Developing the Future

EPPSA STUDY

THERMAL POWER IN 2030

ADDED VALUE FOR EU ENERGY POLICY

European Power Plant Suppliers Association

Contents

Authors: Patrick Clerens, Mike Farley, Luka Jazbec, Nicolas Kraus and Klaus-Dieter Tigges
Editor: Tom De Latte
Special acknowledgment to the EPPSA members who helped make this publication possible.

Introduction

Thermal Power is the generation of electricity by the combustion of fossil fuels (including gas, coal and lignite) and/or biomass using combinations of boilers, gas and steam turbines and turbo-generators. Thermal power has traditionally been central - alongside nuclear power in some countries - in the production of electricity in Europe. Nowadays, with the increasing use of renewable energy, the role of Thermal Power is changing but nevertheless remains vitally important. This report demonstrates the continuing central importance of Thermal Power in the European Union (EU) but also highlights the growing challenges due to the declining economic viability of thermal power plants. The criticism on Thermal Power with regard to carbon lock-in is refuted. The dichotomy between the importance of Thermal Power and the consequences of present-day policies are pointed out.

Executive Summary

This EPPSA report explores the future role of Thermal Power in Europe going forward. It demonstrates its continuing and central importance but also highlights the growing challenges and risks due to declining economic viability.

The review begins (Section 1) with a review of the past, present and future of EU Energy Policy in an attempt to_define its current trajectory and the future place of Thermal Power. EU Energy Policies, especially the short-term targets for 2020 (i.e. 20-20-20) and the long-term aims for 2050 (80-95% Greenhouse Gas (GHG) emission reductions) have set the market on course for a low-carbon electricity system. This trajectory has been reinforced by the 2014 Policy Framework for Energy and Climate Change package with its binding national targets for 2030 of a 43% cut in Carbon Dioxide (CO_2) emissions for the sectors covered by the Emission Trading System (ETS). The importance of Thermal Power and fossil fuel diversity have not been fully recognised, however.

The role of Thermal Power is changing as a result of the increasing deployment of intermittent Renewable Energy Sources (RES). Thermal power plants are moving from mostly "baseload" to a more flexible operation. EPPSA has compared the flexibility requirements of a modern electricity system with the technical capabilities of current and future thermal power plants (Section 2). Operation of the power system in the 'classical' sense, where demand was the main source of variation, is described in a simplified manner (2.2.1), and the role of Thermal Power in such a system is examined (2.2.2). The changes occurring to this operation as a result of an increasing deployment of intermittent RES (i-RES) are defined (2.3.1) and the associated new requirements that this places on thermal power plants are studied (2.3.2). It is recognised that the necessary overall load gradients can be met by small numbers of plants with relatively fast (3%/min) ramping rates or a larger number of plants with slower ramping rates. The flexibility characteristics of thermal power plants are reviewed (2.4.1). The results of new EPPSA surveys (2.4.2) that set out member's views on Best Available Technology (BAT) are given and exemplars of the many flexible plants already in operation are presented. (2.4.3). It is clear from the experience around Europe that existing thermal power plants (coal, lignite, gas and biomass) are capable of balancing the variability of demand and of intermittent generation whilst meeting environmental limits over their full load range. However, many existing thermal power plants are less than optimum:

- They are less efficient than BAT at full load, and they are frequently being operated at reduced efficiency at part-load. This reduction of efficiency at part-load pushes the cost of electricity up through the sub-optimum use of fuel and has an impact on CO_2 emissions

- The cycling of plants reduces the plant life, with the lifetime determined by the number of cycles rather than by the total operating hours, which will be reduced

- Thermal power plants will be running for fewer hours and these at part-load. For example, plants optimised for full load operation at 4,000 to 8,000 hours per year (e.g. 'classical' baseload plants) will be expected to operate between 1,500 to 3,000 hours per year at part-load[1].

[1] VDE (2012), "Erneuerbare Energie braucht flexible Kraftwerke – Szenarien bis 2020", pp. 57

The increasing deployment of intermittent generation has important consequences for the economics of the whole power system and for future investments.

Modern plants that were built for base-load and are now only operating at part-load are less economical than anticipated in their investment case. The case for essential investments in new plants must be made against uncertainties in anticipated running hours, wholesale electricity prices and fuel prices.

EPPSA has analysed a number of studies on the EU energy system in 2030 to examine what role can be foreseen for thermal power plants. A total of 24 scenarios from 7 studies were taken up and compared (sections 2.5.1 to 2.5.4) with regard to electricity generation (MWh) and installed capacity (GW). In addition, they were specifically examined and compared with regard to the additional capacity of thermal power needed by 2030 to account for the decommissioning of existing plants (2.5.5). The key results from the reviewed scenarios are:

- In most decarbonisation scenarios, the absolute thermal power capacity in 2030 ranges from 423 to 485 GW, which is not significantly different from the 479 GW in the 2010 Reference case.

- In the 2010-2030 period, significant investment in dispatchable capacity generally and thermal power capacity in particular is required to maintain generation adequacy; between 166 and 234.3 GW of thermal power capacity additions are required. This means that between 39.4 and 48.3% of installed thermal power capacity in 2030 will need to be built in the years 2010-2030.

It is concluded (Section 3) that Thermal Power will continue to provide a significant added value to the EU through to 2030 and beyond, contributing to affordability, security of supply, sustainability and technological leadership:

- **Affordability.** Flexible and baseload thermal power plants will contribute enormously to the affordability of electricity in 2030. Thermal power (lignite, hard coal, and gas) is significantly less expensive than renewable power in terms of €/MWh, as indicated by the large support subsidies which are necessary to promote the use of renewables. Furthermore, if renewable sources are expected - in 2030 or thereafter – to deliver the electricity currently provided by thermal power, we would need very much more geographically diverse sources outside Europe and thus very long transmission lines.

- **Security of Supply.** Thermal power plants provide essential, secure, dispatchable power, available as required to meet demand. They are not subject to the regular daily intermittency of solar (day/night) or the weather dependent intermittency of solar and wind. Unlike the energy produced by the latter, thermal energy can be stored in the form of the fuel – e.g. a coal heap. There are ample reserves of fossil fuels, including coal and lignite which are indigenous to Europe, and these reserves have increased as a result of the discovery and potential use of shale gas. Security of supply can be assured by using geographically diverse sources of lignite, coal and gas.

- **Sustainability.** The energy efficiency of modern thermal power plants is 33% higher than older plants[2]. However, given the reserves of fossil fuels, the main sustainability issue for fossil thermal power plants is CO_2 emissions. A potential solution to CO_2 emissions is Carbon Capture and Storage (CCS) which will be essential by 2030 in order to reduce emissions from all industrial processes requiring fossil fuels. Europe is fortunate to have huge potential stores for CO_2 within reach, including storage deep beneath the Central North Sea basin, in depleted gas fields and oil fields and in saline formations, sufficient for as much as 100 million tonnes of CO_2 per year by 2030 and 500 million tonnes per year by 2050 – equivalent to 25% of the total EU emissions (at 2007 levels).

- **Technological Leadership.** Europe is a leader in most aspects of Thermal Power technology, including gas turbines (GTs), heat recovery steam generators (HRSG), coal and lignite fired boilers and steam turbines, CO_2 capture, transport and storage systems, and control systems/ancillaries. Many leading global players in Thermal Power have their technology hubs in Europe. New plants and retrofits are being designed and built, many by EPPSA members, for improved efficiency, flexibility (minimum load, reduced start-up times and faster ramp rates) and to cope with thermal cycling. Coal, lignite, biomass and gas power plants can be optimised for flexibility and there is scope for further improvements. Universities and institutes around Europe are very experienced in the area of thermal power plants and CCS, notably in Germany, UK, France, Spain, Norway, Greece, Denmark, Italy and Poland. Technological leadership can lead to business opportunities, both inside the EU and in the rest of the world. Such business, both ongoing and new, perfectly complements the ongoing efforts of the EU and the national governments to bring a

[2] EPPSA case study

halt to de-industrialisation, it creates employment in the form of high level, well-paid jobs and generates tax revenues. Next to technological leadership, however, a stable and predictable home market is a pre-requisite for sustainable business, which, as described above, is missing at the moment.

- **Policy.** EU and MS policy makers must address the dichotomy between, on the one hand, the continuing importance of Thermal Power in 2030 and beyond and, on the other, the lack of economic viability under current policies. Policy makers should accordingly assess the impact of new policies on electricity markets, affordability, investment, business opportunities and RD&D (Research, Development and Demonstration), including flexible power plants and CCS. Adequate funding, a stable regulatory framework and public acceptance need to be combined with enhanced Research and Innovation efforts in order to maintain Europe's leading technological competence in the current and future knowledge-based economy. European centres of Research and Development (R&D) excellence will contribute to creating skills and jobs and exporting efficient, cutting-edge European technology, including to the countries in the Asia-Pacific Region which are estimated to need 275 GW of new coal powered plants in the next five years alone. If the BAT was provided for these future plants, there would be a clear environmental benefit and an attractive market for European companies.

1. EU Energy Policy: Past, Present and Future

1.1. Introduction

Affordable and secure energy provides the basis for the functioning of modern society.

Within the EU, however, energy competences for energy policies are shared between EU-level action and the exclusive rights of Member States (MS) to select their own national energy mix, endangering both the security and affordability of our energy.

Since 2006, attempts have been made to establish a common EU energy policy; these culminated in 2009 in the adoption of a number of directives and the '20-20-20 by 2020' targets and recently, in 2014, with the agreement of a policy framework for climate and energy in the period from 2020 to 2030.

In the following chapter, a brief overview of legislative developments affecting energy is given (1.2.1). Following this, there is an overview of the objectives of EU energy policy since its formulation in 2006 and the significant legislative activity in 2009 which, to a large extent, defines the current trajectory of energy policy and the EU energy system towards 2020 (1.2.2).

Despite the above attempts at formulating a common EU energy policy and short-term as well as long-term goals, however, the present situation is one marked with uncertainty as discussed in sections 1.2-1.4.

1.2. Progress towards a Common EU Energy Policy

1.2.1. European Integration and Energy Legislation: 1951 to 2006

EU energy policy has been important since the beginning of the European integration (i.e. the founding of the European Coal and Steel Community and Euratom):

- 1970s: security of supply (e.g. 'Council Resolution of 17 September 1974 concerning a new energy policy strategy for the Community' and 'Council Resolution of 17 December 1974 concerning energy policy objectives for 1985', dealing with reduction of import dependence)

- 1980s: environment (e.g. 'Directive 88/609/EEC on the limitation of emissions of certain pollutants into the air from large combustion plants')

- 1990s: energy market liberalisation via the first 'Energy Package', consisting of Directive 96/92/EC (Electricity) and Directive 98/30/EC (Gas), introducing unbundling

- 2000s: further liberalisation via the second 'Energy Package', consisting of Directive 2003/54/EC (Electricity) and Directive 2003/55/EC (Gas), establishing of MS-level regulatory authorities; strengthening of environmental legislation, via Directive 2001/80/EC (LCP Directive); increasing concern over climate change leading to the establishment of the EU ETS via Directive 2003/87/EC

1.2.2. Towards a Common EU Energy Policy: 2006-2009

A common EU energy policy and the aims thereof were first explicitly formulated in the Commission's 2006 Green Paper on "A European Strategy for Sustainable, Competitive and Secure Energy" (COM(2006) 105 final). The stated objectives were sustainability, competitiveness, and security of supply.

This Green Paper was followed by the Climate & Energy Package (presented in COM(2007) 1 final, "An Energy Policy for Europe") which re-affirmed the three objectives and outlined an action plan on achieving them. More specifically, the Climate & Energy Package defined three explicit targets to be achieved by 2020, these being the so-called '20-20-20 by 2020' targets:

- A 20% reduction in GHG emissions EU-wide, relative to 1990 levels (binding)

- A 20% share of RES in EU energy consumption (binding)

- A 20% reduction in EU energy consumption (non-binding)

To ensure reaching these targets, the 2009 Climate & Energy legislative package was adopted, consisting of:

- Directive 2009/28/EC, the so-called 'RES Directive', which sets out MS-specific targets, differentiated by national capabilities and potentials, in order to reach the overall RES share; to this end, they are to submit National Renewable Energy Action Plans (NREAPs) on how they aim to achieve their respective shares; the Directive also provides for the possibility of using support measures to promote RES deployment, and prescribes priority feed-in for RES

- Directive 2009/29/EC, amending the EU ETS

- Directive 2009/31/EC, on the geological storage of CO_2 (CCS)

Additionally, in 2009, the Third Energy Package was adopted, which consisted of Directive 2009/72/EC (Electricity) and Directive 2009/73/EC (Gas), which was mainly focussed on unbundling and which accompanied regulations establishing ACER, ENTSO-E and ENTSO-G. The tasks of ENTSO-E and ACER are crucial with regard to electricity, as they are aimed at integrating EU markets into one internal energy market, via market coupling, network code development, and transmission and cross-border exchange infrastructure development via the Ten Year Network Development Plan (TYNDP).

Other important developments in 2009 included the Council's aim to reduce GHG emissions by 80-95% in 2050, relative to 1990 levels, as well as the entry into force of the Lisbon Treaty. The Lisbon Treaty clarifies the position of energy as a shared competence between the EU and the MS (TFEU, Part I, art. 4 (i)). Furthermore, it introduces specific energy provisions under Title XXI – Energy, where it specifies four main aims for EU policy in energy (TFEU, art. 194 (1)):

1. ensuring the functioning of the energy market

2. ensuring security of energy supply

3. promoting energy efficiency, energy saving, and the development of new and renewable forms of energy

4. promoting the interconnection of energy networks

With regard to environmental legislation, 2010 saw the adoption of the Industrial Emissions Directive (IED) (Directive 2010/75/EU) which regulates emissions from industrial activities via more stringent Emission Limit Values (ELVs), entering into force in 2014 (2016 for large combustion plants). The IED combines several previous sectorial directives, and makes permitting subject to application of BATs based on so-called BAT Reference Documents (BREFs).

Finally, in 2012, legislation to support reaching the current energy efficiency target was adopted through the Energy Efficiency Directive (Directive 2012/72/EU).

1.3. The Present State of EU Energy Policy and the EU Energy System

As a result of the binding targets for 2020 and the MS' policies to work towards these targets, there have been significant changes in the electricity generation, some of which are turning out to be in conflict with the high level objectives:

- Integration: ACER and ENTSO-E are developing Network Codes to ensure a minimum level of harmonisation among MS and regional electricity networks, helping the process of integration towards the 2014 deadline for completion of the Internal Energy Market;

- Fragmentation: The design of RES support schemes differs across MS, and due to concern over generation adequacy, several MS are considering or have already implemented capacity mechanisms, again different across MS[3];

- Overall Change: The electricity generation mix in the EU-27 has in recent years seen a steady increase in renewable energy and decrease in fossil-fuel fired generation, as can be seen in Table 1 below:

EU-27 Generation Mix[4] (%)	2010	2011	2012
Fossil-fuel fired	50.40	51.22	48.38
RES	19.58	21.19	22.38
Nuclear	27.20	28.20	27.01
Pumped hydro and other	3.31	1.38	3.27

Table 1 - EU-27 Generation Mix, 2010-2012

- Diversity: There is considerable diversity in the generation mixes of MS, as can be seen in Table 2 below.

[3] For a detailed overview, see DG ENER (2013b), "Capacity Mechanisms in Individual Markets within the IEM"

[4] Eurelectric (2013), "Power Statistics and Trends 2013"; p. 12

MS[5] (2010)	Total Generation (TWh)	Generation Mix (%) (bold indicates biggest share)			
		Fossil Fuels	RES	Nuclear	Other
Austria	71.13	31.6	**67.9**	0	2.4
Belgium	95.12	39.7	8.3	**50.4**	1.6
Bulgaria	46.65	**53.5**	13.8	32.7	0
Cyprus	5.35	**98.2**	0.7	0	1.1
Czech Republic	85.91	**59.8**	7.6	32.7	0
Germany	627.92	**58**	17.8	22.7	1
Denmark	38.76	**57.4**	40.4	0	2
Estonia	12.96	**91.6**	8.1	0	0.3
Greece	57.39	**81.4**	18.4	0	0.2
Spain	303.03	**46.6**	33.2	20.5	0.3
Finland	80.67	**41.1**	30	28.3	0.7
France	569	8.8	14.7	**76.1**	0
Hungary	37.37	**49.3**	8.1	42.2	0.4
Ireland	28.61	**86.3**	13.7	0	0
Italy	302.06	**72.5**	26.6	0	1
Lithuania	5.75	**66.7**	29	0	4.3
Luxembourg	4.59	0	35.4	0	**64.6**
Latvia	6.63	45.1	**54.9**	0	0
Malta	2.11	**100**	0	0	0
Netherlands	118.14	**85.7**	9.5	3.4	1.5
Poland	157.66	**92.5**	7.3	0	0.2
Portugal	54.09	46.2	**53.2**	0	0.6
Romania	60.62	**47.3**	33.5	19.2	0
Slovenia	16.43	**35.5**	30	34.5	0
Slovakia	27.84	22.6	22.7	**52.4**	2
Sweden	148.61	0	**58.2**	40.9	0.9
UK	381.13	**75.8**	7.6	16.3	0.4

Table 2 - Generation Mix by MS, 2010

[5] Eurostat, 2013

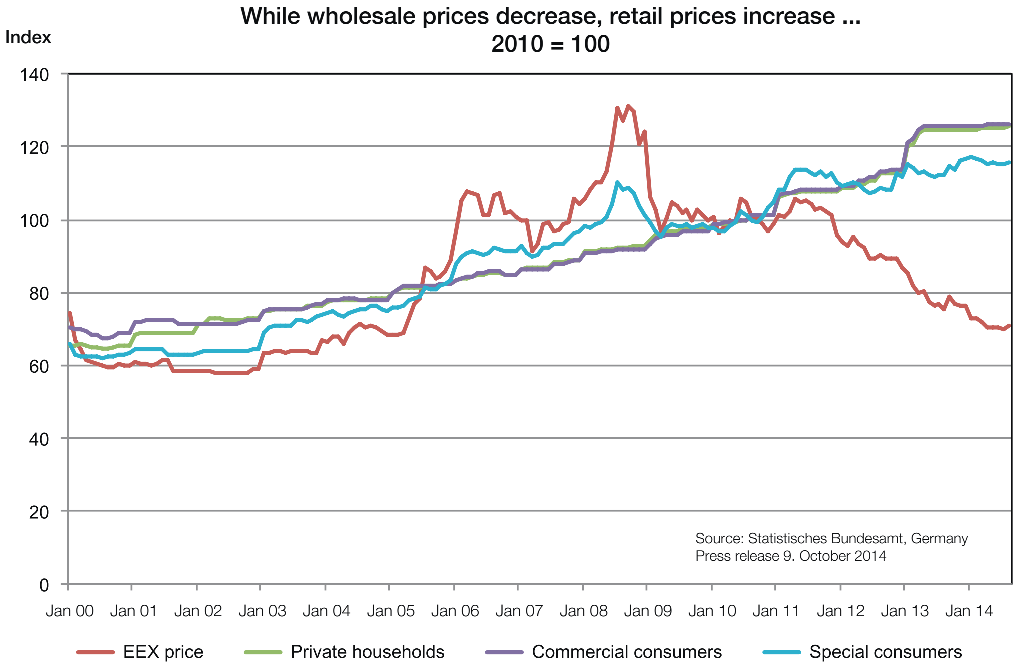


Figure 1 - Changing Electricity Prices, 2000-2014

- Decreasing Wholesale Prices: Increasing integration of variable renewable energy – with zero variable costs – shifts the merit order and exerts downward pressure on wholesale prices (EEX, red line) (see Figure 1 above), undermining the case for investment at a time when much of the EU's generation fleet needs replacing[6];

- Increasing Retail Prices: Renewables support schemes are generally funded through surcharges on the retail price, which means that the end-use electricity prices are increasing (see Figure 1 above), undermining competitiveness and putting a financial burden on domestic and industrial consumers[7].

It is clear that while the aim of the Climate & Energy Package was to support the achievement of EU energy policy objectives, the combination of multiple targets (GHG, RES and Energy Efficiency (EE)) at multiple levels (both EU and MS) with multiple implementing tools (ETS, support schemes) has led to a situation where the three objectives are paradoxically being undermined.[8]

In particular, the effect of renewables support schemes, while successful in increasing the deployment of RES, has had several negative effects on energy markets and energy prices. RES are financially compensated through support schemes, such as feed-in tariffs, and enjoy priority feed-in, i.e. if and when they produce, their electricity must be sold on the market. As their variable costs are practically inexistent and their fixed costs are remunerated through support schemes (outside wholesale markets), RES exert downward pressure on wholesale prices and thereby change the merit order, displacing other generation technologies with a higher variable cost. In some cases, notably in Germany and the UK, this has led to new high capital value plants (e.g. highly efficient Combined Cycle Gas Turbine (CCGT)), being mothballed, such that increasing renewables often result in a production mix of (often) fluctuating RES with zero emissions and older, inefficient plants with higher emissions. At the same time, while wholesale prices decrease, retail prices for both households and industry increase.

Overall, the situation is as summarised by Eurelectric[9]:

- Affordability is undermined as energy bills have, in the past 4 years, risen by 17% for domestic and 24% for industrial consumers
- Security of supply is undermined by the mothballing of 51 GW of capacity
- Sustainability is undermined as CO_2 emissions have increased by 2.4% in 2011-2012

[6] Kakaras et al. (2013), "Solutions from the European Power Plant Suppliers' Perspective"; pp. 7-9

[7] EPPSA (2013), "Energy Supply for Europe – Facts and Perspectives", p. 9

[8] Kakaras et al. (2013), "Solutions from the European Power Plant Suppliers' Perspective"; pp. 7-9

[9] Eurelectric (2013), "10 CEOs Push for EU Energy Policy to Change Direction"

1.4. Future Paths for Energy Policy: Scenarios for 2030 and 2050

1.4.1. Need for a medium term framework

Following the European Council's 2009 commitment to an EU-wide 80-95% reduction in GHG emissions by 2050 relative to 1990 levels, a number of studies by various stakeholders were published, with the aim of exploring if and how such a target might be achieved. To this end, the European Commission published its own "Energy Roadmap 2050" in 2011, exploring a total of five decarbonisation scenarios with different technology assumptions. Each scenario involves an increasing deployment of RES and a substantial transformation of the energy system (see 2.4).

However, while short-term targets for 2020 (i.e. 20-20-20) and long-term aims for 2050 (80-95% GHG emission reductions) had been defined, the medium term was still unclear. Thus, in March 2013, the European Commission published a Green Paper on "A 2030 Framework for Climate and Energy Policies", opening the debate on possible targets for 2030. A key point was that a clear and stable framework for the 2020-2030 period must be developed as soon as possible, as it is crucial for providing a basis for much-needed investment stability.

1.4.2. Policy framework for climate and energy in the period from 2020 to 2030

On the 22nd January 2014, the European Commission published its Communication entitled 'A policy framework for climate and energy in the period from 2020 to 2030'[10] .The Framework, accepted by the European Council at its meetings on the 23rd and 24th October 2014[11] has the following main conclusions:

- Reducing GHG emissions by 40%.

  A centre piece of the framework is the target to reduce EU domestic GHG emissions. The European Council endorsed a binding EU target of a domestic reduction in GHG emissions at least 40% by 2030 compared to 1990. This target will be achieved collectively by the EU in the most cost-effective manner possible, with the reductions in the ETS and non-ETS sectors amounting to 43% and 30% by 2030 compared to 2005, respectively; all MS will participate in this effort, balancing considerations of fairness and solidarity.

  This target should ensure that the EU is on the cost-effective track towards meeting its objective of cutting emissions by at least 80% by 2050. By setting its level of climate ambition for 2030, the EU will also be able to engage actively in the negotiations on a new international climate agreement that should take effect in 2020.

- Increasing the share of renewable energy to at least 27%.

  An EU target of at least 27% is set for the share of renewable energy consumed in the EU in 2030. This target will be binding at EU level. It will be fulfilled through MS contributions and guided by the need to collectively deliver the EU target without preventing MS from setting their own more ambitious national targets and supporting them in line with the state aid guidelines, as well as taking into account their degree of integration in the internal energy market. The integration of rising levels of i-RES requires a more interconnected internal energy market and appropriate back up, which should be coordinated as necessary at the regional level.

  This gives MS the flexibility to transform their energy systems in ways that are adapted to their national preferences and circumstances.

- Energy efficiency to be improved by at least 27%.

  Improved energy efficiency makes an essential contribution to all EU climate and energy policies. Progress towards the 2020 target of improving energy efficiency by 20% is being delivered by policy measures at the EU and national levels. At the EU level, an indicative target of at least 27% for improving energy efficiency in 2030 compared to projections of future energy consumption based on the current criteria has been set. It will be delivered in a cost-effective manner and it will fully respect the effectiveness of the ETS-system in contributing to the overall climate goals. This will be reviewed by 2020, keeping an EU level of 30% in mind. The Commission will propose priority sectors in which significant energy-efficiency gains can be reaped, and ways to address them at EU level, with the EU and the MS focusing their regulatory and financial efforts on these sectors.

[10] European Commission (2014) COM15 final Brussels, 22.1.2014 Communication 'A policy framework for climate and energy in the period from 2020 to 2030'

[11] European Council (23 and 24 October 2014) Conclusions http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf

- Reform of the EU emissions trading system.

  The annual factor to reduce the cap on the maximum permitted emissions will be changed from 1.74% to 2.2% from 2021 onwards. The existing NER300 facility will be renewed, including for CCS and renewables, with the scope extended to low carbon innovation in industrial sectors and with the initial endowment increased to 400 million allowances (NER400).

1.4.3. Policies for energy security

The G7 Energy Ministers (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States) and the EU Commissioner for Energy met in Rome on the 5th and 6th of May 2014 to discuss ways to strengthen the collective energy security.[12]

The conclusions are highly relevant to Thermal Power:

> "In the long term, it is vital to ensure diversification of the energy mix. Recognizing that fossil fuels still remain an important element of our energy mix, we believe that reducing emissions from fossil fuels is necessary to tackle climate change and can enhance our energy security. We intend to promote the use of low carbon technologies (renewable energies, nuclear in the countries which opt to use it, and CCS) including those which work as a base load energy source."

It is therefore disappointing that the EU Council conclusions (Section 1.4.2 above) do not recognise the importance of state-of-the-art Thermal Power as an active contributor to the 2030/2050 objectives.

[12] http://europa.eu/rapid/press-release_IP-14-530_en.htm

2. The EU Energy System and the changing role of Thermal Power

2.1. Introduction

In 2012, after having provided the majority of the EU's electricity supply for decades, thermal power, for the first time in EU history, generated less than half (if only slightly)[13] of it. At the same time, the share of RES, and in particular i-RES such as wind and solar photovoltaics (PV), has been rapidly increasing. This has substantial effects on the way power systems are operated. We examine in this section the effects that the increasing deployment of RES has on the power system and what the future role of Thermal Power will be in light of; (1) the 80-95% GHG emission reductions by 2050 aim and (2) the agreed (2014) 40% reduction in GHG emissions targets and (3) increasing the share of renewable energy to at least 27% of the EU's energy consumption by 2030. This is done both qualitatively as well as quantitatively through a comparison of scenarios for the EU power sector in 2030.

Firstly, the operation of power systems in the 'classical' sense – with demand as the main source of variation - is described in a simplified manner (2.2.1), and the role of Thermal Power in such a system is examined (2.2.2). Secondly, the changes occurring to power system operations as a result of increasing deployment of i-RES are described (2.3.1) and the new requirements that this places on thermal power plants are examined (2.3.2). Thirdly, the flexibility characteristics of thermal power plants are reviewed (2.4.1), taking into consideration the results (2.4.2) of EPPSA surveys that set out the members' views on BAT and give exemplars (2.4.3) of flexible plants in operation. Fourthly, selected scenarios for the EU power sector in 2030 are examined (2.4). Finally, conclusions regarding the role and importance of Thermal Power in a 2030 perspective are made (2.5).

2.2. Power System Operation

2.2.1. The Classical System – Variable Demand, Dispatchable Supply

A defining feature of power systems is that supply and demand must match at all times (within quite tight limits) in order to guarantee system stability. What follows is a simplified description of power system operation in the 'classical' sense, i.e. where demand is variable and supply can be controlled ('dispatchable').

Electricity is different from other supplies in that it cannot be easily stored. The technologies available for storage are either limited in capacity or bring significant added cost.

Demand varies from one moment to another, from hour to hour and day to day, as well as from season to season. However, it mostly follows predictable patterns. For example, changes in the demand pattern over one day generally exhibit the following characteristics: demand is relatively low during the night and higher during the day, with two distinct peaks, one before mid-day and one in the evening. To meet this demand, a system operator utilises different plants, in an order of merit (the 'merit order') depending on their operational performance and cost characteristics. Generally, plants with high capital but low variable costs operate at constant output when demand (and therefore price) is low (i.e. at night), while plants with low capital costs and high variable costs are operated flexibly and are mainly utilised when demand (and therefore price) is high. Plants with intermediate capital and variable costs operate in a load-following mode, i.e. they adjust to smaller changes in demand. These plants are respectively classified as baseload, peak-load, and mid-merit (or load-following) plants.

[13] Eurelectric (2013), "Power Statistics and Trends 2013"; p. 12

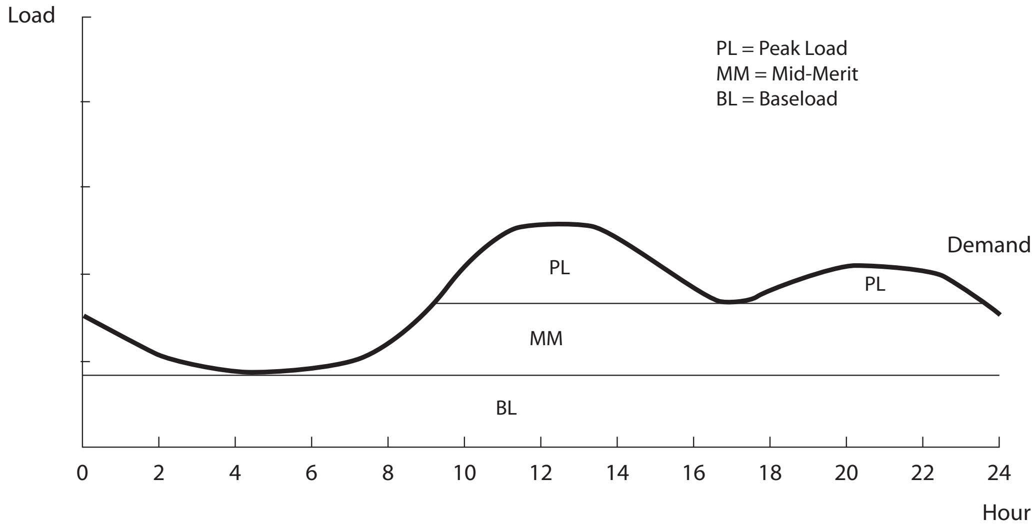


Figure 2 - Simplified Daily Load Curve

Figure 2 above shows a simplified example of a daily load curve, with variation in demand met by different types of plants depending on the level and duration of the changes in demand.

The categories of Baseload, Mid-merit, and Peak load plant were differentiated by the number of hours during which each is utilised during the year, see Table 3:

Plant Type	Hours per year
Baseload	› 5256
Mid-merit	1752-3504
Peak-load	‹ 876

Table 3 - Plant Categories and Operating Hours[14]
(JRC, 2009; p. 20)

The overall power system must be kept secure at all times, i.e. demand and supply have to be equalised at all times in order to keep within the safe limits for the load, frequency and voltage. With regard to such security, different terms are applied for different timescales, whereby

- Stability must be ensured on a timescale of seconds
- Balance must be ensured on a timescale of minutes to days
- Adequacy must be ensured on a timescale of months to years

To ensure stability, system operators must ensure sufficient availability of reserves that can step in and correct any deviations of supply from demand, which can occur for various reasons, including demand spikes, plant failure, as well as fluctuation of variable RES supply. These are classified as primary, secondary, and tertiary reserve, and are distinguished based on reactive speed and duration.

Additional requirements to ensure system security include:

- (n-1) security or redispatch capability
- Supply restoration (restoring the system after a blackout; requires plants with black-start capability, e.g. those capable of starting without an external energy supply)

[14] JRC (2009), "Future Fossil Fuel Electricity Generation in Europe: Options and Consequences", p. 20

2.2.2. The Role of Thermal Power in a "classical" power system

Within a 'classical' power system as described above, a number of power plant types are utilised, all of which are dispatchable. The main plant types are hydropower, nuclear, and thermal power, each of which has contributed a major share of the electricity generation in Europe.

The mixture varies from country to country and has changed due to technological and economic developments through time. The Joint Research Centre of the European Commission summarised their view of the broad European picture as shown in Table 4 below.

Thermal Power is able to provide all of the system services elaborated in 2.2.1. and different types of thermal power plants have fulfilled the roles of baseload, mid-merit and peak-load in the past.

Overall efficiency improvements of both coal-fired and gas combined cycle power plant have brought a reduction of all pollutant emissions per kWh of electricity produced. The efficiency of the newest coal-fired plant now exceeds 46% compared to 30-34% before 1990 and CCGTs have improved from about 50% to approaching 60%.

Other technological advances, such as combustion systems optimisation and operation (e.g. staged combustion and low No_x burners) as well as end-of-pipe pollution control equipment (e.g. de-NO_x systems, flue gas desulphurisation, and particulate control systems such as fabric filters or Electrostatic Precipitators (ESP)) have resulted in very significant reductions of emissions of specific pollutants. Table 5 below gives an overview of the main pollutants associated with thermal power plants and the respective technological developments that have resulted in emissions reductions.

Type	Until early 1990s	Late 1990s	Early 2000s
Baseload	Coal-fired	CCGT	Coal-fired
Mid-merit	Oil	Coal-fired	CCGT, Coal-fired
Peak-load	Oil and diesel engines	Gas Open Cycle Gas Turbine (OCGT)	OCGT

Table 4 - Plant types fulfilling different roles[15]

Pollutant	Technological Solution
NO_x	Low NO_x burners, Selective Catalytic Reduction (SCR), Selective Non-Catalytic Reduction (SNCR), in-furnace optimisation
SO_x	Flue gas desulphurisation (wet, dry, semi-dry)
Dust	Fabric filters, electrostatic precipitators
Heavy metals (Hg, etc.)	Activated carbon filtration and others

Table 5 - Pollution Control

[15] Ibid.

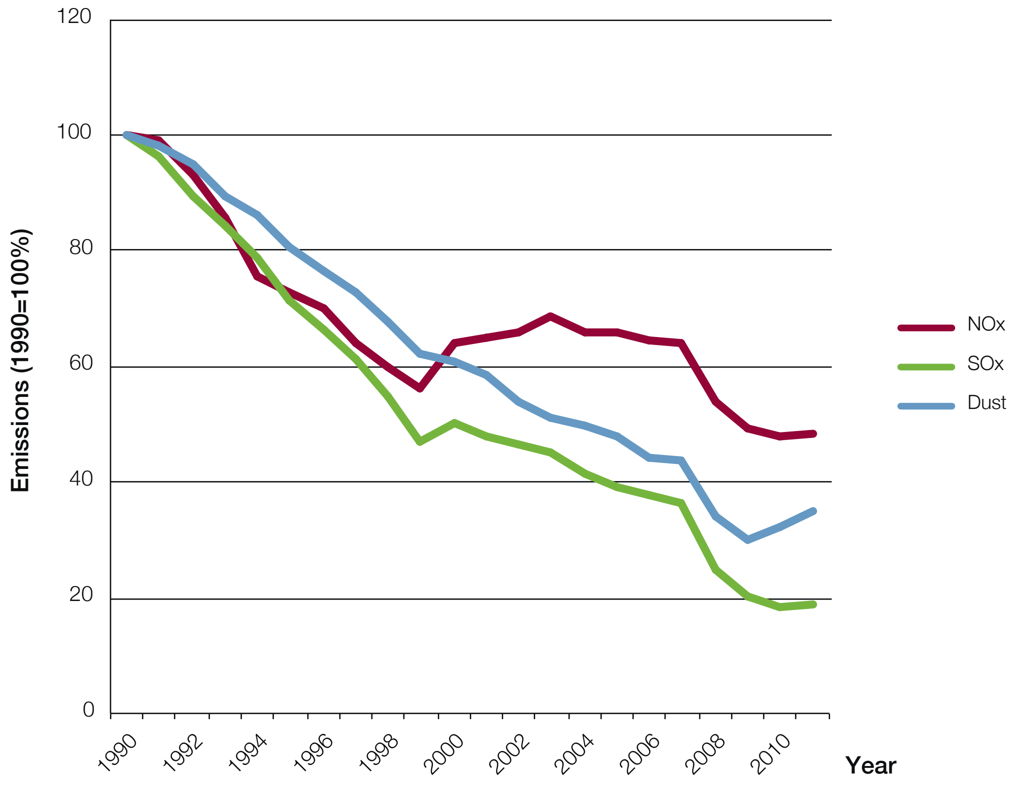


Figure 3 - Reduction of Emissions of NO_x, SO_x and Dust 1990 to 2012

Progressively tighter ELVs[16] have been introduced through EU Directives and compliance with these has brought total emissions of NO_x, SO_x and Dust down as shown in Figure 3.

However, it must be noted that the above developments have aimed to optimise efficiency, costs, and emissions when operating as close to full load as possible, given the requirements of the 'classical' power system. The increasing deployment of RES, and in particular of such i-RES as wind and solar, however, is changing the way power systems operate and therefore the requirements of thermal power plants. This is discussed below.

[16] Note that ELVs are set based on BAT, which reflects not only technical possibilities but also economic availability; thus, from a purely technical point of view, even lower emissions are attainable.

2.3. Power System Operation with Increasing Intermittent Generation

2.3.1 The Changing System: Variable Demand, Increasingly Variable Generation

Electricity generation from RES has been increasing rapidly as a result of the Climate & Energy Package, the binding 20% share of RES in EU energy consumption target in 2020 and the corresponding NREAPs of MS. Additionally, with the objective of 80-95% decarbonisation by 2050, this share is expected to increase even further with time (see 2.4). Most of this increase is coming about by the deployment of wind and solar, both of which are i-RES.

Integration of i-RES has introduced additional variation into the system. Alongside fluctuating demand, there is an increasing amount of fluctuating supply. Furthermore, this fluctuating supply has priority feed-in. Overall, this results in increasing variability of supply, and consequently, the need for system services to ensure an equilibrium between supply and demand at all times, i.e. reserve, balancing, and back-up power, increases.

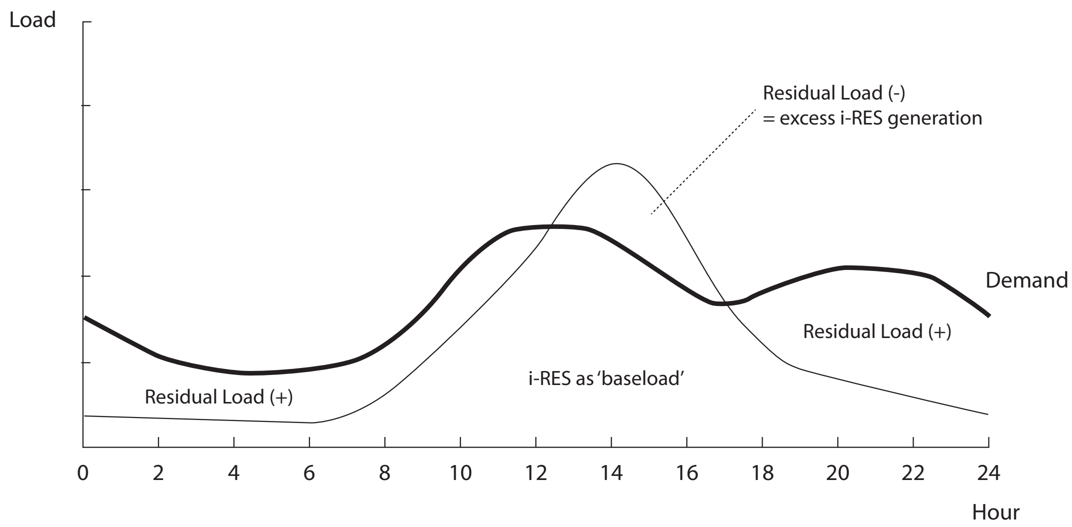


Figure 4 - Daily Load Curve with High Intermittent Generation –schematic

An illustration of the situation in a system with high levels of i-RES penetration can be seen in the daily load curve illustrated in Figure 4 above. The fluctuating yet must-run[17] generation by i-RES takes over the function of 'baseload', while the remaining load (net load minus intermittent generation) is the so-called 'residual load'. In such a system, thermal power plants cover the (positive) residual loads via flexible operation as well as control reserves and balancing[18]. Classical 'base-load' thermal power plants are not used in such situations, but must remain available in case of insufficient generation from i-RES. At the same time, situations are possible where the residual load is negative, i.e. the generation from i-RES is higher than demand. In this case, the excess generation must either be curtailed or may be stored, if sufficient storage is available[19].A real example from Germany, showing the load variation over a week and the impact of intermittent solar and wind is shown in Figure 5. During this week, solar generation varied from 0 to 14 GW and wind from 3 to 20 GW. The maximum renewable generation was 28 GW and the minimum 3 GW, compared to total generation which varied from 57 to 82 GW. To compensate for variations in demand and renewable output, Thermal Power varied from 15 to 44 GW.

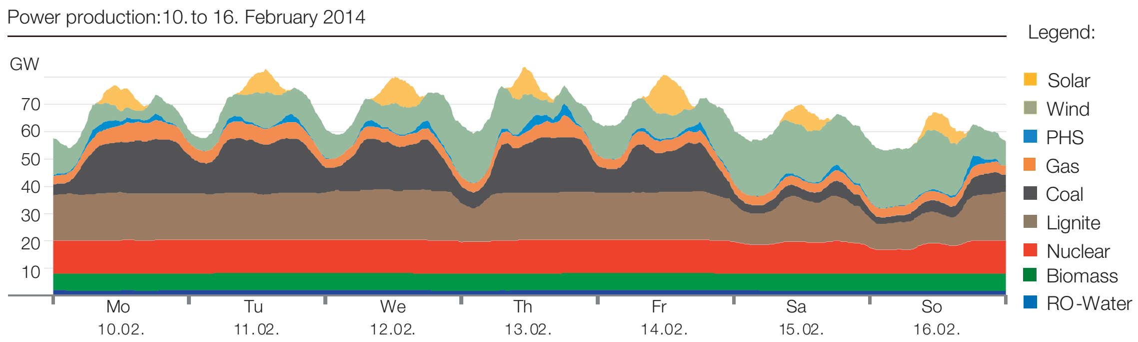


Figure 5 - Weekly Load Curve with high intermittent generation

[17] The purchase of all the electricity that is generated is guaranteed by renewable support schemes

[18] VDE (2012), "Erneuerbare Energie braucht flexible Kraftwerke – Szenarien bis 2020", p. 54

[19] Although it might also be possible to use some excess power to keep thermal power plants warm to reduce start-up duration and make it easier to meet (inevitable) increases in residual load.

Overall, a system with increasing fluctuation in supply as well as changing demand has correspondingly increasing balancing requirements. Enough dispatchable capacity must be available to meet demand at times with little or no generation from intermittent generation, and this capacity must be able to provide this service at varying speeds (e.g. rapid load changes to balance high residual load gradients) and for varying durations, including extremes of several weeks with low wind which can extend right across Europe, as in the example shown in Figure 6)[20,21].

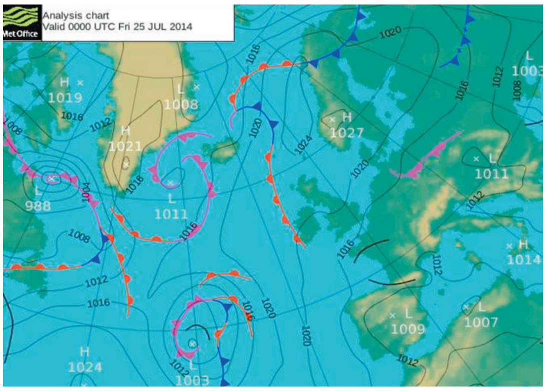


Figure 6 - Low wind across the whole of Europe

The example was in summer but similar low wind conditions can occur across wide areas on the coldest, stillest days of winter. For example in Great Britain on 7th December 2010. Figure 7 shows the generation used to meet peak demand that day. The GB demand was met, but only just. The wind generation produced only 5% of its nameplate capacity.

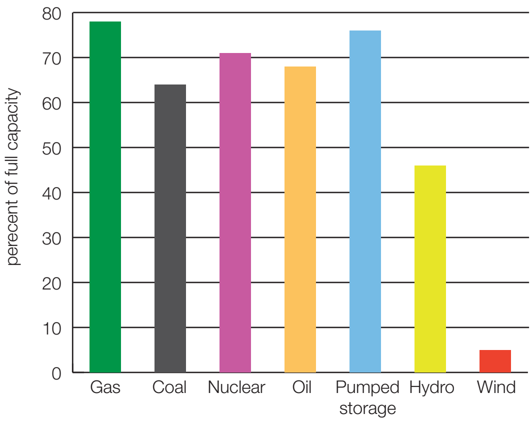


Figure 7 - Electricity generation in Great Britain on a still winter day (7/12/2010)

[20] BET (2013), "Möglichkeiten zum Ausgleich fluktuierender Einspeisungen aus Erneuerbaren Energien"

[21] UK Met Office Fri 25th July.

2.3.2 The Role of Thermal Power in a power system with a large share of intermittent generation

The behaviour of thermal power plants in a system with high shares of i-RES generation varies depending on whether the residual load is increasing or decreasing:

- Decreasing Residual Load: Thermal power plants can reduce their output - or even shut down - quickly in order to balance excess feed-in from i-RES. This presupposes that sufficient thermal power plants are active at sufficiently high levels, otherwise RES curtailment is necessary

- Increasing Residual Load: Thermal power plants can ramp up to meet increasing residual load when generation from i-RES decreases; the exact contribution possible depends on how many plants are active and how many are available as reserve.

As increasing shares of must-run generation from i-RES takes over the function of 'baseload' and the remaining residual load fluctuates more and more, thermal power plants will increasingly be required to provide flexible back-up and balancing. Additionally, thermal power plants will still be required for other system services, such as supply restoration and frequency control.

The magnitude of fluctuations in RES output and the consequential effect on the flexibility requirements of thermal plants, is very dependent on the amount of intermittent renewables deployed, whether wind, PV or both, and on the degree of interconnection of the electricity system (e.g. an island system like the UK or Ireland with limited interconnection vs a system like Germany with a large amount of interconnection with adjacent systems). While the characteristics of wind and solar complement one another over a yearly period, this does not hold true for hourly load gradients, and little correlation exists between solar and wind gradients[22].

As an illustration, with the anticipated wind and PV capacities (42GW onshore wind, 16GW offshore wind and 60GW of PV), VDE suggests a planning value of expected load gradients of 15GW/h (for 1 h duration) and 10GW/h (for 3hr duration) for Germany in 2020.

These overall load gradients must be met by "ramping-up" plants which are already operating at part-load. This can either be done by small numbers of plants with relatively fast (3%/min) ramping rates or a larger number of plants with slower ramping rates.

[22] VDE (2012), "Erneuerbare Energie braucht flexible Kraftwerke – Szenarien bis 2020", pp. 55-56

Figure 8 below illustrates this, showing the total (GW) power plant load capacity which is needed for balancing for three different possible ramp rates (1, 2 and 3% /min) and for three different total balancing requirements (5 GW in 1hour, 10 GW in 1 hour and 15 GW in 1 hour). This shows that the lower the ramping rate of the plants available, the higher the balancing capacity that must be utilised. For example, a load gradient of 10 GW/h can be met by approximately 5 GW of plants which have ramping rates of 3%/min; the same gradient can also be met by plants with lower ramping rates (e.g. 1%/min), but more than 15 GW of capacity thereof is required for the same balancing effect.

The total installed capacity of plants used for ramping depends on the minimum operating load of the plant; for plants whose minimum operating load is 50%, 30 GW of plants will be required to provide 15 GW of balancing capacity.

In such a system, thermal power plants will need to meet the following flexibility requirements[23]:

- The capability to meet higher load gradients with only a small effect on plant lifetime, which in the future may be determined by fatigue due to load cycling rather than by total operating hours;
- Lower minimum loads in order to be able to remain active and be able to quickly step in to balance fluctuating i-RES;
- Higher efficiencies at part-load;
- Environmental performance at part-load and during flexible operation will have to be optimised.

2.4 Flexibility characteristics of thermal power plants

2.4.1 Flexibility characteristics of thermal power plants- VDE review

The current flexibility characteristics of thermal power plants vary according to plant type and configuration, see Table 6, published by VDE where the abbreviation P_N means nominal load which is the maximum continuous rating (MCR). For categories with three figures, the first reflects current fleet average (in Germany), the second reflects current state-of-the-art, while the third reflects expected technological developments.

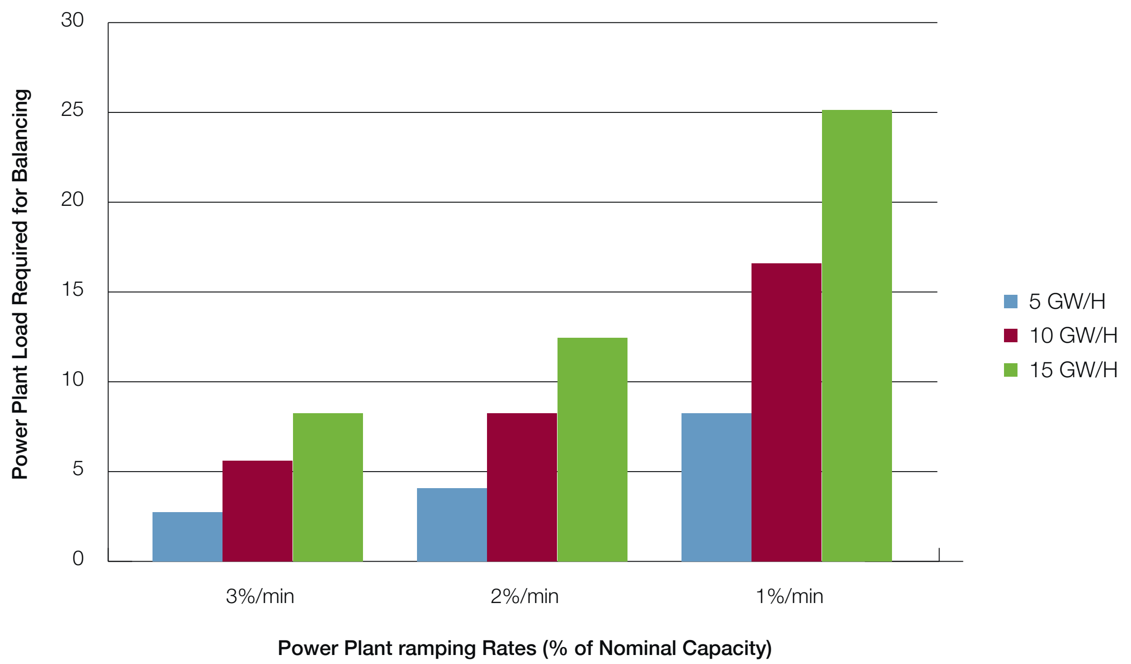


Figure 8 - Effect of Ramping Rates on Required Balancing Load (VDE, 2012; p.59)

[23] Ibid., p. 57

Power Plant Type		Hard coal	Lignite	CCGT	OCGT
Ramp rate	%PN/min	1,5 / 4 / 6	1 / 2,5 / 4	2 / 4 / 8	8 / 12 / 15
In range of	%PN	40 - 90	50 - 90	40*) - 90	40*) - 90
Minimum load	%PN	40 / 25 / 20	60 / 50 / 40	50 / 40 / 30	50 / 40 / 20
Start-up time					
Hot (< 8h)	h	3 / 2,5 / 2	6 / 4 / 2	1,5 / 1 / 0,5	< 0,1
Cold (> 48h)	h	10 / 5 / 4	10 / 8 / 6	4 / 3 / 2	< 0,1

Table 6 - Flexibility Characteristics[24]

Type	Pulverised Fuel					CCGT	Circulating Fluid Bed (CFB)	
	Hard Coal	Coal/ Biomass cofiring	Hard Coal – Indirect Firing	Lignite	Lignite – Pre-dried Lignite	Gas	Coal, Lignite, and Peat	Biomass
Min. Load (% MCR)	< 20 –25[1]	<30	< 10	< 40	< 20	< 40 (CCGT) [2a] < 30 (GT alone)[2a]	30-40	30-40
Ramp Rate	4-5[3] (%MCR/ min)	4 – 6[3] (%MCR/ min)	4-6 (%MCR/ min)	3-4 (%MCR/ min)	4-6 (%MCR/ min)	5-6 (%MCR/min) Average[2a,2b] (CCGT). 9-11%/min of max GT output [2b] (CCGT with Benson HRSG) 7%/min Peak ramp [2c] (GT alone)	For OT units: 3-4[5] (%MCR/min) For all other plant types: 4[5] (%MCR/min)	
Hot start (min) (after <8hoff)	140[6a] 120[6b] 66[6c]	140	120 expected	140 75-80[6c]	120 expected	25 (Benson OT, OT) 30-45 (Drum type)	120	
Warm-start (min) after between 8 and 48hr off	300[6a] 260[6b]							
Cold-start (min) (after > 72hrs off)	480[6a] 380[6b]	300-480	300-480	300-480	300-480	40 (Benson OT) 120-140 (Drum type)	540-600	
Efficiency[4] at full load	46%			43.5%		58-60%	43.3%	

Table 7 - Flexibility Characteristics[25]: BAT based on supplier information

[24] Ibid., p. 24

[25] EPPSA (2014)

2.4.2 EPPSA survey on BAT for flexible power plants

EPPSA has carried out a survey among its members and collected data on the BAT for thermal power plants. This data is summarised above, in Table 7.

Notes on Table 7

1. Depends on coal quality

2a. References GT26 Alstom, 9FB-FE50 General Electric, SGT5-8000H Siemens

2b. Averaged value from 35% MCR stable load to 95% MCR stable load, as per the EU definition of the 'ramping rate'.

2c. Peak ramping rate of GT alone, during a limited time for grid control.

3. Ramping rates can be increased to 7-8%/min (the limit determined by pressure part loading and fatigue) and minimum loads can be reduced by utilising a supplementary fuel i.e. gas or oil

4. Efficiency figures are Lower Heating Value (LHV) figures. Some EPPSA members are now confident of reaching 50% efficiency, over the load range 60-100% and with a ramp rate of 7-8% (using supplementary fuel) by full optimisation of design, including double reheat, use of variable speed drives, without needing to go to 700°C final steam temperature. Note however that efficiencies depend both on the technology and also on local site conditions (sea-water or air temperature, altitude, fuel moisture content…)

5. Potential figures for 2030: 5-6%

6a. Ultra-supercriticals (USCs) designed for base-load

6b. Future USC's at the design stage

6c. Ignition (light-off) to Synchronisation

2.4.3 EPPSA exemplars of flexible power plants

In order to justify the claims made above, EPPSA members have provided details of exemplar plants covering a wide range of technologies, fuels, locations both in Europe and elsewhere. Details of these plants are listed below in Table 8.

Name of Plant	Fuel/Type	Date	Minimum Load (%) (** with back-up fuel)	Ramp rate (%MCR/min) (** with back-up fuel)
Lagisza 460 Mwe	Bit. Coal CFB-OTU	Retrofit 2009	40	4%/min
Lund	Biomass CFB-drum	New 2014	30	4%/min
Kladno	Lignite+ biomass CFB drum	2013	30	3.5%/min
Turow 275 Mwe	Lignite CFB-drum	Retrofits 2002-2004	40	4%/min
Belchatow 858 Mwe	Lignite Supercritical	2011	45% (with coal fire)	between 2% – 6 %
Neurath 1100 Mwe	Lignite USC	2012	45% (with coal fire)	between 2 % - 8 %
Walsum and others	New PC with USC Hard Coal		35%	4.6-6%/min from 50% to 103%
Boxberg	New PC with USC Lignite		35%	3.5-6% from 35 -105%
Bexbach & Heilbronn 7	PC subcritical, Sulzer		20%	
Torrevaldaliga Nord (Italy)	PC with USC		35%	2%/min
NJV	Coal PC OT		25% (20%)** (35%) ***	5% from 35% -95% (7-8%)**
AVV-2	Pulverised wood pellets OT		25% (20%)** (30%)***	4% from 30%-95% (7-8%)**
AMV-1	Pulverised wood and straw pellets OT		25% (20%)** (35%)***	4% from 35%-95% (6%)**
FV-08	Grate Biomass Drum		30-40% (30%)**	3% from 40%-95% (4%)**
Castle Peak B 660 Mwe 160 bar/540/540	Coal Subcrit PC	1989	20% MCR	4.5% MCR
Eraring Upgrade 600 to 750 Mwe 160 bar/540/540	Coal Subcrit PC	Upgrade Oct 2010 –Aug 2012 across four units	20% MCR	3%MCR/min with capability of: 10% MCR/min @ Constant Pressure 5%/min@ Variable Pressure
Yeong heung 5 & 6 930 Mwe 260 bar/566/595	Coal Adv Supercritical PC	06.2014 (#5) 12.2014 (#6)	30% NR	3% TMCR/min (30%TMCR ~ 100%TMCR)
Shinboryeong 1 & 2 1100 Mwe 260 bar/610/621	Coal USC PC	06.2016 (#1) 06.2017 (#2)	30% NR	3% TMCR/min (50%TMCR ~ 100%TMCR)
Turano (Italy)	Gas CCGT Drum HRSG	2010	30%	2.5% /min
EDF Bouchain GE “Flexi Efficiency50” 510MW	Gas CCGT	2015	Est 30%	10%/min 30MW/min
Hamm Uentrop (Germany)	Gas CCGT Low mass flux Benson HRSG	2013		10%/min
GE “Flex- efficiency Combined Cycle” power Plant 592Mwe	Gas CCGT 9HA.02	EDF 2016	40%	60 MW/min
Siemens “FlexPlant” Irsching 570MWe	Gas CCGT SCC 8000H	Jul-11	?	?

Table 8 - Examples of modern plants (including retrofits)

Start-up time – hot (<8h) (from light-off to full load)	Start-up time –cold (>48h) (from light-off to full load)	Suppliers (boiler/ST/GT)	Efficiency at full load (%)	Efficiency at minimum load (%)
		FW/x/x	43.30%	
		FW/x/x		
		FW/x/x		
		FW/x/x	40.40%	
140 min	360 min	Alstom for all	41.00%	No info
min	380 min	Alstom-Hitachi / Alstom	>43.00%	No info
66 min	290 min	Hitachi	46.00%	
75-85	290 min -330min	Hitachi	43.70%	
		Alstom		
140	300	Ansaldo Caldaie-BHK/MHI	43.70%	
		BWE		
		BWE		
		BWE		
		BWE		
120 min	480 min	Doosan/GEC/-	39.40%	34
90 mins	720 min	OEM Blr: IHI-FW ST: Toshiba Upgrade Blr+ST: Doosan	Upgrade 40.90%	Upgrade 36.6%
190 min	510 min	Doosan/ Hitachi/-	45.60%	39.4
190 min	550 min	Doosan/ Doosan/-	46.60%	41.4
55 min	140 min	Ansaldo Caldaie/AEN	57.00%	
30 min for “hot rapid start”	183min	?/GE/GE	61.00%	
		Ansaldo Caldaie/ Siemens		
30 min		?/GE/GE	61.00%	60% at 87% load
30 min	?	?/Siemens/Siemens	60.75%	?

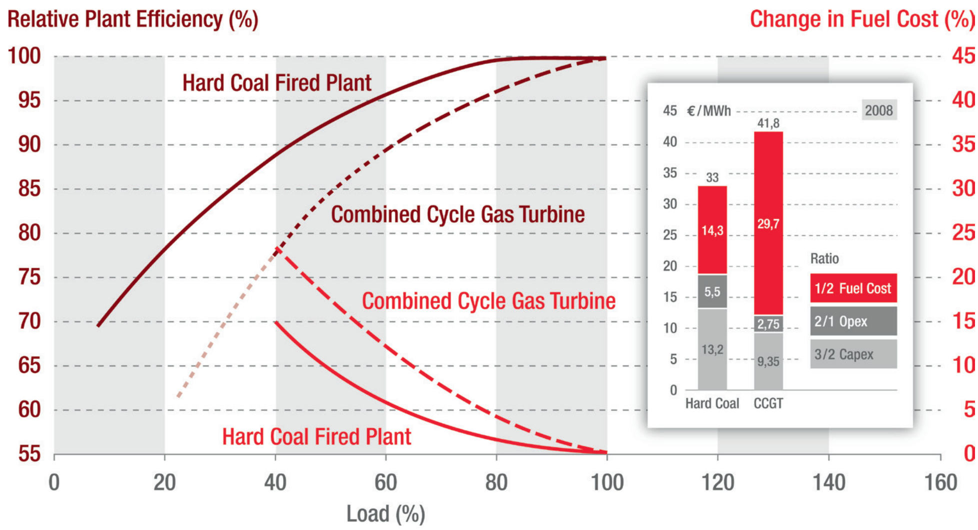


Figure 9 - Plant efficiency and specific fuel costs

There is limited information in Table 7 and Table 8 on efficiency at low/minimum load. However, the data available is consistent with the general understanding that the efficiency falls off as the load reduces, indicated in Figure 9 above. As the load is decreased (right to left on the lower scale) plant efficiency decreased significantly (see dark red curves and left-hand scale) and the cost of fuel used for each MWh generated increase (see light red curves and right-hand scale), pushing up the cost of electricity (the inset box shows in red the portion of the electricity cost which is due to fuel for coal and gas respectively).

CO_2 emissions per MWh of electricity generated also increase as the load reduces below the optimum. As a result, the reduction in CO_2 emissions due to the displacement of fossil fuel generation by i-RES is less than proportionate.

The EPPSA survey also considered emissions of pollutants at part load and during the plant ramping up and down. It is clear that emissions per MWh remain at all times within the limits set by EU Directives and are closely monitored by national environment agencies.

2.4.4 Thermal power plants in a modern electricity system in 2014

The experience around Europe shows that existing thermal power plants (coal, lignite, gas and biomass) are capable of balancing the variability of demand and of intermittent generation whilst meeting environmental limits over their full load range.

The type of plant (and fuel) used for balancing (mid-merit plant) varies in different countries and has changed over time as fuel prices and carbon prices have changed. Initially there was a move to more gas-fired generation, but more recently with falling coal prices and carbon prices there has been a change away from using gas to using hard coal and lignite:

- In Germany, relatively new high efficiency hard coal–fired power plants built for base-load have to be used for balancing. These plants replaced old, less efficient plants and have reduced CO_2 emissions from coal and lignite.
- In the UK, older coal-fired plants whose running hours are restricted by EU emissions legislation (LCPD and IED) are being used for balancing but the number of these plants available is reducing as allocations of permitted running hours are used up. Many of these plants have had successful boiler and pipework modifications to improve their ability to cycle.

Many existing plants, however, are less than optimum:

- Less efficient than BAT at full load (many coal plants are only 30-39% efficient compared to BAT of 46%), and frequently being operated at reduced efficiency at part-load

- Reduction of efficiency at part-load pushes up the cost of electricity through sub-optimum use of fuel and has an impact on CO_2 emissions
- Cycling of plant reduces plant life and the lifetime will be determined by the number of cycles rather than total operating hours, which will be reduced
- Thermal power plants will be running for fewer hours and these at part-load. For example, plants optimised for full load operation at 4,000 to 8,000 hours per year (e.g. 'classical' baseload plants) will be expected to operate between 1,500 to 3,000 hours per year at part-load[26].

There are important economic consequences: New thermal power plants built for base-load and now only operating part-load are less economical than anticipated in the investment case. As a result, some plants have been closed. The case for new investment in Thermal Power must be made against uncertainties in anticipated running hours, wholesale electricity prices and fuel prices. In practice, the case cannot be made and numerous planned gas and coal power plant projects have been cancelled (9.5 GW) or postponed (12.5 GW). These numbers for 2012 are typical of what has happened each year for the last five years.

As demonstrated in Table 8, new plants and retrofits have been designed and built, many by EPPSA members, with improved efficiency, flexibility (minimum load, reduced start-up times and faster ramp rates) and able to cope with thermal cycling. Coal, lignite, biomass and gas power plants can be optimised for flexibility and there is scope for further improvement and a need for continuing RD&D.

2.5 The EU Energy System in 2030: Scenario Comparison

2.5.1 Scenarios towards 2030

2.5.1.1 Scenario Description and Comparison

EPPSA has analysed a number of studies on the EU energy system in 2030 to examine what role can be foreseen for thermal power plants. A total of 24 scenarios from 7 studies were taken up and compared (sections 2.5.1 to 2.5.4) with regard to electricity generation (MWh) and installed capacity (GW). Table 9 below presents a comparison of the studies and scenarios examined by scope, modelling approach, and policy assumptions used.

In addition, in section 2.5.5, they were specifically examined and compared with regard to the additional capacity of thermal power needed by 2030 to account for the decommissioning of existing plants which is expected to be substantial in the coming years.

[26] VDE (2012), "Erneuerbare Energie braucht flexible Kraftwerke – Szenarien bis 2020", pp. 57

Study	Scope	Modelling
JRC (2009), "Future Fossil Fuel Electricity Generation in Europe: Options and Consequences"	Fossil fuel generation in EU-27, up to 2030	Production mix exogenously determined by setting shares of RES & nuclear, and then determining necessary fossil fuel generation & capacity
Eurelectric (2009), "Power Choices: Pathways to Carbon-Neutral Electricity in Europe by 2050"	EU-27 energy system as a whole, up to 2050	Energy sector modelling by PRIMES
Greenpeace (2010), "Energy (R)Evolution: Towards a Fully Renewable Energy Supply in the EU-27"	EU-27 energy system as a whole, up to 2050	Global modelling using MESAP/PlaNet simulation
European Climate Foundation (2011), "Power Perspectives 2030: On the Road to a Decarbonised Power Sector"	EU-27 (plus Norway and Switzerland), power sector only, up to 2030	3-step approach: **1.** defining demand and production mix in 2020/2030 (based on PRIMES data), and calculating capacity (RES share in production mix exogenously set) **2.** creating hourly demand and production curves **3.** grid and system modelling: computing transmission and back-up requirements, simulation of hourly operation
European Commission (2011), "Energy Roadmap 2050"	EU-27 energy system as a whole, up to 2050	PRIMES, GEM-E3, PROMETHEUS
DG ENER (2013), "EU Energy Trends to 2050"	EU-28 energy system as a whole, up to 2050	PRIMES, GEM-E-3, GAINS, GLOBIOM-G4M, PROMETHEUS
ENTSO-E (2013), "2030 Visions"	**Note:** Visions 2030 is not a study but will form part of the 2014 TYNDP. However, data on installed capacity in 2030 was open for public consultation in 2013, and is utilised in the present study for a broader basis of comparison in Section 2.4.5. Money Rules Green Transition Green Revolution	

Table 9 - Overview of Selected Scenarios

Scenario	Policy Assumptions
Business As Usual	
Low Carbon Policy	Policies promoting RES in place (leading to higher RES share, exogenously determined)
Baseline	EU Policies adopted by March 2009
Power Choices	Fulfilment of NREAPs by 2020; for 2030, no RES targets but achievement of 40% GHG reductions driven by carbon pricing
Reference	Based on IEA WEO 2009 reference scenario; no CO_2 reduction target
Energy (R)Evolution	CO_2 reduction targets and phase-out of nuclear energy; no CCS
Advanced Energy (R)Evolution	Stricter CO_2 reduction targets; no CCS
On Track	NREAPs and TYNDPs are fulfilled by 2020; after 2020, constraints are CO_2 reduction target, system reliability (99.97%) and 50% RES
Higher RES	Higher RES share in 2030 (60%)
Less Nuclear and CCS	Less nuclear and CCS due to public opposition
Reference	EU policies adopted by March 2010 (inc. NREAPs)
Current Policy Initiatives	EU policies after March 2010 (inc. TYNDP); includes revised assumptions on nuclear (after Fukushima) and slow progress on CCS
High Energy Efficiency	Stronger climate policies, including CO_2 reduction targets for 2030 and RES-facilitation policies; support for early demonstration to all low-carbon technologies; stringent energy efficiency measures (appliances, buildings); obligation for installations to upgrade to BAT whenever permit is updated; full smart-grid roll-out
Diversified Supply Technologies	Stronger climate policies, including CO_2 reduction targets for 2030 and RES-facilitation policies; support for early demonstration to all low-carbon technologies; all low-carbon energy sources compete on market basis; no specific support for RES or energy efficiency, and public acceptance of nuclear and CCS
High RES	Stronger climate policies, including CO_2 reduction targets for 2030 and RES-facilitation policies; support for early demonstration to all low-carbon technologies; very high RES penetration (off-shore wind, CSP); significant storage
Delayed CCS	Stronger climate policies, including CO_2 reduction targets for 2030 and RES-facilitation policies; support for early demonstration to all low-carbon technologies; similar to Diversified Supply Technologies except issues with acceptance of CCS
Low Nuclear	Stronger climate policies, including CO_2 reduction targets for 2030 and RES-facilitation policies; support for early demonstration to all low-carbon technologies; similar to Diversified Supply Technologies except issues with acceptance of nuclear
Reference	EU and MS policies adopted by spring 2012; takes into account effects of recent unconventional gas developments globally
Slow Progress	National energy policies dominate; no CCS
EU energy policy; partial implementation of CCS	
National energy policies dominate; no CCS	
EU energy policy; full implementation of CCS	

Study	Scenario	2030 GHG Reduction (rel. 1990)	CO_2 Prices
JRC (2009), "Future Fossil Fuel Electricity Generation in Europe: Options and Consequences"	Business As Usual	± 50%	20-105€$_{2005}$/tCO_2
	Low Carbon Policy	-10 to -70%	20-105€$_{2005}$/tCO_2
Eurelectric (2009), "Power Choices: Pathways to Carbon-Neutral Electricity in Europe by 2050"	Baseline	N/A	39 €$_{2008}$/tCO_2
	Power Choices	-40%	52.1 €$_{2008}$/tCO_2
Greenpeace (2010), "Energy (R)Evolution: Towards a Fully Renewable Energy Supply in the EU-27"	Reference	-36.5%	30 $/t$CO_2$
	Energy (R)Evolution	-60.9%	30 $/t$CO_2$
	Advanced Energy (R) Evolution	-65.8%	30 $/t$CO_2$
European Climate Foundation (2011), "Power Perspectives 2030: On the Road to a Decarbonised Power Sector"	On Track	-65% (power sector only)	85 €/tCO_2
	Higher RES	-70% (power sector only)	85 €/tCO_2
	Less Nuclear and CCS	-59% (power sector only)	85 €/tCO_2
European Commission (2011), "Energy Roadmap 2050"	Reference	-40.8%	40 €$_{2008}$/tCO_2
	Current Policy Initiatives	-47.5%	32 €$_{2008}$/tCO_2
	High Energy Efficiency	-56.2%	25 €$_{2008}$/tCO_2
	Diversified Supply Technologies	-55.6%	52 €$_{2008}$/tCO_2
	High RES	-56.7%	35 €$_{2008}$/tCO_2
	Delayed CCS	-56%	55 €$_{2008}$/tCO_2
	Low Nuclear	-55.1%	63 €$_{2008}$/tCO_2
DG ENER (2013), "EU Energy Trends to 2050"	Reference	-30.5%	35 €$_{2010}$/tCO_2
ENTSO-E (2013), "2030 Visions"	Slow Progress	N/A	31 €/tCO_2
	Money Rules		31 €/tCO_2
	Green Transition		93 €/tCO_2
	Green Revolution		93 €/tCO_2

Table 10 - Overview of Selected Scenarios - Emissions Reductions and Carbon Prices

The scenarios also differ with regard to the GHG reductions and carbon prices in 2030. Table 10 above presents a comparison of this data.

2.5.1.2 Assumptions and Inputs: Analysis

The studies and scenarios compared are from the years 2009-2013; as such, their respective reference scenarios reflect projections based on different starting points. Additionally, only the most recent study (DG ENER, 2013) considers the EU-28 instead of the EU-27. Some only consider the power sector, while others consider the EU energy system as a whole.

With regard to decarbonisation scenarios, a wide variety of technology mixes is utilised; some scenarios consider the emphasis placed on certain technologies (most often RES), while others evaluate the effects of public opposition to certain technologies (nuclear, CCS) or disregard them altogether.

Scenarios differ based on the role of GHG reductions; in some, they are exogenous (i.e. defined as inputs to the model) and represent boundary conditions, while in others, they represent outputs based on policy assumptions. This depends on the way a specific study has been carried out, i.e. whether it examines the effect of certain policies or technologies on emissions, or whether it selects desired emissions and examines what technology mixes and/or policies can achieve it. Overall, for the EU as a whole, predicted GHG reductions vary from -30.5% (reference projection) to -65.8%.

Likewise, the role of carbon prices differs from scenario to scenario. In some, carbon prices are modelled, while in others (e.g. ECF), they are exogenously determined. Overall, carbon prices for 2030 across all scenarios range from 25 $€_{2008}/tCO_2$ to 105 $€_{2005}/tCO_2$.

In summary, the scenarios exhibit a wide variety with regard to policy assumptions, carbon prices, and GHG reductions. The sections below address:

2.5.2 The Generation Mix in 2030 (i.e.: the quantity of electricity generated by different plant types taking account of running hours)

2.5.3 The Capacity Mix in 2030 (i.e. the total nameplate capacity for different plant types)

2.5.4 Thermal power capacity in 2030 by type of fuel

2.5.5 New thermal power capacity to be built by 2030 (taking account of plant replacements)

The key conclusions of each analysis are given in italics at the end of each section and summarised in section 2.5.6.

Notes:
Some scenarios, like this report, include biomass with other thermal power, others include biomass with renewables.

In Figure 10, Figure 11, Figure 12 and Figure 13 the results of the scenario modelling are compared with a "reference" year (2010 Reference DG ENER) which is a result of modelling based on business as usual, i.e. unchanged politics, shown in each case in the first column.

In Figure 14 the reference case is JRC 2009 Business as Usual.

2.5.2 The Generation Mix in 2030

2.5.2.1 Comparison of Scenarios

Figure 10 below shows a comparison of the generation mix (i.e. the proportion of the total electricity generated for each type of plant) in 2030 for those scenarios where generation shares were defined for RES (including biomass), nuclear, and thermal power (as fossil fuels only).

Figure 11 below shows a comparison for scenarios where generation shares were composed of RES, nuclear, and thermal power including biomass.

2.5.2.2 Analysis

In all scenarios, the share of RES in the generation mix increases compared to the 2010 Reference case, while the shares of nuclear and thermal power decrease[27].

For scenarios where thermal power does not include biomass: thermal power shares in 2030 reference and baseline scenarios range from 33.7% to 55%. In decarbonisation scenarios, they range from 22% to 36.2% (Eurelectric). However, aside from the Eurelectric scenarios, the 2030 generation mix was exogenously determined, i.e. it is not a result of the scenario model but a limiting boundary condition.

For scenarios where thermal power includes biomass, the picture is somewhat different. Thermal power shares in 2030 reference and baseline scenarios range from 43.2% to 53.3%. *In decarbonisation scenarios, thermal power shares range from 34.1% to 48.4%, i.e. the share of Thermal Power in the 2030 generation mix never falls below a third.*

[27] Except in the JRC Business As Usual scenario.

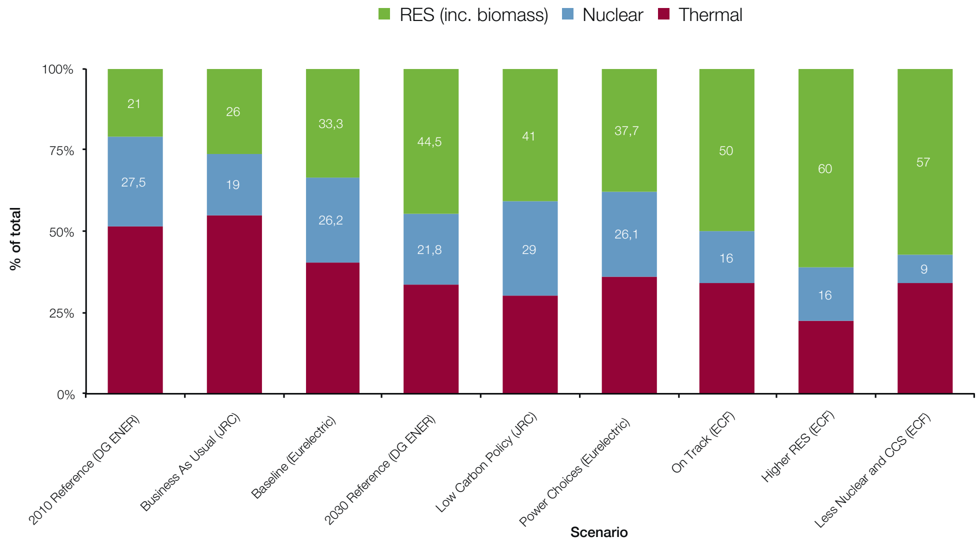


Figure 10 - Generation Mix in 2030 (Thermal = Fossil)

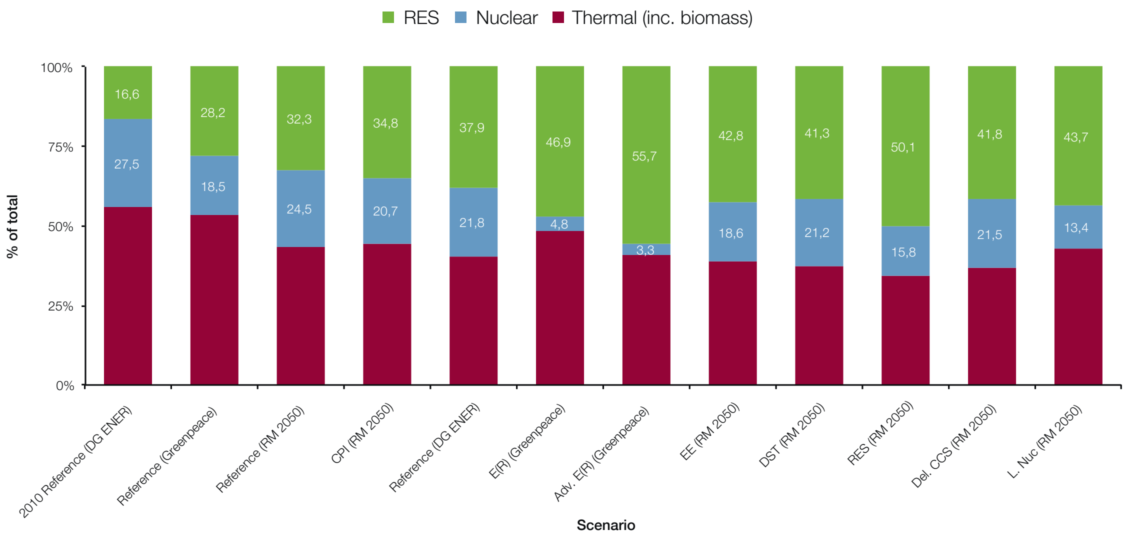


Figure 11 - Generation Mix in 2030 (Thermal incl. Biomass)

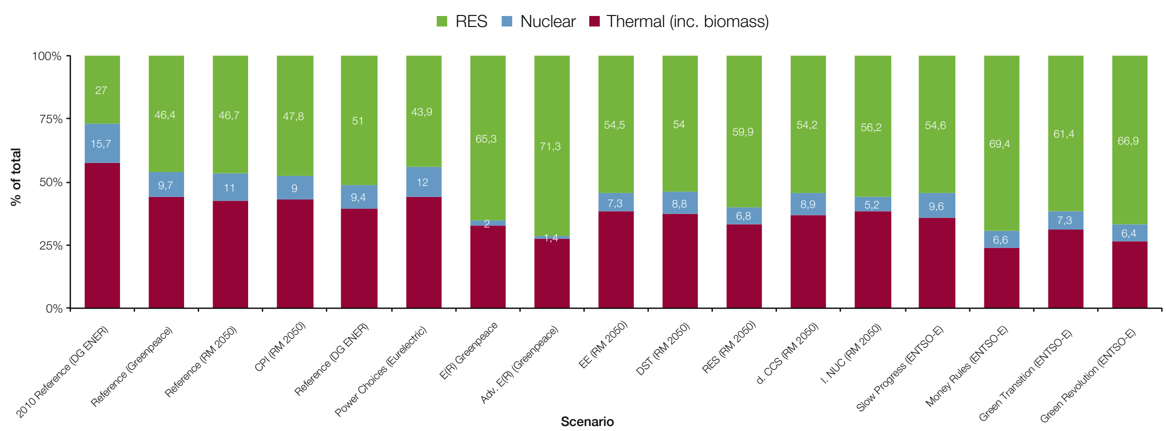


Figure 12 - Capacity Mix in 2030

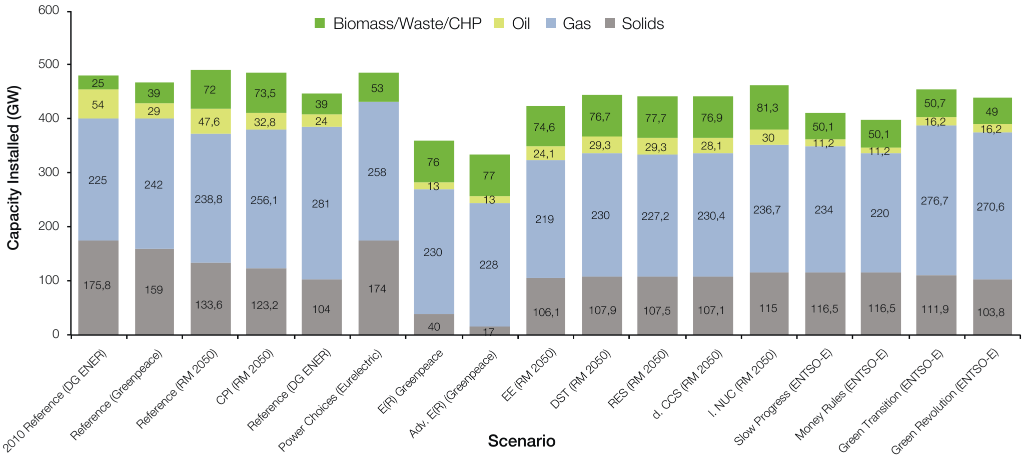


Figure 13 - Thermal Capacity in 2030

2.5.3 The Capacity Mix in 2030

2.5.3.1 Comparison of Scenarios

Figure 12 below shows a comparison of the capacity mix (i.e. the proportion of the total installed capacity for each type of generating plant) in 2030 for the different scenarios examined, with Thermal inclusive of biomass.

2.5.3.2 Analysis

Similar to the generation mix in 2030, all scenarios show a decrease in the share of thermal power capacity in 2030 compared to the 2010 Reference case.

For reference/baseline scenarios in 2030, thermal power capacity shares range from 39.3% to 44%, *while in decarbonisation scenarios, they range from 27.4% to 44%. In only two scenarios (E[R] and Adv. E[R]) are the shares of thermal power capacity below a third of total installed capacity. Yet, in these scenarios, this capacity produces 41 - 48.4% of total electricity in 2030; they are also the scenarios with the most drastic reduction in nuclear power (as phase-out thereof is an explicit objective). This underlines above all the importance of dispatchable capacity in the power system; as one kind of dispatchable capacity is phased out, another increases in importance and generation, even if the share of installed capacity decreases.*

2.5.4 Thermal power capacity in 2030 by type of fuel

This section examines the scenarios with regard to (absolute not relative) Thermal capacity installed by type of fuel. In addition to the scenarios used in previous sections, data from ENTSO-E's 2030 Visions is included in the comparison to widen the basis thereof.

2.5.4.1 Comparison of Scenarios

Figure 13 above shows the absolute installed capacity of thermal power by fuel type28 in 2030.

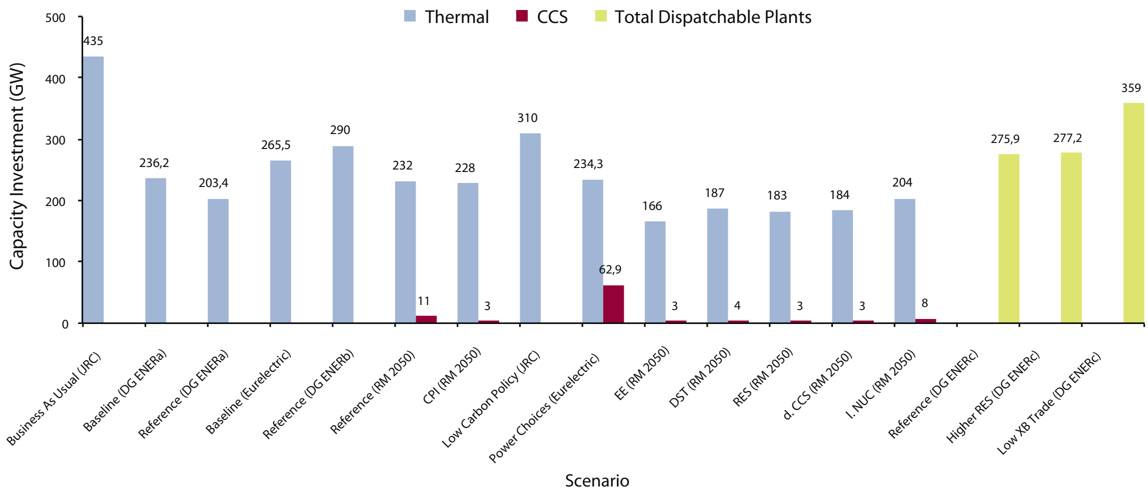
2.5.4.2 Analysis

Compared to the 2010 Reference case, most scenarios (i.e. all except Eurelectric's Power Choices) show a decrease in total thermal capacity. The changes differ depending on the type of fuel. In the decarbonisation scenarios for 2030, solids-fired capacity ranges between 17 – 174 GW; gas-fired capacity ranges between 219 - 276.7 GW; oil-fired capacity ranges between 11.2 – 30 GW; and biomass ranges between 53 – 81.3 GW.

Thus, in all scenarios, solid fossil-fired capacity decreases the most, but - except for two scenarios - remains at more than 100 GW. At the same time, biomass capacity increases. With regard to gas-fired capacity, some scenarios see an increase compared to the 2010 Reference case while others see a decrease, with an overall range from 220 GW to 277 GW, i.e. the scenarios indicate around twice as much gas capacity as coal. *However, despite the decreases, all scenarios show a substantial installed Thermal capacity in 2030. In the scenarios with the lowest capacity (E[R] and Adv. E[R]), the total installed thermal power capacity still amounts to at least 335 GW. In most non-reference/baseline scenarios (9 out of 12), the total installed thermal power capacity is between 423 – 485 GW, compared to a 2010 Reference case of 479 GW.*

---

[28] Note that in Figure 13, the data for biomass/waste/CHP differs depending on the scenario. For all scenarios except the ENTSO-E scenarios (last four on the right), the figures refer exclusively to biomass-waste, whereas for the ENTSO-E scenarios, the figures refer to CHP and non-renewable waste, i.e. biomass and renewable waste are not included. Likewise, the Eurelectric Power Choices scenario does not offer separate data for gas and oil, so the gas category includes oil as well. In all other scenarios, CHP is included in the other categories depending on the fuel used.



2.5.5 Thermal power capacity to be built by 2030

Section 2.4.4 outlines the absolute shares of thermal power capacity installed in 2030 in the different scenarios. Some of this capacity will be taken care of by plants already operating today which will continue to operate in 2030, while others will be by new plants to be built (including plants built to replace old plants that are decommissioned). This section compares scenarios where relevant data was available with regard to thermal power capacity investments required by 2030.

In addition, data on total dispatchable capacity investment needed by 2030 is compared; this is taken from a study commissioned by DG Energy in 2013[29] analysing the investment in dispatchable capacity until 2030 that is required to ensure generation adequacy. In this study, three scenarios are evaluated: a reference scenario, a scenario with higher RES penetration ("Higher RES"), and a scenario with reduced cross-border trade ('Low XB Trade").

2.5.5.1 Comparison of Scenarios

Figure 14 above shows the thermal power capacity investments required by 2030.

[29] DG ENER (2013b), "Capacity Mechanisms in Individual Markets Within the IEM"

2.5.5.2 Analysis

In reference/baseline scenarios, required capacity investments by 2030 for thermal power range from 228 to 435 GW (of which 3 - 11 GW are in CCS capacity).

In decarbonisation scenarios, required new capacity investments by 2030 for thermal power range from 166 to 310 GW (of which 3 – 62.9 GW are in CCS capacity). Excluding the JRC figure[30] changes this to a range of 166 to 234.3 GW. Comparing this range to the total installed capacity of thermal power in 2030 (see 3.4), which ranges from 423 – 485 GW, it can be estimated that *thermal capacity investments required in the 2010-2030 period will account for between 39.4 and 48.3% of all installed thermal capacity in 2030.*

For overall dispatchable capacity (including dispatchable RES and nuclear), the figures range between 275.9 GW, for the reference scenario, to 277.2, for the scenario with higher RES, while reduced cross-border trade raises the figure to 359 GW. This underlines the additional importance of transmission infrastructure for ensuring generation adequacy in the future. EPPSA welcomes the adequate response from the European Council in its 2030 Climate and Energy Policy Framework conclusions.

[30] Excluding the JRC figure may be justified on the basis that it results from the remaining capacity required given an exogenously determined share of RES in the generation mix, as well as the fact that it does not take into account a significant amount of energy-related legislation put into place after its publishing.

Key results from Scenarios review

The share of thermal power in the generation mix decreases in all considered decarbonisation scenarios. For those scenarios where generation is not exogenously determined, thermal power shares in generation range from 34.1% to 48.4% in 2030 (compared to 51.5% in the 2010 Reference case), i.e. the share of thermal power in the 2030 generation mix does not fall below a third.

The percentage share of thermal power in total installed capacity decreases by 2030; in the decarbonisation scenarios considered, thermal power capacity shares range from 27.4% to 44% in 2030 (compared to 55.8% in the 2010 Reference case).

In all except one scenario, absolute thermal capacity decreases by 2030, with the lowest value across scenarios being a minimum of 335 GW in 2030; but in most decarbonisation scenarios, absolute thermal capacity in 2030 ranges from 423-485 GW, which is not significantly different to 479 GW in the 2010 Reference case.

In the 2010-2030 period, significant investment in dispatchable capacity generally and thermal power capacity in particular is required to maintain generation adequacy. Between 166 and 234.3 GW of thermal power capacity additions are required. This means that between 39.4 and 48.3% of installed thermal power capacity in 2030 will be built in the years 2010-2030.

Figure 14 - Capacity Investments Required, 2010-2030

2.6. Conclusions to Section 2

In the 'classical' power system where demand was the main source of fluctuation, thermal power (alongside other sources such as nuclear and hydropower) provided dispatchable generation that was flexible enough to meet demand fluctuations. Plants were classified into baseload, mid-merit, and peak-load, and were dispatched depending on technical and economic considerations. Additionally, they provided important system services such as reserves and balancing provision. In a system with increasing shares of i-RES, the distinction between baseload, mid-merit, and peak-load plant no longer applies in the same way. The 'new baseload' is provided by must-run generation from i-RES, while thermal power plants must meet the remaining residual load and provide essential system services.

While overall generation from thermal power necessarily decreases as the share of i-RES generation increases, this does not necessarily mean that the required installed capacity of thermal power decreases to the same extent. As the residual load changes rapidly and increasingly often, thermal power plants will increasingly be required to provide flexible back-up and balancing. Additionally, thermal power plants will still be required for other system services, e.g. supply restoration.

For this reason, thermal power plant capacity and availability will remain important in the future. Comparative examination of selected 2030 scenarios supports this, as both generation and capacity shares of thermal power plants decrease yet the absolute installed capacity, while decreasing somewhat, remains close to 2010 levels.

At the same time, plant retirements in the 2010-2030 period mean that significant capacity investments (up to 48.3% of expected installed capacity in 2030) will be necessary to ensure system adequacy, balance, and stability.

Given the increasing flexibility requirements of power systems with increasing shares of intermittent generation, such capacity investments should be made in state-of-the-art flexible plants to minimise the costs of decarbonisation.

It is clear from the experience around Europe that existing thermal power plants (coal, lignite, gas and biomass) are capable of balancing the variability of demand and of intermittent generation whilst meeting environmental limits over their full load range. The type of plant (and fuel) used for balancing (mid-merit plant) varies in different countries and has changed over time, together with fuel and carbon prices, leading to a move away from gas to hard coal and lignite. However, many existing plants used for balancing are sub-optimum in terms of thermal efficiency (particularly at part–load) and their operating lives will be reduced due to cycling.

The important economic consequences have been pointed out; new plants built for base-load and now only operating part-load are less economical than anticipated in the investment case. Some such plants have been closed. The case for new investment is even more difficult and must be made against uncertainties in anticipated running hours and wholesale electricity and fuel prices. Most planned thermal power projects, typically 12 GW/year, have been cancelled or postponed. This has led some MS to introduce capacity mechanisms.

New plants and retrofits have been designed and built, many by EPPSA members, for improved efficiency, flexibility (minimum load, reduced start-up times and faster ramp rates) and to cope with thermal cycling. Coal, lignite, biomass and gas power plants can be optimised for flexibility and there is scope for further improvement.

3. The Added Value of Thermal Power in 2030

3.1 Added Value for EU Energy Policy

3.1.1 Affordability

Flexible and baseload thermal power plants will contribute enormously to the affordability of electricity in 2030. Thermal power (lignite, hard coal, and gas) are significantly less expensive than renewable power in terms of €/MWh, as indicated by the large support subsidies which are necessary to promote the use of renewables.

EPPSA has studied the benefits of replacing old coal-fired power plants by new build coal, looking at 26 plants (22GW)[31]. This analysis shows that, taking into account both investment and operational costs until 2030, investment costs are more than offset by the savings in fuel and CO_2 allowances which arise from the improved thermal efficiency and result in CO_2 avoidance with a positive Return on Investment (RoR). Additionally, findings show that **37 million tonnes of coal every year will be saved**, **equivalent to the combined hard coal imported by Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, France, Greece, Hungary, Ireland, Latvia, Lithuania, Luxembourg, Malta, Spain and Romania in 2012**.

Furthermore, if RES are expected - in 2030 or thereafter – to deliver the electricity currently provided by thermal power, we would need very much more geographically diverse sources outside Europe and thus very long and costly transmission lines.

3.1.2 Security of Supply

Thermal power plants provide secure, dispatchable power, available as required to meet demand. They are not subject to the regular daily intermittency of solar (day/night) or the weather dependent intermittency of solar and wind.

Unlike solar and wind energy, thermal energy can be stored in the form of the fuel. This is especially easy for coal which can be stored in stockyards, less so for gas which needs dedicated stores.

There are ample reserves of fossil fuels, including coal and lignite resources which are indigenous to Europe and these reserves have increased as a result of the discovery and potential use of shale gas. Security of supplies can be assured by using geographically diverse and secure sources of lignite, coal and gas. In the light of recent events, it is crucial for Europe to make use of a balanced energy mixed for a stable and secure energy system.

3.1.3 Sustainability

The energy efficiency of modern plants is 33% higher than older plants[32]. Calculations for the 22GW of plant referenced in section 3.1.1 show that the reduction in burnt coal has **reduced CO_2 emissions by 56.4 million tonnes per year**, equivalent to the **combined GHG emissions** in the energy industries **of Sweden, Ireland, Croatia, Cyprus, Latvia, Lithuania, Malta, Slovenia and Slovakia (56.2 million) in 2012**. However, given the reserves of fossil fuels, the main sustainability issue for fossil thermal power plants is the lock-in of CO_2 emissions from plants used in baseload mode – the lock-in argument does not apply to plants that are being operated in a flexible mode when necessary in order to provide back-up for the non-availability of renewable sources. The potential solution to CO_2 emissions from baseload plant initially, and potentially from flexible plant in the longer term, is CCS which will be essential by 2030 in order to reduce emissions from industrial processes requiring fossil fuels.

Europe is fortunate to have huge potential stores for CO_2 within reach, including storage deep beneath the Central North Sea basin in depleted gas fields and oil fields and in saline formations, sufficient to store as much as 100 million tonnes of CO_2 a year before 2030 and 500 million tonnes a year by 2050 – equivalent to 25% of the total EU emissions (at 2007 levels)[33].

The preparation of this report coincided with the announcement of the start of operations of the world's largest CCS Thermal Power plant project at Boundary Dam in Canada. This project has transformed the aging Unit #3 at Boundary Dam Power Station near Estevan, Saskatchewan into a reliable, long-term producer of 110 megawatts (MW) of base-load electricity and will reduce GHG emissions by one million tonnes of CO_2 each year. Boundary Dam Unit #3 has been retrofitted with a post-combustion capture plant and a new steam turbine

[31] EPPSA Case Study

[32] EPPSA Case Study

[33] Scottish CCS report "Central North Sea - CO_2 Storage Hub -Enabling CCS Deployment in the UK and Europe". http://www.sccs.org.uk/expertise/reports/central-north-sea-co2-storage-hub#downloads

designed to supply the heat requirements of the process.

Progress on CCS in Europe needs to be accelerated if full commercialisation is to be achieved in time to meet the 2030 targets. This requires a continuing commitment to RD&D and the European institutions and those MS which envisage CCS within their energy and security plans should agree upon a clear route forward to implementation.

3.2 Added Value for EU Citizens

3.2.1 Technological Leadership

Europe is a leader in most aspects of Thermal Power technology. Many leading global players in thermal power have their technology hubs in Europe. For example:

- GTs: Siemens, Mitsubishi Hitachi Power Systems Europe (MHPSE) in Germany and General Electric in France each offer the highest efficiency CCGTs available in the world, using HRSGs from EPPSA companies.
- HRSG for CCGTs: CMI in Belgium, Siemens/NEM in Holland, Ansaldo Caldaie, STF and Nooter/Eriksen in Italy, and Bilfinger Power Systems and MHPSE in Germany.
- Coal and Lignite boilers: Andritz in Austria Alstom, Bilfinger Power Systems and MHPSE in Germany, Doosan Babcock in UK, Foster Wheeler in Finland, BWE in Denmark, Ansaldo Caldaie and STF in Italy. Several of these companies are participating in the projects to develop a 50% efficient coal power plant.
- Biomass boilers, conversions and co-firing systems: Andritz in Austria, Foster Wheeler in Finland, Alstom in UK and France, BWE in Denmark and Doosan Babcock in the UK.
- Steam Turbines: Andritz in Austria, Alstom in France, Siemens and MHPSE in Germany, Doosan Skoda in the Czech Republic
- Flue Gas Cleaning: Andritz in Austria
- Carbon Capture: Alstom and MHPSE in Germany, Doosan Babcock in UK, Foster Wheeler in Finland and Spain, Fluor in UK. Each of these companies has designed, built and operated pilot plants for carbon capture and is able to offer "capture-ready designs" for post-combustion capture (coal, lignite and gas) or oxy-fuel (coal and lignite). Alstom is working on the FEED study for the coal-fired White Rose CCS project in the UK, supported by the EU NER 300.
- CO_2 transport and storage: National Grid Carbon and Shell in UK, Total in France.
- Control systems and ancillaries: ABB in many countries, Bilfinger Power Systems in Germany.

The above mentioned do not include the multitude of component, raw material and services companies present in Europe.

Universities and institutes around Europe are very experienced in the area of thermal power plants, emissions control systems and CCS, notably in Germany, UK, France, Spain, Norway, Greece, Denmark, Italy and Poland.

Technological leadership can lead to business opportunities, both inside the EU and in the rest of the world. Such business, both ongoing and new, perfectly complements the ongoing efforts of the EU and the national governments to bring a halt to the de-industrialisation, it creates employment in the form of high level, well-paid jobs and generates tax revenues. Next to technological leadership, however, a stable and predictable home market is a pre-requisite for sustainable business, which, as described above is missing at the present time.

3.2.2 Global Dimension

Even though this paper is focussed on the European dimension of energy politics, it is necessary to keep the global evolution of the energy markets in mind and to see how the European industrial presence is necessary on both the European and global level.

To meet the electricity demand, countries which have fossil fuel resources or access to the very liquid market of LNG or coal, will, in the short to medium term, continue to build and use Thermal Power for base-load purposes. It is also expected that, in the medium to long term, Thermal Power will be needed worldwide to balance renewable energy.

This conclusion is supported by the US EIA[34], which states that, although the share of electricity produced worldwide from coal will go down from 40% to 36%, the total electricity production – most of it in non-OECD countries - will double by 2040 (amounting to an 80% rise in absolute terms of the electricity produced by coal worldwide). It is estimated that, in the next 5 years alone,

[34] Energy Information Agency: International Energy Outlook 2013

utilities in the Asia-Pacific region will order 275 GW of new coal powered plants. This is an important point, as an IEA report[35] states that 60% of all coal power plants newly built over the last decade use the least efficient of commercially available technologies, rather than the best available, thus emitting much more CO_2. With the EIA projection of coal based electricity production at 15,000 TWh, even the difference between "average" and "best" is around 1,500,000,000 tonnes/year of CO_2 emissions, or about 4% of today's global CO_2 emissions. If the BAT was specified for future plants, there would be an environmental benefit and an attractive market for European companies.

The decision of the European Investment Bank not to support power plant technologies that produce more than 550g/KWh (i.e. in practice, to support the building of gas power plants but not coal) has had an unintended consequence, penalising European companies with a negative impact on the environment in, inter-alia, Europe. China, for example, is offering low interest rate loans with a long grace period to build coal-fired plants in Africa and the Balkans. Many Chinese-funded projects are well under way in Europe, which authorise only Chinese manufacturers to provide their technologies. These projects are set to exceed the EIB emission limits, EU legislations and exceed the emissions of state-of the art European coal technology[36].

[35] International Energy Agency: Energy Technology Perspectives 2014

[36] https://www.chinadialogue.net/blog/6794-Dirty-Bosnian-coal-plant-shows-holes-in-China-s-green-investment-drive/en

4. Conclusions and Recommendations

1. EU Energy Policies, especially the short-term targets for 2020 (i.e. 20-20-20) and the long-term aims for 2050 (80-95% GHG emission reductions) have set the market on course for a low-carbon electricity system. This trajectory has been reinforced by the 2014 Policy Framework for Energy and Climate Change package with its binding national targets for 2030 and a 43% cut in CO_2 emissions for the sectors covered by the ETS. The importance of Thermal Power and fossil fuel diversity has not been fully recognised, however.

2. The role of Thermal Power is changing as a result of the increasing deployment of i-RES and thermal power plants are moving from mostly "baseload" to a more flexible operation.

EPPSA has compared the flexibility requirements of a modern electricity system with the technical capabilities of current and future plants. The changes occurring to power system operations as a result of an increasing deployment of intermittent generation have been considered and the associated new requirements that this places on thermal power plants have been examined. It is concluded that the necessary overall load gradients can be met by small numbers of plants with relatively fast (3%/min) ramping rates or a larger number of plants with slower ramping rates.

3. The flexibility characteristics of existing and future thermal power plants have been reviewed.

This includes the results of new EPPSA surveys that set out members' views on BAT and give exemplars of many flexible plants already in operation. It is clear from the experience around Europe that existing thermal power plants (coal, lignite, gas and biomass) are already capable of balancing the variability of demand and intermittent generation whilst meeting environmental limits over their full load range.

4. Many existing thermal power plants are less than optimum in terms of efficiency (and carbon emissions) and flexibility.

- They are less efficient than BAT at full load, and they are frequently being operated at reduced efficiency at part-load. This reduction of efficiency at part-load pushes up the cost of electricity through sub-optimum use of fuel and has an impact on CO_2 emissions

- Replacement of older power plants by modern state–of-the-art plants would achieve energy efficiency improvements of the order of one third, similar to the latest EU efficiency target

- The cycling of plants reduces the plant life and the lifetime will be determined by the number of cycles rather than the total operating hours. Plants will be running for fewer hours and these at part-load. For example, plants optimised for full load operation at 4,000 to 8,000 hours per year (e.g. 'classical' baseload plants) will be expected to operate between 1,500 to 3,000 hours per year at part-load.

5. The increasing deployment of intermittent generation has important consequences for the economics of the whole power system and for future investments.

Modern thermal power plants that were built for base-load and are now only operating at part-load are less economical than anticipated in their investment case. The case for essential investments in new plants must be made against uncertainties in anticipated running hours and in wholesale electricity and fuel prices and many planned projects have been cancelled as a consequence.

6. EPPSA has analysed a number of studies on the EU energy system in 2030 and determined what role can be foreseen for thermal power plants.

A total of 24 scenarios from 7 studies were taken up and compared with regard to electricity generation (MWh) and installed capacity (GW). In addition, they were specifically compared with regard to the additional capacity of Thermal Power needed by 2030 to account for the decommissioning of existing plants. The scenarios review demonstrates that whilst in the decarbonisation scenarios Thermal Power's shares of total generation and capacity decrease, the share of generation does not fall below one third and the absolute capacity required in 2030 still ranges from 423-485 GW, which is similar to the base-case of 479 GW. Significant investment in dispatchable capacity in general, and

thermal power capacity in particular, is required to maintain generation adequacy. Over the next 15 years, around 200 GW of new thermal power capacity must be built.

7. **Thermal Power can continue to provide a significant added value to the EU through to 2030 and beyond, contributing to affordability, security of supply, sustainability and technical leadership**

Affordability. Flexible and baseload thermal power plants will contribute enormously to the affordability of electricity in 2030. Thermal Power (lignite, hard coal, and gas) is significantly less expensive than renewable power in terms of €/MWh, as indicated by the large support subsidies which are necessary to promote the use of renewables. Furthermore, if renewable sources are expected - in 2030 or thereafter – to deliver the electricity currently provided by thermal power, we would need very much more geographically diverse sources outside Europe and thus very long transmission lines. **Security of Supply.** Thermal power plants provide essential, secure, dispatchable power, available as required to meet demand. They are not subject to the regular daily intermittency of solar (day/night) or the weather dependent intermittency of solar and wind. Unlike the energy produced by the latter, thermal energy can be stored in the form of the fuel. There are ample reserves of fossil fuels, including coal and lignite resources which are indigenous to Europe, and these reserves have increased as a result of the discovery and potential use of shale gas. Security of supply can be assured by using geographically diverse sources of lignite, coal and gas.

Sustainability. The energy efficiency of modern thermal power plants is 33% higher than older plants[37]. However, given the reserves of fossil fuels, the main sustainability issue for fossil thermal power plants operating is CO_2 emissions. A potential solution to these emissions is CCS which will be essential by 2030 in order to reduce emissions from all industrial processes requiring fossil fuels. Europe is fortunate to have huge potential stores for CO_2 within reach, including storage deep beneath the Central North Sea basin in depleted gas fields and oil fields and in saline formations, sufficient for as much as 100 million tonnes of CO_2 per year by 2030 and 500 million tonnes a year by 2050 – equivalent to 25% of the total EU emissions (at 2007 levels).

Technological Leadership. Europe is a leader in most aspects of Thermal Power technology, including GTs, HRSGs, coal and lignite fired boilers and steam turbines, CO_2 capture, and storage systems, and control systems/ancillaries. Many leading global players in Thermal Power have their technology hubs in Europe. New plants and retrofits are being designed and built, many by EPPSA members, for improved efficiency, flexibility (minimum load, reduced start-up times and faster ramp rates) and to cope with thermal cycling. Coal, lignite, biomass and gas power plants can be optimised for flexibility and there is scope for further improvements. Universities and institutes around Europe are very experienced in the area of thermal power plants and CCS, notably in Germany, UK, France, Spain, Norway, Greece, Denmark, Italy and Poland. Technological leadership can lead to business opportunities, both inside the EU and in the rest of the world. It is estimated, for example, that, in the next 5 years alone, utilities in the Asia-Pacific region will need 275 GW of new coal powered plants. If the BAT was provided for these future plants, there would be a clear environmental benefit and an attractive market for European companies. Such business, both ongoing and new, perfectly complements the ongoing efforts of the EU and the national governments to bring a halt to de-industrialisation, it creates employment in the form of high level, well-paid jobs and generates tax revenues. Next to technological leadership, however, a stable and predictable home market is a pre-requisite for sustainable business, which, as described above, is missing at the moment.

Policy. EU and MS policy makers must address the dichotomy between, on the one hand, the continuing importance of Thermal Power in 2030 and beyond and, on the other, the lack of economic viability under current policies. Policy makers should accordingly assess the impact of new policies on electricity markets, affordability, investment, business opportunities and RD&D, including flexible power plants and CCS. Adequate funding, a stable regulatory framework and public acceptance need to be combined with enhanced Research and Innovation efforts in order to maintain Europe's leading technological competence in the current and future knowledge-based economy. European centres of R&D excellence will contribute to creating skills and jobs and exporting efficient cutting-edge European technology to countries who need thermal power for back up or who cannot make full use of renewable energy.

[37] EPPSA case study

Abbreviations and Acronyms

BAT	Best Available Technology
BREF	Best Available Technology Reference Document
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage
CFB	Circulating Fluid Bed
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
EE	Energy Efficiency
ELV	Emission Limit Value
ESP	Electrostatic Precipitator
ETS	Emission Trading System
EU	European Union
GHG	Greenhouse Gas(es)
GT	Gas Turbine
GW	Gigawatt
HRSG	Heat Recovery Steam Generator
IED	Industrial Emissions Directive
i-RES	Intermittent Renewable Energy Sources
JRC	Joint Research Centre of the European Commission
kWh	Kilowatt Hour
LCPD	Large Combustion Plant Directive
LHV	Lower Heating Value
LNG	Liquid Natural Gas
MCR	Maximum Continuous Rating
MS	Member State(s)
MWh	Megawatt Hour
NER	New Entrants' Reserve
NO_x	Nitrogen Oxide
NREAP	National Renewable Energy Action Plan
OCGT	Open Cycle Gas Turbine
OT	Once-Through
PC	Pulverised Coal
PV	Photovoltaics
R&D	Research and Development
RD&D	Research, Development and Demonstration
RES	Renewable Energy Sources
RoR	Return on Investment
SCC	Siemens Combined Cycle
SCR	Selective Catalytic Reduction
SNCR	Selective Non-Catalytic Reduction
SO_x	Sulphur Oxide
TWh	Terawatt Hour
TYNDP	Ten Year Development Plan
USC	Ultra-Supercritical

Bibliography

- BET (2013), "Möglichkeiten zum Ausgleich fluktuierender Einspeisungen aus Erneuerbaren Energien"
- Delors et al. (2011), "Towards a European Energy Community: A Policy Proposal"
- DG Energy (2013a), "EU Energy Trends to 2050"
- DG Energy (2013b), "Capacity Mechanisms in Individual Markets within the IEM"
- ENTSO-E (2013), "2030 Visions"
- EPPSA (2013), "Energy Supply for Europe – Facts and Perspectives"
- Eurelectric (2009), "Power Choices: Pathways to Carbon-Neutral Electricity in Europe by 2050"
- Eurelectric (2013), "10 CEOs Push for EU Energy Policy to Change Direction"
- Eurelectric (2013), "Power Statistics and Trends 2013"
- European Climate Foundation (2011), "Power Perspectives 2030: On the Road to a Decarbonised Power Sector"
- European Commission (2006), "A European Strategy for Sustainable, Competitive and Secure Energy", COM(2006) 105 final
- European Commission (2007), "An Energy Policy for Europe", COM(2007) 1 final
- European Commission (2011), "Energy Roadmap 2050", COM(2011) 885 final
- European Commission (2013), "Green Paper: A 2030 Framework for Climate and Energy Policies", COM(2013) 169 final
- European Commission (2013), "Delivering the internal electricity market and making the most of public intervention", COM(2013) 7243 final
- Eurostat, 2013
- Greenpeace (2010), "Energy (R)Evolution: Towards a Fully Renewable Energy Supply in the EU-27"
- JRC (2009), "Future Fossil Fuel Electricity Generation in Europe: Options and Consequences"
- Kakaras et al. (2013), "Solutions from the European Power Plant Suppliers' Perspective"
- Treaty on the Functioning of the European Union (2009)
- VDE (2012), "Erneuerbare Energie braucht flexible Kraftwerke – Szenarien bis 2020"

EPPSA
European Power Plant Suppliers Association
Avenue Adolphe Lacomblé 59
B-1030 Brussels
phone +32 2 743 29 86
fax +32 2 743 29 90
www.eppsa.eu

Developing the Future

www.eppsa.eu