Energy transitions in Europe – common goals but different paths

Euro-CASE

Energy transitions in Europe – common goals but different paths

A Euro-CASE report

Euro-CASE energy platform/Steering Committee

About Euro-CASE

The European Council of Academies of Applied Sciences, Technologies and Engineering is an independent non-profit organisation of national academies of Engineering, Applied Sciences and Technology from 23 European countries. It was founded in 1992 upon French initiative by the members of CADAS (Conseil pour les Applications de l'Académie des Sciences). The Executive Committee meets four times a year. The Board meets once a year. Euro-CASE acts as a permanent forum for exchange and consultation between European Institutions, Industry and Research.

Through its Member academies, Euro-CASE has access to top expertise (around 6,000 experts) and provides impartial, independent and balanced advice on technological issues with a clear European dimension to European Institutions, national Governments, companies and organisations.

Mission statement

The mission of Euro-CASE is to pursue, encourage and maintain excellence in the fields of engineering, applied sciences and technology, and promote their science, art and practice for the benefit of the citizens of Europe.

In pursuit of this mission the objectives of Euro-CASE are:

- Maintain a leadership role in promoting attention to excellence in applied sciences and engineering and to related issues of key importance to Europe,
- Ensure that the societal impact of technological change is given proper attention with full consideration of environmental and sustainability aspects,
- Provide impartial, independent and balanced advice on engineering and applied science issues that affect Europe and its people to the European Commission and Parliament, and other European institutions,
- Promote the importance of applied sciences and engineering throughout Europe and to develop greater public understanding and interest,
- Attract young Europeans into careers in applied sciences and engineering in order to ensure future technological progress in Europe,
- Draw on the experience and best practices of the national academies of engineering and applied sciences in Europe, developing appropriate,
- Information networks.

Governance

Euro-CASE is governed by a Board consisting of senior representatives from each Member Academy. An Executive Committee is elected from the Board.
The secretariat is based in Paris, hosted by the National Academy of Technologies of France in the Grand Palais des Champs Elysées.

Energy transitions in Europe – common goals but different paths

Euro-CASE energy platform/Steering Committee

1. Foreword

The Paris Agreement on bringing climate change to a halt was signed after the COP 21 in Paris in November/December 2015. There is today little controversy about the influence of man-made CO_2 emissions on climate change, which mainly results from burning fossil fuels for energy generation. However, presently the efforts of EU Member States to meet the targets of the Paris agreement by reducing CO_2 emissions through a number of measures, are diverging between EU member states to a large extent. This is predominantly due to the different energy systems that have been established in these states over time, which in turn are partly a consequence of the presence or absence of energy resources. It is still far from clear how the objectives of the Paris Agreement will be met given the various uncoordinated approaches to the energy transition in the member states.

Euro-CASE, the European network of engineering academies is aware of this diversity of approaches to CO_2 emission reduction and has therefore established an "Energy Platform" and a Steering Committee to explore the situation and create awareness among the concerned community.

It is hoped that the present report will help all those who support the efforts to make the various strategies for the energy transition a success.

Based on the underlying premise that the European Academy alliances may play a crucial role in shaping national energy policies, which remain the responsibility of Member States, the present Euro-CASE paper is intended to inform Academy members in EU countries about energy issues that all European states and peoples are confronted with and the energy-policies and -efforts that have been put in place to deal with them. This role comprises fact-based consulting of society and politics and may include suggestions for common projects and European cooperation.

This report does also inform about the ambitious climate protection goals of the European Community, which, in principle, should be sealed by binding international contracts.

Furthermore, it does inform about the various efforts to replace CO_2-generating fossil energy sources with renewable energy sources such as water and wind power, photovoltaics, geothermal energy, or biomass and the difficulty in dispatching the electricity from such sources on demand and not as available. Energy storage, in what-so-ever form, is hence a major issue for the energy transition. Other issues include, for example, more efficient energy conversion, heat insulation of buildings, mobility, but also the inertia inherent in existing energy systems that have been built to last and that have consumed considerable investments.

Finally, the report emphasises that the effort to reduce greenhouse gas emissions must be a global effort as highlighted by the Paris agreement and that Europe should play a leading role in this effort.

The President of Euro-CASE and the Chair of the Steering Committee of the energy platform wish to thank all Committee members and the scientific officer for their unrelenting commitment to producing the present report

Prof. Reinhard Hüttl,
President of Euro-CASE

Prof. Eberhard Umbach,
Chairman of the Euro-CASE
Energy Platform Steering Committee

2. Scope and purpose of the paper

It is widely agreed that one of today's grand global challenges is the fight against climate change and – related to it – the reduction of the steep increase of greenhouse gases, especially CO_2, in the atmosphere. This increase is clearly related to our human activities in the past 150 years and has in the meantime reached levels much higher than any value that has ever been determined for the past several hundred thousand years. The main source of CO_2 emissions, the burning of fossil fuels for energy conversion into electricity, heat/cold, and mobility, can only be reduced if we change our energy system nearly completely. The main goal of this transition is the replacement of fossil by non-fossil energy sources like the so-called renewable energies (water and wind power, photovoltaics, geothermal energy, or biomass) flanked by a continuous increase of conversion efficiency and by energy savings for instance by better heat insulation. Such an energy transition is complex, expensive, time-consuming and requires a change of our industrial processes, transport systems and personal habits. Therefore, it has considerable inertia and hence needs a continuous stimulation by incentives and other steering actions, an effort far more arresting and challenging than sending a human to Mars.

In order to be finally successful in fighting climate change the energy transition must be a global effort involving all countries around the globe. Although only a relatively small contributor compared to the US or China, Europe plays an important role in this challenge because it is in many respects leading (or at least amongst the leading regions): for instance, in the energy consumption and hence CO_2 emission per person, in the amount of industrialization and production, and in the awareness that the global resources are limited, our environment must be protected, and the climate change must be limited. Therefore, Europe must lead the way in climate protection and energy transition as good example and with highest possible speed.

But Europe is very heterogeneous and in many respects complex – culturally, historically, economically, and politically. This is also true for the energy systems of the various European countries and the ways and priorities with which the energy transitions are handled. Nevertheless, the European Union has agreed on common, well-defined goals and has committed itself in binding contracts to well defined achievements in climate protection (e.g. United Nations Framework Convention on Climate Change, COP 21 in Paris 2015). These goals have very recently (Dec 2018) been reconfirmed, and a process to define the contributions of the various countries in detail and to monitor their progress in meeting the goals has been set up.

The purpose of the present academy-internal paper is to inform the members of European academies about this energy issue, especially about the energy diversity in Europe and the various approaches of energy transitions. It should also inform about the very ambitious common goals of the European Community in climate protection which were promised to be met by binding international contracts. Based on the knowledge of this diversity and of the complexity of Europe and its different approaches to climate protection and based on the knowledge that the final responsibility remains with the member states it becomes clear that the academies and in particular the European academy alliances may play an important perhaps catalyzing role. This role comprises information and communication as well as fact-based consulting of society and politics and it may include suggestions for common projects and European cooperation.

The structure of this paper is as follows: chapter 2 presents selected data (mostly from Eurostat) with short explanations and comments showing the versatility of the European energy landscape. Chapter 3 addresses the goals of the European Community and the role of EU commission and parliament. In chapter 4 more detailed examples from some of those member states which were represented by members of the Steering Committee are given. And the final chapter 5 draws some obvious conclusions from the information given in the previous chapters.

3. Energy systems in the EU

With the following chapter we want to draw a picture of the status quo of the European energy system. Thus, we will discuss a few selected variables and summarise the quantities for EU-28 as well as draw attention to the diversity of the individual countries. Most of the considerations are based on energy data consolidated by Eurostat[1] and published annually[2].

The starting point for the considerations is the greenhouse gas emissions. They are considered to be the origin for the man-made recent climate change through the greenhouse effect. In order to mitigate the impact of climate change, greenhouse gas emissions have hence to be reduced.

Emissions

Despite all political discussions and decades of efforts to reduce greenhouse gases, global energy-related CO_2 emissions are rising slightly but steadily.[3] The EU contributes a share of approx. 10.6% (3542 Mt CO_2). The chronological course of the total (not only energy-related) emission of greenhouse gases in the EU can be seen in Figure 1. In 2016, GHG emissions were 4.4 billion tons of CO_2 equivalents[4], 22% below 1990 levels. The diamond in the figure marks the EU target for 2020 (20% reduction) for GHG emissions, which in fact have fallen short of this level already in 2016. However, increased efforts are needed to achieve the target value for 2030 (reduction of at least 40%).

A comparison of the individual countries shows a wide dispersion of the relative changes between 1990 and 2016 (Figure 2). This is due to different energy mixes and economic developments in these countries during that period. Lithuania, Latvia and Romania show the strongest reduction in GHG emissions. On the other hand, Portugal and Spain, for example, have experienced an increase of 16%. When looking at the absolute figures[5], it is noticeable that greenhouse gas emissions were highest in Germany (21% of the EU-28 total or 936 million tons of CO_2-equivalents), followed by the United Kingdom and France.

---

[1] Eurostat is the statistical office of the European Union. Its mission is to provide high quality statistics for Europe. It consolidates beyond other topics statistical data on energy collected by the member states and provides analyses. A good overview can be found on https://ec.europa.eu/eurostat/web/energy/data/main-tables (download 5.1.2019).

[2] So for example in the annual report "Energy, transport and environment indicators" published lately in the 2018 edition (https://ec.europa.eu/eurostat/documents/3217494/9433240/KS-DK-18-001-EN-N.pdf/73283db2-a66b-4d34-9818-b61a08883681) (download 5.1.2019).

[3] https://www.bmwi.de/Redaktion/DE/Downloads/Energiedaten/energiedaten-gesamt-pdf-grafiken.pdf?__blob=publicationFile&v=38 (download 5.1.2019) or "BP statistical review of world energy", June 2018 https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf (download 5.1.2019).

[4] "CO_2 equivalent is a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential." (See annual report "Energy, transport and environment indicators", Eurostat.)

[5] The table with absolute numbers can be found in the annex A1.

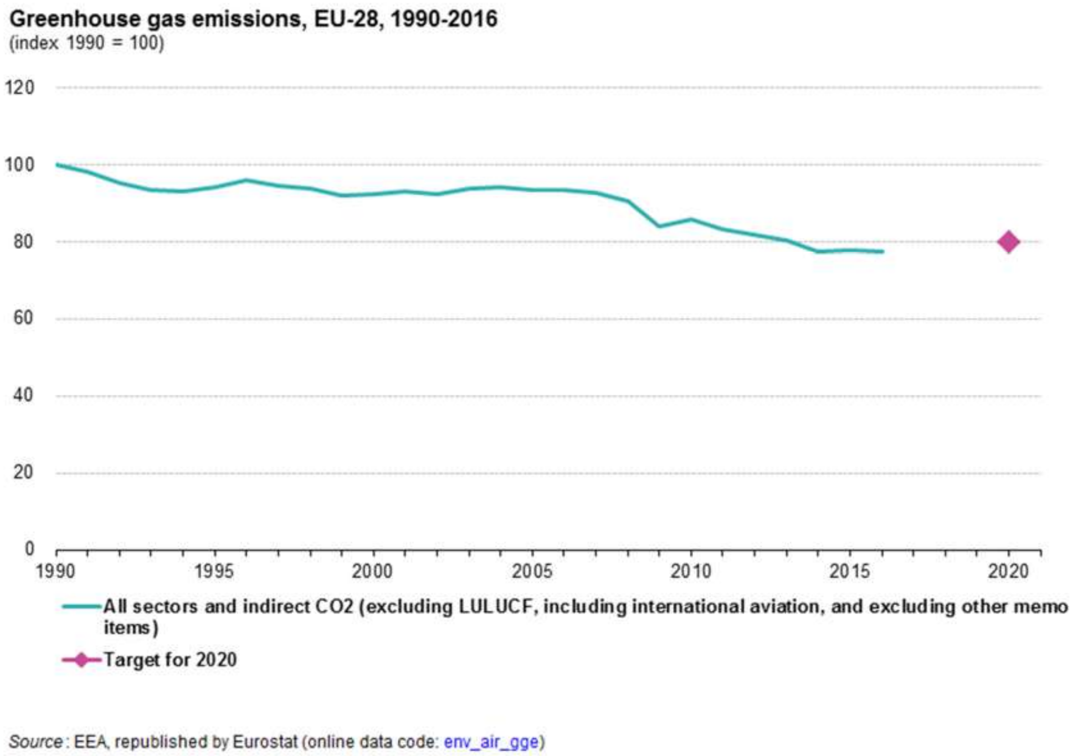


Figure 1: Greenhouse gas emissions in Europe from 1990 to 2016. Source: EEA, republished by Eurostat [(env_air_gge)](), https://ec.europa.eu/eurostat/statistics-explained/index.php/Climate_change_-_driving_forces#General_overview

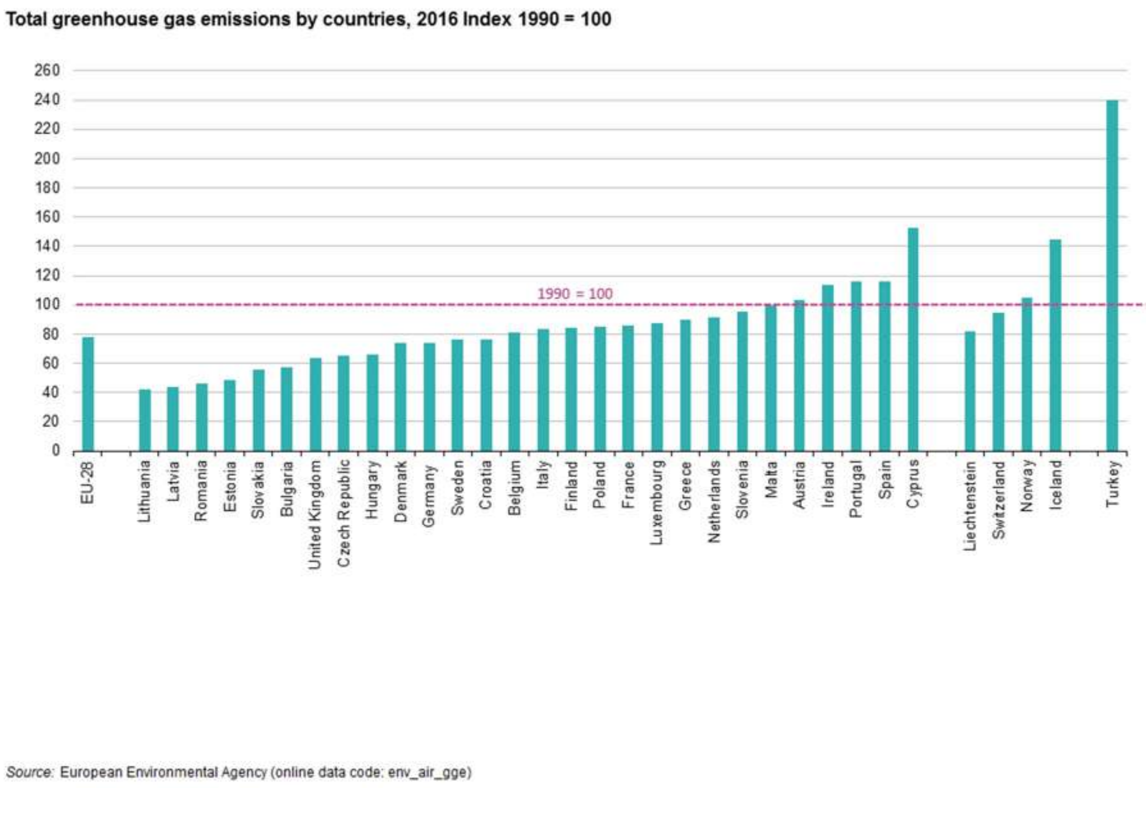


Figure 2: Total GHG emissions by country (Eurostat [(env_air_gge)](), https://ec.europa.eu/eurostat/statistics-explained/index.php/Climate_change_-_driving_forces#General_overview)

The average reduction of 22% is made up of widely scattering values from the individual (IPCC) energy sectors[6]. With the exception of the transport sector (including international aviation), all other sectors show reductions in GHG emissions in absolute and relative terms.[7] This applies in particular to the energy industry and private households.[8] Figure 3 shows the GHG emissions in 2016 by IPCC source sector. Evidently, (fossil) fuel combustion is responsible for over ¾ of the GHG emissions. The largest shares have the transport (24,3%) and the energy industry sector (26,9%). Note, that fuel combustion has mainly a fossil origin but can also have a non-fossil origin, as it is the case for waste combustion.

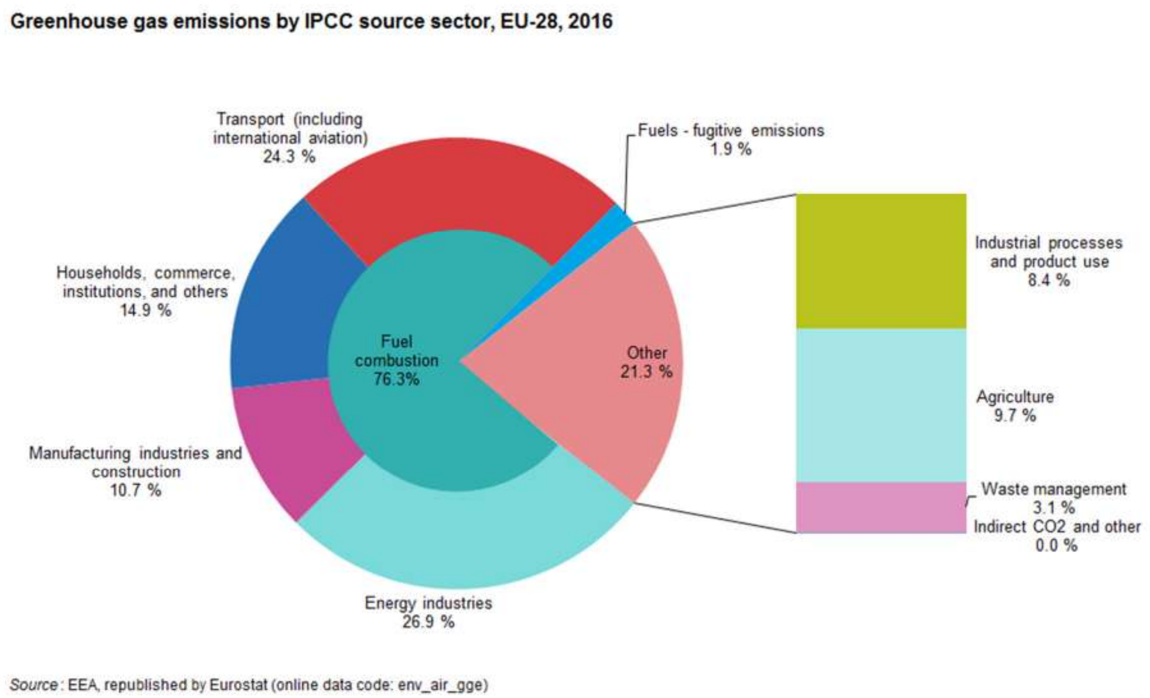


Figure 3: Greenhouse gas emissions by IPCC source sector: Eurostat (env_air_gge), https://ec.europa.eu/eurostat/statistics-explained/index.php/Climate_change_-_driving_forces#General_overview)

Gross inland energy consumption

The gross inland energy consumption[9] amounts to **68 EJ[10]** in 2016 for EU-28. This is the quantity of energy which is necessary to satisfy the energy needs of the 28 EU states. These 68 EJ are produced

[6] IPCC source sectors are according to the technological source of emissions: a) energy (fuel combustion and fugitive emissions from fuels) — which also includes transport; b) industrial processes and product use; c) agriculture; d) land use, land use change and forestry (LULUCF); e) waste management.
[7] EEA, republished by Eurostat (env_air_gge) (download 5.1.2019)
[8] See discussion in https://ec.europa.eu/eurostat/statistics-explained/index.php/Climate_change_-_driving_forces#General_overview
[9] It is the quantity of energy consumed within the borders of a country and calculated: primary production + recovered products + imports + stock exchange –exports – bunkers.
[10] 68 EJ=68 Mio TJ=68*10^{18} J and 1 TJ=0,2778 GWh

by conversion of different primary energy carriers. Figure 4 shows the composition of theses primary energy carriers in 2016 for the EU-28.[11]

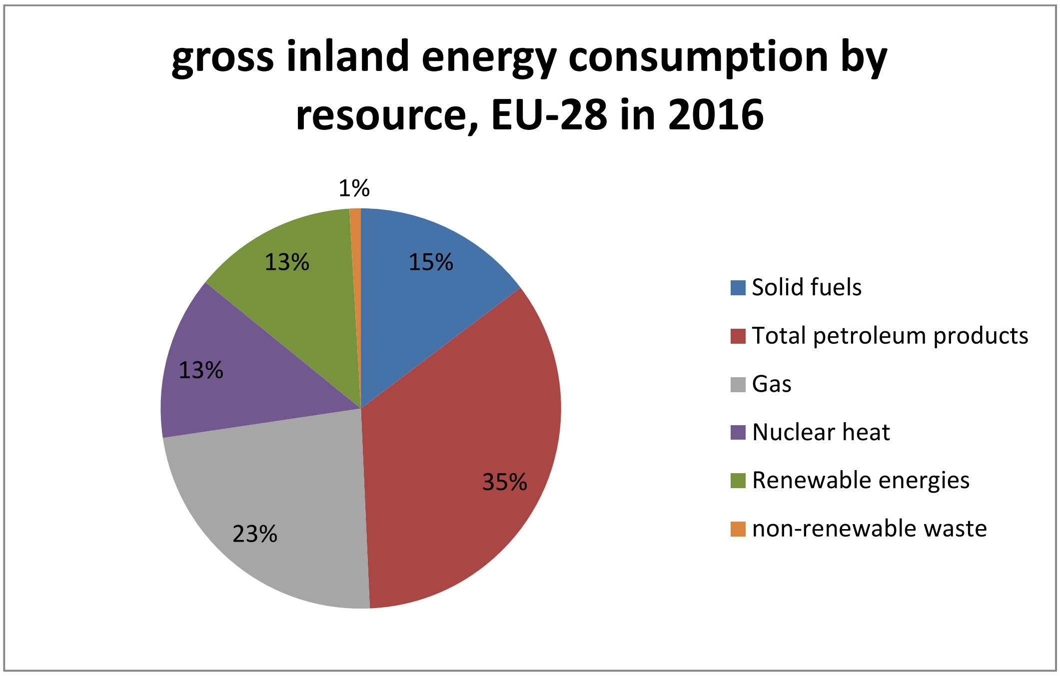


Figure 4: Gross inland energy consumption by resource in the EU 18 in 2016.

Data taken from https://ec.europa.eu/eurostat/web/energy/data/main-tables)

This figure emphasizes the still persisting importance of fossil resources in the energy system: Gas, total petroleum products and solid fuels make over 73%. Nuclear energy sources contribute with 13%. Renewable energies (RE) contribute to the same account (13%). However, there are big differences between the countries which can be seen in Figure 5.

In France, for example, the use of nuclear energy dominates with a contribution of over 40%, but also in Sweden it has a share of over 30%. However, Sweden has a disproportionately large share of RE. Only Latvia, Austria, Denmark and Finland have similarly high RE shares. Countries such as Belgium, Luxembourg, the Netherlands and even the UK lag behind in the use of renewable energies. In Germany RE account for just over 10% of gross energy consumption. Coal dominates in the eastern EU countries such as Estonia, Poland and Serbia. (The temporal development of the gross inland energy consumption can be found in Figure 14 and in the annex A6.)

[11] Definitions: **Solid fuels** are fossil fuels covering various types of coals and solid products derived from coals. They consist of carbonised vegetable matter and usually have the physical appearance of a black or brown rock. **Total petroleum products** are fossil fuels (usually in liquid state) and include crude oil and all products derived from it (e.g. when processed in oil refineries), including motor gasoline, diesel oil, fuel oil, etc. **Gas** includes mostly natural gas and derived gases. **Renewable energies** are energy sources that replenish (or renew) themselves naturally, such as solar, wind, hydro, geothermal, biomass and renewable wastes, etc. **Nuclear heat** is the thermal energy produced in a nuclear power plant (nuclear energy). It is obtained from the nuclear fission of atoms, usually of uranium and plutonium.

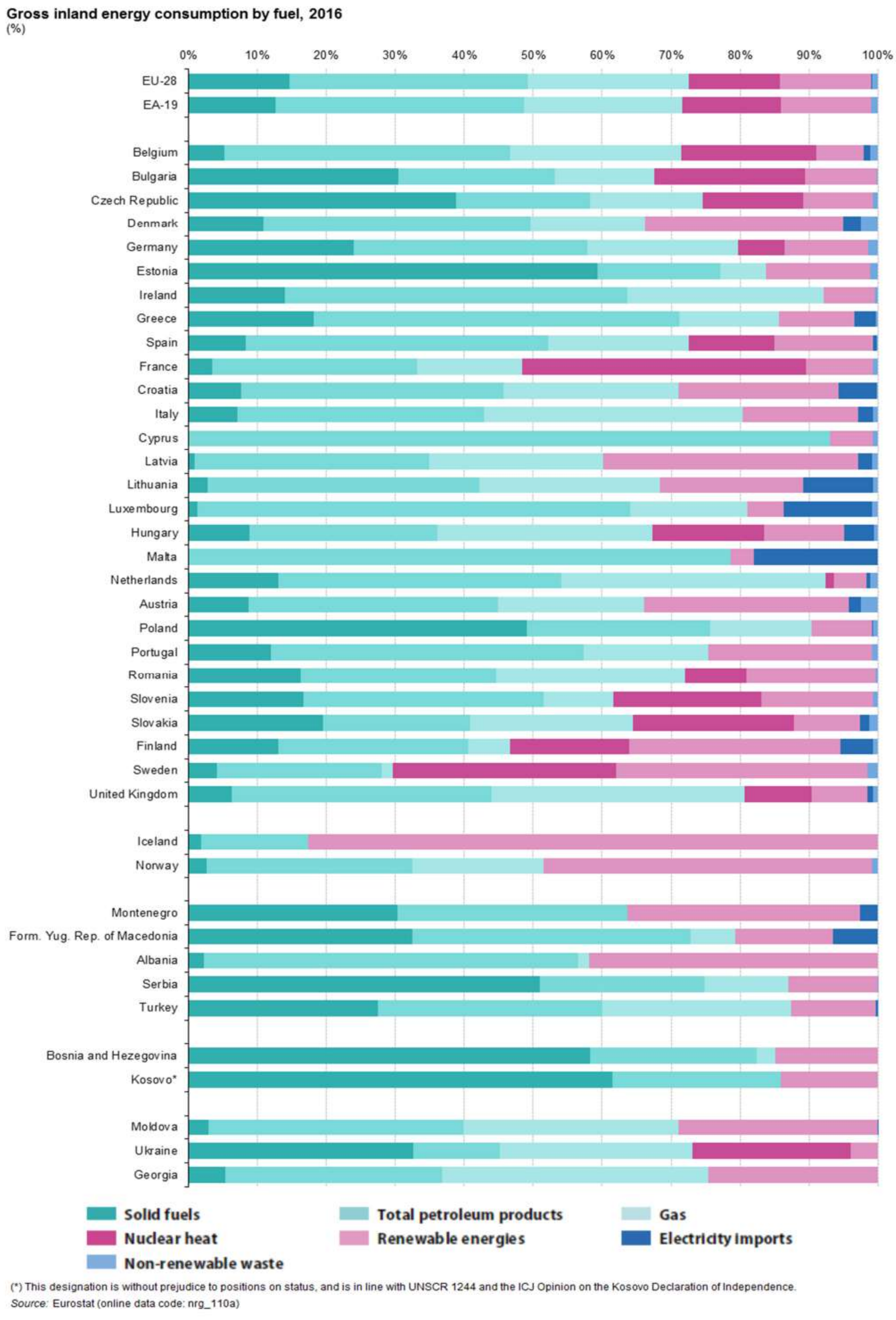


Figure 5: National shares of fuels in gross inland energy consumption in 2016.

Primary energy production

Only 31 EJ[12] of the 68 EJ of energy consumption are produced in the EU-28. 62 EJ are imported, 24 EJ are exported. This results in a net import of about 38 EJ, i.e. more than half our primary energy must presently be imported. The imported energy consists almost exclusively of fossil fuels such as mineral oil, gas and coal. The composition of those primary energy sources that are produced within EU-28 is shown in Figure 6. Fossil energy sources account for more than 40% of EU's primary energy production. After all, nuclear energy is still about 30% of the energy mix and is therefore of a similar order of magnitude to RE.

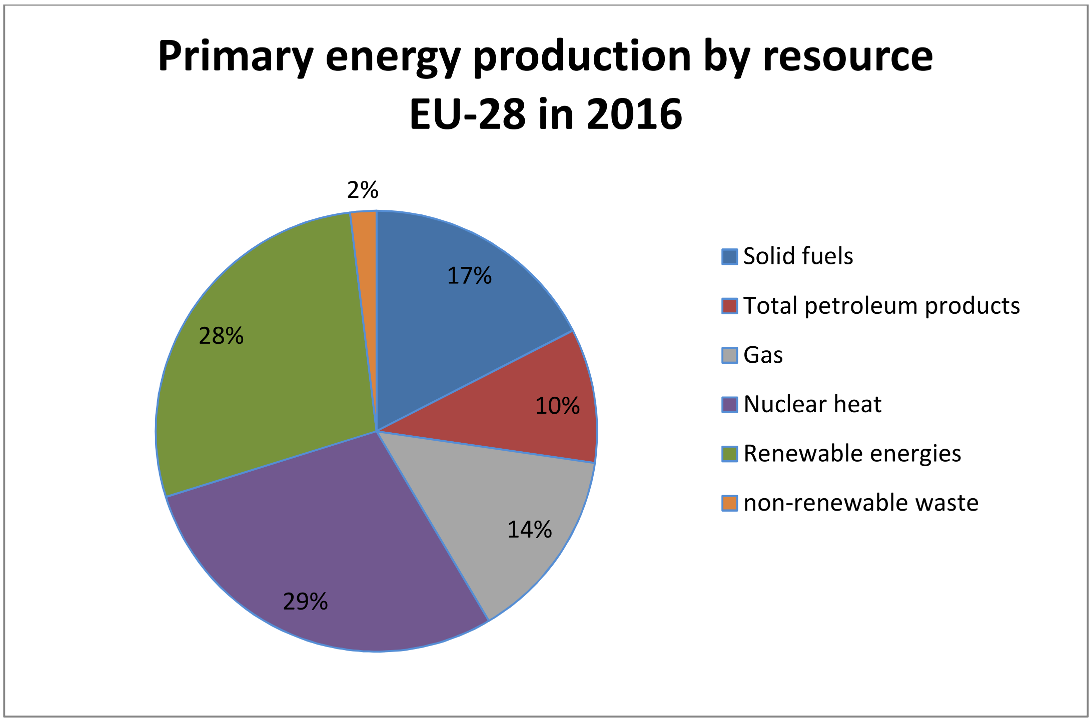


Figure 6: Primary energy production in 2016 by resource.

The temporal development of EU's primary energy production from 1990 to 2016 (**Error! Reference source not found.**7) reveals that nuclear energy production remained relatively constant. Fossil energy sources such as gas, solid fuels and total petroleum products decreased during this period, while primary energy production of RE increased significantly. However, overall primary energy production is declining. This reduction goes hand in hand with an increase in imports of primary energy and energy products making EU-28 more dependent on politically unstable regions. (The temporal development of the final energy consumption can be found in the annex A7.)

[12] 31626642 TJ (31 Mio TJ=31 EJ) (Eurostat nrg_109a)

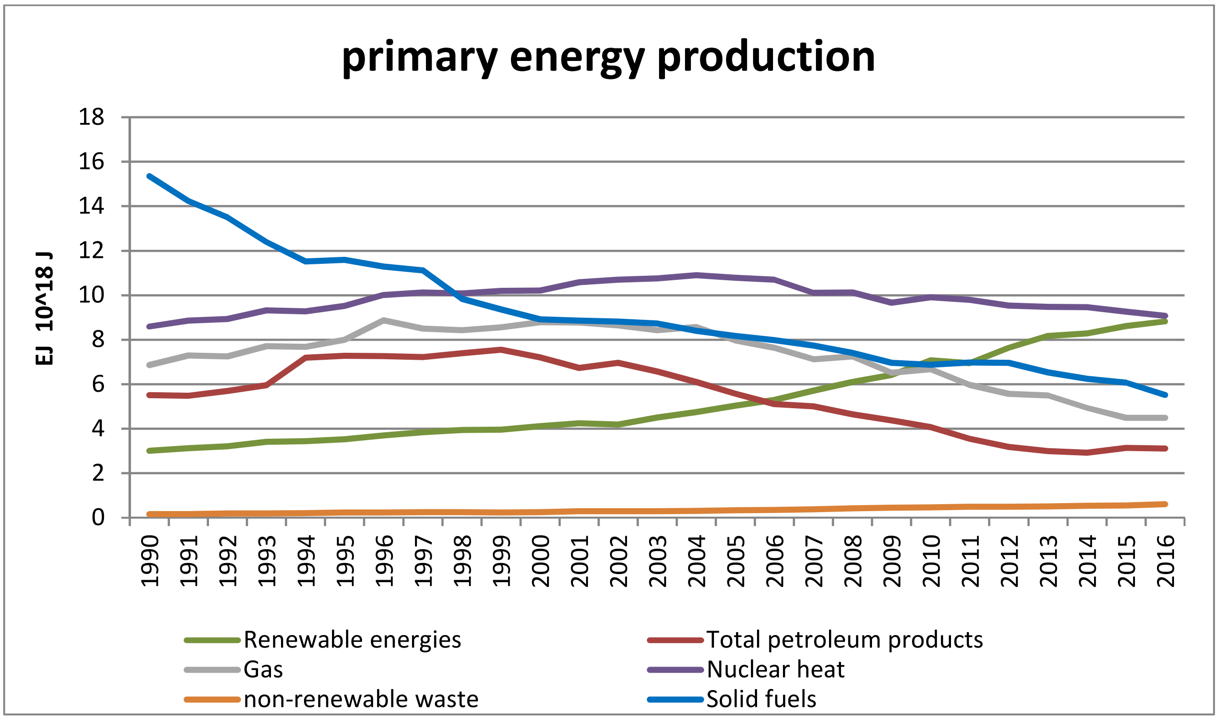
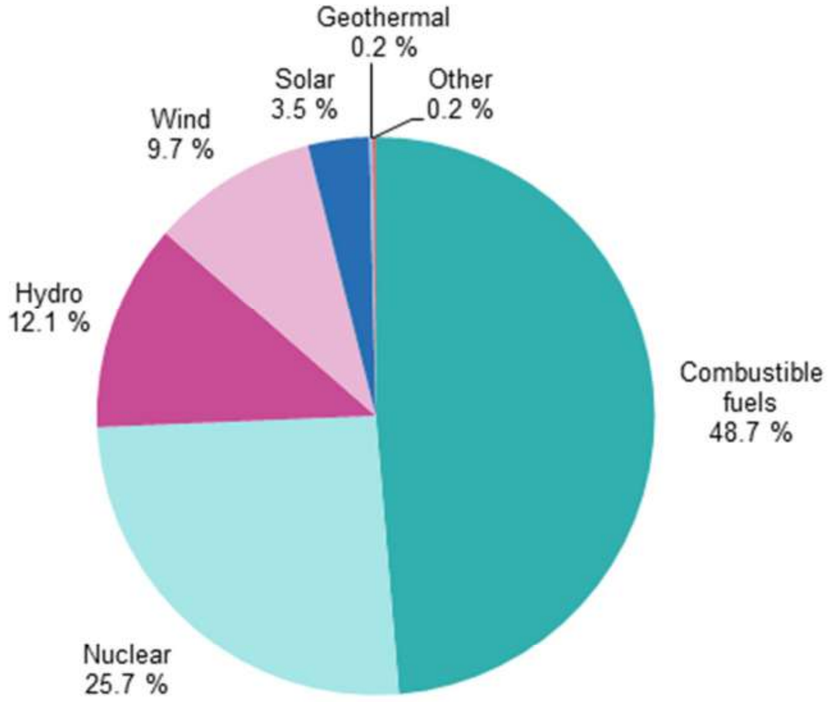


Figure 7: Primary energy production of the EU-28 from 1990 until 2016.

Electricity

In 2016, a total amount of 3.1 million gigawatt hours[13] (GWh) net electricity was generated in the European Union. Within the last 10 years the net electricity generation fluctuated slightly between 3.2 and 3.03 million GWh (2014) but has increased slightly but steadily since 2014. Figure 8 shows that almost 50% of the generated electricity comes from combustible fuels such as gas and coal. Further 25% of the electricity s generated by nuclear power plants. A similar share is accounted for by renewable energies. Among these, hydro power is the most important renewable energy source for electricity generation, followed by wind power. Solar energy only accounts for 3.5% of electricity generation. Wind and solar power show the strongest growth rates in the last 10 years, whereas the hydroelectric power contribution remains approximately constant.

[13] 1GWh=3.6TJ and 1 EJ=1*10^{18} J=1*10^{6} TJ



Source: Eurostat (online data code: nrg_105a)

Figure 8: Net electricity generation in the EU-28 in 2016.

The picture for the individual EU countries is again very diverse. Figure 9 shows the sources of electricity generation in the different countries, sorted by the proportion of fossil fuels. These shares range from over 80% e.g. in Estonia, Poland or the Netherlands to under 10% in France and Sweden. In these two countries, the low share of fossil fuels for electricity production is clearly attributable to electricity generation from nuclear power. This look at the composition of the sources of electricity generation clearly shows the differences between the energy systems in the European countries and thus the large but very different challenges that have to be overcome in order to turn energy production towards climate-neutral energy systems.

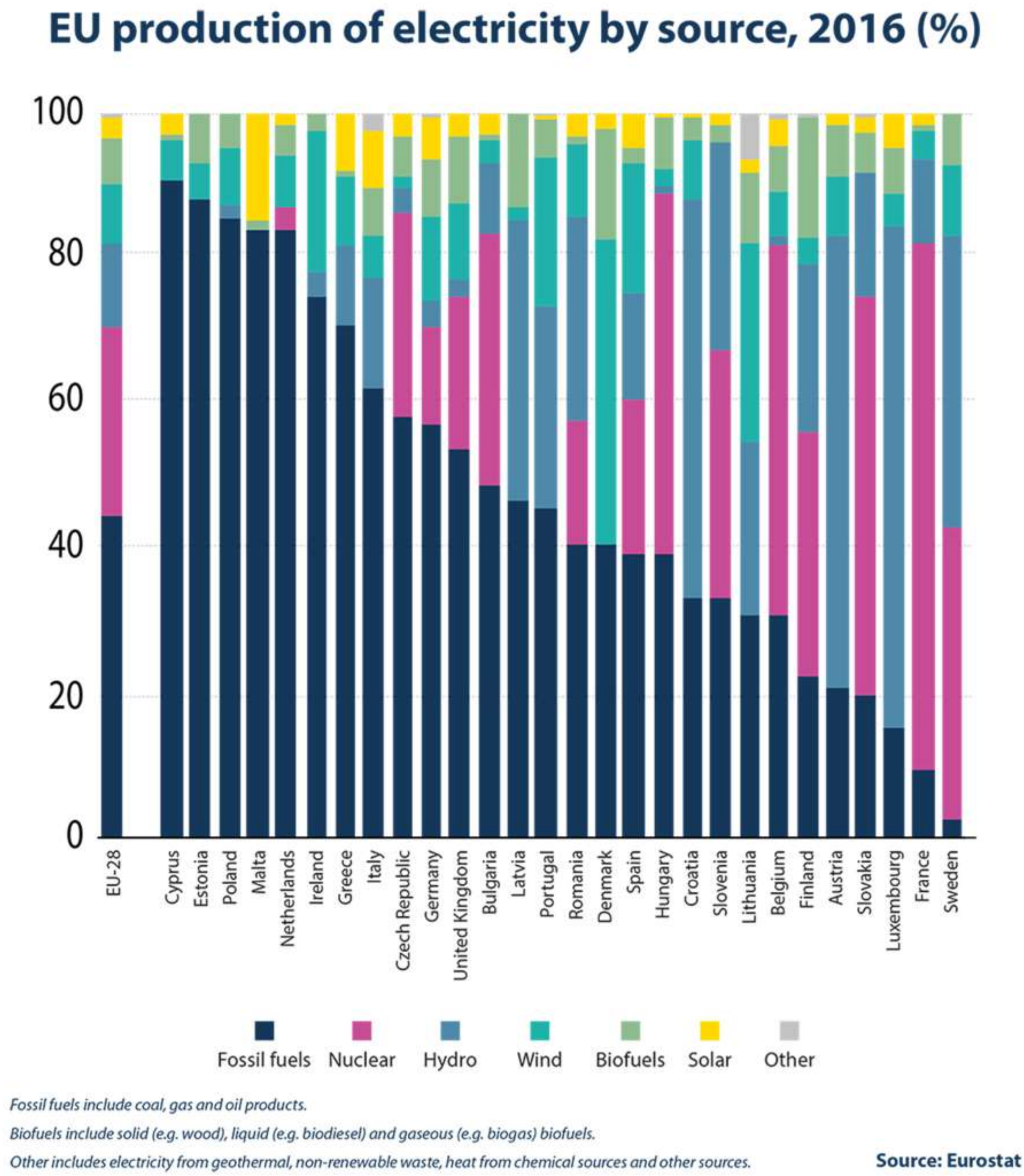


Figure 9: Production of electricity by source and country in 2016.

Renewable energies

The share of renewable energies in the energy system has increased significantly since 1990. Whereas in 1990 about 3 EJ of primary energy were generated from RE, this share has tripled by 2016 (Figure 10). In contrast to hydro power, whose share remained almost constant over the entire period, all other RE contributions increased. Although biomass is a limited resource in Europe, its contribution has increased significantly. In 2016, biomass (e.g. wood, biogas or liquid biofuels) accounted for the largest share of around 60%. Wind and especially PV still contribute only little to the primary production despite their public attention.

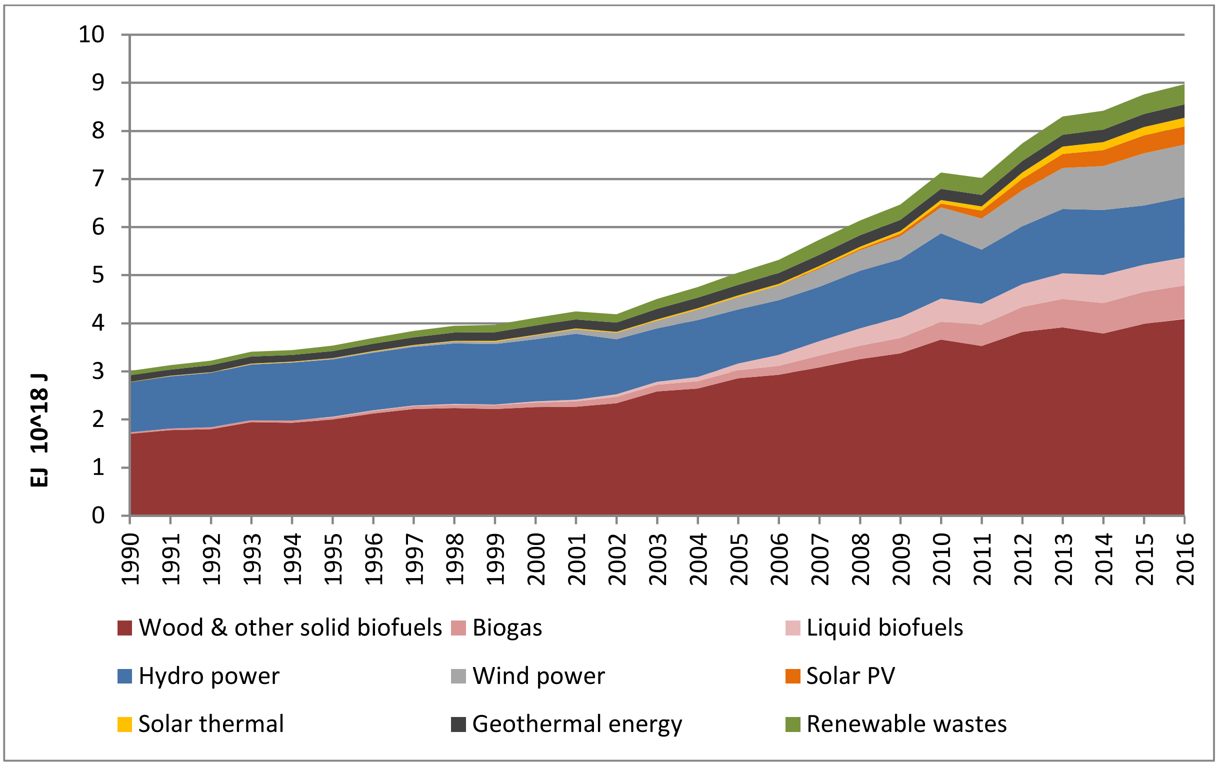


Figure 10: RE shares of primary energy production with time.

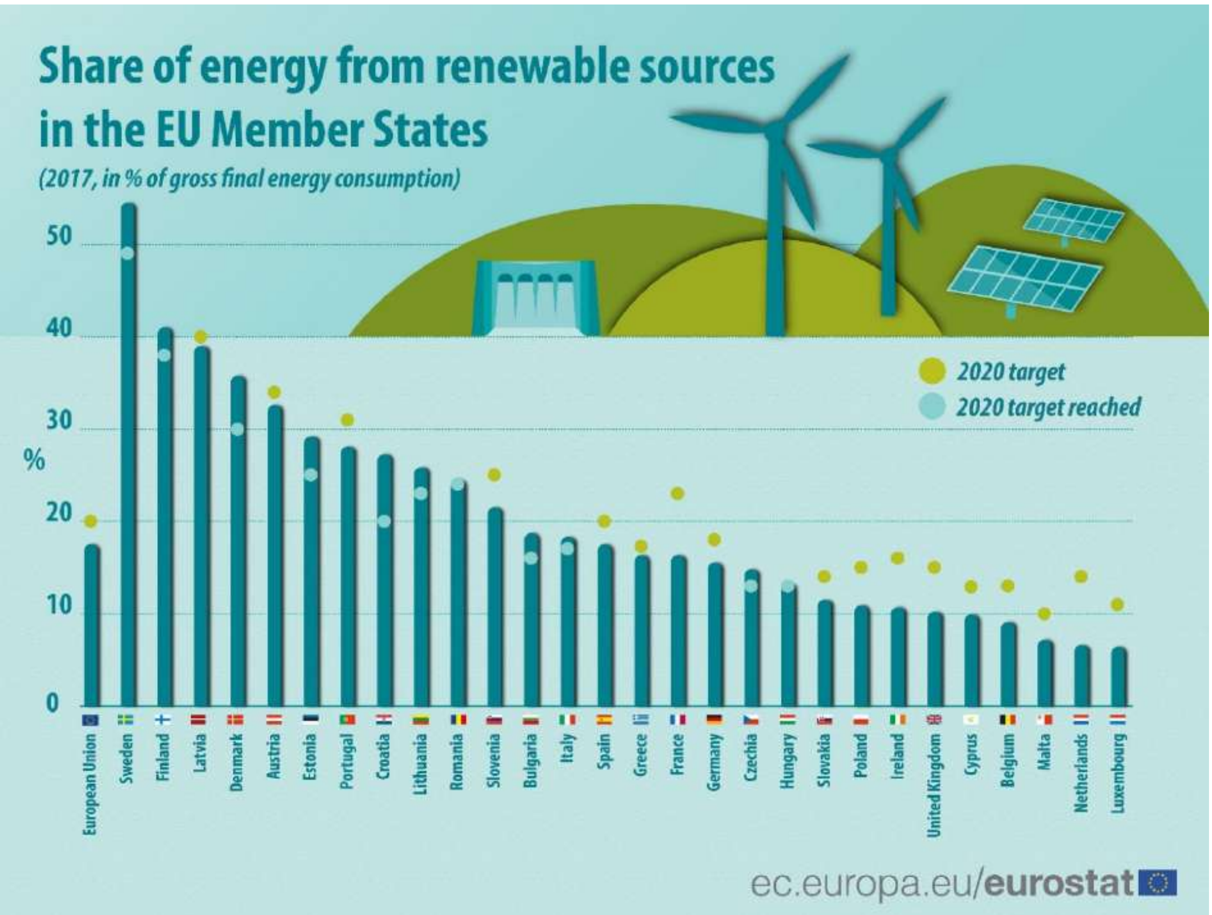


Figure 11: Share of the RE of gross final energy consumption in EU-28 in 2017.

To rapidly increase the share of REs in the energy systems is in the focus of the EU energy transition policy as well as of that of many individual states. **Error! Reference source not found.** shows the comparison between the actual shares of RE and the target values for 2020 in all EU countries. On average, EU-28 is on the right track and, with a little luck, will reach its 2020 target. The individual countries are very different. Some countries such as Sweden, Romania or Italy have already reached the target they set themselves, while other countries such as France, but also Germany or Slovenia will only perhaps reach the target. The share itself shows a wide range from over 50% in Sweden to around 10% in the United Kingdom, or even less in Belgium and the Netherlands. This graph illustrates not only the range of policy objectives, but also the diversity of energy systems in the member countries.

Prices

The differences in the price structure of energy prices in the different countries make it difficult to draw a comparison. In addition to the different supply and demand conditions of the domestic energy markets, the world market prices, weather conditions, the national energy mix, network costs, but also factors such as environmental protection regulations and not least taxes and levies influence the national energy prices. The great variety of prices can be easily surveyed with the help of Figure 12 for electricity prices and Figure 13 for gas prices. Since prices depend on the consumer, this overview is given for medium size households in the first semester of 2017, as an example.

Electricity is usually cheaper in Eastern Europe than in Western countries. For instance, the prices for the kilowatt hour are 7 €ct in Serbia or 11 to 14 €ct in Poland, Czech Republic and Hungary. But also in the Netherlands, where a large part of the electricity is produced by fossil fuels, the price is only 15 €ct per kWh. On the other hand, high electricity prices can be found in Spain or Ireland. Germany occupies the top position with 30 €ct.

Annex A3 shows clearly the different share of taxes and levies that burden the electricity price which – amongst other things – reflects the different energy systems. The detailed data also show that in 2017 the prices for electricity were hardly influenced by the certificate prices for CO_2 emissions via the EU ETS, because these certificate prices increased significantly last year while the electricity prices remained essentially constant.

Gas prices show a similar picture, again referring to households of medium size, price per GJ (Figure 13). Here, Sweden has the highest gas price over 33 € per GJ, and the prices are particularly low in Eastern Europe.

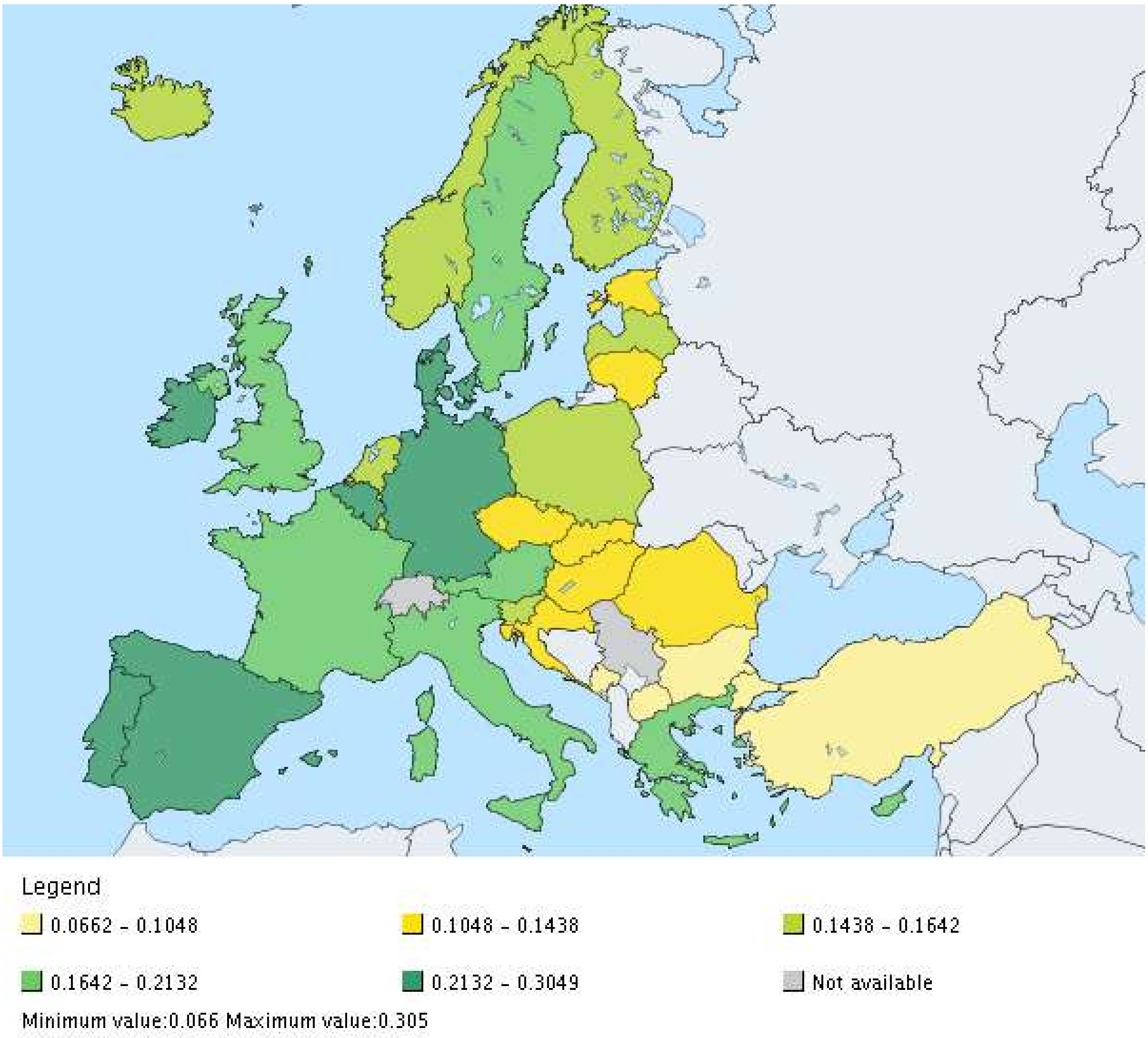


Figure 12: Electricity prices for medium size households[14] in €ct per kWh 2017. (source Eurostat: ten00117)

[14] Electricity prices for household consumers are defined as follows: Average national price in Euro per kWh including taxes and levies applicable for the first semester of each year for medium size household consumers (Consumption Band Dc with annual consumption between 2500 and5000 kWh).

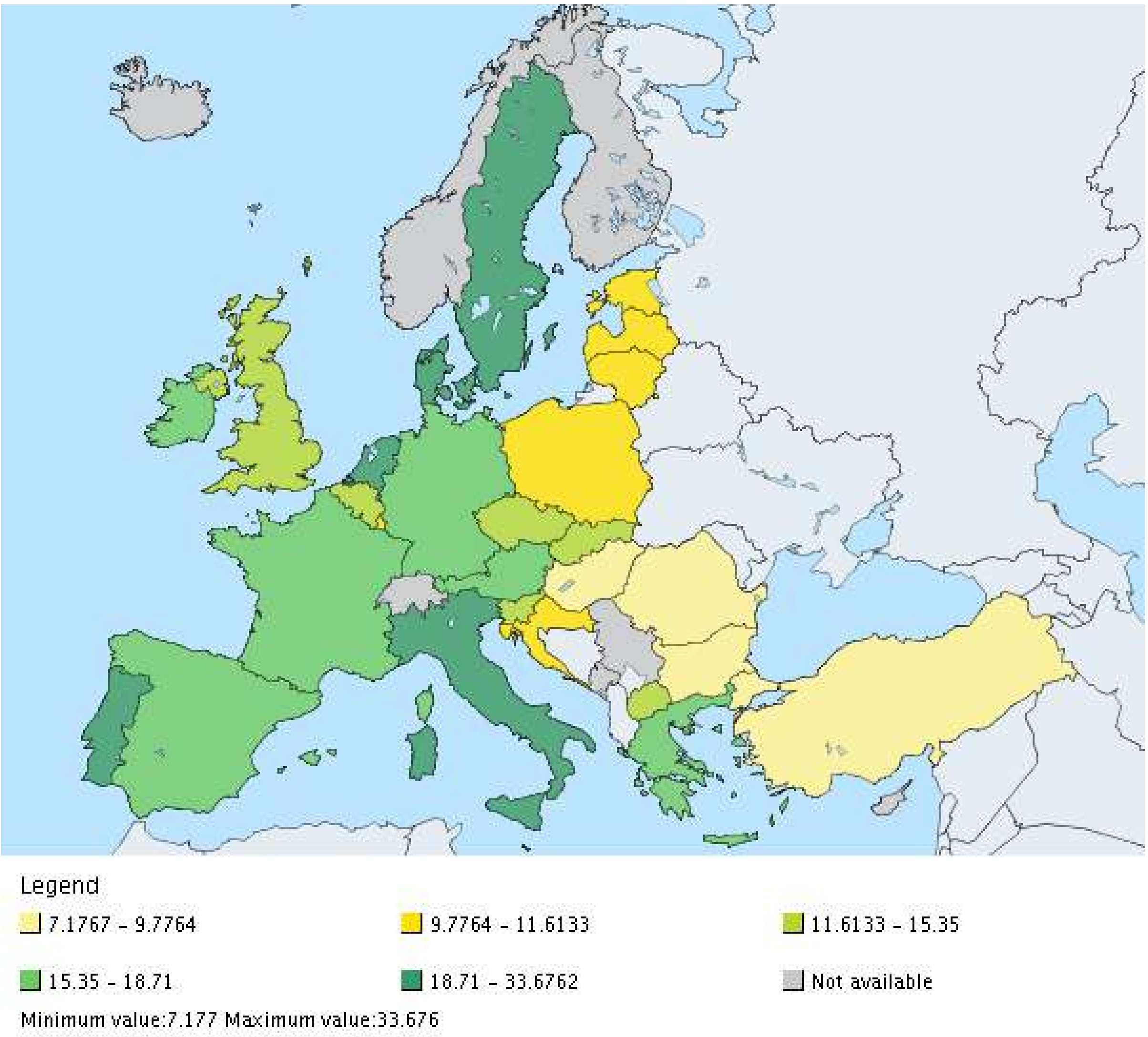


Figure 13: Gas prices for medium size households[15] in €ct per GJ in 2017 (source Eurostat: ten00118)

Energy efficiency

The development of energy efficiency and energy savings is considered as one of the important prerequisites for a successful energy transition in the energy policy discourse. Both measures are regarded as key elements in keeping the necessary conversion of energy production, transmission and supply as low as possible. With the reformulation of the climate and energy policy targets at European level in 2018 (see chapter 3), a new target has also been formulated for energy efficiency: It is to be increased by at least 32.5% by 2030. In addition, the formulation of measures from 2014 is still valid: For example, the EU has committed itself to subjecting its own building stock to energy-efficient refurbishment in the coming years at a rate of 3%. Further efficiency measures are formulated in areas such as the development of towns and municipalities and in the transport sector.

[15] Natural gas prices for household consumers are defined as follows: Average national price in Euro per GJ including taxes and levies applicable for the first semester of each year for medium size household consumers (Consumption Band D2 with annual consumption between 20 and 200 GJ).

The energy efficiency situation is characterised by a number of indicators such as primary energy consumption, energy productivity or energy intensity. The difficulty in describing the efficiency situation is not only the generation of proper indicators that reveal important developments when looking at a long time series. Often also the interpretation of the interdependencies remains based on the consideration of the indicators. Statistical effects and, for example, changing compositions such as the electricity mix over time or economics make it difficult to derive statements. Figure 14 nevertheless shows the temporal development of important indicators.

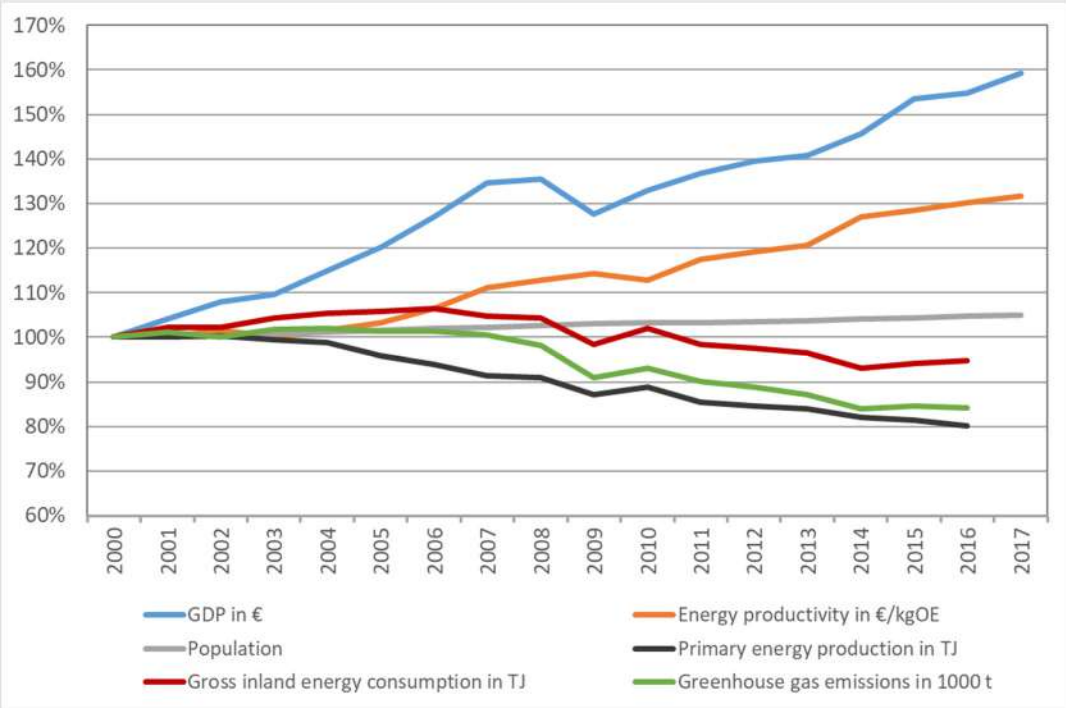


Figure 14: Temporal development of GDP, energy productivity (GDP per gross inland energy consumption), population, primary energy production, gross inland consumption and greenhouse gas emission. (Year 2000=100%). Data taken from https://ec.europa.eu/eurostat/web/energy/data/main-tables)[16]

The gross domestic product (GDP) of the EU-28 has been rising since 2000 with a small reversal of this trend in 2009 (blue curve). In 2016, it amounts to approx. 160% of the value of 2000. For the evaluation of energy intensity and energy productivity, this figure is related to primary energy production or gross inland energy consumption. Both primary energy production (black curve) and gross inland energy consumption (red curve) are lower in 2016 than in 2000. However, for gross energy consumption this trend has only been observed since 2010. Energy productivity as a ratio of GDP and gross inland energy consumption is an indicator of how much economic output (gross domestic product) is generated per unit of energy used. It is thus a measure of energy efficiency. Figure 14 shows an increase in energy productivity from 2005 onwards (orange curve). The political demand of decoupling economic growth from energy consumption has thus been met.

Various reasons can be suggested for the observed increase in efficiency. The increased use of more efficient energy conversion paths in energy generation, for example through an increased efficiency in fuel use or an increased use of cogeneration of heat and power, certainly have contributed. But

[16] 1 Mtoe=4.1868*10^4J=11630GWh

also the general change from an industrial to a service-oriented economy, the change from energy-intensive industry to production methods with lower energy input or the use of applications with higher energy efficiency may have contributed to this increase in energy productivity.

The increase in energy productivity and the changed energy mix (see discussion of primary energy production) are important drivers for reducing greenhouse gas emissions in the EU (green curve in Figure 14). Figure 15 shows the wide dispersion of energy productivity values for 2017 in EU-28, ranging from 17.6 PPS/kgOE in Ireland on the one hand to just over 5 PPS/kgOE in Estonia or Serbia on the other. In addition to factors such as the country-specific weather in winter, the indicator shows most of all the different compositions of industry between the various countries.

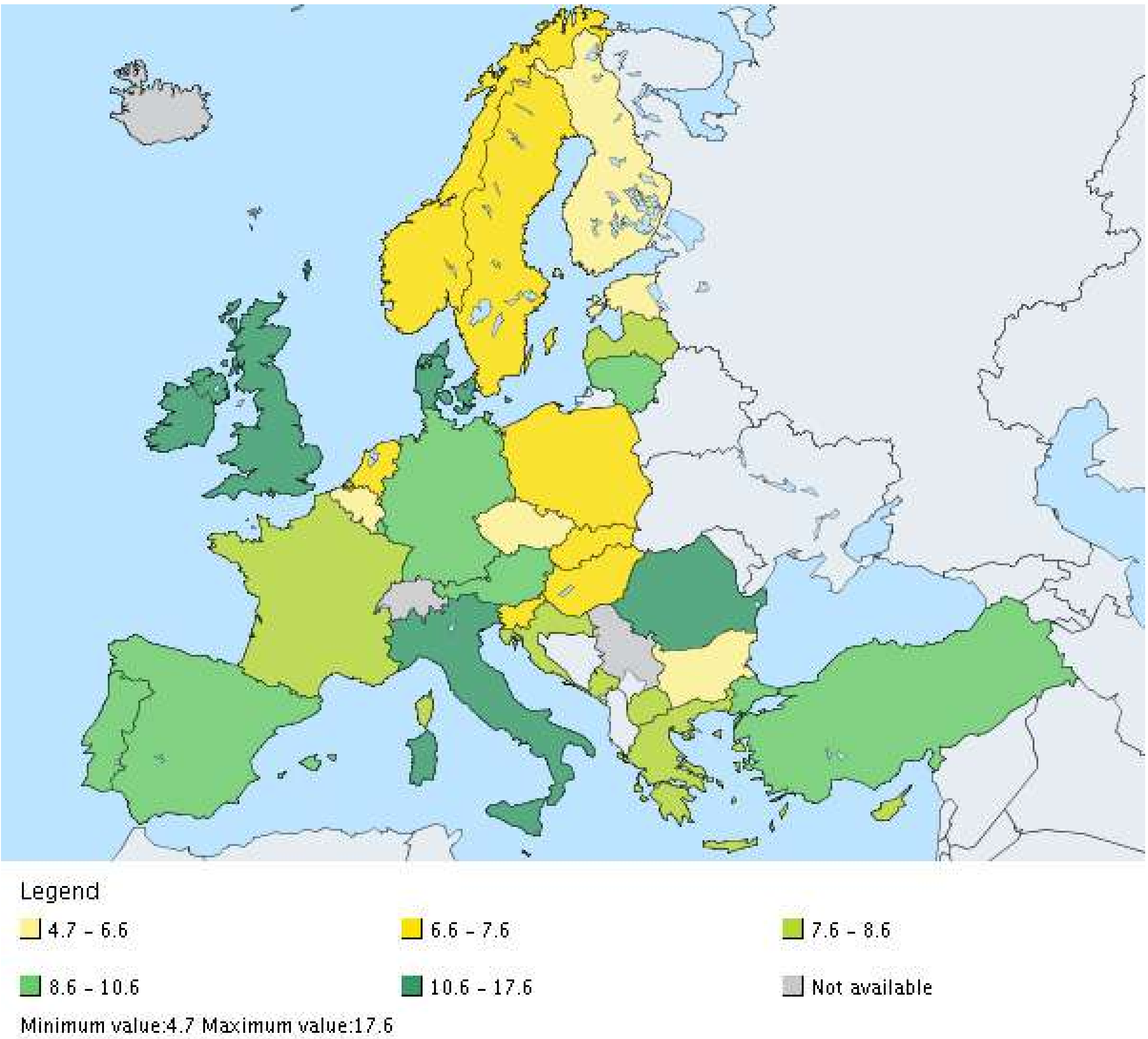


Figure 15:Energy productivity[17] (in PPS/kgOE) in the EU-28 in 2017. Source: https://ec.europa.eu/eurostat/tgm/mapToolClosed.do?tab=map&init=1&plugin=1&language=en&pcode=sdg_07_30&toolbox=legend

[17] This indicator, which is slightly differently defined as that of Figure 14, measures the amount of economic output that is produced per unit of gross inland energy consumption. The economic output is either given in the unit of Euros in chain-linked volumes to the reference year 2010 at 2010 exchange rates or in the unit PPS

4. Vision of the EU and the European Commission

In November 2010 the European Commission announced the first major EU energy strategy, the so-called “2020 Energy Strategy”. Its 20-20-20 targets (reduction of greenhouse gas emissions by at least 20%, increase of share of renewable energies by at least 20%, and energy savings of more than 20% until 2020) will essentially be achieved. Since then the warning messages from climate researchers concerning global temperature rise and steeply increasing greenhouse gas emissions were strongly intensified.

In October 2014 the European Council has reacted on this development by agreeing on a new 2030 Framework for Climate and Energy with new, more ambitious targets:

- 40% cut of greenhouse gas emissions compared to 1990 levels
- at least 27% share of renewable energy consumption
- an indicative target for the improvement in energy efficiency at EU level of at least 27% (compared to projections), to be reviewed by 2020
- support of the completion of the internal energy market by achieving the existing electricity interconnection target of 10% by 2020, with a view to reaching 15% by 2030.

In parallel the United Nations Framework Convention on Climate Change (COP 21 in Paris 2015) and its subsequent conferences have postulated to take measures to limit the temperature rise to at most 2°, better 1.5°, compared to pre-industrial values. Supported by an ad-hoc IPCC report (June 2018), the very recent COP 24 conference in Katowice (December 2018) has strongly confirmed this 1.5° goal and has agreed on a concrete list of measures.

As consequence the European Commission has intensified its efforts: a vision for 2050 has been announced (Nov 2018), new transition targets have been set (June 2018), and new governance regulations for the Energy Union and new (recast) Directives of the Clean Energy Package (Dec 2018, January 2019) have been communicated.

The presented vision is to “achieve climate neutrality by 2050, through a fair transition encompassing all sectors of the economy”. This major goal of the climate policy shall be reached by the EU 2050 long term strategy [https://ec.europa.eu/clima/policies/strategies/2050].

Some of the new energy transition targets for 2030 on which the EU agreed in June 2018 and which are presently valid for the EU overall are slightly more ambitious than the above sketched 2030 goals of 2014, for example:

- share of renewable energies in the total final energy consumption of at least 32%,
- increase of energy efficiency of at least 32.5%,
- reduction of greenhouse gases by 45% as compared to 1990.

The present EU goals are consistent with the ambitious climate goals of the Paris agreement (COP 21) and the most recent commitments resulting from the COP 24 conference in Katowice. The major question, however, remained unanswered in Paris, Katowice, and by the EU: how can these goals be reached and how will countries step up and reach their individual targets on cutting emissions, because the present targets and measures would lead to a global warming of unacceptable 3°. This

---

(Purchasing Power Standard). The former is used to observe the evolution over time for a specific region while the latter allows comparing Member States in a given year.

question is also of utmost importance for the EU since the member states had earlier agreed that no binding targets for individual member states have or will be established by EU Commission or Parliament. Thus the EU has no tool for direct impact by laws, decrees, and/or sanctions.

The solution of this "toothless tiger" problem is tackled by the so-called Winter Energy Package of November 2016, the most important part of which is the Governance Regulation of the Energy Union. The last version of this Governance Regulation was debated and voted by the European Parliament in November 2018 and entered into force as from 24 December 2018; it is central part of the "Clean energy for all Europeans" package. This legislative act establishes the framework for cooperation and coordination on energy and climate matters and represents the umbrella piece of legislation that is intended to ensure the achievement of the 2030 energy and climate targets.

Amongst the most important parts of the Governance Regulation are:

- Streamlining the plethora of current planning, reporting and monitoring obligations which severely lack of coherence and consistency and can lead to duplication and conflict. The regulation integrates 31 existing obligations and deletes another 23. A Climate Monitoring Mechanism that has been integrated in this framework is a very important obligation.
- Updating the current energy and climate goals from the 2020 to the 2030 targets, while also incorporating the EU commitments under the UNFCCC 2015 Paris Climate Change Agreement (see above).
- The requirement for governments to produce Integrated National Energy and Climate Plans (NECPs). These plans must elaborate on the main priorities, strategies and actions to be taken within a 10-year period, covering the five main areas of the Energy Union (security of supply, internal energy market, energy efficiency, decarbonisation, and research and innovation). The plans have to also include a 50-year perspective and must be aligned with the international climate goals. Although the governance regulation also provides binding templates for these national plans, it simultaneously allows the member states a great deal of flexibility in deciding what measures and policies they want to adopt.

In practice, each EU Member State was obliged to draft an integrated national plan for energy and climate (NECP) by 1 January 2019 covering the period 2021 – 2030. These drafts have been submitted and can be read and downloaded (https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/governance-energy-union/national-energy-climate-plans). The Commission presently checks that all member states are contributing to a shared effort, that there are no instances of free-riding, and that the collective EU objectives are met. If a NECP is insufficient in this sense the Commission will communicate the deficiency and will give recommendations for improvement which should be incorporated in the finalized NECP which is due by January 2020.

From 2021, each country has to produce a progress report every two years, which will complement the Commission's evaluation of the implementation of the national plans. Member states are obliged to take into account the recommendations of the Commission and must provide explanations in their subsequent progress reports on how these have been incorporated. This double monitoring process is designed to overcome the difficulties created by the absence of binding national targets.

The future development will show whether these new governance regulations including NECPs and public monitoring are sufficient to reach the above-mentioned ambitious goals because direct sanctions are excluded due to the dominance of national sovereignty in energy matters. Of course, there are several indirect measures to stimulate the national willingness for meeting the targets, for instance additional financial support for those states that reached the targets and followed the recommendations, or indirect sanctions (reduction of support from, e.g., the structural fund or other subsidies) in the opposite case.

The main problem, however, remains: European diversity. The initial situation of the energy systems and the present energy mix in the member states are extremely different, as described in chapter 2. And even more important, the objectives and instruments of the energy transitions in the member states are also very different as sketched in chapter 4. One crucial example may elucidate this statement: the so-called CO_2 price.

Europe has in principle an effective common instrument to reduce CO_2 emissions, the EU Emissions Trading System (EU ETS), established in 2005. The EU ETS works on the 'cap and trade' principle. A cap is set on the total amount of certain greenhouse gases that can be emitted by installations covered by the system. The cap is reduced over time so that total emissions fall. Within the cap, companies receive or buy emission allowances which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world. The limit on the total number of allowances (certificates) available ensures that they have a value. After each year a company must surrender enough allowances to cover all its emissions, otherwise heavy fines are imposed. If a company reduces its emissions, it can keep the spare allowances to cover its future needs or else sell them to another company that is short of allowances. Trading brings flexibility that ensures emissions are cut where it costs least to do so. A robust CO_2 price also promotes investment in clean, low-carbon technologies.

The problem of the present EU ETS is at least two-fold. First, EU ETS covers only 45% of all emitters of greenhouse gases which is insufficient for a sector-overarching optimization of the entire energy system. And second, the initial number of certificates was much too high such that the CO_2 price was way too low. After a settling time, it remained at about 5 Euro per ton CO_2 for several years while experts agreed that only a price beyond 30 – 40 Euro would be successful in significantly reducing greenhouse gases. A recent reform effort has led to a significant price increase in 2018 (from 8 to 25 Euro/t in Dec 2018) but the price is still too low and especially too volatile, and hence does not stimulate major investments.

Several member states thus have established a national CO_2 price as additional CO_2 tax or as lower limit for a national ETS that includes but extends the EU ETS. Member states like Sweden, Great Britain, or France have launched their national CO_2 prices several years ago and claim significant successes, but prices, detailed rules, and exemptions are very different. However, most other states abstained from such tax-like instruments and appear to object against major changes to the EU ETS.

5. Energy transitions in Europe

28 different historical developments under different conditions created 28 different energy systems, which satisfy the different energy needs of the various countries, their inhabitants and economic systems. Thus, also 28 different energy transitions have been started which proceed with different speed and success. In order to give some impression from the diversity of the various national approaches, six examples of energy systems and energy transitions (France, Germany, Serbia, Slovenia, Spain and Sweden) are presented in the following. These short essays show that even if the objectives of the European energy system transformation are formulated jointly by the EU, the way to achieve them will and must be very different.

In the following the energy systems and transition approaches of these six countries (in alphabetical order) are briefly sketched focused on two objectives: A: Purposes, objectives and instruments of the energy transitions and B: Successes and obstacles for the success of the individual energy transitions.

5.1 France

A: Purposes, objectives and instruments of the energy transitions

The French energy transition is generally called “Transition énergétique” (“energy transition”) and aims at a transformation of the French energy system. The French energy policy principles are defined by a law voted by parliament in August 2015, called LTECV (Loi de Transition énergétique pour une croissance verte - Transition Law for Green Growth). The law provides for the development of a National Low Carbon Strategy (SNBC Stratégie nationale bas-carbone), France's roadmap for reducing greenhouse gas emissions. It also sets the parameters for the Multiannual Energy Programming (PPE = “Programmation Pluriannuelle de l’Energie”), reviewed every 5 years for setting policies for the next 5 years (2019-2023) and for looking at the 5-year horizon thereafter (2024-2028). The first PPE period was 2016-2018.

PPE is a tool for steering France's energy policy. All the pillars of energy and energy policy are covered. The PPE thus includes several components:

- security of supply;
- the reduction in energy consumption, particularly of fossil origin (oil, gas, coal);
- diversifying the energy mix by mobilising renewable energies and reducing the share of nuclear energy;
- the balanced development of networks;
- preserving the purchasing power of consumers and the competitiveness of businesses;
- assessment of needs of professional skills in the field of energy and appropriate training.

For defining the 2019-2023 PPE, the French population was called to participate in a public debate organised by the statutory independent national commission (CNDP), the result of which have been published in September 2018. The French government has issued the orientations, which, after a further step of consultation of the French people, should be transformed into an official decree. A major announcement by the French president and Government was issued in November 2018. Twenty objectives have been set, organized around 7 major themes: energy production, buildings, transport, agriculture, industry, waste, and forestry and carbon sinks.

Buildings

2.5 million renovated homes; 10,000 coal heaters and 1 million boilers fuel oil replaced by energy-based heating renewable or high-performance gas; 9.5 million wood-heated homes with a labelled device; 3.4 million homes connected to a heat network.

Transport

1.2 million electric passenger cars; 20,000 gas trucks in circulation; Launch of an industrial strategy for electric vehicles (batteries).

Energy Overall targets

The need to reduce energy consumption in all sectors is reaffirmed (an overall target to reduce final energy demand by 7% in 2023 and 14% in 2028 compared to the 2012 reference year). Primary energy consumption of fossil fuels in France should be reduced by 20% in 2023 and 35% in 2028 compared to the 2012 reference year. Carbon taxation is expected to be introduced while the modalities and objectives for the next periods of the EU scheme (Energy Saving Certificates) will have to be defined by the beginning of 2020.

Renewable energy

- The LTECV provides for an increase in the share of renewable energies in final energy consumption to 32% by 2030. The new PPE confirms those vector-based targets for this horizon (40% renewables in electricity production, 38% in final heat consumption, 15% in final fuel consumption and 10% in gas consumption).
- Among its main objectives, the PPE stipulates to at least double renewable electricity capacity in metropolitan France by the end of 2028, to a level between 102 and 113 GW (compared to 48.6 GW at the end of 2017).
    - By 2030, the production of onshore wind farms will thus triple.
    - By 2030 the amount of energy produced from photovoltaics will be multiplied by 5.
    - Off shore wind farms: During the PPE' five-year period, the first park off Saint-Nazaire will be commissioned and 4 new calls for tenders will be launched.
    - This would lead to the following status in 2023-2028

GW	2023	2028
on shore wind	24,6	31,4 - 35,6
off shore wind	2,4	4,7 -5,2
Solar PV	20,6	35,6 -44,5
Methanisation	0,27	0,34 -0,41
Hydro	25,7	26,4 -26,7
Total	74	102 -113

In terms of heat production, the government plans to reinforce the Heat Fund (substitution of coal by biomass), with a budget increase from €245 million in 2018 to €315 million in 2019 and to €350 million in 2020. By 2028, the annual production of "renewable" gas, mainly via methanisation, is to be increased by a factor of 5 compared to the 2017 level.

Fossil energy

Closure of all coal fire plants by 2022

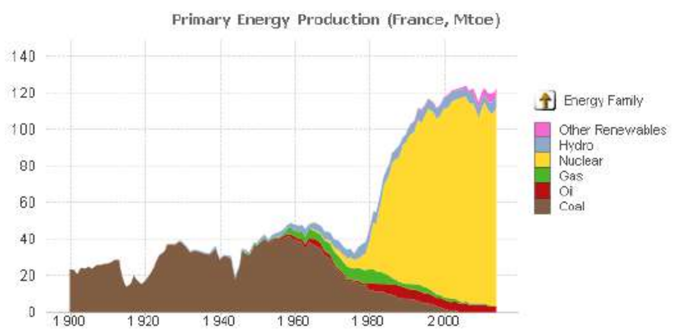
Nuclear energy

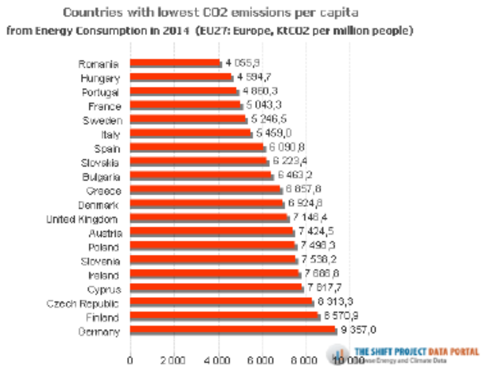
- Maintain the 50% target of electricity supplied by nuclear, but by extending the maturity date to 2035 (instead of 2025 as provided for in LTECV).
- As part of the Multiannual Energy Programming, the government should decide in 2021/22 whether to replace aging reactors with a new nuclear power programme. In the meantime, EDF is developing the design of an improved – essentially more competitive – EPR design.

So far, the targeted electrical mix includes 50% of nuclear generation in 2035; no decision has been taken beyond this date. It is generally considered that the goal of achieving carbon neutrality in 2050, which will be part of the French energy law, requires keeping a share of nuclear electricity in the mix.

B: Successes and obstacles for the success of the individual energy transitions

Thanks to the reduction of coal, oil and gas for electricity production and the large increase of nuclear power since the early 1980s, French emissions of CO_2 have been drastically reduced.





A major difficulty of the French energy transition is the perspective of simultaneously reducing CO_2 emissions and the share of nuclear electricity. Although French emissions of CO_2 per capita are low compared to other large EU countries (only about 50% of Germany's per capita emissions in 2014, see righ-hand figure above from http://www.tsp-data-portal.org/about), the French target ratio for reduction agreed for 2020 compared to 2005 is identical to that of Germany (-10% for Europe and -14% for France and Germany for instance). CO_2 emission of power generation in France is only 10% of German emission per KWH supplied. As a consequence, the impact of developing intermittent renewable electricity on the global emission of power generation is very low.

A second one is in the social acceptance of the transition, notably as people's life-styles and resources are becoming increasingly different between larger cities and the rest of the country. There are in France a lot of controversies on the best way to achieve the aimed-for CO_2 reduction. In order to have better advice, the French President established the High Council for Climate, composed of experts (13 scientists, economists and other experts, chaired by the French-Canadian climate scientist Corinne Le Quéré) that will produce each year an "independent perspective" on France's policy in the fight against climate change. The High Council's annual report will assess, "compliance with the greenhouse gas emissions reduction trajectory" and the implementation of measures to reduce these emissions. However, despite numerous announcements of ambitious long-term objectives and in contradiction with its international commitments, European regulations and French law, France does not respect its short-term objectives, whether in terms of reduction of greenhouse gases, development of renewable energies or improving energy efficiency, even when measures have been implemented that were identified as essential for the ecological and solidarity transition.

Greenhouse gases

- The revised SNBC draft published in December 2018 states that "France will not be able to meet the first 2015-2018 carbon budget" and provisionally estimates this overrun to 72 Mt CO_2eq over the period 2015-2018. The SNBC project takes accounts for this overrun by increasing the carbon budgets until 2023, postponing a large part of the effort to coming years even though France has the long-term objective of achieving GHG neutrality by 2050.
- It is worth noting the objectives for greenhouse gas reductions are mainly exceeded in the transport sectors, in the buildings sector, and in the agricultural sector.

Development of renewable energies

- The target for 2017 of the renewable energy plan was for gross final RE of 30.7. With 25.5 Mtoe[18] achieved, it is 17% below target. This falling behind in France's response to renewable energy is almost unique within the European Union. Eurostat notes the fact that only 4 EU countries, including France, were below “the 2015-16 average of the indicative trajectory established in the Renewable Energy Directive”.
-

Energy efficiency

- France is not meeting the 2017 objectives of the EPP118 or its trajectory for the 2020 objectives under the European Directive. Eurostat noted that French final energy consumption amounted to 147.1 Mtoe in 2017, about 5% higher than the 139.9 Mtoe trajectory provided for under the Directive and will not achieve the 2020 target of 131.4 Mtoe

The reasons for this underachievement are certainly manifold but they have not been analysed in a single document. Among other elements, the Académie des sciences and NATF have recommended:

- Financing of RE for electricity production (mainly PV and wind), in spite of French electricity being already decarbonized at 95%, should be curtailed and the available financing be used for more efficient decarbonisation of the construction and transport sectors.
- REN should be developed for heat applications, transport and construction sectors.
- In order to identify priorities, it should be mandatory to assess the cost and effect on public finances, the trade balance, CO_2 emissions and employment (both in terms of jobs and qualifications created), and this should be done in comparison with other alternatives.

In the near and medium term, there is a real contradiction in wanting to reduce greenhouse gas emissions while at the same time reducing the share of nuclear power.

5.2 Germany

A: Purposes, objectives and instruments of the energy transitions

The German energy transition is generally called “Energiewende” (“energy turn-around”) and aims at a complete change of the German energy system. Most of its present targets were set by the Government in September 2010. They are essentially still valid today apart from the accelerated fade-out of nuclear power which was decided in autumn 2011 after the nuclear disaster following the

[18] 1 Mtoe=4.1868*10^4J=11630GWh

earthquake and tsunami consequences in Fukushima. More recently the German targets were essentially confirmed following the Paris agreement in 2015 – though using different target times and hence different (quantitative) numbers.

The main goals are the following:

1) Reduction of the greenhouse gases referred to the emissions of 1990 while keeping the security of supply on the present high level: 2020: - 40%, 2030: -55%, 2040: -70%, 2050: -80 to 95%.

2) Reduction of the primary energy consumption by -50% in 2050 with respect to 2010.

3) Reduction of the energy consumption in the transport sector by 40% in 2050 (referred to 2010).

4) Reduction of the electricity consumption by 25% in 2050 (referred to 2010).

5) Share of renewable energies in total electricity consumption: 2020: 35%, 2030: 50%, 2040: 65%, 2050: 80%.

6) Share of renewable energies in total final energy consumption: 2020: 18%, 2030: 30%, 2040: 45%, 2050: 60%.

7) The initial number of nuclear power stations (19) must be reduced stepwise to 9 (2011), 8 (2016), 7 (2018), 6 (2020), 3 (2022), and finally to zero in 2023.

The energy transition is managed by several federal ministries with the Federal Ministry of Economic Affairs and Energy as leading house. This ministry also publishes a monitoring report on an annual basis presenting the development of relevant indicators of the energy transition in relation to the targets. In addition, every three years a progress report is published by this ministry which gives a deeper analysis and allows the observation of trends. This “self-monitoring” process is critically accompanied by an independent commission of four renowned energy experts from the scientific community who publish their critical assessment alongside with the governmental reports. The monitoring report must be approved by the Federal Cabinet by the end of every year and submitted to the Parliament.

The “Energiewende” is governed and influenced by hundreds of acts, decrees, and other frame conditions including taxes, subsidies, prescriptive limits, etc. Most of these regulations are sector-specific or concern details, some are effectively counteracting each other. The most prominent act is the Renewable Energy Law (EEG), the first version of which was enacted in 2000 replacing the Act on Sale of Electricity to the Grid (from 1991). Since then the EEG was corrected, complemented and improved by several amendments, the last (called “Energiesammelgesetz”) is presently on the way (Nov 2018). As consequence of the Paris Climate Agreement Germany has decided and published in November 2016 the Climate Action Plan 2050. It confirms the above cited targets and moreover sets detailed targets for the energy consumption in the energy sectors electricity, heat consumption, and transport concerning the share of renewables, the reduction in consumption, and the increase in efficiency. All targets and measures are compiled and reconfirmed in the German draft of the integrated national plan for energy and climate (NECP) which was requested by the EU parliament in the framework of the new Governance Regulations in 2018 (see chapter 3) and which was submitted by the end of 2018.

B: Successes and obstacles for the success of the individual energy transitions

The very ambitious German "Energiewende" is successful in only two fields: the fade-out of nuclear power and the share of renewable sources in electricity production are on track. In contrast, all other indicators are behind schedule and will miss the 2020 targets, some by far. For instance, the reduction of greenhouse gas emissions stagnates since 2009 such that the 2020 target will most likely be missed by more than 100 million tons of CO_2 equivalents; thus 30% instead of 40% reduction referred to 1990 will only be reached. Or: the share of renewable energies in the sectors heat and transport remains at much too small values; for example, in the transport sector it stagnates at 5.3% since 2008. Or: The energy consumption in the electricity and transport sector increased within the last 10 years but should rather have decreased by 10% and 20%, respectively.

The reasons for these failures are manifold. They have been analysed by a joint project of the German national academies called energy systems of the future (ESYS) [Ausfelder et al. 2017[19]; acatech/Leopoldina/Akademienunion 2017[20]]. Reasons are:

- The system of laws and regulations is too complex; there are too many counteracting formalities; many regulations had unforeseen consequences.
- The EEG laws and their amendments are presently setting the wrong, insufficient, and incomplete incentives; they should rapidly be replaced or drastically improved.
- The different energy carriers are treated differently concerning taxes and dues; for example, electricity is much too expensive for consumers (see chapter 2) and industry, thus obstructing, e.g., the required switch to heat pumps for low-temperature heating and the exploration of Power-to-X techniques.
- The present, completely separate treatment of the energy sectors electricity, heat consumption and transport impede the necessary holistic approach and optimization of an integrated energy system. It also impedes the required electrification of the sectors heat consumption and transport.
- A common price for all CO_2 emissions and hence an over-arching instrument with comprehensive steering action is lacking. The existing instrument, the European Emissions Trading System (EU ETS), is ineffective since a lower bound for the CO_2 price is missing and sources emitting more than half of the European CO_2 emissions are not included. Moreover, the present CO_2 price of EU ETS is still too low (about 25 € per ton) and it is highly volatile since it is based on speculations (see also chapter 3).
- Present costs (additional 25 billion € per year) and missing achievements of the energy transition do not fit together; moreover, communication and participation are insufficient. Thus, citizens and industry are increasingly disappointed, the acceptance of the energy transition suffers, and new projects (e.g. wind power stations, overhead transmission lines) experience increasing resistance.

[19] Ausfelder et al. 2017: Ausfelder, F./Drake, F.-D./Erlach, B./Fischedick, M./Henning, H.-M./Kost, C./Münch, W./Pittel, K./Rehtanz, C./Sauer, J./Schätzler, K./Stephanos, C./Themann, M./Umbach, E./Wagemann, K./Wagner, H.-J./Wagner, U.: »Sektorkopplung« – Untersuchungen und Überlegungen zur Entwicklung eines integrierten Energiesystems (Schriftenreihe Energiesysteme der Zukunft), München 2017.

[20] acatech/Leopoldina/Akademienunion 2017: acatech – Deutsche Akademie der Technikwissenschaften, Nationale Akademie der Wissenschaften Leopoldina, Union der deutschen Akademien der Wissenschaften (Hrsg.): »Sektorkopplung« – Optionen für die nächste Phase der Energiewende (Schriftenreihe zur wissenschaftsbasierten Politikberatung), 2017.

- Government and the majority of the society have no vision for the necessary changes and feel not sufficiently responsible to meet the grand challenges. The missing political will and the hence missing long-term legal perspective lead to insufficient planning reliability and prohibit the necessary investments.
- Thus, many decisions are either delayed or go in the wrong direction because the proper legal frame is not yet existing.
- There is insufficient cooperation and consultation on energy issues with the European partners; more efficient solutions are hence prohibited and frustration amongst the European countries is enhanced.
- A continuation of the present development may lead to a significant failure of the "Energiewende". Recent developments ("Coal Commission") and the additional commitments enforced by the new Governance Regulations (see chapter 3) as well as public criticism on the missing progress of the energy transition ("Friday demonstrations") may lead to enforced, more target-oriented actions of the federal government.

The most recent conclusion is that the German "Energiewende" can still be successful and the ambitious targets until 2040 and 2050 can still be met if suitable measures are quickly and efficiently introduced. This has been analyzed in detail by a project of the German national academies (https://energiesysteme-zukunft.de/en/publications/position-paper/coupling-the-different-energy-sectors/).

5.3 Poland

A: Purposes, objectives and instruments of the energy transitions

Poland's consumption of primary energy amounts currently to about 1220 TWh, with hard coal and crude oil as main sources (38% and 32%, respectively), supplemented by lignite (15%), natural gas (5%), and renewable energy sources (hydropower, biomass, wind and geothermal energy). Households and transport still have a key role in final energy consumption, but due to improvement of energy efficiency importance of households is decreasing, while the use of energy in transport is continuously increasing.

The demand for hard coal is mostly and for lignite entirely met by domestic production. As Poland does not possess significant resources of crude oil and natural gas, their demand is mostly covered by imports (96% and 78%, respectively). Until now they are mostly imported from Russia by existing pipelines, but a diversification of their imports is developing. At the moment, one third of the imported crude oil and natural gas come from other countries than Russia.

Electricity production in Poland in 2017 amounted to 170.5 TWh with a similar level of consumption. The structure of its production is like in other countries still based on hard coal (46% in 2017), lignite (31%), with minor – though increasing – share of natural gas (6%) and renewable energy sources (14%). The installed capacity of RES in Poland in 2017 amounted to 8.5 GW (comparing to total capacities of about 43 GW). The share of RES in total final energy consumption in 2016 amounted to 11.3%, the aim for 2020 is 15%. Due to the still large share of domestic energy sources (mostly coal), Poland is one of the least energy-dependent EU states (30%, compared to the EU average 54%).

Poland's thermal needs are satisfied by district heating or by individual household installations, where the main fuel is hard coal or natural gas. Thermal modernization of buildings and new standards of energy insulation of newly constructed buildings have influenced the improvement of energy efficiency and have lowered the demand for heat. However, the air quality still suffers from individual household heating by using low-quality fossil fuels and even wastes and from emissions from transport. This problem is strictly related to the problem of energy poverty which exists in many households in Poland.

For all issues related to energy the Council of Ministers, especially the Minister of Energy is politically responsible. At the moment, Poland's energy policy is based on assumptions given in two strategic framework documents: Strategy of Responsible Development up to 2020 with perspective to 2030 (approved in 2017), and Energy Policy of Poland until 2040 (currently under public consultation). The main legal acts related to energy management are currently: Energy Law (1997, amended almost 100 times!), Act on Renewable Energy Sources (2015), Act on Energy Efficiency (2016), Act on Electromobility and Alternative Fuels (2017). Apart from the two main framework documents, there are numerous other detailed Action Plans, e.g.: Plan of Electromobility Development (2017), Programme of Nuclear Energy Development (2014), Domestic Action Plan on Renewable Energy Resources until 2020 (2010), Strategy of Sustainable Development of Transport until 2030 (project), new State Energy Policy (project) and others.

The Strategy of Responsible Development is currently the main economic framework document. According to it, the main mission of the power industry is to ensure stable energy supply to economy, public sector and households, at economically acceptable prices. In general, this should be realized through effective use of the available energy sources and effective cooperation between energy producers and users. On the operational level the most important issues are: development of energy storage technologies, introduction of smart energy grids, development of electromobility, introduction of energy saving and highly effective technologies, introduction of a power capacity market, creation of Polish gas hub, support of use of geothermal and hydropower sources, systemic restructuring of coal and coal-based industries.

A draft of the „Energy Policy of Poland until 2040" (EPP2040) was submitted to public consultation by the Ministry of Energy in December 2018. The energy policy of the state is defined by the Minister of Energy pursuant to Articles 12, 13-15 of the Energy Law, and is implemented by a range of actors, primary by the Minister of Energy and the whole Council of Ministers.

EPP2040 is one of the nine integrated sectoral strategies following from the *Strategy for Responsible Development*. EPP is consistent with EU's strategic documents. *The National Action Plan for Energy and Climate for 2021-2030* (project announced in January 2019) will be consistent with *EPP2040*. EPP2040 is assumed as the main strategic document in the energy sector in Poland. It addresses the most important challenges that the Polish energy sector will be facing in the next two decades and includes the main target and strategic directions, as well as the corresponding measures to be implemented in the short-term perspective.

The main objective of EPP2040 is to provide energy security, while ensuring competitiveness of the economy, energy efficiency and reduction of the environmental impact of the energy sector, while optimal using Poland's own energy resources. EPP2040 is assumed to be the response to the key challenges faced by the Polish energy sector in the nearest decades and sets the strategic directions for the energy sector, taking actions into account that need to be delivered in the medium-term.

The document contains objectives of the energy policy, as well as the strategic directions and actions to be pursued to achieve these objectives. EPP2040 also gives a forecast of the demand of capacity and electricity production as well as the expected drop in CO_2 emissions by the electric power sector as a result of the implementation of EPP2040.

The following indicators are to be used as the overall measure of the achievement of EPP2040:
- 60% share of coal in the generation of electricity in 2030
- 21% RES in gross final energy consumption in 2030
- introduction of nuclear energy in 2033
- improvement in energy-efficiency by 23% by 2030 relative to the 2007 forecasts
- reduction of CO_2 emissions by 30% by 2030 (in relation to 1990).

Eight strategic directions are defined for a 10-year and 20-year horizon (2030 and 2040):

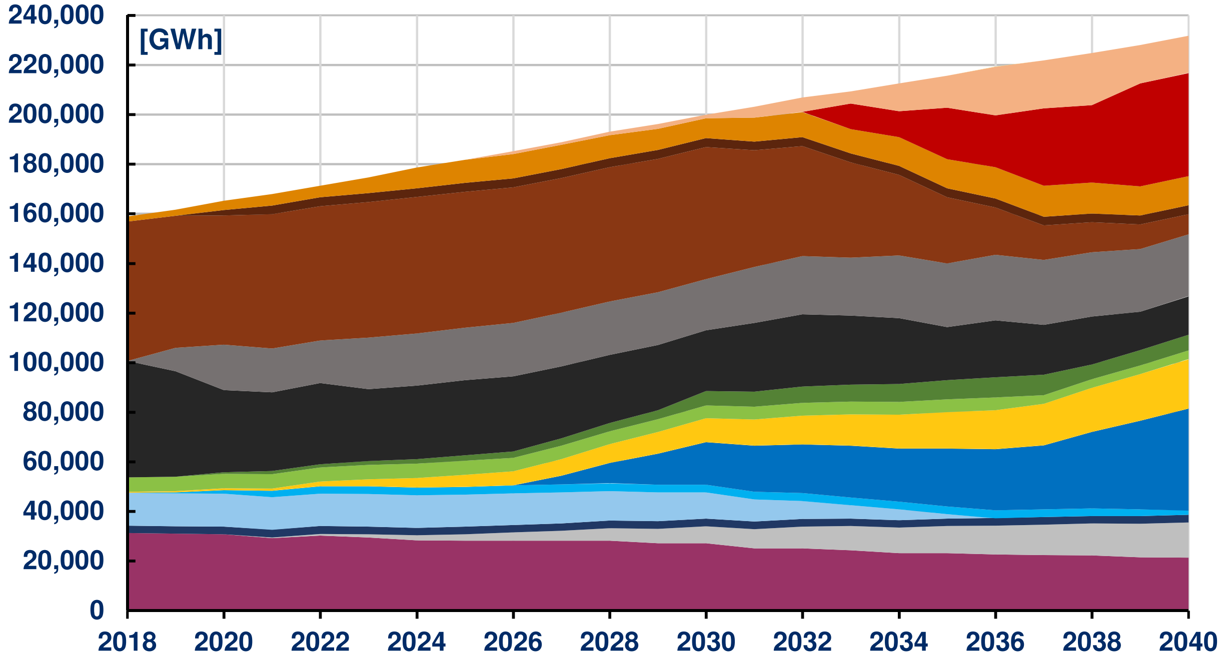
1. Optimal use of domestic energy resources

Poland is capable of covering the demand of coal and biomass with domestic sources, but not that of natural gas and oil. Innovations in coal mining and use must be put in place to improve the competitiveness of Polish coal compared to that from imports and other fuels, as well as to reduce its negative impact on the environment. The demand for lignite will be covered by domestic sources which are located near the locations where it is used. The exploitation of new deposits will depend on the development of innovative methods for using coal due to its high emissivity which reduces its competitiveness due to the increasing costs of CO_2 emissions and the EU climate policy. The demand for natural gas and oil will be mainly covered by imports, with actions to be pursued to ensure real diversification of the directions and sources of supply. Domestic deposits will continue to be prospected for (also using non-conventional methods) to replace the supply from depleted deposits. The demand of oil will be reduced by the growing contribution of biofuels and alternative fuels (e.g. electricity, LNG, CNG, hydrogen).

2. Development of the power capacity and transmission infrastructure

Poland aims to cover its primary energy demand by domestic resources. The national deposits of coal will be the key element of its security of supply and are the foundation of its energy mix. The use of coal will remain stable, but the share of coal in the structure of energy consumption will be declining (to approx. 60% in electricity production in 2030) because of the increase of energy consumption. Given the targeted share of RES in EU's final energy consumption (32%), the importance of renewable energy sources will be growing – their share in domestic electricity consumption may be approx. 27%. The achievement of the share of RES in electricity generation will be mainly based on photovoltaics (from 2022) and offshore wind power (after 2025). Energy storage technologies will need to be developed and gas units as regulatory capacities. In order to reduce emissions from the energy sector, low-efficient units will be modernized and/or decommissioned, and replaced gradually with more efficient plants (including cogeneration installations). The emission reduction efforts will be mainly based on nuclear energy, which is to be introduced in 2033. By 2043, 6 nuclear units with a total capacity of 6-9 GW will be commissioned, which means that in 2035, the share of this technology in energy generation may represent ca. 10%.

Extensive investment programmes will contribute to extend the domestic transmission grid and to streamline cross-border electricity exchange. Underground medium-voltage power lines and digital communication systems will be installed. Smart grids will be deployed to integrate the activities and behaviours of all entities and users connected to such grids.



Forecasted electricity generation by technology until 2040

- New diesel engines or simple cycle gas turbines
- New combined cycle gas turbines
- New nuclear units
- Combined cycle gas turbines: Płock, Żerań, Stalowa Wola, Włocławek
- LIgnite power plants – under construction (Turów)
- Lignite power plants – existing
- Hard coal power plants – planned and under construction (Jaworzno, Opole, Ostrołęka)
- Hard coal power plants – existing
- Biogas power plants
- Biomass power plants
- Photovoltaic power plants
- Offshore wind power plants
- New onshore power plants (2018 RES auction)
- Onshore wind power plants – existing
- Hydropower plants
- New CHP plants and condensing units
- CHP plants - existing

3. Diversification of natural gas and oil supply and development of infrastructure

The strong dependence on one supplier of natural gas requires diversification. Therefore, Northern Gate will be built, consisting of the so-called Norwegian Corridor (Norway-Denmark-Poland connection) and of a LNG terminal. This will also involve development of interconnectors with neighbouring countries. Also a domestic transmission and distribution system and a storage infrastructure will be developed.

For crude oil the dependence on external suppliers is even larger (over 96%). To increase independence delivery by sea based on the development of the Pomeranian Crude Oil Pipeline and liquid fuel storage facilities will be enforced.

4. Development of energy markets

The Polish electricity market is undergoing a transformation responding to challenges and development opportunities, for example by creation of a single energy market or the willingness of consumers to participate in the market. In order to protect the competitiveness of energy-intensive companies, mechanisms will be put in place to reduce excessive burdens.

The market liberalisation for natural gas is planned to be finished as soon as possible (it is still not the case for households). It is also planned to enhance Poland's position in the European market by the establishment of a regional hub for the transmission and trade of gas – for this purpose further development of the service and trading potential will be needed. There are also plans of more in-depth gasification of the country and the use of gas as back-up units for intermittent RES.

The market for petroleum products is relatively stable, even though it is bound to transform in the years to come. The state exercises control over key infrastructure for fuel security. A part of demand for petroleum products will be covered by increased consumption of bio-components (8.5% share in the consumption of fuels in transport in 2020), and alternative fuels (LNG, CNG, hydrogen, synthetic fuels) and development of e-mobility (1 million electric vehicles in 2025).

5. Launch of nuclear energy

The first nuclear unit (with a capacity of 1.0-1.5 GW) will be launched in 2033 followed by five further units every two years (until 2043). The time schedule is based on the expected growing demand for electricity and changes in National Power System due to decommissioning of old coal units. In this way it is possible to diversify the energy generation structure at reasonable costs and with acceptable energy prices for consumers. Current technologies (III and III+ generation) and stringent world nuclear safety standards ensure safety of nuclear power plant operation and waste storage.

Location of the first nuclear unit (Żarnowiec or Kopalino, both near Gdańsk) will be selected in the nearest future, then successive locations will be selected; a new landfill for low- and medium-level waste will be installed.

6. Development of renewable energy sources

The increasing role of renewable energy sources results from the need to diversify the energy mix, the need to contribute to the EU-wide targets in final energy consumption (32%), but also from the global trends in RES development with falling technological costs. Poland declares reaching a 21% share of renewable energy in the final energy consumption in 2030 (in heating and cooling 1.0-1.3% growth per year, in transport 10% share in 2020 and 14% in 2030, in the electricity production up to 27%). Bearing in mind the expected technological development, a special role in reaching the RES target will be played by offshore wind farms, as well as photovoltaics whose work will be correlated with summer peaks of demand for electricity.

In order to use the full RES potential in a manner which is safe for the system, energy clusters and energy cooperatives will be created, which should ensure balancing at the local level, by linking various technologies to energy storage capacities. Individual use of renewable energy sources should also be accompanied by energy storage.

7. Development of the heating sector and cogeneration

Coverage of heating demand takes place at the local level. Therefore, it is extremely important to ensure energy planning at the level of municipalities and regions. A useful tool will be a nationwide heating map (with planned investments).

In areas where there are technical conditions to supply heat from an energy-efficient heating system, customers should use district heat first, unless they use a greener solution. Heat prices are to be acceptable to customers, but should cover justified costs with a return on invested capital. The technical development of district heating is of key importance; this will be related to the development of cogeneration, power plant conversion to heating plants, increased use of renewable energy and waste in system heating, modernization and expansion of the heat and cooling distribution system, and promotion of heat storage and smart grids.

To meet individual heating needs, sources with the lowest possible emissions should be promoted (gas, non-combustible renewables, heat pumps, electric heating, low-emission solid fuels), while gradually moving away from solid fuels.

8. Improving energy efficiency

Energy efficiency involves the implementation of new technologies and innovations. The EU-wide target for 2030 is 32.5%, and Poland declares a 23% energy savings compared to the forecast from 2007. The increase of efficiency will be achieved by the purchase of energy efficiency certificates and by legal and financial incentives for pro-efficiency actions.

Inefficient energy use is often associated with air pollution (combustion of low-quality coal and waste in households, improper service of installations, transport emissions). The main tool to combat this problem is a widespread thermo-modernisation of residential buildings and the efficient and sustainable supply of heat. Implementation of e-mobility and a number of measures planned for the development of an alternative fuel market will also have the effect of reducing emissions in the transport sector.

Electricity generation is and will be crucial. The main forecasts for the electricity generation until 2040 are the following:

Forecasted demand for electric energy and maximal electric power in Poland

	2020	2025	2030	2035	2040
Forecasted demand for electric energy (TWh)	165.0	181.2	198.8	214.3	230.1
Forecasted demand for maximal electric power (GW)	25.5	28.0	30.2	32.3	34.5

As a consequence, the main energy sources for electric energy generation will change as follows:

- Renewable energy sources – for achievement of 26% share of RES in electric energy generation significant new installations are required: photovoltaic farms starting 2022 (1 GW per year) yielding over 20 GW in 2040 and an annual production of ca. 20 GWh (power utilization factor 10-11%) and offshore wind farms starting 2025 yielding over 10 GW in 2040 with an annual production rate of ca. 41 TWh (power utilization factor ca. 45%). There will be slight increase of onshore wind farms, but only until 2025, with a gradual reduction in the next years. Electricity production from other RES will remain marginal – total power up to 4.3 GW, annual production 13-16 TWh.
- Natural gas – due to technical and economic reasons it will be used in cogeneration and gas-steam units as reserve and regulation units, with power capacities rising from only 1.5 GW in 2020 to 9.7 GW in 2040 (additionally 2.7 GW in CHPs). The gas consumption will rise from 2.4

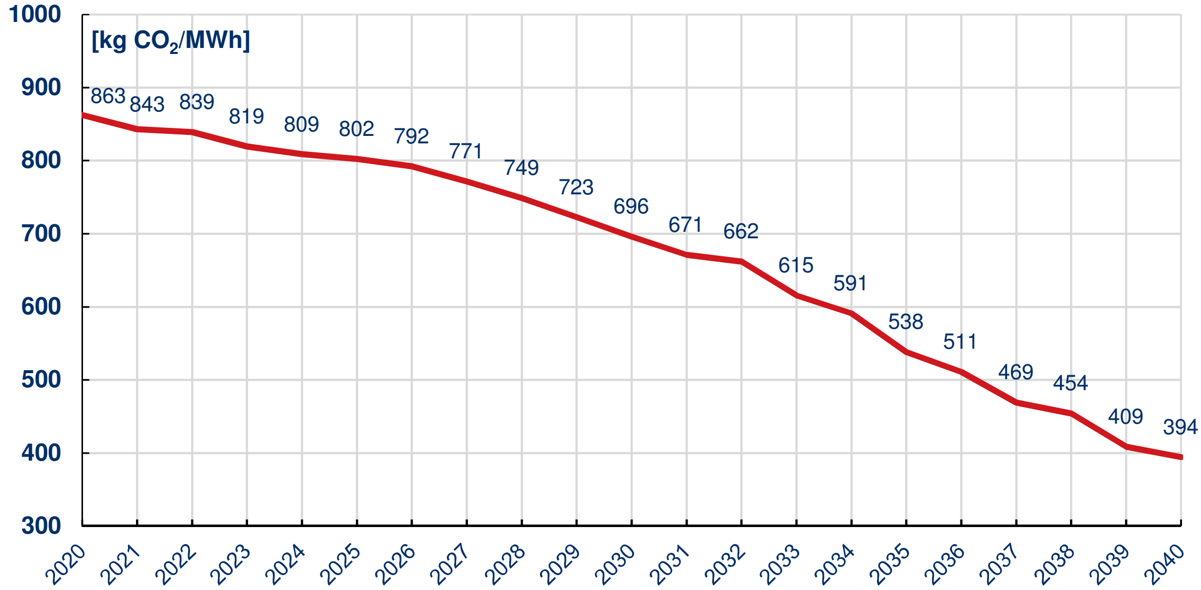
billion m³ in 2020 to 4.2 billion m³ in 2030 and 7.8 billion m³ in 2040; technical import capacities (excluding pipeline imports from Russia) will allow for that after 2022 with forecasted total domestic demand for gas rising to 27.6 billion m³ in 2040.

- Nuclear energy – it is expected to commence the first 1.4 GW nuclear unit in 2033, with further units being launched every 2 years, up to 5.6 GW capacity in 2040.
- Coal – electricity production from obsolete units will be gradually replaced by new more efficient units currently under construction; besides these there will only be one more coal-fired unit: Ostrołęka C. Consumption of hard coal in the power sector will remain stable at ca. 26 million tons/y until 2026 and then gradually decrease to 20 million tons/y in 2040; the share of coal in total electricity generation will decrease from 78% today to 60% in 2030 and 32% in 2040.

Forecast of electric energy production in Poland, by technologies (TWh)

	2020	2030	2040
Lignite power plants	54.3	56.9	11.7
Hard coal power plants	51.3	45.1	40.5
Hard coal central heating plants	23.2	22.3	22.4
Nuclear power plants	0.0	0.0	41.5
Gas power plants	3.7	9.4	26.8
Gas central heating plants	5.8	9.6	11.2
Photovoltaic power plants	0.8	9.6	19.9
Onshore wind power plants	14.7	13.7	1.8
Offshore wind power plants	0.0	17.1	41.1
Other RES power plants	9.5	14.1	13.0
Other CHPs	1.7	2.0	1.9

As a consequence, average net emission in the power and CHP sector is expected to decline significantly, especially after 2030.



Forecast of average net emission in the power and CHP sector [kg CO_2/MWh]

B: Successes and obstacles for the success of the individual energy transitions

The energy transition processes in Poland are complex and only to some extent compliant with previous and current governmental plans. Undoubtedly, they do not keep pace with analogue changes in many other European countries, Of course, it should be remembered that each country has its own specific history of economic development, its foundations and intrinsic energy sources.

After several years without a valid, official energy policy (last document dated from 2009, in 2015 the next project was not accepted), recently a consistent project, the „Energy Policy of Poland until 2040", was presented (see above). It is currently publicly discussed, but many assumptions seem to be at least debatable. Some of them are completely different from those adopted by most other EU countries. The following issues seem to be the most controversial:

- Debatable assumption on the desirability of developing nuclear energy as a way to limit average net unit CO_2 emissions;
- Forcing the construction of a hard coal fired unit Ostrołęka C in NE Poland;
- Lack of coherence regarding plans of maintenance of lignite-fired power stations;
- Current blockage of onshore wind farm development (new law on acceptable distances of new wind farms in relation to built-up areas);
- Unrealistic plans of electro-mobility development until 2025 (1 million electric cars in 2025);
- Too few ambitious plans for the development of RES use in relation to their existing potential (in particular in case of biomass, biogas and biofuels, partly also – geothermal energy);
- Too few ambitious plans for development of energy storage technologies;
- Potential problems and constraints in the further diversification of gas imports, and - in particular – in the construction of a gas hub in Poland;
- Problems with the transformation of individual household heating units from extensive use of low-quality coal and even wastes to the use of RES, especially heat pumps and photovoltaics (with unclear strategy of development of their use), as well as a too slow pace of the development of district heating;
- Too modest plans to improve energy efficiency.

Undoubtedly, the entire Polish energy sector faces enormous modernization challenges over the next dozen years. Besides the issues mentioned above, the main problem and challenge may turn out to be the lack of adequate financial resources to implement all planned investment projects, especially of construction of nuclear power plants, modernization of coal-fired units, expansion of gas blocks, construction of offshore wind farms as well as electricity and gas transmission infrastructure.

5.4 Serbia

A: Purposes, objectives and instruments of the energy transitions

A.1 Politically formulated targets and objectives

Republic of Serbia is the candidate country for the EU membership, so that the Serbian energy transition is strongly influenced by obligations set by the EU Accession process and Agreements signed by Serbia, in particular the Stabilization and Association Agreement and the Energy Community Treaty. Serbian authorities have aligned national legislation with the EU Acquis. The Energy Community Treaty enforces the implementation of the EU legislation in energy, environment, and competition fields. The Serbian energy transition is driven by the Energy Law (2014) and Energy Strategy to 2030 (2015). The share of lignite in the primary energy consumption would decline although remains dominant. The share of oil would also decline, while the share of natural gas, biomass, hydropower and other renewables would rise. The transition is followed by adequate environmental and climate policies.

With regards to the energy supplies, Serbia is self-sufficient only in electricity thanks to its lignite reserves and hydro potential, while for liquid and gaseous fuels is about 90% dependent on imports (the overall import dependence is of the order of 30%). Domestic lignite keeps the major share in the Serbian primary energy balance. In the final energy consumption, oil derivatives dominate, followed by electricity, heat energy, firewood, coal and natural gas. Households in Serbia consume more than a third of energy (almost a half of electricity), followed by industry and transport. One of the priorities for Serbia is to increase security of energy supply. While the power generation matches the electricity demand, this is not the case with natural gas and liquid fuels. Particularly critical is natural gas import from Russia through Ukraine and Hungary which exceeds 80% of total demand. The risk behind is because the gas transition contract via Ukraine, which expires in 2019, might not be extended. Serbia is currently negotiating gas pipeline connection to the “Turkish Stream” via Bulgaria and implementing EC Regulation on conditions for access to the natural gas transmission networks.

The use of renewable energy must be increased by 2020, as provided by the Energy Community Treaty for each signatory country. Serbia has committed itself to reach 27% of gross final energy consumption from renewable sources by 2020. This target, based on the National Action Plan on renewables, includes 36.6% of renewables in electricity, 30% in heating and cooling and 10% in transportation. Majority of energy consumption from renewable sources comes from the large hydro power plants. Poor energy efficiency is one of the major challenges in the energy sector of Serbia. The National energy efficiency action plan puts the goal to achieve 9% of savings in the final energy consumption in 2018 as compared to 2008. The Law on the efficient use of energy (2013) is aimed to help establishing a fund to subsidise energy efficiency projects. With 70% of its electricity generation stemming from coal-fired plants, Serbia is among the largest greenhouse gas (GHG) emitters per capita in Europe (according to the reports submitted to the UNFCCC, about 80% of total GHG Emissions in Serbia comes from the energy sector). Serbia submitted the Intended Nationally Determined Contribution (INDC) to the UN declaring the readiness to reduce its GHG emissions by 9.8% until 2030 compared to 1990 emissions.

A.2 Existing and planned instruments to reach targets

To provide necessary legislative instruments to drive the transition in the energy sector, Serbia adopted systemic laws in energy (Energy Law and the Law on Efficient Use of Energy) and environment (four Laws on environmental protection), each followed by a set of action plans (to increase energy efficiency by 1% annually and to achieve the 27% share of renewables in gross final energy consumption in 2020, etc.) and governmental decrees (Decree on feed-in tariffs provided for production of electricity from renewable energy sources, Decree on subsidies for energy efficiency improvement, etc.).

The Energy Law (2014) transposes the majority of provisions of the EU Third Energy Package in the electricity and gas sectors including a gradual liberalisation of the energy market, as well as limiting the emissions of certain pollutants into the air from large combustion plants. All of these are enforced and monitored according to the Energy Community Treaty, pursuant to the decisions of Energy Community Ministerial Council. The Law on Efficient Use of Energy (2013) provides legal framework for the Budget fund established to subsidise the energy efficiency projects. Energy Sector Development Strategy for the period by 2025 with projections by 2030 (2015) outlines a desired mid-term and long-term energy development and defines strategic preferences and provides the directions for market restructuring and technological modernization of the energy sector. Decree on implementation of the Strategy for the period from 2017 to 2023 provides details on the projects planned to be completed or launched in that period, including necessary investments to be provided.

National renewable energy action plan (2013) encourages investments in renewables and sets goals to increase the share of renewable energy, as well as the method of their implementation. To enhance the investment in renewables, the Government recently extended by the end of 2019 the validity of the existing Decree on feed-in tariffs for subsidizing electricity. In order to align its legal framework with EU's acquis for renewables, Serbia envisages some fundamental changes in the Energy Law to introduce tendering or auctioning process, to eliminate the temporary status of privileged power producer, to introduce balancing responsibility, to designate renewable energy operator, etc. Serbia has ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 2001 and the Kyoto Protocol in 2008, as a non-Annex I Party. To comply with the goals of the Paris Agreement on preventing global warming, Serbia is currently developing the Strategy of low-carbon economy and the Action plan to reduce GHG emissions, as well as the Program for adaptation to the climate change. To provide the legal framework for these to be adopted, Serbia has drafted the Law on climate change, which passed the public debate and is expected to be adopted by the end of 2018.

B: Successes and obstacles for the success of the individual energy transitions

B.1. The progress of the energy transition

As the signatory country of the Energy Community Treaty and currently in the accession process to the EU, Serbia will have to considerably improve energy efficiency and environmental protection and further increase the share of renewable energy sources. A great deal of these is already in progress according to the adopted Program for the Implementation of the Energy Strategy. To comply with the Energy Community Treaty, some of the coal powered power plants will have to be closed in the near future and the rest of them will have effective environmental protection systems installed to continue operation, while the new construction is expected to follow the highest environmental standards. The bulk of new renewable electricity will come from wind (planned capacity is 500 MW by 2020, half of which will be on line in 2018), while solar potential remains under-utilized (10 MW only). However, new hydro capacities are behind the plan: no new large hydropower plants have been built. A waste-to-energy cogeneration facility has recently been contracted. Also, some heating plants are considering the biomass to burn instead of fossil fuels.

B.2 Societal aspects of the energy transition

Serbian energy entities did not commercially operate for decades, as the social policy implementation has been associated with low energy prices. Electricity tariffs have increased since 2000, but electricity prices for residential consumers (about a half of total consumption) are still regulated and remain among the lowest in Europe. On the other side, costly technological upgrades need to be achieved simultaneously with the environmental requirements posed by the process of EU integration. Moreover, a high energy dependence renders Serbia's economy more vulnerable to fuel price shocks, thus affecting the country's prospects for socio-economic growth. Serbia's economy is highly energy-intensive, consuming 2.7 times more energy per unit of output than an average OECD country. However, both the investment potential of consumers and their incentives for to save energy are limited, the second due to still low regulated electricity price, not reflecting the costs of production and delivery. Thus, action priority is to separate social policy from the prices and to implement EU directives on energy end-use efficiency, energy services and energy labelling.

B.3 Obstacles and barriers for the success of the energy transition

Serbia depends on its lignite for energy production, but aims to meet the EU environmental goals by using clean coal solutions. Some efforts in reducing dust, SO2 and NOx emissions from coal plants have already been implemented. Use of hydropower (both large and small plants), and biomass (both agricultural and wood-based) is rather high, but could be used significantly more in energy production. However, Serbia lacks investment for new large hydropower plants, while some subsidised small hydropower plants start to cause concerns about their siting in or near protected areas. Also, Serbia's commitment to have 10% of biofuel in transportation remains questionable.

Another focus in the energy field is the modernization of district heating plants, including fuel switching from fossil to renewable energy sources, especially to wood biomass. Woody and agricultural biomass potential in Serbia is considerable, and not used yet to a large extent. However, agricultural biomass appears to be difficult and too expensive to collect in many cases, while current huge deforestation without reforestation which causes huge harms to the land, and also scientific scepticism on carbon neutrality of forest biomass in general, make its use for energy to a larger extent very questionable.

B.4 A comparison of Serbian and European targets and achievements

Poor energy efficiency and high carbon intensity due to heavy reliance on fossil fuels are among the major disadvantages of the energy sector of Serbia as compared to that of the EU. Energy intensity in Serbia is about four times higher compared to the EU average, and enormous financial, time and other resources would be required to get closer to the EU goals. Serbia has made some progress concerning the increase in share of renewables, but huge efforts would be necessary to move Serbia's climate policy towards the EU targets and get away from the coal while preserving security of energy supply.

Though with numerous difficulties, Serbia is progressing well with its obligation under the Energy Community Treaty, but slower than expected. The Serbian Energy Law is compliant with the EU Third Energy Package, and many obligations provided by it have already been completely or partly fulfilled in order to approach EU legislative. This refers to the achievements in transforming vertically organised monopolies to the legally (fully or partly) unbundled service providers at the deregulated market, to the developed competition at the market, to the improved interconnections necessary to meet the objective of increased security of supply, etc. However, these achievements of Serbia are not equally distributed across all of its energy sectors, with oil and gas sectors lagging behind the electricity sector.

5.5 Slovenia

A: Purposes, objectives and instruments of the energy transitions

Presently, there is a system of legal instruments and targets that define the current implementation of the energy transition. Their "vertically nested "structure is approximately as follows:

- Energy law EZ-1
- National energy programme (NEP)
- Action plans

However, their genealogy is not the same. The energy law EZ-1 was passed only in 2014 (amended in 2015) while the NEP and action plans have longer histories. The Energy law is a comprehensive document which provides legal framework for NEP with action plans, rules of the energy market, manner of implementation of public functions, etc. National energy program (NEP) is a 20 years' program defining the use of energy and financial resources for development of technologies and infrastructure for energy production. Based on SET plan (adopted in 2008), it came into force in 2010 and was intended to be concluded by 2030. NEP objectives are efficient, secure and competitive supply and use of energy and was aligned with EU directives.

Operational targets of Slovene energy policy NEP (all targets relative to year 2008):

- Improve for 20% efficient use of energy until 2020 and 27% until 2030
- attain 25% share of RES in use of gross final energy until 2020 and 30% share until 2030;
- reduce for 21% the emissions of GHG from fuel burning until 2020 and additional 18% until 2030
- attain 10% share of RES in the transport sector until 2020
- reduce for 29% energy intensity until 2020 and for 46% until 2030
- achieve 100% share of nearly zero-energy buildings in the segment of new and renewed buildings until 2020, and in the public sector until 2018
- institute Efficient use of energy (EUE) and Renewable energy sources (RES) as priorities of economy development of the country

Implementation strategy

- upgrading the energy inefficient buildings with more energy efficient
- replacing oil for heating with biomass and other RES
- replacing electricity for sanitary water with RES and solar energy
- construction, extension and recycling of heat from those industrial processes that use thermal energy
- production of electricity from RES
- introduction of RES and other biofuels in transport and in the agricultural sector and introduction of EVs
- development of industrial production of technologies for EUE and exploitation of RES

The strategy is to be implemented in **action plans**. The following action plans have been formulated

- action plan for energy efficiency
- action plan for RES
- action plan for nearly zero-energy buildings
- other action plans or operational programmes for supply or use of energy

Different action programs have been introduced at different times and renewed/upgraded on 3-annual basis.

The **Energy law EZ-1** also introduced the "**Energy concept of Slovenia"** as the basic development document representing national energy program for next 20 years (2035) and as a framework for 40 years (=2055). The Energy concept of Slovenia was planned to be formulated and adopted in 2015. However, its formulation and approval has been greatly delayed. Consequently, there are no "really binding" targets and objectives past 2020, because the long-term framework objectives and strategy are being worked over and will be contained in "Energy concept for Slovenia".

The genealogy of the Energy concept of Slovenia.

The process has started in 2015 and went through several phases, which included: first draft for public consultation (earl 2015), public consultation (2015), workshops with stakeholders' groups (2015, 2016); tendered study for long term energy balances for (10!) and it may be pointed out that

IAS has been one of the serious contributors in this process, starting with preparing and publishing in July 2015 "Position IAS to evolution of energy segment in Slovenia to 2030 with a view to 2050", and participant in consultations and workshops. The Resolution on energy concept of Slovenia that was prepared by previous government in March 2018 to be adopted in the parliament has not been approved and passed in the parliament due to change of government in 2018. What is more, it will be seriously reconsidered. In particular, 7 main challenges have been identified, and of these, inter alia: the share of self-supply (in conjunction with to dispersed RES production), increased share of RES, increased share of Hydro-electric power, energy efficiency in use, smart grids and electricity market. This means that the present strategic objectives and targets for 2030 and beyond will be modified. The responsible ministry officials estimate that the renewed proposal of the Resolution on energy concept of Slovenia will have been approved on the governmental level and sent into parliamentary procedure by end of 2019; and passed by the Parliament in the first half of 2020.

NECP - National Energy and Climate plan

In response to EC directive (2017) Slovenia has to prepare until end of 2019 Integrated National Energy and Climate Plan to 2030 (with the view to 2040) that will define objectives, politics and measures in five dimensions of the energy union: decarbonization; energy efficiency; energy supply security; internal market; technology development to 2030 (research, innovation and competitiveness).

Ministry for infrastructure has with participation of other sectors (ministries) (in cross-sectorial working group) already prepared and submitted a draft based on already prepared and accepted long-term and medium-term documents. A wide public consultation and dialogue has been started in first part of 2019; supported also with coordinated participation of stakeholders within Strategic council for energy transition, established by Chamber of economy in April 2019.

B: Successes and obstacles for the success of the individual energy transitions

Progress of energy transition - targets

- (+) Slovenia has already reached its 2020 targets on GHG emissions
- (+) It Is close to meeting its 2020 target for renewables
- (-) With only 1,6% it is lagging considerably behind the 10% target for increasing the share of renewables in the transport sector
- (+) In the renewable electricity, it is doing well in hydropower, with 34% share (in 2016)
- (-) but wind power potential is hardly used and solar is well under its potential
- (-) Dispersed/decentralized production of renewable electricity is lagging considerably behind its potential and potential impact on economy: all sources 7% share in 2016, of these: 41% small HE, 25% solar, 12% biogas, 6% biomass, 1% wind.

Overall, Slovenia has performed well and in agreement with European targets.

Progress of energy transition – systemic measures and instruments (political barriers)

- (-) Delayed formulation and acceptance of Energy concept of Slovenia, which instead of 2015 may be accepted in late 2019, after a new cycle
- (-) Deficiencies of the proposed Energy concept of Slovenia prepared by the previous government
    - Lack of linking energy transition policy and the economy system development in the country, e.g. concentrated vs. dispersed RES production
    - Lack of criteria & methodology steering the investments and enabling adaptation of the Concept to changing boundary conditions during its life (to 2050), based on

defined systemic criteria and sound state-of-the-art techno-economical methodology taking into account total costs of competitive measures for achieving strategic goals and associated investments.
  - Inability to integrate different partial goals of interest groups into national strategic envelope (c.f. 10 scenarios)

Public acceptance & engagement

Majority of Slovene population support increasing share of renewable energy and the environmental policy; in polls and surveys typically around 2/3 or more. Also, they participate considerably in the energy transition in the segment of private & residential houses in action plans for renewables and for increasing energy efficiency and a fair segment of them are inclined to venture into new solutions. Relative majority represent great potential for expanding both the dispersed electricity production by solar power, biomass and biogas, and for increasing energy efficiency both by passive houses and coupling of energy media; providing proper electricity market design and business models enabled by new technologies were put in place.

Obstacles and barriers for the success of the energy transition

The greatest systemic obstacle is the delayed formulation and acceptance of Energy concept of Slovenia and the deficiencies inherent in its last proposal – c.f. the paragraphs: *Deficiencies in systemic measures and instruments*; and *The genealogy of the Energy concept of Slovenia*.
A number **of specific obstacles** are explicit in the domain of smart grids. They influence directly or indirectly a number of objectives in the fields of

- Efficient use of energy
- Share of RES in dispersed energy production
- Types and costs of energy storage, to be used for energy balancing
- Engaging the innovation and capital of private prosumers, in EUE and in dispersed RES
- other

They can be classified into Regulatory and Market barriers. The following is representative but incomplete.
Regulatory barriers Smart grids:

- Lack of regulatory provisions and willingness to allow *pilot operation* of new solutions in the electricity market that would represent a paradigm change to existing market and system design and the roles of players. By definition they do not operate within the constraints of existing regulations
- New business model for DSO should be introduced giving it responsibility and (corresponding income) for congestion management and balancing the distribution grid
- The cost of energy transfer in the distribution grids should be included in the network fee

Market barriers Smart grids

- Dominant influence of existing players in electricity grid (TSO) and in energy production (big energy producers, e.g. large fossil-fired plants, NPP). Together, they represent massive opposition to: i) change of paradigm concerning the role of prosumer (curtailment vs. trading of flexibilities), ii) introduction of new market and system structure, allowing new roles and players.
- Dynamic pricing of flexible energy based on actual local energy flexibility needs should be introduced instead of tariff systems

Local energy flexibility markets should be made possible to engage local flexibility of prosumers in balancing the increasing misbalances due to inflexible RES production.

5.6 Spain

A: Purposes, objectives and instruments of the energy transitions

Energy transitions may be understood as gradual changes in the structure of the energy mix over time, in one country or region, which could also include other questions such as behavioral questions of consumers, the market, and so on. However, the actual understanding of energy transitions has to do with changes in the energy mix that have a purpose or purposes, and objectives.

In Spain the objectives for 2020 and 2030 were determined in the context of the aims agreed in the European Union (EU), in particular in 2017 for 2020 objectives and in 2014 and 2016 for 2030 objectives which in 2019 have been updated and revised. For the year 2020 there is an objective to reduce GHG (Greenhouse gas) emissions 10% compared to those of 2005. This reduction is distributed among EU ETS (Emissions Trading Scheme) and non-ETS sectors (10% for the non ETS sectors and 21% for ETS sectors). Both reductions are related to those of 2005. Globally the 10% reduction is equivalent to 30% with respect to 1990. For renewable energies (RES), the objective is to achieve a 20% of renewables in final energy (10% in transport) by 2020. In relation to energy efficiency (EE), the objective is an improvement by 20% of it with respect to the trend (business as usual) of 1990. Furthermore, there is an objective of electricity interconnections of 10% for 2020.

The government of Spain, that took office in June 2018, created a new Ministry, the Ministry for "Ecological Transition". In November 2018 this Ministry circulated a draft for a law on "Climate Change and Energy Transition". This draft contained objectives and proposals related to RES, electricity grids, fossil fuels, mobility, buildings, adaptation measures to climate change, justice in energy transition, economic funds, taxation and governance. Sometime later, in February 2019, the Ministry for Ecological Transition published the "Strategic framework of Energy and Climate". This framework consists in three key documents for the energy transition. The first one is the draft of the law of "Climate Change and Energy Transition" (Anteproyecto de *Ley de cambio climático y transición energética*), which is under public consultation till 1st April 2019. This draft does not coincide exactly with the previous document referred above. The second document is the draft of the "Integrated National Energy and Climate Plans 2011-2030" (*Plan Nacional Integrado de Energía y Clima 2021-2030* -PNIEC) and the third one is the "Strategy for a Fair Transition" (*Estrategia para una Transición Justa*).In the draft of the law, several issues are addressed, namely the objectives for 2030 and 2050 -which shall be referred below-; mobility without emissions, -which specifies that by 2040 vehicles should emit zero grams of CO_2 per kilometer; the no granting of licenses for exploration and production of hydrocarbons and the banning of hydraulic fracturing; measures for a fair energy transition, as well as measures related to the adaptation to climate change and finally the research, development and innovation. The main objectives included in this draft are following. For 2030 a reduction of GHG at least 20% with relation to 1990; 35% of renewables in final energy consumption; 70% of renewables in electricity generation; 35% improvement in energy efficiency versus the base line of the European regulation. Furthermore, for 2050 it establishes as objectives a reduction of 90% of GHG emissions and 100% of electricity generation from renewables. Other objectives, or relevant issues, are related to the promotion of biomethane and other renewable fuels and the obligation for the suppliers of conventional fuels (above a certain levels of sales) to install recharging points for electric vehicles, and the annual bidding of at least 3,000 MW of renewables.

The "Integrated National plan for Energy and Climate" also includes general and specific objectives, as well as policies and measures. As far as the general objectives are taken into account the plan considers a 21% reduction of GHG vs. 1990 to be achieved; 42% of renewables in final energy and 74% of renewables in electricity generation and improvement of 39.6% in energy efficiency. These figures mean a stronger commitment than those included in the draft of the law. GHG emissions reductions are focused principally in the electricity and transport sectors. In this regard, the plan considers a reduction of 44 Mt CO_2 eq. in electricity generation by 2030 -in 2015 these emissions amounted to 74 Mt CO_2 eq.[21] -and a reduction of 28Mt CO_2 eq. in transport -which in 2015 were 83 Mt CO_2 eq. In mobility the CO_2 reduction is based on modal changes in transportation and in the penetration of electric vehicles (5 million in 2030).

For the objective of 42% renewables in final energy by 2030 the plan relies on the high penetration of renewables in electricity generation and in thermal energy as well as the citizens' participation in the energy system. By 2030, in accordance with the draft of the plan, the installed capacity in electricity shall be 50 GW of wind, 37 GW of solar photovoltaic, 27 GW of combined cycle power plants, 16 GW of hydro, 8 GW of hydro reversible pumping, 7 GW of solar thermoelectric, 3 GW of nuclear and coal should be in between zero and 1.3 GW.

The energy efficiency objective of 39.6% improvement (in final energy) implies a reduction progression of 1.9% annually, and an improvement of 3.6% of energy efficiency by 2030. The plan contains also policies and measures related to the dimensions that the EU governance requires such as energy security, internal energy market -including a 15% of interconnection capacity by 2030- and research, innovation and competitiveness. The plan contemplates 20 measures in decarbonization, 10 in energy efficiency (for instance, energy rehabilitation in buildings would mean the rehabilitation of 1,200,000 homes in Spain), 4 in energy security, 10 for the internal energy market and 9 for research, innovation and competitiveness.

Table 1: Main energy and climate objectives (Source: own elaborations).

	GHG	RES	EE	Other
EU 2020	Reduction by 10% compared to 2005; -10% in non-ETS sectors; -21% in ETS sectors	20% in final energy (compared to 1990 business as usual) -10% in transport	20% improvement	-10% of Electricity interconnections
EU (draft of the law of "Climate Change and Energy Transition)	20% reduction in relation to 1990	35% of renewables in final energy consumption 70% of renewables in electricity generation	35% improvement in energy efficiency	
Spain 2050 (draft of the law of "Climate Change and Energy Transition)	Reduction of 90%	100% of electricity generation from renewables		
PNIEC	21% reduction of GHG vs. 1990 to be achieved	42% of renewables in final energy 74% of renewables in electricity generation	39.6% improvement in energy efficiency	

[21] In this respect the plan considers that the CO_2 price shall be 35 €/ton, which means that coal shall not be competitive with gas.

B: Successes and obstacles for the success of the individual energy transitions

The first consideration related to the success or failure of the energy transition till now, has to do with the achievements in the above-mentioned objectives, that is in terms of GHG emissions reduction, renewables penetration, energy efficiency and the level of electricity interconnections. In relation to the objective of the reduction of GHG emissions, the progress is in accordance with the objective to 2020 [in 2018 GHG emissions were 12.95% above 1990 reference, that is a reduction of 26.14% since 2005]. Two factors are considered here as contributors to the success: the development of renewables in electricity generation and the economic crisis that after 2008 reduced dramatically energy demand in electricity, gas and oil products.

Renewables in final energy were 16.2% in 2015, this percentage was due mainly to the incorporation of wind and solar, mainly photovoltaics, but also solar thermoelectric, for electricity generation. The penetration of biofuels, for various reasons, has been rather low [around 4%]. So, for obtaining the objectives by 2020, new construction of wind, solar photovoltaics and other renewables such as biomass, has to be carried out. In fact, around 8,000 MW have been awarded in the official biddings in 2017. In relation to energy efficiency, the National Action Plan of Energy Efficiency of 2014, included an objective of 119.8 Mtep of primary energy and of 80.2 Mtep of final energy by 2020. In 2015 those data were 117 Mtep and 80.5 Mtep respectively.

The above-mentioned figures support the idea that the compliance with the 2020 objectives in GHG, and probably in renewables, provided construction of awarded capacity in renewables is built on time, and some new capacity is awarded. However, energy efficiency measures and incentives have to be reinforced, in order to comply with this objective. The analysis of the successes or failures, has to take into consideration the cost to obtain such a progress. In this respect the deployment of wind and solar electricity generation had a great cost; estimated around [2,922 and 3,856 M€ respectively for 2017] that affects the price of electricity and the competitiveness of some industries.

Looking to 2030, the first consideration, is to what extent the objectives in the draft of the Law for 2030 shall be in the definitive Law, as the government has not the majority neither in the Congress nor in the Senate and new elections will take place in April 28th. Presumably the new government will need to find agreements with various political groups. It shall also be key how the objectives are effectively related to instruments in the "Integrated National Plan for Energy and Climate", and more importantly how they are put in practice and monitored.

Therefore, the first obstacle for the energy transition is to obtain a high degree of consensus, taking into account the time horizon of the transition 2030-2040 (and even 2050). The objectives, the regulation and the instruments need a wide and ample consensus, however not only among the political parties but also with the firms, the NGO, and other stakeholders. As a consequence, it is really essential to provide an adequate predictability and stability to the process, so to obtain the different objectives. Another relevant issue, in the case of the electricity system, is the timing for the final operating life of nuclear reactors. Forty years of operations for the existing nuclear reactors mean around mid-2020 for four units and mid 2030 for the remaining ones[22]. Coal fired power stations are another key topic for the electricity system. It is likely that those units that have already

[22] Recently an agreement has been announced, by which the nuclear power reactors of Almaraz should finalize operation in 2027-2028. Presumably from that date other reactors should be finalizing operations being the last one (Trillo) in 2035.

invested in DSOx and DNOx, may continue operations, if they have competitive coal and if CO_2 allowance prices are not high, at least during a significant part of the 2020s.[23]

The second obstacle is to attain a high degree of CO_2 emission reductions by 2030 and 2050 focusing mainly in the electricity system. Some considerations are relevant here. First electricity accounts for around 24% of final energy. Even if all electricity would be produced from renewable sources, the percentage of renewables in final energy would not be greater than 46%. So, it is clear that electricity should attain a higher penetration in final energy. Nevertheless, high electricity prices and competition from other energies in final uses or the difficulties of substitution (i.e. natural gas for high temperature uses in industry or in domestic uses and oil products in road transportation) do not make electricity penetration, in some sectors, an easy task.

The third obstacle has to do, with the difficulties for introducing renewables (biofuels) and electric vehicles in transport at a scale that may make a large contribution to CO_2 emission reductions[24]. The fourth obstacle is related to the difficulties in obtaining a high rate of continuous improvements in energy efficiency in industry and in the tertiary and domestic sectors -nearly 2% annually.

Other relevant issues for a successful transition are those that at present are not specified in detail or not much analysed or discussed from a technical point of view. Some of them are the following: a) to what extent distributed generation, prosumers and demand side response shall be developed, b) which shall be the role of the Distribution System Operators (DSO) in relation to new entrants, prosumers and micro grids and c) which shall be the role of the combined cycles of natural gas versus electricity storage.

To finalize, it may be said that great transformations in big and mature energy systems, in such a reduced schedule of around ten years, is a very complex issue with is affected by many factors. To obtain the ambitious objectives, there is a need to do an exercise of realism beyond the political intentions.

5.7 Sweden

A: Purposes, objectives and instruments of the energy transitions

Objectives in Sweden

Sweden is to become one of the world's first fossil free welfare nations. The objective for Sweden is to have no net emissions of greenhouse gases into the atmosphere by 2045, and there after achieving negative emissions. In June 2017, The Swedish Parliament adopted a new climate policy framework and a climate strategy for Sweden. The Climate Policy Framework consists of three pillars; a Climate Act, climate goals, and a Climate Policy Council. The Climate Act entered into force on 1 January 2018. The Climate Policy Council will assist the Government by providing an independent assessment of how the overall policy presented by the Government is compatible with the climate goals. Sweden's climate and energy policy targets are:

[23] A document of reference for examining different scenarios for 2030 for the electricity mix is:"Comisión de Expertos de Transición Energética. Análisis y propuestas para la descarbonización". March 2018

[24] In the PNIEC, 5 million of electric vehicles are considered, this number being very ambitious according to some studies.

- By 2045, Sweden is to have no net emissions of greenhouse gases to the atmosphere and should thereafter achieve negative emissions. In addition to the general climate goal, Sweden has set an emission target for domestic transport (not including domestic air travel), which means a reduction in emissions from this sector of at least 70% by 2030, compared with 2010.
- By 2040, 100% of electricity production is renewable. This is a target, not a deadline for banning nuclear power, and does not mean closing nuclear power plants through political decisions.
- By 2030, Sweden's use of energy is to be 50% more efficient than in 2005. The target is expressed in terms of primary energy use in relation to gross domestic production (GDP).

To achieve the target of no net emissions of greenhouse gases until 2045, at least 85% of the reduction must be on Swedish territory, compared to the emissions 1990. Up to 15% of the reduction can be achieved by measures in other countries. A governmental investigation has been appointed to investigate different solutions to obtain negative emissions, e.g. CCS or changed land use, and suggest instruments to implement them. The investigation will present its results in January 2020. The objectives of the EU constitute the basis for the adopted energy and climate goals in Sweden. The EU targets for 2020 have been transformed into directives and regulations which have been incorporated into Swedish law. The climate and energy goals adopted by the Swedish Parliament specify that:

- The proportion of energy use from renewable sources in 2020 shall be at least 50% of the total use of energy.
- The proportion of energy use from renewable sources in the transport sector shall be at least 10% in 2020.
- Energy consumption shall be 20% more efficient in 2020 compared to 2008 (a cross-sectoral goal of reduced energy intensity).
- The emissions of greenhouse gases, from activities not covered by the EU´s system for emissions trading, shall in 2020 be 40% lower than in 1990.

Instruments

Below is an overview of some important instruments for the transformation of the Swedish energy system and reducing greenhouse gases.

Energy taxes in Sweden

Energy taxation is a collective term for excise duties on fuels and electricity. Energy, carbon dioxide and sulphur taxes are regulated in the Energy Tax Act. Energy tax is paid on the majority of fuels and is based on the energy content. Carbon dioxide tax is paid per emission of one kilo of carbon dioxide on all fuels, except biomass and peat. The tax on Carbon dioxide was introduced in 1991 and has gradually been increased. There is also VAT on energy including the taxes.

Market based policy measure for renewable electricity: Green Certificate Electricity system

Sweden introduced a Green Certificate Electricity system in 2003, and Norway joined the system in 2012. The electricity certificate system is market based and intended to increase electricity production from renewable energy sources in a cost-effective manner. Electricity producers receive one certificate for each megawatt hour of produced renewable electricity over a maximum of 15 years. Customers are obliged by law, to buy certificates to a certain proportion (quota) of their electricity consumption. The quota is adjusted each year to achieve the target of a certain amount renewable electricity. The electricity system is recently prolonged to 2030 but will probably be phased out after that. It has been very successful.

Subsidies

There are different kind of subsidies for renewable energy, for example on investments in solar panels, and use of biofuels.

Subsidy programme: "The Climate Leap"

The purpose with "The Climate Leap" is to strengthen local and regional climate efforts through support to climate investments, for instance in a town, municipality, company, school or county. Individuals are also entitled to apply for contribution. Within the programme subsidies are given to for example solar panels and charging stations for electrical vehicles.

Subsidy programme: "The Industry Leap"

Industry stand for more than 30% of greenhouse gas emissions in Sweden. A big part of the emissions is process related and are difficult to reduce without new technologies and process solutions. Major investments are needed in technology not yet fully developed, and hence the risk is big. "The Industry Leap" is a long-term subsidy program (2018-2040) aiming at industries with process related emissions, e.g. iron and steel, chemistry, refineries, and mineral industries. The support includes the whole chain from research and innovation, to demonstration and pilot plants.

Governmental programs and regulations

Beside taxes and subsidies, there are several Governmental programs and initiatives to achieve a sustainable energy system. Below are some examples.

Roadmaps for fossil free competitiveness

Fossil Free Sweden was initiated by the Swedish government ahead of the COP21 climate change conference in Paris in 2015. The ambition is to make Sweden one of the first fossil free welfare countries in the world. Participation in the initiative is voluntary. Up till now, more than 350 enterprises, municipalities, associations and other types of actors have joined the initiative and have developed roadmaps for how to become fossil free.

Swedish smart grid

The task of the Swedish smart grid forum is to promote a dialogue about the possibilities of smart grids, and to help international business opportunities and partnerships within the smart grid field.

B: Successes and obstacles for the success of the individual energy transitions

Sweden´s energy system has developed over 100 years. In the beginning of the last century the development of hydropower took place. After the World War II, Sweden began to develop nuclear power, and planned for a comprehensive expansion to meet the forecasted rapidly growing demand for electricity. Sweden didn´t fulfil the ambitious nuclear programme of 24 reactors but brought 12 reactors into operation between 1972 and 1985. Today eight reactors are in operation but in a few years, it will probably only be six, due to economic reasons. Wind power production has increased sharply in recent years and now stands for 10% of the electricity production. The Swedish electricity system has hardly no fossil fuels, except in a few back-up power plants, and in imported electricity.

District heating was introduced in Sweden 1947, but the expansion accelerated after the oil crises in the 1970s, and oil as fuel was replaced with biofuel and electricity including large heat pumps.

Biofuels are mainly a by-product from the forest industries. During the same period oil was also replaced with electricity as heat source in single family houses, and from the 1990s onwards, the direct-acting electricity has been supplemented with heat pumps for a more efficient use of electricity (more than 50% of the houses have heat pumps). Between 1970 and 1990, the share of oil products in the final energy consumption in Sweden, decreased from 66% to 37% and has today (2016) a share of 23%, including a small amount of natural gas. (Natural gas is only established in a smaller area in the south of Sweden, as an extension of the Danish network.) Oil is predominantly used in the transport sector, and accounts for 76% of the oil consumption 2016.

Sweden is very successful in waste incineration, and half of the household waste is recovered as energy for district heating or electricity production. A substantial amount is also treated biologically, 15%, and the biogas produced is used as fuel. Almost every city in Sweden has district heating, and fossil free district heating is the dominant source of heat for premises and multi-family houses. Electricity and heat pumps are the dominating source for heating in single family houses. The residential and service sector is hence almost fossil free in Sweden.

Success factors in Sweden´s energy system:

- District heating based on renewable energy.
    - Most important driving forces were energy and carbon taxes (from 1991).
- Electrification enabled by hydro power and investments in nuclear power.
    - The most important driving force was to get rid of oil, due to fiscal causes and security of supply in the 70s and 80s, and now for climate reasons. Electrification contributed to a big reduction of oil consumption for heating and in industries.
- Heat pumps
    - The most important driving force was, and still is, to reduce the cost for heating and to improve energy efficiency in buildings.
- Waste incineration
    - The most important driving force is tax on waste landfills.
- Energy efficiency in buildings and industries.
    - The most important factor is modernization and upgrading in industries, and Building regulations in the residential sector. Profitability is a prerequisite for energy efficiency measures.

There is a political consensus and a common understanding in the society that climate change is a reality and a threat to the living conditions on earth as they look today. Seven out of eight parties in the Parliament stand behind Sweden's climate goals. Acceptance in industry and among people in general, is high, but there are of course exceptions.

Challenges and weak spots in the transformation of the energy system:

- Fossil dependency in the transport sector.
- Industries still dependent on fossil fuels.
- Large increase in demand for biomass – will there be enough?
- Security of supply in the electricity system due to the transformation in the power system.

Sweden´s ambitious targets for the transport sector might be difficult to reach. Domestic transport is to 80% dependent on fossil fuels, but the alternatives are coming. The use of biofuels is continuously increasing and has currently a share of 20%. The biofuels available on the market today are ethanol, biogas and biodiesel. The main part of the biofuels sold on the Swedish market, is mixed with ordinary gasoline or diesel. (5% ethanol in petrol, and 7% FAME in diesel). The number of electric vehicles is increasing but has still a very low market share. Out of 4.8 million passenger cars in Sweden, only 70,000 are electric cars.

The industry in Sweden is in general very energy intensive and based on natural resources. The major part of the energy is consumed in the pulp and paper industry (51%), steel and metal industry (15%) and chemical industry (9%). The pulp and paper industry is almost fossil free, with an energy consumption based on biofuels and electricity. The major challenges are within the steel and metal industry, with its associated mining industry. Coal is required to reduce iron ore to pure iron, and fossil fuels are required in several steel and metal processes. Sweden is running a project to develop completely new technologies where hydrogen is used instead of coal for the reduction of iron ore. The hydrogen will be produced by electrolysis of water. Several industries are aiming at using more biomass in order to reduce their climate impact. There is a discussion in Sweden whether there will be enough biomass for all purposes, and how the biomass market will develop. Based on Sweden´s forest industries, biomass plays an important role in the energy supply. Most biofuels used are residuals from the forest industry, where timber is the main product driving the market. The share of biomass in the energy consumption is 25%, while fossil fuels have 29%. Although a great share of the fossil fuels can be replaced with electricity, a large amount must be replaced with biofuels, in industries, ships and aircrafts, etcetera. It will be a challenge to provide the market with required volumes of biomass, that is sustainable.

Electricity is the other option to get rid of fossil fuels. Sweden has a robust electricity system with high reliability, but the system is changing. Nuclear power that for many years has accounted for almost half of Sweden's electricity production is gradually being shut down due to poor profitability and aging plants. New power plants are mainly wind power. This is changing the conditions within the technical system, both in terms of the ability to maintain the energy and power balance and the stability of the grid. Electrification is essential to be able to meet the climate goals, but the system must be considered reliable, otherwise the major investments needed will not be done. Compared to many other countries, emissions of greenhouse gases are low in Sweden. The average is 3.8°tCO_2/capita, compared to 9.0 tCO_2/capita in OECD.

Swedish targets compared with EU targets

The objectives of the EU constitute the basis for the adopted energy and climate goals in Sweden. (The EU targets for 2020 have been transformed into directives and regulations which have been incorporated into Swedish law. These include The Renewable Energy Directive, The Energy Efficiency Directive, The Energy Performance of Buildings Directive, The Ecodesign Directive and the Energy Labelling Directive.)

EU-targets:

- Reduction of greenhouse gas emissions
- Energy Efficiency
- Renewable energy in the energy supply
- Renewable energy in the transport sector

Reduction of greenhouse gas emissions

EU´s targets are to reduce greenhouse gas emissions with 20% by 2020 and with 40% by 2030, compared to 1990. Sweden´s national goal is to reduce greenhouse gas emissions from activities outside EU ETS with 40% by 2020, compared to 1990. So far, Sweden has reduced its emissions of greenhouse gases from sources outside EU ETS, with 30% between 1990 and 2017. It will not be possible to reach the 2020-goals in Swedish territory, but if flexible mechanisms according to the Kyoto Protocol and measures in other EU-countries are included, Sweden has already reached the target (2016). The total reduction of greenhouse gases in Sweden was 26% between 1990 and 2017.

Energy efficiency

EU´s targets are to reduce energy consumption by 20% through improved energy efficiency until 2020, and by 27% until 2030, compared to 1990. Sweden´s national goal is to achieve 20% more efficient use of energy in 2020, compared to 2008. Energy intensity is defined as the energy supply in relation to GDP in fixed monetary value. The energy intensity was 16% lower 2016, compared to 2008.

Renewable energy in the energy supply

EU´s targets are that 20% of total energy consumption should originate from renewable energy sources by 2020, and 27% in 2030. According to the EU directive, renewable energy in Sweden shall reach a share of 49% in 2020.

Sweden´s national goal is that the share of renewable energy in the total energy consumption should be at least 50% in 2020, and at least 10% in the transport sector. The total share of renewable energy in the energy consumption was 54% in 2016, and in the transport sector it was 30% (37%, 2017), according to the calculation method in the Renewable Energy Directive[i]. Sweden has reached the EU goals.

6. Comparison and concluding remarks

The above compilation of selected information on the various energy systems of EU-28 member states, of the common goals of the European community, and of the variety of paths and measures to proceed towards a more climate-friendly, sustainable development of the European energy landscape are in many respects impressive. It is easily understandable that different climate and weather conditions (cold or warm winters; much or little wind or sunshine) or available primary energy resources like coal, natural gas, biomass or hydropower result in different compositions of the national energy systems. It is less obvious, however, that some states rely strongly on nuclear power for their electricity production while others have completely refrained from the nuclear option. Or that some states quickly step out of nuclear energy and switch off their reactors on the shortest possible time scale, while other states built new reactors or think about it, or intend to prolong the runtime of their nuclear power stations as much as possible. Historical and political developments, the influence of ideologies and certain parties, the influence of energy providers and industry in general, the public (or published) opinion, and related movements (climate protection, green economy; sustainability; no nuclear; etc.) have also played a significant role in shaping the energy systems and their developments.

The result is that today we have an enormous diversity of energy systems in Europe. Taking the **electricity production** as example we have member states that rely nearly completely on fossil fuels as primary energy source like Poland or the Netherlands (80 – 90%) and other which use nearly no fossil fuels like France or Sweden (below 10%). Half of the EU-28 members use nuclear power (e.g. France 75%, Slovakia, Belgium, Hungary 50%, Sweden 40%, Slovenia 34%), the other half has no nuclear-based electricity (e.g. Austria, Italy, Denmark, Portugal). Some countries rely strongly on hydropower (e.g. Luxemburg 70%, Austria 60%, Croatia 55%, Sweden 40%), while for instance Denmark, Belgium, Hungary and the Netherlands have no access to it. Some regions have a lot of electricity from wind power (Denmark 45%, Lithuania, Portugal, Spain, Ireland, all 20 – 30%) while several others have no or nearly no wind electricity (e.g. Malta, Czech Republic, Hungary, Slovenia, Slovakia, Latvia). Photovoltaics makes still only a small contribution to electricity production; only Malta exceeds the 10% mark a little (15%). And finally, biomass: most member states use biomass but in only two of them the contribution to electricity production exceeds 10% (Finland 20%, Denmark 15%).

In contrast to the electricity sector the situation is very similar in the **mobility sector** in the various member states. The reason is simply that by far most of the energy in this sector is needed for individual cars and trucks, and these use predominantly fossil oil products. There are differences in the amount of admixtures REs, for example of bio-ethanol to gasoline or bio-diesel to diesel, but these make not much difference. In any case, decarbonization of the mobility sector remains a huge challenge in all member states until significant numbers of electric vehicles (battery, hybrids, or fuel cell vehicles) are being used provided these are fueled by fossil-free electricity or “green” hydrogen. The mobility sector is lagging far behind all promises concerning CO_2 emissions as well as penetration by renewable energies (exception: Norway, which does not belong to EU-28).

The **heat/cold sector** which is responsible for nearly half of the total final energy consumption can be subdivided in supply for buildings (heat/cold, warm water, share about 2/3) and for industry (especially process heat, share about 1/3). Of course, the industrial needs strongly depend on the degree of industrialization of a country and the types of energy-requesting industrial processes.

Perhaps due to the EU ETS system, industry is already on the way of reducing energy consumption and CO_2 emissions by various measures including severe consideration of revising some processes which contribute large amounts of CO_2 (e.g. production of steel, paper and pulp, cement), or by optimizing processes towards the (fluctuating) availability of REs ("demand side management"). The heat supply of buildings is satisfied in very different ways in Europe: electricity heating (and cooling) in countries which have a mild climate (Southern Europe) while heating with fossil fuels (coal, oil, gas) dominates in the Northern countries. Here, district heating plays already now and may increasingly play an important role (e.g. in Sweden, Poland, Germany), since in communities district heating is much more efficient than individual heating. If sufficient "green" electricity is available, heat pumps are very well suited to increase energy efficiency and reduce CO_2 emissions (like in Sweden, where more than half of the houses have heat pumps). In any case, heat insulation is perhaps the most important measure which can help to reduce the energy demand in the heat sector, but it requires continuous effort and support. The present rates of refurbishment and insulation of buildings is generally much too low (on average clearly below 1%). Rates around 2% appear possible and are required if the energy efficiency goals of EU-28 and of its member states shall be reached.

In reviewing the data and information given in this paper one can conclude that EU-28 is on its way into a sustainable, climate-friendly future, but the speed and success rate are presently clearly too low to meet the promised targets and agreements, for instance the binding contract signed at COP 21 in Paris 2015. For the EU commission the situation is complicated because the member states of EU-28 have completely different energy systems and frame conditions and proceed with very different speeds towards climate protection and replacement of fossil fuels. Since the member states are sovereign in their decisions, they can set up their own laws and regulations independent of their effectivity and success probability. This is clearly seen in chapters 3 and 4 of this paper and in chapter 2 where Figure 11 reveals that more than half of the member states lag behind their promises to replace fossil fuels by renewable energies, and Figure 2 displaying the CO_2 reductions since 1990 looks only good because the 2020 target (minus 20% greenhouse gas reduction) was rather unambitious. The reduction targets of the future will hardly be met with the present speed which can be derived when the national curves are extrapolated based on the recent development (see, e.g., Germany, section 4.2). There are only few member states which are well fulfilling and even over-fulfilling their promises, in particular the Scandinavian countries, at the head Sweden (see, e.g., section 4.6), while the East European countries have problems to keep pace due to their political and economic situation. It remains to be seen whether the new governance regulations (see chapter 3) will introduce a change in that all member states are similarly successful.

Annex

A1: Greenhouse gas emissions in absolute numbers

*Table 2: **Greenhouse gas emissions in absolute numbers** for several years from 1990 to 2016. The table is taken from https://ec.europa.eu/eurostat/statistics-explained/index.php/Greenhouse_gas_emission_statistics_-_emission_inventories#Trends_in_greenhouse_gas_emissions*

Total greenhouse gas emissions by countries (including international aviation, indirect and excluding LULUCF), 1990 - 2016
(Million tonnes of CO2 equivalents)

	1990	1995	2000	2005	2010	2016	Share in EU-28*
EU-28	**5 719.6**	**5 386.7**	**5 277.7**	**5 351.2**	**4 909.1**	**4 440.8**	**100.0%**
Belgium	149.8	157.7	154.5	149.0	136.9	122.1	2.8%
Bulgaria	104.7	75.5	59.8	64.5	61.1	59.7	1.3%
Czech Republic	200.1	159.4	150.8	149.0	141.5	131.3	3.0%
Denmark	72.2	80.2	73.1	68.9	65.8	53.3	1.2%
Germany	1 263.7	1 138.3	1 064.3	1 016.0	967.0	935.8	21.1%
Estonia	40.5	20.3	17.4	19.3	21.2	19.7	0.4%
Ireland	56.6	60.3	70.4	72.1	63.6	64.2	1.4%
Greece	105.6	111.8	128.9	138.9	121.0	94.7	2.1%
Spain	292.5	334.0	395.2	450.6	368.3	340.5	7.7%
France	555.1	552.1	565.3	568.6	527.7	475.4	10.7%
Croatia	32.4	23.2	26.0	30.2	28.3	24.7	0.6%
Italy	522.7	538.5	562.5	589.4	512.9	438.2	9.9%
Cyprus	6.3	7.8	9.1	10.1	10.3	9.7	0.2%
Latvia	26.7	13.0	10.6	11.6	12.7	11.7	0.3%
Lithuania	48.5	22.4	19.5	23.0	20.9	20.4	0.5%
Luxembourg	13.2	10.7	10.6	14.3	13.4	11.5	0.3%
Hungary	94.3	76.0	74.1	76.6	66.1	62.1	1.4%
Malta	2.3	3.0	3.1	3.2	3.3	2.3	0.1%
Netherlands	225.9	238.9	229.4	225.4	223.7	207.0	4.7%
Austria	79.6	81.1	82.1	94.6	87.0	82.0	1.8%
Poland	467.9	438.9	390.4	398.6	407.4	397.8	9.0%
Portugal	61.5	72.1	85.4	89.3	72.8	71.2	1.6%
Romania	247.5	181.1	141.2	148.2	122.7	113.4	2.6%
Slovenia	18.7	18.8	19.1	20.6	19.7	17.8	0.4%
Slovakia	74.0	54.0	49.6	51.3	46.4	41.2	0.9%
Finland	72.3	72.8	71.2	71.1	77.2	60.8	1.4%
Sweden	72.9	75.0	70.6	68.7	66.5	55.5	1.2%
United Kingdom	812.1	769.6	743.4	728.1	643.7	516.8	11.6%
Iceland	3.9	3.7	4.5	4.4	5.3	5.6	
Lichtenstein	0.2	0.2	0.2	0.3	0.2	0.2	
Norway	52.3	51.7	55.5	56.0	56.4	54.7	
Switzerland	56.7	56.0	57.1	58.3	58.5	53.5	
Turkey	211.3	243.0	295.1	336.0	408.5	506.8	

*Share in EU-28 total in year 2016

Source: European Environment Agency (online data code: env_air_gge)

eurostat

A2: Greenhouse gas emission

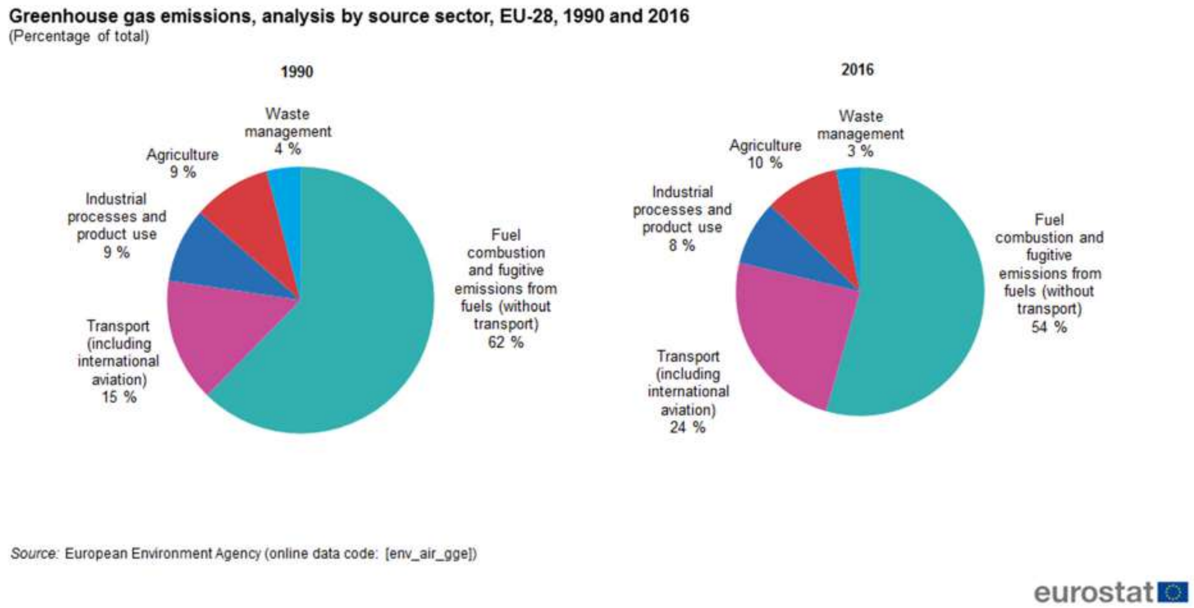


Figure 16: ***Greenhouse gas emission*** *(https://ec.europa.eu/eurostat/statistics-explained/index.php/Climate_change_-_driving_forces#General_overview*

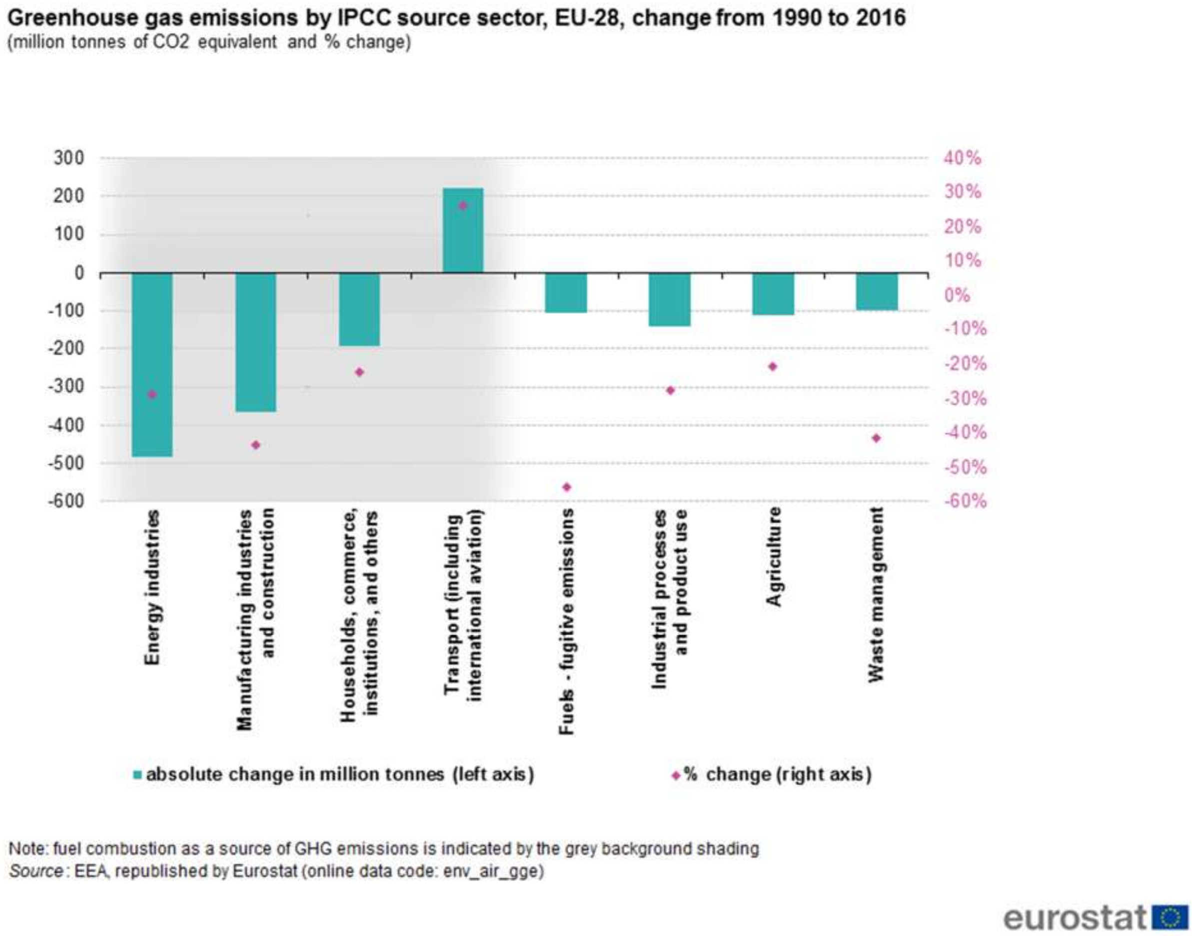
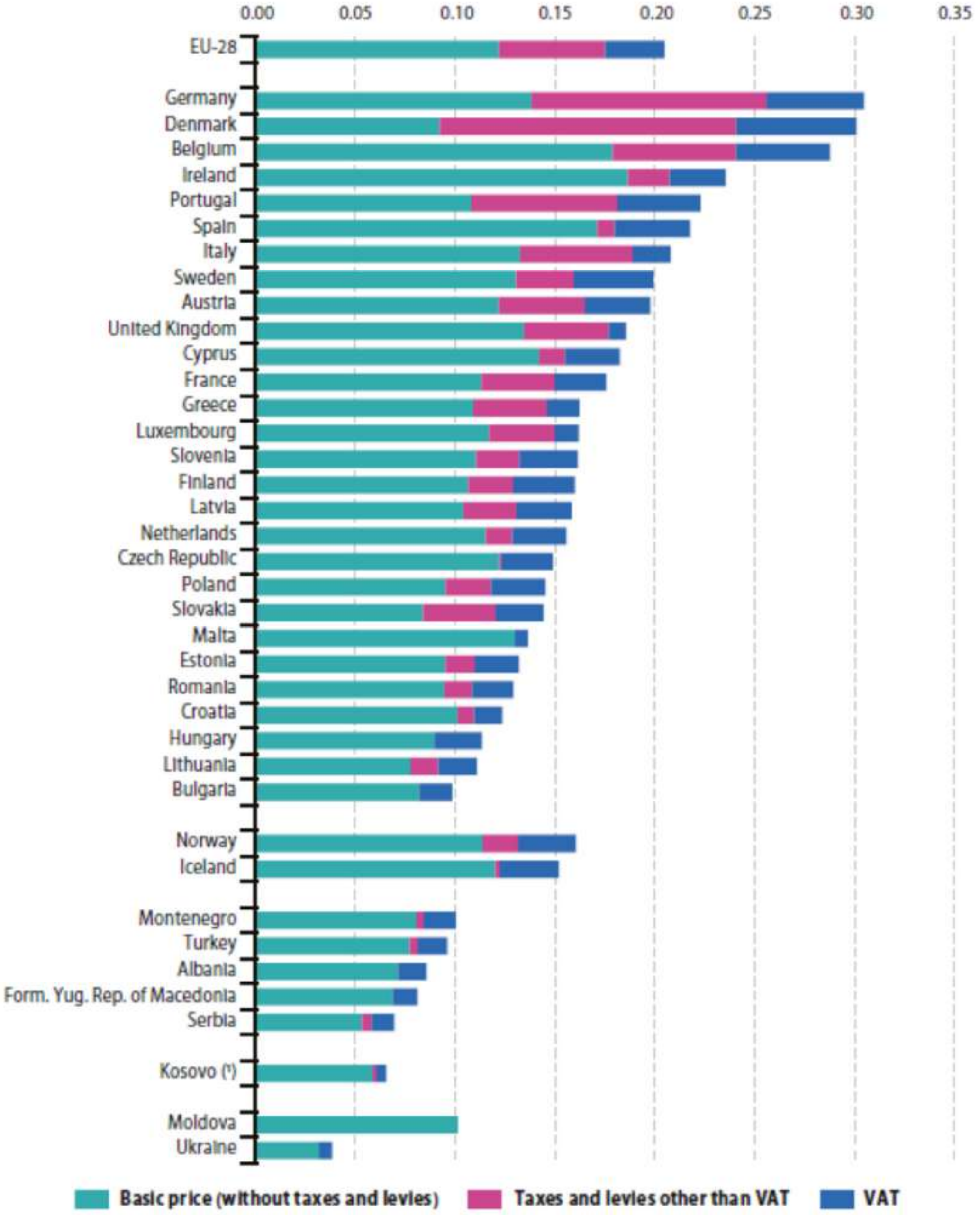


Figure 17: Greenhouse gas emissions by IPCC source sector

A3: Prices for electricity

Figure 1.1.1: Electricity prices for household consumers, registered in the second half of 2017
(EUR/kWh)



Note: annual consumption: 2 500 kWh < consumption < 5 000 kWh.
(¹) This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence.

Source: Eurostat (online data code: nrg_pc_204)

Figure 18: Prices for electricity: Due to the country-specific burden of taxes and duties as well as the existing domestic energy markets, the pricing of various energy products in the EU is very heterogeneous. Source Eurostat (online data code nrg_pc_204).

A4: Visualisation of electricity prices: How much do we pay to power a lightbulb in 2017?

Figure 19: Visualisation of electricity prices: How much do we pay to power a lightbulb in 2017? (https://ec.europa.eu/eurostat/web/energy/visualisations).

A6: Temporal development of the gross inland energy consumption

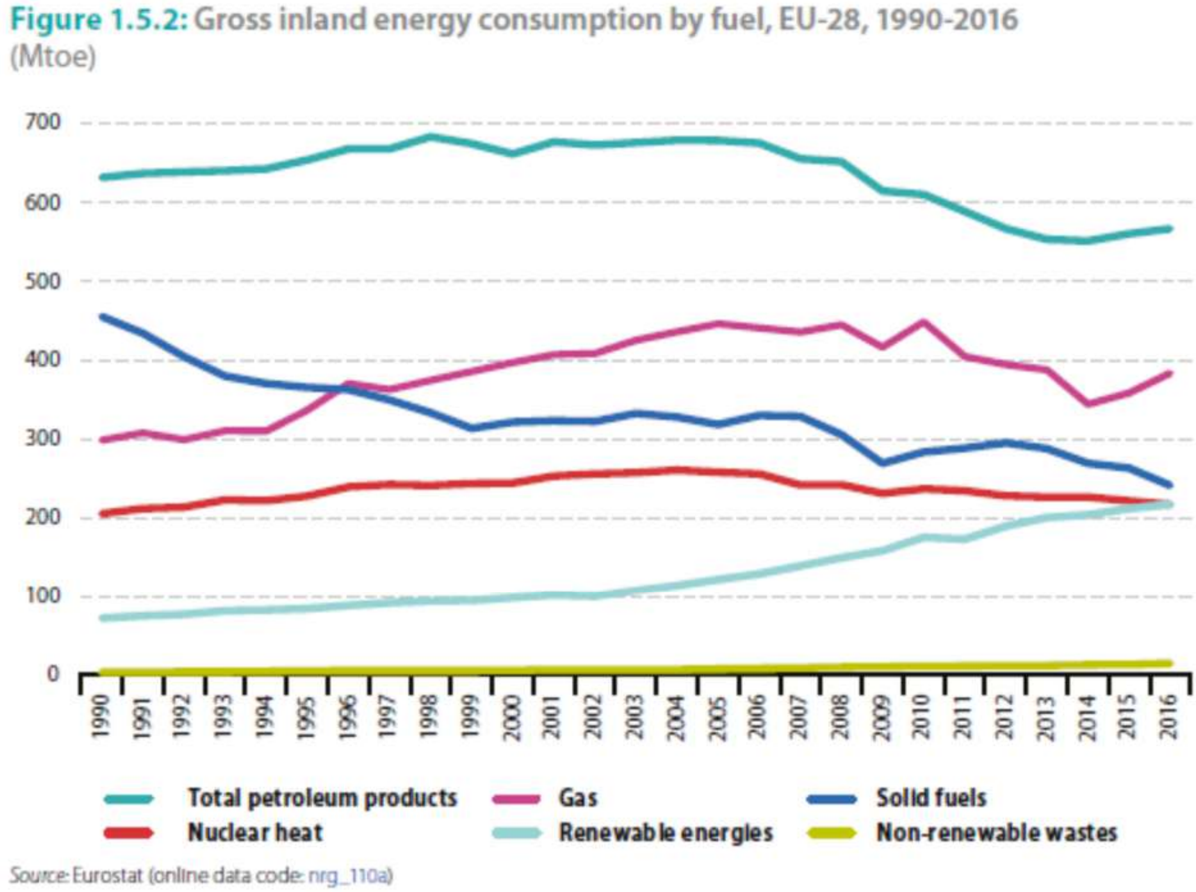


Figure 20: Gross inland energy consumption by fuel over the years 1990-2016; taken from https://ec.europa.eu/eurostat/web/products-statistical-books/-/KS-DK-18-001?inheritRedirect=true&redirect=%2Feurostat%2Fweb%2Fenergy%2Fpublications

A7: Final energy consumption

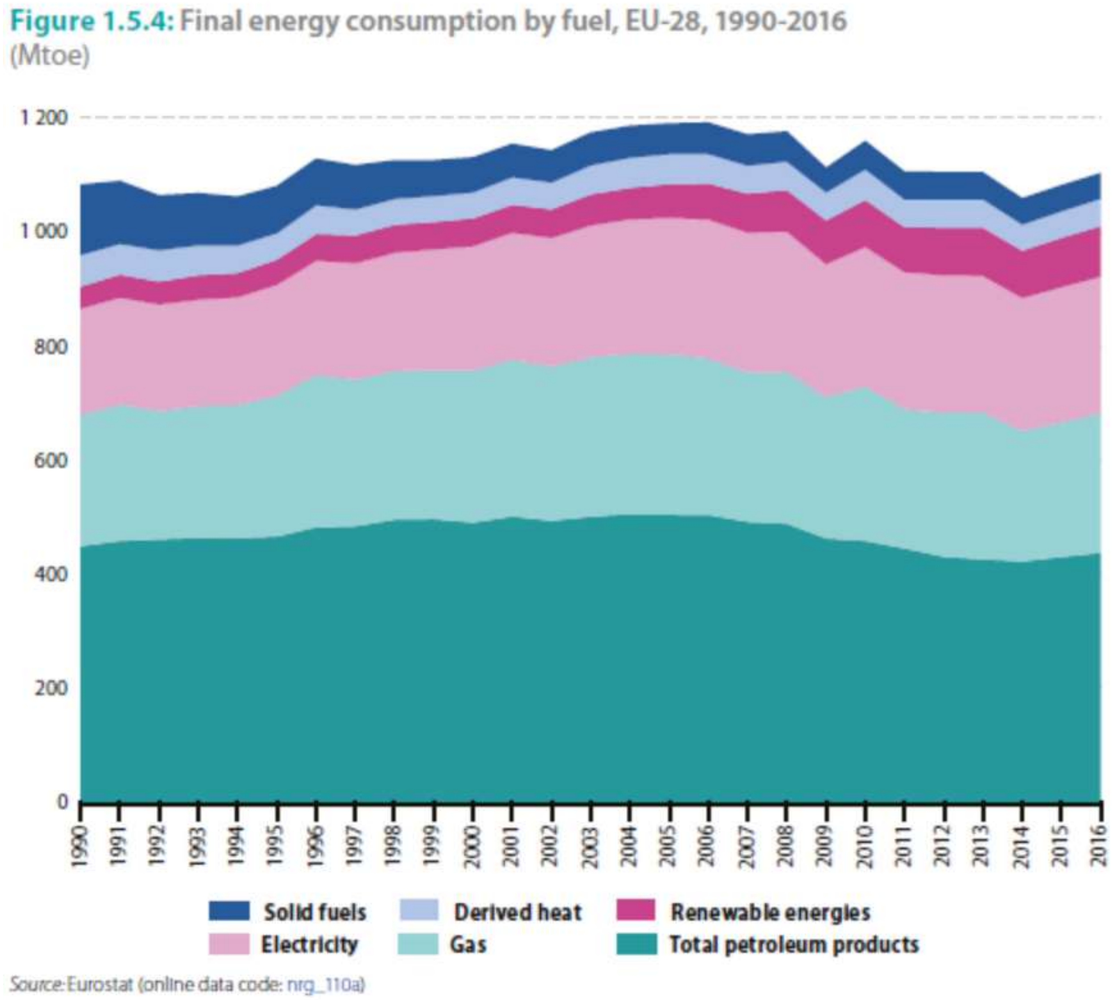


Figure 21: Final energy consumption by fuel over the years 1990-2016. It is the energy consumed in the final sectors; taken from https://ec.europa.eu/eurostat/web/products-statistical-books/-/KS-DK-18-001?inheritRedirect=true&redirect=%2Feurostat%2Fweb%2Fenergy%2Fpublications

1 Mtoe=$4.1868*10^4$J=11630GWh

Energy Platform Steering Group Members and Staff

Members		Academy and other	Country
Umbach	Eberhard	acatech and ESYS	Germany
Byman	Karin	The Royal Swedish Academy of Engineering Sciences (IVA)	Sweden
Galos	Krzysztof	Polish Academy of Sciences	Poland
Loughhead	John	Royal Academy of Engineering	UK
Marinšek	Zoran	Slovenian Academy of Engineering	Slovenia
Mesarović	Miodrag	Serbian Academy of Engineering Sciences	Serbia
Minster	Jean-François	Académie des Technologies	France
Pelegry	Eloy Álvarez	Real Academia de Ingeniería	Spain
Scientific Officer		**Academy and other**	**Country**
Schätzler	Katharina	acatech and ESYS	Germany
Staff		**Academy**	**Country**
Caristan	Yves	Académie des Technologies & Euro-CASE	France
Gehrisch	Wolf	Académie des Technologies & Euro-CASE	France
Pipunic	Nadia	Euro-CASE	France

Euro-CASE, with national academies of Engineering, Applied Sciences and Technology from 23 European countries as members, has access to top expertise from around 6,000 experts and provides impartial, independent and balanced advice on technological issues with a clear European dimension to European Institutions, national Governments, companies and organisations.

This report describes the different energy systems that have been established in EU countries over time; due in part to the presence or absence of specific energy resources. It does also inform about the ambitious climate protection goals of the European Community. Explaining how to reconcile the diverging national approaches to CO_2 reduction with the EU-goals is attempted in this report.