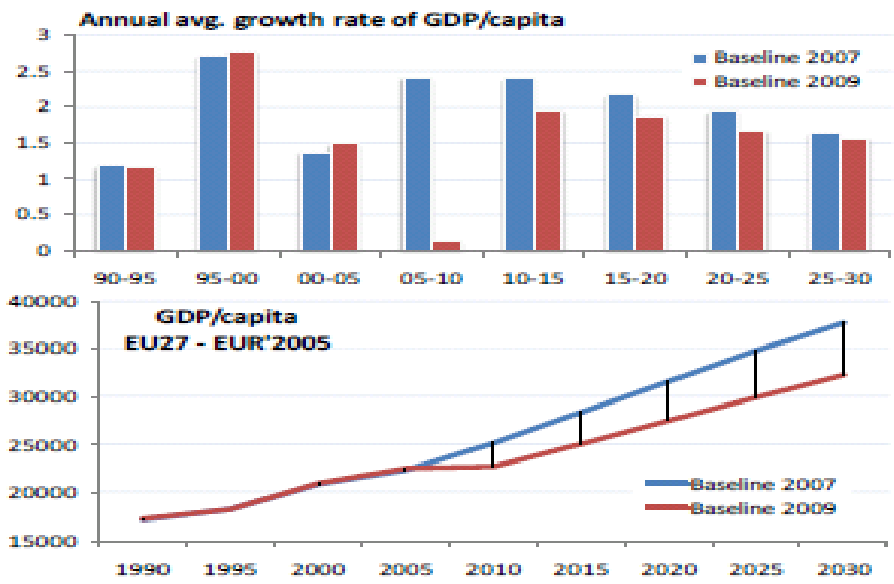
The International Energy Agency's World Energy Outlook 2011[277] warned that if "bold policy options are not put in place over the next several years, it will become increasingly difficult and costly to meet the goal of limiting a global temperature increase to two degrees Centigrade". Even if new policies are adopted to stimulate investment, such as subsidies for clean energy, tighter emission regulations or taxes on pollution, the IEA predicts that the world is on track for a rise in temperatures of 3.5 degrees, and if the new policies are not brought in, the rise could be 6 degrees Centigrade. The agency called for measures to increase efficiency, including tighter standards across all sectors and a partial phase-out of fossil fuel subsidies, which it estimated rose to a record €315 billion in 2010. The trends in global CO_2 emissions 2012[278] report has estimated that a total of 420 billion tonnes of CO_2 was cumulatively emitted due to human activities (including deforestation) since 2000. The scientific literature suggests that limiting average global temperature rise to 2°C above pre-industrial levels – the target internationally adopted in U.N. climate negotiations – is possible if cumulative emissions in the 2000–2050 period do not exceed 1,000 to 1,500 billion tonnes CO_2. If the current global increase in CO_2 emissions continues, cumulative emissions will surpass this total within the next two decades.

Thus, the achievement of the 2°C target will be a major challenge and that a declining emissions path by 2030 will only be achievable, if the global political will to shoulder the cost is accepted.

The demographic projection for the EU is for very small growth from 502 million in 2012 to about 517 million in 2025[279]. Most of this growth will occur in Northern Europe. However in the long-term, GDP per capita increases (in real terms) at an average rate just below 2 percent per year see Figure 147[280]. This growth is an important driver in terms of energy projections and household income. However, the EU is committed to reducing greenhouse gas emissions to 80–95 percent below 1990 levels by 2050. The current EU policies and measures to achieve their 2020 targets are ambitious but will only help to achieve a 40 percent reduction in CO_2 emissions by 2050 that is only half of the 2050 goal. This gives an indication of the level of effort and change, both structural and social, that will be required to make the necessary emissions reduction, while keeping a competitive and secure energy sector.

[277] IEA World Energy Outlook 2011,Paris France 2011
[278] Trends in global CO2 emissions 2012 report, PBL Netherlands Environmental Assessment Agency The Hague/Bilthoven, 2012 PBL publication number: 500114022
[279] 2012 Population Reference Bureau, 2012 World Population Data Sheet, 1875 Connecticut Ave., NW, Suite 520, Washington, DC 20009 USA, website: www.prb.org
[280] Energy Trends to 2030 Update 2009, European Commission, Directorate-General for Energy

Figure 147: GDP growth per capita (EU27)



Source: European Energy Roadmap 2050

A key strategic aim in achieving the 2050 goal is to increase the share of RES substantially to at least 55 percent in gross final energy consumption in 2050, up 45 percent from today's level at around 10 percent[281]. The share of RES in electricity consumption reaches 64 percent in a high energy efficiency scenario and 97 percent in high renewables scenario that includes significant electricity storage to accommodate varying RES supply even at times of low demand.

5.2.2 Relative importance of these Strategic Trends

The main strategic trends as discussed above provide strong evidence for the growth of renewable energy sources (RES) over the next four decades. Renewables will be driven by the growth in demand for clean energy which itself is driven by the need to reduce global CO_2 emissions. Of course, this demand could be curtailed if the necessary policy decisions and the associated regulatory frameworks are not put in place by governments. A decline in policy support for renewable energy in many developed countries is a key feature of the current recession. This decline reflected the austerity pressures, particularly in Europe and legislative deadlock in the United States Congress[282]. This policy hiatus comes at a time when fully competitive renewable power is starting to be a realistic possibility within a few years. The decline in support by policy makers is posing a threat to continued growth in investment in the RES sector in 2013 and beyond. That in turn puts a question mark over the necessary investment in clean energy that will be required to reach sufficient levels to start to reduce global carbon emissions before 2020.

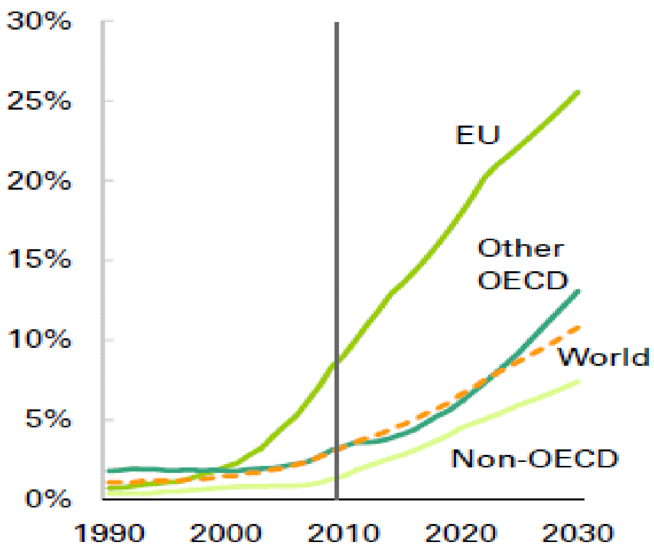
However, even though there may be delays in policy action there is no doubt that renewables will continue to gain market share particularly in the power generating subsector. Currently the EU is leading the way, but from 2020 China and the United

[281] Energy Roadmap 2050 (COM(2011) 885 final of 15 December 2011) ISBN 978-92-79-21798-2
[282] Global Trends in Renewable Energy, Frankfurt School of Finance & Management gGmbH 2012

States will become the largest sources of growth[283]. By 2030, renewables will supply 11 percent of world electricity. The EU will have 26 percent of its power coming from renewables by 2030 (see Figure 148). The rest of the OECD follows with a lag, and then the non-OECD countries also start ramping up their share of renewables in power.

The different renewable energy technologies available today all have different technical maturity, costs and development potential. Whereas hydro power has been widely used for decades, other technologies, such as the gasification of biomass or ocean energy, have yet to find their way to market maturity. Some renewable sources by their very nature, including wind and solar power, provide a variable supply, requiring a 'smart' coordination of the grid network.

Figure 148: Share of power generation by renewables



Source: BP Outlook 2012

But although in many cases renewable energy technologies are 'distributed' - in that their output is being generated and delivered locally to the consumer – in the future the trend is towards large-scale applications like offshore wind parks, photovoltaic power plants or concentrating solar power stations. Thus it is possible to develop a wide spectrum of options to market maturity, using the individual advantages of the different technologies, and linking them with each other, and integrating them step by step into the existing supply structures. This approach will provide a complementary portfolio of environmentally friendly technologies for heat and power supply and the provision of transport fuels.

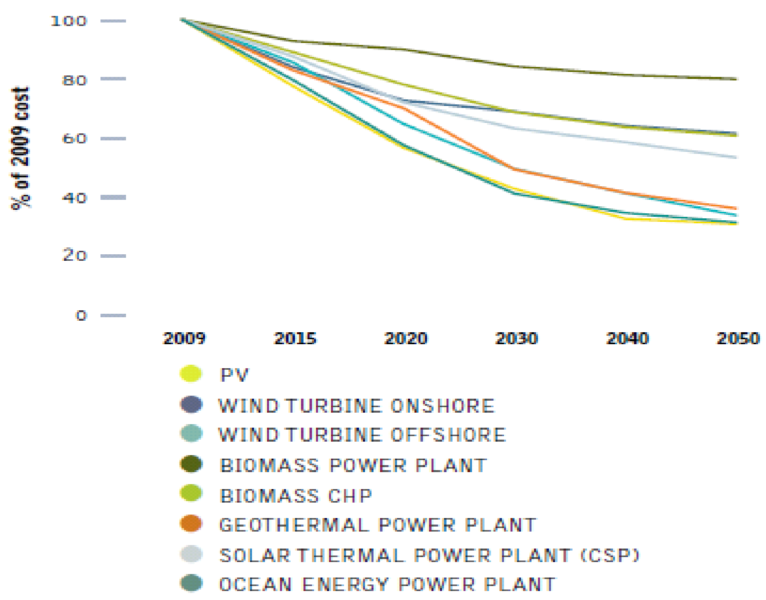
Many of the renewable technologies employed today are at a relatively early stage of market development. As a result, the costs of electricity, heat and fuel production are generally higher than those of competing conventional systems - a reminder that the environmental and social costs of conventional power production are not reflected in market prices. It is expected, however that large cost reductions can come from technical advances and economies of scale. The dynamic trend of cost developments

[283] BP Energy Outlook 2012, op cit

over time plays a crucial role in identifying economically sensible expansion strategies for scenarios spanning several decades.

A key issue for RES is the investment and operating system costs since cost will be a major deciding factor in the present and future potential of the renewable sector. The Greenpeace Report[284] has developed a cost model for a number of renewable technologies derived from the respective learning curves. Figure 149 shows the investment trends for Wind, Biomass, Geothermal, Solar and Ocean Energy.

Figure 149: Future development of investment costs for renewable energy technologies (normalised to 2010 cost levels)



Source: Greenpeace 2012

It is important to note that the expected cost reduction is not a function of time, but of cumulative capacity (production of units) and experience, so there needs to be a continuing increase in sales. Most of the technologies will be able to reduce their specific investment costs to between 30 percent and 60 percent of current levels once they have achieved full maturity (typically after 2040).

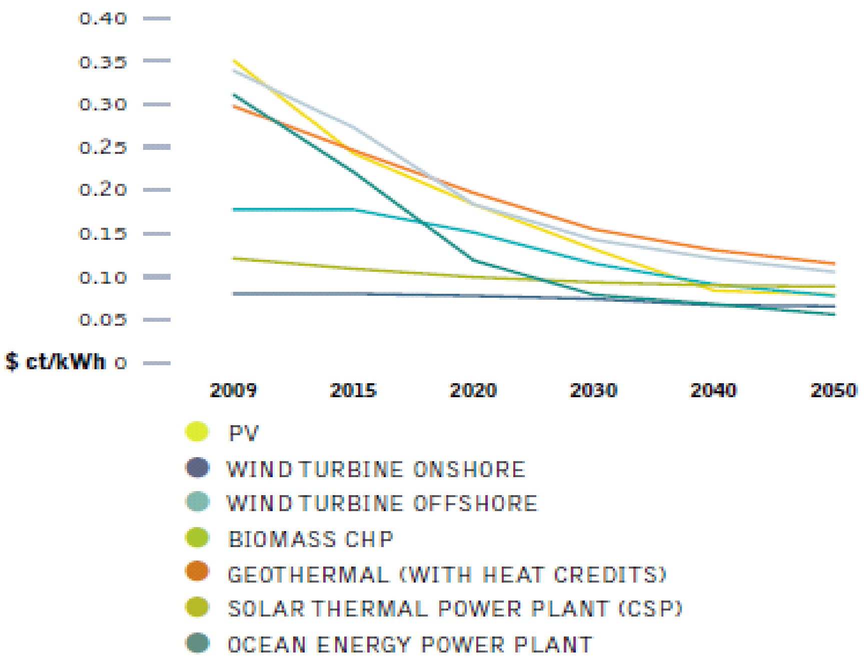
As investment costs for renewable energy technologies are reduced so too are the generating cost as shown in Figure 5.21[285]. Generation costs in 2009 were around $0.08 to $0.35/kWh for the most important technologies, with the exception of photovoltaic. In the longer-term, costs are expected to converge at around 6 to 12 USD cents/kWh (examples for OECD Europe). These estimates depend on site-specific conditions such as the local wind regime or solar irradiation, the availability of biomass at reasonable prices or the credit granted for heat supply in the case of combined heat and power generation.

According to Greenpeace[286] the development of the electricity supply market is characterised by a dynamically growing renewable energy market (see Figure 150). This

[284] Greenpeace Report 2012, op cit
[285] Ibid
[286] Greenpeace Report 2012, op cit

will compensate for the phasing out of nuclear energy and reduce the number of fossil fuel-fired power plants required for grid stabilisation.

Figure 150: Expected development of electricity generation costs from renewable options



Source: Greenpeace 2012

By 2050, 94 percent of the electricity produced worldwide will come from renewable energy sources. 'New' renewables – mainly wind, PV and geothermal energy – will contribute 60 percent of electricity generation. The Energy [R]evolution scenario projects an immediate market development with high annual growth rates achieving a renewable electricity share of 37 percent by 2020 and 61 percent by 2030. The installed capacity of renewables will reach 7,400 GW in 2030 and 15,100 GW by 2050.

Figure 151 shows the global development of the different renewable technologies over time with hydro and wind still being the main contributors of the growing market share to 2020. After 2020, the continuing growth of wind will be complemented by electricity from photovoltaics (PV), solar thermal (CSP), ocean energy and bioenergy. The Greenpeace Energy [R]evolution scenario[287] shows a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 31 percent by 2030, therefore the expansion of smart grids, demand side management (DSM) and managed storage capacity will be required. It is interesting to note the increased penetration and high growth rates of PV. The combination of CSP and PV make solar the largest renewable contributor to power generation by 2050 under the Greenpeace (R)evolution scenario.

By 2050, according to Greenpeace, 96 percent of the electricity produced in OECD Europe will come from renewable energy sources. 'New' renewables – mainly wind, solar thermal energy and PV – will contribute 71 percent of electricity generation.

[287] Ibid

Figure 151: Global renewable electricity generation capacity under the reference scenario and the energy (r)evolution (GW)

		2009	2020	2030	2040	2050
Hydro	REF	995	1,250	1,425	1,564	1,695
	E[R]	995	1,246	1,347	1,428	1,484
Biomass	REF	51	98	155	215	272
	E[R]	51	162	265	390	490
Wind	REF	147	525	754	959	1,135
	E[R]	147	1,357	2,908	4,287	5,236
Geothermal	REF	11	18	27	37	47
	E[R]	11	65	219	446	666
PV	REF	19	124	234	351	471
	E[R]	19	674	1,764	3,335	4,548
CSP	REF	0	11	24	40	62
	E[R]	0	166	714	1,362	2,054
Ocean energy	REF	0	1	4	13	18
	E[R]	0	54	176	345	610
Total	REF	**1,224**	**2,028**	**2,622**	**3,179**	**3,699**
	E[R]	**1,224**	**3,724**	**7,392**	**11,594**	**15,088**

Source: Greenpeace 2012

The Greenpeace Energy [r]evolution scenario projects increased market penetration with high annual growth rates achieving a renewable electricity share of 49 percent by 2020 and 71 percent by 2030. The installed capacity of renewables will reach 1038 GW in 2030 and 1,498 GW by 2050.

Figure 152 shows the comparative evolution of the different renewable technologies in OECD Europe over time. Up to 2020 hydro and wind will remain the main contributors of the growing renewables market share.

Figure 152: OECD Europe renewable electricity generation capacity under the reference scenario and the (r)evolution (GW)

		2009	2020	2030	2040	2050
Hydro	REF	193	210	220	227	234
	E[R]	193	207	215	218	219
Biomass	REF	21	30	37	43	49
	E[R]	21	48	60	72	70
Wind	REF	76	195	256	295	313
	E[R]	76	276	414	496	516
Geothermal	REF	2	3	3	4	5
	E[R]	2	8	30	45	53
PV	REF	14	45	79	115	152
	E[R]	14	197	270	489	518
CSP	REF	0	2	4	5	6
	E[R]	0	12	32	55	82
Ocean energy	REF	0	0	2	9	11
	E[R]	0	3	18	31	40
Total	REF	**306**	**486**	**602**	**699**	**770**
	E[R]	**306**	**750**	**1,038**	**1,407**	**1,498**

Source: Greenpeace 2012

After 2020, the continuing growth of wind will be complemented by electricity from biomass, photovoltaics and solar thermal (CSP) energy. The Greenpeace Energy [R]evolution scenario shows a high share of fluctuating power generation sources (photovoltaic, wind and ocean) of 37 percent by 2030, therefore the expansion of smart grids, demand side management (DSM) and storage capacity e.g. from the increased share of electric vehicles will be used for a better grid integration and power generation management.

5.2.3 RES inclusion in energy/PV scenarios

The potential for large errors in long-term forecasting is well known so that the various scenarios reviewed in this document cannot be taken as a given. However, the increasing population trend is fairly certain, discounting a catastrophic event, and this will drive the demand for more energy. This in turn will increase the CO_2 emissions, unless intervening measures are taken, with the likely negative impacts on global warming. Thus one can say with some certainty that the pressure to provide clean sources of energy will not go away but is likely to intensify. This pressure is already yielding policies and regulations from Governments particularly from the OECD states supporting renewables. However, the developing countries are also beginning to take action, but at a slower pace. The current economic crisis has not helped matters as short-term thinking and actions are causing a slowdown in the move towards clean energy. This economic hiccup is quite normal in any economic cycle but it can play havoc with the forecasters view. Over a forty or fifty year time horizon, which is the time span needed when looking at energy demands and CO_2 reductions, the current recession will become another blip, although a large blip in the world's economic history.

Taking the uncertainties of the various forecasts into consideration it is more than likely that there will be increased supply of renewables. Once a key tipping point is reached, investment inertia of the renewable sector will ensure that the investment continues. For example, the momentum of projects currently in place by the wind industry will ensure that it will continue to increase its share of electricity generation and this in turn will hasten the requirement for smart grids and storage infrastructure to cope with the intermittent nature of the energy sources. Similarly, the PV sector has grown rapidly particularly due to competition and incentives. This growth trajectory is likely to continue but at a slower rate due to the economic downturn. Other renewables such as biomass, hyrdo and geothermal are likely to grow more slowly in the short-term due to specific issues of land usage and society resistance to large scale dam construction.

Thus, wind and PV are in pole position to take advantage of the ever increasing demand for clean energy and as such wind and PV are set for significant growth. Both of these technologies are extremely clean with a low carbon footprint, they use free fuel and there is an abundance of the energy source, particularly direct sun energy, and they do not need vast amounts of scarce water to function. Both sources have some issues, the main one being the intermittent nature of the supply. Again PV has a more predicable cycle than wind and it can be matched to peak generation loads. However, both PV and wind will need some kind of power back-up for the foreseeable future to deal with the intermittent nature of the supply, or as has been found in the United States - a spread across an extensive geographical area, ensuring that adequate wind is always available.

So there is a certain basic logic to the detailed numeric forecasts in terms of the growth of renewables. The issue is the timing and the sequence of events on the road to clean energy.

The economic cycle (both medium and long-term) will always play a role and the normal industrial life cycle (growth, decline, rationalisation and concentration) associated with any industrial sector will always be part of the mix. However, the undeniable trends indicate that there will be an ongoing increasing trajectory for renewables which will ensure that the sector will develop to become a significant force, particularly within the power generation sector in the medium-term and the more general energy industry in the long-term. In particular, wind and PV will play a key role in the renewable sector with both of them being focussed on power generation in the short-term.

All forecast scenarios reviewed in this study show significant increases in the use of PV. All the major nations are investing significant amounts of R&D in PV technologies as it is seen as a key technology for the future. The EU, the United States and China have their own initiatives in place and again this will drive the PV industry forward. Currently the EU is leading the way with the number of installations which are mainly centred in Germany, Italy and Spain. This lead by the EU is likely to be overtaken by China and the United States after 2020. Thus PV is becoming an important player in the renewable sector and a major global industry is likely to emerge from this activity.

Thus, while clean energy will improve our environment and help to reduce CO_2 in the atmosphere, it is also becoming an important industry sector in its own right and countries are trying to position themselves to take advantage of the economic activity it can bring to them. China has taken the lead in terms of the low cost manufacturing of PV modules, while the EU has being content to outsource most of its PV manufacturing to China. On the other hand, the United States has a strategy of keeping PV jobs in the United States and it has imposed tariffs on Chinese manufactured PV components. Its 'Sunshot[288]' Solar strategy document sees job creation in the sector as a goal. Thus, there will be global competition for jobs in this sector and governments will need to promote friendly PV policies if they wish to see local job creation.

The countries participating in the IEA PVPS Programme have a diversity of PV production, applications and policy interests. Almost 28 GW of PV capacity was installed in the IEA PVPS countries during 2011 – about double the amount as in the previous year. This brought the cumulative installed capacity to 63.6 GW. By far the greatest proportion (60 percent) was installed in Italy and Germany alone. If China, the United States, Japan and France are also included, then over 86 percent of PV installations in 2011 occurred in six countries.

The dominance of the grid-connected markets extended even further, now accounting for over 98 percent of the cumulative installed PV capacity. Off-grid markets largely tend to be ignored. This is unfortunate as these applications have the scope to dramatically change the lives of some of the world's most disadvantaged peoples, and as

[288] DOE, (2011), SunShot Initiative, U.S. Department of Energy

has been found in the mobile phone sector, these markets can be profitable and can drive innovation that can be later transferred to the developed countries. The off-grid market itself is healthy with sustained, solid growth over decades, largely unsupported by public funding.

After significant increases in R&D expenditure in 2010 compared to 2009, the situation remained relatively flat into 2011. The main exceptions were Japan, Korea and the United States who all experienced modest funding increases. The clear leader in total R&D funds is the United States; other reporting countries with significant R&D spending are Japan, Korea and Germany (see also chapter 4).

In 2011, solar photovoltaic grade silicon feedstock supply was dominated by China, the United States, Korea, Germany and Japan, with smaller levels of production in Canada and Norway. Of the main movers in 2011, China increased production by 87 percent, and also increased imports by 36 percent from the previous year. Korea increased polysilicon production capacity by 60 percent.

China, Germany, Korea, Malaysia, Japan and the United States are the dominant producers in the ingot and wafer section of the PV industry value chain with additional manufacturing capacity in Italy, Switzerland, France and the United States. Crystalline silicon wafer prices dropped by over 40 percent during 2011 causing some companies to re-evaluate their business models.

Total PV cell production for 2011 in the IEA PVPS countries is estimated to be 29.9 GW, a 70 percent increase from the previous year and around 80 percent of global PV cell production. China was the lead producer of PV cells in 2011, manufacturing around 20 GW of cells, double the amount manufactured in China in 2010. Other PVPS countries manufacturing at the GW scale in 2011 included Germany with 2.5 GW; Japan with 2.7 GW; Malaysia with an estimated 2 GW; South Korea with 1 GW and the United States with 1.1 GW. Taiwan produced 4.3 GW of PV cells; other major non-PVPS countries manufacturing PV cells are the Philippines, Singapore and India.

PV module production in PVPS countries accounted for more than 90 percent of the modules produced globally in 2011. The picture for PV module production is similar to that for cell production with 34 GW of wafer based and thin-film modules produced in the IEA PVPS countries. Again, the largest producers were China producing 21 GW (approaching 60 percent of the global production); Germany 2.3 GW; Japan 2.5 GW; Malaysia an estimated 2 GW; Korea 1.7 GW and the United States 1.3 GW.

Thin-film PV manufacturers are facing heightened cost competition with crystalline silicon PV products. A number of companies with smaller production capacities, and new entrants trying to raise their production capacities, have reviewed their plans and restructured their businesses. In 2011, activities concerning concentrating PV (CPV) cell/modules were reported by several member countries.

In 2011, drastic changes were observed in the global business environment for the PV industry. The global PV market largely shifted from a seller's market to a buyer's market due to the magnitude of capital investment in production. PV prices declined largely because of the gap in supply and demand, rather than the traditional effects of mass production and R&D.

5.3 Summary of PV trends

2011 saw an increase in the number of GW-scale manufacturers, a widening of the supply/demand gap, a maturing of the supply chain and the emergence of trade tensions.

On average, the cost of the PV modules in 2011 accounted for approximately 50 percent of the lowest achievable prices that have been reported for grid-connected systems. In 2011 the average price of modules in the reporting countries was about €1.1/W, a decrease of almost 50 percent compared to the corresponding figure for 2010, following a decrease of 20 percent the previous year.

The lowest achievable installed price of grid-connected systems in 2011 varied between countries, with the average price of these systems being about €2.8/W, about 17 percent lower than the average 2010 price. Prices as low as around €1.5/W were reported; typically prices were in the range €2/W to €3.4/W.

The total value of business in 2011 amongst the IEA PVPS countries (now including China) was approximately €85 billion. Total direct employment is reported to be around 900,000 persons across research, manufacturing, development and installation. The large increase compared to the previous year's figure is due to the inclusion of the massive Chinese PV sector. Comparing directly with the countries reported in 2010, the number of labour places has remained at roughly the same levels in 2011.

Nearly all the PVPS countries now offer or are about to implement feed-in tariffs (FiT) of some description for PV electricity. FiT approaches have successfully driven grid-connected PV investments in large-scale plants, smaller-scale building-integrated applications, and combinations of both. They can be national-scale, state-based or even operate at the local community or utility level. FiTs have been clearly seen as the prime mechanism for promoting strong growth in grid-connected PV applications, although they are by no means the only method of PV promotion that can deliver positive results. FiTs have also been associated with explosive markets, profiteering, political interference, over-reliance on imports, market collapses, business closures and so on. In today's environment a well-functioning FiT scheme usually implies the ability to adjust incrementally for changes in PV system prices and other factors.

Within the medium-term the market will achieve price parity with other suppliers of energy for generating electricity. This will occur at different times in different markets. Support policies will begin to shift from handouts of public money to focus more on enabling strategies, appropriate regulation and development of innovative business models.

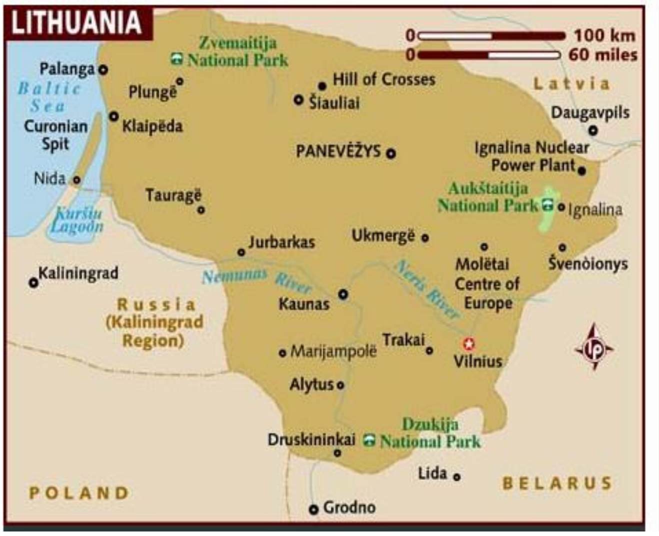
The regulatory approach known as the 'renewable portfolio standard' (RPS) is a powerful policy tool to increase renewable energy deployment, particularly in more competitive electricity markets. Sustainable building regulations are an emerging force in a large number of countries and will significantly grow the commercial sector building PV market that has hitherto been under-represented in many national markets. Municipalities, regional and local jurisdictions have demonstrated a rapidly growing interest in PV technology. Worldwide, electricity utilities are now investing in very large-scale PV plants or asking how they can benefit from meeting their customers' interest in PV plants or PV electricity, often driven by government mandates and increasingly leading to the pursuit of business opportunities. While the up-front capital requirements of PV installations remain a common barrier to deployment, third-party financing schemes (including leases and power purchase agreements) that address high up-front capital requirements are becoming more common.

The next chapter: Chapter 6 focuses on Lithuania, provides an initial economic context of Lithuania, reviews its energy policy and plans, assesses the impact of global energy trends, RES trends and PV on Lithuania and provides an outline of the next steps in the form of a proposed plan and schedule, while acknowledging that other related studies are being undertaken as part of this contract and that they will also contribute to any policy decisions. It also provides a short list of background papers and reports relevant to any future decision on PV in Lithuania.

6 The Lithuania case

6.1 Context

6.1.1 Economic Context



Lithuania is 65,200 km^2 in size, has a population of 3.4 million and its main languages are Lithuanian, Polish and Russian. In 2011, its GDP was €32,600 billion (est.) and GDP per capita purchasing power is €15,078 (est.). It regained its independence in 1990. Lithuanian's national currency is Litas, and the rate is fixed with the euro at 3.45 lt to the euro. Lithuania is bordered on the south by Poland and Kaliningrad, on the east by Belarus and on the north by Latvia. It has an 800 kilometres of coastline on the Baltic Sea to the west.

European Union Membership. Lithuania was invited to begin negotiations to join the EU in December 1999 and was formally invited to join in December 2002 at a summit in Copenhagen. In 2003, the Lithuanian EU referendum took place in May of 2003, and over 90 per cent of those who voted supported EU membership. Lithuania joined the EU on 1 May 2004.

Recent Economic Results. Lithuania had one of the highest growth rates in Europe between 2000 and 2007, i.e., in 2006 the economy in Lithuania grew by 7.5 percent. However, the economy was hit hard by the financial crisis of 2007–2010 with a consequent fall in GDP, according to the IMF. Lithuania hopes to join the euro as soon as possible (possibly in 2014).

In 2009, the Lithuanian economy shrank by 14.8 percent, unemployment climbed to 13.7 percent, and salaries fell by 12.3 percent, the worst performance since comparable records began in 1995. Growing unemployment and lower income contributed to some limited social unrest in early 2009. That same year the government approved heavy budget cuts and passed a €1.8 billion stimulus plan. In 2010, Lithuania's GDP grew slightly by 1.4 percent and recovered greatly in 2011 (when GDP grew by 5.9%) and an estimated 2 percent in 2012[289]. The World Bank forecasts Lithuanian growth of 3.5 percent in 2013 and it forecast that the Euro Area would fall into recession in 2012 with -0.3 per cent and a GDP growth of 1.1 per cent in 2013.

289 Global Finance http://www.gfmag.com/gdp-data-country-reports/231-lithuania-gdp-country-report.html

6.1.2 Lithuanian energy strategy and programmes

On gaining its independence, Lithuania inherited a modern energy sector, but with a comparatively high energy intensity (i.e., using a relatively high volume of energy per unit of GDP), due to the long period of very cheap energy and conversely low incentives for energy saving and energy efficiency. Lithuania developed its first national energy strategy in 1994, which looked forward to 2015. It was revised in 1999 and further updates were undertaken in 2004 and 2007.

6.1.2.1 Recent developments in the Lithuania energy market

The 1999 national energy strategy was based on the following principles[290]:

- Reliable and safe energy supply with least cost
- Energy efficiency enhancement
- Improvement of the energy sector management and implementation of market economy principles in the energy sector
- Reduction of the negative impact on the environment; assurance of nuclear safety requirements
- Integration of the Lithuanian energy sector into energy systems of the European Union
- Regional co-operation and collaboration

These 'principles' form a broad context for Lithuania's energy strategies and developments since then.

MAED: The model that is widely used in Western countries for analysing and forecasting energy demand is called MAED, and was used in this study. It predicted final energy consumption, taking into consideration the impact of different factors on it. Energy consumption in the MAED model was specified not only by the economic sectors (industry and its sectors, agriculture, transport, service sector and households) but also by industrial processes, elements of the transport system, social needs of the population etc. In all scenarios the final energy demand in the year 2020 does not exceed the 1990 level.

The main source of electricity in Lithuania is the nuclear plant, Ignalina NPP. Over the last five years it has generated 80-85 percent of the total electricity production and with the lowest production cost. Other energy plants included Vilnius CHP-3 (combined heat and power), Kaunas CHP and existing hydro power plants (providing 170 MW). Integration of Lithuania into the European Union and closer co-operation with other Baltic, Western and Northern European states required changes in the structure of the national electricity grid system and its organisation.

290. *Seimas of the Republic of Lithuania, (5 October 1999), Resolution No VIII-1348, Vilnius*

Despite the efforts put into safety upgrading of Ignalina NPP some Western politicians and technical experts were of the opinion that the risks of RBMK reactors cannot be adequately reduced. Thus, the closure of Ignalina NPP became one of the conditions of Lithuania's entry into the European Union.

The national energy plans also proposed to develop a programme of education and research for specialists from the energy sector, to bring Lithuanian management, technical and research capabilities up to the standard of other EU member states. Further liberalisation of the market and creation of a more cost effective energy sector were identified as the main instruments for the implementation of National Energy Strategies.

Electricity sector: The basic idea in the electricity sector was to separate production, transmission (high voltage network) and distribution, by creating independent companies. The electricity transmission sector and nuclear power plant was scheduled to remain as the property of the State and the remaining sectors were to be privatised. In the end, half of the distribution network and nearly all the heat supply (generating units), gas supply sector and oil refinery were privatised.

Sources of supply included nuclear power, oil and oil products, natural gas, hydro, other renewable (wind, solar and geothermal) and waste energy sources.***Nuclear power in Lithuania***

In summary:

- Lithuania closed its last nuclear reactor, which had been generating 70 percent of its electricity, at the end of 2009
- Electricity was a major export until the closure of Lithuania's nuclear plant
- A new nuclear plant is planned to be built by GE Hitachi. It involves vendor equity as well as participation by other Baltic states. A 2012 referendum has introduced some uncertainty regarding this however

In the northeast of the country, Lithuania hosted the two largest Russian reactors of the RBMK type. Construction started in 1978 and they came on line at the end of 1983 (unit 1) and in 1987 (unit 2), with a 30-year design life. Lithuania assumed ownership of them in 1991 after the collapse of the Soviet Union. They are light-water, graphite-moderated types, similar to those at Chernobyl in the Ukraine. Construction of a third reactor at Ignalina commenced in 1985, but was suspended after the 1986 Chernobyl accident, and the unit was later demolished.

Originally the Iganlina plants were designed to provide power not only for Lithuania but also for neighbouring Latvia, Belarus and the Russian exclave of Kaliningrad. In 1989, 42 per cent of the power was exported, but this fell throughout the 1990s.

In 2004, Lithuania produced 13.9 billion kWh out of a total 19.3 billion kWh from the two reactors (i.e., 72 percent of its electricity requirements). Only one continued after 2004 (see Figure 153). In 2007, electricity production was 14.0 billion kWh gross, 70per cent (9.8 billion kWh) from the only operating nuclear reactor, and 17per cent (2.4 billion kWh) from gas. Net exports were 1.4 billion kWh. Per capita electricity consumption in 2007 was about 3,400 kWh.

Figure 153: Shutdown of nuclear power reactors in Lithuania

Reactor	Type	Net MWe	First power	Closed
Ignalina 1	RBMK	1185	12/1983	End of 2004
Ignalina 2	RBMK	1185	8/1987	End of 2009

The Ignalina plant was operated by Ignalinos Atominé Elektriné (IAE) and supplied power to the national utility, Lietuvos Energija, at very low cost. Electricity prices increased dramatically following the closure of the plant at the end of 2009. In January 2010 – the month following the shutdown of Ignalina 2 – electricity prices increased by 33.3 percent.

In February 2007, the three Baltic states (Lithuania, Latvia and Estonia) and Poland agreed to build a new nuclear plant at Ignalina, initially with 3,200 MWe capacity (2 x 1600 MWe).

There are many other factors affecting the project, not least of which is a shared desire of several countries in the region to not be too dependent on Russia for energy. Following approval of the final Environmental Impact Assessment (EIA) by the Ministry of the Environment (April 2009), the development of a business model and financing plan by a consortium led by Rothschild investment bank and with support from the European Commission, Lithuania sought partners and strategic investors. At an early December 2010 meeting in Warsaw, prime ministers of Lithuania, Latvia, Estonia and Poland confirmed their support for the project. In May 2011 "competitive proposals from potential strategic investors" were received, from Westinghouse and Hitachi GE. In July, the government selected Hitachi as strategic investor, though it would be GE Hitachi that does the engineering, procurement and construction.

GE Hitachi will build a single 1350 MWe Advanced Boiling Water Reactor, several of which are operating and under construction in Japan and Taiwan. This was expected to operate from 2020. There was a high level of public support for the project throughout this period. The cost of the project was estimated at €4.92 billion.

However, a non-binding referendum held in conjunction with a national election in October 2012 has clouded the prospects for the Visaginas project. The referendum question asked if voters wanted new nuclear power capacity built, and 63 percent said no. The matter will be decided by the new Lithuanian government.

Without Visaginas, both Lithuania and its two Baltic neighbours will remain largely dependent on Russia for electricity, and will boost the economic prospects of the 2,400 MWe Baltic plant now under construction in Kaliningrad, 50 km from Vilnius.

6.1.2.3 *Current sources of supply and demand*

According to the data of Statistics Lithuania, in 2011, compared to 2010, gross inland fuel and energy consumption increased by 3.3 per cent and amounted to 7,289.9 thousand tonnes of oil equivalent (TOE). In 2010 it was 7,054.2[291].

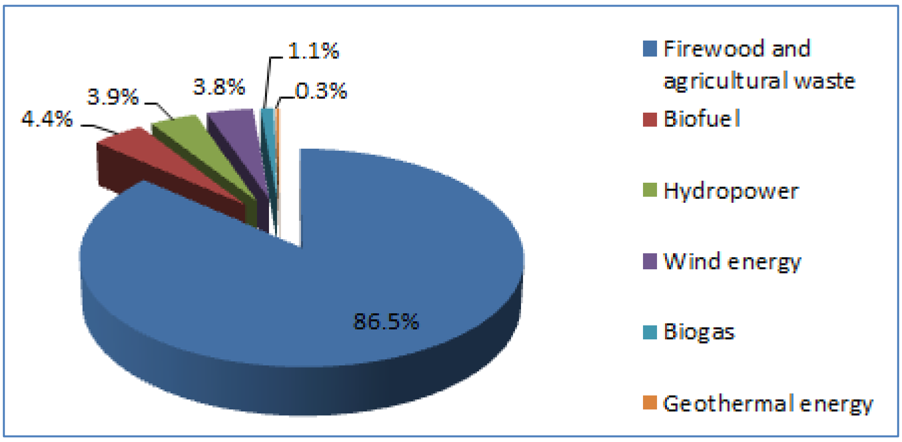
Two energy sources, natural gas (37.3 percent) and petroleum products (33.5 percent) account for more than 70 percent of consumer energy consumption. Lithuania remains highly dependent on imported fuel which has greatly increased since the closure of its remaining nuclear plant in 2009, when its energy dependency increased from 48.9 to 79.5 percent. In 2011, its energy dependency decreased slightly to 79 percent, however, it still exceeds the EU average by a considerable amount.

In 2011, imports of fuel and energy increased, compared to 2010:

- Natural gas – by 9.7 percent
- Coal – by 23.6 percent
- Electricity – by 23.8 percent

In order to diminish its dependence on imported fuel and reduce the impact of fossil fuel on the environment, a wider and more intensive use of renewable energy resources (RES) is seen as the answer. The consumption of RES in Lithuania has not changed significantly in recent years however (see Figure 154)[292].

Figure 154: RES production in Lithuania, 2011



Source: National Statistics, 2012

Firewood and agricultural waste: Recent analysis of consumption patterns revealed that in 2011 households were the major consumers (61.0 per cent). The boiler plants of centralised heat supply enterprises and power plants consumed 25.8 percent of wood fuel and agricultural waste.

Biofuel and biogas: The use of these fuels for the production of energy has been increasing, growing steadily since 2006 (growth of 378% to 2011)[293]. In 2011, biofuel production was 95.2 ktoe up from 19.9 ktoe in 2006, but lower than 114.1 ktoe in 2010.

[291] Statistical Yearbook of Lithuania 2012 at http://www.stat.gov.lt/uploads/metrastis/1_LSM_2012.pdf
[292] www.stat.gov.lt/en/catalog/pages_list/?id=1604&PHPSESSID=.
[293] www.stat.gov.lt/en/catalog/pages_list/?id=1604&PHPSESSID=.

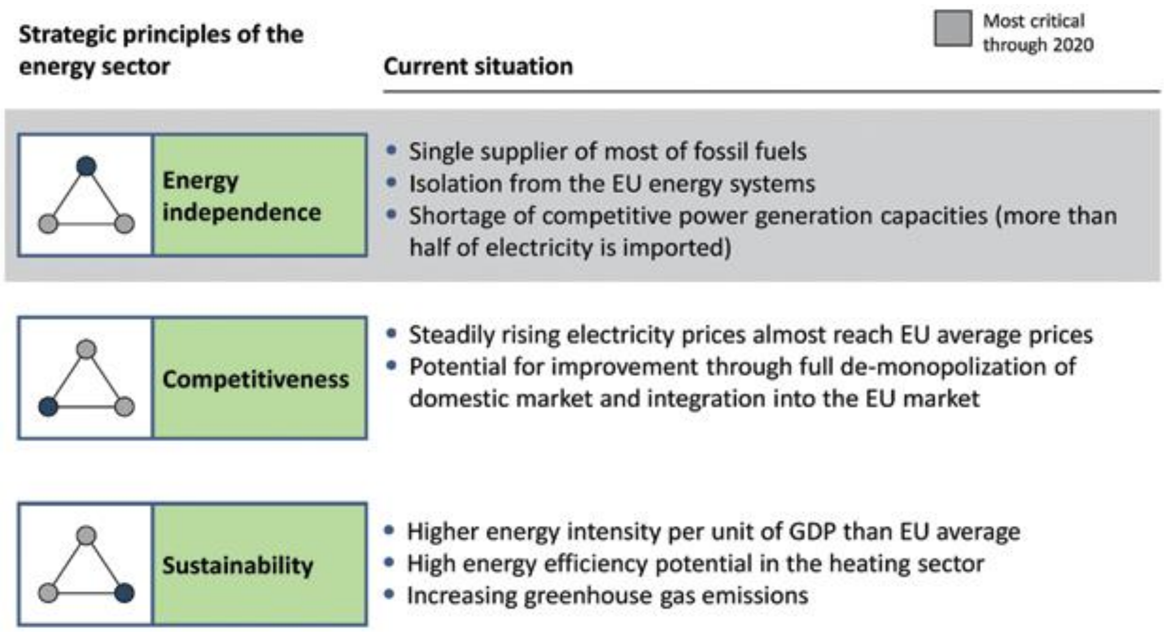
Wind farms: These are rapidly increasing in Lithuania; in 2011, electricity production on wind farms increased 2.1 times compared to 2010 and accounted for 9.9 percent of the total electricity production in the country.

Solar energy: The use of solar energy is low. In 2011, solar energy produced and supplied to electricity networks amounted to only 76 MWh (in 2010, 2.4 MWh).

Overall, in 2011 electricity produced from RES accounted for 23.1 percent of the total electricity produced in the country.

Biofuel: Production and consumption of biofuels in Lithuania are regulated by international obligations related to a reduction in greenhouse gas emissions and an increase in biofuel use in transport. The main types of biofuel consumed in Lithuania are biodiesel and bioethanol. In 2011, 14.6 thousand tonnes of bioethanol (9.9 per cent less than in 2010) and 40.0 thousand tonnes of biodiesel (1.8 per cent more than in 2010) were consumed in Lithuania.

In 2011, compared to 2010, the final energy consumption was reduced by 1.5 per cent. The major consumers were transport and household which consumed 32.7 and 32.5 per cent of energy, respectively. The industrial sector accounted for 19.2 per cent of the final energy consumption (in 2010, 18.0). The largest portion of consumption was made up of petroleum products in the transport sector, RES and centrally supplied heat in the household sector. Lithuania's major strategies are based on three key principles:



6.1.2.4 Future strategies

In 2012, Lithuania published a new energy strategy called the National Energy Independence Strategy[294]. The strategy defined the objectives and national targets for the implementation of strategic initiatives until 2020(See table 6.1, below). It also laid

[294] National Energy Independence Strategy of the Republic of Lithuania was approved by Resolution No XI-2133 of the Seimas of the Republic of Lithuania of 26 June 2012

down guidelines for the development of Lithuania's energy sector until 2030 and then until 2050.

The main goal of this strategy is to ensure Lithuania's energy independence before the year 2020 by strengthening Lithuanian's energy security and competitiveness.

Lithuania is facing challenges in the energy sector in three critical areas including security of energy supply, competitiveness and sustainability of the energy sector. As shown in the previous section, most of the energy resources used in Lithuania are imported. The closure of its nuclear plant and its poor inter-country connections means Lithuania can only import energy supply from a very limited number of countries.

The sectoral objectives and targets are shown in Figure 155.

Figure 155: Lithuanian energy objectives and targets by sector, 2020

Sector	Main Objectives	2020 Target
Heating	• Increased efficiency • Shift from gas to biomass	Decrease consumption by 30-40 percent [savings of 2-3TWh]
Gas	• Shift from gas to renewables energy sources (RES) • Other gas sources – Liquefied Natural Gas & access to European gas	
Oil	• Shift from oil to RES • Increase competition	20% of RES in electricity production
Electricity	• Full integration into the European energy systems • Ensuring sufficient local competitive supply • Implementation of the 3rd EU Energy Package	12- 14 TWh per year

Investment of 22-27 billion Lts will be required, roughly half from the private sector, to achieve the 2020 targets. The state will aim to reach the target of no less than 23 per cent of renewable energy in final energy consumption, including no less than 20 per cent of renewable energy.

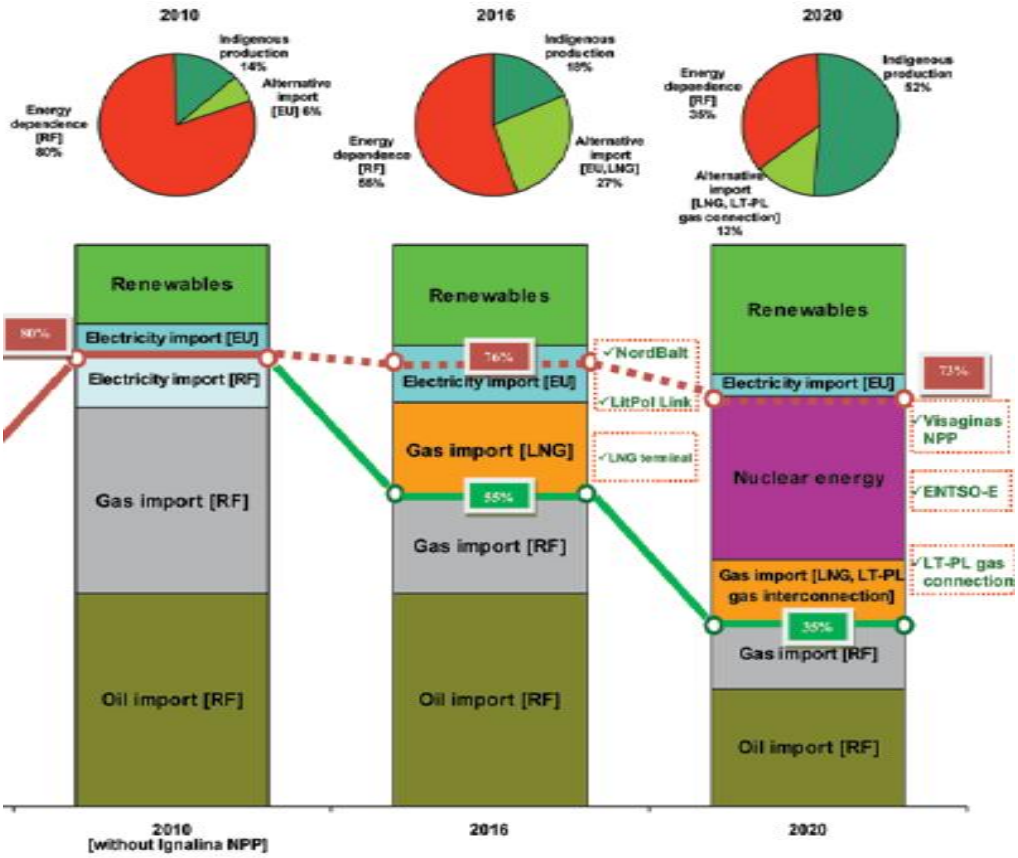
Clear conditions of support to RES will be introduced, giving preference to the most economically and technically feasible solutions of renewable energy. See Figure 156 for the current and planned Lithuanian energy mix.

In 2020, the Lithuanian energy sector will be fully independent of energy supply from a single source. In the period through 2050, Lithuania will progressively move towards a fully sustainable and low greenhouse-gas-emitting economy. In 2050, the demand for electricity will be fully satisfied through the use of nuclear power and renewable energy sources. Centrally supplied heat will be produced only from renewable energy sources.

Lithuania aims at achieving energy independence by 2020. In particular, Lithuania finds the price of gas from Russia extremely high and plans to break Russia's monopoly over its country's energy imports through the implementation of a series of energy projects.

The most important elements of Lithuania's strategy are a new nuclear power plant, a liquefied natural gas terminal, establishing power interconnections with the EU, and moving from the old Soviet grid. In February 2011, a resolution by EU energy ministers agreed that there should be "no isolated energy islands left" by 2015. This largely refers to the three Baltic countries, which are still part of the Soviet grid.

Figure 156: Lithuanian primary energy-mix; reducing energy dependence on single external energy supplier



The Minister for Energy provided the following timetable for achieving the country's goal of achieving energy independence by 2020[295]:

- **Before the end of 2014.** Ownership unbundling should be fully implemented in Lithuania.
- **By the end of 2014.** Vilnius to oversee the building of a floating LNG terminal when the current long-term contract of Lithuania with Gazprom expires. An agreement was signed last week with the port authority of Klaipeda and transmission pipelines should be operational by the end of 2013.
- **2016.** Synchronisation of the country's transmission system with that of the EU's ENTSO-E system. The European Commission has been given a mandate to negotiate with Russia and Belarus, and the country has adopted a law on achieving this synchronisation. The Russian enclave of Kaliningrad appears to be a problem, but if Russia wants to build a nuclear power plant there, it is also in its interest that the enclave is synchronised with the EU Power links to Poland, Sweden and Finland are being built. The deadline of the power ling to Poland is 2016.
- **2020-2022.** A new nuclear power plant at Visaginas is expected to be completed. The parliament has passed all the necessary laws and the minister

295 Ministry of Energy: http://www.enmin.lt/en/activity/veiklos_kryptys/strateginis_planavimas_ir_ES/

of finance has issued a positive opinion in regard to state obligations. The question of Poland's participation in the project is still outstanding. Lithuania's participation now is at 38 percent, Estonia's at 22 percent, Latvia at 20 percent and Japan's Hitachi Ltd is holding a 20 percent stake. The total estimated cost is in the order of €5 billion. Construction is expected to begin in 2015.

Commentators believe the LNG terminal is a definite possibility, but there is some doubt over the nuclear power plant as its capital and operating costs may be higher than anticipated. The cost of LNG terminal is affordable for Lithuania - the only challenge is to find available (and guaranteed) LNG supplies at reasonable price. Whereas the Visaginas plant is expected to cost €7 billion [20 per cent of GDP of Lithuania, 40 per cent of Estonia's GDP or 32 per cent of Latvia's GDP], a cost which is likely to increase during the construction, especially taking into account new safety requirements of post-Fukushima 'nuclear era'. Furthermore, Visaginas is likely to face competition from the Baltic Nuclear Power Plant (NPP) in Russia which could have direct access to consumers in Estonia, Latvia and Lithuania (Russia's electricity grid is synchronously interconnected with the Baltic countries).

6.2 Impact of trends of global energy sector to the short-, mid- and long-term development perspectives of Lithuania energy sector

At the global level the key trends driving the future supply and demand of energy are shown in Figure 157. In the earlier analysis in Chapter 2, the impact of the first three trends **economic growth rate, consumption growth rate, and demographic changes** were found to be very closely related to the increasing demand for energy. However, for the purposes of analysis the world was divided into OECD and non-OECD groups of countries. It was noted that the bulk of the growth under these trends will primarily occur in the non-OECD group. Thus in the short and medium-term they will have little impact in Lithuania.

Figure 157: Impact of international energy trends on Lithuanian energy supply and demand

Key Influences	Short-term (5 years)	Medium-term (5-15 years)	Long-term (>15 years)
(1) Economic growth rate	Insignificant	Low	Medium
(2) Energy consumption growth rate	Insignificant	Low	Medium
(3) Demographic changes	Insignificant	Medium	Medium
(4) Investment requirements	Low – restructuring costs required first	Medium based on EU 2020 targets	High to grow RES
(5) CO_2 emissions	Medium	Medium	Medium
(6) Technology development and improvement	Low	High	High
(7) Global energy intensity	Medium	Medium	Medium
(8) Price	High	Medium	Medium
(9) RES	High	High	High

Source: Authors assessment

However in the longer-term one would expect that the general standard of living in Lithuania will converge towards the European average and this in turn is likely to increase the demand for energy.

Investment requirements: The dominant factor influencing investment is the EU's commitment to reducing greenhouse gas emissions to 80-95 per cent below 1990 levels by 2050.

The Commission analysed the implications of this in its 'Roadmap for moving to a competitive low-carbon economy in 2050'. In this roadmap goals have been set for both 2020 and 2050. The 2020 goal is to reduce emissions by about 40 per cent. This will require a high level of effort and change, both structural and social, to achieve the emissions goal, while at the same time maintaining competitive and secure energy sector. Part of this roadmap indicates a transition from today's energy system with high fuel and high operational cost, to an energy system based on higher capital expenditure but with lower fuel costs. The analysis also shows that cumulative grid investment costs alone could be €1.5 trillion to €2.2 trillion between 2011 and 2050, with the higher range reflecting greater investment in support of renewable energy. Lithuania is already committed to participating in this change.

CO_2 emissions: Successive editions of IEA's annual outlook reports have shown that the climate goal of limiting warming to 2 °C is becoming more difficult and more costly with each year that passes. It will remain a key target of the EU's energy programmes and will affect all member state national programmes.

Coal has met nearly half of the rise in global energy demand over the last decade, growing faster even than total renewables. Whether coal demand carries on rising strongly or changes course will depend on the strength of policy measures that favour lower-emissions energy sources and the deployment of more efficient coal-burning technologies.

Energy intensity: This is widely recognised as a key option in the hands of policy makers but current efforts fall well short of tapping its full economic potential. In the last year, major energy-consuming countries have announced new measures. China is targeting a 16 percent reduction in energy intensity by 2015; the United States has adopted new fuel economy standards; the EU has committed to a cut of 20 percent in its 2020 energy demand and Japan aims to cut 10 percent from electricity consumption by 2030.

A steady increase in hydropower and the rapid expansion of wind and solar power has cemented the position of renewables as an indispensable part of the global energy mix by 2035; renewables will account for almost one-third of total electricity output. Solar will grow more rapidly than any other renewable technology. Renewables become the world's second-largest source of power generation by 2015 (roughly half that of coal) and, by 2035, they approach coal as the primary source of global electricity. Consumption of biomass (for power generation) and biofuels grows four-fold, with increasing volumes being traded internationally.

Other issues: Nearly 1.3 billion people remain without access to electricity and 2.6 billion do not have access to clean cooking facilities (see Chapter 4).

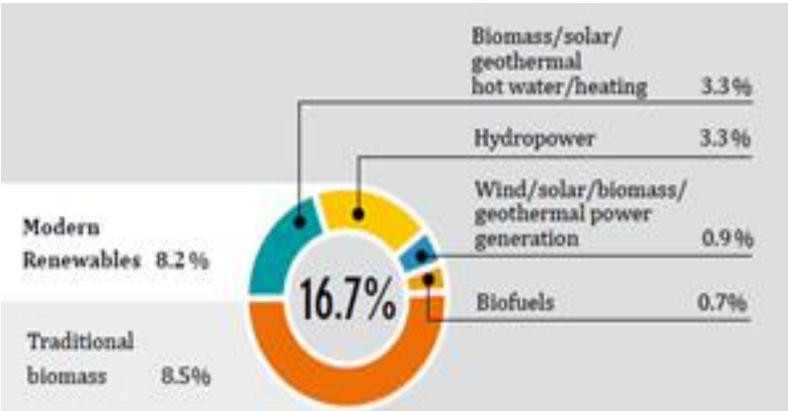
In the future, price relationships between regional gas markets will tend to become more equal as liquefied natural gas trade becomes more flexible and contract terms evolve, meaning that changes in one region of the world are more quickly felt elsewhere (see Chapter 2 and 5).

Water needs for energy production are set to grow at twice the rate of energy demand. Water is essential to energy production in power generation; in the extraction, transport and processing of oil, gas and coal; and, increasingly, in irrigation for crops used to produce biofuels. One estimate of the water withdrawals for energy production in 2010 were 583 billion cubic metres (bcm). Of that, water consumption – the volume withdrawn but not returned to its source – was 66 bcm. The projected rise in water consumption of 85 percent over the period to 2035 reflects a move towards more water-intensive power generation and expanding output of biofuels (see Chapter 4).

6.3 Impact of trends of global renewable energy sector to short-, mid and long-term development perspectives of Lithuanian renewable energy sector

Renewable energy sources (RES) supplied an estimated 17 percent of global final energy consumption in 2010 (see Figure 158)[296]. The UN Secretary General's goal is the doubling of the share of renewable energy in the global energy mix by 2030. RES has continued to grow strongly despite policy uncertainty in some countries, the spread of production of renewables is expanding as markets grow and new policies are established.

Figure 158: Global renewable energy sources (RES), 2010



Source: REN21,2012

In 2011, the level of RES installed continued to increase over 2010 level

- Renewables accounted for nearly half of the estimated 208GW of new electric capacity installed in 2011
- Renewable electric power capacity worldwide reached 1,360 GW (+8 percent) in 2011
- Non-hydro renewables exceeded 390GW, a 24 percent increase over 2010

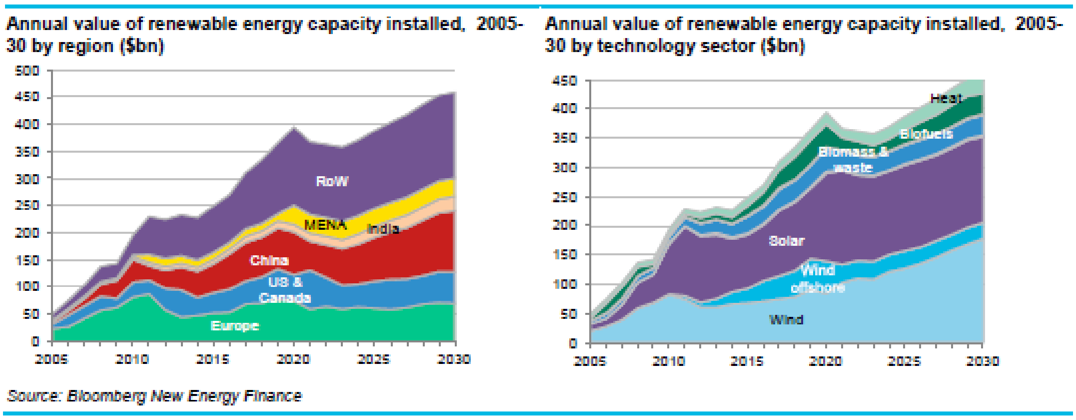
[296] *REN21, (2012), Global Status, Report 2012, Renewable Energy Network for the 22st Century,*

- Renewable energy comprised more than 25 percent of global power generation capacity
- 20.3per cent of global electricity was produced from renewable energy

Figure 159 shows the value of installed RES by region and the annual value of capacity installed 2005-2030.

There was a changing policy landscape in many countries during 2011. There were industry uncertainties, declining policy support, international financial crisis and barriers to trade.

Figure 159: Projections of installed capacity by region and value, 2005-2030



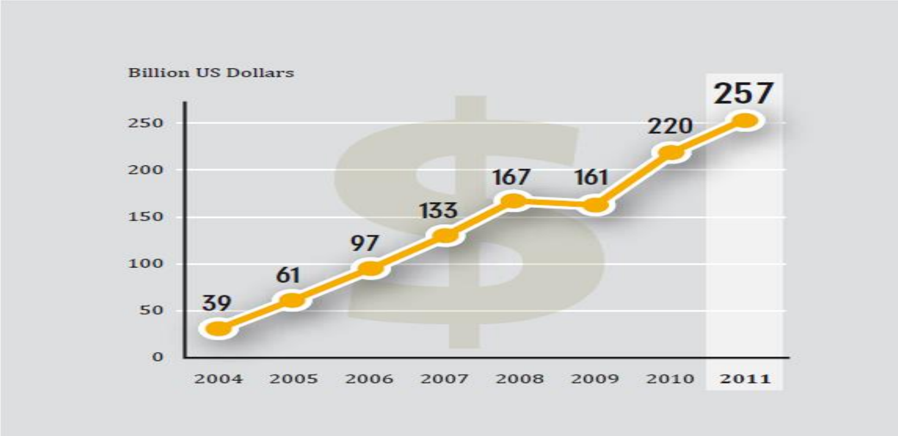
Investment is the key factor in the adoption of RES. Global investment in RES has grown rapidly in recent years, driven by concerns about climate change, the increasing cost of fossil fuels and national economic policies to create jobs. Looking forward, global investment in renewable energy projects will rise from €150bn in 2010 to €304bn in 2020 and to €354bn by 2030, according to Bloomberg New Energy Finance analysis.[297] Over the next 20 years this growth will require nearly €5.4 trillion of new capital (see Figure 160).

New spending on solar energy increased 36 per cent to €105 billion in 2011, outpacing the €58 billion invested into wind power. Spending in the United States rose by a third to €43 billion, surpassing the 1 percent gain in China to €36 billion.

The United States closed in on China in the race to be the lead investor in Renewable Energy, with a 57 percent leap in its outlays to €39 billion. India however, displayed the fastest expansion rate for investment of any large renewables market in the world in 2011, with a 62 percent increase to €9 billion.

[297] *Bloomberg, (Nov 2011), Global Renewable Market Outlook,* , Bloomberg New Energy Finance, London http://www.bloomberg.com/news/2012-01-12/clean-energy-investment-rises-to-a-record-260-billion-on-solar.html

Figure 160: Growth in investment, 2004-2011



Source: Bloomberg New Energy Finance

The WilderHill New Energy Global Innovation Index, or NEX, which tracks 97 clean energy shares worldwide, fell 40 percent last year, and in October hit its lowest value since 2003 as manufacturers faced pressure from falling prices, overcapacity and competition from Asia, according to Bloomberg New Energy Finance.

Key trends in renewable energy sources (RES) are (see Figure 161):

- Rising level of global investment
- Cost reductions per installation – especially in PV and onshore wind
- Availability of technology
- Diversification into new markets
- Industry consolidation
- Emergence of increasingly vertically integrated supply chains

Figure 161: Impact of international RES trends on Lithuanian energy supply and demand

Key Influences	Short-term (5 years)	Medium-term (5-15 years)	Long-term (>15 years)
Rising level of global investment	Medium	High	Very high
Cost reductions per installation	Medium	High	Very high
Availability of technology	High	High	High
Diversification into new markets	Low	High	High
Industry consolidation	Insignificant	High	High
Emergence of increasingly vertically integrated supply chains	Medium	High	High
Wood & Hydro	High	Medium	Low
Wind energy	High	Medium	Low
PV cells	High	High	High
Wave energy	Low	Low	Medium

Some commentators argue that corn-based ethanol is not and is unlikely to be a viable energy alternative in the future. Indeed it is argued that the same can be said for nearly all biofuels.

6.3.1 Regional Outlook

Europe is the world's largest regional market for renewables with 25 percent of world investment and will remain so until 2015, but will contract over this period as governments review the value of clean energy support mechanisms in the face of severe sovereign debt problems. Growth in the European market is anticipated to resume post 2015 at an annual growth rate of 8 percent as investment is scaled up to achieve the European renewable energy target by 2020.

Europe's economic challenges will not affect the non-OECD countries. In China investment in renewable energy is expected to continue to increase, and by 2014 China will become the largest single market for renewable energy with an annual spend of just under $50bn, accounting for 21 percent of the world market. The United States and Canada are also expected to have no slowdown in new projects, and together should exceed €38 bn of investment by 2020.

The most rapid growth will be seen in the developing economies of India, the Middle East and North Africa, Africa and Latin America, which are projected to experience growth rates of 10-18 percent per year between 2010 and 2020. By 2020 the markets outside of the EU, US, Canada and China will account for 50 percent of world demand.

6.4 Impact of the main factors influencing global PV market to Lithuanian PV sector

As already noted in Chapters 4 and 5, the number and capacity of PV installations grows each year.

Installations: Almost 28 GW of PV capacity was installed in the IEA PVPS countries during 2011 – about double the amount as in the previous year. This brought the cumulative installed capacity to 63.6 GW. By far the greatest proportion (60 per cent) was installed in Italy and Germany alone. If China, the United States, Japan and France are also included, then over 86 per cent of PV installations in 2011 occurred in six countries. Grid-connections now account for over 98 per cent of the cumulative installed PV capacity.

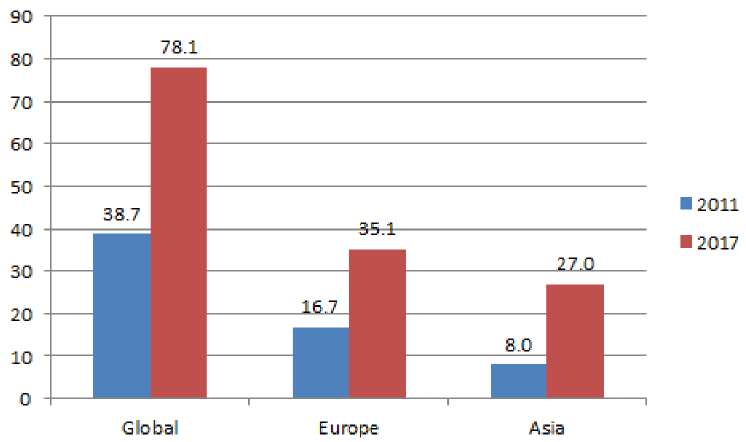
According to a recent report global[298] revenues from solar cells and modules totalled nearly $38.7 billion in 2011 and should decline to $28.6 billion in 2012. Total revenues are anticipated to reach $78.1 billion in 2017after increasing at a five-year compound annual growth rate (CAGR) of 22.3 percent. Europe is the largest market share of the market and should increase from nearly $16.7 billion in 2012 to $35.1 billion in 2017, a CAGR of 16.1 percent - Asia is expected to increase from nearly $8 billion in 2012 to $27 billion in 2017, a CAGR of 27.6 percent (see Figure 162).

[298] ReportLink, (Sept. 2012), Global Markets and Technologies for Photovoltaic Systems, http://www.reportlinker.com/p0969861/Global-Markets-and-Technologies-for-Photovoltaic-Systems.html #utm_source=prnewswire&utm_medium=pr&utm_campaign=Solar_Photovoltaic

PV cell production: For 2011, in the IEA PVPS countries is estimated to be 29.9 GW, a 70 per cent increase from the previous year and around 80 per cent of global PV cell production.

China was the lead producer of PV cells in 2011, manufacturing around 20 GW of cells, double the amount manufactured in China in 2010. Other PVPS countries manufacturing at the GW scale in 2011 include Germany with 2.5 GW; Japan with 2.7 GW; Malaysia with an estimated 2 GW; South Korea with 1 GW and the US with 1.1 GW. Taiwan produced 4.3 GW of PV cells; other major non-PVPS countries manufacturing PV cells are the Philippines, Singapore and India

Figure 162: Growth in PV installations, 2011 AND 2017 (Billion USD)



Source: ReportLink, Global Markets and Technologies for Photovoltaic Systems, 2012

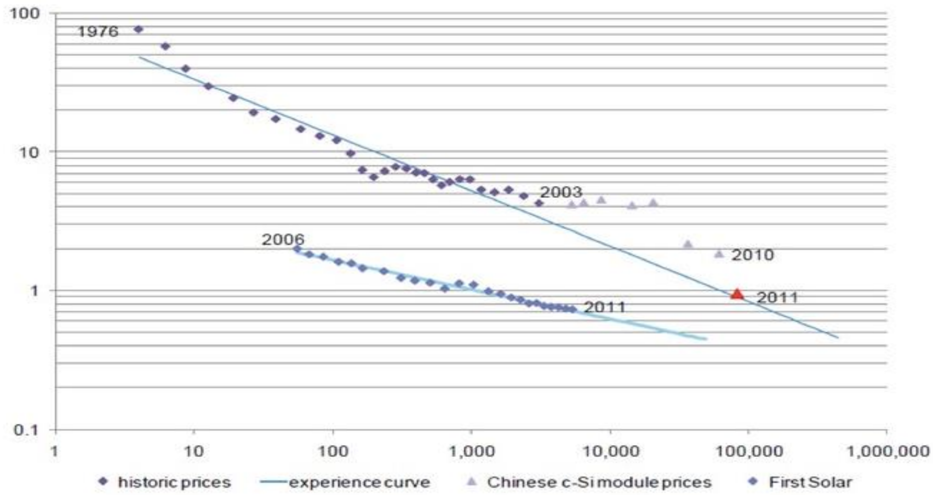
Silcone production: In 2011 solar photovoltaic grade silicon feedstock supply was dominated by China, the US, Korea, Germany and Japan, with smaller levels of production in Canada and Norway. China increased production by 87 per cent, and also increased imports by 36 per cent from the previous year. Korea increased polysilicon production capacity by 60 per cent. Crystalline silicon wafer prices dropped by over 40 percent during 2011, causing some companies to re-evaluate their business models.

Production costs: From $5/kwh in 1978, the cost of electricity generated by solar power has dropped to $0.20/kwh in 2010. A simple extension of this curve would bring the cost of electricity delivered by solar sources to parity with other generating sources by 2015 (See Figure 163)[299].

In this chart, the overall experience curve is shown in the upper blue line, indicating that costs had reduced to the long anticipated point of $1 per watt by the end of 2011.

[299] Mathews John, (June 2012), Newsflash: solar power costs are falling below fossil fuels, The Conversation
http://theconversation.edu.au/newsflash-solar-power-costs-are-falling-below-fossil-fuels-7215

Figure 163: PV module cost curve, 1976-2011



Source: Mathews, John, 2012

But the years immediately preceding this show that costs hovered for several years (2004 to 2008) at around four times this level ($4/W) – a phenomenon now understood to be due to the fact that suppliers were able to purchase modules at that price because feed-in tariffs were the dominant influence rather than cost of silicon.

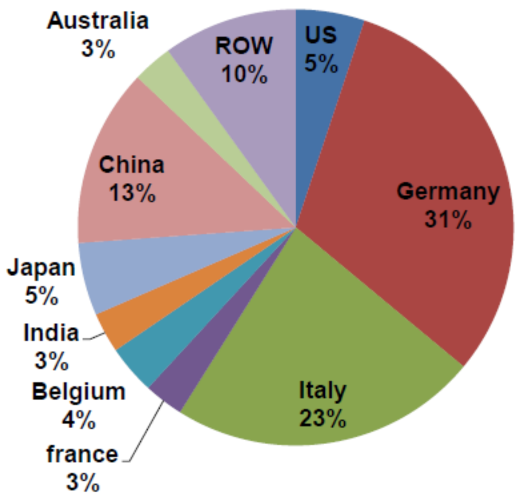
Worldwide, electricity utilities are now investing in very large-scale PV plants or asking how they can benefit from meeting their customers' interest in PV plants or PV electricity, often driven by government mandates and increasingly leading to the pursuit of business opportunities. While the up-front capital requirements of PV installations remain a common barrier to deployment, third-party financing schemes (including leases and power purchase agreements) that address high up-front capital requirements are becoming more common.

In 2011, drastic changes were observed in the global business environment for the PV industry (see Chapter 4). The global PV market largely shifted from a seller's market to a buyer's market due to the magnitude of capital investment in production. PV prices declined largely because of the gap in supply and demand, rather than the traditional effects of mass production and R&D activities. 2011 saw an increase in the number of GW-scale manufacturers, a widening of the supply/demand gap, a maturing of the supply chain and the emergence of trade tensions. Figure 164 shows PV demand and installations by country. Over 60% of the installations were in Europe.

Some lessons can be taken from the recent past. PV manufacturing is a relatively new global manufacturing market. It has gone through a period of dramatic and difficult change over the last ten years, a not untypical evolution for a relatively new market:

- A period of scarcity of silicone with very high prices (over twenty's times today's prices) several years ago

Figure 164: Country installation shares 2011 – Demand 23.6 GWP, Installations 24.4 GWP



Source: Paula Mints, Navigant Consulting, 2012[300]

- Recognition of the growth and opportunities in the manufacturing of PV cells and modules and active investment from the stock market which provided equity for new manufacturing entrants
- High competition from China which captured more than 50 per cent of the world market
- Close down of the Spanish PV market after a short period of very rapid expansion supported by generous feed in tariffs
- European nations led by Germany and Italy have reduced guaranteed rates for electricity produced from renewables to keep power prices from surging during the economic slump in the last two years
- The last two years also suffered from an acute market over-supply, followed by a drop in prices and the current restructuring of the market

For example, despite very high import duties three U.S. solar companies including Solyndra LLC went bankrupt in 2011, in part because of falling prices triggered by increasing competition from Chinese manufacturers.

Next year looks like being another challenging year, with the European financial crisis continuing to fester and the supply chain working its way out of some challenging overcapacity. In the United States the Energy Production Tax expired at the end of 2012. Its extension stalled in Congress last summer amid fierce opposition from some conservative House Republicans. The last chance to extend the measure is in the budget deal that has yet to be finalised between Obama and Republicans in early 2013. United States clean energy investment were higher than China's for the first time since 2008, lifted by government support programs for renewable energy, some of which have since expired.

300 http://www.irecusa.org/wp-content/uploads/Mints.pdf

Subsidies have played an important part in the level of PV installations. Between the mid-1980s and the early 2000's there were no subsidies and consequently very few installations. However, when Germany decided to support the solar market with the generous feed-in tariffs, manufacturers like First Solar, Trina Solar, and Yingli Green Energy were established to fill the demand. Manufacturers across the board are working to make modules not only cost-effective but more efficient. SunPower has exceeded 20 per cent efficiency for modules, and while a 40 per cent efficient cell in the lab looks attractive, until it can be mass produced in a cost-effective manner, it's of no merit.

Each solar panel assembler uses different sourcing strategies, and the levels of vertical integration vary across the industry. At one extreme, SolarWorld, based in Germany, is highly integrated, controlling every stage from the raw material silicon to delivery of a utility-scale solar power plant. At the other extreme, some large manufacturers are pure-play cell companies, purchasing polysilicon wafers from outside vendors and selling most or all of their production to module assemblers. A number of solar manufacturers seem to be moving toward greater vertical integration for better control of the entire manufacturing process. Vertical integration also reduces the risk of bottlenecks holding up delivery of the final product (see also Figure 165).

Figure 165: Impact of international PV trends on Lithuanian PV industry

Key Influences	Short-term (5 years)	Medium-term (5-15 years)	Long-term (>15 years)
Level of installation continues to rise – virtually all grid connected	Opportunity for Lithuania in Europe	Medium	High
Silicon production continues to expand – reducing prices	Low – current over-supply	Medium – as demand rises	Low as balanced growth becomes the norm
Cyclic production of PV modules	High - due to over-supply	Low	Low
Slow increase in PV cell efficiency	Low	Low	Medium
Dependent on FiT supports	High	Medium	Low
Reducing cost of watt produced	Medium – dependent on FiTs	Low -- price difference goes	Low
Cheaper production cost in China	Low impact - only 10% of cost	Lower as Chinese wages increase	None

Finally an important question remains, will there be sufficient demand in China to use half or more of their output? The indications are positive. The Chinese government called for new PV and BIPV applications from regional governments in late 2012, under the Golden Sun programme to boost PV growth in the country and help local PV manufacturers.

The proposed measures set out in December 2012 include:

- Put in place a mechanism to encourage corporate mergers and acquisitions to accelerate research and development
- Strengthen the coordination of PV power generation planning and support grid restructuring proposals; place a cap on production of polysilicon and PV cells and modules

- Actively explore the domestic PV market and promote PV power generation.
- Continue the development of the country's feed-in tariff and state financial support policies
- Improve the electricity pricing mechanism

In addition, the Chinese Ministry of Finance has earmarked €7.3 billion of funding for solar power. On a local level, the largest amount of €37 million will go to Ningxia Hui Autonomous Region and the lowest amount of €116,000 to Hubei Province[301]

6.5 Impact of strategic documents shaping the future for PV to Lithuanian PV sector and political-economic environment

The following reports, articles, documents and websites contain information relevant to considerations about developing PV in Lithuania.

6.5.1 A possible approach to a Lithuanian PV industry

One of the key challenges in developing the Lithuanian PV industry is where to start. The literature and the example of others provide a useful base for elaborating plans in this area. Of particular interest in this context is a study by Roland Berger, Strategy Consultants and Prognos A.G. for the German Solar Industry Association.[302] This section draws on that study.

The photovoltaic sector in Germany has developed dynamically since 2000. During 2010, 7.4 GW was installed and 5.9 GW was added in 2011[303]. Within the solar economy, numerous companies have developed that manufacture and install products for this growth industry – from machines and plant construction to modules and system components. Many of these companies have become leaders on the global market, although they are currently being surpassed by Chinese and Korean competitors. The industry is currently going through a rationalisation but it will continue to expand and grow over the next 30 years. Inevitably it will go through periods of price increases, price falls, contractions, rationalisations and severe competition. However, it still represent an excellent opportunity to develop an internationally, successful industry.

Photovoltaic vision 2023

A clear longer-term vision for a PV manufacturing industry in Lithuania, is the first stage in developing a successful industry.

PV electricity combines distinct advantages; PV electricity is generated close to consumers, it is easy to install and maintain and it offers unlimited availability. In generation it is virtually without competition from other uses and takes place at times of the day with high demand – so that it covers demand peaks. These advantages ensure

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[301] PV Tech, (20 Dec 2012), china_to_increase_investment_in_domestic_market http://www.pv-tech.org/news/china_to_increase_investment_in_domestic_marketT

[302] Roland Berger Strategy Consultants and Prognos A.G., (2010), Directions for the Solar Economy: PV Roadmap for 2020, for the German Solar Industry Association.

[303] PV Magazine, (14 December 2011), Top 5 countries by 2011 PV installations announced.

affordable and sustainable power generation that can be integrated into the overall power system and make a significant contribution to the power supply.

The vision of the German PV industry is based on the claim that the sector can guarantee competitive, affordable, safe and clean power generation from solar energy by the year 2020. The solar industry will be a key pillar in the system transformation to clean and independent power generation based on 100% renewable energies in Germany and around the world.

The Lithuanian industry needs to develop an equivalent or more ambitious vision.

Main targets within the plan would include:

- Make PV a key component of Lithuania's future power system, providing any essential incentives in the early years
- Establish a sustainable, successful exporting PV manufacturing industry in Lithuania by 2020 with appropriate supports including training and R&D
- Have a specific employment targets, e.g., 10,000 jobs.
- Improve manufacturing efficiency thus cutting system prices by up to 20 percent below grid parity by 2023 thereby achieving independence from support measures in main European markets
- Establish the Lithuanian PV brand as high quality-low price in all its markets
- Secure specific market shares in Europe and other selected world markets, e.g., 3 percent of the European market and 5 percent of the sub-Sahara region or some of the former USSR countries
- Generate a net economic contribution to the Lithuanian economy of €XX billion (to be defined and agreed).
- Invest at least 5 percent of sales in R&D

The stakeholders

Involve all the relevant stakeholders in the implementation programme. The relevant stakeholders are:

- Companies in the PV industry including manufacturers distributors and operators of PV systems and system components
- Representative associations - the PV industry, RES and energy suppliers, particularly electricity suppliers, distributors and grid operators
- Relevant policy makers: politicians and government departments, regional and local authorities
- Other political stakeholders, individuals and consumer energy associations
- Electricity customers
- Investors in PV industry and PV installations

- Technical, research and training institutions

Scheduling of measures along a timeline can be based on the following periods:

- Short-term measures to be undertaken in 2013 and 2014 - typically these measures would include the completion of this study and the associated studies under this contract[304], plus any subsequent elaborations, assessments and preparation of the plan to develop a PV industry in Lithuania and identify a strategy that is viable in the Lithuanian context. The plan should also identify clear and unambiguous roles for all the stakeholders involved in the development.

  The key activities would include:

  - legislative change, public service support and policies
  - measures and supports to ensure the industry is quickly established on a firm footing
  - provide necessary skills, technologies and R&D as required during the development phase
  - setting out realistic times for completion of each stage of the plan

- Medium-term measures to be taken between 2015 and 2018 - to begin the establishment of the PV industry building on the private sector resources that already exist and on the R&D expertise that exists, providing the public supports that ensures this development materialise, including the establishment of a FiT scheme that supports the use of PV in Lithuania itself

- Long-term measures to be taken in the period after 2019 and over the following five years - to develop the skill and expertise of the industry and enter strategic markets where the Lithuanian PV sector has a competitive/unique advantage

6.5.2 Main reports on PV

1. Alan Goodrich, Ted James, and Michael Woodhouse, *Solar PV Manufacturing Cost Analysis: U.S. Competitiveness in a Global Industry*, National Renewable Energy Laboratory, October 10, 2011. http://www.nrel.gov/docs/fy12osti/53938.pdf.

2. Alim Bayaliyev, Julia Kalloz, and Matt Robinson, *China's Solar Policy,* George Washington University, Subsidies, Manufacturing Overcapacity & Opportunities, December 23, 2011, p. 16, http://solar.gwu.edu/Research/ChinaSolarPolicy_BayaKallozRobins.pdf.Arnufl

[304] The other studies include:

- Prospective photovoltaic (PV) technologies and their competitiveness
- PV market and market segments
- Scenarios for Lithuanian PV industry development
- Critical capabilities necessary for the achievement of desired future state

3. Barbose Galen, Darghouth Naïm, and Ryan Wiser Ryan, (Nov. 2012), *Tracking the Sun V: An Historical Summary of the Installed Price of Photovoltaics in the United States from 1998 to 2011*, Berkeley Lab. http://emp.lbl.gov/sites/all/files/LBNL-5919e-REPORT.pdf

4. Castello S, De Lillo A, Guastella S, and Paletta F, (2012). National Survey Report of PV Power Applications in Italy 2011. Paris, France: International Energy Agency.

5. DOE/EIA, (Jan 2009), Solar Photovoltaic Cell/Module Manufacturing Activities 2009, U.S. Energy Information Administration

6. Durand, Y. 2012. National Survey Report of PV Power Applications in France 2011. International Energy Agency, Paris.

7. European Photovoltaic Industry Association, *Market Report 2011*, January 2012. http://www.epia.org/publications/photovoltaic-publications-global-market-outlook.html.

8. European Photovoltaic Industry Association, *Solar Photovoltaic Electricity Empowering the World*, 2011. http://www.epia.org.

9. EPIA, *Solar Generation 6*, *Solar Photovoltaic Electricity Empowering the World*, 2011.

10. Green Rhino Energy, Value Chain Activity: Manufacturing Solar Glass, http://www.greenrhinoenergy.com/solar/industry/ind_15_solarglass.php.

11. Jacob Funk Kirkegaard, Thilo Hanemann, and Lutz Weischer, et al., *Toward a Sunny Future? Global Integration in the Solar PV Industry*, Peterson Institute for International Economics, May 2010.

12. Jager-Waldau, *Research, Solar Cell Production and Market Implementation of Photovoltaics*, European Commission, DG Joint Research Centre, July 2011. http://re.jrc.ec.europa.eu/refsys/pdf/PV%20reports/PV%20Status%20Report%202011.pdf

13. Platzer Michaerl D, (June 2012), U.S. Solar Photovoltaic Manufacturing: Industry Trends, Global Competition, Federal Support, Congressional Research Office.

14. Reportlinker.com: Global Markets and Technologies for Photovoltaic Systems

15. http://www.reportlinker.com/p0969861/Global-Markets-and-Technologies-for-Photovoltaic-Systems.html #utm_source=prnewswire&utm_medium=pr&utm_campaign=Solar_Photovoltaic

16. SEIA, *U.S. Solar Market Insight Report*, 2011 Year-in-Review Executive Summary, March 2012. http://www.slideshare.net/SEIA/us-solar-market-insight-report.

17. SEIA, *U.S. Solar Energy Trade Assessment 2011*, August 2011.

18. Solar Foundation, *National Solar Jobs Census 2011*, October 2011.

19. U.S. Energy Information Administration (EIA), *Solar Photovoltaic Cell/Module Shipments Report*, January 2012

20. Wissing, L. (2012). National Survey Report of PV Power Applications in Germany 2011. IEA, Paris, France.

21. Yamada, H. and O. Ikki. 2012. National Survey Report of PV Power Applications in Japan 2011. IEA, Paris, France.

6.5.3 Relevant up-to-date articles

1. http://www.pv-magazine.com/
2. http://www.pv-tech.org/
3. http://cleantechnica.com/

This report has reviewed the current drivers and influences on future global energy markets and looked at the future prospects of the different components of the energy mix, with a focus on renewables and, in particular on the photovoltaic markets. The final chapter, Chapter 7, draws preliminary conclusions on Lithuania's potential in relation to the global and/or regional energy market.

7 Conclusions

The main conclusions that can be drawn from this study are detailed below.

Conclusion 1: The global demand for energy will continue to increase in the foreseeable future

Conclusion 1 is based on the following:

Increasing demand for energy	Reducing demand for energy
(1) Growing population – from 7 billion to 9 billion by 2050. This will impact more in the non-OECD countries than in OECD countries	(1) Application of existing energy saving technologies will reduce the energy demand by up to 50%
(2) Increasing GDP is linked with increased demand for energy in most high growth economies in non-OECD countries	(2) Rising energy prices dampens the level of demand
(3) The numbers of middle class people (who typically use more energy than the lower classes) are increasing in key countries, e.g., China, Africa and India.	

Note: These points are drawn from Chapter 2 primarily.

Conclusion 2: The proportion of renewables in the future global energy mix will increase dramatically between 2013 - 2050

Conclusion 2 is based on the following:

Increasing demand for renewable energy sources (RES)	Reducing demand for renewable energy sources (RES)
(1) Many RES are freely available, such as hydro, geothermal, wind and solar	(1) Price of substitutes influences the use of RES, eg, cheap U.S. coal in Europe in 2012 reduced the use of more expensive natural gas
(2) Greater security of supply as many RES tend to be locally produced whereas oil and gas is frequently imported	(2) Many renewables are more expensive than fossil fuels and they require incentives/subsidies to support their use
(3) Need to reduce the use of fossil fuels as they are a finite resource and many people do not wish to use nuclear power	(3) New discoveries of oil or gas will encourage their use, instead of RES
(4) Global Warming. Most countries now accept the need to reduce carbon emissions, especially carbon dioxide and methane.	(4) Variability of Supply. Countries have major differences in availability, conditions and policies relating to the use of RES. This is related to capability, stage of development and requirements.
(5) The EU is committed to the use of 20% renewables by 2020 and to reducing greenhouse gas emissions to 80–95% below 1990 levels by 2050.	(5) Lack of storage methods, transmission logistics and capacity in their present limited level of effectiveness and efficiency are still a major problem (e.g. batteries and grid systems).
(6) EU member states have a legal requirement to draw up plans using more RES and achieve their agreed targets	(6) Levels of investment in the necessary infrastructure across the world varies. The current recession has significant impact on investment.

Note: These points are drawn from Chapters 3 and 4 primarily.

Conclusion 3: PV offers the best opportunity within the renewables sector

Conclusion 3 is based on the following:

Why PV?	Why not PV?
(1) Hydro and geothermal are much more site specific than either wind or PV. Biomass and wood are also quite site specific.	(1) The competition is tough – Germany and China are the main PV competitors. The main competitor in wind is Denmark, and China is just developing an industry
(2) PV has more long term potential than other RES since it has an inexhaustible supply and it can be matched to peak power demand	(2) Diverse technical challenges are facing PV, while there are few technical challenges facing wind generation.
(3) Unlike most traditional fuels, PV has no (or very little) requirement for water supplies in producing power.	(3) For PV, links will have be created with financial intermediaries and with local installers
(4) PV is at an early stage of development and therefore there are still significant opportunities for innovation to reduce costs.	(4) The PV industry has been quite cyclical and is currently at the bottom of a cycle
(5) PV manufacturing can be undertaken in any country and unlike wind generators the plant can be easily packaged and transported.	
(6) The PV business model is still evolving and there are various opportunities along the value chain which can still be exploited.	

Note: These points are drawn from Chapters 3 and 4 primarily.

Conclusion 4: PV is the most suitable sector of RES to develop a new manufacturing industry

Conclusion 4 is based on the following:

Why PV manufacturing?	Why not PV manufacturing?
(1) Solar Power is freely available and installations can be located on house roofs, commercial buildings and on land which is not suitable for agriculture or other economic activities	(1) High capital cost of manufacture and installation of PV still requires incentives and support to compete with traditional fuels. However, this is a gradually reducing problem
(2) PV has high growth potential and the industry is at early stage development. Thus there are still many opportunities for new industry entrants	(2) Technical challenges. Although progress is being made there are still problems with energy efficiency, design of converters and batteries
(3) PV systems provide suitable energy supplies in remote regions, not provided with electricity transmission lines. This is currently important in China and will be so in India and Africa	(3) Lack of storage methods, transmission and logistics (e.g. batteries and power lines)
(4) Used in conjunction with gas based production, PV provides a reliable energy source for variable demand	(4) Other countries may be exploring PV opportunities
(5) The worldwide industry is contracting and rationalising; soon it will be expanding again	(5) Power transmission lines have significant power losses over distance

Note: These points are drawn from Chapters 3 and 4 primarily.

Conclusion 5: It is worthwhile to further explore the opportunities for Lithuania in PV manufacturing

Conclusion 5 is based on the following:

Why Lithuania?	Why not?
(1) Lithuania has an existing business and technical group (PCT) capable of providing initial development support	(1) The provision of incentives (likely to be required) poses some economic risk
(2) There are significant opportunities for innovative product design which will simplify PV products and components and hence reduce costs	(2) Lithuania has, at present, no anti-dumping protection (e.g. against German producers)
(3) Lithuania's geographical location in Europe and in relation to neighbours and countries to the South-east is considerable advantage	(3) There are regulatory deficiencies which will need to be addressed
(4) Potential markets and production of components (within the value chain) can be segmented to Lithuania's advantage	
(5) The cost of manufacturing can be reduced with low labour rates combined with modern world class manufacturing techniques and a well-educated workforce	
(6) Lithuania is close to one of the largest global RES markets. So transport costs, customer support, logistics and installation are not going to be big issues. These are key factors as a market develops and gets more mature	
(7) If Lithuania develops competitive production and marketing capability, it will attract European and world investors	
(8) Good geographical location to supply Southern Europe, Turkey and former Russian countries	

Note: These points are drawn from Chapters 3 and 4 primarily.

But this study has only examined the PV market potential from the energy market perspective, the other studies are necessary to complete the evaluation. The other studies are:

- State of art and next generation photovoltaic (Study II)
- Present and prospective PV applications and challenges for the PV industry (Study III)
- The dynamics of PV industry: integration and competitiveness in the energy sector (Study IV)
- State of the art analysis of Lithuanian PV technology cluster and potential for its development (Study V)