E3G

Investment momentum for decarbonising the EU power sector

Evidence review on current investment and future scenarios

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1. Introduction

There is growing recognition that the EU power sector will need to be significantly decarbonised over the next 20 years in order for EU and national carbon targets to be met. While there have been policy changes at both EU and Member State level to reflect this ambition, it is not yet clear whether under current policy frameworks investment in low carbon power generation will be sufficient to achieve the level of decarbonisation required.

This document reviews current evidence on investment momentum in the EU power sector in the context of the need to move towards a largely decarbonised power sector across Europe by 2030. While consistent data on power sector investment across the EU is not readily available, this document uses published estimates of levels of investment and new generation capacity to assess current investment momentum. It also looks at plausible scenarios of future investment needs based on current policy frameworks, and compares these to alternative low carbon scenarios.

As well as an EU overview, five country case studies are presented: UK, Germany, France, Spain and Poland. The paper focuses narrowly on power generation, and therefore has not addressed in detail the levels of investment required for a range of related goals for the power sector, including research and development for new technologies; demand reduction and energy efficiency; interconnections and smart grids; and achieving wider carbon reductions through electrifying the transport and heat sectors.

The review finds that a significant increase in investment volumes will be needed in all future scenarios for new generation capacity across Europe, to replace decommissioned plant and meet demand. Total investment volumes increase under all scenarios. The amount of investment needed to meet decarbonisation goals is higher than under "business as usual" scenarios, but is of a broadly similar magnitude. When fuel costs are taken into account, the overall additional costs of low carbon generation may be negligible[1]. However, although there has been a recent growth in investment in renewables and low carbon technologies, 'business as usual' investment patterns and new fossil fuel generation capacity in the planning pipeline risk 'locking in' high carbon generation and making future carbon reduction targets impossible to meet.

[1] Ecofys 2009

1.1 EU overview

Power generation in the EU is at a crossroads. Up to half of current generation capacity will be decommissioned over the next 20 years, and policy pressures on climate change and energy security are changing investment frameworks. To meet present and forecast levels of demand, new power generation capacity will be needed. This presents a risk, but also an opportunity. Construction of new fossil fuel power plants could 'lock in' high carbon emissions for the lifetime of the new plants and prevent the EU from meeting ambitious CO_2 reduction targets for 2020 and 2050. Significant investment in low and zero carbon generation capacity, on the other hand, could not only reduce power sector emissions but also prepare the ground for the decarbonisation of other sectors such as heat and transport.

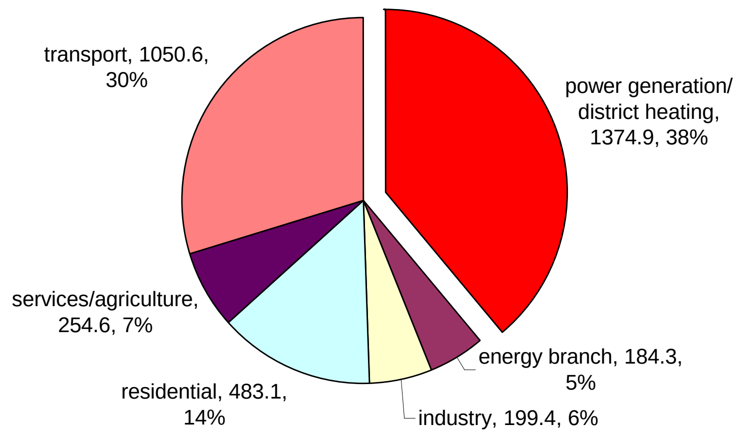
While investment in renewable energy has grown rapidly in recent years, indications suggest that a large amount of new fossil fuel generation capacity is in the planning and development pipeline. However, investment climates remain very uncertain, as a result of price, regulatory and delivery risks as well as factors resulting from the global economic downturn.

1.2 Current energy profile

Power generation in the EU currently accounts for 1,375 $MtCO_2$, over a third of Europe's total CO_2 emissions and 28% of its greenhouse gas emissions (GHGs)[2]. Fossil fuels led by coal dominate production, with nuclear accounting for just under a third of generation (Figure 1).

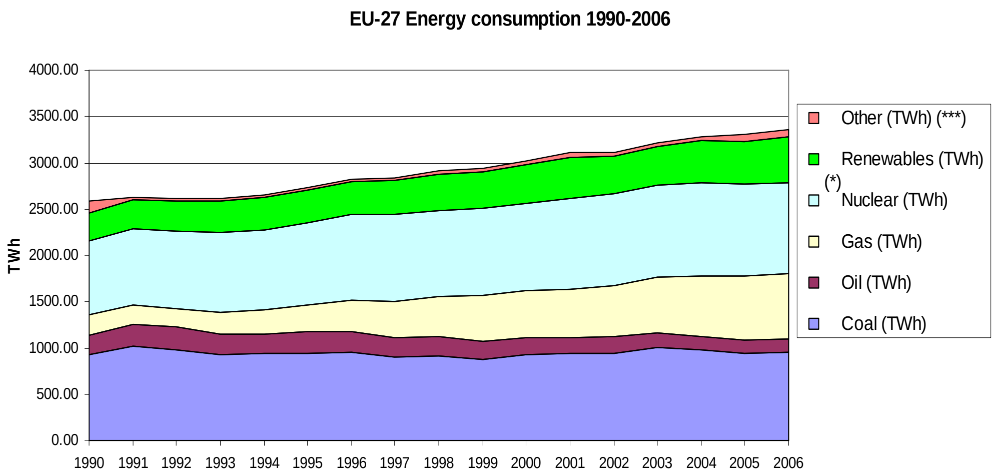
[2] EC DG-TREN 2008a.

Figure 1: EU-27 CO2 emissions by source



Source: EC DG-TREN 2008a

Figure 2: EU-27 Power consumption by source 1990-2006



Source: EC DG-TREN 2009a

However, this profile will be subject to change. Much of Europe's generation capacity was built in a wave of investment following the oil crises of the 1970s and is reaching the end of its life. Compliance with EU environmental regulations (Large Combustion Plants Directive and the Industrial Emissions Directive) means that a significant proportion of coal-fired power plants will close or reduce operations by 2016 to 2020. Overall, between 393.7 and 439 GW of generation capacity will be decommissioned between 2006 and 2030[3]. This represents well over half of current installed capacity in Europe[4]. Planned phase-out of nuclear power in some countries also creates the need for replacement capacity. Estimates on total new capacity needed to replace decommissioned plants and meet power demand range from 666.4 GW (European Commission)[5] to 822 GW (Eurelectric)[6].

In addition, meeting the EU's 20% renewables target by 2020 will require 35-40% of power generation to be met from renewable sources, against 14% of current generation[7].

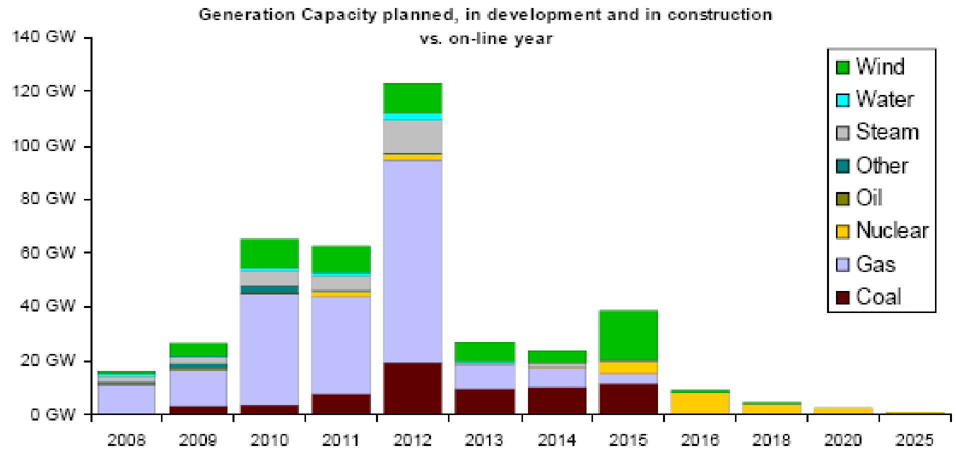
1.3 Current investment momentum in the EU power sector

In 2007, the OECD estimated that investment in the EU electricity industry is currently running at an average of USD 30 billion per year, or about €20 billion at today's exchange rates[8]. Detailed breakdowns of financial investments by country or technology are not currently publicly available. However the European Commission (EC) has approved a directive, to be implemented in 2010, requiring member states to report on levels and types of investment in the energy sector, as a way of tracking progress on energy goals[9].

The bulk of new capacity in the planning pipeline will be powered by fossil fuels, especially gas-fired generation.

[3] EC DG-TREN 2008a; Eurelectric 2007
[4] 739GW in 2005. EC DG-TREN 2008a
[5] EC DG-TREN 2008a
[6] Eurelectric 2007
[7] EC JRC 2009
[8] OECD 2007
[9] Euractiv 2009

Figure 3: New power generation capacity 2008



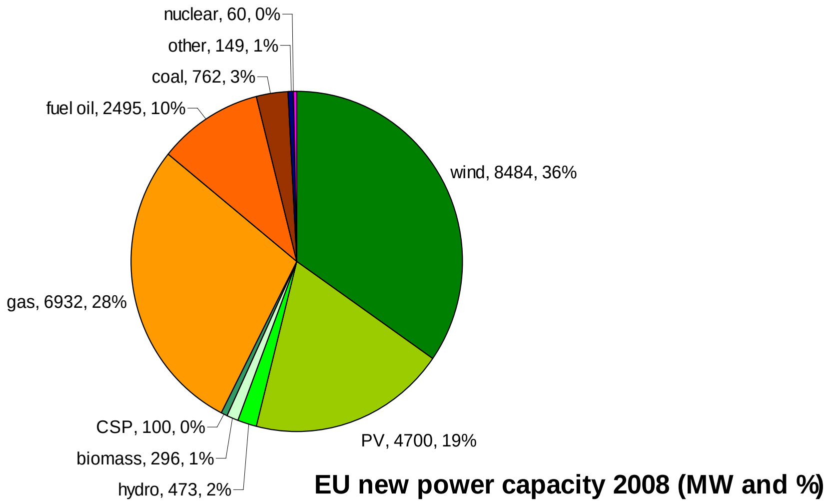
Source EC DG-TREN 2008b

Particular concerns have been raised about coal, due to its high emissions intensity. As of 2007, Greenpeace estimated that there were 68 large coal plants in the phases of proposal, development, permitting or construction in Europe, with a total capacity of 64,026 MW[10]. 33 plants with a total of 33,435 MW capacity are planned in Germany, 8 (8,700MW total) in the UK, and 6 (3,526MW) in Poland. The IEA reports that 8 GW of new coal capacity was under construction in Europe in 2008, predominantly in Germany, Poland and Italy[11].

However, not all planned generation is delivered; power sector projects are capital intensive with long lead in times and high level of risk. In 2008, only 762 MW of new coal generation capacity was completed – only 3% of total new capacity[12], and a number of planned coal plants have been delayed or cancelled in the current economic downturn.

[10] Greenpeace 2007
[11] IEA 2008
[12] EU JRC 2009

Figure 4: New generation capacity delivered in 2008



Source EC JRC 2009

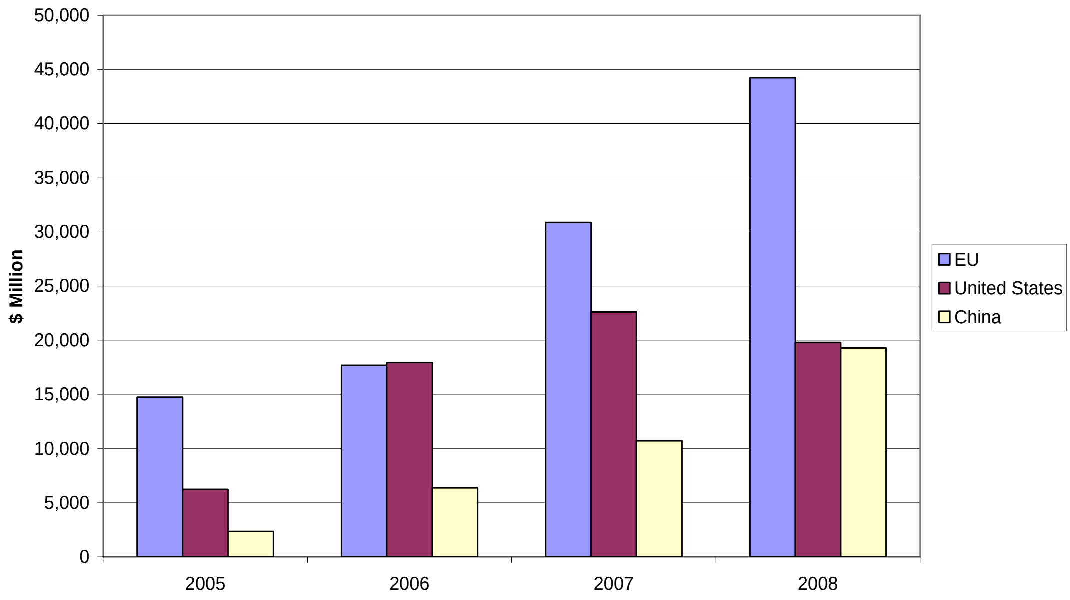
By contrast, in 2008 new wind installations overtook new gas generation capacity for the first time and 57% of new power capacity was from renewable sources[13].

New Energy Finance figures point towards a steep increase in investment in renewable energy in recent years, albeit from a low base. In 2008 there was €44 billion of new asset financing in sustainable energy in the EU – 3 times the level of 2005[14]. This marks the EU as a global leader in financing sustainable energy assets, ahead of the United States and China (Figure 5).

However, early indications suggest that this rate of growth has not been sustained into 2009, due in part to the global economic downturn. It should also be noted that Spain accounted for over half of new asset financing in 2008 due to generous subsidy systems that came to an end in late 2008, so it is unclear whether this level of investment will be continued.

[13] EC JRC 2009. Based on EWEA (2009) European Wind Map 2008 and industry sources.
[14] New Energy Finance data, accessed December 2009.

Figure 5: New asset financing in sustainable energy, 2005-2008



Source: New Energy Finance

1.4 Implications of recession

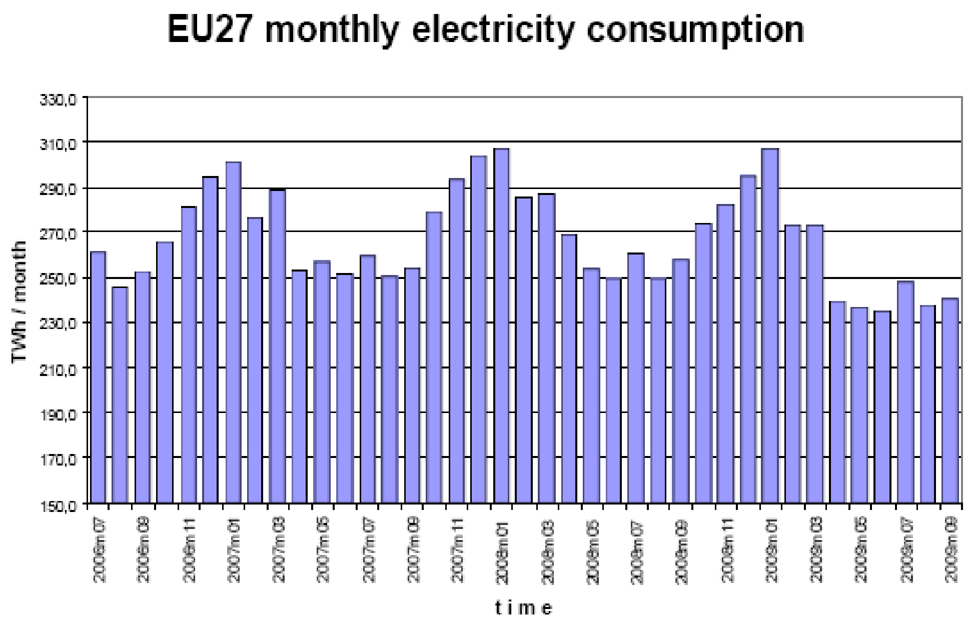
The current global economic downturn may prove disruptive to investment momentum and patterns of power generation. There are growing indications that the recession has cut demand, lowered emissions, raised the cost of capital, lowered carbon prices and fossil fuel costs, and led to a number of power sector investments being delayed or cancelled.

Particularly striking is the drop in electricity demand. Baseline scenarios based on PRIMES energy modelling project a steady 1.3% increase in electricity generation year on year[15]. However, in 2008 electricity consumption was 0.1% lower than in 2007, and in the first 9 months of 2009 consumption dropped by

[15] Ecofys 2009

over 5% compared to 2008[16]. Carbon emissions from combustion plant in the EU ETS also fell by 3.3% in 2008 over 2007[17].

Figure 6: EU27 Monthly Electricity Consumption



Source: EC DG-TREN, 2009b

Many of the scenarios reviewed here were modelled or published before the full extent of the global economic downturn was known. They may therefore model higher baseline power demand than will occur in practice.

1.5 Future scenarios for power generation in Europe

Four baseline scenarios for Europe have been considered as part of this study:

- the European Commission's 'Energy Baseline to 2030'[18]
- Eurelectric's baseline scenario in the 'Role of Electricity' (RoE) report[19]

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[16] EC DG-TREN 2009b
[17] EEA 2009
[18] EC DG-TREN 2008a

- Greenpeace's reference scenario for its 'Futu[r]e Investment' report[20]
- the International Energy Agency's World Energy Outlook 2008 reference scenario[21].

Each represents a forward projection of current policy and investment momentum to 2030, based on assumptions on demographic change, economic growth and relative prices.

Five alternative low carbon scenarios for Europe have been considered:

> The EC's 'New Energy Policy' scenario to 2020[22]

> The EC's 'RES & EE' scenario to 2030[23]

> Eurelectric's 'Role of Electricity' scenario to 2030[24]

> Greenpeace's 'Futu[r]e Investment' scenario to 2030[25]

> The IEA's World Energy Outlook 2009 low carbon (450ppm) scenario to 2030[26]

> The Ecofys SERPEC study with projections to 2030[27].

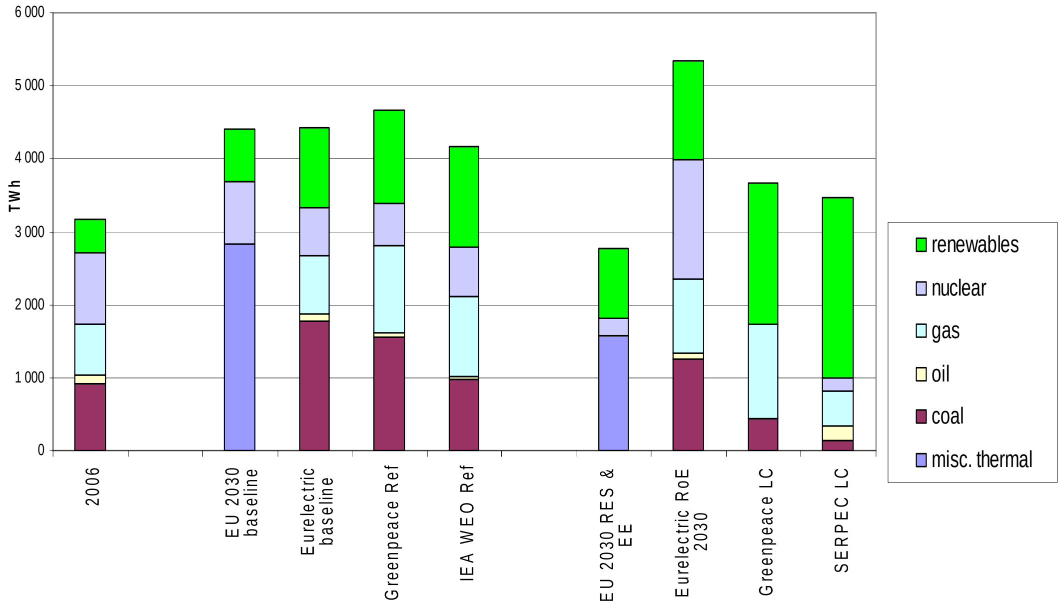
In addition to the modelled scenarios, figures from CERA and E.ON/VGB[28] on the amount of investment necessary to meet rising demand and carbon targets have been used.

[19] Eurelectric 2007
[20] Greenpeace/EREC 2007
[21] IEA 2008
[22] EC DG-TREN 2008b
[23] EC DG-TREN 2006
[24] Eurelectric 2007
[25] Greenpeace/EREC 2007. The Greenpeace scenario is based on OECD Europe rather than the EU, so comparisons with the other scenarios based on the EU-27 should be seen as approximate.
[26] IEA 2009
[27] Ecofys 2009
[28] E.ON 2009. EON/VGB project that 475GW new capacity is needed to 2020, with an average capex of €1300/kW. CERA projects 324GW new capacity to 2020, with an overall investment of €568 billion.

1.6 Future energy profiles

The projected energy mix in 2030 for the main scenarios is shown in Figure 7 below[29]:

Figure 7: EU Current Generation and 2030 Scenarios



Each of the baseline scenarios involves an expansion of coal and gas-fired generation plants, a continuation of nuclear power and an increase in renewables in line with current policy. The baseline scenarios also reflect rising energy consumption as a result of economic growth, demographic change and consumer demand.

The low carbon scenarios vary in their approach:

> The EC's New Energy Policy scenario assumes 'vigorous action' at member state level to meet the EU's 20:20:20 goals on renewable energy and energy efficiency

[29] The EC New Energy Policy scenario, IEA 450 scenario and CERA/EON/VGB estimates are not shown as they do not give comparable figures for 2030.

> The EC's RES & EE scenario involves meeting current EU aspirations on energy efficiency and renewables (which would require significant new policy), and involves a substantial reduction in overall energy consumption.

> Eurelectric's Role of Electricity scenario involves the electrification of other sectors such as heating and transport as a means for reducing emissions

> Greenpeace's 'Futu[r]e Investment' scenario involves a phase out of nuclear power across Europe, combined with a large increase in renewables and energy efficiency, together with a major roll-out of combined heat and power to reduce carbon emissions from buildings.

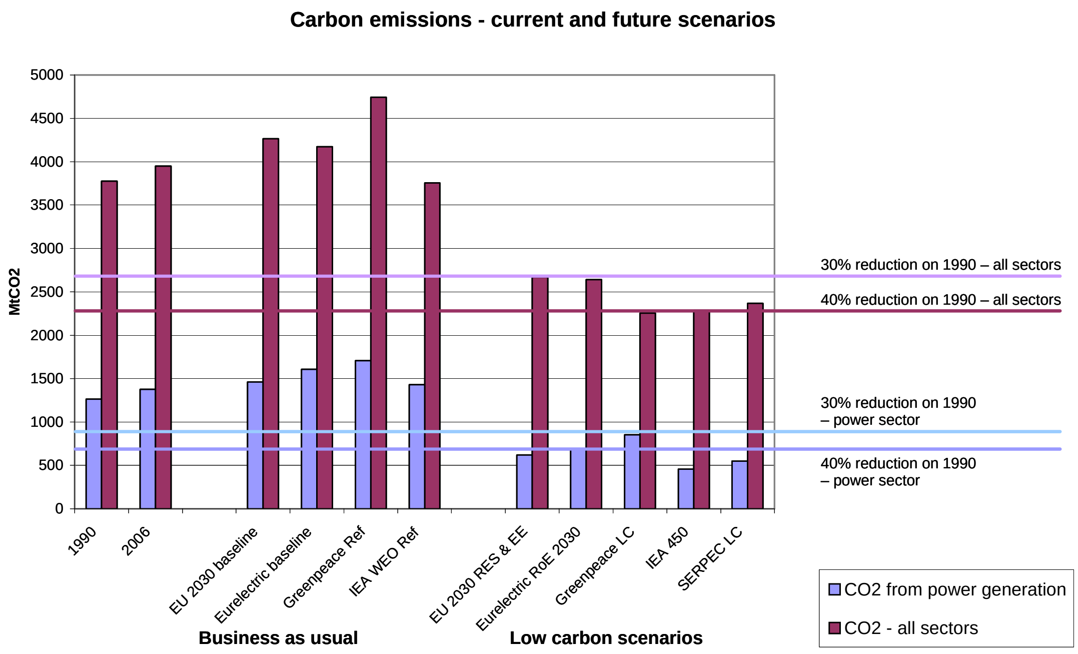
> IEA's 450 scenario is a global scenario based on stabilising atmospheric GHG concentrations at 450 ppm by 2050 (after an initial overshoot). EU level actions include increasing renewables and developing CCS, reducing emissions from buildings and transport and replacing nuclear capacity.

> The Ecofys SERPEC scenario involves "full deployment of low-carbon technologies in each cycle of renewal of technologies". It incorporates technologies for energy efficiency, but does not include the emissions reduction potential from behaviour change. While specific investment totals are not listed, the model projects that "the additional costs to society of reaching such reductions can be negligible" due to savings in fuel costs.

1.7 Carbon emissions

All of the baseline scenarios show either rising or stable emissions from both the power sector and overall emissions until 2030. This demonstrates that under current policies and investment trajectories, EU carbon targets will be missed by a considerable distance.

Figure 8: EU carbon emissions in 2030



The low carbon scenarios all involve significant reductions in carbon emissions over the current and projected levels. However, it should be noted that even the low carbon scenarios reviewed here do not involve the major decarbonisation of the power sector that may be necessary to support emissions reductions throughout the economy. The Eurelectric RoE scenario and EC RES & EE scenario would deliver a carbon reduction of approximately 30% over 1990 levels by 2030, in contrast to the EU's target of a 30% reduction by 2020 if a global deal at Copenhagen is achieved. The Greenpeace, SERPEC and IEA 450 scenarios achieve a 40% CO_2 reduction by 2030 – but do not approach a zero emissions power sector.

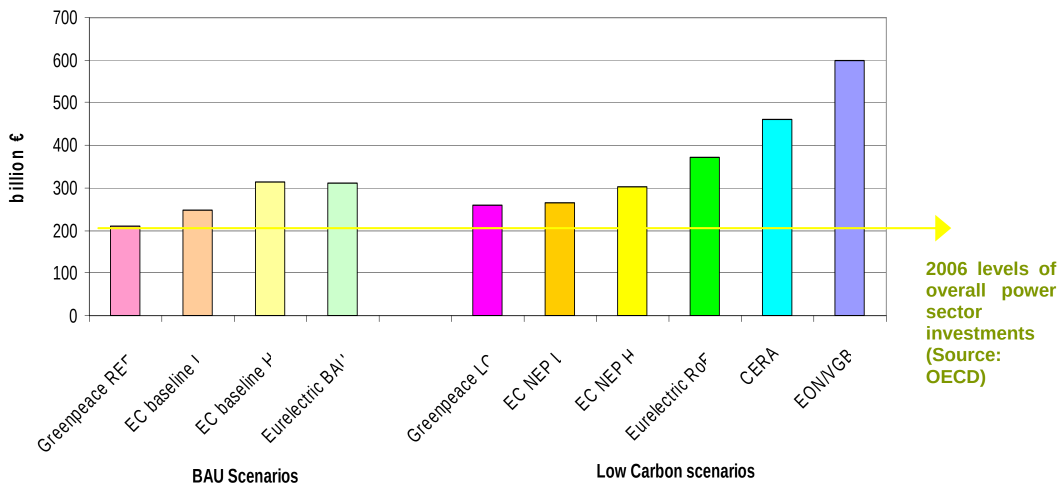
1.8 Investment needed

To replace decommissioned plant and meet rising demand under baseline scenarios, it is estimated that investment volumes of €200-300 billion will be necessary over the next 10 years (Figure 9). This suggests that – if continued over the next 10 years – the average of €20 billion per year invested in the EU power sector in the first half of this decade may be insufficient to meet current demand, let alone achieve carbon reductions.

Assessments on investments needed to meet the EU 20% RES targets for 2020 suggest €672 billion will be required from 2005-2020, including €308 billion on renewable electricity generation and €53 billion on renewable CHP[30].

Estimates of the investment needed for low carbon scenarios until 2020 vary from €260 to €600 billion, and for 2030 range from €530 billion to €1115 billion[31]. This suggests an emerging investment gap of between €60 billion and €400 billion by 2020, and between €100 and €600 billion by 2030. The investment needed to deliver a near-zero emissions power sector by 2030 is likely to be even higher.

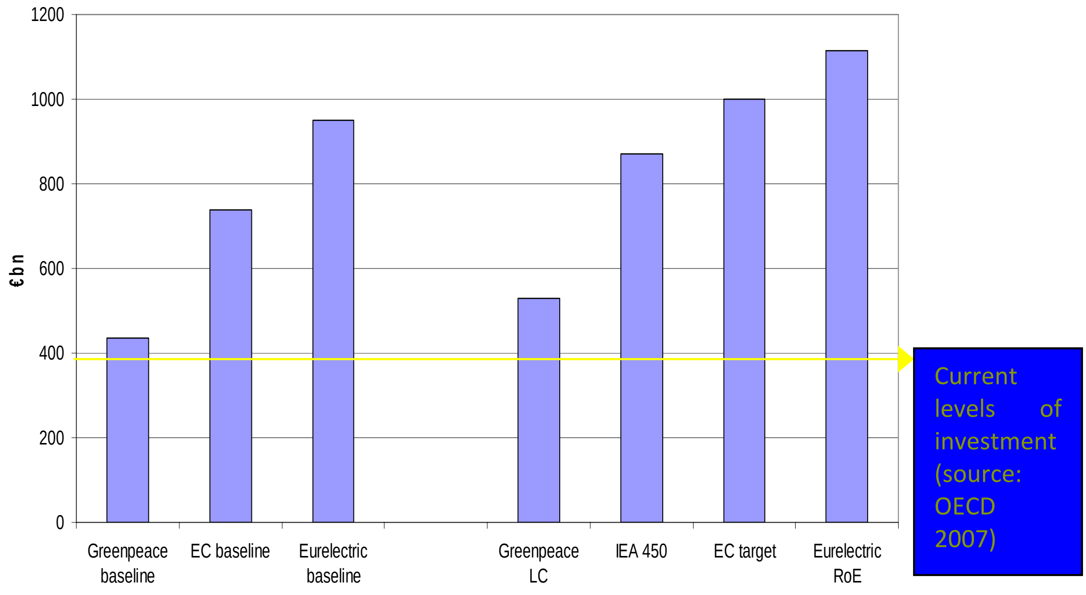
Figure 9: Investment in the EU power sector to 2020



[30] Ecofys et al 2008

[31] The IEA's 450 scenario will require investment of USD 1300 billion in the low carbon power generation sector in the EU by 2030 (77% renewables, 16% nuclear, 7% CCS). 2020 figures are not given.

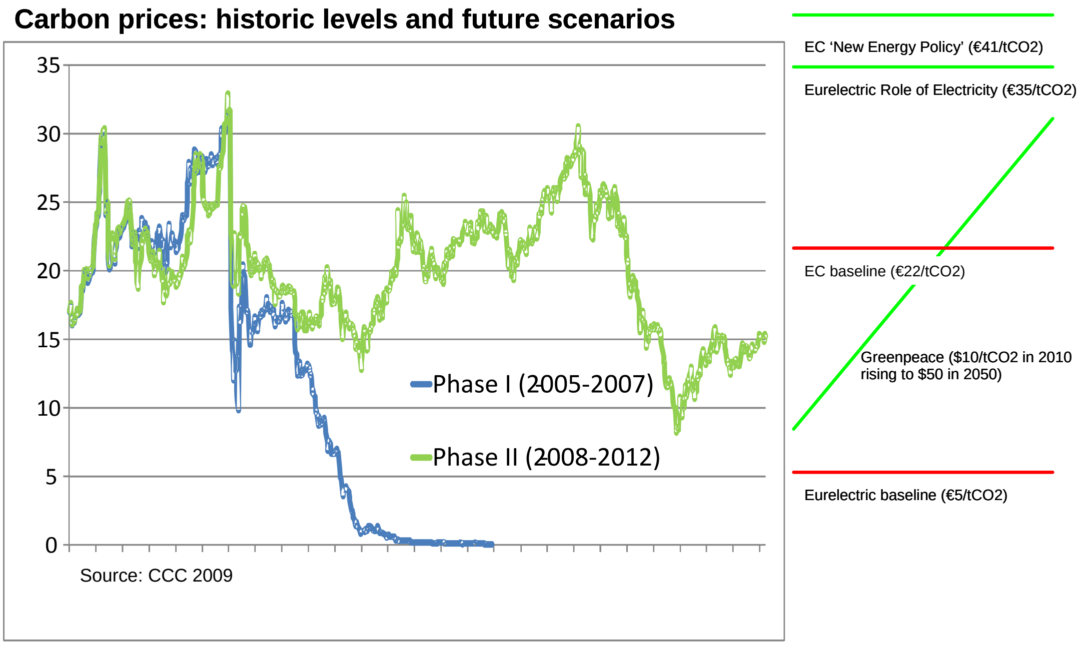
Figure 10: Investment in the EU power sector to 2030



1.9 Carbon price to support investment

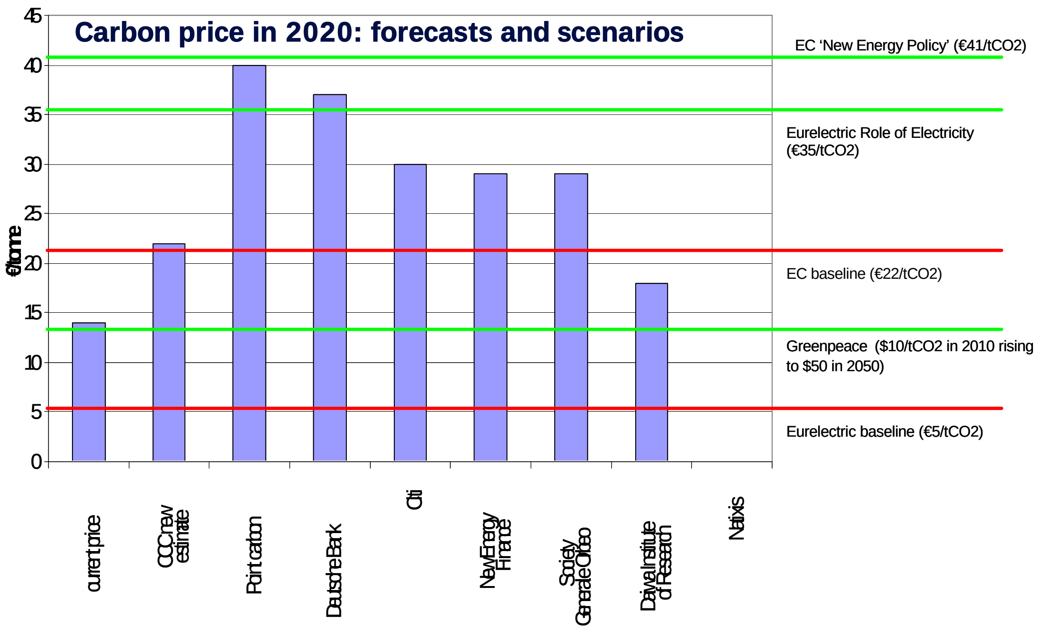
The future scenarios considered here involve varied projections of the EUETS carbon price to 2020: ranging from €5 per tonne (Eurelectric baseline) to €41 per tonne (New Energy Policy). However, EUA prices have so far been stochastic and have not yet reached the levels required to support low carbon investment under the future scenarios.

Figure 11: Historic EUA prices and future scenarios



Source: CCC 2009

Figure 12: EUA price forecasts to 2020 and future scenarios

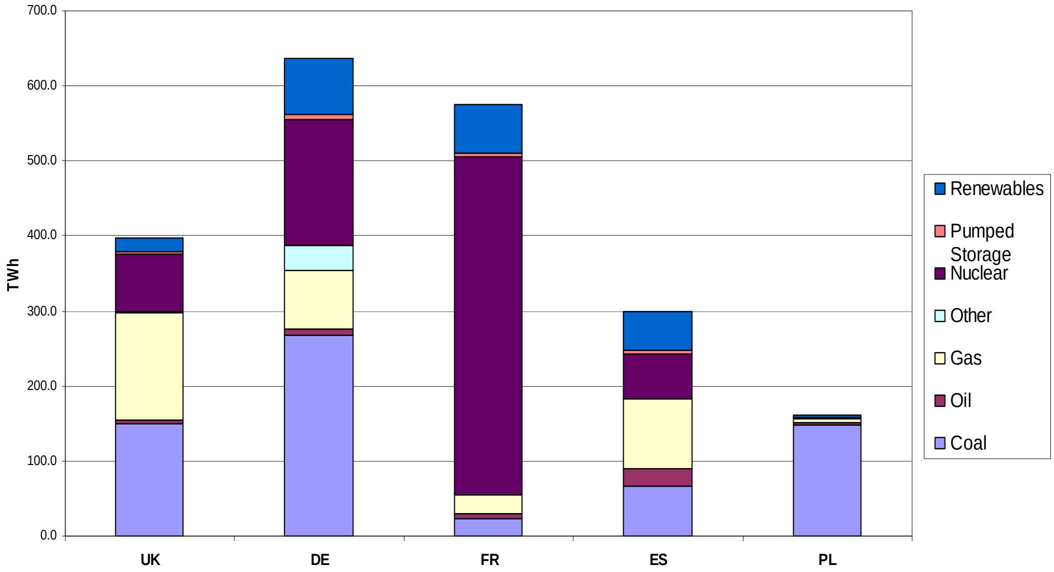


Source: CCC

2. Country case studies

Five EU countries are considered in more depth in this paper: UK, Germany, France, Spain and Poland. The current generation mix differs significantly between the countries, with France dominated by nuclear and Poland almost exclusively coal generation.

Figure 13: Electricity generation mix - selected EU countries

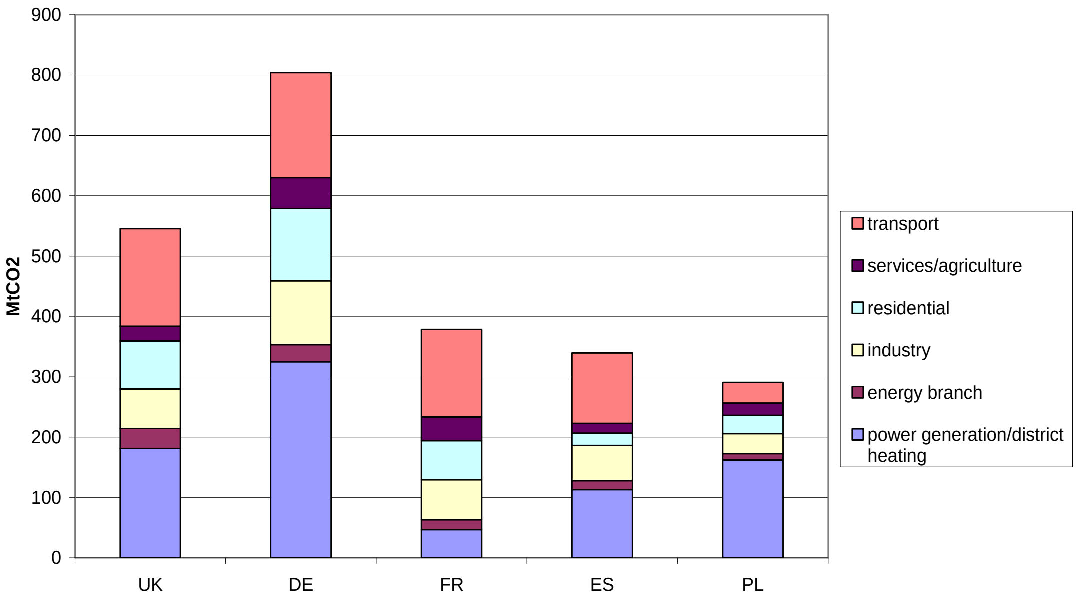


Source: EC DG-TREN 2009a

Collectively, the five countries represent 62% of total power generation in Europe, including 68% of EU coal, 76% of nuclear and 44% of renewables. They also represent over 60% of the EU's total CO2 emissions and over 60% of EU emissions from the power sector.

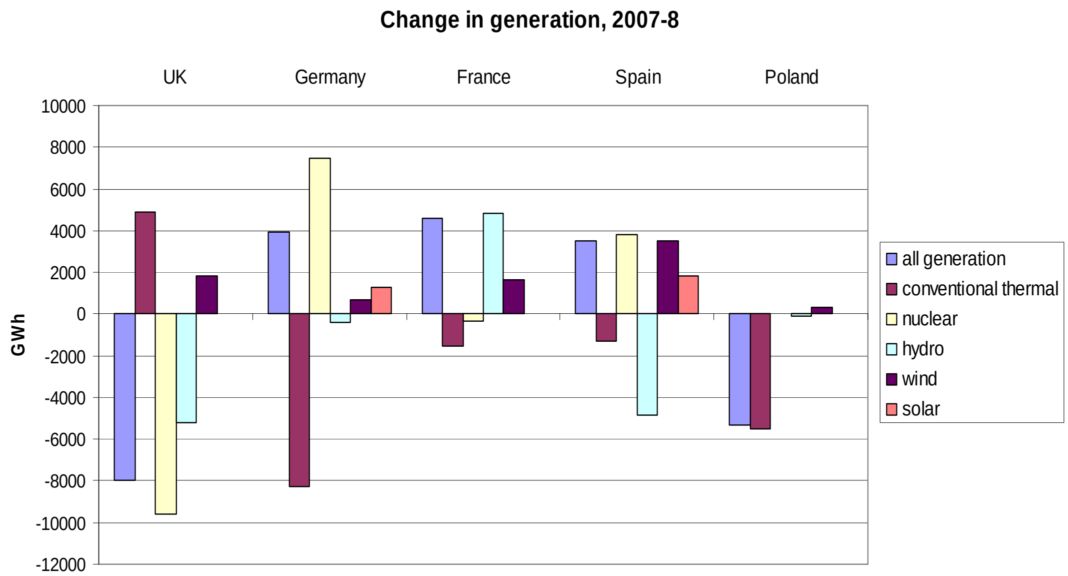
Carbon emissions from power generation range from 14% of the total in France to 55% of total emissions in Poland.

Figure 14: Carbon emissions by source for selected countries



Source: EC DG-TREN 2009a

Figure 15: Changes to power generation, 2007-8



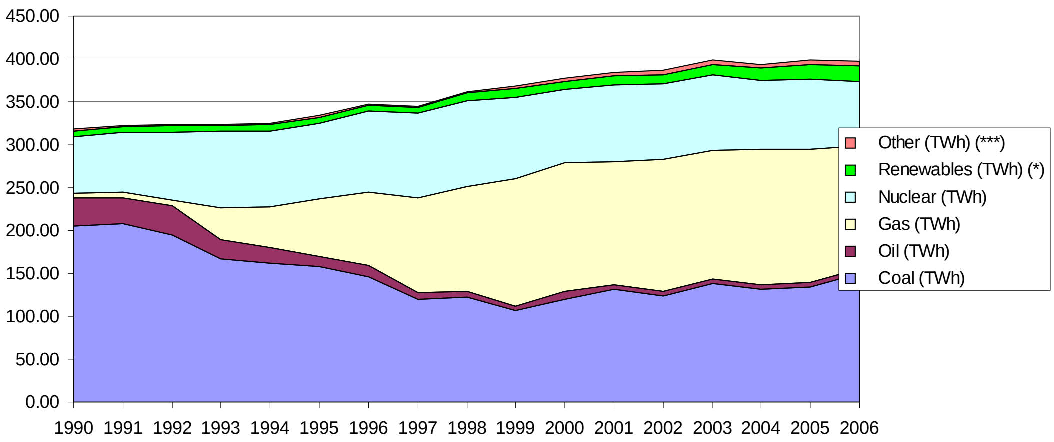
Source: Eurostat 2009

The five countries reviewed here also vary in terms of annual trends in electricity generation, with higher levels of nuclear generation in Germany and Spain, and an increase in gas and coal generation in the UK.

2.1 UK

The UK power generation mix is dominated by coal, gas and nuclear, with very low levels of renewables (currently 5.5%). Gas production has increased steeply since 1990, replacing some coal and meeting rising demand. Power generation represents a third of the UK's overall carbon emissions.

Figure 16: UK power generation 1990-2006



Source: EC DG-TREN 2009a

2.1.1 Current investment and policy overview

The UK has a comparatively liberalised energy market with a retail market dominated by six large suppliers: EDF, Eon, Scottish and Southern, NPower/RWE, Scottish Power and Centrica/British Gas. There are also several large independent generators (e.g. Drax).

The current grid mix is likely to change significantly in coming years. Under the Large Combustion Plants Directive, coal plants with a capacity of up to 7.4 GW are scheduled to close by 2016[32]. Combined with other plants reaching their

[32] Eurostat 2009b

end of life, declining levels of North Sea gas and rising electricity demand, this has led to forecasts of a 'generation gap' of up to 35 GW by 2016[33].

However, the drop in power demand following the recession has made the threat of a supply gap less likely to happen. Against forecast rises in energy demand, power generation fell for three successive years from 2006 to 2008, and in the first eight months of 2009 was 7.6% below the same period of 2008[34]. Despite the reduction in power demand, CO2 emissions from combustion installations covered by EU ETS have risen for each of the last four years, and in 2008 were 6.6% higher than in 2005[35].

The UK's Climate Change Act (2008) set legally binding carbon targets for the UK of 34% by 2020 and 80% by 2050 over 1990 levels. It also created an independent Committee on Climate Change (CCC) to advise on carbon budgets and monitor progress. In its first report, the CCC recommended that in order to meet the 80% economy-wide emissions cut by 2050, the power sector would have to be almost completely decarbonised by 2030.

The UK has a EU renewables target of 15% of final energy demand by 2020, compared to 2.25% in 2008[36]. To meet this target, a Renewable Energy Strategy has been produced which suggests more than 30% of electricity should be generated from renewable sources by 2020, compared to 5.5% in 2008[37]. The current primary instrument for supporting deployment of renewable energy is the Renewables Obligation, which has been extended until 2037. The Energy Act 2008 also introduced a Feed In Tariff for small scale renewable projects, which currently represent less than 1% of UK generation[38].

The UK government has also signalled a change to its nuclear policy and now expects construction on a new generation of nuclear power stations to begin by 2013[39].

Current capital expenditure by UK energy utilities (including electricity and gas) has been estimated at approximately £8 billion in 2008, up about 40% on 2007 levels[40].

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[33] ICE 2009
[34] DECC 2009a
[35] EEA 2009
[36] DECC 2009c
[37] DECC 2009c
[38] DECC 2009c
[39] DECC 2009b
[40] Ofgem (2009)

2.1.2 Future generation and investment scenarios

A number of scenarios have been produced by different groups to project 'business as usual' and alternative investment needs for the future. These scenarios vary according to projections of future demand and appropriate energy mix to achieve low carbon outcomes. Investment scenarios reviewed here include:

> Ofgem "Discovery" (2009)

This study includes two 'baseline' scenarios: 'slow growth', characterised by low investment and limited demand, and 'dash for energy', where security of supply concerns take priority. It also includes two low carbon scenarios: 'green stimulus', where investment in low carbon energy is used as a means of economic recovery, and 'green transition' where energy demand remains more limited.

> CBI "Decision Time" (2009)

This includes a baseline scenario based on current policy and an alternative low carbon scenario characterised by a large expansion of nuclear and limits to the amount of wind generation installed.

> Ernst & Young "Securing the UK's Future Energy Investment" (2009)

This paper assesses the investment needed to meet UK energy goals. It updates a previous estimate of £234 billion by 2025 to £199 billion in light of reduced demand from the recession.

> Policy Exchange/Dieter Helm "Delivering 21st Century Infrastructure for Britain" (2009)

This paper forecasts investment needs across a range of infrastructure, including the power sector.

The following scenarios are of relevance for projecting future power generation but do not quantify investment needs:

> The Committee on Climate Change "Building a Low Carbon Economy" (2008)

> UKERC "Energy 2050" project (2009)

> Tyndall Centre "Decarbonising the UK" (2007)

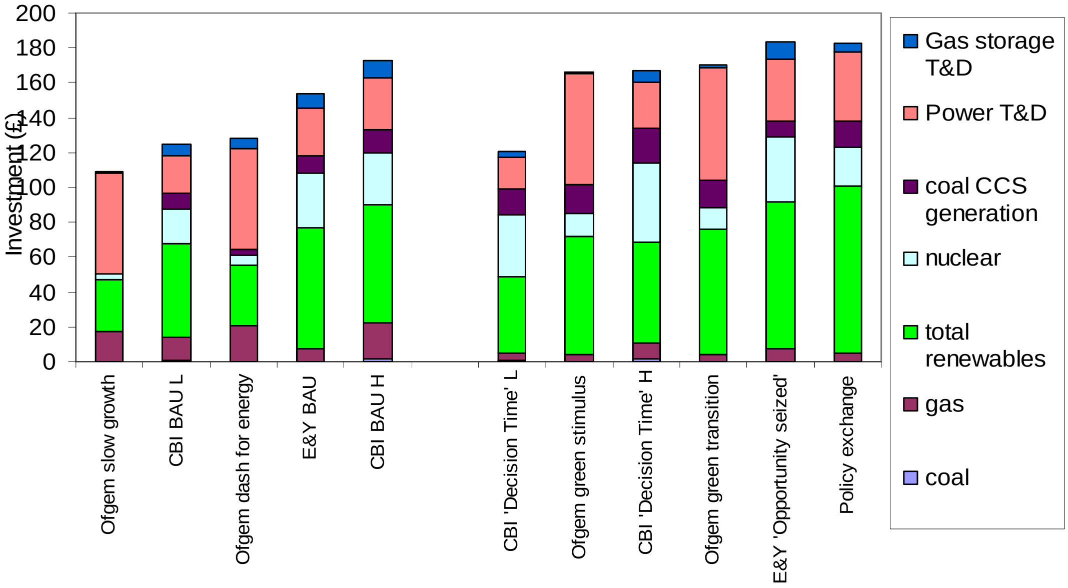
> Centre for Alternative Technology "Zero Carbon Britain" (2007)

The baseline scenarios project that between £109 and £173 billion of power sector investment will be needed until 2025 including transmission and distribution, but excluding investment in efficiency and heat. This averages at between £7.3 and £11.5 billion per year – compared with an estimated £8 billion spent by all UK energy utilities (not just power sector) in 2008 and £5.7 billion in 2007.

To meet the low carbon generation scenarios, £121 to £183 billion will be needed by 2025, an average of £8.1 to £12.2 billion per year – suggesting that current investment momentum is well below the levels required to decarbonise UK electricity generation. The bulk of estimates are towards the higher end of this range: Ofgem has stated that investment rates will have to double over the next 10 to 15 years in order for the low carbon scenarios to be met[41]. The UK's Renewable Energy Strategy also suggests £100 billion of investment will be needed by 2020 to meet the strategy's targets[42]. Grid connections will play a significant role: the CCC estimates that £15 billion will be required to develop the offshore transmission network for 40 GW of offshore wind generation to be connected to the grid.

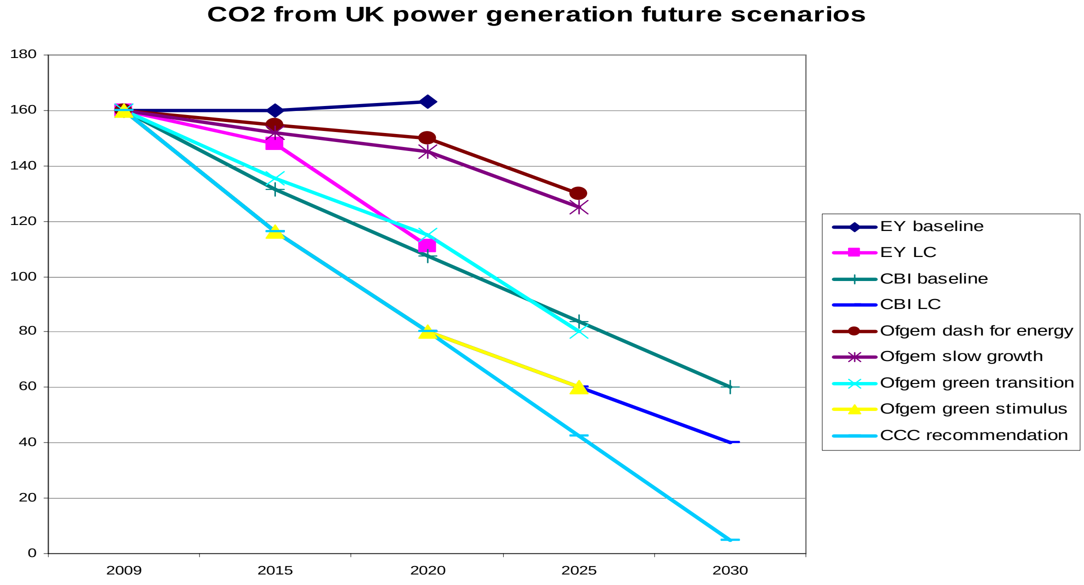
[41] Ofgem 2009
[42] DECC 2009c

Figure 18: UK power investment needs to 2025 (£ billions)



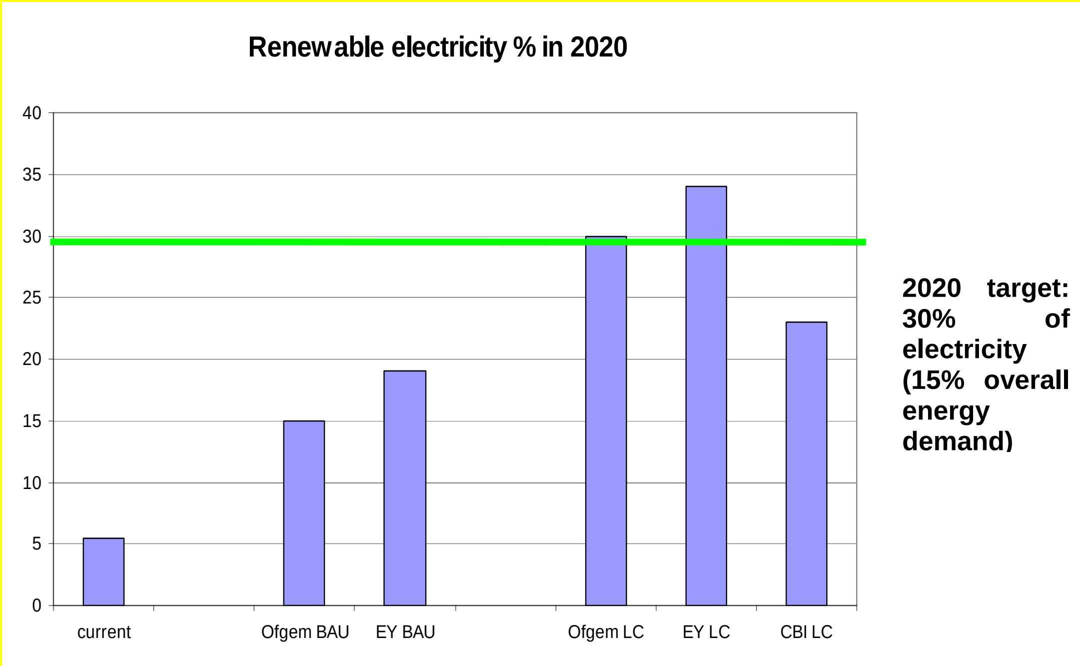
The 'business as usual' scenarios considered here do not lead to a significant decarbonisation of the power sector and may cause carbon targets to be missed by some distance. It should be noted, however, that even the low carbon scenarios assessed here fall short of the trajectory towards a near total decarbonisation of the power sector that the Committee on Climate Change has recommended to meet the 2050 80% reduction target.

Figure 19: CO2 from UK power generation to 2030 (MtCO2)



Business as usual scenarios also fall well short of meeting the UK's renewable energy targets for 2020 (15% of total energy consumption; 30% of electricity).

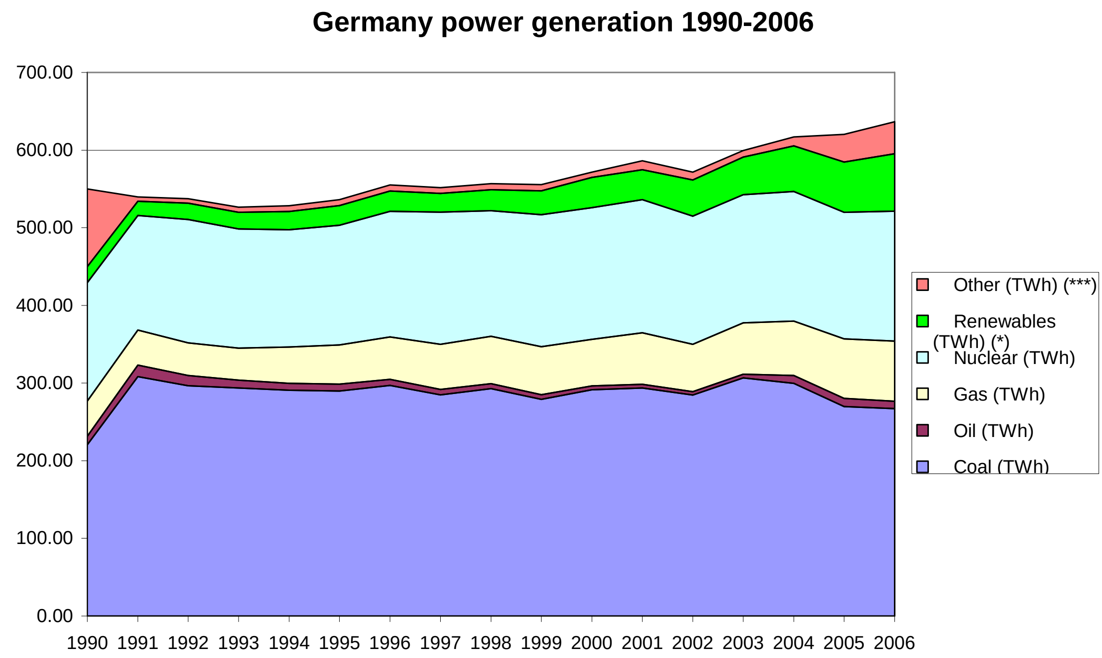
Figure 20: UK renewable electricity generation in 2020



2.2 Germany

Germany is the largest emitter in the EU. Its power sector accounts for 325 $MtCO_2$ (40% of total German emissions), and is led by coal including lignite (42%), nuclear (26%), gas (12%) and renewables (12%). Growth in energy demand has been relatively constant over the last 15 years.

Figure 21: Germany power generation 1990 to 2006



Source: EC DG-TREN 2009a

Roughly half of coal generation is from lignite. Nearly all lignite is domestically-mined, whereas most hard coal is imported due to lower costs on the world market.

2.2.1 Current investment and policy overview

Investment momentum in Germany is currently directed to both coal and renewables, while under current policy nuclear is being phased out.

German power generation is dominated by four large companies: EON, RWE, Vattenfall and EnBW. All have significant investment in coal and lignite power plants, which represent 42% of German electricity generation. Coal in Germany has traditionally been supported by generous subsidies. Hard coal subsidies peaked at €6.7 billion in 1996, with €2.7 billion supporting the industry in

2005[43]. An agreement in 2007 will lead to the phase out of subsidies by 2018, after a review in 2012.

As with the UK and a number of other EU countries, the Large Combustion Plants Directive will lead to the closure of a number of coal-fired plants by 2016, and other plants are reaching the end of their natural lifecycle. In total, around half of German power generation capacity will have to be replaced by 2020[44].

As a result, a significant quantity of new coal generation is in the planning and development pipeline. As of 2007, 33 new coal plants were planned with a total capacity of 33,435 MW[45].

However, recent economic analysis challenges whether new coal capacity will be profitable in the context of uncertain carbon prices and movements in coal and electricity prices[46]. This affects hard coal more than lignite, but new lignite plants also become unprofitable at relatively low CO2 prices.

In 2007, renewable and sustainable energy in Germany attracted asset financing of USD $2,776 million[47] . The overall annual turnover in the renewables sector is €13.1 billion[48]. The share of renewables in final total energy consumption has more than doubled since 2000 and now stands at 9.5%; as of the end of 2008, renewables had increased to 15% of electricity production[49].

Much of this investment is driven by government support through the feed in tariff. In 1990 Germany instituted the first feed in tariff law in Europe, and this was followed in 2000 by the EEG (Renewable Energy Act) which sets the current framework. The FIT operates over 21 years, with different price levels for different technologies and a declining level of support to encourage new investment. IEA estimates show that between 2000 and 2012, the feed-in tariff will cost EUR 68 billion in total[50]. The IEA has criticised the generous support for solar:

[43] Frondel et al 2006
[44] PIK et al 2009
[45] Greenpeace 2007
[46] PIK et al 2009
[47] UNEP 2009
[48] BMU 2009
[49] BMU 2009
[50] IEA 2007

"The subsidies provided to solar photovoltaics are very high in relation to output; they will eat up 20% of the budget but contribute less than 5% of the resulting generation."

However, the strong domestic support for PV has also made German companies leading exporters of solar panels and has lowered the cost of the technology through economies of scale. Following the 2009 election, the new German government has indicated that the feed in tariff for solar will be reduced as it has become more independently competitive.

Nuclear currently accounts for 26% of generation in Germany, but under the terms of an agreement from 2000, nuclear generation will be phased out by 2022. However, following the 2009 German election results, an extension to the life of existing nuclear power stations is likely.

Germany has set several challenging carbon and energy targets:

- "By 2020 greenhouse gas emissions must fall to 40% below their 1990 levels. By the end of 2007 Germany had achieved -21.3%.
- Energy productivity must grow by 3% per annum. That means that in 2020 we must be twice as energy-efficient as we were in 1990.
- The proportion of renewable energies must steadily increase, specifically:
    - to 50% of primary energy consumption by 2050;
    - from about 9% of final energy consumption today to 18% by 2020;
    - from about 15% of gross power consumption now to at least 30% by 2020;
    - from about 7% of today's thermal energy requirement to 14% by 2020.
- The contribution made by biofuels is to increase by 2020 so as to permit a 7% reduction in greenhouse gas emissions compared to using fossil fuels.
- The contribution of Combined Heat & Power (CHP) to power generation is to double to 25% by 2020."

In 2007, the German government adopted the 'Meseberg Programme' of policies to promote sustainable energy towards meeting these targets.

Overall, the Meseberg Programme will require an increase of over €30 billion per year in net investments. This includes an additional €10 billion per year to be invested in power generation and grids – a near doubling of overall investment volumes. In 2005, €12 billion was invested in the power sector – of which €5 billion has been classified as 'emissions-reducing'[51].

2.2.2 Future generation and investment scenarios

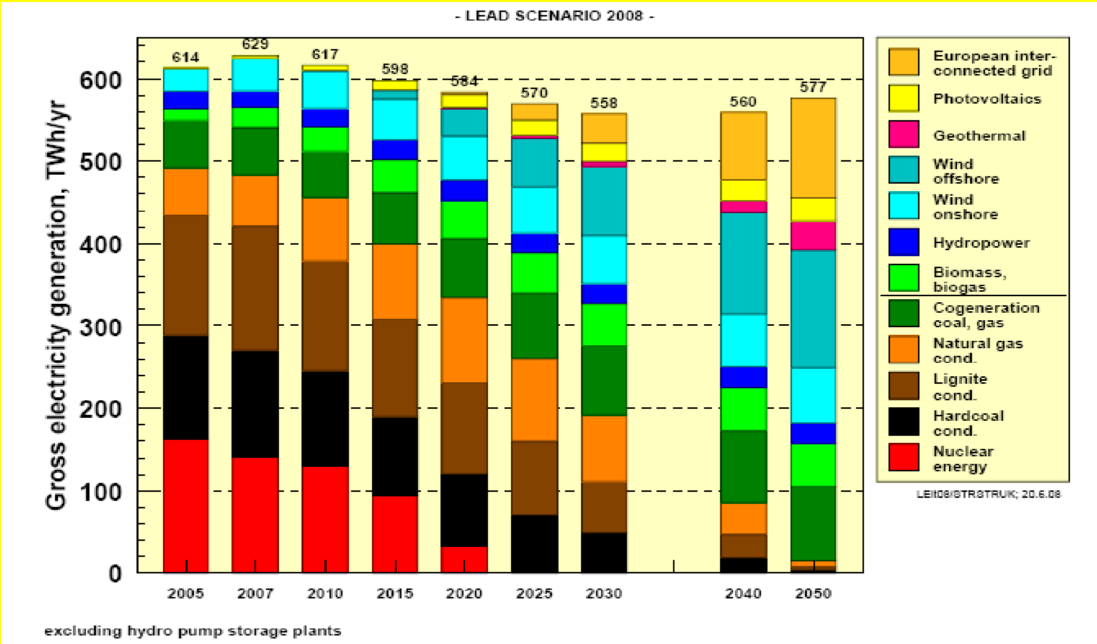
The German government publishes an annual LEAD scenario to model how its target for an 80% reduction in CO2 by 2050 can be met. The 2008 LEAD scenario is based upon measures set out in the Meseberg programme – i.e. current government policy.

The scenario models the phase-out of nuclear power by 2022, and envisages a continuing role for coal and lignite power until 2025-2030. According to the scenario, a maximum of 9 GW of new coal capacity can be built by 2020 to replace decommissioned plants – a fraction of the 33 GW in the development pipeline. The scenario also envisages a steep decline in coal and lignite after 2030, suggesting that construction of new plant over the next decade could either jeopardise future emissions targets or risk creating stranded assets. As the Potsdam Institute notes, just five 2,000 MW lignite power stations would account for Germany's entire 2050 carbon budget if the 80% target is to be met[52].

Post-2020, the LEAD scenario envisages a greater role for an interconnected European grid for imports of low-carbon electricity into Germany.

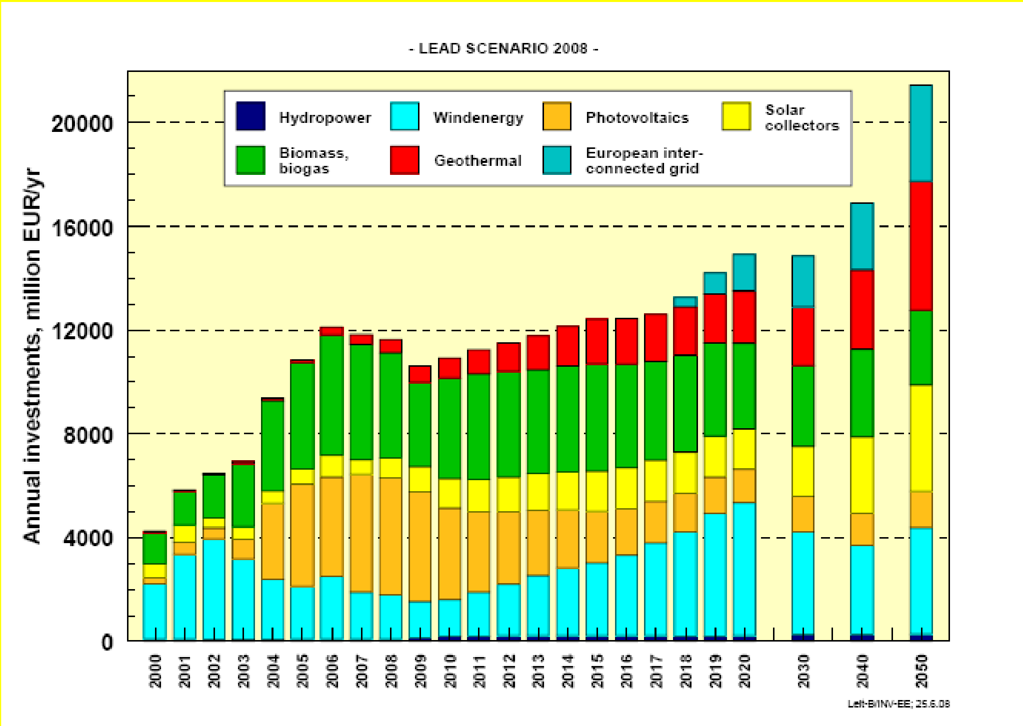
[51] BMU 2008b
[52] PIK et al 2009

Figure 22: Germany future generation mix, LEAD scenario



It is important to note, however, that under the LEAD scenario carbon emissions in Germany will be reduced by 36% on 1990 levels by 2020 - meaning additional measures and additional investment will be required to meet the 40% reduction target.

Figure 23: Renewables investment required in Germany, LEAD scenario

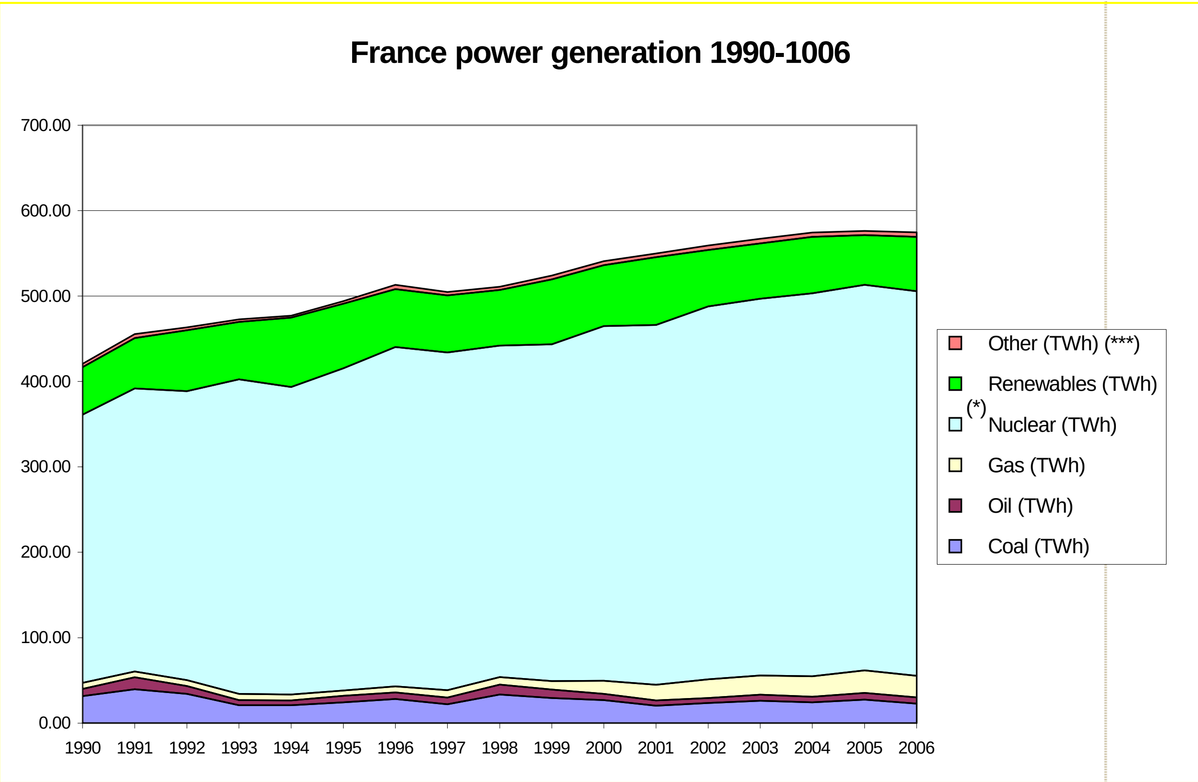


Turnover in renewable energy in the LEAD scenario remains relatively constant at approximately €12 billion. The short decline shown above is due in part to reduced subsidy levels for photovoltaics. Investment rises after 2020 to more than €15 billion per year. Cumulative investment in renewable energy between 2008 and 2020 amounts to €160 billion.

2.3 France

Power generation in France is already relatively low carbon: 78% of generation is nuclear, with a further 11% from renewables (mainly hydro). The power sector makes up 12% of France's CO_2 emissions, compared to over a third across the EU as a whole.

Figure 24: France power generation 1990-2006



Source: EC DG-TREN 2009a

France is a significant electricity exporter to neighbouring countries, including the UK (11.4 TWh in 2008), Belgium (9.5 TWh), Germany (12 TWh), Switzerland (18.3 TWh), Italy (17.9 TWh) and Spain (4.1 TWh) - but overall exports have been declining[53].

2.3.1 Current investment and policy overview

France's power electricity market is highly centralised: electricity production is dominated by EDF (responsible for 84% of supply), a state-owned utility, and 95% of transmission is run by state-owned RTE[54].

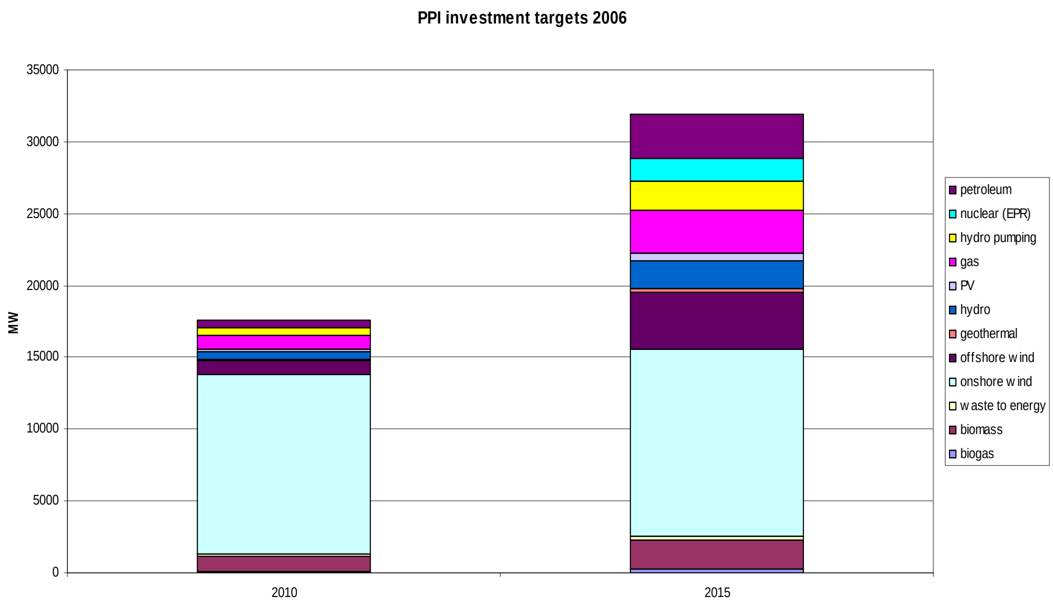
Investment in electricity generation is determined by the government through its "Programmation pluriannuelle des investissements de production

[53] RTE 2009
[54] DGEMP 2006c

d'électricité" (PPI): if the generation capacity is not met through market investment, the government can put out tenders to make up the gap.

The most recent PPI, in 2006, set investment targets of nearly 18 GW by 2010 and almost 32 GW by 2015 – dominated by onshore wind and a new EPR nuclear reactor at Flamanville.

Figure 25: France power sector investment targets for 2010 and 2015



Source: DGEMP (2006a)

The targets are set by capacity rather than expenditure. However, using CERA estimates on average capital cost per KW, the investment plan would require €28.5 billion from 2006 to 2010, and €55 billion from 2006 to 2015.

Separate estimates suggest that the Flamanville EPR nuclear reactor will cost €4bn by the time it opens. An additional EPR (also 1650 MW) was announced earlier this year for the Penly site in Seine-Maritime.

In addition to the investment in new capacity, EDF currently spend €2 billion per year on maintaining existing nuclear plant[55]. The current level of investment for maintaining the existing grid by operator RTE is set at €1 billion over the period 2009-2011[56].

However, the expansion in wind energy set out in the PPI requires increasing investment in transmission capacity. Currently, just 6,000 to 7,000 MW of wind generating capacity can be connected to the existing network, compared to 17,000 MW planned in the PPI. RTE estimate a further €1 billion to 2020 will be required to support connections to the grid[57].

The tendering system for large generation plant is matched by a Feed-In Tariff (with obligatory purchase and tax credits) for small-scale renewables. France also operates an energy savings certificate/obligation scheme, with a savings target of 54 TWh has been set for the period from 1 July 2006 to 30 June 2009[58].

In 2005, France set a target to achieve a 'Factor 4' (75%) reduction in greenhouse gas emissions by 2050. France also has a EU target under the 20:20:20 programme to achieve 23% of final energy consumption (all sectors) from renewables by 2020, which will require a higher renewables share in the electricity sector.

France has also adopted a target of two million electric vehicles on the road within 10 years – suggesting that electricity demand will increase while leading to emissions reductions in other sectors.

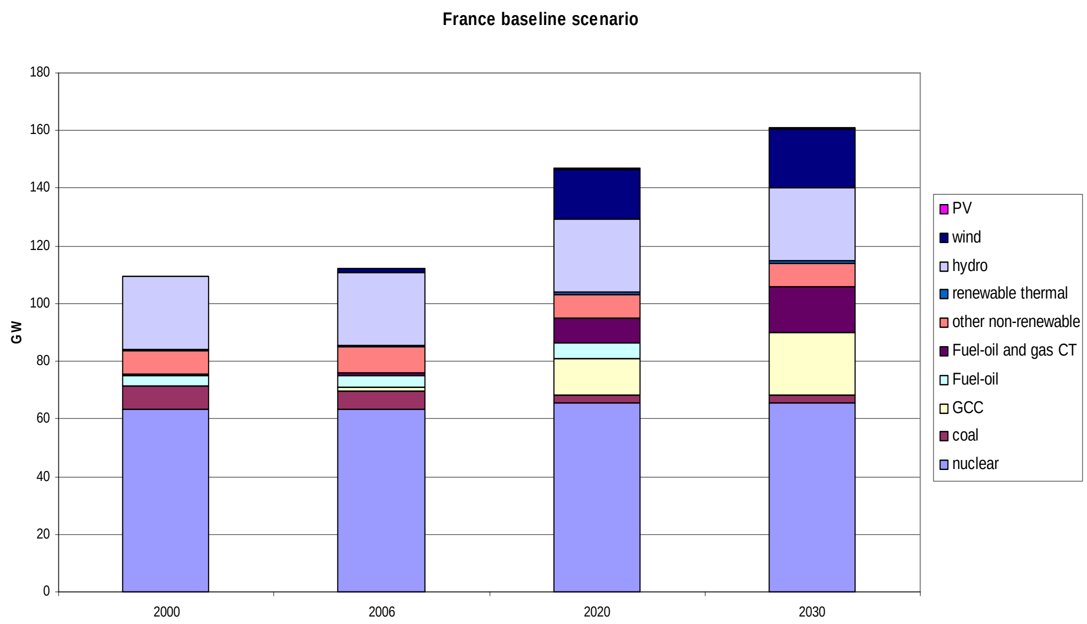
2.3.2 Future generation and investment scenarios

A baseline scenario of future energy production is produced every four years by France's General Directorate for Energy and Raw Materials (DGEMP), most recently in 2008. This baseline is a forward projection of current policies and forecast pricing. The baseline scenario includes a significant rise in energy consumption, new wind capacity, and a continuation of current nuclear capacity (through extending the life of existing plants and commissioning new plant to make up for closures).

[55] EDF 2009
[56] RTE 2008
[57] RTE 2008
[58] DGEMP 2006b

Despite the increase in wind generation, the baseline scenario misses the EU renewables and carbon targets by some distance. The overall share of renewable energy in "enlarged" final energy consumption would grow to 13.4% in 2020 (versus France's 23% target) and to 13.7% in 2030, compared with the 10.3% share observed in 2006.

Figure 26: France baseline power generation scenario to 2030



Source: DGEMP 2008

Under the baseline scenario, electricity consumption rises by 29% over 2006 levels by 2020 and 46% by 2030. It leads to a 6% increase in overall CO2 emissions and a 47% increase in power sector emissions by 2020 and an increase of 91% in the power sector and 14% overall by 2030.

This suggests that despite the low carbon intensity of power generation in France and the planned investments in wind and other renewables, current investment frameworks will be insufficient (by some distance) to meet France's climate change and renewable energy targets.

Further modelling work on future energy scenarios in France is undertaken by the network operator RTE. In its biennial "Generation Adequacy" reports, RTE forecasts supply and demand over 15 years in order to ensure security of supply. While security of supply is sufficient until 2013, by 2015 considerable new capacity will be needed in addition to the existing capacity that will remain in operation and current capacity under construction – due in part to the LCP Directive.

Under RTE's 'baseline scenario', at least 4GW in new capacity will be needed by 2015; 12GW is necessary by 2020, and 16GW is needed by 2025. In the alternative scenarios considered, adding more wind/renewables (25GW), more nuclear (+10GW) or demand side management means more potential to export electricity and overall emissions of 20MtCO2 from the power sector. By contrast, scenarios involving less nuclear (-10GW), less renewables (15 GW wind) or higher demand means less capacity for export and higher CO2 emissions from power generation (30-50MtCO2). The 23% renewables target by 2020 is only met in the 'high RES' scenario, which achieves 27%.

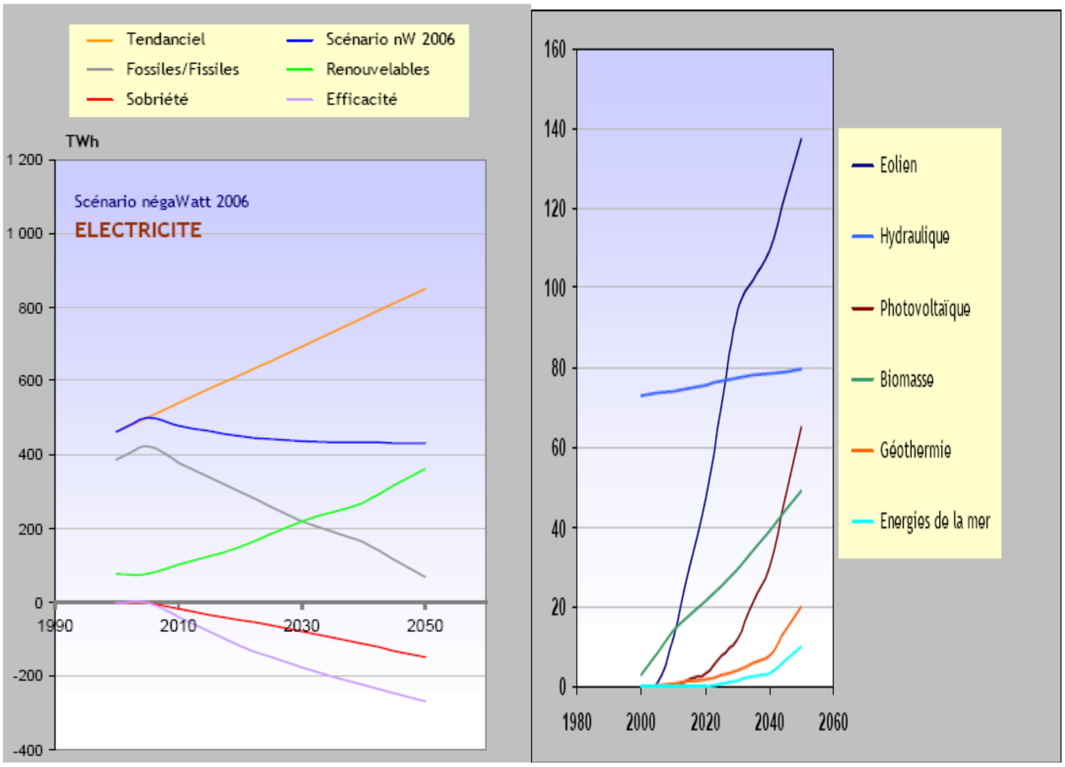
A number of alternative future scenarios have been developed that demonstrate how France's "Factor 4" 2050 carbon reduction target can be met:

> NegaWatt (2006) includes a levelling out of overall electricity consumption through efficiency and demand reduction ("sobriété"), as well as a sharp increase in renewables

> NegaTep (2006), written as a critique of the NegaWatt scenario, includes a 60% increase in overall electricity consumption (while maintaining a 78% nuclear proportion of the electricity mix) as a way of decarbonising the transport and heat sectors

> Institute for Energy and Environmental Research (2006) have developed several scenarios to demonstrate how carbon targets can be met while phasing out nuclear power by 2040.

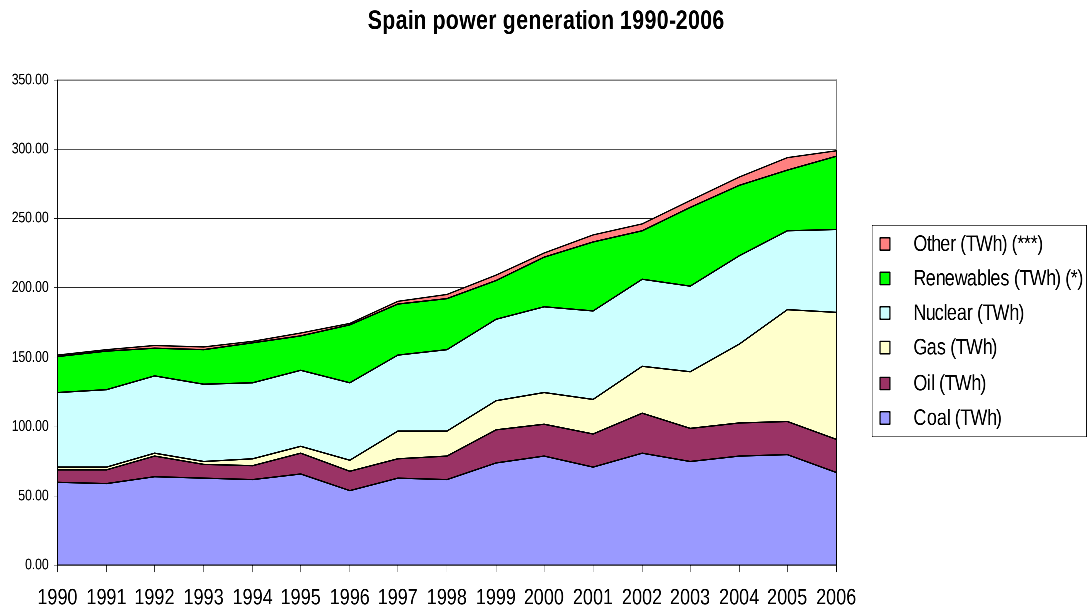
Figure 27: Emissions reductions and renewables capacity in NegaWatt scenario to 2050



None of the alternative scenarios include estimates of investment needed; however all involve substantial change well beyond projections of what will be achieved through present policy.

2.4 Spain

Figure 28: Spain power generation 1990-2006



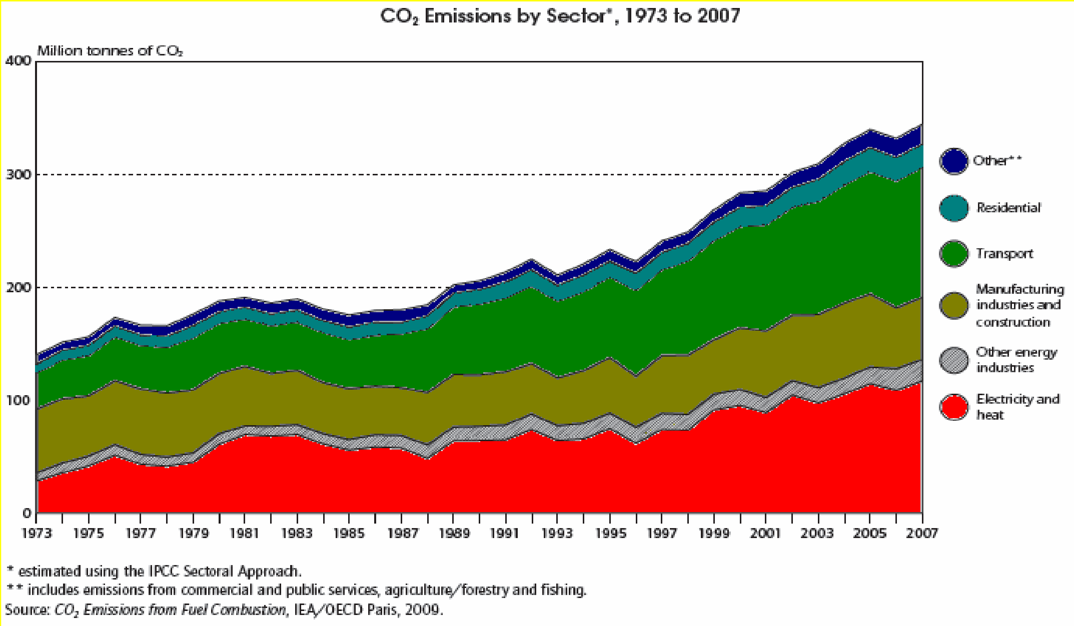
Source: EC DG-TREN 2009a

Power generation in Spain is a diversified mix of coal, oil, gas, nuclear and renewables. Three fifths of electricity supply is from fossil fuels. Strikingly, electricity consumption has doubled since 1990.

This has led to a sharp rise in carbon emissions: in 2007, CO2 emissions were 53% above 1990 levels, compared to a Kyoto target of a 15% rise over the same period[59].

[59] EC DG-TREN 2008a

Figure 29: Spain CO2 emissions by sector



Source: IEA 2007

However more recent indications suggest that power sector emissions have dropped by up to 15% as a result of the recession (combined with expansion of renewables and gas)[60].

2.4.1 Current investment and policy overview

Spain has an EU target to generate 20% of final energy demand from renewable sources by 2020, compared to 8.7% currently[61].

In 2008, investment by power companies in Spain amounted to €6.95 billion, of which €4.34 billion was for electricity production and €2.61 billion was invested in transmission and distribution[62].

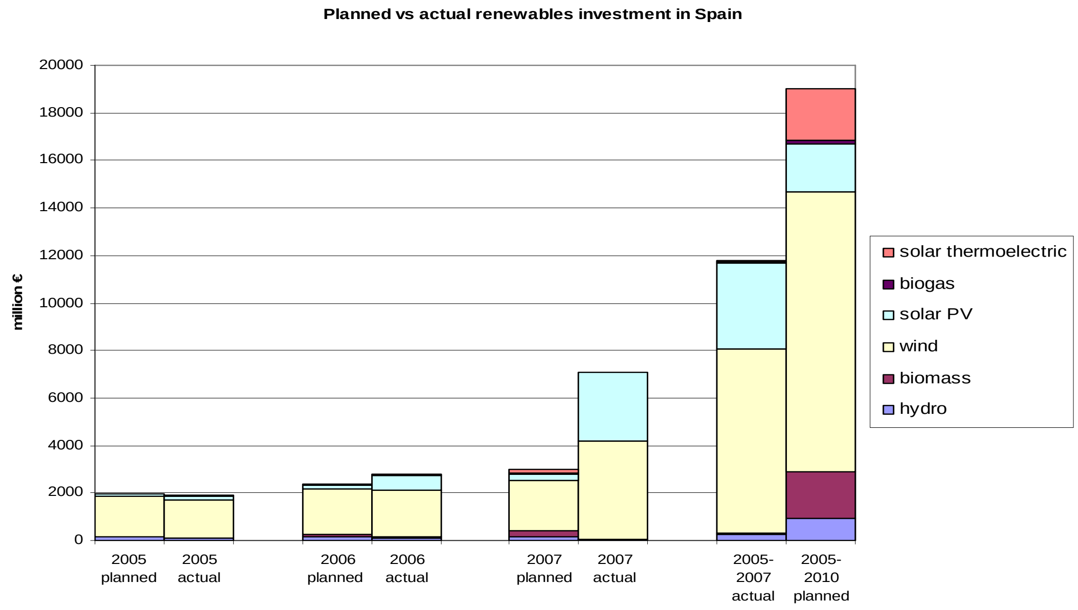
A significant proportion of new investment in the power sector has been catalysed through Spain's feed in tariff. In 2005 a renewable energy plan was introduced and set a national target of 30.3%, with capacity targets for 2010

[60] FEDEA 2009.
[61] Ecofys et al 2008b
[62] MITYC 2008

including wind (20,155 MW), PV (400 MW), solar thermal (4.2 million sq.m), solar thermal electric (500 MW) and biomass (1,695 MW)[63].

However, take-up of the FIT was higher than initially expected. By 2007, 62% of planned investment to 2010 had already been taken place, including 179% of solar PV and 62% of wind capacity. This led to the government reducing rates of the feed-in tariff and caps on the overall level of support.

Figure 30: Renewables installation in Spain exceeds planned investment



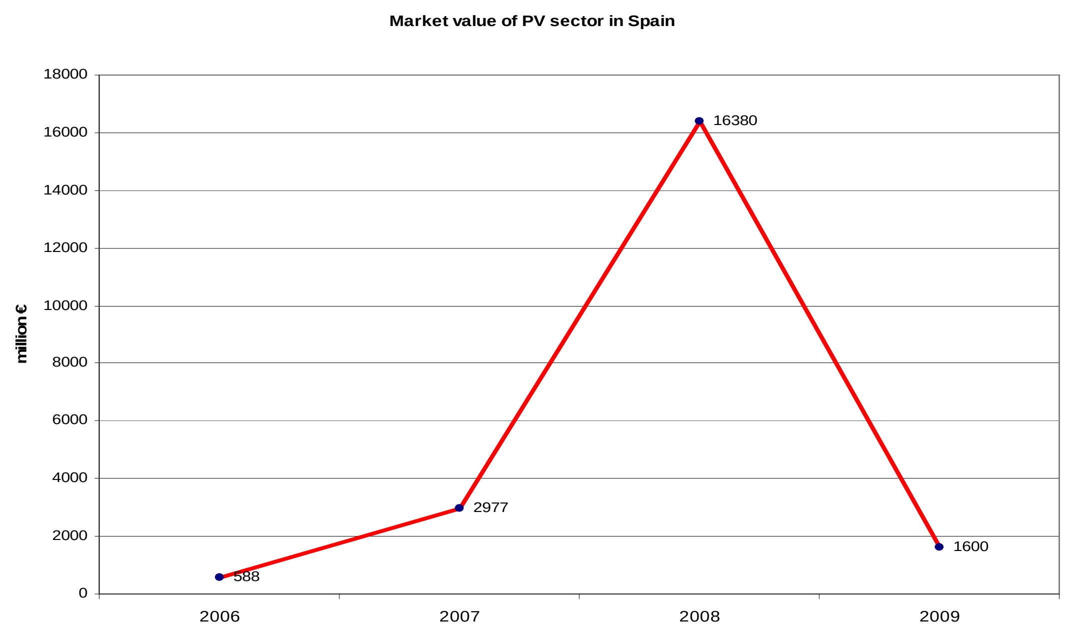
In 2008, 2-3GW of new solar capacity was installed in Spain, as investors sought to take advantage of FIT support before scheme ended – meaning that Spain installed as much PV in 2008 as the global total in 2007[64]. UNEP and New Energy Finance estimate that sustainable energy benefited from USD 17.4 billion of asset finance investment in 2008, 35% of the European total.

It is unclear how much of this investment momentum will be sustained into the future. The Spanish PV industry association has forecast a collapse of the market value of the PV sector in Spain from over €16 billion in 2008 to €1.6

[63] Ecofys et al 2008b
[64] UNEP 2009

billion in 2009 – with up to 20,000 jobs have been lost as a result of the changes[65].

Figure 31: Market value of PV sector in Spain



Source: ASIF 2009

Significant investment has also gone in to the development of the electric grid in recent years, including establishing a single Iberian electricity market with Portugal, building interconnectors with France and investing in balancing and control centres to deal with intermittent generation. In 2007, investment in the grid was €608m, nearly three times the €215m invested in 2003.

Coal-fired generation has been traditionally supported through subsidies to the coal industry. While these have reduced in recent years, the IEA has called for them to be withdrawn more rapidly[66].

[65] ASIF 2009
[66] IEA 2009a

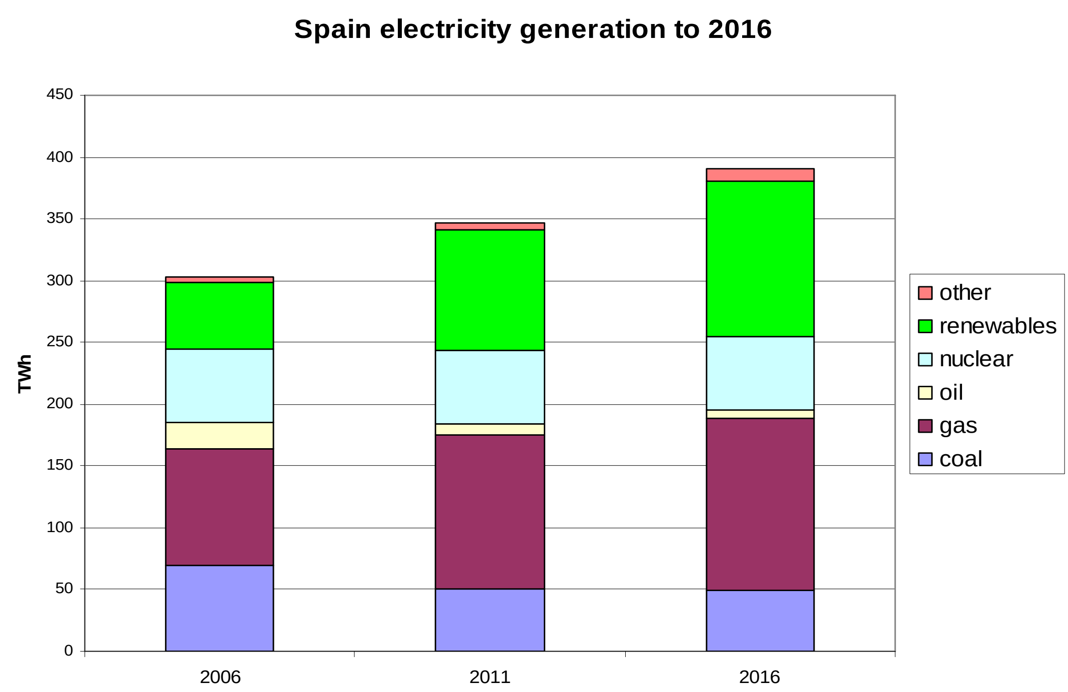
Spain currently operates a capacity payments system to increase energy security, but there are debates about the effectiveness of this system as it applies even when the system is not under stress[67].

A new sustainable mobility strategy was published earlier this year, which includes a target for a target of one million hybrid and electric cars by 2014[68]. A new energy strategy for Spain is expected to be published in January.

2.4.2 Future generation and investment scenarios

The Spanish government has produced a baseline energy scenario until 2016, to assist with planning for distribution capacity. Under this scenario, by 2016 nuclear stays constant, coal generation reduces by 30%, gas increases by 48% and renewables expand by 139%. Overall energy consumption rises by 29%.

Figure 32: Spain electricity generation baseline scenario to 2016

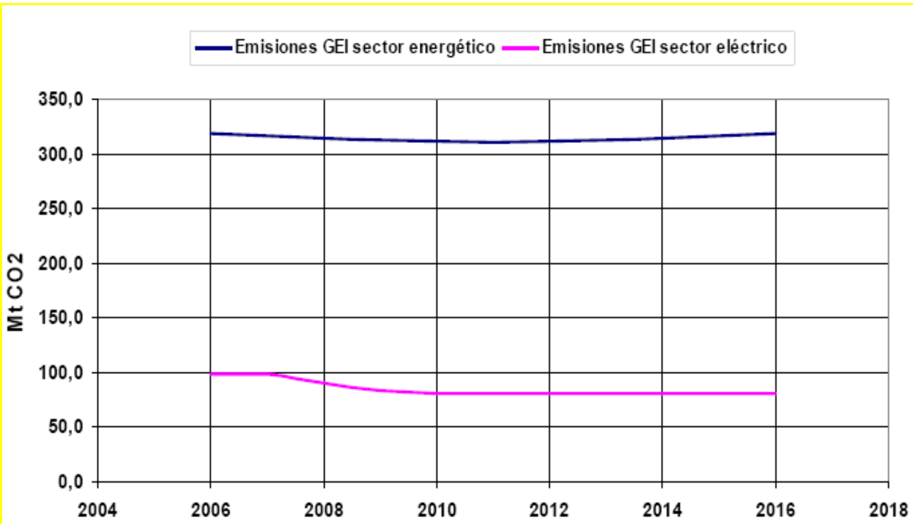


[67] Batlle 2007
[68] IEA 2009a

Source: MITYC (2008)

Despite the forecast expansion in renewables, however, overall carbon emissions show no significant change from 2006 to 2016, and emissions from the power sector are reduced by less than 20%.

Figure 33: Spain carbon emissions to 2016, baseline scenario



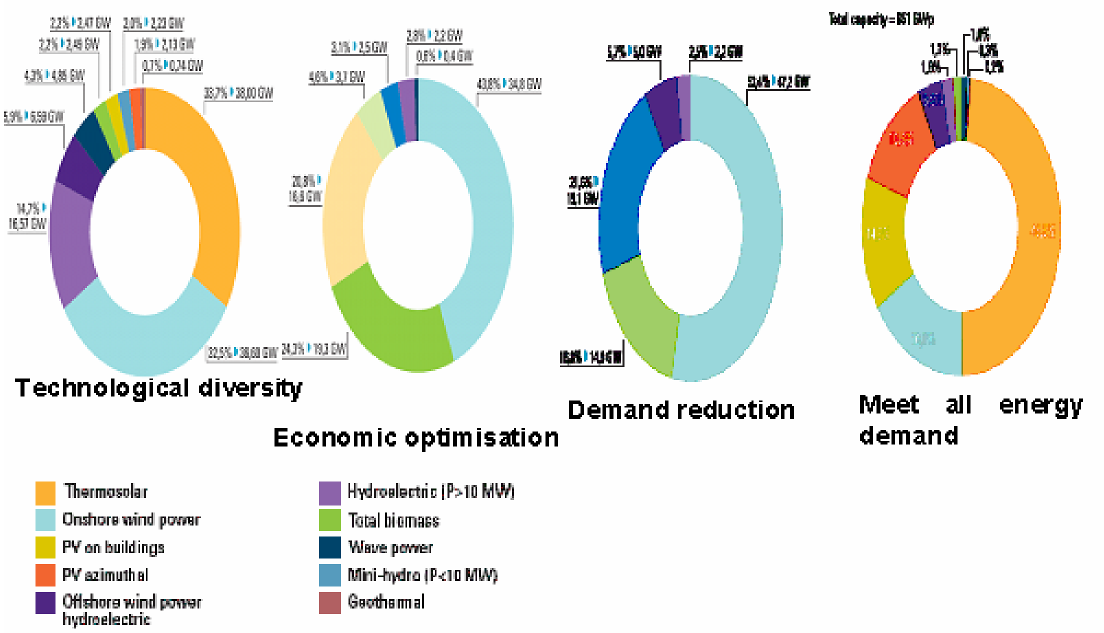
Source: MITYC (2008)

Alternative scenarios for power generation in Spain have focused on Spain's considerable renewables potential. Greenpeace's Renewables 2050 report finds that renewables could meet 56 times total electricity demand (and over 10 times total energy demand) in Spain by 2050[69]. A supplementary report suggests that generation costs of a 100% renewables 2050 scenario will be lower than the cost

[69] Greenpeace 2005

of combined cycle gas turbines or nuclear – but does not quantify total investment needed.

Figure 34: Four options for 100% renewable power generation in Spain



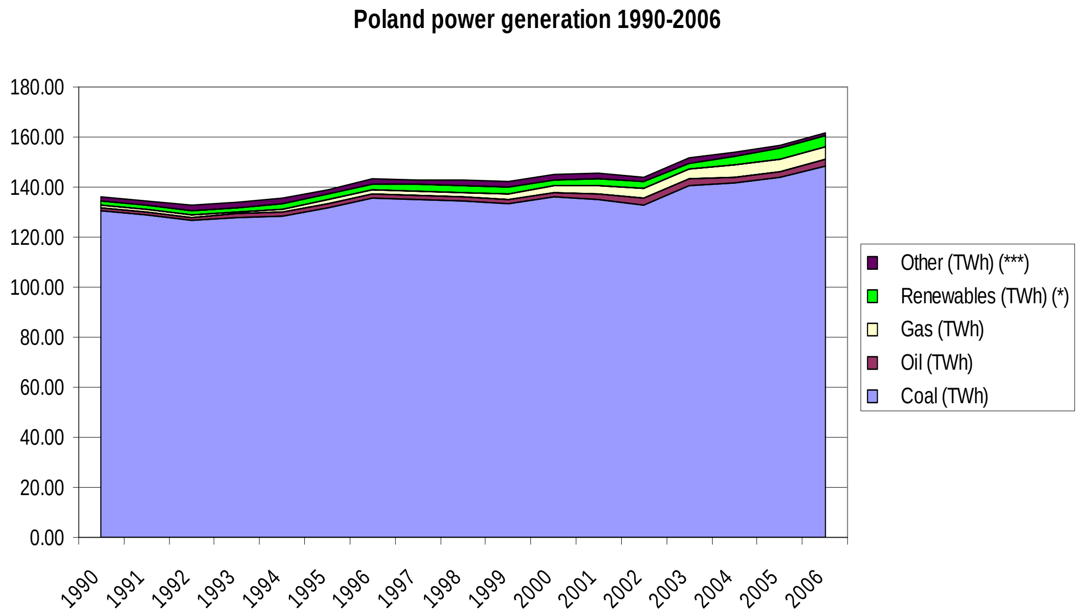
Source: Greenpeace 2005

2.5 Poland

Poland's power generation mix has been dominated almost exclusively by coal, supported by a large domestic coal mining industry. In 2006, 92% of power generation came from coal-fired plant, and only 2.6% was renewables. 56%

(162Mt) of Poland's CO2 emissions come from power generation – much higher than the EU average of 36%[70]. The energy intensity of the Polish economy is also very high: energy consumed per unit of GDP is twice the European average[71].

Figure 35: Power generation in Poland 1990-2006



Source: EC DG-TREN 2009a

2.5.1 Current investment and policy overview

Poland's 'Energy Policy until 2030' sets out several key priorities for the power sector in Poland, including energy efficiency, expansion of capacity, promotion of renewables and nuclear power and upgrading the grid.

Given the high energy intensity of Poland's economy, the Polish government has set itself objectives of achieving "zero-energy economic growth, i.e. economic growth with no extra demand for primary energy" and "reducing the energy

[70] EC DG-TREN 2008a
[71] Ministerstwo Gospodarki 2009a

intensity of Polish economy to the EU-15 level". A 'white certificate' scheme is planned to implement this.[72]

Much of Poland's current power generation infrastructure is aging and will require renewal or replacement. Polish government projections suggest that 570 MW of coal or lignite generation will be withdrawn from 2008 to 2010, with 2898 withdrawn 2011 to 2015 and a further 4125 MW from 2016 to 2020. It is suggested that 1778 MW of new coal or lignite capacity will be built from 2008 to 2010, with a further 992 MW of existing plant modernized. 1980 MW plant are planned from 2011 to 2025 (with 5332 MW modernized), and 2600 new plant built from 2016 to 2020.

Poland has an EU renewable energy target of 15% of total energy by 2020 – compared to 7.2% in 1995. Poland's wind power sector has been expanding rapidly, albeit from a very low base. In 2008, 196 MW of wind capacity was installed, (almost twice the 2007 figure), giving a total capacity of 472 MW. It is estimated that more than 10,000 MW of wind projects are planned or under development[73]. A renewables obligation is being implemented to increase levels of renewable energy.

The Polish government's 'Energy Policy until 2030' does not adopt a numerical CO2 reduction target. Instead, it proposes:

"Reducing CO2 emission to the technically plausible extent without disturbing energy security, in particular balancing energy demand and supply, but not introducing a change to production technology which would hinder security by over-dependency on fuel and energy import".

Poland does not have any nuclear power stations in operation, but new Government policy supports the construction of a new reactor by 2020.

It is anticipated that up to two CCS demonstration plants will be built in Poland. A CCS plant at Belchatow is expected to be supported with €180 million of European Union funding.

Poland's 'Energy Policy until 2030' also highlights the need for expanding and upgrading transmission and distribution in Poland, and interconnectors with neighbouring countries. Current capacity for exchange with neighbouring

[72] Ministerstwo Gospodarki 2009a
[73] Krasnodebski et al 2009

countries is less than 10%; a goal has been set for increasing this to 25% by 2030[74].

'Grey' figures suggest that in 2007 capital expenditure for wind power plants was PLN 2 billion (€480 million) and PLN 3.5 billion (€840 million) for other power sector projects. This is expected to rise to PLN 2.8 billion and PLN 4.5 billion respectively by 2010.[75]

However doubts have been raised about the financial viability of new investment in the coal sector. Under a special exemption in the EU climate package, Poland is able to allocate EUETS allowances for free to the power sector until 2012. However from 2013 power companies will have to purchase a proportion of their allowances at auction, leading to full auctioning by 2020. This will significantly increase cost and uncertainty for coal and lignite-fuelled plants.

A complicating factor is liberalisation. In 2008, all four of the major Polish energy companies were state majority-owned. Sale of all four companies is expected by 2010. This transfers the risk of volatile future coal and carbon prices from the state to the private sector.

2.5.2 Future generation and investment scenarios

Estimates of the investment needed to deliver new and replacement capacity, meet renewables targets and develop interconnections and CCS suggest that current levels of investment will need to expand by a factor of 3 or more. It has been estimated that by 2020 a total of €32.4 billion will be needed for new capacity, €9.6 billion to meet renewables targets, €1.3 billion for the interconnector to Lithuania and €0.65 billion for a Carbon Capture and Storage trial[76]. This compares to an annual investment of €1.3 billion in 2007.

[74] Ministerstwo Gospodarki 2009a Goals of ability for exchanging at least 15% of electricity used in Poland by 2015, 20% by 2020 and 25% by 2030;
[75] PMU 2009
[76] Krasnodebski et al 2009

Figure 36: Power sector investment in Poland: 2007 and future needs

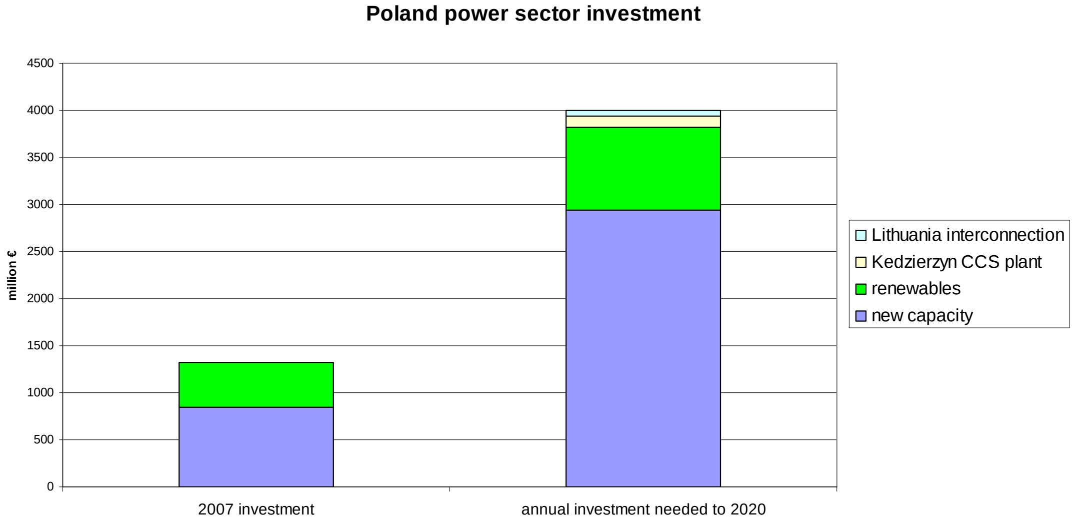
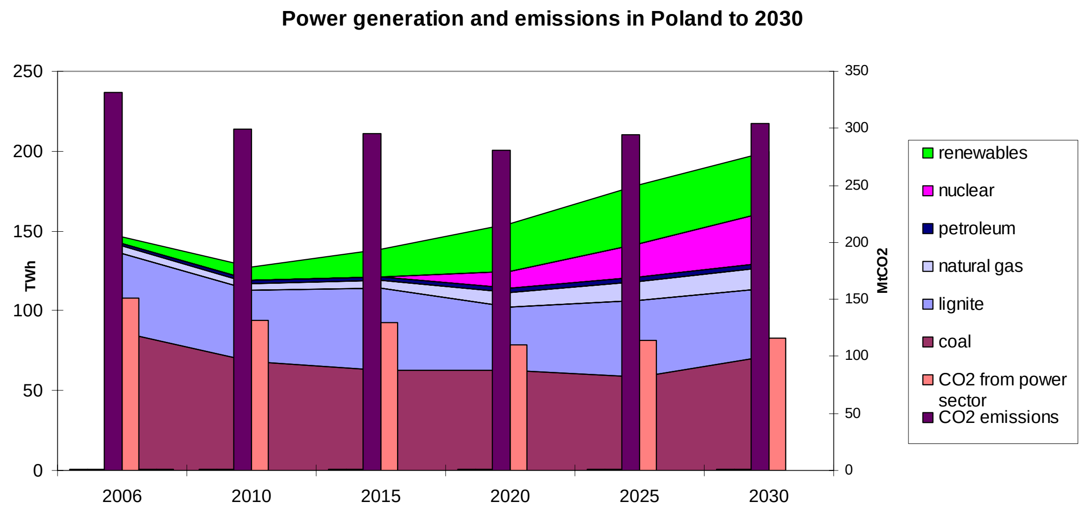


Figure 37: Power generation and emissions in Poland to 2030, baseline scenario



Under Poland's 'Energy Policy to 2030', coal and lignite remain the main sources of power generation over the next 20 years, supplemented by rising renewable and nuclear capacity. After a slight fall in energy demand to 2010, energy consumption continues to rise.

However, this baseline fails to achieve significant reductions in carbon emissions or a decarbonisation of the power sector. It would achieve a 16% reduction in CO2 overall by 2020 over 2006 levels – dropping to an 8% reduction by 2030. Emissions from the power sector fall by 27% over 2006 levels by 2020, and 23% by 2030. While this meets Poland's EU carbon reduction targets for 2020, it fails to create a long-term path towards decarbonisation.

3. Conclusions

From the EU summary and country case studies presented in this paper, it is clear that a considerable amount of investment will be needed in the European power sector between now and 2030 to replace decommissioned plant and meet demand, and expenditure will almost certainly need to rise above current levels. Estimates suggest that €200-300 billion will be spent over the next 10 years in business as usual scenarios or €260 to €600 billion in low carbon scenarios, compared to a current annual average investment of €20 billion.

There is some evidence of a movement in investment momentum towards low carbon power generation: investment in sustainable energy has increased tenfold over five years, and renewables represented more than half of new installed capacity in 2008. However this positive message comes with a number of important caveats:

> 'Business as usual' scenarios based on currently policy frameworks and investment behaviour suggest carbon targets will be missed by some distance without changes in policy

> There is significant unabated fossil generation still in the development pipeline, which could 'lock in' high emissions and jeopardise future carbon reduction targets

> The current and historic carbon price in the EUETS is too variable and too low to support low carbon scenarios.

> Further uncertainty is introduced by the global economic downturn. While a fall in power demand will make decarbonisation of the power sector easier to achieve, falling carbon and fossil fuel prices also undermine the investment case for low carbon generation.

Despite very different starting points and different investment frameworks, there is evidence "business as usual" approaches in each of the country case studies will not produce carbon reductions on the scale required. Base case projections for each of the five countries all miss CO_2 reduction targets for 2020, in some cases by a considerable distance.

Estimates from the UK and Poland suggest continued investment at current levels would not even be sufficient to meet forecast demand. Experience from Spain (and to a lesser extent Germany) shows volatility in government support for low carbon energy leads to uncertainty over whether current investment momentum will be sustained.

Overall, the evidence suggests that policy interventions to influence power sector investment frameworks – whether at EU or member state level – will be necessary for a low carbon EU power sector to be delivered.

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