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The POTEnCIA Central scenario

An EU energy outlook to 2050

Mantzos L.
Wiesenthal T.
Neuwahl F.
Rózsai M.

Joint Research Centre

EUR 29881 EN

Contact information
Name: JRC POTEnCIA
Email: JRC-C6-POTENCIA@ec.europa.eu

EU Science Hub
https://ec.europa.eu/jrc/en/potencia

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Contents

Abstract

This report describes the evolution of the EU energy system until the year 2050 under the assumption that no further policies and measures are introduced beyond the end of 2017. The results show that both the energy and the carbon intensity of the European economy remain on a declining path in the 'Central' scenario set-up, but will miss mid-century targets. This evolution is driven by the continued impact of policies that are already in place in combination with technology progress, as well as by structural changes and the development of the prices of fossil fuels and of the CO_2 allowances under the EU Emissions Trading System. The EU target to reduce GHG emissions by at least 40% from 1990 levels in 2030 will not be met under the assumptions of the scenario, confirming the need for additional policies and measures.

The Central scenario was developed with the JRC´s energy model POTEnCIA and serves as reference point to which policy scenarios can be compared. It is the result of a transparent and iterative interactive exercise between the JRC, other Commission services and Member States' national experts within the POTEnCIA modelling framework.

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Authors

Leonidas Mantzos, Tobias Wiesenthal, Frederik Neuwahl, Máté Rózsai

Executive summary

This report describes the evolution of the EU energy system until the year 2050 under the assumption that no further policies and measures are introduced beyond the end of 2017. The results show that both the energy and the carbon intensity of the European economy remain on a declining path in this scenario set-up, but will miss the mid-century GHG-neutrality target announced in 2018 by the EC. This evolution is driven by the continued impact of policies that are already in place in combination with technology progress, as well as by structural changes and the development of the prices of fossil fuels and of the CO_2 allowances under the EU Emissions Trading System. In 2030, energy and greenhouse gas emission reduction targets set by the 2030 EU framework for climate and energy are not reached, indicating the need for additional policies and measures.

The Central scenario was developed with the JRC´s energy model POTEnCIA and serves as reference point to which policy scenarios can be compared. It is the result of a transparent and iterative interactive exercise between the JRC, other Commission services and Member States' national experts.

This report is accompanied by the release of the comprehensive model output with detailed information by sector and country on an annual basis between 2000 and 2050, as well as the underlying exogenous assumptions. The historical period 2000-2015 is based on and further complements the decomposition of statistical data as performed in the publicly available JRC-IDEES data-box.

Policy context

Over the last 15 years, the EU has set up a comprehensive policy framework to reduce its GHG emissions and contribute towards limiting the global average temperature increase to well below 2°C above pre-industrial levels and pursuing efforts to achieve a 1.5°C temperature change. As a result substantial progress was made in decoupling energy use and emissions of GHG from economic activity.

The EU has recently adopted an extensive legislative framework for energy and climate policies that implies increased efforts as concerns GHG emission reductions, energy efficiency improvements and renewables for 2030. It further includes supporting measures such as the expansion of energy transmission grids and an enhanced governance process, as well as, the CO_2 emissions standards for new cars, vans and heavy goods vehicles, etc. The Energy Union, in addition, provides a basis to develop a long-term-vision for 2050; in November 2018 the Commission has brought forward a proposal to become a net-GHG neutral economy by 2050.

This study aims at assessing the trends in the EU Member States' energy demand and supply that result from their economic growth combined with technological and market changes, while accounting for the policies in place up to the end of the year 2017. It therefore draws the picture of an evolution of the EU energy system without taking into account the recently agreed 2030 energy and climate framework.

Main findings

The EU's gross inland energy consumption shrinks by 13% between 2015 and 2050 despite a 68% increase in GDP, meaning that the energy intensity of the EU economy nearly halves over this period. At the same time the mix of energy sources that fuel the EU´s energy system is foreseen to undergo profound changes: the use of conventional energy forms enters a declining path (with the most profound reduction projected for solid fuels) at the same time renewable energies continue their boom in particular in power generation. As a consequence, CO_2 emissions are cut by 24% in 2020 relative to 1990 levels with further decrease to 30% by 2030, and 53% by 2050.

Although a comparison to the GHGs emission reduction targets is not directly possible as non-CO_2 greenhouse gases are not yet included in the modelling underlying this scenario, the results obtained in terms of CO_2 emissions in the Central scenario imply that, in the context of the policies in place until the end of 2017, the EU target to reduce GHGs emissions by at least 40% from 1990 levels in 2030 will not be met. However, the 20% reduction set for 2020 is expected to be met.

Driven by the EU Emissions Trading System and by the drop of costs in renewable energy technologies, the EU power generation capacities undergo a vast transformation towards decarbonisation. By 2050, more than four fifths (83%) of net electricity is generated without emitting CO_2 (from 55% in 2015), of which 72% coming from renewable energy sources. The large shares of variable renewables are enabled by flexible storage (e.g. batteries complementing pump storage) in combination with increased possibilities for load following for some novel uses (e.g. electric vehicles charging and hydrogen production). Consequently, conventional thermal power plants operate significantly less in the future, progressively acting just as back-up power unless equipped with CCS. By 2050, power plants equipped with carbon capture technologies account for 8% of the net electricity generation in the EU.

This transformation of the power sector is facilitated by the significant electrification in end-use sectors, which leads to an increase in electricity demand by 27.5% by 2050 compared to 2015. The pronounced uptake of electro-mobility accounts for almost 60% of the additional electricity demand, with the remaining share stemming from the continued electrification of industrial processes and other end-uses. This enhanced sector coupling is a main driver for reducing the carbon intensity in these demand sectors, and widens the scope for an increasing share of intermittent renewables in the power system.

The limited growth of electricity demand in the residential and services sectors (their electricity needs in 2050 are around 4.2% higher than in 2015) reveals two contrasting trends. Electricity grows in importance as a means to satisfy thermal energy needs. Consumption of electricity for air conditioning and electric heat pumps in the domestic sectors almost doubles, this increase is, however, partially counterbalanced by the projected reduction of conventional electric space heating as a mean of satisfying heating needs in buildings. Furthermore, the consumption for specific uses such as lighting and that of electric appliances declines, as substantial efficiency gains successfully offset the escalating penetration and use,

Overall final energy demand for thermal end-uses in the residential sector and in services is successfully decoupled, from the rise in the number of households and surface area per dwelling, and from the growing economic activity in services, respectively. Firstly, remarkable improvements in the thermal insulation of the building's envelope effectively dampen the need for thermal energy services, notably space heating. This is driven by the implementation of stringent building codes in line with the Energy Performance of Buildings Directive, whose full effects, however, take a long time to materialise due to the inertia of the building stock's renewal. Secondly, the consumers' shift towards more efficient options (e.g. heat pumps) when investing in new devices, alongside the projected technical progress of the equipment used to satisfy the thermal energy needs, further contribute to this decoupling.

A combination of structural changes towards the manufacturing of products with higher value added and lower energy intensity, and continuous efforts to improve energy efficiency and rationalise production methods result in the energy consumption of the industrial branch facing a limited increase of 6% over the coming decades despite a 60% growth in economic activity. At the same time CO_2 emissions maintain a decreasing path thanks to electrification, the increasing role of distributed heat and the progressive shift towards less carbon-intensive energy carriers. Starting from the 2030s, as carbon capture becomes economically attractive for certain industrial processes, the CO_2 emission reduction pace accelerates resulting overall in the CO_2 emissions of the EU´s industrial sectors to drop in 2050 to a level close to 41% lower than today´s.

Energy consumption in transport stabilises despite a growing activity for both passenger and freight. Here, the savings in energy use from passenger transport more than offset a 17% increase in freight energy demand in 2050 from 2015 levels. Such savings can be attributed to the reductions achieved in road transport, stemming both from electric vehicles taking up substantial market shares and from efficiency improvements in vehicles with internal combustion engines, which keep dominating the vehicle stock.

These transformations affect almost all of the EU´s sectors. In economic terms they result in 34% increase in the energy-related operating and maintenance (O&M) costs (i.e. excluding the costs of capital in the demand side) per unit of energy consumed. Expressed relative to GDP, however, these costs reduce by almost 2.4 percentage points (from 12.2% of GDP in 2015 down to 9.8% in 2050).

At the same time significant investment expenditure is required, totalling 72.5 trillion € over the time period 2016-2050, representing 11.5% of the cumulative GDP. The bulk of this investment expenditure links to equipment whose primary purpose is other than the satisfaction of energy service needs, such as vehicles and electric appliances, together accounting for more than 68% of the total projected investment.

Key conclusions

The scenario presented indicates that the EU economy further decouples its energy use – and even more so - CO_2 emissions from economic activity. This reflects the continued transformation of the EU energy system driven by technology progress in interdependence with policies and structural changes. The Central scenario shows that the *full implementation* of energy and climate policies in place by the end of 2017 can successfully lower energy demand and CO_2 emissions in key areas such as buildings and transport (especially road), although their full potential often takes time to materialise due to the inertia in renewing existing capital (or vehicle) stocks.

Enhanced electrification - made possible by emerging technologies like electric vehicles, heat pumps etc. - opens new possibilities for decarbonising sectors and end-uses that until now have not massively adopted low-carbon solutions. An effective solution is thus provided by sector coupling via electricity flows and the parallel decarbonisation of the power sector. The former will develop by growing shares of electricity being consumed, stored and exchanged across sectors. The latter is the result of a rising CO_2 allowance price that reflects the declining cap under the Emissions Trading System, and of the increased cost competitiveness of solar photovoltaics and wind energy.

Nonetheless, the Central scenario also indicates that policies in place by 31/12/2017 will not lead the EU towards an emission pathway compatible with the objective of the Paris Agreement. The results in terms of CO_2 emissions imply that the EU's energy and climate **objectives set for the year 2030 are missed.** Moreover, in 2050, CO_2 emissions remain at 47% of their 1990 levels, and hence well above the levels of the Commission's Long-Term Vision for 2050 to achieve climate neutrality.

1 Introduction

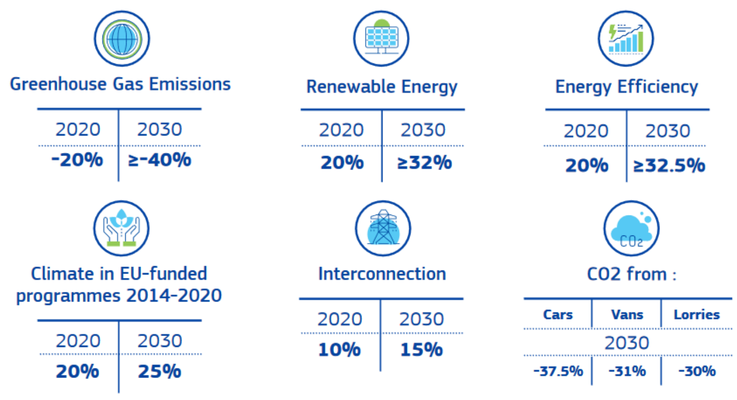
1.1 Motivation

Driven by the growing evidence of the on-going climate change and its severe expected impacts, the EU has set up a comprehensive policy framework to reduce its GHG emissions and contribute towards a global temperature increase well below 2°C and pursuing efforts to achieve a 1.5°C temperature change. The EU, having made substantial progress in decoupling energy use and emissions of GHG and air pollutants from economic activity, is overall on track to meet the 2020 climate and energy package targets on reducing GHG emissions, improving energy efficiency and enhancing the share of renewables, even though there is a need to further intensify efforts on energy efficiency (European Commission, 2019a).

The EU has adopted an extensive legislative framework for energy and climate policies that implies increased efforts as concerns GHG emission reductions, energy efficiency improvements and renewables for 2030. It further includes supporting measures such as the expansion of energy transmission grids and an enhanced governance framework, as well as, the CO2 emissions standards for new cars, vans and heavy goods vehicles. In this context, Member States will finalise by the end of 2019 their integrated National Energy and Climate Plans, which will include national contributions to the collective EU targets, following the drafts submitted by the end of 2018 and subsequent recommendations.

Stepping up the 2030 ambition level concerning the reductions in GHG emissions is currently under discussion, also in view of the EU to become a climate-neutral economy by 2050 (von der Leyen, 2019). This strategic long-term vision for a climate-neutral economy by 2050 was proposed by the European Commission in November 2018 (European Commission, 2018).

Figure 1. EU Climate and Energy objectives



Source: European Commission, 2019b

The deep decarbonisation efforts required in order to move towards climate neutrality entail the fundamental transformation of all sectors of the economy, and the mobilisation of a wide range of resources, encompassing not only the technological but also the financial dimension and consumers' preferences and choices.

Modelling tools are means to improve our understanding of the complex interactions between technology, consumer's behaviours and cross-sectoral interactions in a consistent manner. Indeed model-based assessments have been playing an increasing role in the evaluation of medium- to long-term pathways for climate change mitigation and energy policies, not only at EU level but also in many national administrations.

Mathematical models have been developed and adapted in order to be able to assess the wide portfolio of energy and greenhouse gas emission reduction policies, such as emissions trading, technology standards, as well as policies aimed at increasing energy efficiency or at promoting the penetration of renewable energies including intermittent power generation. Properly designed, they can also accurately reflect the ongoing changes in the energy markets, in technology, and in citizen's preferences.

In parallel, calls for transparency in the tools, data and processes underpinning the development of new policy proposals have been more frequently voiced.

In view of these needs, the EC Joint Research Centre in collaboration with other services of the European Commission developed the new in-house energy system model POTEnCIA (Policy-Oriented Tool for Energy and Climate change Impact Assessment) as a means to analyse the energy system transformation in a detailed and transparent manner, and to bring together national analyses from a pan-European viewpoint. In this context, the historical data inputs have also been made public in the JRC-IDEES data-box, and the tool together with all its assumptions was presented and discussed at various workshops.

POTEnCIA has been designed to assess the impact of energy-, transport- and climate related policy options through comparative scenario assessments. This implies the need for a 'counterfactual' scenario that serves as reference point for the comparison with alternative policy scenarios. Considering the significance of this reference point, it needs to adequately reflect the characteristics of the energy systems of each Member State while being, at the same time, consistent at EU level.

For this reason the **Central scenario** described in this report has been developed through an open, transparent and interactive process involving the national experts delegated by the EU Member States.

Box 1. POTEnCIA and JRC-IDEES

POTEnCIA (Policy-Oriented Tool for Energy and Climate change Impact Assessment) is a new energy system model, which has been developed by the European Commission's Joint Research Centre in close collaboration with other Commission services, notably DGs CLIMA, ENER, and MOVE. It captures all energy demand and supply sectors for each of the EU Member States, and provides results on an annual basis up to the year 2050 (Mantzos and Wiesenthal, 2016). This EC in-house model can be used to support the policy services of the EC in assessing the impacts of alternative energy and climate policy options on the energy sector.

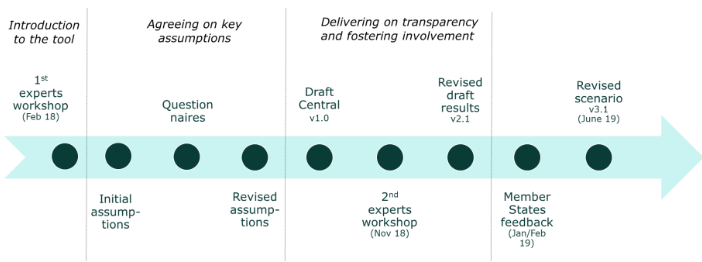
JRC-IDEES (Integrated Database of the European Energy System) has been developed in parallel to the POTEnCIA model. It provides very detailed information on the energy system and its underlying drivers for all 28 EU Member States in annual time steps starting from the year 2000 up to 2015 in the current version (2017 in the new version currently being produced). JRC-IDEES is both the key input to the POTEnCIA model and a stand-alone product that can be used to assess the historic evolution of the energy sector and its underlying drivers. It can therefore also be used with other energy sector models that projects future scenarios (Mantzos et al., 2017). JRC-IDEES is publicly available at https://ec.europa.eu/jrc/en/potencia/jrc-idees

1.2 The process

Considering the role of the Central scenario, its development was carried out in close interaction with Member States' national experts and forms an integral part of the roll-out process of the new energy modelling tool POTEnCIA. This interactive process involved:

- The creation of Special Groups on JRC-IDEES and POTEnCIA, respectively
- The creation of a platform for the controlled exchange of information with Member States national experts and EC colleagues, implemented through the JRC Research Collaboration Portal (https://rcp.jrc.es/). Two project spaces for 'POTEnCIA' and 'JRC-IDEES' were created.
- The publication of JRC-IDEES2015v1.0 as key input to POTEnCIA. Prior to its publication, a consultation with national experts took place, involving a workshop. At the time of writing, more than 400 users have been granted access to the database (including Member States experts, academia, other modelling teams, institutions, industries and industry associations).
- Member States' administrations were invited to provide input concerning the relevant implemented policies and their visions on the evolution of their energy system via a questionnaire;
- Assumptions and preliminary results were made available for comments through the JRC Research Collaboration Portal, accompanied by explanatory notes and country-specific analytical charts files;
- National experts were invited to provide comments on the different versions of scenario results as to adequately reflect the expected evolution of the national energy systems in the context of the Central scenario.

Figure 2. Interaction with national experts on the POTEnCIA 'Central' scenario



In addition to the above, two workshops with national experts on the POTEnCIA model were organised in 2018, complemented by a workshop on JRC-IDEES. All events were organised by JRC in close collaboration with other services of the European Commission.

- On February, 26-27, 2018, the first national experts' workshop on the POTEnCIA model took place in Brussels with more than 60 participants from 25 Member States. The objective of this event was to make Member States' representatives familiar with the new modelling tool, and to start the joint work towards the development of the Central scenario. To this end, the model features and the details of the model output were presented at the example of a so-called *'Entry-Point'* scenario, complemented by a discussion on key (macro-economic, demographic and technological) assumptions.
- The 2nd JRC-IDEES workshop took place in Seville on May, 23-24, 2018. The purpose of the workshop was to report on the status quo of JRC-IDEES, to discuss the comments of Member States' experts on the database and clarify any key questions, and to introduce the next steps envisaged. The workshop had an attendance of 34 experts over the two days representing 17 Member States, complemented by the participation of colleagues from various services of the European Commission.
- On November, 30, 2018, the 2nd Member States experts' workshop on the POTEnCIA model was held in Brussels, which focused on the discussion of the draft Central scenario. More than 30 national experts from 22 Member States and colleagues from other Commission services actively participated in the workshop. The workshop was complemented by bilateral meetings with national experts.

1.3 The Policy-Oriented Tool for Energy and Climate change Impact Assessment (POTEnCIA)

The JRC energy system model POTEnCIA is a mathematical economic model of the energy system that has been developed and is operated by the European Commission Joint Research Centre (Mantzos and Wiesenthal 2016; Mantzos et al., 2017). It is designed to compare alternative pathways of the EU energy system and related CO_2 emissions, covering all energy demand sectors (i.e. residential, services, industry, transport and agriculture) and energy supply. The model covers each EU Member State separately while also offering the option to address the EU energy system as a whole.

Model output is provided in annual time steps for the time horizon 2000-2050. Historical data (2000-2015) consistent with Eurostat statistics are based on the JRC Integrated Database of the European Energy System (JRC-IDEES), which was developed in parallel to the POTEnCIA model and is publicly available.

Structure and approach

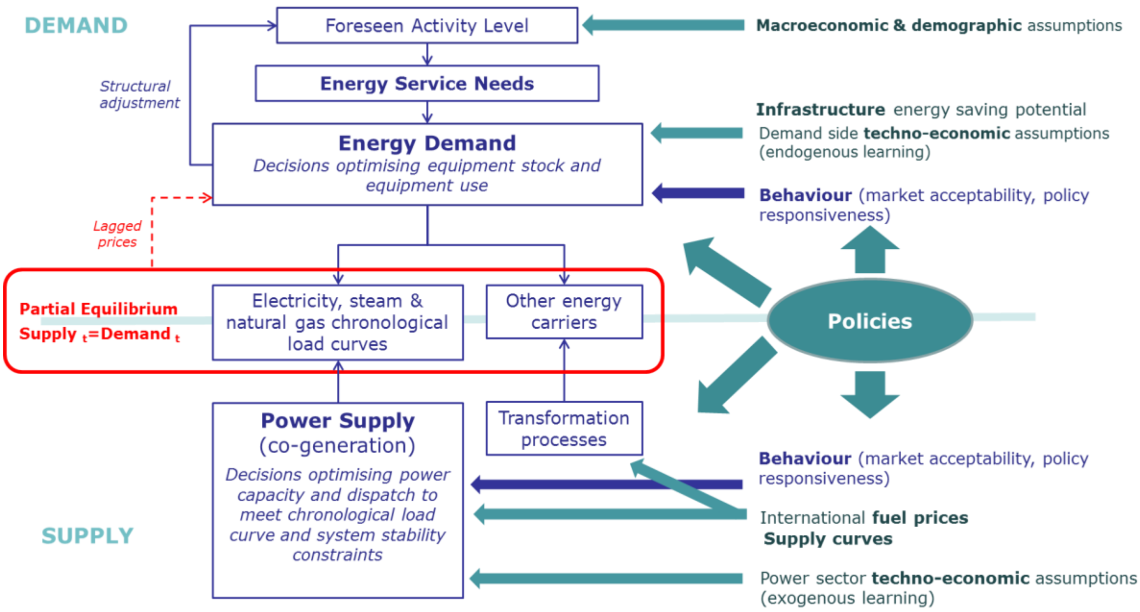
POTEnCIA follows a hybrid partial equilibrium approach. It combines behavioural decisions with (imperfect) optimisation, using detailed techno-economic data, therefore allowing for an analysis of both technology-oriented policies and of those addressing behavioural change. Special features and mechanisms are introduced in POTEnCIA to appropriately represent the transformation of today's energy system and to assess a wide variety of potential energy related policies and measures.

For each demand and supply sector, POTEnCIA makes use of the concept of the representative agent that implicitly seeks to minimise its cost and/or to maximise its benefit (profit, utility, etc.) under constraints related to behavioural preferences, technology availability, level of activity desired, degree of comfort sought, equipment installed, fuel availability and environmental considerations. Discrete choice modelling is applied as concerns the energy actors' investment decisions.

The behaviour of the representative agents within POTEnCIA is captured by complex causational equations. Non-linear relationships are also introduced in the model to represent the scarcity of resources, the level of exploitation of existing infrastructure, and technology dynamics.

At the overall energy system level, the model determines the equilibrium across sectors through the (scarce) resource prices (including traditional energy carriers and renewable energy, taking into account efficiency and environmental –e.g. CO_2 related– costs), in relation to their potentials. In this process different agents act as price-takers, price makers or simultaneously both. This equilibrium is repeatedly determined in each year of the projection period, incorporating dynamic relationships that reflect the previous decisions of economic agents from one year to the next. Given the complexity of the simultaneous market clearing problems and taking advantage of the dynamic recursive annual time steps, POTEnCIA makes use of the equilibrium prices with a one year lag. Such lag also reflects the observed delays with which price signals pass on to economic agents.

Figure 3. The POTEnCIA model at a glance



Furthermore, the fact that POTEnCIA solves in annual time steps eases the explicit identification of capital stock vintages on the demand and supply side (both by means of number of installations and as regards vintage equipment characteristics), allowing for an accurate representation of the energy system structures and characteristics at each point in time. Vintages dynamically evolve over time in relation to possible scrapping and/or premature replacement of energy using equipment, as well as to the adoption of non-energy-related measures that affect their operating characteristics. The overall stock characteristics are updated on an annual basis taking into account the investment performed in each specific year, the scrapping of obsolete equipment and the updated characteristics of previous vintages, according to a perpetual inventory model.

The POTEnCIA model, although it is an economic model of the entire energy system, deals with energy consumption at the level of a 'representative consumption unit'. In other words, it goes well beyond sectoral aggregates and therefore allows to more clearly define the scope for policy action by e.g. avoiding the erroneous allocation of existing energy equipment to newcomers. Such representative consumption unit consists of, for example, an industrial installation needed to produce one unit of industrial output; a household installation for thermal uses in the residential sector; a (representative) electrical appliance; a vehicle for private transport.

Every demand sector - i.e. residential, industry, services, transport and agriculture – requires a certain energy service in order to meet the foreseen activity levels in a given year (e.g. tonnes of steel produced; mobility; indoor temperature). This energy service is met by optimising both the stock (investment in new equipment and retirement of old one) and the use of the energy-consuming equipment under various constraints. Behavioural equations apply as regards the operation and use of energy using equipment.

The investment choices made by the 'representative agent' are represented by considering discrete physical assets rather than investments of a certain capacity. For example, a new household requires a space heating boiler of a certain size, water heating equipment of another size and a certain number of appliances, etc. Installations have specific time dependent techno-economic characteristics. These vintage-specific characteristics are explicitly considered over the entire modelling horizon both on the demand and supply side. As a consequence, POTEnCIA can provide consistent time series of different futures of the energy system, explicitly quantifying also the costs of stranded investment and early retirement.

For network-supplied forms of energy (electricity and derived heat), capacity planning and dispatching decisions are optimised to fulfil chronological load curves (at the level of one representative day per year), also considering system stability constraints. The representative load curves are computed by linking exogenously-defined load profiles at the level of individual energy uses to the corresponding energy requirements identified by the demand-side optimisation.

Power generation is modelled in POTEnCIA following a non-linear optimisation approach simultaneously addressing capacity planning and power plants dispatching under the following conditions:

- demand constraints (synchronised chronological load curves for electricity and distributed heat demand);

- power plant-related operational constraints;
- fuel supply constraints (including chronological load curves for intermittent renewable energy forms, such as wind and solar energy, as well as for natural gas);
- system reliability and reserve margin constraints;
- grid constraints; and
- policy constraints.

Both for the capacity expansion and for the unit commitment/dispatching problems, the model is solved simultaneously for electricity-only and cogeneration plant capacities.

Several sector-specific assumptions are introduced in the model. These concern the different planning horizons, the formation of expectations about prices, technologies, resources, etc., and the role of those expectations in economic decision making. Expectations about future markets are also accounted for.

Application

POTEnCIA is designed to assess the impacts of alternative energy and climate policies on the energy sector, under different hypotheses about the institutional/technological conditions within the energy markets. It can be used to analyse the effects of:

- existing and proposed legislation (EU wide and/or Member State specific) related to energy production and use;
- policies accelerating or delaying technology progress and deployment, as well as introducing standards and/or labelling;
- greenhouse gases reduction policies;
- policies aiming at the increased use of renewable energy sources;
- policies focusing on increased efficiency of energy use;
- policies promoting the use of alternative fuels;
- different pricing regimes and taxation policies;
- price peaks caused by scarcity of certain energy carriers;
- different regimes for the electricity market related to decentralisation and liberalisation;
- alternative behaviours of representative agents (both energy suppliers and consumers) affecting both their investment decisions and use of equipment;
- policies related to the development of energy networks (including the impact of modifications in the cross-country interconnection capacities).

1.4 This report: quick guide

The introduction (Section 1) of this report lays out the process followed in developing the Central scenario and describes the key features of the modelling tool applied. Section 2 summarises the main assumptions underlying this scenario, notably those on the evolution of the economy and demographics, on policies in place, and concerning technology progress in the power sector.

Section 3 illustrates the evolution of the EU energy sector overall and including main policy indicators.

The trends observed in the energy demand sectors are explained in Section 4 to Section 8 for the residential sectors, services, transport, industry and agriculture, forestry and fishing, respectively. In-depth discussions are introduced for some selected sub-sectors.

Section 9 provides a comprehensive overview of the evolution of the power sector in terms of power plant installed capacities, electricity generation and costs, as well as, an illustration of the plants' operation for a representative day.

Annex 1 directs the reader to the comprehensive data repository where the detailed numerical results of the Central scenario are freely available for download, along with a documentation of the assumptions made in the Central scenario modelling.

Annex 2 reports in selected figures and tables the main results for the EU and for the EU Member States individually. The comprehensive model output with detailed information by sector and country on an annual basis between 2000 and 2050 is published alongside this report together with the underlying exogenous assumptions.[1]

All cost figures are expressed in **constant € of the year 2010**.

The energy figures are consistent with the historical series of Eurostat energy balances as of the end of the year 2017. The statistical methodology for the construction of the Eurostat energy balances was subject to a revision, coming into force in 2019, implying consequential differences regarding, *inter alia*, the following:

- **International aviation** in the new methodology is not anymore accounted for as final energy consumption but as energy supply (accounted for in international bunkers). This may result in changes in some transport sector indicators such as the determination of RES-T shares.
- **Ambient heat** (heat pumps) is explicitly accounted for as renewable energy in the new methodology. This may result in changes in the determination of RES-HC shares.

Unless otherwise stated, all figures in this report refer to the EU as a whole, usually expressed as the aggregate of the results of the EU Member States at the time of writing this report, namely Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Lithuania, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom.

[1] https://ec.europa.eu/jrc/en/potencia

2 Scope and assumptions of the Central scenario

2.1 Scope

The purpose of developing the Central scenario is to inform on the potential evolution of the EU and national energy systems with policies in place by the end of 2017. Hence, it can serve as a reference point to which policy scenarios can be compared.

The Central scenario is not designed to meet the EU's energy and climate targets set for the year 2020 by construction. It is rather a scenario accounting for the existing policies and measures that were in place by the end of 2017.

Policies that were adopted after that year are not taken into consideration. For example, the Clean Energy for All Europeans Package with its 2030 energy and climate targets, the phase IV of the EU Emission Trading System, CO_2 emissions standards for new vehicles for 2025 and 2030, and other policy initiatives of the three Mobility Packages are not incorporated in the Central scenario.

Box 2. The Central scenario in a nutshell

Scenario with existing policies and measures (until end of 2017)

... that assumes that these policies will deliver

- using historical data up to the year 2015 (JRC-IDEES2015 v1.0)

  ... including only partially more recent data up to 2017

- with international fuel prices aligned with the Reference 2016

  ... but updated with data until 2017

- and GDP growth rates in line with the 2018 Ageing Report

  ... while accounting for short-term forecasts

It serves as reference point to which policy scenarios can be compared to.

2.2 Key assumptions and policies in place

The Central scenario is based on the following key assumptions.

Demographics

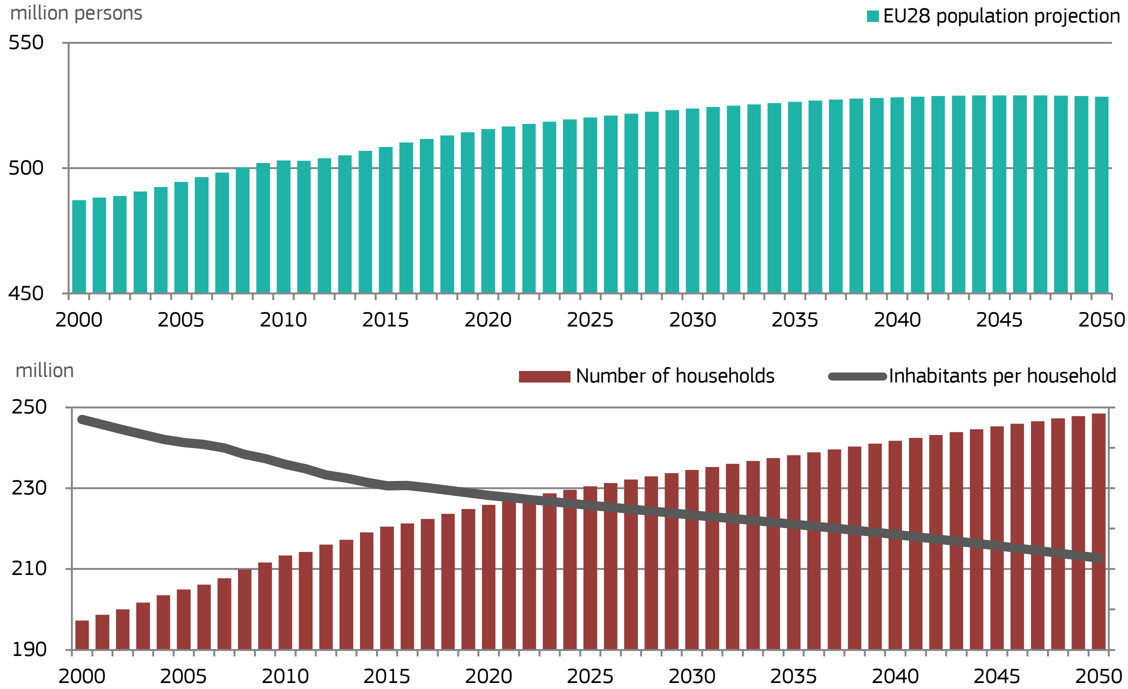
Both historical data[2] and projections are taken from Eurostat.

The number of households is derived as the ratio of total population of a country over the corresponding inhabitants per household (both coming from EUROSTAT Population Statistics). Implicitly, this assumes that there are no empty houses.

For the future evolution of the number of households, it is assumed that the observed declining household sizes trend continues, reaching an average of 2.13 inhabitants per household in 2050 compared to 2.31 in 2015. This results in an increase of the number of households at an average annual rate of 0.3% over the projection period 2015-50, well above the population growth rate (0.1% over the same period).

[2] Population on 1 January by age and sex (code: demo_pjan). Last update of data: 2017-01-13
Average household size - EU SILC survey (code: ilc_lvph01). Last update of data: 2017-01-23
Distribution of households by household size (code: ilc_lvph03). Last update of data: 2017-01-23

Figure 4. Assumptions on the evolution of population and household number



Macro-economic data and activity projections

Historical data based on the Eurostat national accounts are complemented by the Structural Business Statistics in order to obtain higher levels of disaggregation. All data are expressed in constant prices of €2010, obtained from the data expressed in current prices by applying the corresponding chain-linked volumes implicit price deflators for the GDP, the household consumption expenditure and the sectoral gross value added (GVA).[3]

Short-term projections (2017-19) for GDP, GVA and private consumption expenditure are taken from the forecasts published in the DG ECFIN AMECO database (version spring 2018).

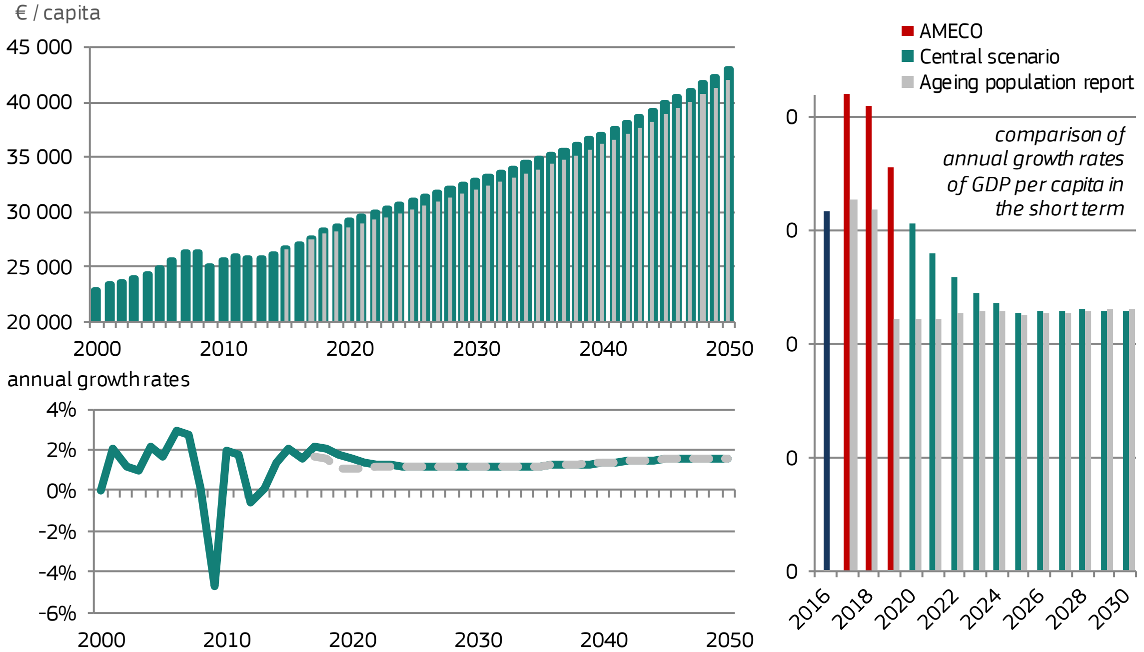
GDP projections from 2020 onwards are based on the assumptions of GDP growth per capita of the "2018 Ageing Report" (EPC and DG ECFIN).[4] Adjustments are introduced in a country-specific manner over the period 2020-2025 to bridge between the short- and long-term projections, as shown in Figure 5. At the EU 28 level, this results in the GDP growing faster in the Central scenario than in the underlying sources especially in the years 2017-2022. Overall, at the EU aggregate level, GDP per capita grows at an average annual rate of 1.38% over the projection period 2015-2050.[5]

[3] The use of constant prices instead of chain-linked volumes is motivated by the following: (1) the non-additivity characteristics of the chain-linked volume measures of GDP, apart from the reference year, which make the possibility to analyse structural shifts in the economy quite difficult unless a re-adjustment approach is followed from the lower to the upper levels as to match the GVA statistics; (2) the need for compatibility with the Structural Business Statistics that provide additional information going beyond NACE64; (3) the need for consistency and continuity between historical data and projections that by default are expressed in constant €. This means that for the calculation of the value added at the sectoral level the aggregate GVA deflator is applied (reported in nama_10_gdp – PD10_EUR / B1G Price deflator, 2010=100, euro / Value added, gross) rather than deflators that would reflect the chain-linked volumes for the specific sectors (which are also available in the EUROSTAT database).

[4] https://ec.europa.eu/info/sites/info/files/economy-finance/ip065_en.pdf

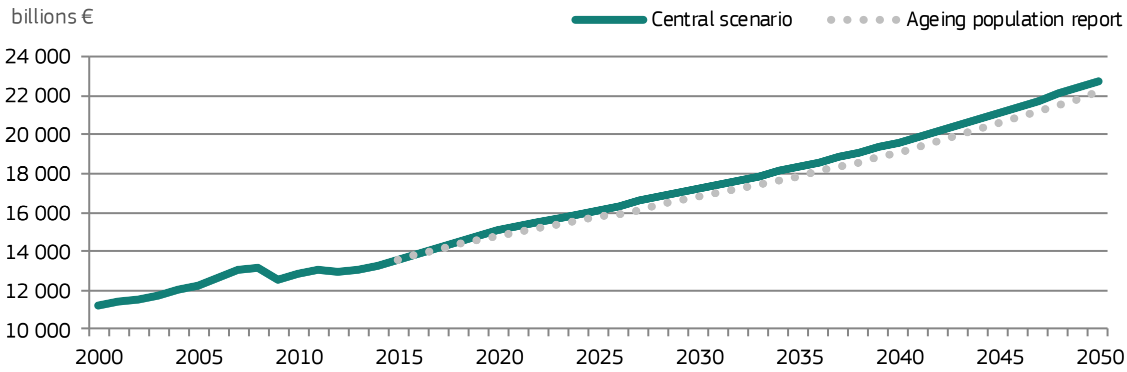
[5] This compares to a growth of 1.31% p.a. in the Ageing Population Report.

Figure 5. Assumptions on the evolution of GDP per capita



Combined with the population projections, this corresponds to an average total EU GDP growth of 1.49% p.a. over the period 2015-2050. The income per capita increases at an average annual rate of 1.3%, whereas the total income per household grows at the slower rate of 1.1% p.a. due to the declining household size.

Figure 6. Assumed evolution of GDP

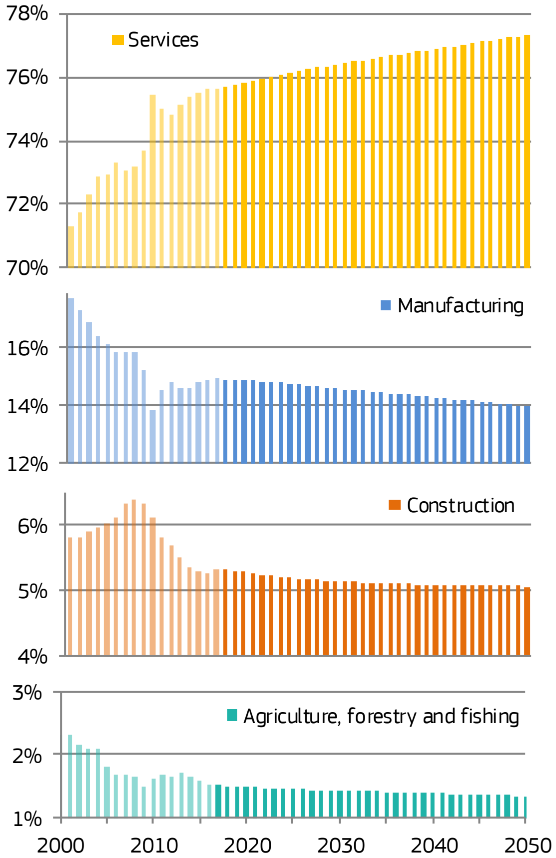


The restructuring of the EU economy observed over the past decades is projected to continue.[6] At the aggregate EU level, the services sector further expands its market share to reach 77.3% of the total value added generated in 2050 (+1.7 percentage points from 2015 levels), whereas manufacturing declines from a share of 14.9% in 2015 to 14.0% in 2050. Construction mildly declines (5.3% to 5.1%), whereas the market share of agriculture further reduces from 1.6% to 1.3%.

Within the manufacturing sector, energy-intensive sectors continue to lose market shares to the non-energy-intensive industries. The sectors experiencing the fastest growth are transport equipment and food, beverages and tobacco industries.

[6] The assumed evolution of the structure of the EU Member States national economies is based on own assumptions and feedback provided from both other Commission services and national experts. It is developed on a country-by-country basis and follows a 'conventional wisdom' approach, i.e. no radical changes are introduced due to lack of knowledge of singular events; instead, rather smooth trends are followed. To the extent possible, historically observed correlations are taken into consideration; note, however, that the assessment over the past 15 years shows that such correlations are often non-conclusive. Finally, the sectoral growth assumptions are checked for consistency with the general equilibrium model JRC-GEM-E3

Figure 7. Market shares of sectoral value added in the EU economy

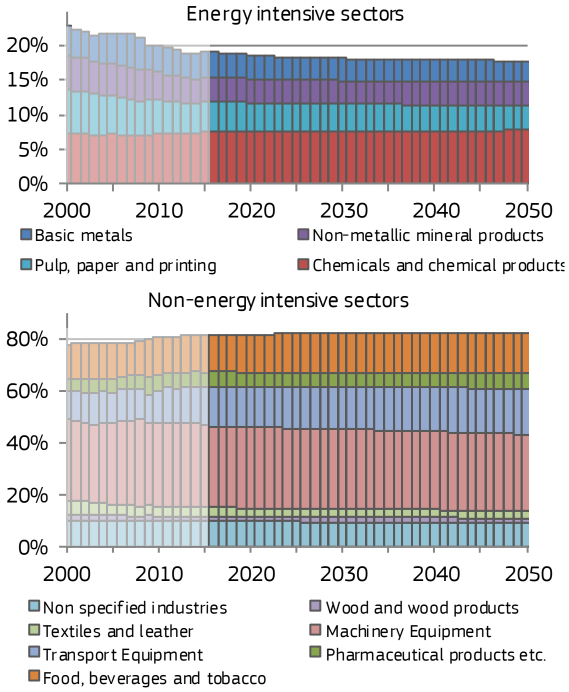


The activity of industrial sectors is projected based on the evolution of their sectoral GVAs, which is used as a proxy value for the production volumes. These are further translated into physical production volumes as relevant drivers for the energy demand of industrial sectors. For certain sectors, the identification of the output is self-evident (e.g. tonnes of steel within the 'Iron and Steel' sub-sector). In other sectors with a more heterogeneous product output, the concept of a representative output is introduced. For example, the sector 'Non-ferrous Metals' (other than aluminium) includes copper, lead, manganese, nickel, tin, and zinc; these are expressed by means of tonnes of 'lead-equivalent' (Mantzos et al., 2017). Such common reference point is also introduced for sectors without a clearly defined product, where it represents an energy consumption-weighted economic output index relative to the EU average. This concept makes it possible to disentangle the influence of the different industrial structures and/or products on energy consumption from that of the installed energy equipment, making the latter comparable across countries and over time.

The value added intensity, i.e. value added per unit of output, is assumed to evolve over time, linked to a variety of factors like wages (household income), material costs, historical trends and the sector's GVA growth rate.[7] On this basis, a first exogenous assumption concerning the evolution of the production outputs is created under the assumption of constant energy prices. These activity levels are then endogenously revised within the POTEnCIA model to reflect the impact of evolving energy costs on production volumes.[8]

Similarly, projections for activities that act as driver for energy demand are generated for all demand sectors and energy uses. They are based in a first place on macro-economic and demographic assumptions, taking into account saturation and (limited) convergence effects to the extent applicable, and then revised endogenously in response to evolving energy costs.

Figure 8. Market shares of sectoral value added in manufacturing



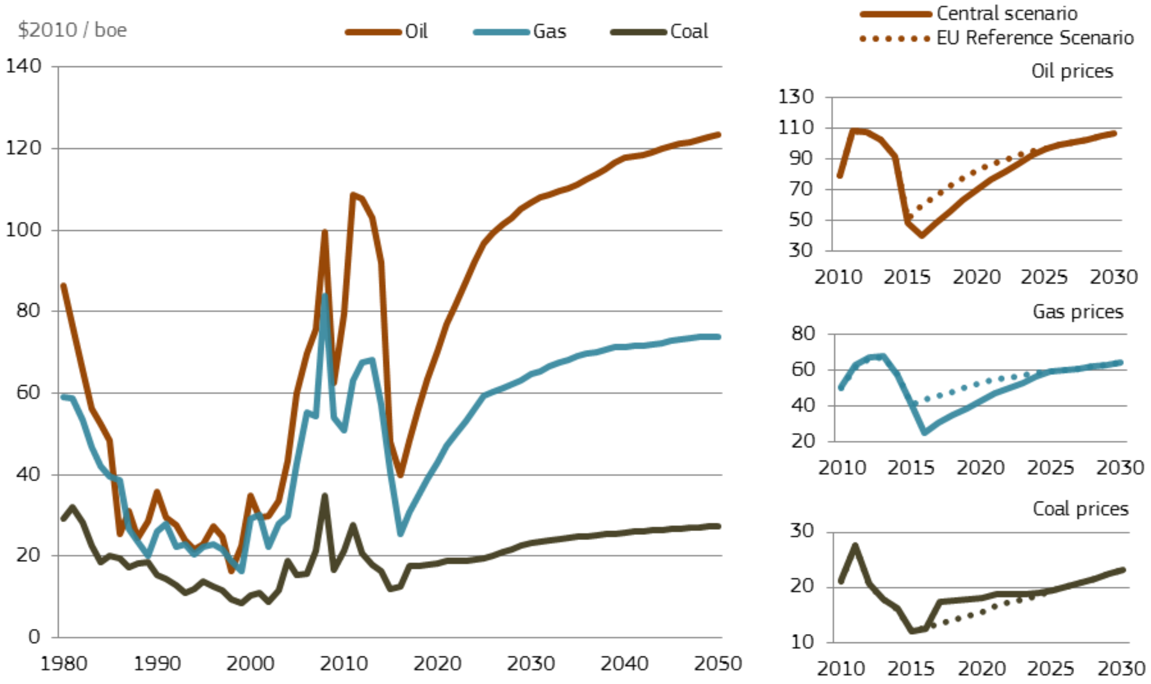
[7] Value added intensity is prescribed to experience only a limited convergence across countries in order to reflect prevailing product diversification and specialisation.

[8] This mechanism represents the industry´s response to evolving energy-related costs and can be interpreted on the basis of different drivers and effects. On the one hand it will capture structural dynamics (additional to those exogenously assumed) related to product specifications, such as for instance the specialisation in higher value-added product grades in response to increased competitive pressure on energy-prices. On the other hand, it will also reflect production level adjustments due to the demand being affected (taking also into account international trade developments) by energy-cost-induced price changes. The latter effect can be more explicitly characterised through the linkage with a global macroeconomic model (which for POTEnCIA has been established with the computable general equilibrium model JRC-GEM-E3). In the Central scenario, however, the sectoral value added follows a fixed exogenously prescribed pathway.

International fuel prices

The evolution of international fuel prices used as exogenous input to the POTEnCIA 'Central' scenario is taken from the EU Reference Scenario 2016 (European Commission, 2016) with some updates to account for the observed evolution in the latest years. This allows to better capture the observed evolution of energy requirements between 2015 and 2017, which are largely reflected in the Central scenario.

Figure 9. International Fuel Price assumptions for the POTEnCIA Central scenario



Sources: EU Reference Scenario 2016; historical data up to 2017 from World Bank (Gas and Oil) and BP Statistics (Coal)

The international fuel prices as assumed in the Central scenario are displayed in Figure 9.

Discount rates

In the theoretical case of unlimited access to financing capital and the absence of risk aversion, the discount rate with which an energy agent performs investment decisions should be equal to the (real) financing cost of capital. However, budgetary constraints, risk factors and/or asymmetric information apply and therefore the perceived cost of capital for the energy consumer may be higher than the nominal capital costs annuities.

In POTEnCIA a clear distinction is made between the interest rate the agent has to pay for a credit (the nominal discount rate), and the perceived discount rate (i.e. the nominal plus a risk premium) with which investment decisions are made.

All costs are calculated with the former, i.e. the 'nominal discount rate'. On the contrary, investment decisions take place on the basis of the perceived discount rate (i.e. also accounting for risk premia).

In POTEnCIA, the perceived risk premium and/or subjective financing capability is differentiated across sectors and Member States. Budgetary constraints have a limited impact on the investment decision for large industrial investors and power generators (except for novel technology options like, for example, CCS power plants). However, they affect individual choices to a much larger extent. Hence, the subjective financing capability rates applied in investment decision making for households or private transport can differ substantially across Member States, linked to the level of income. Under the typical assumption of an economic convergence in the EU these differences dynamically decrease in the long run.

Table 1. Nominal discount rate and premium due to risks and budgetary constraints

%	Nominal discount rate	EU average risk premium 2015([1])	Range of risk premia 2015	EU average risk premium 2050	Range of risk premia 2050
Power generation	4	7.4	4-13.4	5.9	4-9
Energy intensive industries	4	4.1	4-5.9	4.1	4-5.7
Non-energy-intensive industries	4	4.5	4-6	4.5	4-5.8
Residential	4	14.1	10.7-18.1	13.7	10.9-16.4
Tertiary	4	9.0	7.4-12.3	8.8	7.3-11.3
Transport	4	7.3	5.4-16.1	7.2	5.5-14.6

([1]) Note that the risk premium and budgetary constraints differ across Member States, and the latter also over time reflecting evolving incomes. Furthermore, risk premia differ across technologies (e.g. in power generation).

2.3 Technology dynamics

Demand side

POTEnCIA fully captures technology learning effects of the energy equipment on the demand side in an endogenous manner.[9] The formulation of technology dynamics applied in the model allows distinguishing between radical and more progressive technology changes and their impact on equipment costs. It captures the deployment and learning effects that partially or fully offset over time the additional costs incurred by technology progress.

Incremental innovations emerge as longer-term market response to slowly evolving framework conditions (e.g. prices, consumers' perceptions etc.). In terms of equipment, they materialise in form of reducing the capital costs, often expressed over the cumulative sales. This is commonly described as technology learning effects (subsuming learning by searching, learning by doing, but also consumer acceptance and economies of scale; Sagar and van der Zwaan, 2006). In many cases, cost reductions are achieved despite concurrent gradual improvements in the equipment itself, e.g. in form of efficiency gains. Alternatively, moderate and slowly evolving efficiency improvements occur without any increase in costs.

Changing framework conditions that require more radical innovations to be delivered by the market, e.g. stepping up the efficiency within a short timeframe, lead to an initial increase in the manufacturing costs. However, accelerated technology learning will gradually offset the additional costs initially incurred by the induced technology shock. Conversely, obsolete, declining technologies only experience marginal improvement in their performance, and -in view of the limited effort put on R&D- exhibit only a slight cost decrease.

Exceptions to the endogenous treatment of technology dynamic mechanisms on the demand side are considered in POTEnCIA in cases where the technology evolution is primarily determined by their global market deployment, such as for example for batteries. Here, the evolution of battery costs is exogenously defined based on an in-depth review of potential scenarios for Li-ion batteries (see Tsiropoulos et al., 2018).

An illustration of the model mechanisms for the example of battery electric vehicles and vehicles with gasoline- and diesel-powered internal combustion engines can be seen in Figure 10 to Figure 15 below.

[9] The definition of the techno-economic characteristics of demand side technologies in the starting year, however, is based on a broad variety of studies, including besides other the ASSET project (de Vita et al., 2018), JRC expertise (including Hofmeister et al., 2017, Grosse et al., 2017, Moya and Pavel, 2018, Moya et al, 2015, Perez Fortes et al., 2014, Pardo and Moya., 2013, Pardo et al, 2011), Bloomberg New Energy Finance, the preparatory studies accompanying the Eco-design policies, and specifically on industry the Best Available Technologies Reference documents, Wyns et al. (2018), Fleiter et al. (2013)

Figure 10. Development of battery pack costs and representative sizes

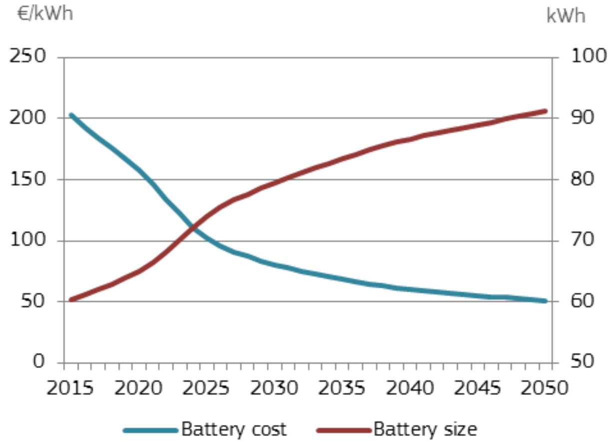


Figure 11. Evolution of capital cost per battery electric vehicle

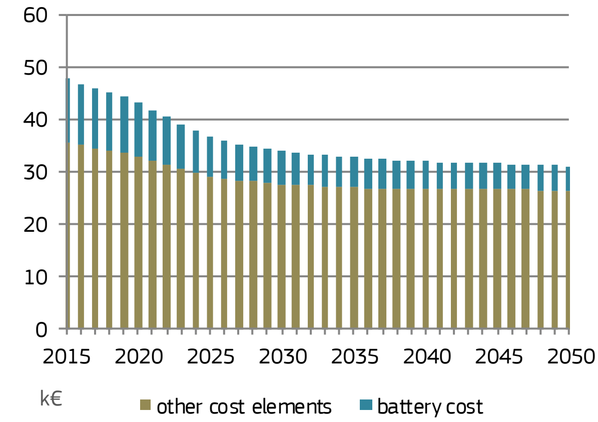


Figure 12. Capital cost evolution per main vehicle powertrain types

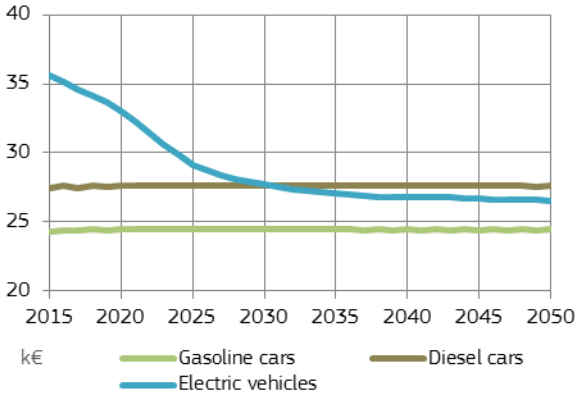


Figure 13. Vehicle efficiency improvements per main vehicle powertrain types

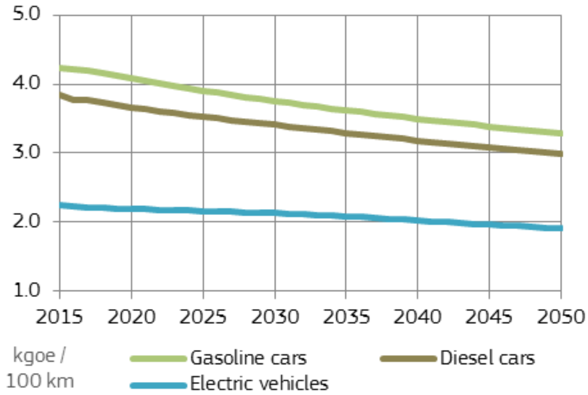


Figure 14. Levelised cost per km-driven

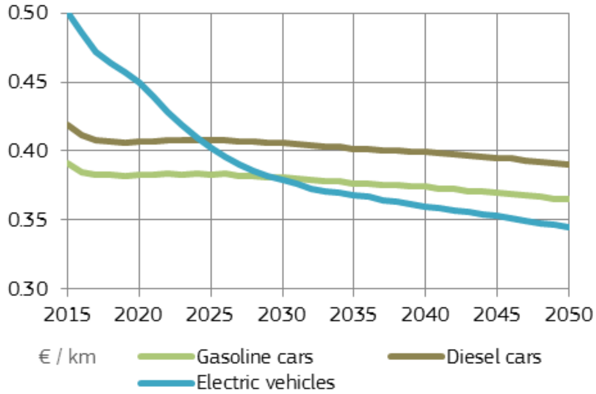
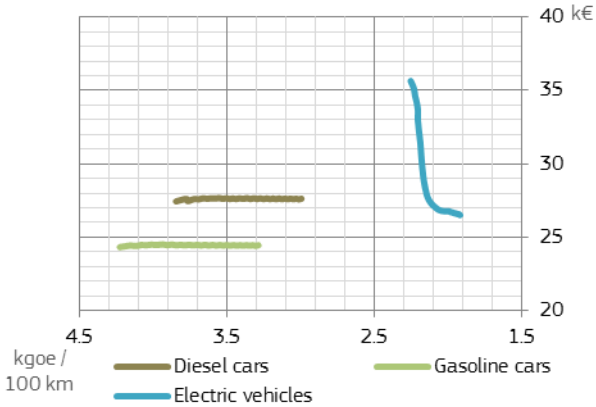


Figure 15. Efficiency improvements versus capital costs



Power generation

Technology dynamics on power generation equipment are not endogenous in POTEnCIA due to the fact that the market for power equipment is primarily a global one and the size of the EU market is too small to trigger substantial learning effects in isolation. In order to capture the learning effects at the most appropriate and relevant level where they occur, the evolution of power equipment markets needs to be considered at the global scale.[10]

The assumed evolution of power generation techno-economic characteristics is based on a wide literature-study, including in particular.

- The technology pathways described by the EU-funded project Advanced System Studies for Energy Transition (ASSET; de Vita et al., 2018)
- Technology expertise across the JRC (Tsiropoulos et al., 2018; Jager-Waldau, 2018, Watson et al., 2019, Vazquez Hernandez et al., 2017)
- Bloomberg New Energy Finance (2019)

Moreover, draft data on power generation technologies were presented during the POTEnCIA workshops and made available to national experts, which gave rise to their modifications in some cases.

The complete set of techno-economic assumptions used in the Central scenario as concerns power generation technologies form part of the published Central scenario set of files.

Box 3. Economic and technical lifetime

POTEnCIA differentiates between the economic and the technical lifetime of the equipment in order to better capture the cost structure that informs investment decisions. Table 2 shows some examples of the differences assumed between the two parameters. The economic lifetime is the mortgaging period used to compute the annuities of the capital costs that need to be paid by the investor. Thus, in POTEnCIA it is assumed that for the period from the end of the economic lifetime until the end of the technical lifetime no capital costs are incurred

Table 2. Examples of economic and technical lifetime

	Economic Lifetime	Technical Lifetime
Residential – space heating boiler	4	16
Residential – electric appliances	1	4-13 depending on the appliance(1)
Services – space heating boiler	5	16
Industry – large kiln (e.g. cement)	20	36
Transport – car	5	10(1)
Power generation – gas-fired CCGT	20	32

Notes (1): For vehicles and electric appliances a Gompertz-type survival function applies instead of a fixed technical lifetime. The reported figure denotes the average age of the stock in 2015.

2.4 Policies in place

Policies in place

The 'Central' scenario reflects policies and measures in place until the end of 2017, a summary of which is presented and discussed hereafter.

At EU level, in particular the following policies and measures are reflected:

- The EU Emission Trading System: In the Central scenario, a continuation of the EU ETS phase 3 until the end of the projection period is assumed (Directive 2009/29/EC). In particular, a decrease of the cap for stationary allowances each year by a linear reduction factor of 1.74% of the average total quantity of

[10] This can be implemented through the global energy system model JRC-POLES and global learning effects can then be fed back to POTEnCIA.

allowances issued annually in 2008-2012[11] is incorporated until 2050. The price of the emission allowance is endogenously derived (see Box 4).

- **Energy Performance of Buildings Directive** (EPBD, Directive 2010/31/EU): In line with the EPBD all new buildings are assumed to be nearly zero-energy buildings (nZEBs) by 31 December 2020 (public buildings from 31 December 2018 onwards). Information on the minimum energy performance requirements[12] for nZEBs has been gathered based on various sources of information[13] including comments received from national experts. For the sole purpose of input to the Central scenario one aggregate value per country for the residential sector´s nZEBs and one for the services sector's nZEBs have been identified (see Table 3).

Table 3. nZEB assumptions

Assumptions [kWh/m2/yr]	Residen-tial	Services
AT	125	125
BE	45	95
BG	40	40
CY	100	125
CZ	50	75
DE	60	150
DK	40	45
EE	65	110
EL	75	100
ES	50	100
FI	150	237
FR	80	110
HR	60	90
HU	105	88
IE	45	100
IT	45	60
LT	80	108
LU	45	60
LV	95	95
MT	75	220
NL	25	50
PL	75	125
PT	35	130
RO	105	90
SE	85	100
SI	80	55
SK	45	65
UK	45	150

- **Energy Efficiency Directive** (2012/27/EU): Cumulative energy savings that are to be achieved through **EED Art.7** measures are identified for each country and on a sector-by-sector basis for the years 2016-2020 based on Annual Reports and the National Energy Efficiency Action Plans while taking into account the already achieved cumulative savings from the implementation of article 7 from 2014-2016. In the Central scenario, it is assumed that the foreseen cumulative savings are achieved by 2020 (and the corresponding effort is quantified).
- **Eco-design requirements**: Minimum technology performance requirements set by the Eco-design regulations are respected, most importantly concerning lighting, white appliances and space heating boilers. In order to reflect these requirements in the technology breakdown of the model, extensive use was made of the underlying preparatory studies.[14]
- In line with the **CO_2 performance standards** set by Regulation (EC) No 443/2009, the EU fleet-wide average emissions of new passenger cars are required to be no higher than 95 grams of CO_2 per kilometre as of 2021, and no higher than 147 grams of CO_2 per kilometre by 2020 for new vans. Manufacturers are given additional incentives to put on the market zero- and low-emission cars emitting less than 50 g/km through a "super-credits" system, which applies over the period 2020-2022 and is fully incorporated (see Box 7).
- **Alternative Fuels Infrastructure Directive** (2014/94/EU): National Policy Frameworks (NPFs) through which some Member provided their national targets and objectives established for the deployment of alternative fuel infrastructure, are implicitly reflected for battery electric vehicles and plug-in hybrid electric vehicles. More specifically, the additional information on the target stock of electric vehicles by 2020 alongside more recent information received via the questionnaires submitted by Member States in the context of preparing the Central scenario were used as guidance to cross-check the consistency of the short-term deployment of electric vehicles in the 'Central' scenario.
- The completion of the **Trans-European Transport Networks** core network by 2030 and of the comprehensive network by 2050 is taken into consideration in the assumed evolution of transport activity of rail in the Member States.
- The **Renewable Energy Directive** (2009/28/EC): National renewable energy action plans and progress reports submitted under the renewable energy directive have been taken into consideration, complemented by information provided through the questionnaires and feedback received on draft results of the Central scenario. An effort was made to adequately reflect national policies introduced as to implement the directive rather than meeting national renewable targets set by the directive by construction. Moreover, priority dispatching principles have been followed in the initial years of the projection period.

In addition, national policies enacted prior to 2018 are also assumed to be implemented and permanently maintained.[15]

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[11] A reduction of 38 264 246 allowances each year

[12] The requirements refer to the primary energy consumption for space heating, space cooling, hot water, ventilation, lighting and auxiliary systems net of renewable energy used on-site.

[13] Including D'Agostino et al., (2016, 2019); Tzortzaki, A. (2017) and on-going JRC work, as well as, information from the Building Stock Observatory and the ZEBRA2020 project.

[14] https://circabc.europa.eu/faces/jsp/extension/wai/navigation/container.jsp

[15] Note that through the detailed decomposition and the identification of trends in the historical evolution of the EU energy system performed in JRC-IDEES, the impacts of earlier energy and climate policies are implicitly reflected.

3 General trends in the evolution of the EU energy system

3.1 Overview and key indicators

In the Central scenario **primary energy consumption not only continues its decoupling from economic growth but also contracts in absolute terms**. The implementation of the policies adopted by the end of 2017 together with behavioural changes, technological progress and an increasingly efficient transformation sector allow for the EU's primary energy needs to smoothly continue over the projection period the declining trend observed (with some upswings) during the last decade. This reduction in energy requirements is accompanied by significant changes in the fuel mix that allow for a further **decoupling of CO_2 emissions from energy use** as illustrated below.

Figure 16. Key indicators for the EU energy system

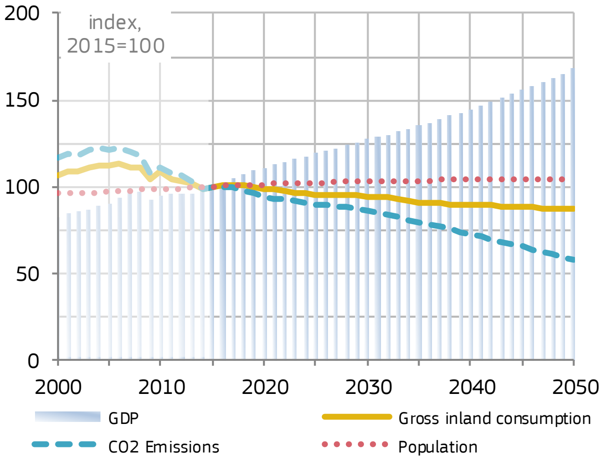
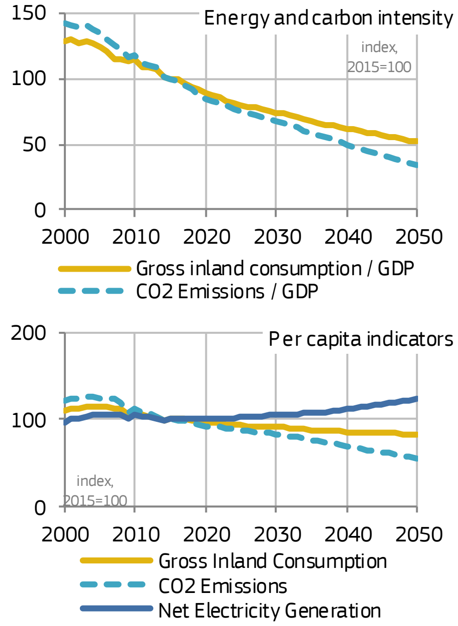


Figure 17. Energy and carbon indicators



The energy intensity of the EU energy system is projected in 2050 to almost halve from 2015 levels, whereas the corresponding carbon intensity reduction (again expressed per unit of GDP) reaches 65% (Figure 17). This implies that each unit of energy consumed in the EU in 2050 is projected to emit one third less CO_2 compared to the 2015 levels.

From the perspective of energy consumption and CO_2 emissions per capita, the projected reductions are less pronounced (-17% and -44% respectively in 2050 from 2015 levels) but still of relevance. The increasing importance of electricity in satisfying energy needs is worth remarking, with net electricity generation per capita, contrary to the decreasing trend of overall energy consumption, increasing almost 25% in 2015-2050.

The changes that span the whole energy system, in combination with the assumed increase of international fuel prices over the projection period, result in a significant increase in the energy-related O&M costs faced by consumers, which are some 34% higher per unit of energy consumed in 2050 compared to 2015.[16] This is partially offset by the efficiency gains in the energy system, which leads to a reduction in the energy consumption for delivering the same energy service. The related overall cost as a percentage of GDP (again not accounting for capital costs) reduces significantly, by almost 2.4 percentage points (from 12.2% of GDP in 2015 down to 9.8% in 2050).

At the same time significant investment expenditure needs to take place over the projection period as a result of replacement of existing equipment, increasing energy service needs and improvements in infrastructure that allow for lowering the energy requirements. In total an amount of 72.5 trillion € is spent in 2016-2050 in investment explicitly or implicitly related to the EU energy system. This amount represents 11.5% of the cumulative GDP (ranging between 8.9% and 12% on an annual basis). On a per capita basis this equals a spending of around 3700€ annually for each EU citizen. However, the bulk of this investment expenditure links to equipment whose primary purpose is other than the satisfaction of energy service needs, such as vehicles and electric appliances. The latter account together for more than 68% of the total projected investment.

[16] The demand side capital stock costs are excluded from these figures as the bulk of these costs, are related to equipment (e.g. vehicles, electric appliances) whose primary purpose is not the satisfaction of the energy service needs of consumers. Hence, they cannot be directly attributed as energy system costs. On the contrary, the corresponding costs of capital for the supply side are fully captured as they are passed to consumers through fuel prices.

Table 4 summarises the evolution of the key policy indicators that link to the goals set in the Energy Union for 2020, 2030 and beyond. The EU target set for the year 2020 to reduce energy consumption by 20% compared to the levels of the year 2007 baseline projections – equalling 1483 Mtoe of primary and 1086 Mtoe in terms of final energy consumption[17] – is missed marginally under the assumptions of the Central scenario. In 2030, on the contrary, energy consumption remains well above the targets set in the revised Energy Efficiency Directive that stipulates a 32.5% improvement in energy efficiency by then, which translates into primary and final energy consumption of less than 1273 Mtoe and 956 Mtoe, respectively. As regards RES and GHGs emissions reduction targets, the Central scenario illustrates that the 2020 targets will be met but reaching the 2030 ones requires additional action.

Table 4. Policy indicators and key figures concerning the evolution of the EU energy system

Central results EU	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	1 083	1 192	1 083	1 102	1 098	1 085
EU target				*1 086*	*956*	
Primary energy consumption [Mtoe]	1 569	1 713	1 529	1 499	1 424	1 303
EU target				*1 483*	*1 273*	
RES [%] - Share of energy from renewable sources		9.1%	17.0%	20.0%	24.5%	39.5%
EU target				*20.0%*	*32.0%*	
RES-E [%] - Share of electricity from renewable sources		15.0%	28.9%	37.4%	48.1%	73.0%
Total CO_2 emissions (with international aviation, without LULUCF) [Mt CO_2]	4 534	4 440	3 658	3 440	3 151	2 121
reduction to 1990		*-2%*	*-19%*	*-24%*	*-30%*	*-53%*
Emissions in current ETS sectors |(EU) [Mt CO_2]		2 396	1 925	1 708	1 550	802
reduction to 2005				*-29%*	*-35%*	*-67%*
Emissions in current ESD sectors [Mt CO_2]		2 044	1 733	1 732	1 602	1 318
reduction to 2005				*-15%*	*-22%*	*-35%*

In other words, the policies currently in place (as implemented by the end of 2017) are in the right direction across all policy domains but insufficient to meet the targets set for 2030 and even more those proposed for 2050.

For the projected evolution of the EU energy system in the context of the Central scenario, changes both in the demand and the supply side contribute to the results obtained, as described in more detail in the following.

3.2 Final demand sectors

Total *final energy demand* remains remarkably stable over the entire projection period. Following the increase observed in the last years, it falls back to the 2015 levels by 2050. This overall trend, which is rather similar across all sectors (industrial energy demand rises by 6% over 2015 levels in 2050, with domestic and transport sectors' demand respectively declining by 2% and 1% over the same period), implies - in view of the assumed activity growth - substantial energy intensities improvements in the range between -33% from 2015 levels for industry to

Figure 18. Final energy demand by sector

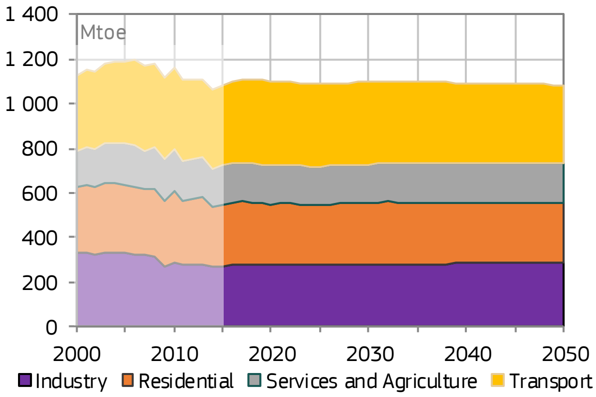
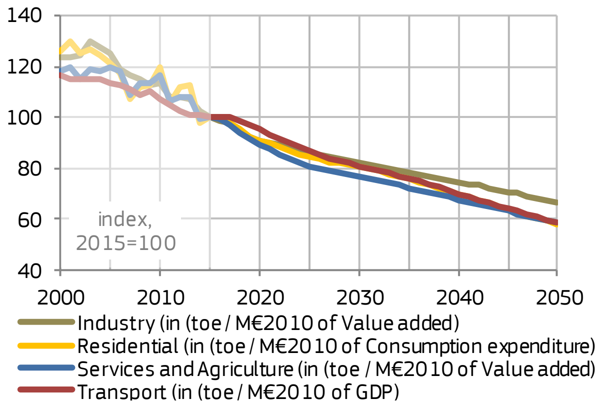


Figure 19. Indexed evolution of energy intensities



[17] European Council, 2014a: Conclusions of 23 and 24 October 2014 [EUCO 169/14]

-42% for the residential sector (see Figure 18 and Figure 19).

There are four major drivers that span all sectors and lead to these improvements in the demand side:

- **Structural changes in the economy,** including: shifts across sectors; the evolution of the value added intensity of industrial products, that allows reducing the physical production amount needed per unit of value added generated; as well as saturation effects with regards to individuals' energy service needs.
- **Actions that relate to non-energy-consuming equipment** but significantly affect the consumption of energy. The better-optimised operation (from an energy viewpoint) of industrial installations, as well as substantial improvements in the thermal insulation of building envelopes (leading to a steady decrease in the energy consumed per square meter of surface area) are among the most effective measures that fall under this category.
- **Changes in the *structure of* energy use that can reduce energy requirements,** including the adoption of more efficient processes for industrial sectors, different growth patterns for energy service requirements in buildings, modal shift in combination with the penetration of more efficient vehicle types in the transport sector.
- Changes in the fuel mix (also linking to the above mentioned drivers) including **the further electrification of the demand side,** an increasing contribution of distributed heat, a growing penetration of renewable energy forms, and an overall shift towards more efficient energy carriers. These changes in the fuel mix occur to the detriment of solid fuels (which by 2050 become an almost obsolete energy carrier for the demand side of the EU energy system) and liquids (which face strong downwards pressure across all sectors including transport with the take-off of vehicle fleet electrification).

The changes in the fuel mix lead in 2050 to a reduction of the demand side energy related CO_2 emissions by some 23% from 2015 levels. Industrial sectors, despite the projected increase of energy requirements, exhibit the strongest decline (-40.5%) followed by the domestic sector (-20%) and transport (-17%) in which the progressive electrification of mobility, further enhanced by higher biofuel shares, allows for an increasing delinking between energy consumption and CO_2 emissions.

The significantly more pronounced decline of CO_2 emissions in industrial sectors largely links to the fact that energy intensive industries covered by the European Emission Trading System (EU ETS; see below) are faced with a rising ETS price that after 2030 renders carbon capture economically viable for a number of specific industrial CO_2-rich streams. Consequently, the CO_2 emissions of industry contract by 41% between 2015 and 2050, when also accounting for the process-related ones.

This also becomes evident in the carbon intensity of the energy use in industry, which undergoes a steep decline beyond the mid 2030s. The related reductions in other demand sectors are less pronounced and evolve more continuously due to gradual fuel switching (Figure 21).

Figure 20. Energy related CO_2 emissions by sector

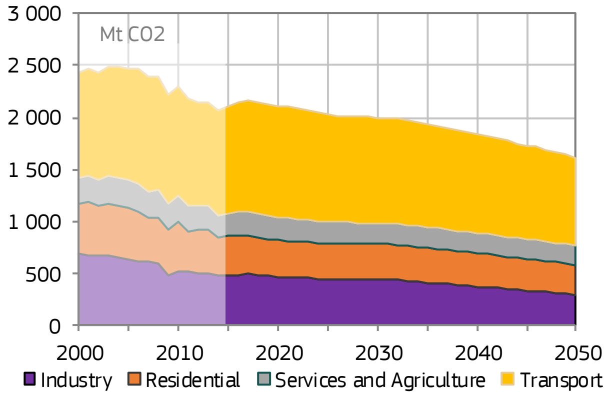
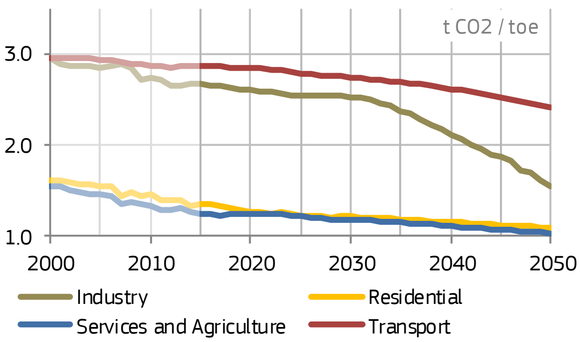


Figure 21. Evolution of carbon intensities in the demand side



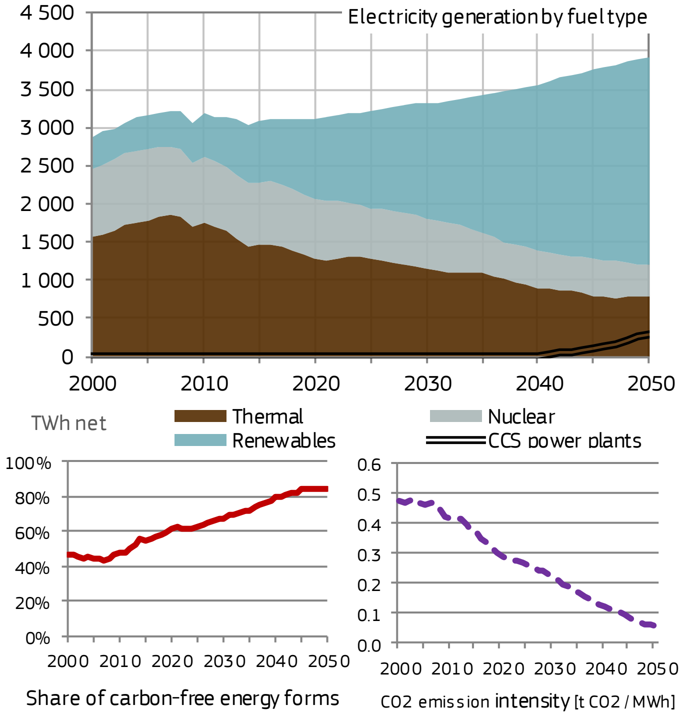
3.3 Supply sectors

In addition to the projected changes in the demand side, the continuous further electrification of the EU energy system alongside the evolving ETS market and the declining costs of renewable power generation technologies, lead to a gradual **transformation of the power generation sector**.

With three quarters of the cumulative investment over the projection period (1143 GW out of 1508 GW) directed into wind and solar power plants, the role of renewable energy forms in meeting electricity requirements becomes predominant by 2050. By then electricity production from wind, solar, hydro and to a limited extent novel renewable energies accounts for 69% of total net electricity generation (45% in 2030) from 26% in 2015. In absolute terms electricity generation from renewable energies increases 3.5 times over the projection period.

This crucial increase more than compensates for the projected decrease of electricity generation from nuclear power plants, resulting in the share of carbon-free electricity generation (including generation from biomass) to grow by some 30 percentage points (from 55% to 84%).

Figure 22. Electricity generation



Electricity generation from conventional thermal power plants is consequently faced with a strong downwards pressure. Nonetheless, biomass-based electricity generation increases its market share – accounting for 20% of conventional thermal generation in 2050 from 7% in 2015. In addition, beyond 2040 CCS options become increasingly competitive in the sector, contributing in 2050 for some 40% of conventional thermal electricity generation. The remaining amount that is met by combustion plants is dominated by natural gas, reflecting its increasing role as a balancing/load tracking technology.

Structural changes in the sector are also clearly reflected in the evolution of the transformation input for nuclear and conventional thermal power plants, which decline substantially from 2015 levels. More specifically the fuel input in nuclear power plants declines by almost 50% whereas that in conventional thermal power plants almost halves despite the increasing contribution of CCS (which due to the high own energy consumption lowers the net thermal efficiency of the plant).

The projected changes over the projection period materialise into a substantial decline of CO_2 emissions which in 2050 reach levels below 20% of those observed in 2015. In view of the increase of electricity demand in the same period, this translates in an improvement of the carbon intensity of electricity generation by more than 85%.

The other transformation sectors of the EU energy system are also affected by the changes in the demand side. District heating becomes increasingly important, with heat generated increasing by close to 70%. At the same time, technology progress and changes in the fuel mix allow for a limited reduction of the corresponding CO_2 emissions (1%).

Refineries activity is faced with strong downward pressure because of changes in the fuel mix in the demand side, most importantly in the transport sector through electrification of road transport. As a result, refinery throughput is projected to decline by 18%. At the same time, transformation processes that link to the production of novel energy forms, such as synthetic fuels and hydrogen, emerge in the long run but still remain of limited importance in the context of the Central scenario.

The consumption of the energy sector also declines by 22%, whereas the corresponding reduction in CO_2 emissions exceeds 40%.

3.4 Gross inland energy consumption

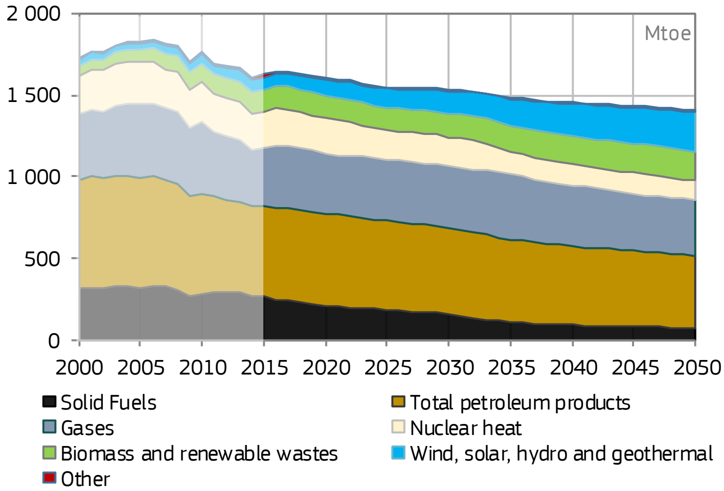
As a combined effect of all the changes projected for the demand and the supply side, ***gross inland energy consumption*** shrinks by 13% between 2015 and 2050 despite a 68% increase in GDP. Even more importantly, its **fuel mix undergoes substantial changes**, marked by two main trends: the more than tripling of renewable energies from sources such as solar, wind and hydro (with a more limited but still important increase in biomass use, +30%), and the strong decline in solid fuels use, which only exhibits some stabilisation trends beyond 2040 as solid-fuel-fired plants equipped with CCS become a cost effective option in the power sector.

In 2050 renewable energy forms become the second most important energy carrier of the EU energy system. Their combined share exceeds 30% (12.7% for biomass and 17.4% for other renewable energies) from 13% in 2015 (8.4 and 4.6% respectively).

Liquid fuels remain the most important fuel source throughout the projection period despite the significant decline in their use both in absolute terms (-21%) and as a relative share (31.3% in 2050 from 34.4% in 2015).

On the contrary, natural gas increases its market share from 22% to 25%. Its absolute consumption level slightly increases in the medium term and then falls back to today's level in the long run, manifesting the role of natural gas as transition fuel.

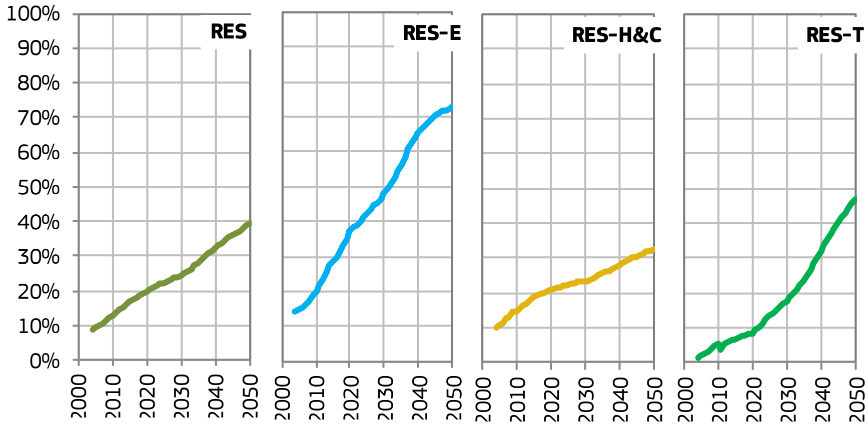
Figure 23. Evolution of gross inland consumption by fuel type



The decrease in nuclear heat reflects on one side the phase-out policies that are in place in several EU Member States, and on the other the decommissioning of aged nuclear plants at the end of their lifetime, which are only partially replaced by new nuclear investments when economically profitable.

Finally, solid fuels become an almost obsolete energy form for the EU energy system unless they are used in fuel-specific industrial processes or in CCS power plants for electricity generation. In absolute terms their demand constantly declines over the projection period falling to below 28% of 2015 levels by 2050. Correspondingly, their share of the gross inland consumption collapses to 5.2% from 16.1%.

Figure 24. Shares of energy from renewable sources



The **share of renewable energies** in the EU energy system more than doubles over the projection period exceeding 39% of the gross final energy consumption by 2050 (from 17% in 2015).[18] By 2020, renewables account for 20% of gross final energy consumption, reaching the EU target set for this year. On the contrary, the target of a share of at least 32% by 2030 set by the revised Renewable Energy Directive is missed by about seven percentage points.

As discussed above, renewables experience a particularly rapid expansion in the power sector driven mainly the steep uptake of solar and wind. Towards the end of the projection period, however, their growth slows down slightly in response to system stability issues, the entry of CCS into the power sector, and the sustained need for co-generation plants to supply the rising demand of derived heat.

The share of renewables in transport (RES-T) reaches 8.5% in 2020, further rising to 47% by 2050, up from 6.6% in 2015. While in the first half of the projection period this is dominated by the increasing role of biofuels (with also renewable electricity in rail contributing), the rise observed in the second half of the period can to a large extent be attributed to the take-off of renewable electricity in road transport. Moreover, other renewable fuels such as aviation biofuels and renewable hydrogen start to also play a role in the longer run.

[18] The calculation of the share of renewables follows the EUROSTAT SHARES tool, which incorporates the accounting criteria of Directive 2009/28/EC on promotion of the use of energy from renewable sources; further information at https://ec.europa.eu/eurostat/web/energy/data/shares .

The share of energy from renewable sources in heating and cooling (RES-HC) rises steadily to reach 32.7% by 2050, up from the current 18.8%. On the one hand this is driven by (the renewable-based part of) distributed heat and by biomass, whose use rises in particular in industry where it more than doubles. On the other hand, the contribution of ambient air close to triples over time due to the continuously increasing deployment of heat pumps, which by 2050 account for 13% of the total stock of households, and for 23% of that in the tertiary sector (including both electric and gas heat pumps in the latter). The use of solar thermal installations grows rapidly both in industry and in the domestic sectors, but its contribution to overall final energy demand remains limited.

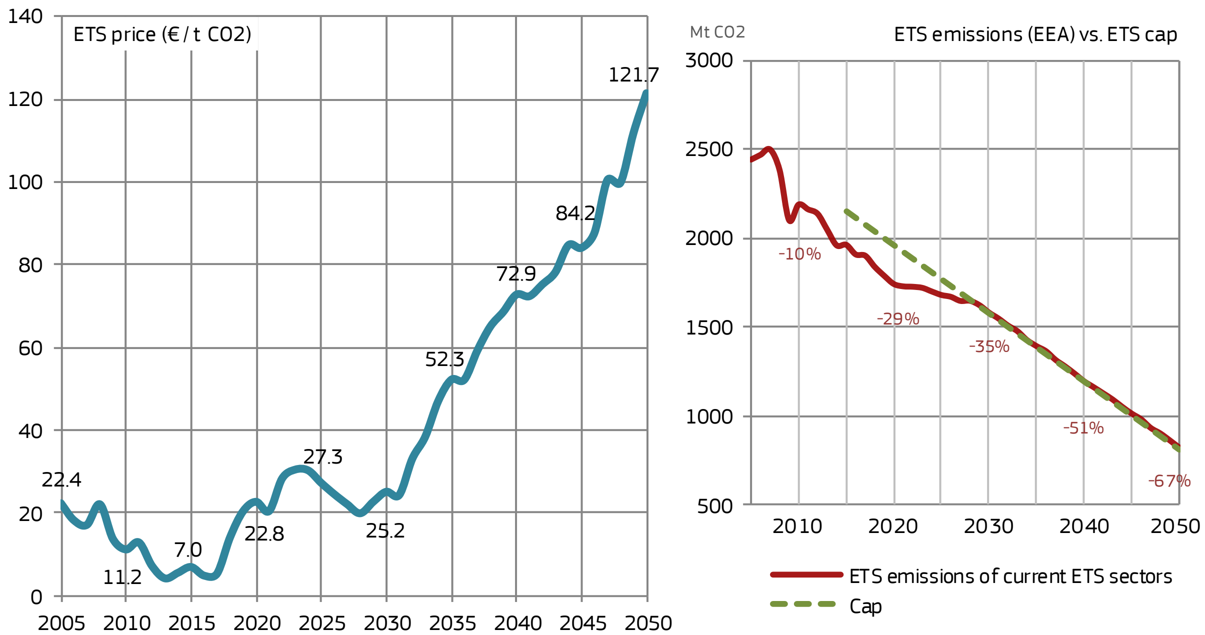
3.5 CO_2 emissions

CO_2 emissions decline steadily throughout the projection period: they are cut by 24% in 2020 and further decrease to remain 30% below 1990 levels by 2030 and 53% below by 2050.

Although a comparison to the GHG emission reduction targets is not directly possible as non-CO_2 greenhouse gases are not yet included in the modelling underlying this scenario,[19] the results obtained in terms of CO_2 emissions in the Central scenario imply that the EU target to reduce GHG emissions by at least 40% from 1990 levels in 2030 will not be met under the assumptions of the scenario (i.e. not accounting for policies in place beyond the end of 2017). However, the 20% reduction set for 2020 is expected to be met.

While a reduction in CO_2 emissions occurs in all sectors, they fall most rapidly in the sectors covered by the EU Emissions Trading System (EU ETS). This is a direct consequence of the assumed continuation of the EU ETS phase III throughout the projection period, implying a continued year-on-year cut in the cap for stationary allowances by a linear reduction factor of 1.74% of the average total quantity of allowances issued annually in 2008-2012.

Figure 25. Evolution of the ETS market and prices in the Central scenario



The results indicate that until the year 2029, CO_2 emissions of installations covered by the EU ETS remain below the cap. This (decreasing) surplus of allowances results in an (endogenously modelled; see Box 4) ETS price that ranges between 20 and 30 €/tCO_2 until 2030, while the CO_2 emissions that fall under the ETS are capped at 35% below 2005 levels by then. Note that this does not include the recent Revision of the EU ETS which raised the linear reduction factor in order to reach emissions of 43% below 2005 levels by 2030. Thereafter, CO_2 emissions get on the pathway prescribed by the cap to contract by 67% in 2050 compared to 2005. This implies a steady increase of the ETS price that reaches 73 €/tCO_2 in 2040 and above 120 €/tCO_2 in 2050.[20]

[19] A link between POTEnCIA and other modelling tools is currently under development to coherently capture the emissions of non-CO_2 GHG.

[20] Note that the costs of allowances that are auctioned are assumed to be passed through to the consumers, reflected e.g. in the evolution of the electricity price and/or of the price of the corresponding carbon-intensive goods/services.

Box 4: Modelling of the Emissions Trading System

The approach followed for modelling the ETS was to define an exogenous trajectory on the quantities of ETS CO2 allowances that corresponds to the cap prescribed. The emissions of the sectors falling under the ETS must by construction not overshoot this constraint. The corresponding ETS prices are endogenously calculated as to meet the evolving ETS cap; in other words the ETS prices represent the dual values of this constraint.

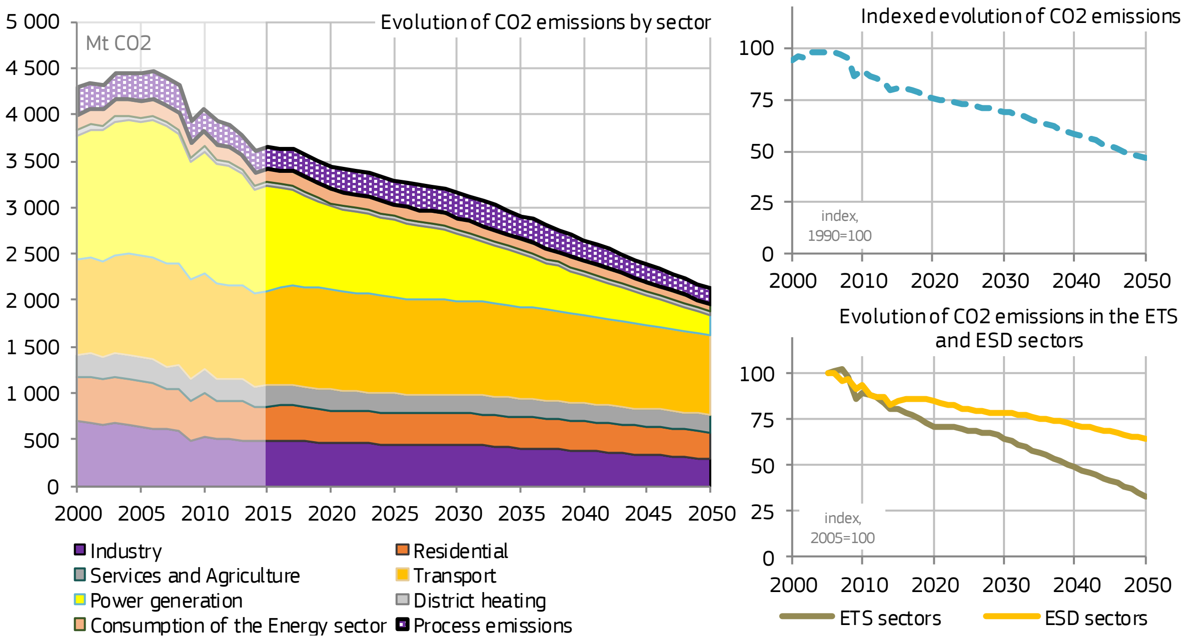
In POTEnCIA the allocation schemes introduced (auctioning and/or free allocation) can be adapted to the various sub-sectors. From a pure economic modelling viewpoint, there is no difference in the decisions as regards investment and energy use between auctioning and free allocation; their only difference occurs in the calculation of the cost of providing a service (which can trigger second-order effects).

Since POTEnCIA does not model the energy system of the non-EU countries that participate in the ETS (i.e. Iceland, Liechtenstein and Norway), a similar behaviour in terms of ETS emission reduction profiles is assumed, resulting in a constant ratio between the EU and non-EU ETS emissions.

In the presence of such ETS prices the energy system responds through fuels shift towards zero (and low) carbon sources, efficiency improvements and – towards the end of the projection period - the adoption of carbon capture and storage options (CCS).

Hence, by 2050 CO_2 emissions falling under the scope of the ETS are 67% below their 2005 levels (-58% relative to 2015). The amount of CO_2 captured (both in industrial processes and in the power sector) rises gradually beyond 2035 and corresponds to 3% of the total CO_2 generated (7% of emissions under the ETS) by 2040 and 14% (30%) by 2050.

Figure 26. Evolution of CO2 emissions



Emissions in sectors not covered by the Emissions Trading System (the so-called **Effort Sharing Decision** or ESD sectors)[21] shrink by 15%, 22% and 35% in 2020, 2030 and 2050, respectively, compared to the year 2005. This comparatively more modest decrease is to a large extent due to the scenario set-up that does not consider important demand side emission reduction measures agreed after 31/12/2017, such as the 2030 CO_2 performance standards for new light and heavy goods vehicle fleets, revised efficiency requirements and enhanced renewable shares. Although this scenario does not account for targeted policy incentives beyond the already implemented policies, emission reductions are achieved due to long-lasting effects of current policies in place in combination with technological progress. For example in the transport sector, meeting the CO_2 emission performance standards

[21] The Effort Sharing legislation concerns emissions from most sectors not included in the EU Emissions Trading System (EU ETS), such as transport, buildings, agriculture and waste (but not LULUCF). It establishes binding annual greenhouse gas emission targets for Member States for the periods 2013–2020 and 2021–2030. At EU level, the national targets will collectively deliver a reduction in ESD emissions of around 10% by 2020 and of 30% by 2030, compared to 2005 levels.

for new cars and vans by 2021/2020 fosters the decarbonisation of (passenger) road transport and ultimately accelerates the electrification of the corresponding fleet. The near-zero energy building standards made compulsory by the Energy Performance of Buildings Directive deliver their full savings potentials only in the long run due to the inertia of the building stock. Similarly, the full impact of efficiency standards set, besides others, by the Eco-design Directive, also takes place progressively with the replacement of installations. At the same time, the market continues to offer increasingly efficient options for e.g. specific electric appliances, lighting, heating etc., which are chosen by the consumers on economic grounds responding to higher fuel and electricity prices.

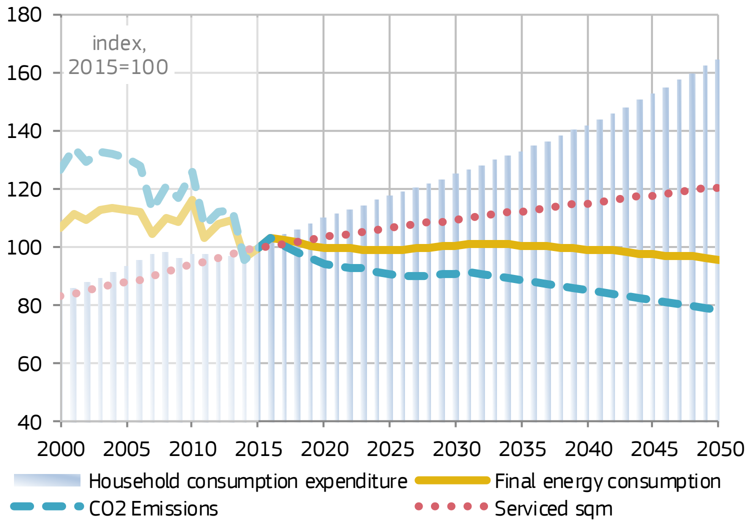
4 Residential sector

4.1 Overview and key trends

Final energy consumption in the residential sector remains broadly stable throughout the projection period. The recent upsurge observed in the last three years is projected to be reversed due to policies in place and in the decade 2020-30 the energy demand moves back to levels similar to those observed in 2015. After some limited fluctuations it eventually gets onto a steadily declining pathway and the sector's final energy demand by 2050 is effectively 4% below its 2015 levels.

This evolution is the consequence of pronounced underlying trends that counterbalance each other; the substantially growing demand for energy services is effectively offset thanks to significant efficiency improvements.

Figure 27. Key indicators in the residential sector



The number of households grows by almost 13% over the projection period following the rise in population and the lower number of inhabitants per household, continuing historical trends. In combination with larger household surfaces (driven by increasing income levels), the overall useful surface area expands by 21%. Rising incomes also drive up comfort levels. This causes a surge in new end-uses (space cooling), as well as in the ownership and use of specific electric appliances. However, saturation effects become visible for mature end-uses (such as space heating) and contribute to moderate the growth of the overall energy service needs.

Final energy consumption is reduced both for thermal end-uses and in some specific electricity uses, supported by policies such as building codes and technology standards, as illustrated in the following sections. Combined with a progressive decline – driven by technology choices - in the carbon intensity of the fuel mix, CO_2 emissions fall by 22% between 2015 and 2050.

4.2 Thermal end-uses

Final energy demand for thermal end-uses – i.e. space heating and cooling, hot water and cooking – in the residential sector falls by 4% over the projection period. On a per-household basis, this corresponds to a deeper reduction by almost 15%. These reductions are achieved despite the increasing dwelling surface area and rising comfort levels. The latter affect most notably the demand for space cooling services that, on a per household basis, more than triples by 2050 (even with the assumption of constant climatic conditions – see Box 5). The corresponding energy service needs for space heating purposes also increase by close to 35%, whereas those for water heating remain rather stable or decline (+5% and -16% respectively). Both trends link to the declining household size (in terms of persons) and the latter also to rising income levels that foster a tendency to eat out and consume more convenience food and to the assumed increasing penetration of new technological options (such as the induction technology) that, while not delivering significant changes in the technical characteristics of the equipment used, reduce substantially the time of cooking and consequently the amount of energy service required.

> Box 5: Heating Degree Days
>
> In the Central scenario heating degree days are kept constant at the levels of the year 2015 throughout the projection period. This choice was made with a view to assessing the evolution of the energy system without including "second-order" effects associated with changes in climatic conditions.

Furthermore, **policies in place**, in particular the minimum energy performance standards set for new buildings, requiring them to be 'nearly zero-energy buildings' according to the Energy Performance in Buildings Directive result in improvements in the thermal insulation of the building's envelope that effectively contain the need for energy services.[22] The assumed implementation of the national nZEB standards[23] means that the non-renewable primary energy requirements for new residential buildings comprising space heating and cooling, hot water, lighting and ventilation fall to around 60 KWh/sqm/year at the EU level from 2021 onwards. The related costs for improving the buildings' thermal integrity[24] amount to an average of around 190€/sqm in the early 2020s, and subsequently drop to 120 €/sqm by 2050.

Investments in non-energy-equipment related options allow satisfying an increasing share of energy service needs without consuming energy. In 2050 more than 14% of a dwelling's energy service needs are projected to be satisfied through these options as a consequence of the nZEB standards, even if their full impact materialises only with a substantial delay due to the inertia of the building stock: residential buildings built between 2021 and 2050 cumulatively make up only one fifth of the 2050 total stock.

In new dwelling constructions some 28% of energy service needs are met through non-energy-equipment related options from a peak of more than 45% in the first years of the implementation of the EPBD. This declining trend for new constructions reflects the changes in the cost-optimal solution found in fulfilling the building codes: while in early years, investments in building insulations are the dominant options, over time reductions result from the deployment of very efficient equipment and embedded renewables, combined with dwelling insulation. This becomes evident in the re-increase of the new buildings' energy service demand for space heating.

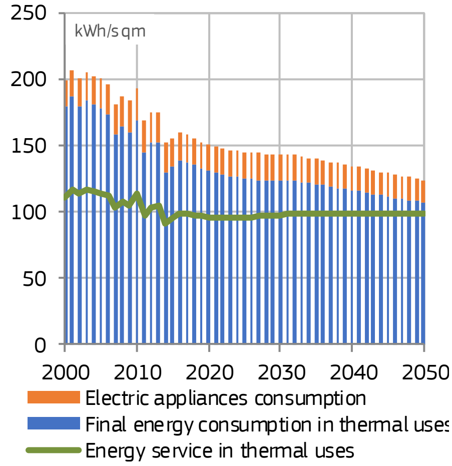
Furthermore, in the Central scenario, the full implementation of EED Art 7 contributes to lowering the residential energy demand in the first years of the projection period. Since it requires energy savings to be achieved over the period 2014-2020, to a large extent it acts by moderating the energy service demand (i.e. by limiting / making more efficient the operation of the equipment).

The impact of the EPBD is clearly reflected in the fact that the energy service per household that needs to be met by energy consuming equipment is limited in 2050 to just 11% over the 2015 level, whereas in the absence of investments in non-energy-equipment related options it would have been almost 30% higher than in 2015.

Additionally, over the period the efficiency in satisfying those thermal energy services improves by more than 20 percentage points and in 2050 exceeds 90%, resulting in the final energy requirements to meet these services to contract. The observed efficiency gains stem from a combination of technological progress within a given technology group, and consumers' decisions to choose more efficient options (e.g. heat pumps) when installing new devices.

The underlying improvements on a per sqm basis (i.e. not accounting for the effect of the larger dwelling sizes) are shown in Figure 28. Satisfying the marginally increasing thermal energy service demanded per sqm (+3% in 2015-2050) requires 20% less energy consumption. This is made possible by several interdependent factors.

Figure 28. Final energy versus energy service



- Firstly, the efficiency of new installations is well above that of the existing stock and further improves over time as technology evolves (e.g. from conventional to condensing boilers). This technology progress is in initial years supported by policies in place that set minimum efficiency requirements (Eco-design) and energy labelling.

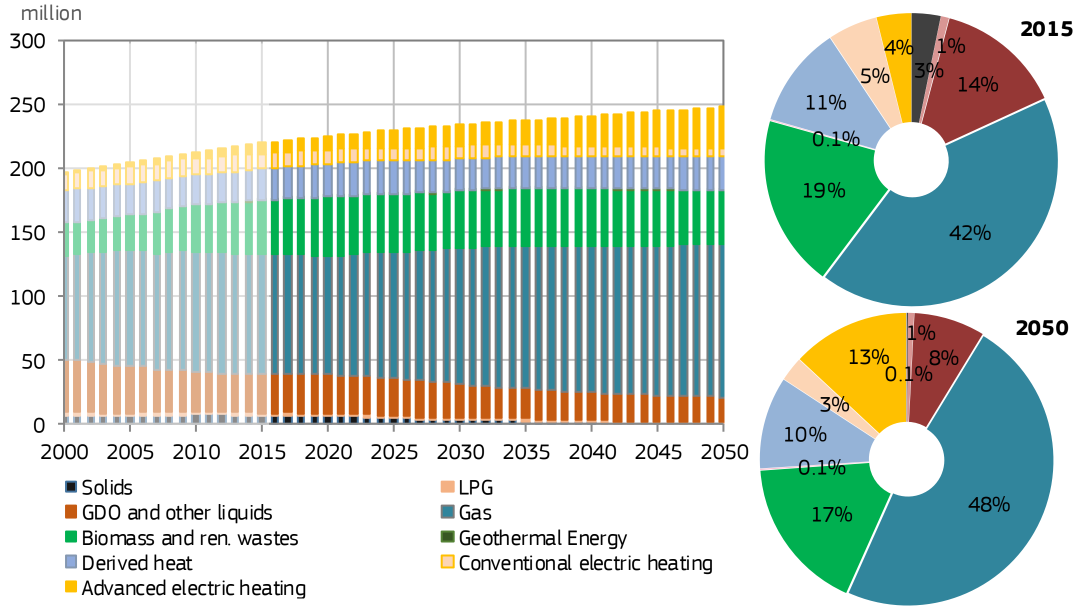
[22] Investments in non-energy-equipment related options such as insulation are explicitly considered in the POTEnCIA model as part of the economic decision-making. Investments in 'infrastructure efficiency improvements' not only occur when installing new energy equipment but are an option also for existing equipment, where they would then induce an underutilisation. The costs for infrastructure efficiency improvements are explicitly reported for each sector.

[23] Note that there are usually multiple standards reflecting different building types and/or climatic conditions within a country; these have been transformed into one value each per country for residential and non-residential buildings for the purpose of this scenario (see section 2.4)

[24] From a modelling perspective this corresponds to a dual 'efficiency value' specific for each Member State and year. At the EU aggregate the efficiency value is in the order of 100€/MWh in the 2020s and reduces to some 60 €/MWh towards 2050.

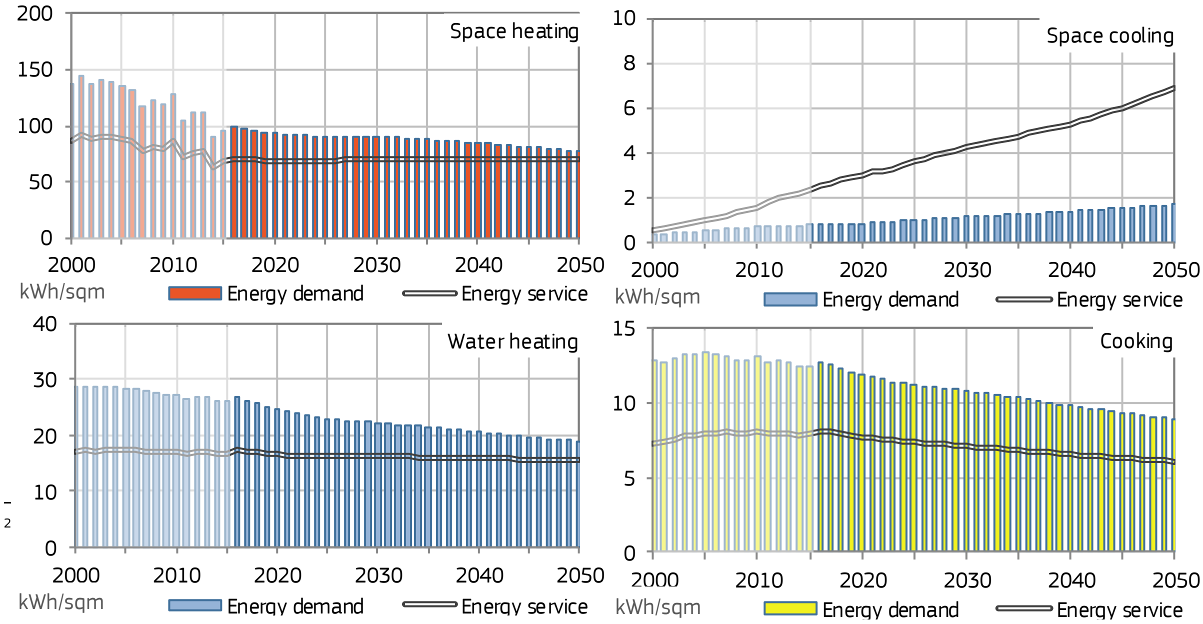
- Secondly, a simultaneous fuel and technology switch takes place, in particular concerning space heating. Less efficient diesel oil-fuelled heating is replaced by natural gas boilers and heat pumps, which become the dominant choices for new investments. Almost half (48%) of new households opt for natural gas fired heating by 2030 compared to some 40% today, and the share of new households investing in heat pumps increases to 17% by 2050. Their total market shares of the overall stock expand to 48% and 13%, respectively, up from 42% and 4% today. Despite the uptake of heat pumps, the share of electricity in the space heating final energy demand remains rather stable over time due to the very high efficiency of heat pumps, which implies that the final energy consumption needed to fulfil the thermal energy need is comparatively low.

Figure 29. Evolution of number and market shares of households by space heating energy carrier



- Thirdly, space cooling is the main driver for the incremental energy service needs. Its demand expands rapidly, reflecting the fact that in many Member States the use of space cooling remains today well below the desired comfort level. The space cooling share in the total energy service needs (expressed in terms of useful energy) expands from 2.4% today to more than 7% by 2050 at the EU aggregate level, with very pronounced differences across countries that reflect heterogeneous climatic but also economic conditions. Since air conditioning systems have efficiencies of more than 300% today that further rise to 400% by 2050,[25] its contribution in terms of final energy demand remains limited.

Figure 30. Final energy demand and thermal energy service for residential end-uses

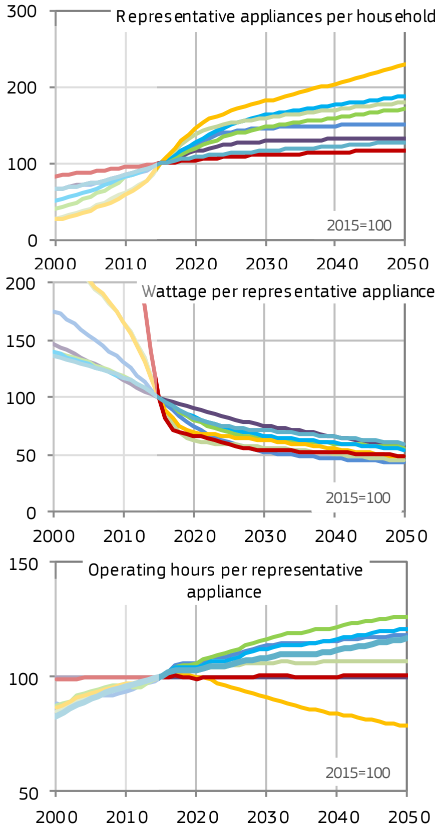


- Lastly, the role of solar energy in providing domestic hot water services expands significantly across all Member States. In 2050 solar energy accounts for 17.5% of the energy consumed for water heating purposes (from less than 4% in 2015), quadrupling in absolute terms from its 2015 level.

4.3 Specific electricity uses

Specific electricity uses comprise white appliances (disaggregated into refrigerators and freezers, washing machines, clothes dryers and dishwashers), brown appliances (TV and multimedia; ICT equipment), lighting and other appliances (the latter including vacuum cleaners, irons, ventilation fans etc.).[26]

Figure 31. Main characteristics of the representative appliances



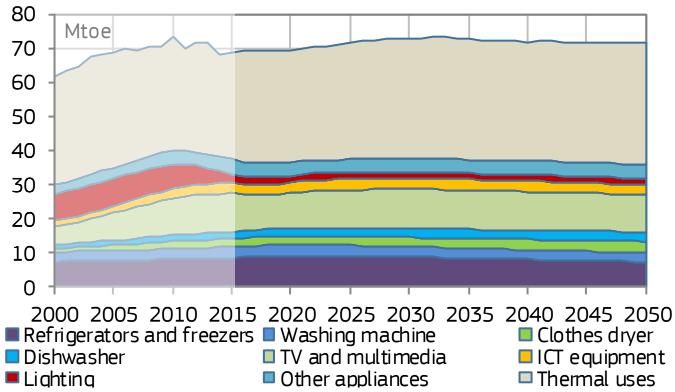
Growing income levels have led to a continuous increase in the number of appliances per household, and this trend continues even though saturation effects come into play. At the same time, appliances are used more frequently. The ICT bundle is an exception, since the proliferation of devices (more than doubling) means that not all appliances are always used at the same time.

This escalating demand, however, does not translate into a pronounced increase of the corresponding energy consumption due to the significant improvements in the efficiency of specific electricity uses. Pushed for by policies such as minimum efficiency standards and energy labelling, electric appliances have achieved remarkable improvements in their efficiency – expressed here as Watt per appliance. This trend continues over time, albeit at a slower pace since no additional technology policies are assumed for the long run.

Overall this leads to a reduction of 4% in the aggregate electricity use for appliances and lighting by 2050 relative to the year 2015, with heterogeneous responses in the evolution of demand across different appliance types.

Within white appliances, the penetration rate of clothes dryers and dishwashers almost doubles. This rise in their number together with their more frequent use[27] is in part mitigated but not offset by technical progress, resulting in a pronounced growth of their electricity demand by almost 40%. As the consumption of refrigerators/freezers and washing machines eventually shrinks after an increase in the first years, in 2050 the total consumption of white appliances falls back to the levels of the year 2015.

Figure 32. Residential electricity consumption by use



For TV and multimedia and for ICT equipment, technology dynamics (and in the latter case reduced operating hours; see above) curb their demand and effectively lower it by 4% over the projection period, resulting in broadly stable shares of specific electricity consumption.

Following the phase-out of incandescent light bulbs and the mass deployment of highly efficient LED lights, the use of electricity for

[26] Note that POTEnCIA defines for each group a certain reference appliance at EU level that remains constant over time, e.g. a washing machine of 6kg; a refrigerator of 220 litres and freezer of 110 litres. In this respect, a high number of washing machines or TVs per household may also be interpreted as larger appliances.
For others, a 'representative device' is defined as a given package or bundle of individual devices. 'ICT equipment' comprises a well-defined set of ICT equipment such as desktops, computers, mobile devices etc. 'TV and multimedia' subsumes e.g. TV sets, satellite receiver, Dvd player, playing console, sound system. The characteristics of the so-defined packages that form a representative device are determined taking into account the market presentation and the techno-economic properties of the different equipment types that they consist of. They are constant over time.

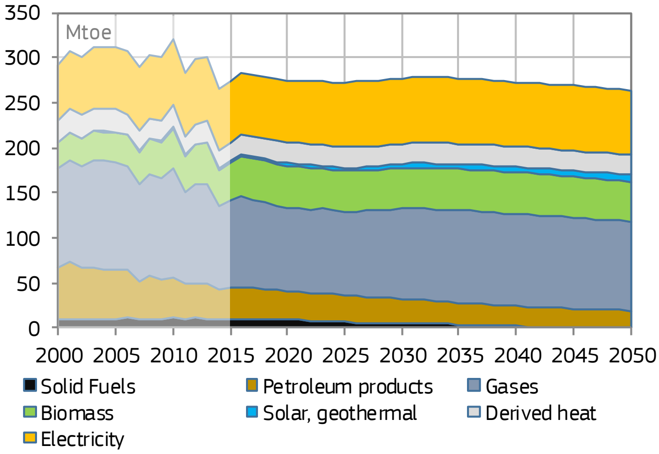
[27] The hours of use of a representative device differ across the Member States due to cultural differences, population size, economic growth and market penetration factors.

lighting purposes shrinks rapidly by around 35%, by 2025 such that its share in the total demand for specific electricity uses reduces to only 5% by 2050.

4.4 Fuel mix, CO_2 emissions and energy-related costs

As a consequence of the trends described above, **moderate shifts occur in the fuel mix of the residential sector's final energy**. Natural gas use exhibits a strong increase beyond 2025 (rebounding from the observed and continuing declining trend until then) to reach a share of 39.5% of energy consumption in the sector in 2050 (from 35.5% in 2015). This gain in market share, compensates to some extent for the decline of solids who become an obsolete energy form for the residential sector by 2050, and liquids, whose demand halves by 2050. The market share of derived heat remains stable, whereas that of biomass exhibits a limited decline (+0.7 and -0.5 percentage points respectively in 2050 from 2015 levels). The use of solar thermal energy more than quadruples over the projection period to contribute almost 3% by 2050, while the use of geothermal energy remains unimportant. As discussed above, the share of electricity experiences modest changes compared to the observed past trend. The increase of its market share in residential energy consumption by close to 2.5% (to reach 27.2% by 2050) is driven by its use in thermal end-uses, in particular by a vigorous expansion in the demand for space cooling. Although the share of households installing heat pumps for space heating also rises, the corresponding final energy demand increase is limited due to their very high efficiency; this growth is also offset by the decline in the use of conventional electric heating systems.

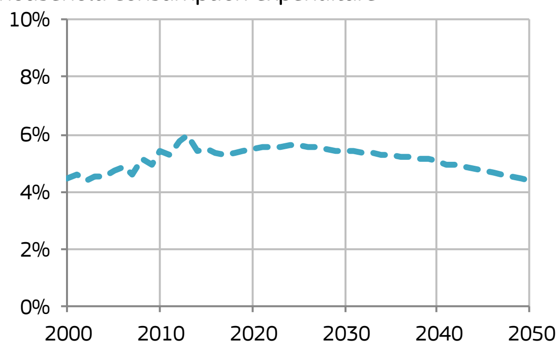
Figure 33. Residential energy consumption by fuel type



As a consequence, the carbon intensity of the sector's energy demand undergoes a limited contraction from 1.35tCO_2/toe to 1.1 tCO_2/toe. In combination with the lower energy demand **the residential sector's total CO_2 emissions shrink by 22%** in 2015-2050. When expressed per sqm of useful surface area, this decline in CO_2 emissions becomes more pronounced and exceeds 35%, clearly reflecting the more than important role of the adoption of non-energy-equipment related options that lead to a substantial decline of direct energy service needs.

The deployment of highly efficient equipment and enhanced thermal insulation more than counterbalance the rising energy prices, resulting in **declining importance for energy-service related costs over income**. Their share of the household consumption expenditure follows a declining pathway throughout the projection period accounting **for less than 4.5% in 2050 from 5.5% in 2015**, while at the same time the cost per unit of energy consumed is projected to increase by close to 39%.

Figure 34. Total energy-service related costs as % of household consumption expenditure



This is made possible by significant investment both in energy related equipment and in non-energy-equipment related options. The **overall investment expenditure in the residential sector** is projected to reach close to 25.5 trillion € for the period 2016-2050, accounting for close to **7.4% of the cumulative household consumption expenditure**. In per capita terms this translates in an amount of close to 1400€ spent annually in such investment. However, the bulk of this expenditure links to the purchase of electric appliances (around 77%; more than 1000€ per capita), whose primary purpose is not the satisfaction of energy service needs. Investment in non-energy-equipment related options also becomes increasingly important, accounting for 45% of the remaining investment expenditure (10% of the total). Finally, 13% of the total investment expenditure is absorbed by energy using equipment for heating /cooling purposes.

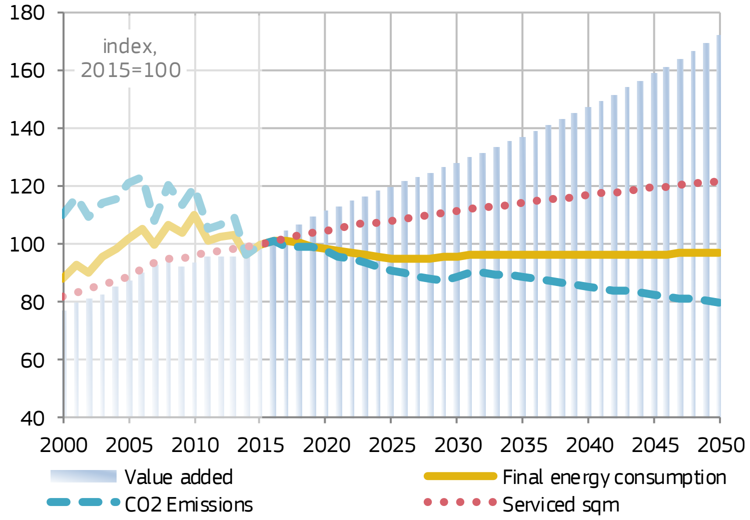
5 Services

5.1 Overview and key trends

The services sector continues to expand its GDP share at the expense of manufacturing and to a lesser extent construction and agriculture. Its value added grows by 72% over the projection period.

Like the residential sector, however, the sector's final energy consumption and CO_2 emissions become progressively disentangled from its activity growth and the induced rise in energy service needs. While energy demand remains quite stable and in 2050 is just 3.2% below 2015 levels, CO_2 emissions are effectively cut by 20% over the same period.

Figure 35. Key indicators of the services sector



The transitory rebound in the sector's CO_2 emissions seen in Figure 35 can be explained by the stock substitution of zero-carbon heating systems (biomass and electric) that reach the end of their useful lifespan and are replaced primarily by natural gas.

5.2 Thermal end-uses

The economic growth leads to a rise in the service sector's serviced surface area of 22%, equivalent to the need for an additional 4 million new representative building cells[28]. At the same time, the final energy consumption for thermal uses can be stabilised and even experiences a limited reduction of 2% over the projection period.

This is achieved despite satisfying a growing thermal energy service demand. Energy service needs for space cooling rise by 74% over the projection period, resulting from an increasing number of services being equipped with space cooling devices and their increased use, and the overall growth in the services sector's number of buildings and correspondingly in the useful surface area. The rising overall surface area in combination with increasing comfort levels also drive a 38% growth in energy service needs for space heating. Population and income are the main drivers for catering and hot water provision, whose energy service needs grow by 32% and 31%, respectively.

Expressed per sqm of surface area, thermal energy service needs grow by 16% over the projection period, whereas final energy demand is cut by 19%. The substantial reductions in the final energy required to satisfy the related service needs can be associated to the effects of the Energy Performance in Buildings Directive, according to which new buildings need to be nearly zero-energy buildings as of 2021 (2019 for public buildings). The implementation of the related national building codes (see section 2.4) translate at EU level in contracting the non-renewable primary energy requirements of new service buildings for space heating, lighting and ventilation at around 120 kWh/sqm in 2020, further shrinking to less than 100 kWh/sqm in 2050.[29] This fosters investments that enhance the insulation of the buildings' thermal envelope. The related costs amount to some 270-285 €/sqm during the first years of the implementation and then drop to levels around 150 €/sqm by 2050.

The strengthened thermal integrity of buildings progressively contributes in meeting the thermal energy service needs. By 2050, 11% of the thermal service needs are satisfied through these non-energy-equipment related options.

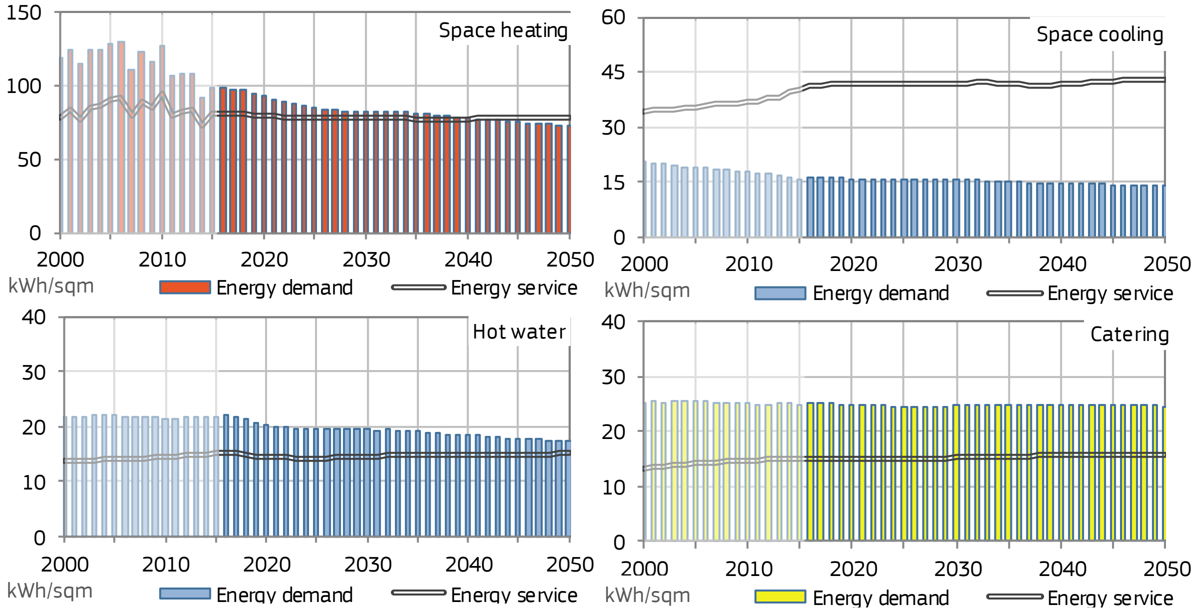
In new buildings, the corresponding share of thermal energy services satisfied by means of the buildings thermal integrity peaks at around 50% in the first years of the implementation period, and subsequently decreases to 22% by 2050. This change indicates that the cost-optimal solution found for fulfilling the nZEB energy performance

[28] In POTEnCIA and the underlying JRC-IDEES database, a representative building cell in the service sector has been defined to have 450 m2 across all countries, constant over time.

[29] Meeting the transposed building codes requires a sustained, slowly declining effort throughout the projection period The corresponding efficiency values reaches maximum levels of 140 €/MWh, declining to around 100 €/MWh afterwards. Note that these efforts vary considerably across Member States, reflecting both different conditions and building codes.

requirements changes over time. Whereas in the initial years they are primarily met by investing in building insulation, in later years they are increasingly satisfied through a combination of building insulation and energy equipment related options (e.g. boilers, heat pumps). This is explained by the increased system efficiency of providing thermal energy services[30] that increases by 23 percentage points between 2015 and 2050 in combination to the substantial improvements in efficiency of the transformation sector, as well as the uptake of local renewables. Both the switch from less efficient types of heating systems to electric and gas heat pumps, and the progressive technological improvements within the specific end-uses contribute to this rise in efficiency.

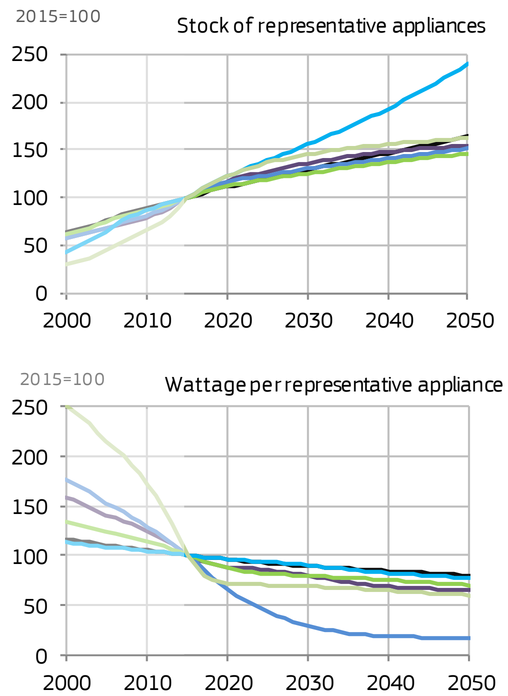
Figure 36. Final energy demand and thermal energy service for the end-uses in the services sector



5.3 Specific electricity uses

Specific electricity uses in the services sector include building and street lighting separately, ventilation, commercial refrigeration, ICT and multimedia, and miscellaneous building technologies. The number of representative devices[31] for ventilation, building lighting and miscellaneous building technologies grows substantially in response to their rising penetration and to the service sector's increasing surface area. Miscellaneous building technologies include a wide variety of building-related types of equipment (ranging from vacuum cleaners, to elevators, to hospital equipment, etc.). Favourable economic conditions and currently low penetration levels (referring to a "full pack" of such equipment) turn these into the fastest developing specific electricity use. The energy use for ventilation also increases rapidly, responding to the needs for controlled ventilation in low-energy buildings.

Figure 37. Appliances in services



The number of representative appliances related to street lighting, commercial refrigeration and multimedia also expand to satisfy the growing demand for these services, although some reach a certain level of saturation. The main drivers for the deployment of these technologies are population and income growth. ICT-related services also link to population and income growth reflecting on the one hand the citizen's increased need for e.g. data centres and internet hubs, and on the other

[30] Defined as the ratio between useful and final energy consumption.

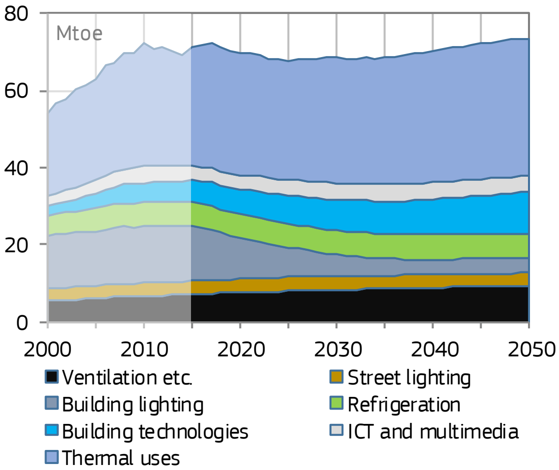
[31] As mentioned in footnote 26, POTEnCIA introduces the concept of a representative device for each end-use to ensure comparability across countries and over time. This can either relate to a single appliance, or to a "cluster" of devices grouped under e.g. 'ICT and multimedia' or 'Miscellaneous building technologies'.

the increasing use of this type of services in the sector (expanding beyond the number of employees working in offices in order to better reflect the broader scope of offering this services in schools, hotels, etc.).

Significant gains in efficiency manage to successfully counteract the surging demand for such services. Improvements are most pronounced in building lighting (to a lesser extent in street lighting, as a transition to low-consumption technologies started earlier in this case) due to the swop to highly efficient options such as LED lighting: the luminous efficacy of a new light bulb in the mid-2020s is already twice that of today's levels, increasing to four times by 2050. Lighting aside, all other representative devices also see a substantial decrease in their wattage, with reductions between 15% and 20% between 2015 and 2050. Efficiency improvements nonetheless slow down over time since no new policies are assumed that set more stringent requirements than those in place today.

Driven by efficiency improvements, final electricity consumption for specific electricity uses falls by 4% over the projection period, despite a resurge observed in the last period during which additional efficiency gains cannot fully offset the continuous demand increase for ventilation and miscellaneous building technologies that have not come close to saturation levels by then.

Figure 38. Electricity consumption by use in services



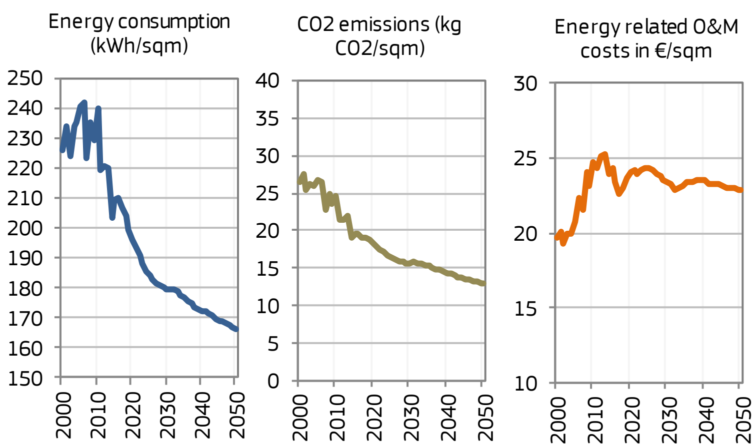
At the same time, **the share of electricity rises throughout all thermal end-uses**. In absolute terms, additional electricity demand comes primarily from the provision of catering and of hot water with electricity. The very high efficiencies of air conditioning systems imply that the rising demand for space cooling services does not translate into a rise of equivalent magnitude in the corresponding final energy need. Driven by the retirement of conventional electric space heating systems, the electricity demand for space heating reduces overall during the first half of the projection period despite the uptake of electric heat pumps. The latter does not translate into a surge of electricity demand due to their high efficiency. Their continuous deployment thereafter, however, drives the electricity demand for space heating up again until the projection horizon.

Overall electricity demand in the services sector reaches its minimum levels around 2025 (about -5% compared to 2015). A re-increase afterwards leads to consumption levels 3% above those of the year 2015 in 2050.

5.4 CO_2 emissions and energy-related costs

As the service sector's final energy demand is increasingly met by less carbon-intensive fuels, its carbon intensity reduces by 17% over the projection period. In combination with the sector´s marginal reduction in overall energy demand, this results in **CO_2 emissions that by 2050 are 20% below 2015 levels**.

Figure 39. Energy consumption, CO_2 emissions and energy related costs per useful area in services



Electricity and natural gas slightly expand their dominance in the sector´s fuel mix and by 2050 provide more than half (51.2%) and almost one third (32.1%) of the final energy demand, respectively. The use of solar thermal energy increases 8-fold. Its contribution to the overall thermal needs remains limited, even if almost half of the buildings are fitted with solar thermal installations. The use of derived heat increases slightly and satisfies about 7% of the demand. Conversely, consumption of diesel oil and other liquids almost halves (-44%) over time, and solids, that already today have less than 1% of the market, almost completely disappear.

On a per-sqm basis, the reductions in energy and especially in CO_2 emissions are sharper, as they respectively fall by 21% and 34% over the projection period. The energy-related O&M costs per surface area experience a modest decrease by some 6%, reaching 23 €/sqm in 2050.

The associated **investment expenditure in the services sector** is 6 trillion € for the period 2016-2050, accounting for close to **1.4% of the cumulative value added**. Much of this expenditure is however related to electric appliances (around 63% of the total), which have different purposes than the satisfaction of energy service needs. Investment in non-energy-equipment related options, such as building insulation accounts for 57% of the remaining investment expenditure (21% of the total). The remaining 16% of the total investment expenditure is absorbed by energy using equipment for heating /cooling purposes.

6 Transport

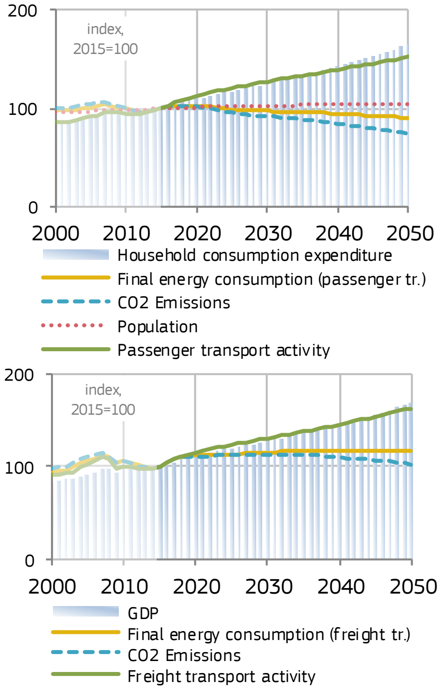
6.1 Overview

Both passenger and freight transport activities continue on a growing pathway throughout the projection period, leaving behind the slump of the economic downturn. During the first half of the projection period, passenger and freight transport activities grow slightly faster than household consumption expenditure and GDP, respectively. This trend is reversed only afterwards.

Air passenger transport[32] and high speed rail are the fastest growing passenger transport modes. The sustained rise in high speed rail is supported by the assumed completion of the comprehensive TEN-T network. Even though all modes increase in absolute terms, the share of aviation[33] in passenger transport activity increases by 11 percentage points to reach 33% of the total passenger-km by 2050, while that of rail increases from 6% up to 9%, mainly driven by high speed rail has share doubles to account for almost 3% by 2050. **Road transport nevertheless remains the principal mode,** serving close to 60% of the passenger transport demand by 2050, compared to 70% in 2015.

Aggregated over all modes, in 2050 every person in the EU travels on average 22 000 km, up from 15 000 km per capita in 2015.[34] Nonetheless, the related final energy consumption to satisfy the demand for passenger transport shrinks by 13% on a per capita basis.

Figure 40. Key indicators of passenger and freight transport



In freight transport, the predominance of road transport remains and its share even marginally expands in the decade 2020-30 before it gradually gets back to today's levels. Light commercial vehicles continuously experience higher growth rates; in terms of overall road freight transport activity, their share however exhibits only a limited increase reaching 7.2% in 2050 (compared to 6.4% in 2015). Freight aviation, although it also undergoes a continuous increase, still contributes only modestly to the total freight transport activity (2.5% in 2050).

Figure 41. Passenger transport activity per capita

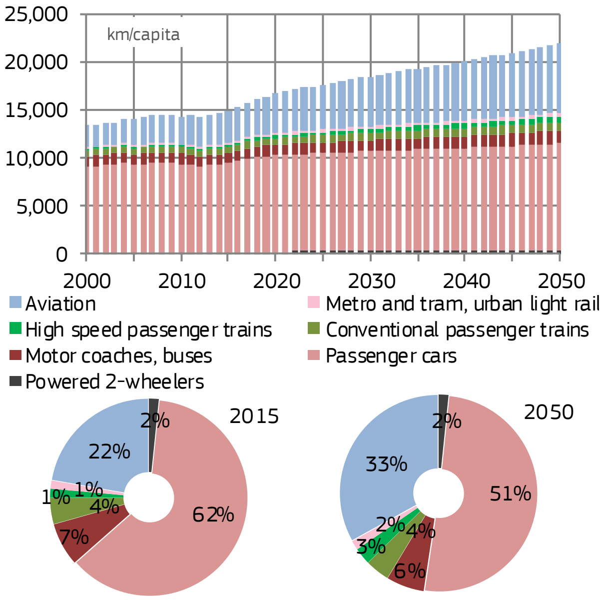
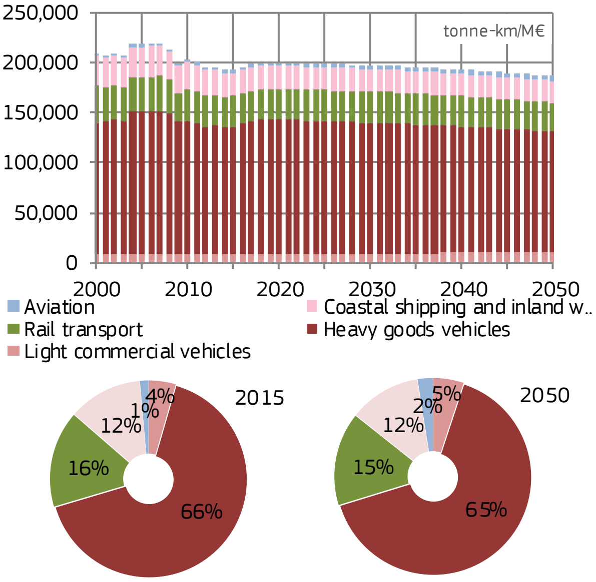


Figure 42. Freight transport activity per GDP



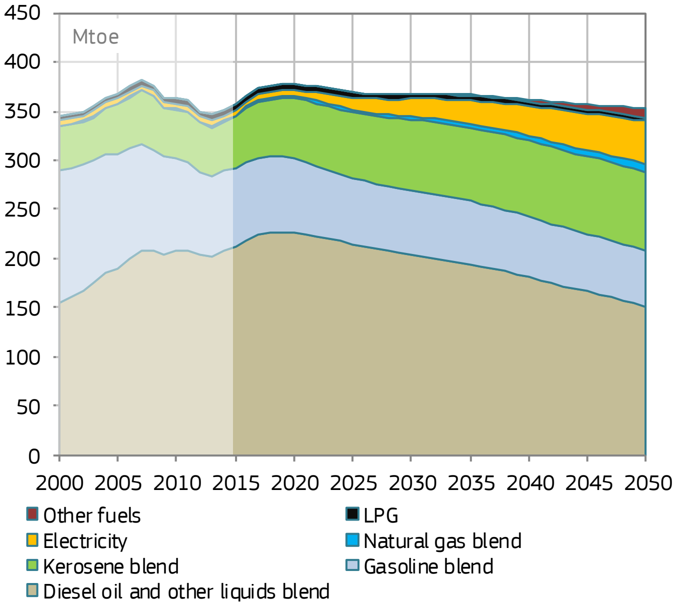
[32] Since the Central scenario has been constructed based on the Eurostat energy balances previous to the 2019 methodology change, energy consumption related to international aviation is accounted for as a part of final demand (see Section 1.4).

[33] In the remainder of this Section unless otherwise stated the aviation sector is discussed as a single entity without distinguishing between the domestic, intra- and extra-EU parts. Nevertheless, specific features relating to this distinction are highlighted where particularly relevant.

[34] International flights are allocated in equal terms to the country of departure and arrival. Hence this aggregate figure includes only half of the actual distances flown on extra-EU flights.

Despite the growth in activity levels, and although load factors are in general following a decreasing trend except for passenger rail and aviation, **the final energy consumption of transport can be broadly stabilised**: it peaks in the near future at 5% above its 2015 levels and is then progressively cut to 1% below the 2015 level in 2050. This is made possible by energy savings in passenger transport, which offset a 17% increase in freight energy demand. The former can be fully attributed to the reductions achieved in road transport, while passenger aviation and passenger rail increase their final energy demand by almost 53% and 18%, respectively, due to the sustained increase in activity. Savings stem primarily from improved vehicle efficiency and are also supported by modal shifts in passenger transport.

Figure 43. Transport energy consumption by fuel



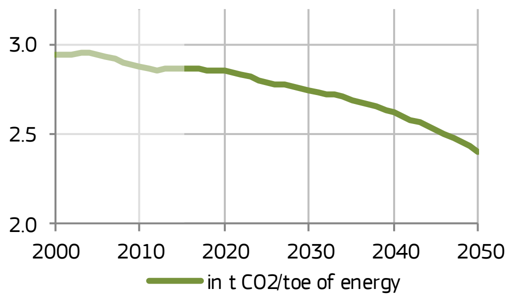
Substantial changes in the fuel mix are taking place with a progressive shift from liquid fossil fuels towards less carbon-intensive energy carriers. The **share of renewables in transport** (see footnote 18) expands steadily to 17.7% in 2030. Afterwards it experiences a steeper increase to reach 47% in 2050.

The progressive uptake of electro-mobility means that electricity accounts in 2050 for 14% of the road transport energy demand, up from virtually nothing in 2015. Including also a 30% increase in electricity consumption in rail, the use of electricity in the transport sector rises by a factor of 8 over the projection period. In 2050, the share of electricity in the overall transport energy demand exceeds 12%.

The share of biofuels in the total transport energy demand grows at a more modest pace to exceed 5.5% by 2050, 1.5 percentage points above the 2015 level. Until 2030, biofuel consumption is entirely driven by its use in road transport, primarily as biodiesel blend (even though in relative terms bio-gasoline increases more rapidly). Towards the end of the projection period, bio-based kerosene becomes a commercially available alternative and satisfies 5% of the aviation energy demand in 2050.

Other alternative fuels take over increasingly important roles in specific niche markets, but their overall contribution to the transport sector's energy demand remains limited. For example, natural gas becomes an attractive option for buses and coaches, also in view of reducing local air pollutant emissions; in 2050 it accounts for over 12% (2.5 times above its share in 2015) of the fuel consumption of those vehicles, compared to some 2.5% in overall transport demand. Hydrogen rapidly gains relevance only in the last decade of the projection period as a fuel in long-haul international road freight transport and in buses and coaches. In both cases it satisfies around 4% of energy demand in 2050; at the level of the transport sector as a whole, its share of the energy demand it satisfies remains small at little more than 1% in 2050.

Figure 44. Carbon intensity of the transport sector



Cumulatively, these changes lead to a **16% contraction in the carbon intensity** of the transport sector's fuel mix.

CO_2 emissions of the transport sector are in 2050 17% lower than in 2015; after an increase in the initial years (a trend that can be observed already in the reported data until 2017), they contract throughout the projection period at a pace that accelerates in the last decade. The emission cuts are driven by reductions in the passenger transport sector (26.1%) that offset the rise in freight transport (+2.4%).

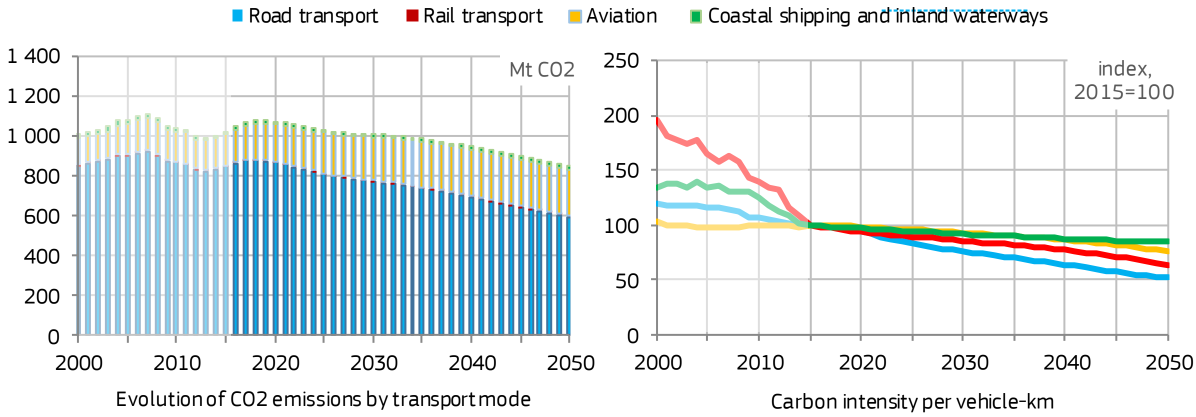
Both in relative and in absolute terms, the largest cutbacks occur in road transport, notably passenger cars. Despite a 27% increase in passenger activity and 62% more freight activity compared to 2015, in 2050 the road transport's direct CO_2 emissions shrink by 30% relative to 2015 levels.[35] On a vehicle-kilometre basis, by 2050 passenger cars (average stock) emit around 40% of today's cars, and heavy good vehicles 65-70% of today´s stock levels. This is

[35] Once the indirect CO_2 emissions from electricity generation are accounted for, this is still more than 27% less than 2015

primarily prompted by the mutually reinforcing effects of a vast uptake of low-carbon vehicles - accelerated by legislation on the CO_2 performance standards for light commercial vehicles for 2020/2021 - and technology progress that renders zero- or low-carbon options competitive, also in the context of rising fossil fuel prices.

Despite an 80% growth in for the passenger rail activity, primarily in high speed rail that roughly triples, and an almost 60% increase in freight activity, rail transport emissions decline by 7.5% in the projection period. This reflects a substantial drop of the carbon intensity of rail activity, achieved through efficiency improvements and

Figure 45. CO_2 emission and carbon intensity in transport



increased electrification complemented by better logistics that lead to higher load factors for passenger trains (and rather constant levels for freight rail).

The high growth of air transport results in a 50% increase of the aviation sector´s CO_2 emissions despite a 25% improvement in carbon intensity per passenger or freight movement, achieved through a combination of better logistics, improved fuel efficiency and blending of biomass-derived liquids in jet fuel reaching 5% in 2050.

Box 6. Marine bunkers

International marine bunkers cover the quantities of fuels delivered to merchant ships of all flags that are engaged in international trips transporting goods or passengers.

International marine bunker activity experiences sustained growth over the projection period, reaching a level in 2050 that is 54% higher than in 2015: EU marine bunkers provide in 2050 fuel for more than 21 trillion tonne-kilometres of goods movements, 95% of which are towards extra-EU territories. This drives a substantial increase in energy consumption, which is however moderated by efficiency gains that are driven by technical and operational improvements in the context of a policy framework agreed in 2011 by the International Maritime Organisation (IMO). Part and parcel of this framework are the Energy Efficiency Design Index (EEDI), which sets compulsory energy efficiency standards for new ships, and the Ship Energy Efficiency Management Plan (SEEMP), a management tool for ship owners. Slow steaming, primarily driven by increasing international fuel prices, has also been playing an increasing role.

As a consequence, the energy intensity per tonne-kilometres of international shipping, which has already decreased more than 20% between 2000 and 2015, experiences a further 20% contraction by 2050. Bunker fuel consumption in 2050 is ultimately 24% higher than in 2015.

Besides those mentioned above, which are mainly directed towards energy efficiency, no further policy specifically addressing carbon emissions from international marine shipping is assumed to come into play in the Central scenario. In this context the International Maritime Organisation greenhouse gas strategy, agreed in April 2018, is not reflected in the Central scenario. Therefore, only marginal fuel substitution takes place during the projection period. In 2050, conventional fuel still makes up almost the entirety of the fuel delivered by international marine bunkers. CO_2 emissions associated to bunker fuel are 21% higher in 2050 than in 2015.

Coastal and inland waterway shipping also increase their CO_2 emissions significantly (+30%). Reductions in their carbon intensity remain limited, and cannot outweigh the almost 60% growth in activity. This results from a combination of the long lifetime of the fleet, limited efficiency improvements and almost no decarbonisation of the fuel mix. Petroleum-based liquid fuels supply almost 100% of energy demand and biofuels only slowly gain market shares but remain below 2% in 2050.

The service related costs (including maintenance and fuel costs but not accounting for capital costs) per passenger-km follow a constantly declining pathway throughout the projection period ending in 2050 at -16% from 2015 levels. This decrease is driven by the significant technological improvements and modal shifts, which more than counterbalance the increasing trend of fuel prices (in 2050 one toe of fuel used in passenger transport is projected to cost some 40% more than in 2015). Still, the increase of passenger activity levels is such that the corresponding costs per capita increase by slightly above 23%. As during the same period the household consumption expenditure per capita increases by 59%, the spending for passenger transport as a share of household consumption expenditure reduces (from 8.1% in 2015 down to 6.3% in 2050).

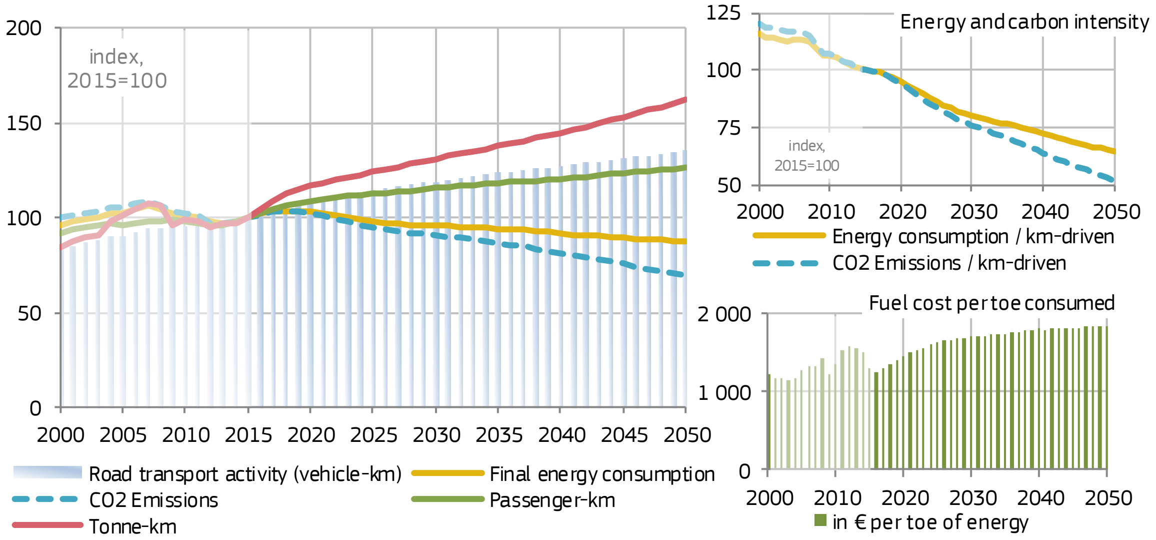
As regards freight transport, the service related costs per tonne-km driven exhibit a limited growth over the projection period (+3.7% in 2050 from 2015 levels). As in the case of passenger transport, this increase is much lower than the corresponding increase of fuel prices (+47%).

The transport sector is the sector with the highest investment expenditure needs in the EU energy system. In 2016-2050 close to 37.5 trillion € (54% of total investment expenditure) need to be spent for the purchase of new vehicles. Close to 70% of this expenditure is directed in private modes of transport (private cars and powered two-wheelers). Thus, an EU citizen spends on average 1400€ annually (around 7% of the household consumption expenditure) in replacing and purchasing additional vehicles.

6.2 In focus: Road transport

Road transport remains the most important mode in terms of freight and passenger transport activity volumes, even though for passenger transport it reduces its dominance. Growing activity levels, combined with declining load factors,[36] translate into a 35% rise of vehicle-km between 2015 and 2050. At the same time, road transport achieves the largest cuts in CO_2 emissions across all transport modes, both in absolute and relative terms, resulting from significant improvements in energy and carbon-intensity, the latter almost halving over time. After rail, road becomes the transport mode with the second highest share of renewable-based fuels. In view of these pronounced trends, this section focuses into road transport to look into the underlying factors, concentrating - without exhaustiveness - on some main features.

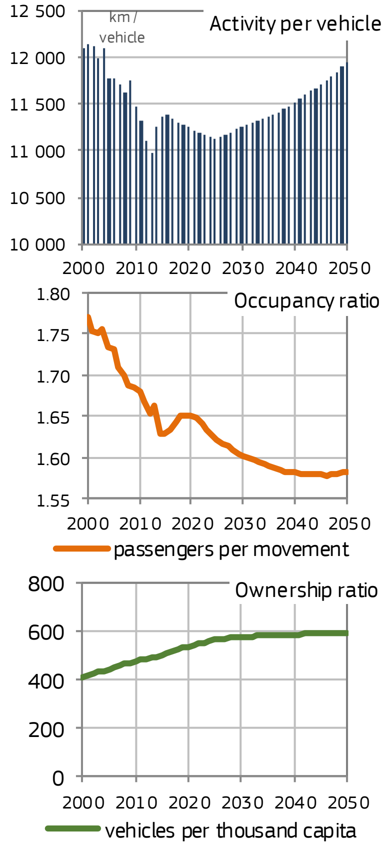
Figure 46. Key indicators of road transport



Within passenger road transport, **cars remain the mean of choice** and satisfy 87% of activity demand. Motor coaches, buses and trolley buses keep shares around 10% that slowly grow to 10.7% by 2050. Powered two-wheelers grow half a percentage point to reach a market share of 2.8%.

[36] Improved logistics cannot fully counterbalance the reduction in the load factors of trucks, which reflects the fact that the volume/weight ratio of goods changes continuously to be less heavy and more bulky. Logistics nevertheless contribute to a more optimal use of the vehicle stock, reflected by an increase in the annual distance travelled of trucks.

Figure 47. Indicators for passenger cars



The occupancy rate of passenger cars experiences further decline, yet at a slower pace than observed in the past and with a clear stabilisation towards the end of the projection period. As a consequence, the vehicle-kilometres driven by cars grow by 2050 to a bit less than one third above the 2015 levels.

The annual kilometres driven by an average car, however, remains broadly constant. In 2050, a car is driven some 11950 km per year at the EU average (with pronounced differences across countries), 5% up from 2015 levels. However, significant differences prevail as regards the way the different technology types, but also the way different vintages within the same technology type are used.

For a specific vehicle the distance travelled annually depends on a number of factors the first of which being the running (fuel) costs, typically lower for newer, more efficient vehicles. In addition, age dependent, increasing maintenance costs lead to reduced activity levels for older vehicles. In addition, the increasing car ownership ratio further contributes in differentiating the way the different vintages are used. For example in a family with two vehicles the older one serves in satisfying specific transport needs, such as work commuting, whereas the newer one is also used for leisure purposes, including long distance trips, and in response to the drivers mentioned above. The increasing technological diversity of vehicle types with distinct operating cost characteristics makes such differences significantly more pronounced.

Figure 48 and Figure 49 show how the activity (in terms of vehicle-km) performed per vintage is not proportional to the vintage stock but higher for newer vintages and lower for the older ones. The differences in the way the different vehicle types and vintages are operated are fully captured and reflected in the Central scenario results. In 2050, the annual distance driven by the average newly-registered vehicle is 10% above that of the overall stock, whereas the average cars of the oldest vintages drive up to -37% less than the stock average.

Figure 48. Evolution of vehicle-km by vintage

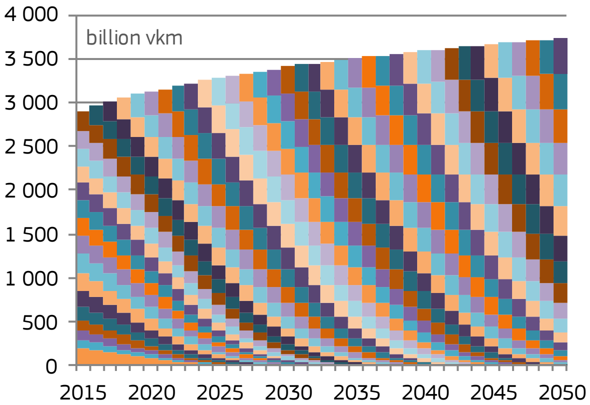


Figure 49. Evolution of car stock by vintage

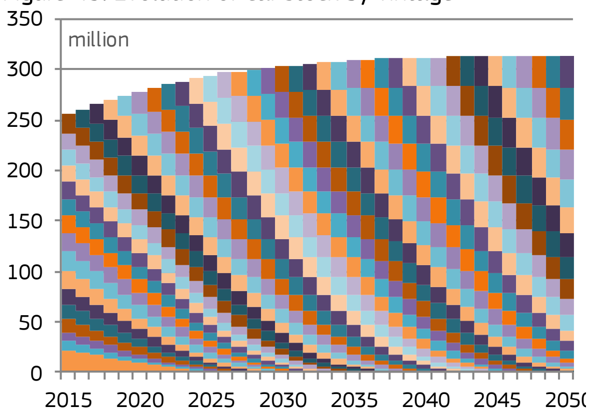
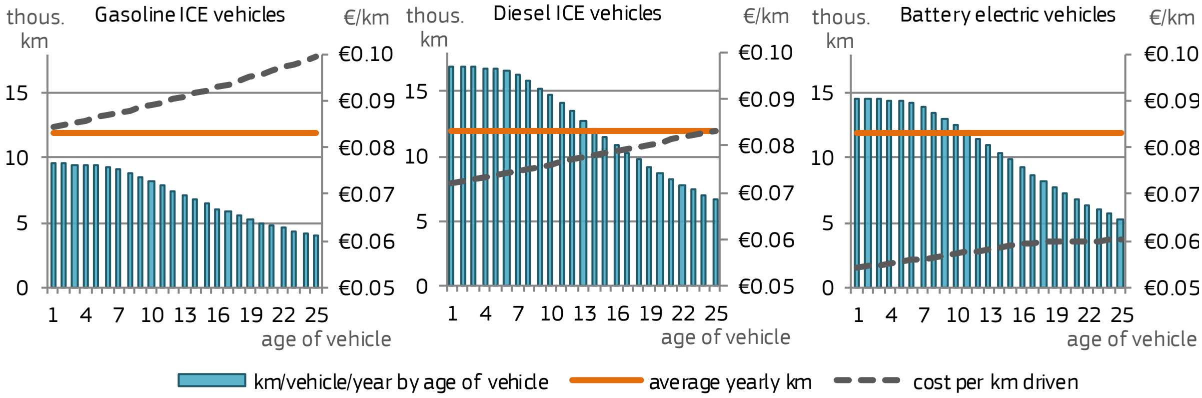


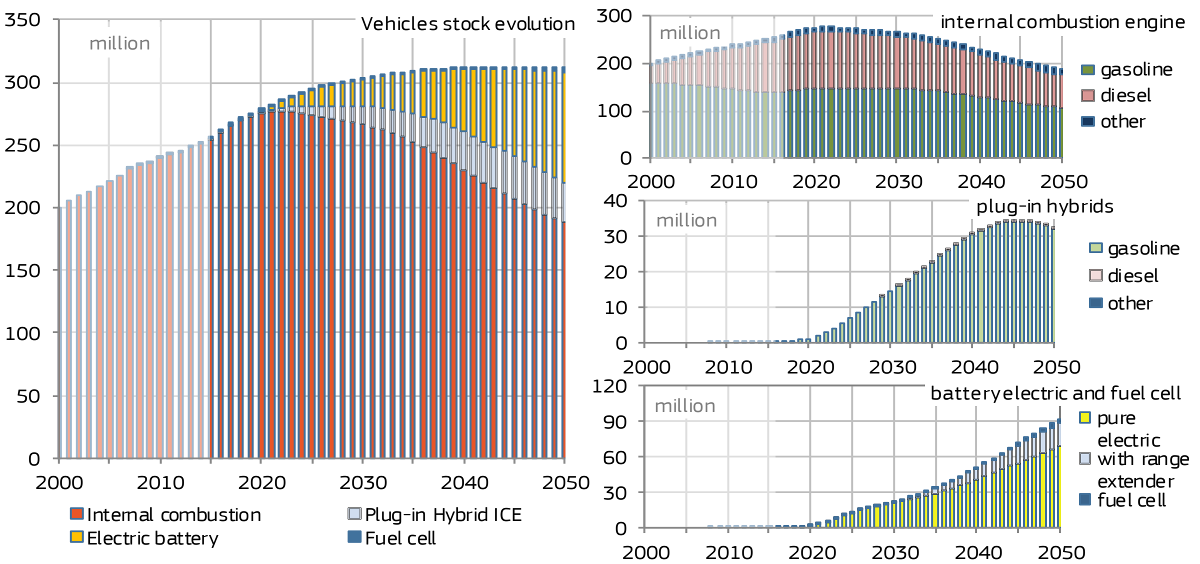
Figure 50 highlights the prevailing differences in the way different vehicle types and vintages are operated in 2050 in comparison to the average distance travelled. Recent-vintage electric vehicles are operated at levels higher than the average distance travelled (22% more for newly registered ones), making evident the presence of rebound effects that lead to the overutilization of part of the stock as a result of its lower operating cost in relative terms. Despite their higher operating costs, diesel vehicles with an age of less than 13 years are also operated above average. This result reflects the continuation over time of observed trends as regards diesel cars being historically driven more. On the contrary, even the newly registered gasoline vehicles are operated some 20% less than the average as their higher operating costs make them less attractive in terms of usage levels.

Figure 50. Annual distance travelled for selected passenger car types per vintage in 2050



The **vehicle stock per capita continues the historical growing trends** sustained by higher income levels and some convergence across Member States. As of the mid-2030s, however, saturation effects prevail and the number of vehicles stabilises at around 590 per 1000 inhabitants until 2050 (500 in 2015). With the population dynamics assumed this implies a fleet of 312 million cars by 2050, up from 255 million in 2015. The additional car demand in combination with the replacement of the existing vehicle stock translates into the cumulative (2016-50) registration of 930 million cars, creating big opportunities for new technologies to enter the market.

Figure 51. Evolution of passenger cars stock

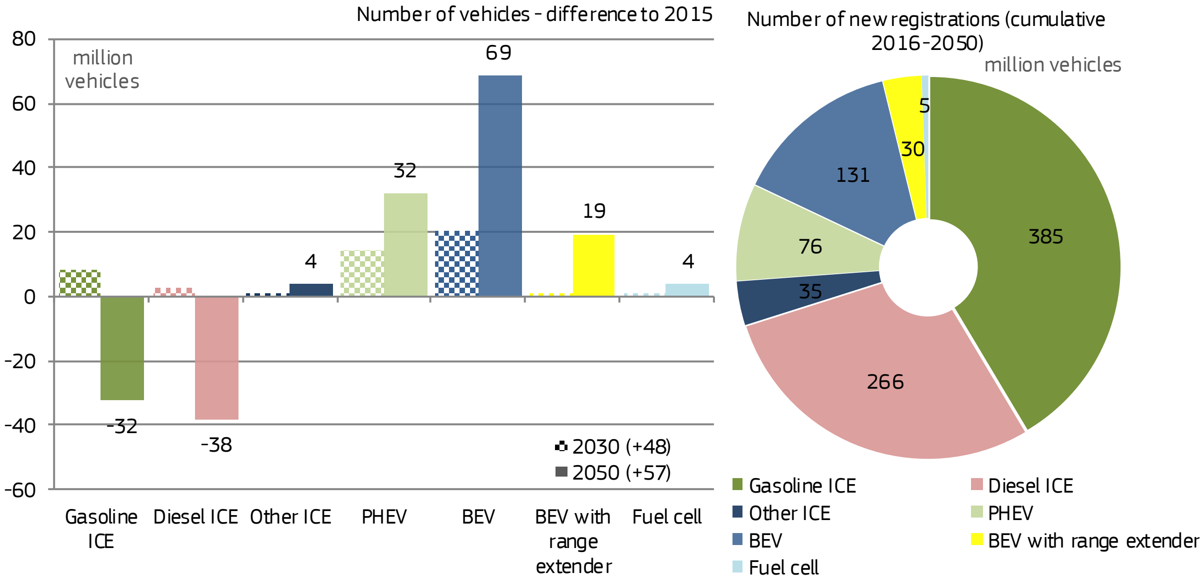


The new technology diffusion over the projection period is significant. In particular electric vehicles (battery and plug-in hybrids) gain substantial market shares thanks also to the simultaneous range increases and price cuts enabled by improvements in battery technology (see also Section 2.3 on the assumed battery cost evolution). They make up 17% of new vehicle registrations in 2030 and more than one third in 2040; from the mid-2040s onwards around four out of ten new cars are electric. In the second half of the projection period fuel cell vehicles also start to enter the market to reach a share of almost 2% of new registrations by 2050. Overall, electric vehicles make up more than one quarter of the cumulative new registrations over the projection period, and account for 40% of the stock in 2050.

Investments in natural gas, LPG and flexi-fuel vehicles also experience a moderate growth. However, their market shares remain low, around 4% of the overall stock by 2050.

Despite the high growth of emerging vehicle technologies, **internal combustion engine vehicles (ICEV) keep dominating the vehicle stock**. They become efficient enough to remain an economically viable option for some time, thus sustaining the only gradual disappearance of consumer's scepticism concerning electric options. The specific energy consumption of new ICEVs in 2050 is about 23% below the level of new vehicles in 2015, and 46% below the average level of the stock in 2015.

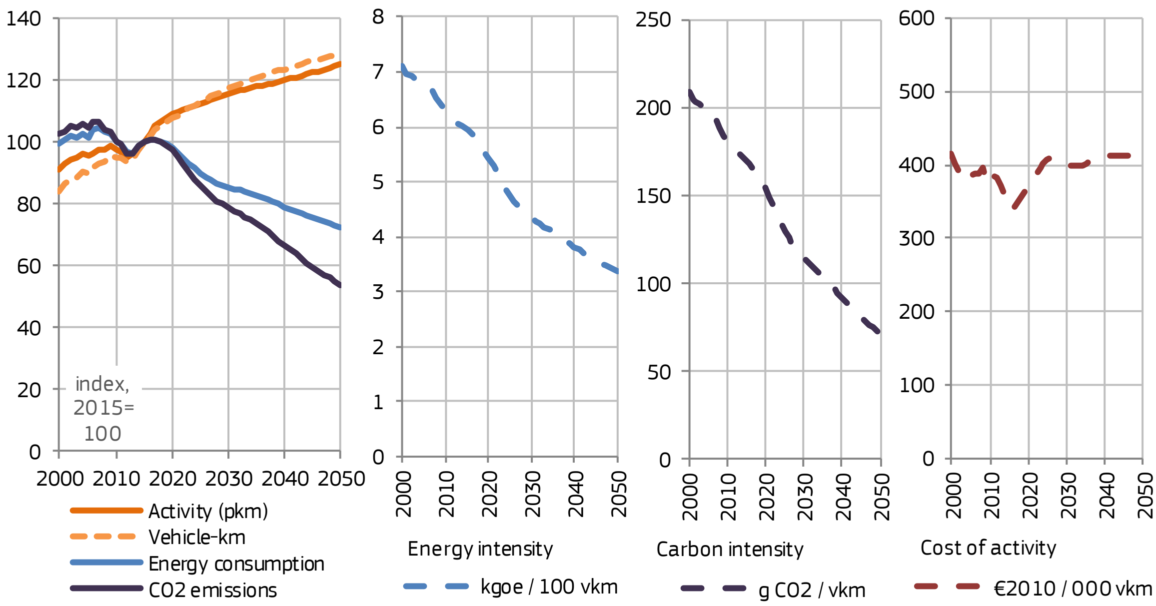
Figure 52. New registration of passenger cars



In the short run, the reduction in the CO_2 emissions of new vehicles (achieved through efficiency improvements and uptake of alternative vehicles) takes place as a response to existing legislation: from 2021 onwards, the EU-wide fleet of new vehicles must not exceed 95 g CO_2/km on the NEDC test cycle. This target is met when counting for super-credits in line with the legislation (see Box 7).

Without additional policy incentives, however, hardly any further reductions materialise in the decade thereafter and in 2030 the EU-wide average emissions of new vehicles are still 92 g CO_2/km. This limited decrease between 2021 and 2030 is far less than the 37.5% emission reduction target (on the WLTP test cycle) over this time period set by regulation (EU) 2019/631 on post-2020 CO_2 emission performance standards for cars and vans, which was not considered in this scenario. Nonetheless, due to the renewal of the vehicle stock and its overall expansion, the average CO_2 emissions per kilometre of the vehicle fleet drop by 23%.

Figure 53. Overview of the passenger cars fleet



Thereafter, new vehicle emissions further contract to 58 g CO_2/km in 2050 (resulting in 71 g CO_2/km average stock emissions). The main drivers for this are the continued improvement in efficiency throughout all powertrain types, the reduction in battery costs and the inertia in consumers' preferences being eventually overcome, as well as rising fossil fuel prices. By 2050 the car stock comprises almost 40% electric vehicles (incl. PHEVs, BEVs, FCVs).

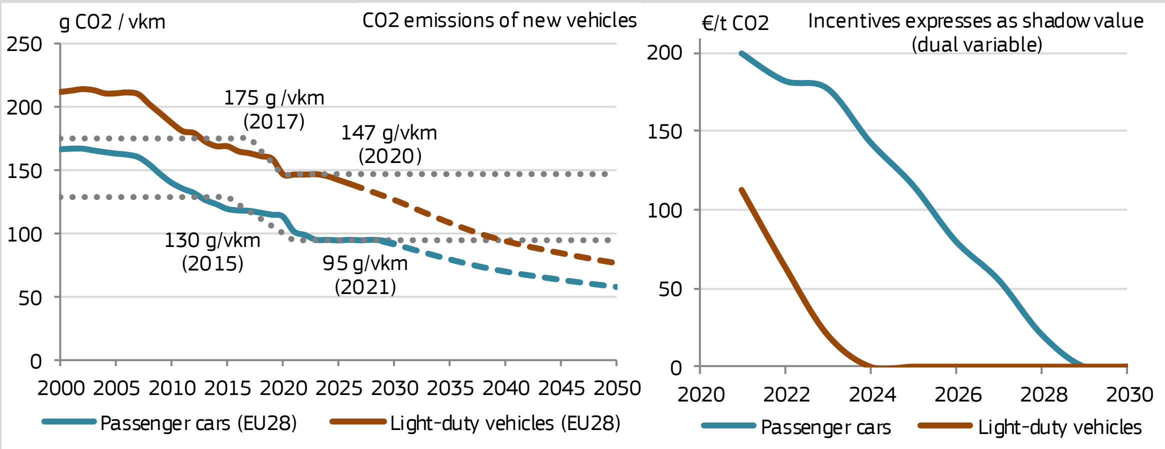
The annual costs per average car in the EU fleet rise by 26% over the projection period. This increase is primarily driven by the purchase costs of vehicles, while the fuel and O&M part of the total costs continuously shrinks despite rising international fuel prices. The reduction in O&M costs reflects the growing share of electric vehicles with fewer moving parts, reduced braking abrasion and no need for periodic oil changes. Per unit of activity, costs rise by almost 20% until the mid-2020s and remain afterwards broadly stable with only mild further increases.

Box 7. CO_2 performance standards for new vehicles

The Central scenario reflects the CO_2 performance standards set by Regulation (EC) No 443/2009 and Regulation (EU) 510/2011 i.e. for new cars the fleet average of 95 grams of CO_2 per kilometre by 2021, and for new vans a fleet average of 147 grams of CO_2 per kilometre by 2020 (on the NEDC test cycle).

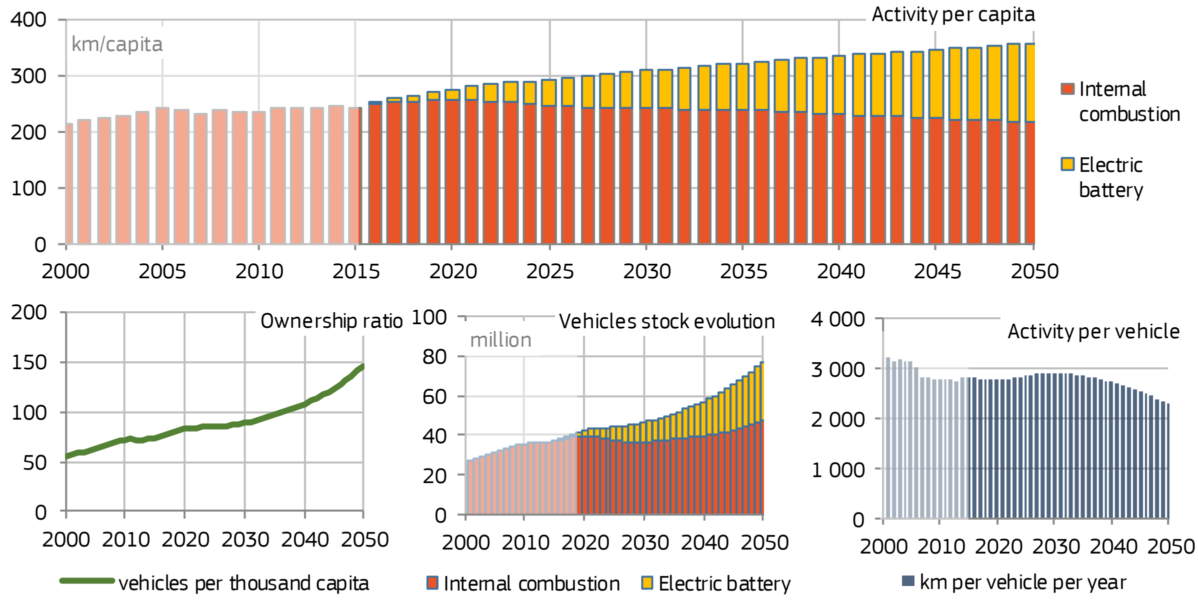
They are implemented as CO_2 emission limits of the average new vehicle at EU level, with the emissions expressed according to the NEDC test cycle. In addition, super-credits are being taken into account. In this context, note that POTEnCIA explicitly differentiates between test cycle and real-life consumption (and CO_2 emissions), as is consistently shown also in the historical data series on transport within JRC-IDEES.

Meeting the exogenous constraints set at the EU level, translates into an endogenously calculated shadow value for passenger cars and LCVs, respectively. After the achievement of the emission standard in the target years (2020 for LCVs and 2021 for cars), it is assumed that the limits are kept constant. As a consequence of technology dynamics, however, the corresponding shadow value decreases rapidly over time.



Emerging vehicle options such as the electric two-wheelers drive the growing (faster than that of passenger cars) activity of **powered two-wheelers** (50% up by 2050). At the same time, their CO_2 emissions fall to 77% of the 2015 levels. The two-wheel fleet also undergoes a pronounced electrification over time; by 2050 almost 40% of the fleet has become electric. The increasing role of smaller sized, electrically powered two-wheelers is also reflected in the decline of the average annual mileage performed per vehicle.

Figure 54. Indicators for powered two-wheelers ownership and use



In road freight transport a rather divergent evolution takes place between light commercial vehicles (LCVs) and heavy goods vehicles (HGVs, trucks). The latter are further split into domestic trucks, for which a national fleet can be identified, and international long-haul trucks that serve international road transport across Europe.[37]

Light commercial vehicles are the road transport means with the highest activity (expressed in tonne-km) increase in relative terms (+84% 2050 vs 2015). Unlike heavy goods vehicles, their load factors moderately increase, although they remain low at around 300kg per movement. Like cars, they also manage a full decoupling of energy use and CO_2 emissions from activity, the latter falling by 26% over the projection period.

Figure 55. Indicators for light commercial vehicles

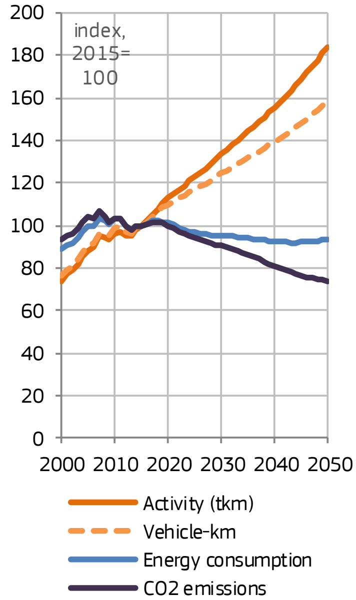
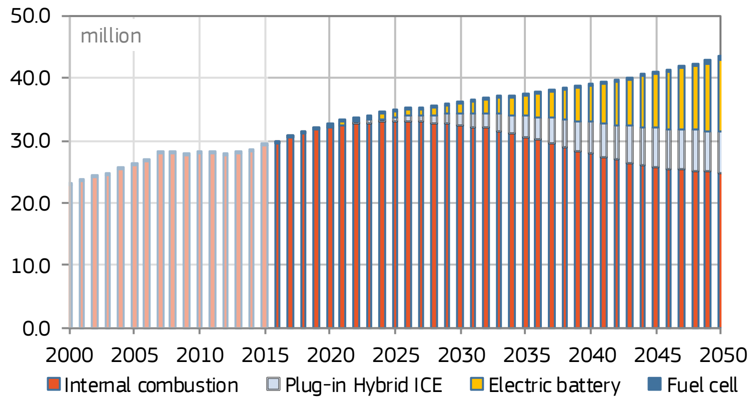


Figure 56. Evolution light commercial vehicles stock



This steep reduction in the CO_2 emission intensity stems – like for passenger cars – from EU legislation setting CO_2 performance standards for LCVs: the EU-wide fleet of new vans must not exceed 147 grams of CO_2 per kilometre from 2020 onwards. This triggers reductions in the specific energy consumption of new ICE-powered vans, which on average consume 26% less fuel in 2050 than a new van purchased in 2015.

At the same time, electric vans face a significant market uptake, even beyond that of passenger cars. Already by 2035, more than 30% of new vans are electric. By 2050 electric vans (battery and plug-in hybrids) account 42% of the stock (an additional 1.2% are fuel cell vans).

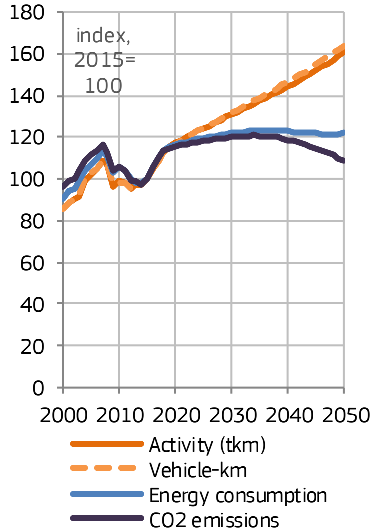
[37] Since the country of activity and the country in which the truck is registered are not closely related for international road transport, a common EU-wide fleet is introduced in POTEnCIA.

For heavy goods vehicles, battery electric options are attractive mainly just for niche markets and their share remains low, accounting for 2% of investments by 2050. Instead, hydrogen fuel cell vehicles reach in 2050 a share of 5% of new purchases in the domestic trucks market, and 7% that of long-haul international freight transport. At the same time, the use of synthetic liquid fuels and natural gas increases over time. By 2050, synthetic liquid fuels and natural gas respectively provide 4% and 3% of the heavy goods vehicles' energy demand, further complemented by hydrogen with another 3%.

Nonetheless, **the majority of emission reductions takes place due to the substantial improvement in the vehicle efficiency**; for domestic trucks, a new vehicles improves its efficiency by 31% (2015-50), whereas this efficiency gain is more limited in long-haul international road freight (-24%).[38]

However, these changes remain insufficient to fully outweigh the increase in demand. CO_2 emissions increase to some 19-21% above 2015 levels between the mid-2020s and 2040, and can effectively be reduced only afterwards. By 2050, they are still 9% up compared to 2015.

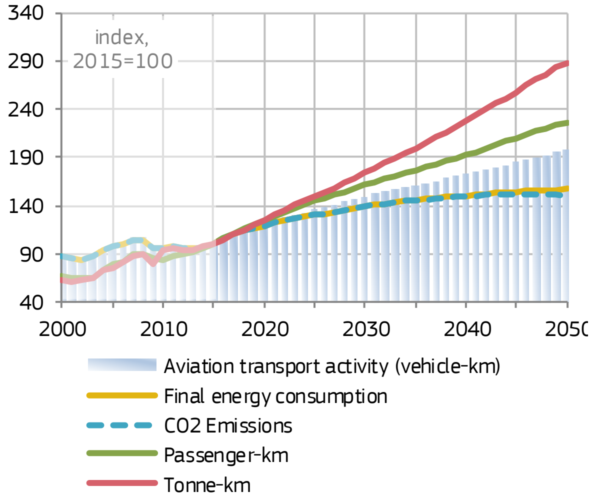
Figure 57. Indicators for heavy goods vehicles



6.3 In focus: Aviation

Aviation, primarily air passenger transport, experiences the steepest increase in demand, continuing the rapid expansion observed in the last decades.[39] With air passenger activity more than doubling (increase by a factor of 2.3) and freight activity almost tripling (increase by a factor of 2.9) from 2015 levels, aviation expands its role as the second most important means in terms of passenger-km volume and satisfies one third of passenger transport demand by 2050, whereas its role in freight transport remains limited (2.5% of the total tonne-kilometres by 2050).

Figure 58. Key indicators of aviation



The number of both intra- and extra-EU international flights doubles, while the number of domestic flights increases slightly more moderately by 74%. This means that by 2050, every person flies on average around 7270 km per year - more than 60% of which on extra-EU international routes -, up from 3335 km today. For international aviation, this rapid increase has already started to take place and is expected to marginally slow down towards the second half of the projection period due to saturation effects.

Despite this surge in demand, **the increase in the aviation's final energy demand can be limited** to remain at 57% above 2015 levels by 2050. This result from both improved logistics, which lead to a further increase in the planes' occupancy rates and load factors and to further optimised flight routes, and technical efficiency improvements. In 2050, a new plane is projected to consume about 30% less energy[40] than a new plane today. Alternative aircraft, such as those using an open rotor design, enter the commercial fleet only beyond 2030; while their use increases in particular to serve domestic flights – in 2050 they satisfy 10% of domestic demand - , at the level of the whole aviation sector they represent only 2% of the stock. Due to the need to substantially expand the existing fleet and to the replacement of the existing stock[41], the penetration of new planes in the market allows for an efficiency improvement of 21% of the overall fleet.

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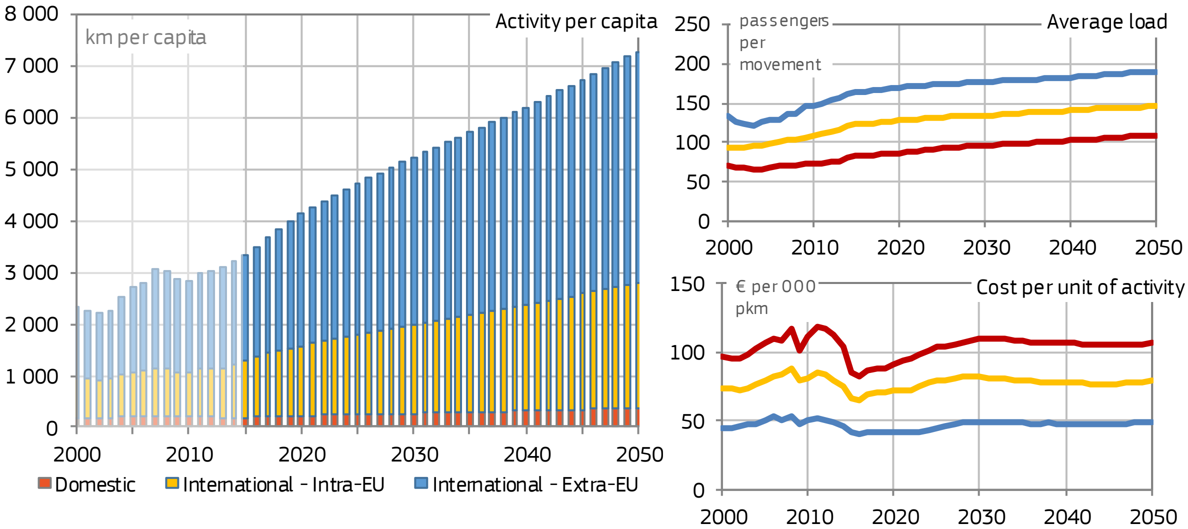
[38] Being fuel use (together with personnel costs) one of the two main cost factors in international hauling, efficiency gains have already been exploited to a larger extent in the present day.

[39] Only high speed rail experiences a faster growth in passenger transport activity; however, rail activity as a whole grows less than aviation

[40] With differences between domestic, intra-EU and extra-EU international flights, due to the different flight lengths and the subsequently changing contributions of the take-off fuel consumption to the overall demand.

[41] POTEnCIA makes use of the concept of a representative plane (i.e. with the same seat capacity, evolution of technical efficiency) at EU-level in order to enhance comparison across countries and due to the fact that planes operate throughout all countries.

Figure 59. Aviation overview



With kerosene-propelled planes remaining dominant throughout the projection period, the carbon intensity of aviation evolves in line with its energy intensity until bio-based kerosene becomes economically attractive. Boosted by rising fossil kerosene price and EU ETS, the alternative bio-kerosene[42] rapidly expands its share from 0.4% in 2040 to 4.8% in 2050 as the price of bio-kerosene becomes competitive with that of fossil jet fuel. As a result, the CO_2 emissions of the aviation sector are 39% above their 2015 levels by 2030 and continue to increase until the mid-2040s. After this point, their growing trend slows down and is eventually reversed, such that in 2050 they are 50% up from 2015 levels.[43]

Driven by rising fuel and CO_2 allowance prices and by rising capital costs, in the initial years of the projection period the costs per passenger-km increase steadily in the aviation sector. Before 2030 they rebound back to the levels observed in 2010, to then broadly stabilise at those levels thereafter.

[42] Under the EU ETS Directive the emission factor for biomass is zero.

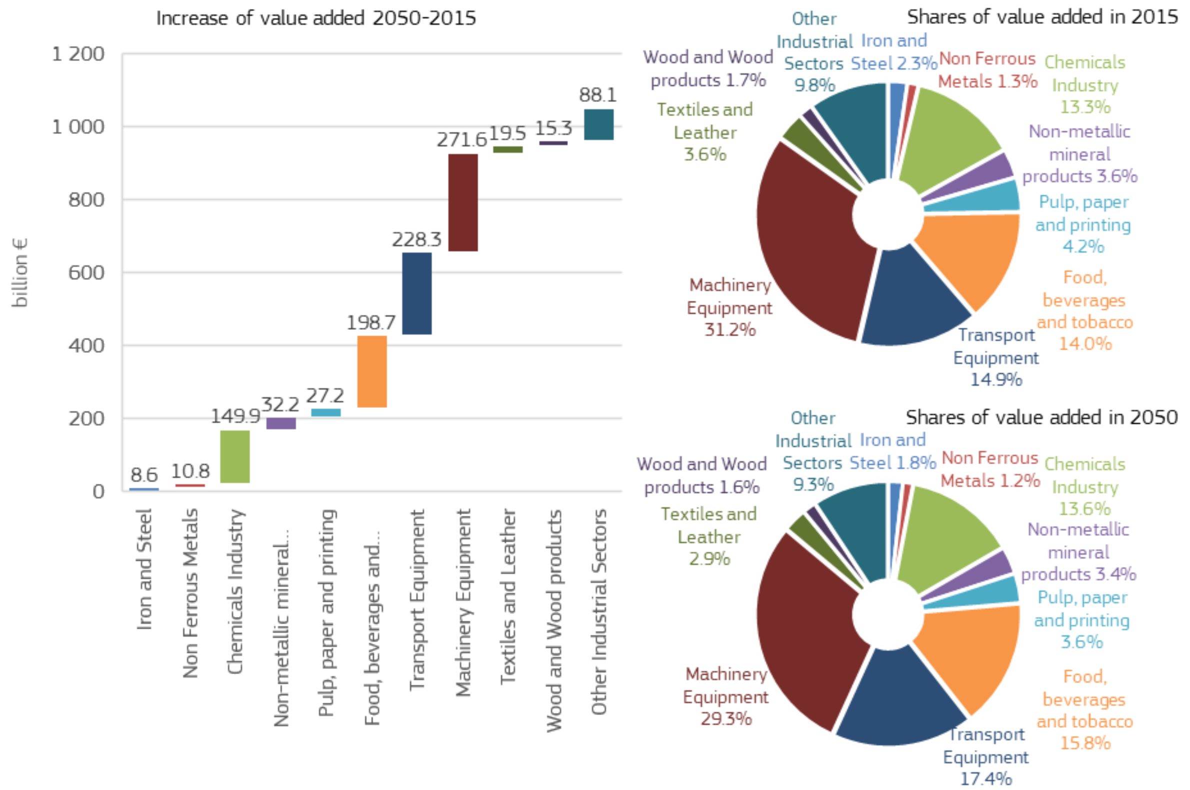
[43] The ICAO Carbon Offsetting and Reduction Scheme for International Aviation, or CORSIA, that aims to stabilise CO2 emissions at 2020 levels (by requiring airlines to offset the growth of their emissions after 2020) is not included in the Central scenario as its cut-off date is end of 2017.

7 Industry

7.1 Overview and key trends

While remaining part of the backbone of the EU´s economy, the manufacturing sector represents today a smaller share of the overall economic activity of the EU than it did decades ago. In 2000, 15.9% of the EU´s GDP was generated by industrial sectors, today this share is down to 13.4% and, at a much lower pace, keeps reducing over the projection period until it reaches 12.6% in 2050. The manufacturing sector also internally undergoes a restructuring, continuing the simultaneous shift of the share of value added generated from energy intensive to non-energy-intensive industries: in 2050 the energy intensive industries make up 23.6% of the manufacturing added value, down from 24.7% in 2015. In particular, the steel and the pulp and paper sectors lose in relative terms, while the chemicals sector further expands its leading economic weight among the energy intensive industries, accounting for 13.6% of the manufacturing value added in 2050, up from 13.3% in 2015.

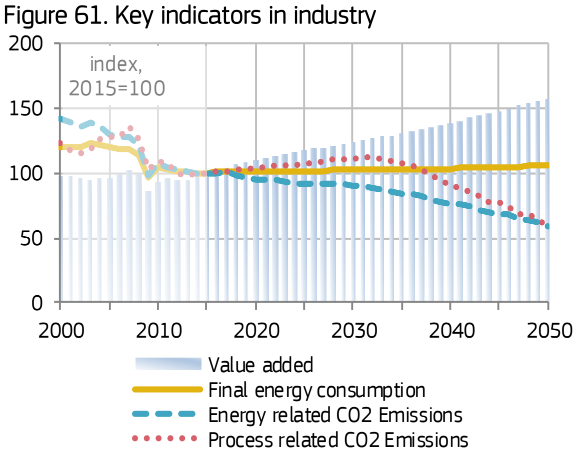
Figure 60. Value added changes in industry



Among the non-energy-intensive industries, the manufacturing of transport equipment and the food industry experience the highest growth, accounting respectively for 17.4% and 15.8% of the manufacturing value added in 2050 compared to 14.9% and 14% in 2015, respectively.

The value added generated by the manufacturing sectors grows by almost 60% over the projection period despite its decreasing contribution to the overall economic activity of the EU. At the same time, the energy intensity expressed as energy consumption per unit of value added generated keeps on a long-term decreasing trend and in 2050 is two-thirds of that in 2015, such that the growth in energy consumption is contained to about 5% above the current level, or an increase of 16 Mtoe. This comes as a result of the continuous efforts deployed by the industry to improve energy efficiency and rationalise production methods, as well as from the fixed capital turnover and of structural changes towards the manufacturing of products with higher value added and lower energy intensity.

Figure 61. Key indicators in industry



These drivers do not have the same intensity in all industries: following their greater exposure to energy costs, the energy intensive industries reduce their energy intensity faster than other industries. As a consequence, the relative weight of non-energy-intensive industries increases *vis-á-vis* the energy intensive industries (from the current 35% to 38% of the total energy use in manufacturing in 2050).

Figure 62. Evolution of energy consumption in industry by fuel type

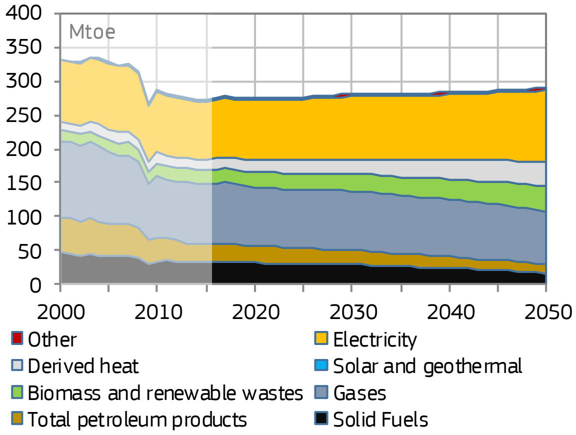
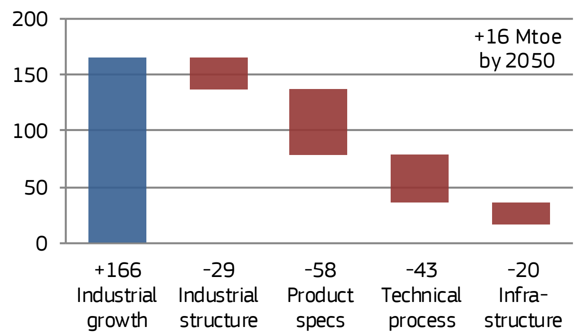


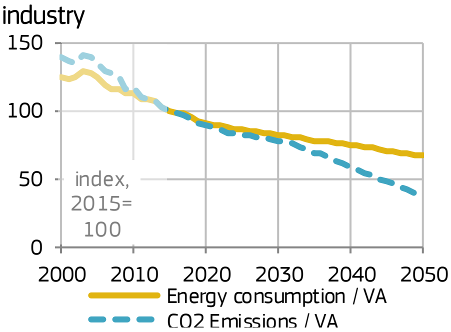
Figure 63 summarises the influence of various drivers on the **16 Mtoe increase in the final energy consumption of the manufacturing industry as a whole** between 2015 and 2050. From left to right, the decomposition shows that, all other things being equal, the effect of the economic growth of the manufacturing sector alone would have resulted in an increase of 166 Mtoe of final energy consumption. However, the changes in industry structure (shift from more to less energy intensive subsectors) mitigates such an increase by 29 Mtoe. At the same time, changes in product characteristics (these may include a variety of industry-specific trends such as a shift towards higher grade metal alloys, or towards cement formulations incorporating higher fractions of raw materials not requiring pyro-processing) translate in less physical production being required to generate the same value added, and/or in less energy being needed to produce the same physical amount of product. This brings about further energy savings that can be quantified in almost 58 Mtoe. Technical process changes further account for 43 Mtoe less final energy consumed. These include production process substitutions (e.g. from primary to secondary production routes, or from pyro- to more efficient hydro-metallurgical processes), fuel shifts (e.g. from coal to natural gas or biomass), as well as technical improvements of the energy-using equipment (e.g. more efficient furnaces, boilers, motor drives, etc.). Further savings (20 Mtoe) are conversely achieved through improvements of the infrastructure efficiency. This factor subsumes measures that reduce the energy requirements of the production process by for instance: further rationalising the use of energy (e.g. by shifting from batch to continuous production); reducing energy wastage (e.g. by avoiding metal reheating by directly charging the hot basic metal into the hot-rolling step); or optimising waste heat recovery.

Figure 63. Drivers of energy consumption change in industry



Thanks to the continued progressive shift towards carbon-lean energy sources and the implementation of carbon capture options in the long run, the fall of the carbon intensity outpaces the energy intensity reduction, reaching a level that is barely one third of the current CO_2 emission per unit of value added in 2050. The underlying trends include the continuous decline of the role of solid fuels and petroleum products (respectively down to 5.8% and 4.5% in 2050, from almost 13% and 10% in 2015), displaced by a growth of biomass and waste use (13% in 2050, up from below 9% in 2015) and by an even faster penetration of distributed heat (12.3% in 2050 vs 5.5% in 2015) as it takes up an increasingly important role in satisfying industrial steam needs. Electrification also gains ground substantially (36.5% of industrial energy consumption in 2050 vs 31.3% in 2015) at the expense of carbon-intensive fuels, although its share increase is somewhat limited by the high-temperature heat needs of several energy-intensive industries that call for combustion-based processes.

Figure 64. Energy and carbon intensity in industry



Increases in fossil fuel prices and in the price of the ETS CO_2 emission allowance are major drivers behind the decarbonisation trend.

Substantial differences are observed in the evolution of different types of CO_2 emission sources: the overall slowly declining trend until the early 2030s is the result of the shift towards less carbon-intensive fuels, which is however partially offset by increasing process emissions, in particular in the non-metallic minerals and chemical sectors.

From this point on, however, with the CO_2 allowance price reaching 50 €/tonne, the pace of CO_2 emission reductions accelerates dramatically as carbon capture becomes economically attractive in particular for certain CO_2-rich emission streams (generally including process emissions) in the industries that are covered by the ETS. Combined with the overall evolution, this results in 2050 in a 40% reduction of the EU´s industrial sectors CO_2 emissions, equivalent to 280 Mt.

Figure 66 summarises in factor decomposition terms the influence of various drivers on the 280 Mt reduction in the CO_2 emission of the manufacturing industry, including energy-related and process emissions, between 2015 and 2050. The decomposition mirrors the factors and, to a large extent, the conclusions of the one presented above for the final energy consumption.

Economic growth of the manufacturing sector, in the absence of other changes would have resulted in an increase of 423 Mt of CO_2 emissions. However, structural changes from more to less energy intensive subsectors mitigates 114 Mt of that increase. Changes in product characteristics save a further 146 Mt, while technical process changes, bringing about 222 Mt of emission reductions ceteris paribus, are the single most important mitigation factor. This includes changes in production routes, fuel changes, as well as improvements of the energy-using equipment. Energy infrastructure changes deliver an additional 53 Mt emission reductions. Carbon capture in 2050 contributes 168 Mt to the overall reduction of the Industry´s CO_2 emissions.

Figure 65. CO_2 emissions in industry

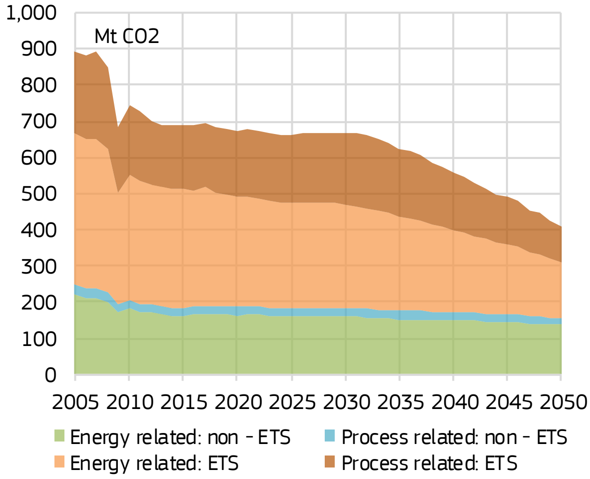
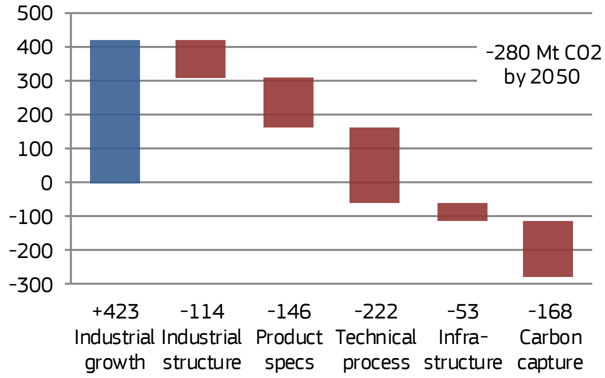


Figure 66. Drivers of CO_2 emission change in industry



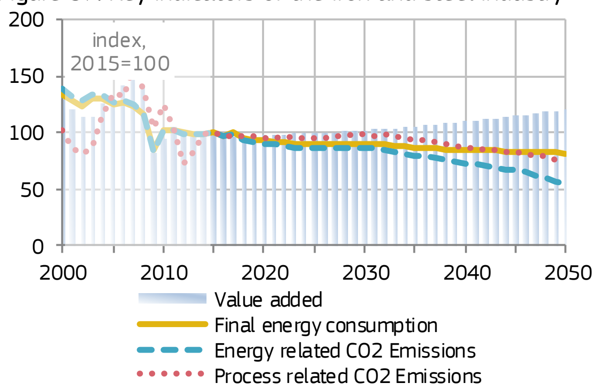
The total energy-related O&M costs per unit of energy consumed increase steadily throughout the projection period, reaching a level in 2050 33% higher than 2015´s. However, the energy efficiency improvements, broader rationalisation of energy use and structural changes intervening at the same time outpace the cost increase, resulting in the stabilisation of the energy-related O&M costs expressed as a share of the value added generated: throughout the 2030s they remain at around 95% of the 2015 level, and eventually they further reduce in 2050 to 85% of it.

The cumulative energy-related investment expenditure during the same period totals 1.6 trillion €, equivalent to 2% of the gross value added generated.

7.2 In focus: Iron & steel

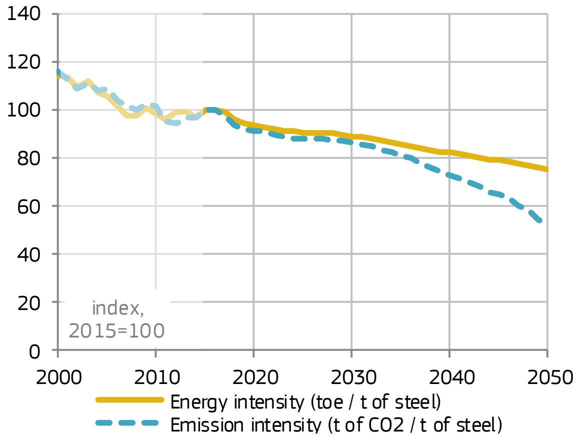
The iron & steel sector comprises two main production routes: primary production in integrated steelworks, where several processing steps are used to convert iron ore to metallic iron first and then to steel, and secondary production where electric furnaces are mostly used to make new products from steel scrap. The iron & steel sector accounts today for 2.3% of the value added generated by the EU's manufacturing industry and for 18% of its energy use. Owing to the shift towards higher value added products, the 20% increase in value added experienced over the projection period translates into only 9% more physical output. This growth is unevenly distributed between the output of

Figure 67. Key indicators of the iron and steel industry



integrated steelworks and electric furnaces, with the former growing only 3.5% and the latter above 17%, accounting for the bulk of the overall output growth in the sector. In 2050 electric furnace steel accounts for more than 42% of the EU´s steel production (39% today). Despite its lower energy consumption (less than one third of the final energy consumed per tonne of finished product made by the integrated steelwork route is needed for electric arc steel), electric furnace (secondary) steel can only replace integrated steelworks (primary) steel up to a limited extent due, among other factors, to the availability of steel scrap of appropriate characteristics.

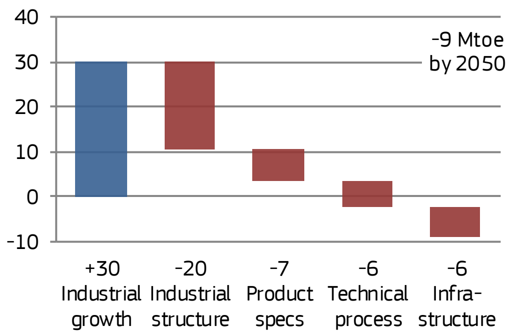
Figure 68. Energy and carbon intensity of steel production



At the same time, energy efficiency improvements result in reductions of the energy requirements per tonne of output amounting to 24% in the case of integrated steelworks and 14% in the case of the less energy-intensive electric furnace steel. This leads to a decrease of 18% in the final energy consumed by the sector, essentially all occurring in integrated steelworks (21% reduction), while the energy consumed by electric steel furnaces remains stable as energy intensity improvements are offset by the increasing production levels.

Overall, in 2050 the iron & steel industry consumes 9 Mtoe less final energy than in 2015. The influence of various drivers on this reduction is summarised in the form of a factor decomposition in Figure 69. From left to right, the decomposition shows that, all other things being equal, the effect of economic growth would have resulted in an increase of 30 Mtoe of final energy consumption in the Iron & Steel industry. However, much of this increase (almost 20 Mtoe) is avoided by the changing industry structure: the iron & steel sector simply does not grow as fast as the rest of the economy. Changes in product characteristics (e.g. shifts towards higher grade metal alloys) result in less tonnes of steel being needed to fulfil the given function and generate the same value added; this avoids the use of 7 Mtoe of final energy. Technical changes in the energy using processes save a further 6 Mtoe; these include changes in the production pathways (e.g. from primary to secondary production), fuel shifts (e.g. the substitution of part of the coal input by natural gas and biomass), as well as technical improvements of the energy-using equipment (more efficient furnaces, boilers, motor drives, etc.). Further savings (6 Mtoe) are finally achieved through improvements of the infrastructure efficiency, allowing for further rationalising the use of energy (e.g. by shifting from batch to continuous production); reducing energy wastage (e.g. by avoiding metal reheating by directly charging the hot basic metal into the hot-rolling step); or optimising waste heat recovery.

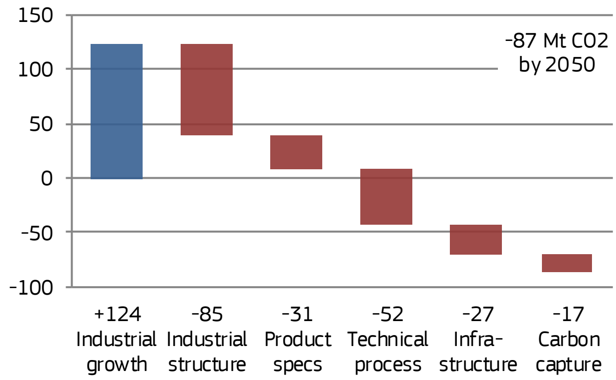
Figure 69. Drivers of energy consumption change in iron and steel



In terms of CO_2 emission intensity, a similar reduction of around 45% is seen for both production routes over the projection period, from an average 1.9 to 1.05 tonnes CO_2 per tonne of steel in the case of integrated steelworks and from 128 kg to 71 kg for electric arc steel.[44] These reductions take place for energy-related emissions steadily throughout the projection period. Process emissions, conversely, mostly stagnate until the end of the 2030s as process substitution options to reduce them are slower to become available and penetrate the market. In the last decade of the projection period, however, with the increased uptake of alternative processes such as using natural gas and marginally also hydrogen as reducing agents, and with CCS processes reaching maturity and becoming increasingly competitive in an environment of growing CO_2 allowance prices, process emissions also fall rapidly. As a consequence, CO_2 emissions from steel production are in 2050 43% lower than in 2015 (44% less for integrated steelworks and 35% less for the electric furnace process), corresponding to 87 Mt less CO_2 emissions.

[44] As these figures do not account for the upstream emissions of power generation (which are especially relevant in the case of secondary steel), the simultaneous decarbonisation of the power sector reinforces the downwards trend. When accounting also for the emissions related to power generation, the total reduction in the carbon intensity of EAF steel may be estimated at around 75% over the period 2015-2050

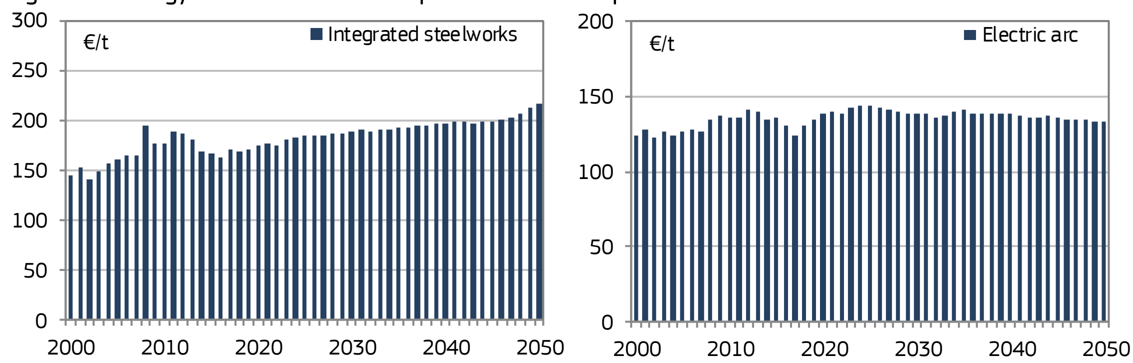
Figure 70. Drivers of CO_2 emission change in iron and steel industry



The influence of the various drivers in delivering the 87 Mt reduction in the CO_2 emission of the Iron & Steel industry is summarised in Figure 70. Economic growth of the manufacturing sector would have resulted in an increase of 124 Mt of CO_2 emissions in the absence of other changes. However, changes in the structure of the manufacturing industries already mitigate 85 Mt of that increase. Changes in product characteristics save a further 31 Mt, while technical process changes achieve 52 Mt of emission reductions. Energy infrastructure changes deliver an additional 27 Mt emission reductions. Carbon capture in 2050 contributes a further 17 Mt to the overall reduction of the Iron & Steel Industry´s CO_2 emissions.

Cost-wise, rather different trends are seen for integrated steelworks and for secondary steel, as shown in terms of energy-service costs in Figure 71. While for electric steel the major cost component is represented by electricity costs that remain relatively constant throughout the projection period (see Section 9.5), for primary steel fuel costs increase by one third.

Figure 71. Energy-service related costs per tonne of steel produced



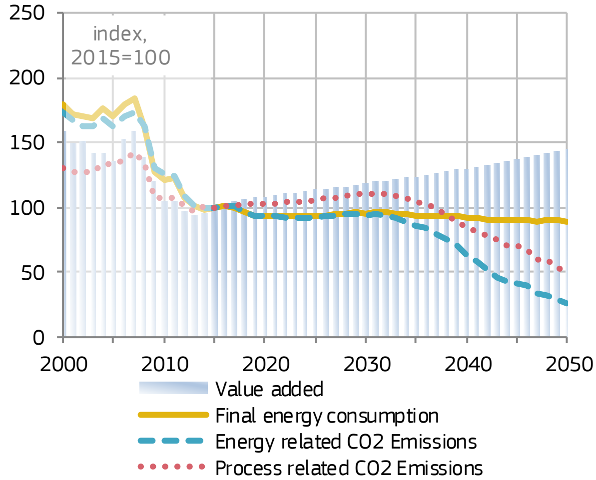
This results in total energy-service costs per tonne of the steel produced increasing 27% for integrated steelworks and slightly declining (-5%) for electric arc steel in 2050.

7.3 In focus: Cement

The cement sector accounts today for 1.4% of the value added generated by the EU's manufacturing industry and for 4% of its energy use. The most energy- and CO_2- intensive process of cement production is the production of clinker, used as binder in cement products, by high-temperature firing of the raw meal in the cement kiln. CO_2 is released from fuel combustion (energy-related emissions) and from the calcining of limestone (process emissions).

Over the projection period, the cement sector grows 45% in economic terms and its physical production increases by 22% by weight. At the same time, energy consumption decreases, being in 2050 10% lower than in 2015 thanks to a steadily decreasing energy intensity that sees a 26% reduction in the energy required per tonne of product. Among the most important factors contributing to this drop in energy

Figure 72. Key indicators of the cement industry



intensity are the fixed capital turnover resulting in the progressive retirement of older kilns for more modern and energy efficient ones,[45] as well as changes in cement product formulation.[46]

Figure 73. Drivers of energy consumption change in cement industry

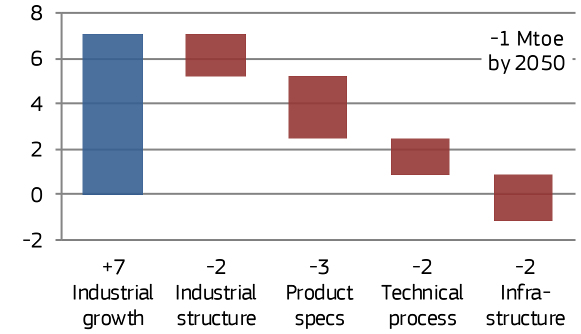


Figure 74. Energy and carbon intensity of cement production

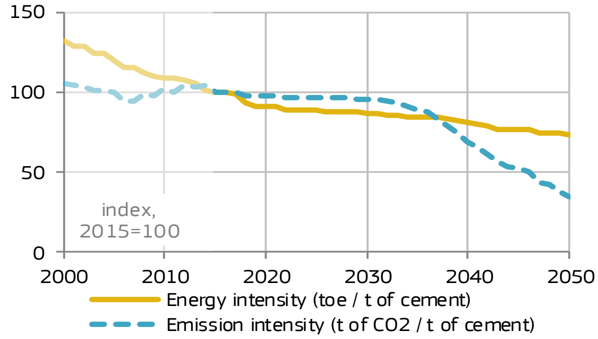
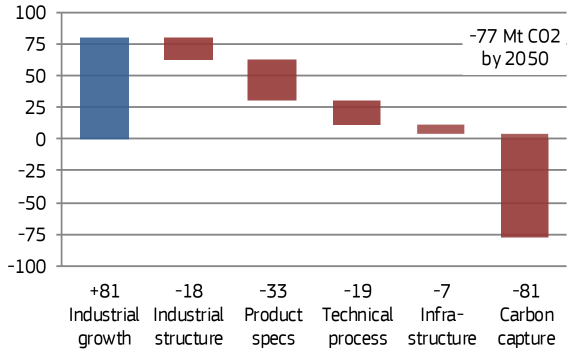


Figure 75. Drivers of CO_2 emission change in the cement industry



Overall, in 2050 the cement industry consumes 1 230 ktoe less final energy than in 2015. The influence of various drivers on this reduction is summarised in the form of factor decomposition in Figure 73. From left to right, the decomposition shows that, had all other drivers remained equal, the effect of economic growth would have resulted in an increase of 7 000 ktoe of final energy consumption of the cement industry. Of this increase, almost 2 000 ktoe are avoided by the changing industry structure. Changes in product characteristics (e.g. product formulation with less clinker in cement) result in less tonnes of clinker being needed to fulfil the given function and generate the same value added; this avoids the use of 2 700 ktoe of final energy. Technical changes in the energy using processes save a further 1 630 ktoe; these include fuel shifts (e.g. the substitution of part of the coal input by biomass), as well as technical improvements of the energy-using equipment (more efficient kilns, etc.). Finally, 2 440 ktoe are saved through improvements of the infrastructure efficiency, allowing for further rationalising the use of energy.

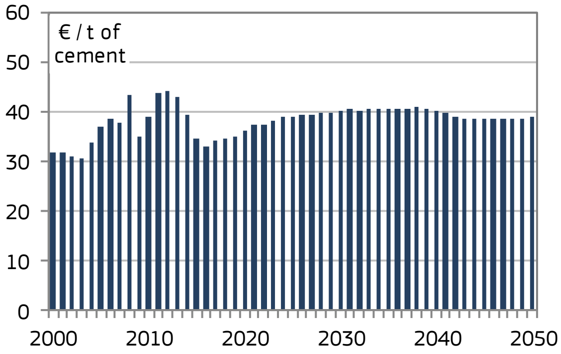
Over the same period, the CO_2 emission intensity reduces by 65%, from an average of 775 kg CO_2 to 271 kg CO_2 per tonne of cement. Reflecting the fact that the cement industry has already exploited a substantial proportion of the fuel substitution options available at low cost,[47] this evolution takes place only slowly until the mid of the 2030s, to then quickly pick up pace with the accelerated substitution of biomass for fossil solid fuels and the deployment of alternative processes such as electric kilns and CCS. As a consequence, CO_2 emissions from cement production are in 2050 58% lower than in 2015, corresponding to 76 Mt less CO_2 emissions.

[45] The energy consumption of clinker production is strongly dependent on the kiln technology: producing one tonne of clinker with a state-of-the-art dry kiln with multiple preheat stages and pre-calciner requires less than half the energy needed with a wet kiln.

[46] Part of the clinker fraction of cement may be replaced by alternative materials that do not require pyroprocessing, thus allowing energy and CO_2 emission savings. Such materials include natural pozzolans, blast furnace slag, or fly ash from coal- and biomass-fired power plants. The latter is also used as cement substitute in concrete.

[47] Between 2000 and 2015, in the EU the share of the thermal energy requirements of clinker production that is satisfied by alternative fuels such as biomass and waste increased from merely 7% to 27%. While this share keeps increasing over the projection period, the fraction represented by biomass has historically been limited on the one hand by the high firing temperature required of cement kiln fuels, and on the other hand by the economic incentive for cement kilns to co-incinerate high calorific value non-renewable waste such as end-of-life tyres. As a consequence, on average the replacement of coal by alternative fuels has not resulted in a reduction of the CO_2 intensity of the fuel mix used over this period.

Figure 76. Energy related costs per tonne of cement produced



The influence of the various drivers in delivering the 76 Mt reduction in the CO_2 emission of the cement industry is summarised in Figure 75. Economic growth of the manufacturing sector would have resulted in an increase of 81 Mt of CO_2 emissions in the absence of other changes. However, changes in the structure of the manufacturing industries mitigate 18 Mt of that increase. Changes in product characteristics, such as the increased use of raw materials that do not release CO_2 on pyroprocessing, save a further 32 Mt, while technical process changes achieve 18 Mt of emission reductions. Energy infrastructure changes deliver an additional 7 Mt emission reductions. Carbon capture, delivering 80 Mt emission reduction is in 2050, plays a key role in the overall reduction of the cement industry´s CO_2 emissions.

Cost-wise, the major cost component to the energy-service related costs of the sector is fuel costs, which go up by a quarter over the 2015 level in the course of the 2030s, to then fall back to around 17% more than in 2015 in the 2040s. This in 2050 implies energy-service related O&M costs per tonne of cement produced 14% higher than in 2015.

7.4 In focus: Food, beverages and tobacco

The food industry (including also the manufacturing of beverages and tobacco products) accounts today for 14% of the value added generated by the EU's manufacturing. Although it is not considered an energy-intensive industry (its energy intensity is less than the average of the whole industrials sector and its energy-related O&M costs are limited to some 8% of the value added generated, or less than 2% of its turnover), it is one of the largest industries in the EU and experiences continuous growth driven not only by the EU market but also, being the EU the largest exporter of food and drink products worldwide, by raising population numbers and living standards in trading partner regions.

As a consequence, it accounts for a substantial (and growing) share of the final energy consumption not only of the EU´s manufacturing industries (10.6% in 2015, growing to 12.8% in 2050), but also of that of the EU´s economy as a whole (2.7% in 2015, growing to 3.4% in 2050).

Being energy, on average, a relatively minor chapter in the overall cost structure of the food industry, the economic incentive to investing in energy reduction is in general less than in more energy-intensive sectors. Indeed the energy costs expressed as a share of value added generated remain within the range between 7.5% and 8.5% throughout the projection period up to 2050. This explains why the reduction of energy intensity between 2015 and 2050 is limited to less than 30%, not enough to offset the sector's growth. In 2050 the food sector uses 26% more energy than in 2015.

Figure 77. Key indicators of the food, beverages and tobacco industry

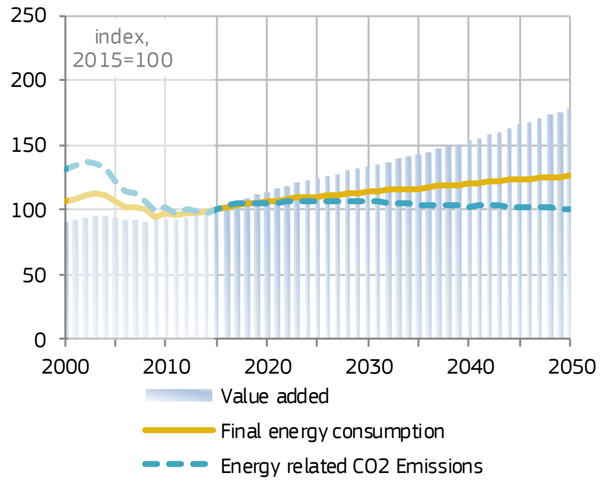
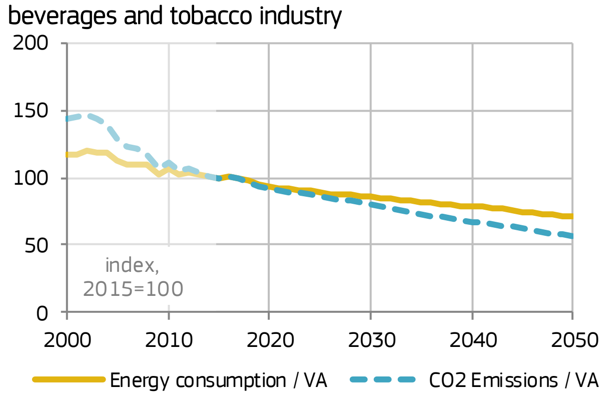
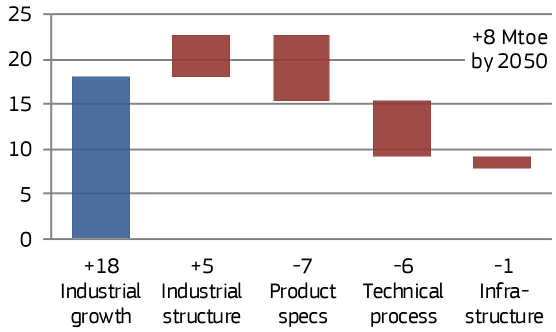


Figure 78. Energy and carbon intensity of the food, beverages and tobacco industry



Overall, in 2050 the food industry consumes 7 700 ktoe more final energy than in 2015. The influence of various drivers on this reduction is summarised in factor decomposition terms in Figure 79. From left to right, the graph shows that, other things being equal, the effect of economic growth in general implies an increase of 18 000 ktoe of final energy consumption of the food industry. On top of this, the changing industry structure explains 4 600 ktoe additional energy use, as the food industry grows faster than the average of the manufacturing sector. Changes in

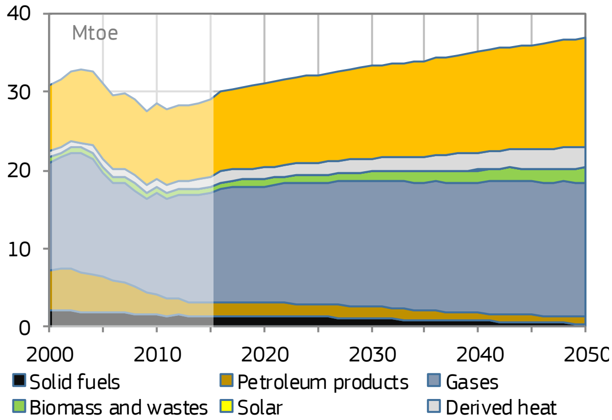
Figure 79. Drivers of energy consumption change in the food industry



product characteristics (e.g. specialisation on higher value added products) result in the level of physical production growing slower than the value added generated; this avoids the use of 7 400 ktoe of final energy. Technical changes in the energy using processes save a further 6 200 ktoe; these include fuel shifts as well as technical improvements of the energy-using equipment and process changes (e.g. microwave or induction cooking). Finally, 1 340 ktoe are saved through improvements of the infrastructure efficiency, allowing for further rationalising the use of energy, optimizing waste energy recovery, etc.

During the same period, the most important structural change observed in the food industry is the progressive marginalisation of solid and liquid fossil fuels (their respective shares are 1% and 2.2% in 2050, down from 4.4% and 6.3% in 2015). These fuels are replaced by solid biomass (5% in 2050 vs 3% in 2015), distributed heat (7.5% in 2050 vs 4.3% in 2015), and a moderate increase in electrification (37% in 2050 vs 34% in 2015). Solar energy increases almost by a full order of magnitude, but its absolute contribution remains small. Natural gas keeps its dominant role, satisfying a share of the sector´s energy needs that remains almost constant at around 47-48% through the projection period.

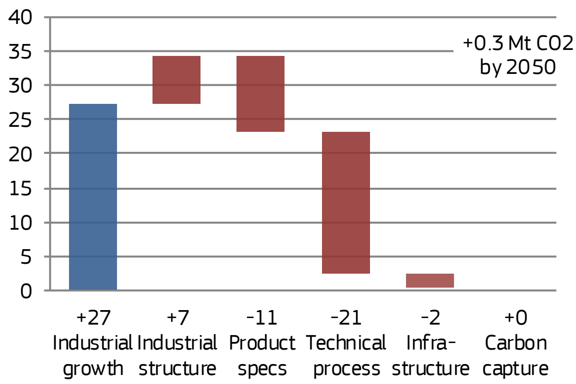
Figure 80. Energy consumption by fuel in the food industry



These changes in the sector's energy mix counterbalance the effects, in terms of CO_2 emissions, of rising energy use. Overall, after an increase in the 2020s that is limited to around 5% over the 2015 level, CO_2 emissions gradually fall back to that same level. However, as electricity contributes more than one third of the energy needs of the food sector, the extent of the decarbonisation simultaneously taking place in the power sector further contributes to a falling carbon footprint of the EU food production´s energy needs.[48]

The almost zero net change in CO_2 emission of the food industry between 2015 and 2050 is the results of a number of counterbalancing drivers, the contributions of which are summarised in the decomposition of Figure 81. Economic growth of the manufacturing sector would have resulted in an increase of 27 Mt of CO_2 emissions in the absence of other changes, to which another 7 Mt are added due to changes in the structure of the manufacturing industries. Changes in product characteristics save however 11 Mt, while technical process changes achieve more than 20 Mt of emission reductions. Energy infrastructure changes deliver an additional 2.2 Mt emission reductions.

Figure 81. Drivers of energy consumption change in the food industry



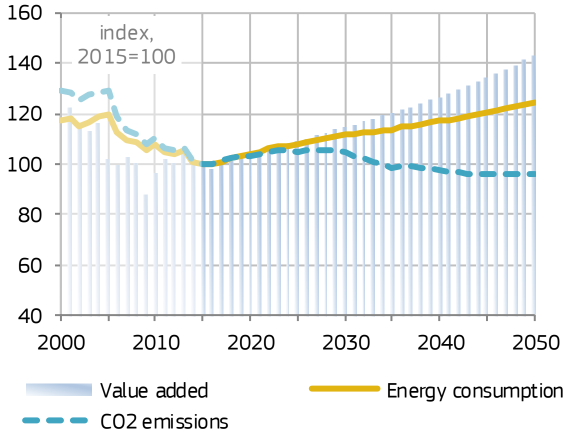
[48] For the EU in 2015, the upstream CO_2 emissions related to the generation of the electricity used in the food industry may be estimated at a value that is almost 80% of the direct CO_2 emissions in the sector; owing to a fall of more than 90% in the CO_2 intensity of electricity generation, in 2050 the related indirect emissions are only 8% of the direct ones. Overall, the sum of direct and indirect emissions falls by 40% over the projection period.

8 Agriculture, forestry and fishing

Agriculture, together with forestry and fisheries, represented in 2015 1.59% of the gross value added generated in the EU. With a 43% cumulative growth of the sector between 2016 and 2050, at the end of the projection period this share is down to 1.35%. At the same time, the physical output index of the sector grows 37% and the final energy consumption in 2050 is up by a quarter compared to 2015 levels. Energy consumption in 2050 is thus more than 3% of the total final energy consumed in the EU, up from 2.45% in 2015.

No major restructuring of the sector occurs over the projection period, with the shares of energy used for farming machines, heating and other uses remaining close to the current levels. Energy intensity, expressed as energy consumed per physical unit of output, decreases only marginally, by less than 10% over the whole period.

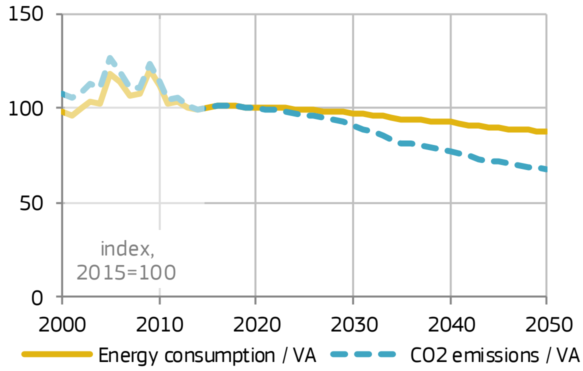
Figure 82. Key indicators in agriculture



Given the relatively slow pace in undergoing structural and energy intensity changes, growing fuel prices result in an increase of the total energy-related O&M costs, from the current 11% of sectoral value added to 13% in 2030. In the remaining part of the projection period they remain largely stable at this level.

Fuel switching does however take place over the period, as a decrease is seen for fossil solid fuels (2.2% of the overall energy consumption in 2050, down from 3.8% in 2015) and diesel oil (34% in 2050, down from 50% in 2015)[49]. This fuel consumption decline is offset by sustained growth of natural gas (from short of 15% in 2015 to above 20% in 2050) and especially solid biomass (from 6% in 2015 to almost 15% in 2050) and biogas, both increasing three-fold over the projection period. Solar energy enters the sector with a 20-fold increase from 2015 to 2050, although it overall contribution to the total thermal energy needs of the sector remains limited to ca. 1%. Distributed heat also increases two and a half-fold to reach 2.2% of the overall energy needs, while the share of electricity use remains unchanged at 19%. The use of heavy fuel oil, driven by the fisheries subsector, also remains relatively unchanged.

Figure 83. Energy and carbon intensity in agriculture



In terms of CO_2 emissions, these changes in the fuel mix compensate for the increasing energy consumption of the sector: after an initial rise by 5% of the 2015 level between the mid-2020s and the mid-2030s, the CO_2 emissions of the sector drop again to a level some 4% below that of 2015 in the 2040s.

[49] The use of diesel oil reducing in absolute terms by 16% over the projection period, this is the combined effect of increasing fuel demand for farming machines (+21%) and a sharp reduction for heating purposes (-65%), for which it is progressively replaced by other energy sources.

9 Power generation

9.1 Electricity and steam demand

Electricity consumption grows continuously throughout all final demand sectors, to reach in 2050 a level 25% above 2015´s. The **pronounced uptake of electro-mobility** in road transport (Section 6.2) accounts for more than half of the additional electricity demand, with the remainder stemming from the continued electrification of industrial processes and end-uses (Section 7.1).

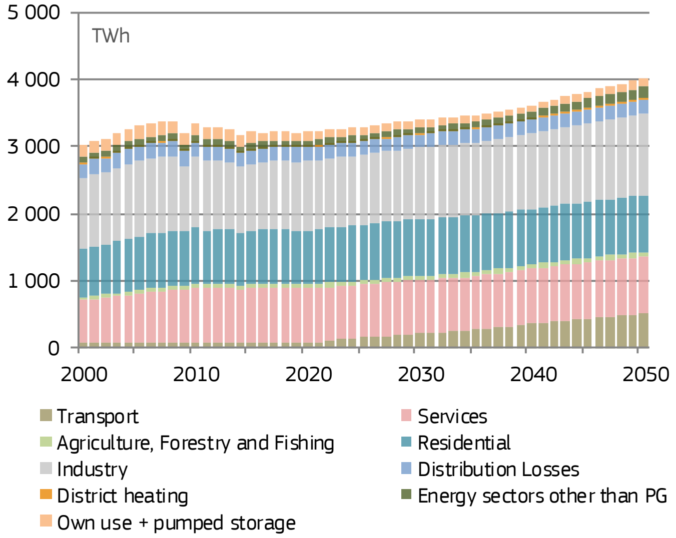
Electricity demand in the residential and services sectors remains relatively stable, resulting from reductions in specific electricity uses that are offset by the growing importance of electricity in satisfying thermal energy needs (Sections 4 and 5). Consumption of electricity for air conditioning and electric heat pumps in the domestic sectors almost doubles, an increase that is however partially counterbalanced by the reduction of conventional electric space heating.

The most pronounced growth in electricity consumption (tenfold) is projected to take place in the district heating with electric boilers becoming an increasingly attractive option over the projection period. Electricity accounts for close to 7.5% of the fuel input in district heating plants in 2050 (from 1.2% in 2015). Still the market share of the specific consumption over the total electricity demand remains insignificant (marginally exceeding 0.5% in 2050).

Additional demand also occurs in the energy sector itself (+11% in 2015-2050), e.g. the consumption in refineries and hydrogen production, and through distribution losses.[50]

The changes in the role of different end-uses in consuming electricity are reflected in the **evolving shape of the electricity demand load curve**. While peak load increases more or less in line with the increase of electricity demand, the valleys become shallower and the load curve of the representative day flattens over time. The ratio between peak and valley load of the representative days (see Figure 85) reduces from 1.7 to 1.62 by 2050. This can

Figure 84. Evolution of electricity consumption by sector



Box 8. The concept of the representative day

POTEnCIA works on satisfying the chronological load curve with hourly time segment for one representative day, which is the most likely load pattern for performing investment decisions and dispatching in a given year. This is not to be confused with a 'typical day' load pattern that is the average of the daily load in a given year. Historically, the hourly chronological load curve of a representative day is constructed through the implementation of a clustering approach based on the data provided by ENTSO-E.

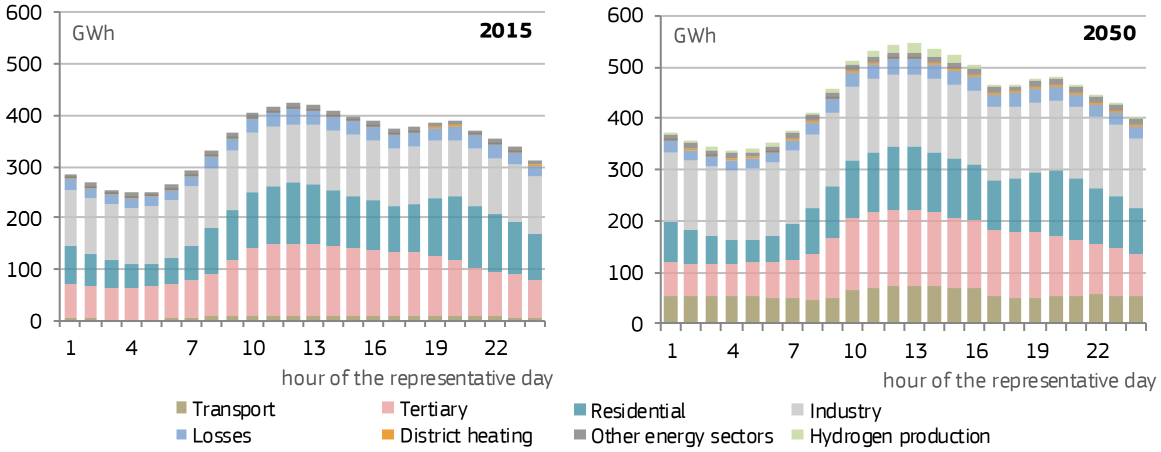
Even though the representative day reflects the peak and valleys of the actual hourly load curve better than an average load curve, statistically insignificant real peak loads are not captured. For example, the ratio between the actual peak observed in one hour in the year 2015 and the peak of the representative day in that year is 1.15 at EU level; this ratio varies across countries.

To ensure that sufficient generation capacity is available to also meet such extreme conditions, a number of stability mechanisms are introduced (see Section 9.4). These go beyond the typical notion of the reserve margin and consider both the capacity in use versus the total capacity installed, and the ratio of the capacity in operation and the peak load of the representative day. This approach is currently further enhanced through the linkage with an hourly dispatching model. It is foreseen to explicitly model in POTEnCIA the evolution of hourly demand load curve time-series (i.e. 8760 hours) throughout the projection period.

[50] This total describes the net electricity demand to be satisfied by the power sector. It does not exclude the own uses in the power sector needed to power plant auxiliaries (see Box 9).

be explained by the above-described changes in the end-uses of electricity: industrial uses have a more constant load profile and in the domestic sectors the electricity demand shift from specific electricity uses to thermal uses flattens those sectors' profile.

Figure 85. Hourly electricity demand in the representative day

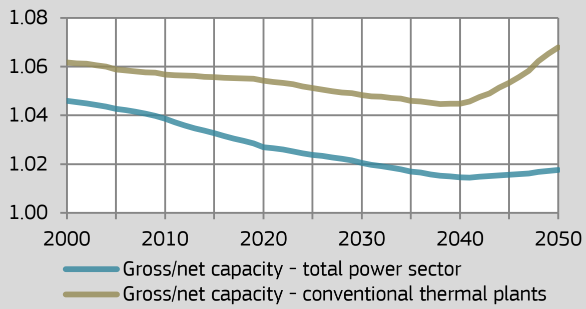


Box 9. Own uses in the power sector – gross/net generation

The difference between net electricity generation and gross generation relate to the own electricity demand in the plant auxiliaries (e.g. controls, pumps, air pollution control devices, motors). Net capacity refers to the plant's capacity available to satisfy consumers' electricity needs, while gross capacity further includes the capacity required to generate the own consumption. Investments costs are expressed relative to gross capacity.

The gross/net capacity ratio of the overall power plant fleet develops dynamically in the Central scenario. In the short run it maintains the decreasing trend historically observed, driven not only by the deployment of wind and solar (that have no own demand) but also by the shift between fuels and technologies in the conventional thermal power plant fleet. In the early 2040s, however, this trend reverses and the gross/net ratio faces an important upsurge. This primarily relates to the pronounced energy use of CCS processes.

Hence, own demand decreases from 5% of overall gross electricity generation today to third this value in 2040. Afterwards, it experiences a significant upswing and exceeds 6% by 2050.



Flexible uses of electricity become more important, such as the charging of electric vehicles and the production of hydrogen through electrolysis that by 2050 consumes more than 55TWh. Their consumption is increasingly shifted towards the mid-day hours due to the abundant electricity generation from solar photovoltaics (for details see Section 9.4).

Demand for derived heat in final demand sectors increases by 48% over the projection period, notably in industry where it grows throughout all sectors. The largest rise in absolute terms occurs in those industries that already today are important users of derived heat, i.e. the chemical industry, pulp and paper and food industries (see Section 7). But also in the residential and tertiary sector the role of derived heat expands to some extent (+5%).

The steam consumption in final demand sectors is complemented by the derived heat absorbed in the energy sector, mostly occurring in refineries and other energy branches, and by distribution losses. Their cumulative share in overall heat demand declines over time from 16% to 11% in 2050.

9.2 Power plant capacities

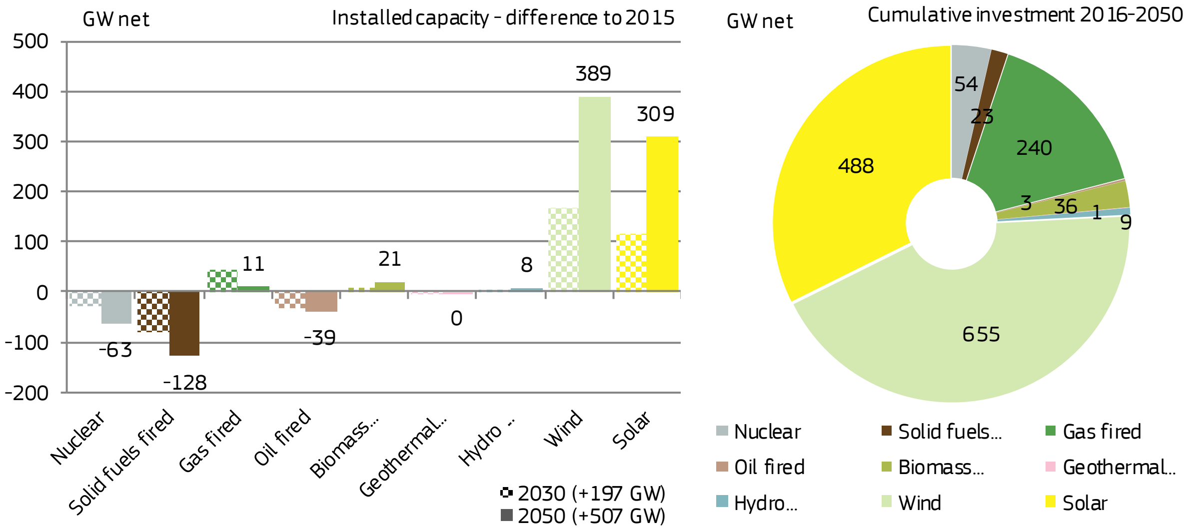
Rising demand for electricity and steam, the replacement of the existing power plant capacities and the uptake of variable renewable sources with the implied need for back-up power require major investments in the European power sector. Cumulative investments over the projection period reach 1.51 TW_{net} (1.53 TW_{gross}), out of which 105 GW_{net} in CHP power plants.[51] Net installed capacities in 2050 total 1.49 TW, 51% up from the 2015 level.

The European power plant park undergoes a **vast transformation towards decarbonisation**. While in 2015 fossil-fuel based power plants account for 46% of the net installed capacities, 80% of the installed net capacities are carbon-free by 2050 despite nuclear capacity almost halving. The share of renewables alone is 76%. An additional 3% (representing close to 15% of the fossil-fuel-fired capacities) are equipped with carbon-capture techniques.

The transformation is primarily driven by the ETS (phase III) whose assumed continuation leads to a substantial rise in the allowance price in particular beyond 2030. By 2050, the ETS price exceeds 120 €/tCO_2, up from 25 €/tCO_2 in 2030 (see Section 3). Power plant investors are not assumed to have precise knowledge on the future CO_2 price in their investment decision-making. Nevertheless, they take into account both the prevailing policy framework and expectations on its possible future evolution when designing their generation portfolio.

At the same time, technology progress results in solar photovoltaic becoming the cheapest power generation technology, followed by (onshore) wind. **Solar PV and wind** therefore become the dominant choice for new investment, continuing the trends already observed today.

Figure 86. Power generation investments



Wind energy accounts for 43% (equivalent to 655 GW) of the overall investments over the projection period – about 73% of which being onshore despite the substantially higher growth rate of offshore installations. By 2050, wind installations account for more than 35% of the net installed capacity.

Solar PV investments accumulate to almost 490 GW over the projection period, bringing the solar PV share in total net installed capacities to 27% in 2050. The contribution of solar-thermal power plants remains small over the entire projection (cumulative investments of 2.5 GW) due to a much slower cost reduction pathway than in the case of solar PV and to the lower availability of suitable sites.

Hydropower capacities experience only a limited expansion due to the low remaining potential, in particular when taking into account local environmental concerns. No new investments in hydropower from reservoirs (dams) take place except for direct replacements of parts to avoid their decommissioning.[52] Run-of-river hydropower still holds potential in some Member States and its capacity increases by 7.5% over the projection period.

Concerning **nuclear power**, the projected evolution considers the explicit phase-out policies as well as, on the other hand, the ongoing projects, notably in Finland, France, Hungary, Slovakia and the UK. With rising allowance prices on one side and the ongoing decommissioning of baseload power plants on the other, new nuclear power plants again enter the system significantly as of the mid-2030s. About half of the cumulative investments of 54 GW_{net} takes place in France to compensate for the decommissioning of a substantial number of nuclear plants coming to the end of their technical lifetime as of 2030 and beyond.[53] Nuclear type IV reactors become available only

[51] On-going and planned investments are fully considered. They are based on the JRC-IDEES database and updates with more recent information, including those provided by Member States' national experts in the context of the review of JRC-IDEES2015 and of the POTEnCIA Central scenario development.

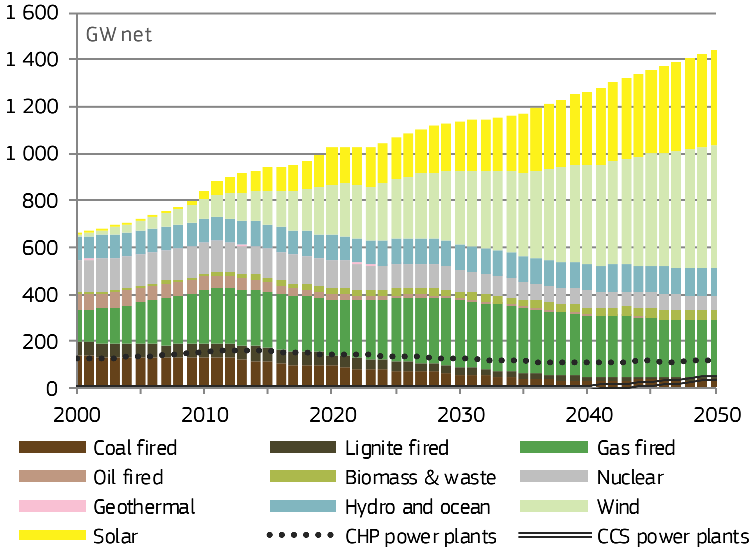
[52] Similarly no major expansion in pump storage takes places over the projection period, except for known on-going projects and the replacement of existing ones.

[53] Nonetheless, the total installed nuclear capacities in France more than halve over the projection period.

towards the end of the projection period, but fail to enter the market based on economic conditions under the prevailing scenario assumptions.

Cumulative investments into **conventional thermal** (fossil fuel- and biomass-fired) power plants rise to 300 GW_{net} (321 GW_{gross}) between 2016 and 2050, implying a 28% decrease in their installed capacity over time. Trends are very heterogeneous across fuels and technologies.

Figure 87. Net installed power generation capacities



Except for ongoing or planned investments, hardly any new solid fuel fired capacities are commissioned before the year 2030. Afterwards, investments in new coal- and lignite-fired power plants take place exclusively when equipped with carbon capture and storage (CCS) once this technology becomes mature and competitive in an environment of rising ETS allowances prices. All in all, cumulative investments over the entire projection period amount to 20 GW_{net} in coal (2 GW_{net} in lignite), more than 65% of which equipped with CCS (the remaining being investments that occurred before 2025 except of two CHP units with a total net capacity of 785 MW that are invested in 2035). In terms of net installed capacities these trends imply that the market shares of coal and lignite fired power plants shrink to 2% and 0.5% in 2050, respectively (from 11% and 6% in 2015).

80% of all investments into conventional thermal power plants are natural gas fired plants (some 235 GW_{net}). While their share in total net installed capacities remains relatively stable throughout the first two decades of the projection period, it drops thereafter to 17% in 2050. This time profile confirms the role of natural gas as a transition fuel owing to its comparatively low carbon content and the high efficiency of gas-fired plants. In the medium and longer term, the role of natural gas fired plants in ensuring power system stability vis-a-vis the rapidly increasing shares of variable renewable energy sources dominates. Their load-tracking and back-up functions are reflected in the low utilisation rates of many gas-fired power plants (see Section 9.3).

Towards the end of the projection period, natural-gas fired power plants become increasingly equipped with CCS technologies. Natural-gas fired cogeneration power plants are also found a competitive option to provide steam; two thirds of the cumulative investments in CHP capacities are into natural gas-fired plants.

Oil-fired power plants remain at market shares below 1% over the projection period primarily with the role to provide low-capital-cost backup power. The limited drop observed in the beginning of the projection period relates to the ongoing retrofitting of some oil-fired power plants in islands to cleaner fuels. The use of fuel oil in power generation continues its declining trend and no new investments are projected.

Net installed capacities of solid biomass and waste-fired power plants doubles over the projection period to reach 41.5 GW_{net} despite some marginal decline beyond the mid-2040s. On one side they are driven by the favourable policy environment set through the ETS, on the other their growth is hampered by a combination of the higher fuel costs, air quality concerns and, in some countries, resource availability constraints. In 2050 they constitute a mere 2.8% of the installed capacity, up from 2.1% in 2015.

Electricity production from derived gases is essentially decoupled from the needs and constraints of the power sector. Instead, it primarily links to the availability of the fuel and hence to the activity of - and to the fuels involved in - the industrial process (mainly steel production in integrated steelworks). The related installed net electricity generation capacity shrinks by 40% and remains overall small (0.3%).

9.3 Electricity and steam generation

Net electricity generation increases by 28% between 2015 and 2050 to satisfy the continuously growing demand (see Section 9.1). It experiences also a major shift towards carbon-free sources. **By 2050, 79% of net electricity is generated without emitting CO_2,** in particular from intermittent renewable energy sources (without biomass and waste) that account for 69% of the total, up from 25% in 2015. Generation based on solid biomass and wastes accounts for another 4% in 2050, with CO_2 emissions occurring only through the combustion of waste input streams. At the same time, the share of nuclear electricity generation shrinks from 26% in 2015 down to 11% in 2050.

To this add 7.5% of net electricity generated in power plants equipped with CCS that capture approximately 90% of the CO_2 emissions compared to comparable plants without CCS. Accordingly, the carbon intensity of European electricity generation drops by a factor of 7 over the projection period, falling to 0.05 t CO_2/MWh by 2050. All in all, the power sector's CO_2 emissions contract by 81 % over the projection period.

Figure 88. Net electricity generation

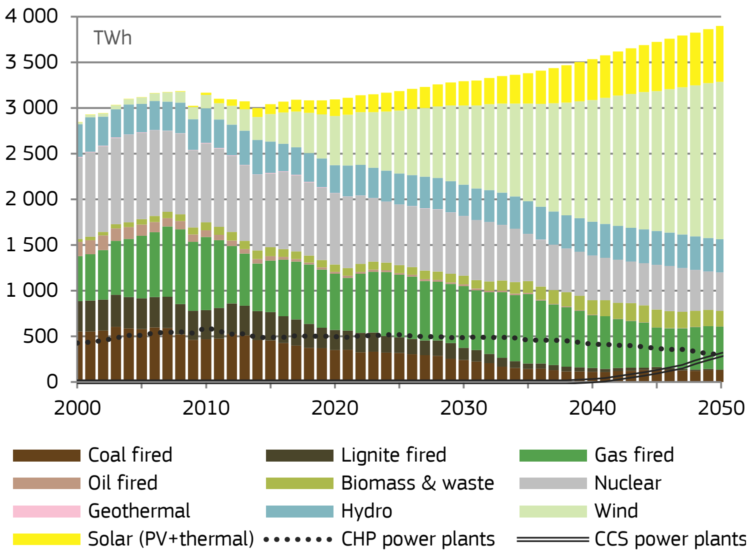
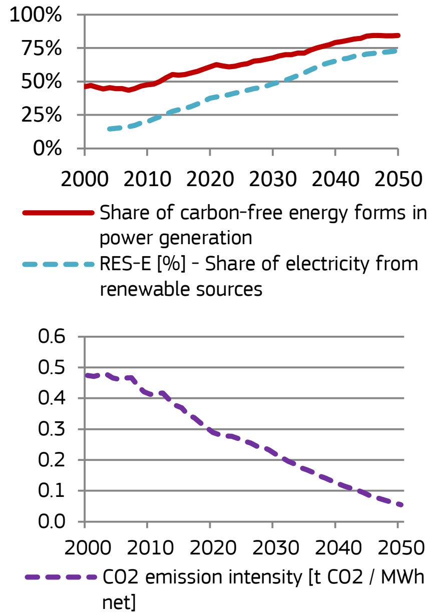
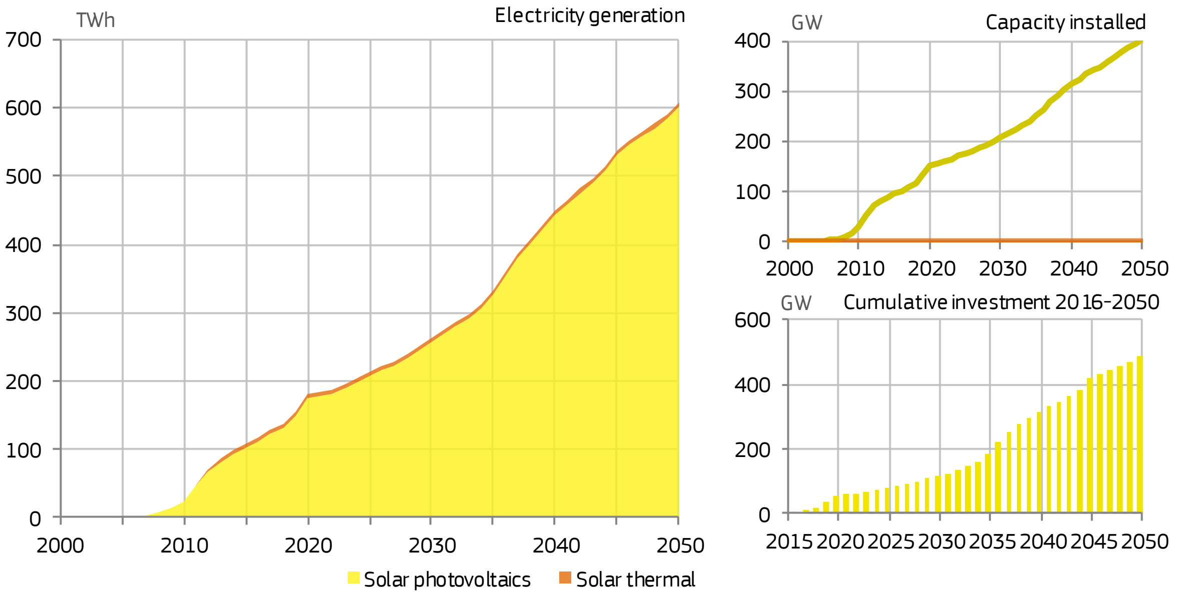


Figure 89. Power generation indicators



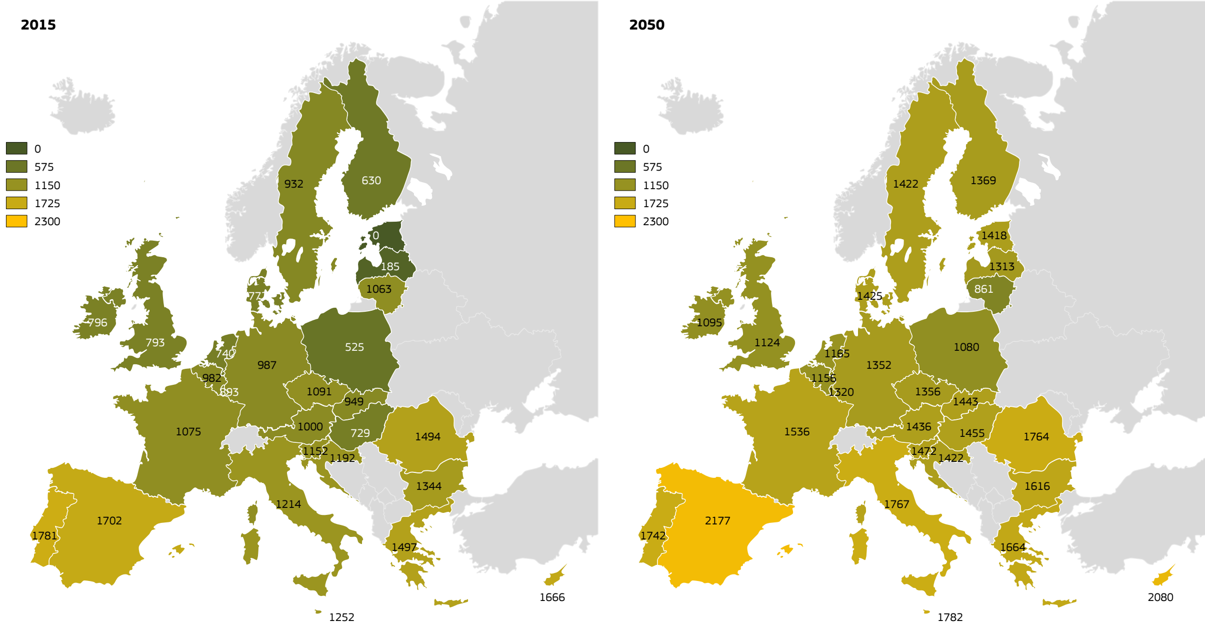
This profound decarbonisation process mirrors the evolution of the generation capacity towards low- and zero-carbon options (Section 9.2). It further reflects on the one hand the very low operating costs of renewables (except biomass) in particular also vis-a-vis rising fossil fuel and ETS allowance prices, and on the other hand the need to maintain conventional thermal generation both to satisfy parts of the heat demand with CHPs and to back-up during non-availability of especially solar, but also wind energy.

Figure 90. Solar power



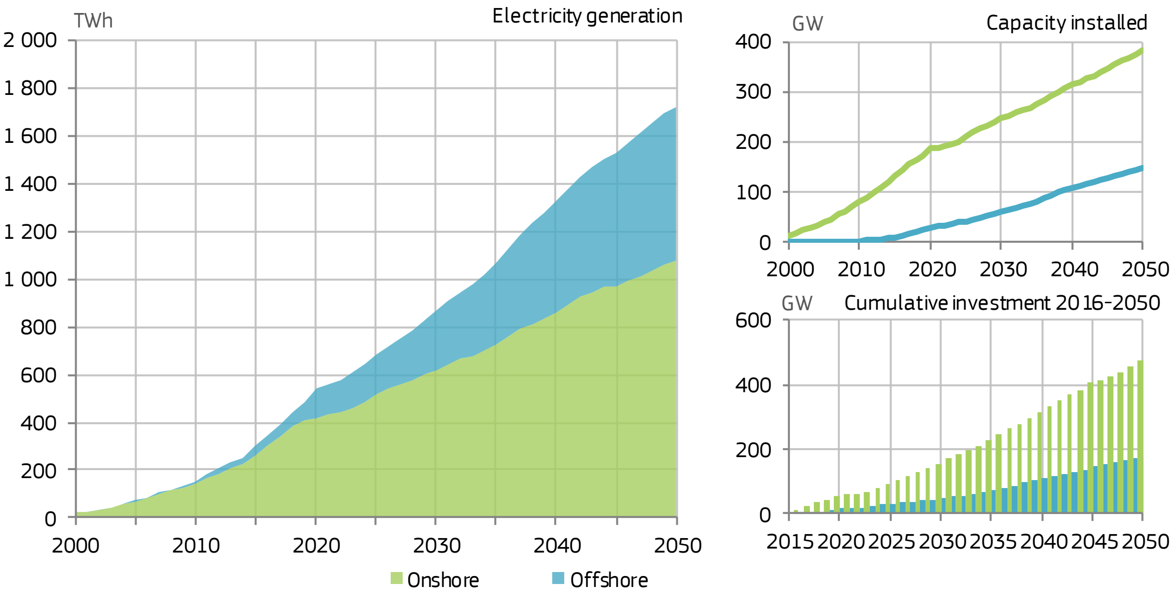
The success story of renewables observed so far continues, notably for solar PV and wind energy. Electricity generated from solar PV grows by a factor of almost 6 over the projection period and becomes the second most important source of electricity by 2050, providing more than 15% of the total. Due to the increased use of tracking systems, in particular in larger PV plants, and to further improvements in the cell design, the average full-load

Figure 91. Operating hours of solar photovoltaics in the EU countries



operating hours of solar PV rise by 40% over the projection period. Towards the end of the period, however, in few Member States with very high solar shares, some minor curtailment takes place and the operating hours mildly decrease. This is mainly due to system stability considerations that shortly before 2050 also prompt a mild deceleration in the solar growth rates. In general, however, large PV shares can be accommodated into the system thanks to growing possibilities for storage (both pumped hydro and battery), a rising share of flexible loads in total demand (e.g. hydrogen production, EV charging) and the good synchronicity of air conditioning demand with PV generation hours [for detailed information see Section 9.4).

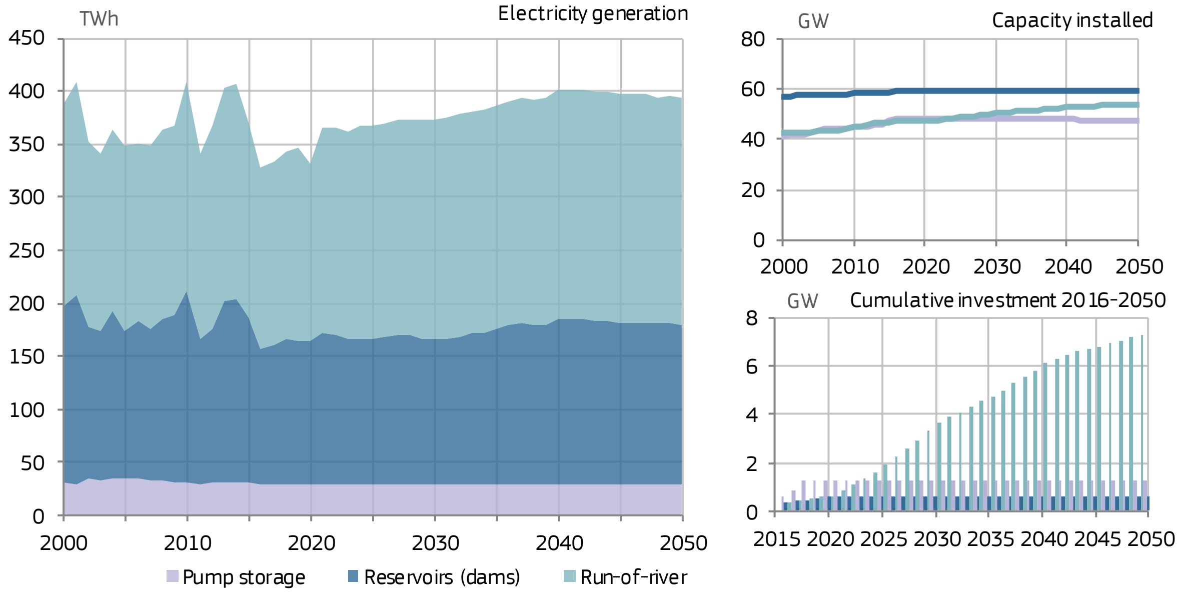
Figure 92. Wind power



Wind energy becomes the single most important source of electricity from the mid-2020s onwards, and by 2050 contributes 42% of the overall net generation. Of this, offshore wind energy accounts for more than one third. Between 2015 and 2050, net generation grows by a factor of 4 for onshore wind and more than 14 times for offshore wind (making a factor of 5.5 for wind altogether). Investments in wind energy become more attractive not only because of the progressive unit cost reductions, but also because technology improvements lead to a wider spectrum of wind speeds in which new turbines can be operated. Accordingly, the operating hours of new turbines increase by 42% and 16% over the period for on- and offshore, respectively. As a result, driven also by the repowering of many existing sites with the highest wind potentials, the EU´s onshore wind park operates on average about 2800 hours in 2050 (with major differences across Member States), 40% up from the 2015 average. The more favourable conditions at sea allow offshore wind to be operated for an average 4400 hours by 2050. Similar to solar PV, wind energy curtailment to ensure system stability takes place only in very few Member States during the last decade of the projection period, and is very limited in absolute terms.

Hydropower, until recently the main source of renewable electricity, quickly loses out to wind and solar. Generation levels from hydro-reservoirs – following the observed drop in 2016 - remain overall broadly stable in absolute terms. At the same time, electricity from run-of-river plants increases by more than 10% due the increase in the net capacity installed and the low operating costs.

Figure 93. Hydro power



In an environment of booming renewables and rising fuel and ETS allowance prices, **conventional thermal power plants are operated significantly less in the future.** This becomes particularly evident in the electricity-only conventional thermal power plants that are not equipped with CCS, as they are on average operated less than 1000 hours per year in 2050 (from more than 3000 hours on average in 2015). For example, in 2050 the (limited number of) electricity-only coal fired plants without CCS operate around 1400 hours,[54] whereas gas-fired electricity-only capacities are on average used for 820 hours. The operation of CHP plants is substantially less affected due to their primary role in delivering steam while simultaneously generating electricity. The situation looks entirely different for the (limited number of) conventional thermal power plants equipped with CCS: they are operated to fulfil baseload demand and to recover the larger investment costs, their operation being hardly affected by the rising ETS allowance price as most of their emissions are captured. As consequence of their lower operating hours and decreasing capacities, net electricity generation from conventional thermal power plants (including CCS) almost halves over the projection period.

Coal- and lignite-based electricity generation substantially declines until the mid-2030s, responding to the rising ETS price that renders new investments into solid fuel plants unattractive and increases the operating costs of existing plants. In addition, in countries with very high shares of wind and solar energy, the limited flexibility of large coal- and even more lignite-fired plants poses additional constraints to their ability to dispatch electricity into the grid. By 2050, net electricity generation from coal and lignite plants that are not equipped with CCS basically disappears from the system, both from CHP and electricity-only plants. With electricity-only plants operating just a quarter of the hours they did in 2015, the net electricity generated by solid-fuel fired plants declines substantially faster than the installed capacities. Due to the emergence of plants equipped with CCS, however, generation from coal holds its decline around 2040. In total, **coal-based electricity generation declines by 70% over the projection period, whereas lignite gradually becomes an obsolete option (-97.5%).**

Conversely, **gas-fired electricity generation experiences a temporary increase before it falls back to below 2015 levels** by the end of the projection period. In particular during the 2020s and 2030s, its market share rises from around 17% in 2015 to slightly above 20%. It contracts again to below 12% in 2050, driven by a number of factors, which are discussed in the following.

[54] This level of operation should not be considered by default as a fragmented operation of units within each and every day but also reflects the fact that different units may be operated in different periods of the year.

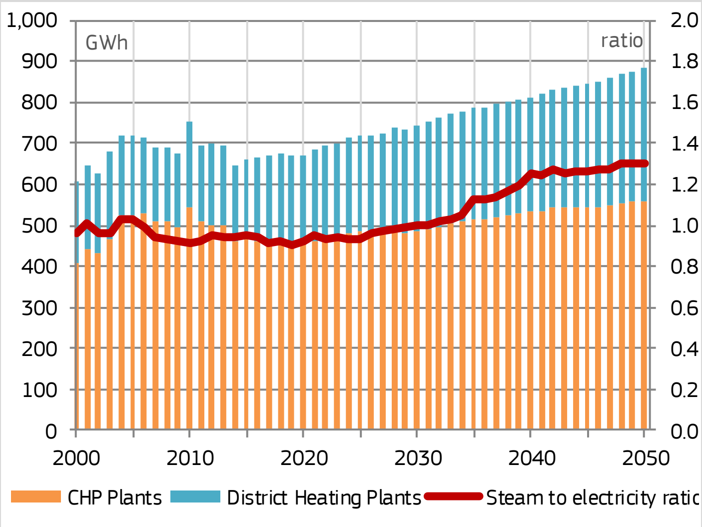
Firstly, gas-fired power plants further expand their dominant role in co-generation of heat and power. By 2035, almost 60% of the electricity generated in CHP plants comes from gas-fired installations, up from 50% in 2015. During this period, the operation of gas-fired CHP plants recovers from the low levels observed around 2015 and settles at around 4000 hours annually. Thereafter, however, coal-based CHP in combination with CCS takes over growing shares of the market.

Secondly, gas-fired power plants are increasingly operated to balance the intermittent renewables generation due to their high flexibility and comparatively low costs associated with load tracking. As a consequence, the average operating hours of electricity-only gas plants decrease from around 2000 hrs to around 1000 hrs and below in the last five years of the projection period. Hence, despite the increase in installed capacities, net electricity generation from electricity-only gas plants without CCS reduces by more than 50% over the projection period after some temporary increases in the 2020s and 2030s.

Thirdly, gas-fired electricity generation comes back in plants equipped with CCS in the 2040s. However, CCS first becomes economically attractive for coal-fired power plants and gas-fired CCS plants enter with some delay. By the end of the projection period, gas-fired CCS plants nevertheless account for more almost two thirds of the electricity generated in CCS plants, and 5% of total net electricity generation.

Box 10. Distributed heat

Demand for distributed heat rises by 45% over the projection period. Even though district heating plants take over a growing role in satisfying this demand, CHP plants still provide more than 64% of the overall distributed steam, down from 71% in 2015. Notably, the steam to electricity ratio of cogeneration becomes more optimal over the scenario period.



Finally, gas-fired power plants remain competitive over time despite rising natural gas and ETS allowance prices due to changes in the fuel composition and efficiency gains. In particular, biogas increases its share in gaseous fuels used as transformation input by almost 2 percentage points, leading to a 1.3% reduction in the carbon intensity of gas-fired plants.

Solid biomass and waste-fired net electricity generation expands by 75% over the projection horizon with a peak in the mid-2040s. It reaches a maximum contribution of 5.2% of electricity generation in 2045 before its share falls back to 4.3 % by the end of the projection period (versus 3.2% in 2015). This peak is essentially driven by the trends in electricity-only plants as biomass-based CHP generation, after a sustained increase in the 2030s, remains rather stable afterwards. With the rise of CCS baseload plants on one side and more variable renewables on the other, biomass-fired electricity-only plants need to operate in a flexible manner after 2045. This results in a severe reduction of their operating hours (and hence electricity generation), also in view of the higher operating costs induced by cycling operation that add to the elevated fuel price. In terms of composition of the fuel input, the fraction of non-renewable waste (including both municipal and industrial waste), which currently accounts for 16.3% of the overall biomass and waste input to power generation, is drastically reduced as the circular economy[55] paradigm gradually gains additional ground in the EU´s waste management system. As a consequence, the contribution of this fraction drops by a factor of 10 to only 1.7% of the biomass and waste input in 2050.

Electricity generated from **derived gases and refinery gases** is primarily driven by the availability of these fuels. Due to the changes in the production processes and in the fuels and reduction agents used by the iron & steel industry (Section 7.2), electricity generated from derived gases decreases by 30% and its contribution to the total electricity generation in the EU shrinks to a share of 0.5%. Refinery gas-based electricity remains below 0.1% of the total.

[55] The waste hierarchy, one of the guiding principles of the circular economy concept, sets an order of priority for waste treatment, whereby energy recovery is preferred to disposal but less favoured than waste prevention and material reuse and recovery options.

Continuing historic trends and further dis-incentivised by the ETS, electricity generation by **heavy fuel oil** is completely phased out over the projection period. Electricity generated by diesel oil, driven out of the market by high fuel prices, quickly falls to very low levels maintaining with time only a marginal role in peak devices in a system dominated by renewables. The use of diesel-fired engine plants in small isolated systems also gradually disappears, replaced by gas, renewables and interconnections with mainland.

In line with the decrease of **nuclear** capacities resulting from the decommissioning of old plants that are only partially offset by new installations, net electricity generation from nuclear decreases steadily throughout the projection period and in 2050 is little more than half of 2015 levels. The remaining capacities can be operated under baseload conditions with the operating hours even rising from 2030 onwards. In total, nuclear power plants contribution to overall net electricity generation drops from more than one quarter to slightly above 10% in 2050.

Figure 94. Electricity generation by production type

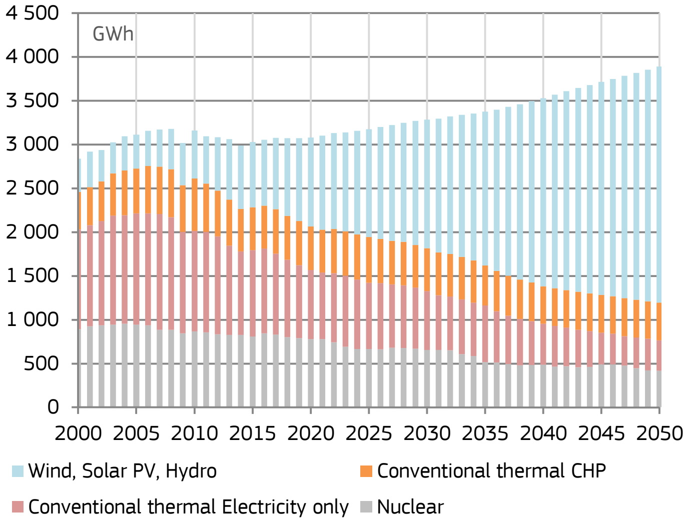
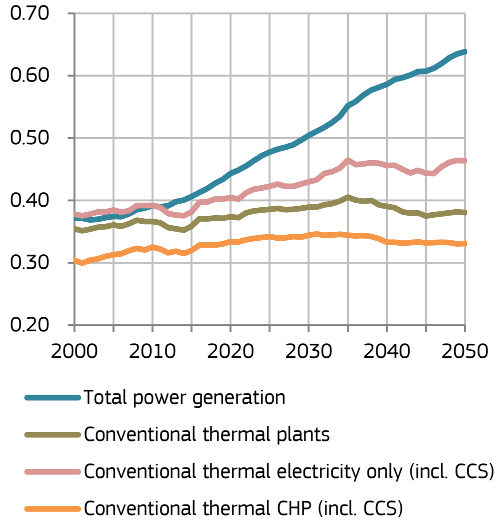


Figure 95. Power plant net electric efficiencies



Following the above trends, **the overall system efficiency of net electricity generation rises** from 41% in 2015 to almost 63% by 2050. Most of these efficiency improvements are due to the shift from thermal power plants to wind and solar PVs, which by convention have an efficiency of 100%. On the contrary, efficiency improvements in conventional thermal power plants remain limited (+2 percentage points). Underneath this stable trend are different and partially contrasting forces, resulting in nearly stagnating efficiencies: on the one hand, a shift towards more efficient fuels and technologies takes place (gas-fired CCGTs replacing solid-fuel fired generation, for instance), enhanced by technological progress, which brings up efficiencies until the early 2040s. This is partially counteracted by the suboptimal use of some power plants that primarily act in satisfying flexibility needs of the system. Afterwards power plants equipped with carbon capture enter the system and dampen the efficiency as a result of their elevated own consumption, further fostered by the fact that CCS first enters in coal-fired plants.

Figure 96. Transformation input in conventional thermal power plants

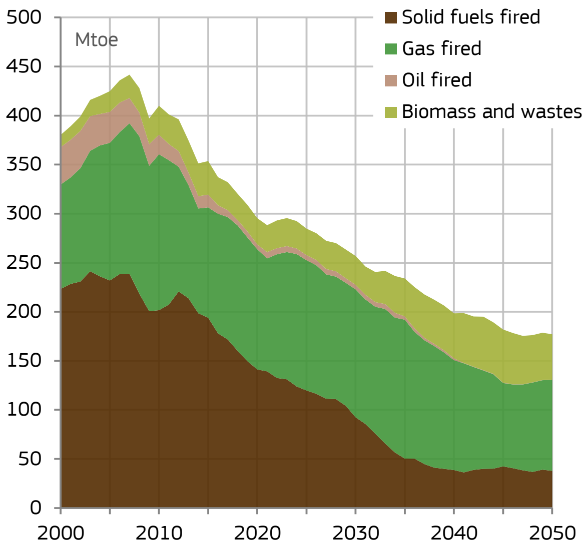
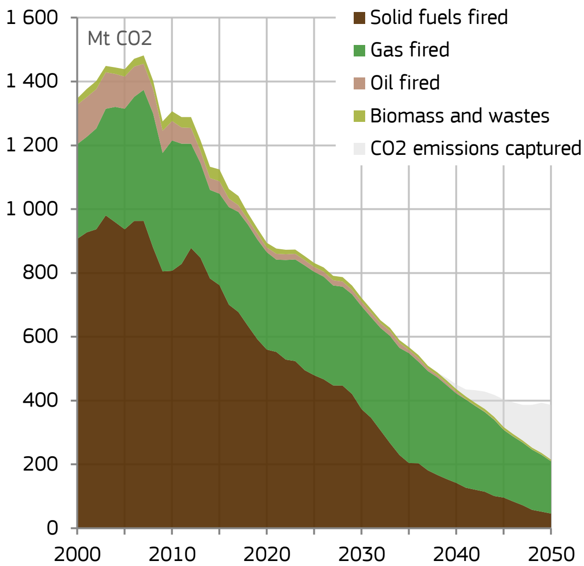


Figure 97. CO_2 emissions in the power sector



However, towards the end of the projection period, as investment in CCS units are dominated by gas fired ones, the efficiency rebounds and increases again.

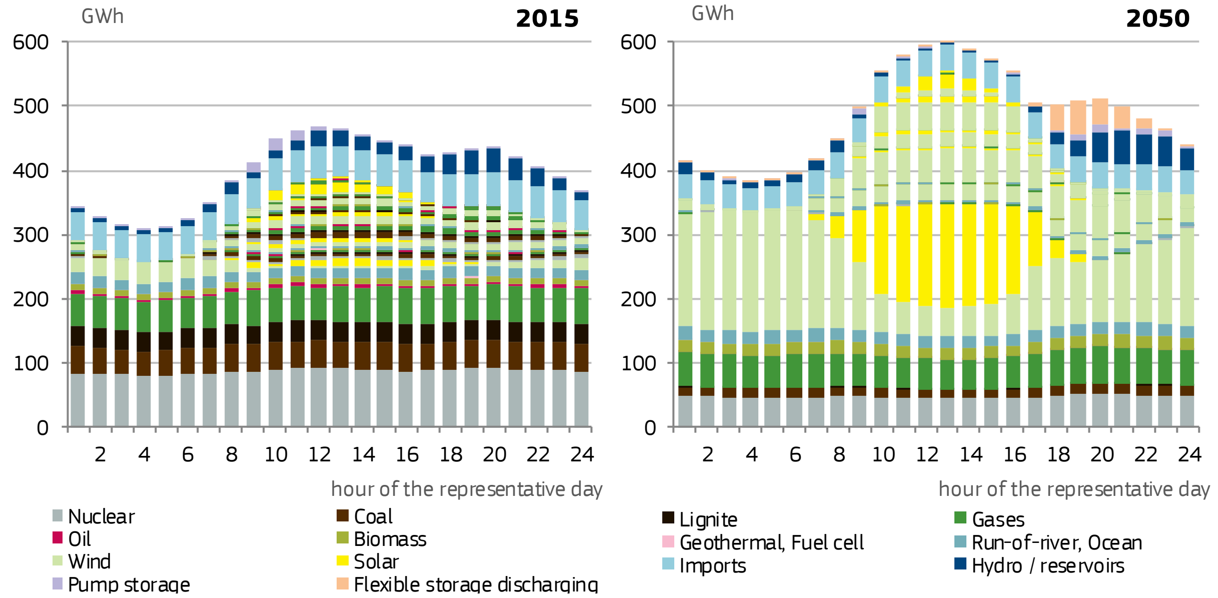
Transformation input to conventional thermal power generation halves over the projection period as a result of the above trends. During the last five years of the projection period, however, transformation input into conventional thermal power plants stabilises primarily due to the uptake of CCS generation.

Hence, the **power sector's CO_2 emissions** shrink by 81% between 2015 and 2050, despite the 28% rise in net electricity generation and 20% increase in steam generation in CHP plants. CO_2 emissions captured in the power sector rise rapidly beyond 2040; in 2050 the emissions captured amount to 171.5 Mt CO_2, which compares to remaining power sector emissions of 215 Mt CO_2.

9.4 'Dispatching' for a representative day

The power system needs to satisfy the electricity demand load (see Section 9.1). In order to gain insights into the operation of the power sector, this section illustrates the operation of power plants for one representative day of the year 2050.

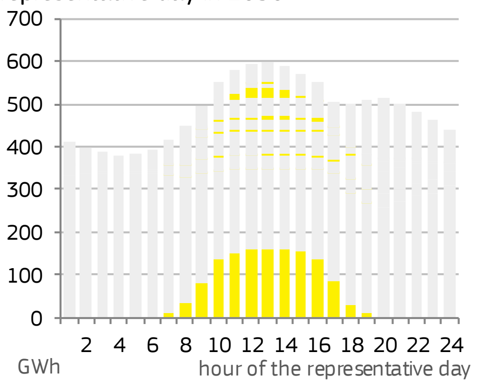
Figure 98. Electricity supply for the representative day



In 2050, the shape of the overall generation pattern is dominated by solar PV (reflecting the natural light availability) while the availability of wind energy becomes almost constant along the representative day. Figure 98 illustrates the hourly generation load patterns between 2015 and 2050 alongside the load regime to which they contribute.[56]

This outcome illustrates how electricity generated from variable renewable energy sources, notably PV, is contributing substantially also in the baseload regime (see also Figure 99). This is the result of its very low operating costs, and of the increased flexibility of the system, and the (marginally growing) importance of baseload in the overall demand.

Figure 99. Solar generation for the representative day in 2050



[56] This is the result of the dispatching module of POTEnCIA that simultaneously addresses both the chronological (hourly) load pattern of the demand for one representative day and 7 different load regimes (ranging from the base load to the peak load). Power plant units are dispatched while considering the duration of the respective load regimes, therewith explicitly taking into account additional costs and fuel use that may occur as a consequence of cycling operation and spinning when operating certain power plant types within specific load regimes.

In more detail, accommodating large amounts of PV generation into the system despite their fix generation patterns is made possible by a number of interlinked factors on both the demand side and within the power sector.

Figure 100. Electricity demand in hydrogen production in 2050

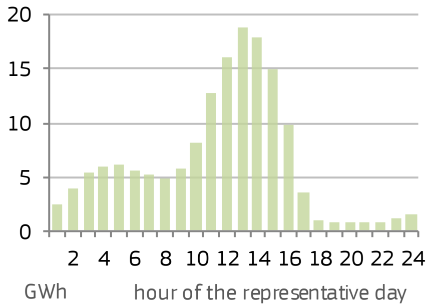
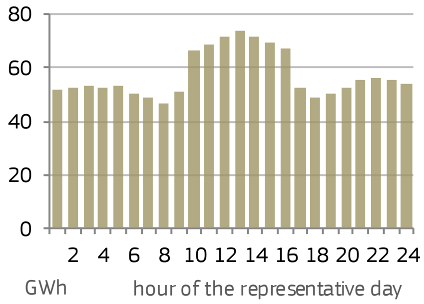


Figure 101. Electricity demand in transport in 2050



The substantial increase in electricity consumption of flexible end-uses allows for **load shifting** (see also Section 9.1). This occurs in particular in transport due to the flexibility in charging electric vehicles. In the residential sector, the increased weight of electricity use for space heating compared to its use for specific electric appliances also allows for a limited load shift by making use of the thermal inertia of the system, while the robust increase in demand for space cooling is to a high degree synchronous with the PV availability. New electricity buffers gain some importance, in particular electrolytic hydrogen production when excess electricity supply is available. In 2050, hydrogen production accounts for 55 TWh of electricity consumption (almost 1.5% of the total), to satisfy the demand stemming primarily from transport, whereas the use of electrolytic hydrogen in industry starts only towards the end of the projection period.

Figure 102. Gas-fired electricity generation in 2030

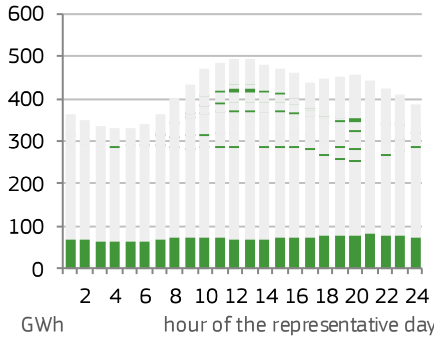
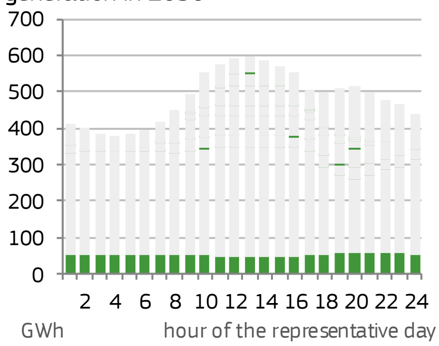
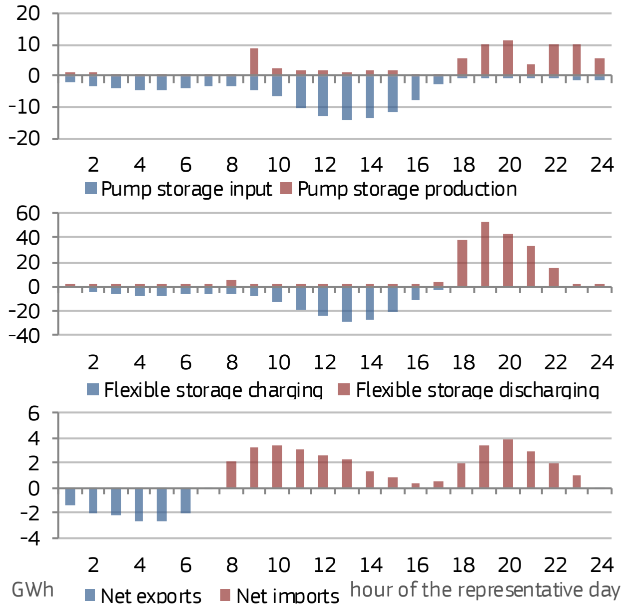


Figure 103. Gas-fired electricity generation in 2050



Conventional thermal power plants are operated increasingly in load-following mode, which becomes evident in their low operating hours. This is particularly pronounced for electricity-only plants, whereas for CHP plants it is less so. Figure 102 indicates that in 2030 a significant part of the natural gas electricity-only power plants are operated in load-following mode, whereas CHP plants, which by then account for 46% of gas-fired electricity generation, contribute to the baseload. By 2050 (Figure 103), however, the need for flexible operation decreases as a response to the massive entry of storage options that reduce the load-tracking needs from conventional plants. The majority of natural-gas fired electricity generation stems from either CHP and/or CCS plants that are operated preferably in baseload conditions.

Figure 104. Electricity storage options, imports/exports



The availability of **battery storage** plays an increasing role in balancing the load throughout the hours of the day, thereby acting as an enabler for high shares of PV electricity generation. In 2050, almost 2% of the daily electricity consumption is shifted from hours of abundant generation to hours with low supply. This is further complemented by pumping storage. In general, flexible storage batteries are found to be discharged preferentially in the hours following their charging, whereas pumping storage is more suitable for longer-term storage.

Finally, hourly **imports and exports** further act in balancing the system. This becomes more obvious when focusing on individual countries, while the role of electricity exchanges of the EU with neighbouring countries is limited.

The above discusses how system stability is ensured for a representative day. The representative day, however, hides single instances of extreme nature that can occur within a year, such as moments of low variable renewables availability or plant outages, and/or demand peaks.

Nonetheless, **generation adequacy** is ensured throughout the projection period. Even if no capacity credits were assumed for variable renewables, the reserve margin expressed as net installed capacities excluding wind and solar relative to the generation peak of the representative day remains above 1.4 until the mid-2030s (Figure 105). Its later decline can be put in context by a wider interpretation of system adequacy that takes into consideration a number of additional effects to reflect the long run evolution in the power system.[57] The key elements are given hereafter.

Figure 105. Power generation system indicators

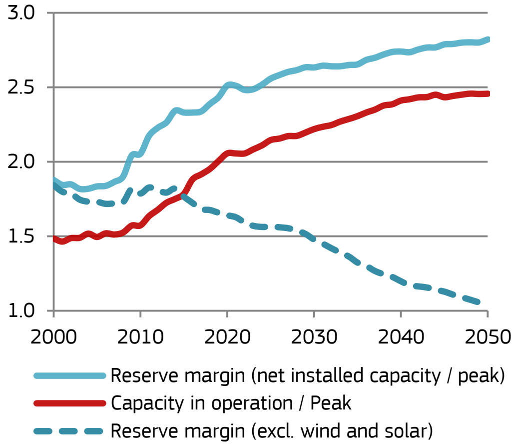
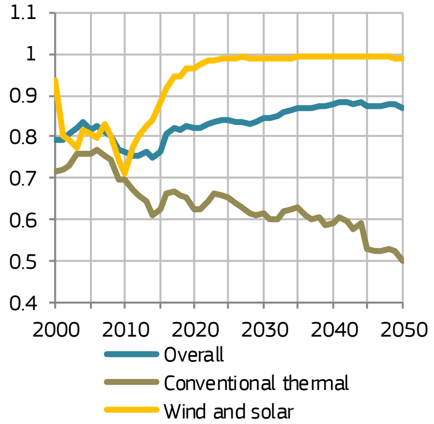


Figure 106. Capacities in operation versus installed capacities



Firstly, the high penetration of wind energy implies that wind farms are spread over large extensions of land, making it unlikely for incidents occurring within a given zone to affect overall generation in an extreme way. In this respect, a certain amount of – geographically spread - wind turbines can be seen as 'bundled' together in order to provide safe capacity.[58]

Secondly, technological evolution allows widening the turbines' suitable wind ranges (i.e. lowering the cut-in and increasing the cut-out wind speed). Moreover, the share of offshore wind increases', improving also the overall capacity factor. Both tendencies imply not only longer average operating hours for wind energy, but also contribute to lower abrupt fluctuations in output.

Thirdly, the rise in interconnector capacities and the move towards a more integrated European electricity market makes it possible to better balance unforeseen singular incidents. Even though on an annual average the sum of all imports remains broadly constant throughout the projection period, its role becomes more evident when looking into the 'dispatching' of a representative day.

Fourthly, existing (mainly reservoir pumping) and novel (e.g. batteries) storage options together with variable loads (e.g. H_2 production via electrolysis; in part EV charging) contribute to the flexibility of the system, enabling load shaving in case of unforeseen events while making use of short-term storage (see above). In this respect, capacity credits also apply for PV generation when combined with storage options.

Finally, the (at first glance counter-intuitive) fact that both flexible gas- and even more so diesel-fired electricity generation occurs during the hours of abundant electricity supply is due to their role in ensuring the stability of the

[57] POTEnCIA addresses the system stability in the power sector going beyond the notion of the reserve margin. Endogenously derived signals are sent from the dispatching of the power plants to the capacity planning, affecting both the level of investment needs and the attractiveness of competing investment options.

[58] This bundling can be assumed for instance for wind power, but also for conventional thermal plants. For example, a 1kW wind energy unit with 1750 hours of operation under normal conditions cannot replace one kW of base load power. However, under the assumption that no limits exist in the maximum natural hours of wind availability, justifiable when considering an extensive geographical spread regarding the wind parks location, multiple units (in this example five) could be considered to operate in series as to generate energy throughout the entire duration of the load. Hence, these multiple units together could contribute not only to the electricity generation but also to the power of the base load regime, under the assumption of permanent wind availability in some spots all over the country/zone considered.

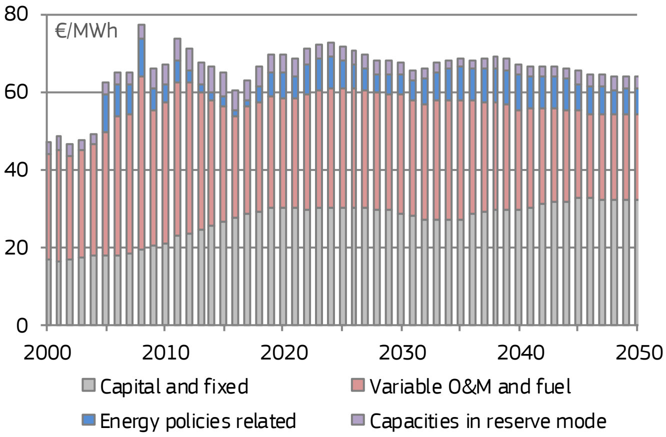
system throughout the year, as days in which the solar production is significantly lower and/or the demand peak higher than in the representative day require operating gas- and diesel-fired peaking plants. This also explains certain production levels throughout all hours of the representative day, as events requiring back-up power may occur at any hour. Since their number is limited, however, the overall contribution over a year remains small.

Together, these factors translate into a rather elevated ratio of the overall net installed capacity over the peak of the representative day, even when considering that the yearly peak lies above that of the representative day.[59] However, not all of these capacities are operated continuously throughout time. On the contrary, an important amount of the thermal capacity is effectively in reserve during much of the year and only acts as back-up power for single events.[60] Hence, the conventional thermal capacity in operation remains well below the installed capacity throughout the projection period, creating such safety margin (see Figure 106). The drop observed in the last five years of the projection period results from the entry of CCS power plants that are basically operated under baseload conditions and hence induce additional idle non-CCS thermal capacity. Wind and solar are essentially operated at full capacities.

9.5 Costs

The unit costs of electricity generated remain remarkably stable despite the far-reaching changes in the power sector and the important electrification trends in final demand. The unit costs peak at some 12% above year 2015 levels in the mid-2020s before they stabilise at levels around 3%-5% above 2015's. From 2040 onwards electricity generation costs enter a declining pathway with the unit cost reaching at levels marginally below those of 2015 from 2045 onwards (-1.4% in 2050).

Figure 107. Electricity generation cost



Driven by the switch to renewable sources with no fuel costs, but also due to the lower operation of conventional thermal power plants, a growing share of the overall generation costs is accounted for by capital costs, reaching 39% of the total in 2050, up from 32% in 2015. While the steep cost reductions occurring in solar and wind effectively translate into a reduction in the capital costs per kW invested in the first two decades of the projection period, this trend is halted thereafter due to the uptake of investments in capital-intensive CCS plants.

Fuel costs increase marginally until the 2030s and drop thereafter to be 25% below the 2015 levels by 2050. Rising international fuel prices (Section 2.2) are offset primarily by the substitution of conventional thermal plants with wind and solar, supported also by efficiency gains of the power sector.

The direct policy costs due to the need to buy CO_2 emission allowances under the ETS account for between 8% and 13% of the total unit costs. The rise in the CO_2 allowance price is effectively counteracted by the vigorous reduction in the carbon intensity of electricity generation.

The hourly profile of electricity generation costs undergoes a profound change over time, reflecting the transformation in the generation mix by hour and the additional above-described mechanisms.

[59] As explained in Box 8, the actual peak observed in 2015 lies 1.15 times above the peak of the representative day in that year for the EU. It can be argued that this ratio will reduce by 2050 due to the growing shares of flexible demand loads. However, even if this ratio is maintained, sufficient capacities would be available.

[60] A certain amount of capacity being not in operation in a given year does not mean that the same power plant units are put on 'idle' throughout time; on the contrary, it is likely that events requiring the activation of back-up power occur at different moments across zones.

Figure 108. Power generation hourly costs in 2015

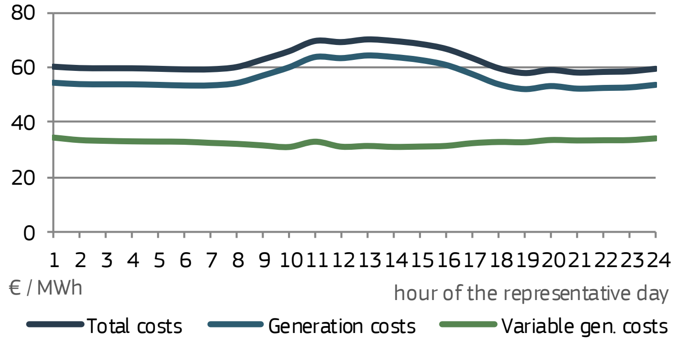
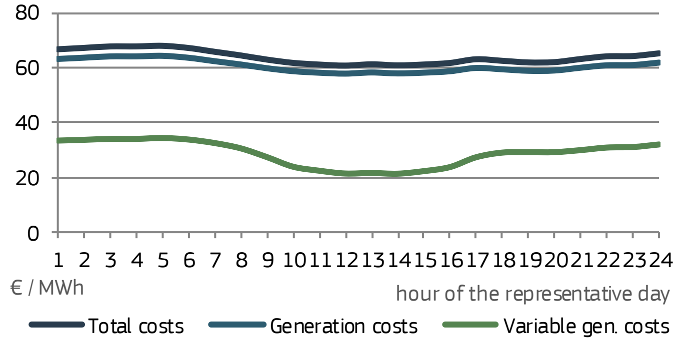


Figure 109. Power generation hourly costs in 2050



In 2015, variable generation costs are broadly stable throughout the representative day, with a rather marginal drop during the hours of PV production that produce at near-zero variable costs. At the same time, however, the elevated historic capital costs of PV (expressed in annuities of the capital that are allocated to the different time segments according to the generation) together with the costs for peaking plants lead to an overall generation costs that reach their highest levels between noon and 15:00. A further cost component is the (capital and other fixed) costs associated with capacities in reserve mode.

By 2050, the hourly power generation cost profile is reversed. With PVs providing significant shares of the overall generation during the daytime hours (almost 40% at 13:00), variable costs are roughly 30% below those during night-time hours. With the flexible storage in batteries, the low-cost stored PV surplus generation also brings slightly down the variable costs in the early evening hours when batteries are discharged to meet the demand.

At the same time, the extent of the drop in the cost of PV modules is such that also in terms of capital costs PV become one of the cheapest power generation options by then. Hence, and despite the capital costs for some peak devices, overall generation costs are at their lowest around midday. Generation costs are highest, conversely, during the hours when demand is limited, in particular the early morning hours.

The evolving hourly electricity generation cost profiles translates into **different electricity prices[61] across demand sectors that change over time**, taking into account the distinct hourly demand load patterns of different users.[62]

[61] POTEnCIA uses a combination of marginal and average cost pricing, while ensuring a full recovery of costs. In the calculation of the electricity tariff, the model considers the operational costs, the payback of fixed costs, and the specific load profiles of the demand sectors for each energy use. Moreover, the annuities of the capital of capacities that are not in operation are identified and added to the total generation costs. In addition, mark-ups are introduced to reflect market power. The pricing further takes into account the grid costs through a non-linear cost function.

[62] Moreover, the hourly variable electricity generation costs provide a clear signal to the different consumers for load shifting.

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Annexes

Annex 1. Guide to the Central scenario output and assumptions in the Research Collaboration Portal

The Central scenario results are made available through the POTEnCIA project space in the Research Collaboration Portal (RCP, https://rcp.jrc.es) of the Joint Research Centre (JRC). In order to gain access, please:

- Register first to the portal (please not the portal uses the EU Login service for authentication. Therefore, during the registration process you may need to set up an EU login account if you do not yet have one).
- Then send an email to JRC-C6-POTENCIA@ec.europa.eu to request access providing either your email or the username of your registration.
- After processing your request, you will receive an email with the project space invitation.
- Sign in to the portal and click on the project name on the left to enter the project area.

With registering to the portal, you will be able to directly access any updates and additional materials that are foreseen to come.

Use conditions

The Central scenario results are intended to be used in-line with the reuse policy of the European Commission. The related license information can be found at: https://data.jrc.ec.europa.eu/licence/com_reuse.

Downloadable materials

The Central scenario results can be found in the *Public* area of the project space. The files are organized by Member States, each one having a compressed file.

Within the zip files, the folders are organized based on their content and their time resolution

- *Assumptions* - the assumptions behind the Central scenario
- *5_year_reports*- scenario results in 5 years steps
    - *Industry* - results of the industrial sectors
    - *Residential*- results of the residential sector
    - *Tertiary*- results of the services, agriculture, forestry and fishing sectors
    - Transport - results of the transport sectors and the bunkers
    - *PowerGeneration* – power generation results
    - *EnergyBalances* - the detailed energy balances of the Central scenario
- *Annual_reports*- annual scenario results (having the same structure as the 5 years reports)
    - *Industry* - results of the industrial sectors
    - *Residential*- results of the residential sector
    - *Tertiary*- results of the services, agriculture, forestry and fishing sectors
    - Transport - results of the transport sectors and the bunkers
    - *PowerGeneration* – power generation results
    - *EnergyBalances* - the detailed energy balances of the Central scenario
- *Year_spec_reports* - snapshot of the representative day for a selectable year

In the above folders the following files can be found:

The quick overview file

Central_2018_<*Country*>_overview.pdf

A leaflet providing a quick overview of the most important scenario result

The graphical overview file

Central_2018_<*Country*>_slides.xlsx

Contains visual analytics on the following sheets:

- *Overview* - Energy system overall trends and system indicators
- *Overview_1* - Overall energy system: Gross inland energy consumption by fuel
- *Overview_2* - Overall energy system: CO2 emissions by sector
- *Overview_3* - Overall energy system: Indicators for renewable energies (RES-Shares)
- *Overview_4* - Overall energy system: Energy system costs
- *Overview_5* - Overall energy system: Overarching trends

- *Policy* - Policy variables
- *art7* - Energy Efficiency Directive: Article 7 implementation
- *EPBD* - Energy Performance of Buildings (EPBD): Nearly Zero-Energy Buildings (NZEB) implementation
- *CO2standards* - CO2 Standards for private cars and light duty vehicles
- *CO2standardsEU28* - CO2 Standards for private cars and light duty vehicles
- *ETSEU28* - CO2 emissions in the Emissions Trading System (ETS) sectors

- *Demand* - Demand Side sectors overview
- *Demand_1* - Final energy demand

- *Domestic* - Residential and Tertiary sectors
- *Domestic_1* - Residential and Tertiary sectors: Energy consumption
- *Domestic_2* - Residential and Tertiary sectors: Changes in the fuel mix
- *Domestic_3* - Residential sector: Evolution of number of households
- *Domestic_4* - Residential sector: Consumption indicators
- *Domestic_5* - Residential sector: Electricity consumption details
- *Domestic_6* - Residential sector: Energy consumption in thermal uses
- *Domestic_7* - Services sector: Evolution of serviced surface area
- *Domestic_8* - Tertiary sector: Consumption indicators
- *Domestic_9* - Tertiary sector: Electricity consumption details
- *Domestic_10* - Tertiary sector: Energy consumption in thermal uses
- *Domestic_11* - Residential and Tertiary sectors: Key trends
- *Domestic_12* - Residential and Tertiary sectors: Key indicators and costs

- *Industry* - Industrial sectors
- *Industry_1* - Industrial sectors: Overview of trends
- *Industry_2* - Industrial sectors: Energy consumption by fuel
- *Industry_3* - Industrial sectors: Energy consumption by sector and CO2 emissions
- *Industry_ISI_1* - Industrial sectors: Iron and steel sector overview of trends
- *Industry_ISI_2* - Industrial sectors: Iron and steel - Integrated steelworks production overview
- *Industry_ISI_3* - Industrial sectors: Iron and steel -Electric arc production overview
- *Industry_NFM_1* - Industrial sectors: Non-ferrous metals sector overview of trends

- *Industry_NFM_2* - Industrial sectors: Non ferrous metals - Alumina production overview
- *Industry_NFM_3* - Industrial sectors: Aluminium production overview
- *Industry_NFM_4* - Industrial sectors: Non ferrous metals - Other non-ferrous metals production overview
- *Industry_CHI_1* - Industrial sectors: Chemical sector overview of trends
- *Industry_CHI_2* - Industrial sectors: Basic chemicals production overview
- *Industry_CHI_3* - Industrial sectors: Other chemicals production overview
- *Industry_CHI_4* - Industrial sectors: Pharmaceutical products etc. production overview
- *Industry_NMM_1* - Industrial sectors: Non-metallic mineral products sector overview of trends
- *Industry_NMM_2* - Industrial sectors: Cement production overview
- *Industry_NMM_3* - Industrial sectors: Glass production overview
- *Industry_NMM_4* - Industrial sectors: Ceramics & other Non-Metallic Minerals (NMM) overview
- *Industry_PPA_1* - Industrial sectors: Pulp, paper and printing sector overview of trends
- *Industry_PPA_2* - Industrial sectors: Pulp production overview
- *Industry_PPA_3* - Industrial sectors: Paper production overview
- *Industry_PPA_4* - Industrial sectors: Printing and media reproduction overview
- *Industry_FBT_1* - Industrial sectors: Food, beverages and tobacco sector overview of trends
- *Industry_FBT_2* - Industrial sectors: Food, beverages and tobacco sector production overview
- *Industry_TRE_1* - Industrial sectors: Transport Equipment sector overview of trends
- *Industry_TRE_2* - Industrial sectors: Transport Equipment production overview
- *Industry_MAE_1* - Industrial sectors: Machinery Equipment sector overview of trends
- *Industry_MAE_*2 - Industrial sectors: Machinery Equipment production overview
- *Industry_TEL_1* - Industrial sectors: Textiles and Leather sector overview of trends
- *Industry_TEL_2* - Industrial sectors: Textiles and Leather production overview
- *Industry_WWP_1* - Industrial sectors: Wood and Wood products sector overview of trends
- *Industry_WWP_2* - Industrial sectors: Wood and Wood products production overview
- *Industry_OIS_1* - Industrial sectors: Other Industrial Sectors overview of trends
- *Industry_OIS_2* - Industrial sectors: Other Industrial Sectors production overview

- *Transport* - Transport sectors
- *Transport_1* - Transport sector: Key trends
- *Transport_2* - Passenger Transport: Evolution of activity per capita
- *Transport_3* - Freight Transport: Evolution of activity per unit of GDP
- *Transport_4* - Transport sector: Evolution of energy consumption
- *Transport_5* - Transport sector: Evolution of CO2 emissions
- *Transport_6* - Transport sector: Road transport overview of trends
- *Transport_7* - Transport sector: Road transport energy consumption
- *Transport_8* - Transport sector: Passenger cars - Mode overview
- *Transport_9* - Transport sector: Evolution of passenger cars stock
- *Transport_10* - Transport sector: New registrations of passenger cars
- *Transport_11* - Transport sector: Indicators for passenger cars ownership and use
- *Transport_12* - Transport sector: Powered two-wheelers - Mode overview
- *Transport_13* - Transport sector: Indicators for powered two-wheelers ownership and use
- *Transport_14* - Transport sector: Motor coaches, buses and trolley buses - Mode overview
- *Transport_15* - Transport sector: Evolution of motor coaches, buses and trolley buses stock

- *Transport_16* - Transport sector: Indicators for motor coaches, buses and trolley buses ownership and use
- *Transport_17* - Transport sector: Light duty vehicles - Mode overview
- *Transport_18* - Transport sector: Evolution light duty vehicles stock
- *Transport_19* - Transport sector: Indicators for light duty vehicles ownership and use
- *Transport_20* - Transport sector: Heavy duty vehicles - Mode overview
- *Transport_21* - Transport sector: Indicators for heavy duty vehicles ownership and use
- *Transport_22* - Transport sector: Rail transport overview of trends
- *Transport_23* - Transport sector: Indicators for passenger rail
- *Transport_24* - Transport sector: Aviation overview of trends
- *Transport_25* - Transport sector: Indicators for passenger aviation

- *PowerGen* - Power generation
- *PowerGen_1* - Power generation: Electricity generation by fuel, main indicators
- *PowerGen_2* - Power generation: Installed capacity
- *PowerGen_3* - Power generation: Investment
- *PowerGen_4* - Power generation: Transformation input and CO2 emissions
- *PowerGen_5* - Power generation: Wind power plants
- *PowerGen_6* - Power generation: Solar power plants
- *PowerGen_7* - Power generation: Hydro power plants
- *PowerGen_8* - Power generation: Geothermal, fuel cell and sea-borne energy power plants
- *PowerGen_9* - Power generation: System indicators
- *PowerGen_10* - Power generation: Operational characteristics
- *PowerGen_11* - Power generation: Heat production
- *PowerGen_12* - Power generation: Generation and investment costs

Summary file

Central_2018_<*Country*>_summary_yearly.xlsx / Central_2018_<*Country*>_summary_5years.xlsx

Contain an overview of the scenario on the following sheets:

- *PolVar* - Policy variables and dual values
- *Overview* - Overview
- *Industry* - Industrial sectors overview
- *Residential* - Residential sector
- *Tertiary* - Services sector, Agriculture, forestry and fishing
- *Transport* - Transport
- *PowerGen* - Power generation
- *EnergyBalances* - Energy balances
- *Emissions* - Emission balances
- *ETS* - current ETS sector balances
- *RESshare* - Share of energy from renewable sources

Assumption folder files

Assumptions_Central_2018_<Country>.xlsm

Contain the country specific assumptions behind the Central scenario on the following sheets:

Assumptions:

- *Macro* - Population, GDP, Household consumption expenditure
- *IND* - Industrial sectors and Agriculture
- *RES* - Residential sector
- *SER* - Services
- *TRA_Passenger* - Passenger transport
- *TRA_Freight* - Freight transport
- *Bunkers* - Bunkers
- *Definitions* - Matching NACE codes with the sectoral structure of the model

Overview charts:

- *ChGDP_CE* - GDP and Household consumption expenditure
- *ChGVA_CE* - Gross value added and Household consumption expenditure
- *ChSectorsVA* - Sectoral value added
- *ChSectorsInd* - Sectoral indicators
- *ChCross* - Sectoral comparisons
- *ChGDPciomp* – Central scenario versus Ageing population
- *ChInd* - Industrial sectors and Agriculture
- *ChResBld* - Residential sector - households
- *ChResAppl* - Residential sector - electric appliances
- *ChResTh* - Residential sector - thermal uses
- *ChSerBld* - Services sector - buildings
- *ChSerAppl* - Services sector - electric appliances
- *ChSerTh* - Services sector - thermal uses
- *ChTraPass* - Transport sectors - Passenger transport
- *ChTra*_PassMode - Passenger transport modes
- *ChTraFre* - Transport sectors - Freight transport
- ChTra_FreMode - Freight transport modes
- *ChBunkers* – Bunkers

IntFuelPrices_Central_2018.xlsx

Contain the assumptions on the international fuel prices

PG_technology_Central_2018.xlsx

Contain the power generation technology assumptions together with a visual comparison on the following sheets:

- *tech_base* - power generation technology in base year
- *tech_proj* - evolution of the power generation technology over the projection period
- *tech_cost* - graphical comparison of power plant types

Industry folder file

Central_2018_<*Country*>_ind_yearly.xlsx / Central_2018_<*Country*>_ind_5years.xlsx

Contain the scenario results of industrial sectors the following sheets:

- *Summary* - Industrial sectors overview

- *ISI* - Iron and Steel
- *ISIsv* - production capacities, infrastructure improvement
- *NFM* - Non Ferrous Metals
- *NFMsv* - production capacities, infrastructure improvement
- *CHI* - Chemicals Industry
- *CHIsv* - production capacities, infrastructure improvement
- *NMM* - Non-metallic mineral products
- *NMMsv* - production capacities, infrastructure improvement
- *PPA* - Pulp, paper and printing
- *PPAsv* - production capacities, infrastructure improvement
- *FBT* - Food, beverages and tobacco
- *FBTsv* - production capacities, infrastructure improvement
- *TRE* - Transport Equipment
- *TREsv* - production capacities, infrastructure improvement
- *MAE* - Machinery Equipment
- *MAEsv* - production capacities, infrastructure improvement
- *TEL* - Textiles and Leather
- *TELsv* - production capacities, infrastructure improvement
- *WWP* - Wood and Wood products
- *WWPsv* - production capacities, infrastructure improvement
- *OIS* - Other Industrial Sectors
- *OISsv* - production capacities, infrastructure improvement

Residential folder files

Central_2018_<*Country*>_res_yearly.xlsx / Central_2018_<*Country*>_res_5years.xlsx

Contain an overview of the residential sector on the following sheets:

- *RES_summary* - Residential sector summary
- *RES_sector* - Residential sector energy use
- *RES_appliances* - Residential specific electric uses
- *RES_hh-type* - Residential / Thermal uses: Detailed split of energy consumption for thermal uses by type of household
- *RESU_hh-type* - Residential / Thermal uses: Detailed split of energy service by thermal use and type of household

Central_2018_<*Country*>_res_det_yearly.xlsx / Central_2018_<*Country*>_res_det_5years.xlsx

Contain the detailed results of the residential sector the following sheets:

- *RES_summary* - Residential sector summary

Thermal uses:

- *RES_hh_num* - Number of households
- *RES_hh_fec* - Final energy consumption
- *RES_hh_tes* - Thermal energy service
- *RES_hh_iei* - Energy service satisfied by infrastructure improvements
- *RES_hh_eff* - System efficiency indicator of total stock
- *RES_hh_emi* - CO2 emissions

- *RES_hh_fech* - Final energy consumption per household
- *RES_hh_tesh* - Thermal energy service per household
- *RES_hh_ieih* - Energy service satisfied by infrastructure improvements per household
- *RES_hh_emih* - CO2 emissions per household
- *RES_hh_fecs* - Final energy consumption per surface area
- *RES_hh_tess* - Thermal energy service per surface area
- *RES_hh_ieis* - Energy service satisfied by infrastructure improvements per surface area
- *RES_hh_emis* - CO2 emissions per surface area

Thermal uses in new and renovated households:

- *RES_hh_num_in* - Number of new and renovated households
- *RES_hh_fec_in* - Final energy consumption
- *RES_hh_tes_in* - Thermal energy service
- *RES_hh_iei_in* - Energy service satisfied by infrastructure improvements
- *RES_hh_eff_in* - System efficiency indicator of total stock
- *RES_hh_emi_in* - CO2 emissions
- *RES_hh_fech_in* - Final energy consumption per household
- *RES_hh_tesh_in* - Thermal energy service per household
- *RES_hh_ieih_in* - Energy service satisfied by infrastructure improvements per household
- *RES_hh_emih_in* - CO2 emissions per household
- *RES_hh_fecs_in* - Final energy consumption per surface area
- *RES_hh_tess_in* - Thermal energy service per surface area
- *RES_hh_ieis_in* - Energy service satisfied by infrastructure improvements per surface area
- *RES_hh_emis_in* - CO2 emissions per surface area

Specific electric uses:

- *RES_se-appl* - Residential / specific electric uses
- *RES_RF* - Refrigerators and freezers
- *RES_WM* - Washing machines
- *RES_DR* - Clothes dryers
- *RES_DW* - Dishwashers
- *RES_TV* - TV and multimedia
- *RES_IT* - ICT equipment
- *RES_LI* - Lighting
- *RES_OA* - Other appliances (vacuum cleaners, irons etc.)

Number of households - detailed structure:

- *RES_hhdet_num* - Number of households
- *RES_hhdet_out* - Retired equipment
- *RES_hhdet_in* - New equipment installations
- *RES_hhdet_in_new* - New equipment installations in new and renovated households
- *RES_hhdet_in_repl* - New equipment installations via replacement

Thermal uses - detailed structure:

- *RES_hhdet_fec* - Final energy consumption
- *RES_hhdet_tes* - Thermal energy service
- *RES_hhdet_iei* - Energy service satisfied by infrastructure improvements
- *RES_hhdet_eff* - System efficiency indicator

- *RES_hhdet_emi* - CO2 emissions
- *RES_hhdet_fech* - Final energy consumption per household
- *RES_hhdet_tesh* - Thermal energy service per household
- *RES_hhdet_ieih* - Energy service satisfied by infrastructure improvements per household
- *RES_hhdet_emih* - CO2 emissions per household
- *RES_hhdet_fecs* - Final energy consumption per surface area
- *RES_hhdet_tess* - Thermal energy service per surface area
- *RES_hhdet_ieis* - Energy service satisfied by infrastructure improvements per surface area
- *RES_hhdet_emis* - CO2 emissions per surface area

Thermal uses in new and renovated households - detailed structure:

- *RES_hhdet_in_fec* - Final energy consumption
- *RES_hhdet_in_tes* - Thermal energy service
- *RES_hhdet_in_iei* - Energy service satisfied by infrastructure improvements
- *RES_hhdet_in_eff* - System efficiency indicator
- *RES_hhdet_in_emi* - CO2 emissions
- *RES_hhdet_in_fech* - Final energy consumption per household
- *RES_hhdet_in_tesh* - Thermal energy service per household
- *RES_hhdet_in_ieih* - Energy service satisfied by infrastructure improvements per household
- *RES_hhdet_in_emih* - CO2 emissions per household
- *RES_hhdet_in_fecs* - Final energy consumption per surface area
- *RES_hhdet_in_tess* - Thermal energy service per surface area
- *RES_hhdet_in_ieis* - Energy service satisfied by infrastructure improvements per surface area
- *RES_hhdet_in_emis* - CO2 emissions per surface area

Detailed information by household type:

- *RES_hh_SLD* - Solid households
- *RES_hh_LPG* - LPG households
- *RES_hh_GDO* - Diesel oil households
- *RES_hh_NGS* - Gas households
- *RES_hh_BMS* - Biomass households
- *RES_hh_GEO* - Geothermal households
- *RES_hh_DHT* - Derived heat households
- *RES_hh_AEL* - Advanced electric heating households
- *RES_hh_CEL* - Conventional electric heating households

Tertiary folder files

Central_2018_<*Country*>_ter_yearly.xlsx / Central_2018_<*Country*>_ter_5years.xlsx

Contain the overview of the services, agriculture, forestry and fishing sectors on following sheets:

- *SER_sum_sqm* - Services sector summary - per useful surface area
- *SER_sector* - Services sector energy use
- *SER_appliances* - Services sector specific electric uses
- *SER_costs* - Services sector costs split
- *SER_sum_emp* - Services sector summary - per employee
- *SER_sum_cap* - Services sector summary - per capita
- *SER_sum_rbc* - Services sector summary - per representative building cell

- *SER_sum_va* - Services sector summary - per value added
- *AGR* - Agriculture, forestry and fishing

Central_2018_<*Country*>_ter_det_yearly.xlsx / Central_2018_<*Country*>_ter_det_5years.xlsx

Contain detailed results of the services, agriculture, forestry and fishing sectors on the following sheets:

- *SER_summary* - Services sector summary

Services sector: Thermal uses:

- *SER_hh_num* - Number of buildings
- *SER_hh_fec* - Final energy consumption
- *SER_hh_tes* - Thermal energy service
- *SER_hh_iei* - Energy service satisfied by infrastructure improvements
- *SER_hh_eff* - System efficiency indicator of total stock
- *SER_hh_emi* - CO2 emissions
- *SER_hh_fech* - Final energy consumption per building
- *SER_hh_tesh* - Thermal energy service per building
- *SER_hh_ieih* - Energy service satisfied by infrastructure improvements per building
- *SER_hh_emih* - CO2 emissions per building
- *SER_hh_fecs* - Final energy consumption per useful surface area
- *SER_hh_tess* - Thermal energy service per useful surface area
- *SER_hh_ieis* - Energy service satisfied by infrastructure improvements per useful surface area
- *SER_hh_emis* - CO2 emissions per useful surface area

Services sector: Thermal uses in new and renovated buildings -

- *SER_hh_num_in* - Number of new and renovated buildings
- *SER_hh_fec_in* - Final energy consumption
- *SER_hh_tes_in* - Thermal energy service
- *SER_hh_iei_in* - Energy service satisfied by infrastructure improvements
- *SER_hh_eff_in* - System efficiency indicator of total stock
- *SER_hh_emi_in* - CO2 emissions
- *SER_hh_fech_in* - Final energy consumption per building
- *SER_hh_tesh_in* - Thermal energy service per building
- *SER_hh_ieih_in* - Energy service satisfied by infrastructure improvements per building
- *SER_hh_emih_in* - CO2 emissions per building
- *SER_hh_fecs_in* - Final energy consumption per useful surface area
- *SER_hh_tess_in* - Thermal energy service per useful surface area
- *SER_hh_ieis_in* - Energy service satisfied by infrastructure improvements per useful surface area
- *SER_hh_emis_in* - CO2 emissions per useful surface area

Services sector: Specific electric uses:

- *SER_se-appl* - Specific electric uses in services
- *SER_VE* - Ventilation and others
- *SER_SL* - Street lighting
- *SER_BL* - Building lighting
- *SER_CR* - Commercial refrigeration
- *SER_BT* - Miscellaneous building technologies
- *SER_IT* - ICT and multimedia

Agriculture:

- *AGR* - Agriculture sector summary
- *AGR_fec* - detailed split of final energy consumption
- *AGR_ued* - detailed split of useful energy demand
- *AGR_emi* - detailed split of CO2 emissions

Transport folder files

Central_2018_<*Country*>_tra_yearly.xlsx / Central_2018_<*Country*>_tra_5years.xlsx

Contain the overview of the results of the transport sectors and bunkers on the following sheets:

- *TRA_Passenger* - Passenger transport - Overview
- *TRA_Freight* - Freight transport - Overview
- *TRA_Totals* - Freight transport - Aggregated results
- *TRA_Road_Act* - Road transport / activity and cost data
- *TRA_Road_EnEm* - Road transport / energy and emission data
- *TRA_Rail_Act* - Rail, metro and tram / activity and cost data
- *TRA_Rail_EnEm* - Rail, metro and tram / energy and emission data
- *TRA_Avia_Act* - Aviation / activity and cost data
- *TRA_Avia_EnEm* - Aviation / energy and emission data
- *TRA_Navi_Act* - Coastal shipping and inland waterways / activity and cost data
- *TRA_Navi_EnEm* - Coastal shipping and inland waterways / energy and emission data
- *TRA_Bunk_Act* - Bunkers / activity and cost data
- *TRA_Bunk_EnEm* - Bunkers / energy and emission data

Central_2018_<*Country*>_tra_det_yearly.xlsx / Central_2018_<*Country*>_tra_det_5years.xlsx

Contain the detailed results of the transport sectors and bunkers on following sheets:

- *TRA_Summary* - Transport sector overview
- *TRA_Activity* - Activity indicators (passenger/tonne kms)
- *TRA_Vkm* - Vehicle-km driven
- *TRA_Energy* - Total energy consumption
- *TRA_Fuels* - Total energy consumption by fuels
- *TRA_Co2Emissions* - Total CO2 emissions
- *TRA_PkmCo* - Energy related costs per passenger/tonne km
- *TRA_PkmCoTot* - Total energy related costs per passenger/tonne km
- *TRA_Stock* - Stock of vehicles (operational)
- *TRA_StockTot* - Stock of vehicles (total)
- *TRA_Inv* - New vehicle registrations
- *TRA_ReplNrr* - Normal replacement of vehicles
- *TRA_ReplPmr* - Premature replacement of vehicles
- *TRA_VEff* - Vehicle-efficiencies / stock
- *TRA_VEffInv* - Vehicle-efficiencies / new vehicles
- *TRA_EnergyInt* - Energy consumption per activity
- *TRA_Co2EmissionsVkm* - Emission intensity: CO2 emissions per vehicle-km
- *TRA_Co2EmissionsInt* - Emission intensity: CO2 emissions per activity
- *TRA_ShareActivity* - Market shares of activity

- *TRA_ShareEnergy* - Shares of total energy consumption
- *TRA_ShareCo2Emissions* - Shares of total CO2 emissions
- *TRA_AnCo* - Annual energy related costs per vehicle
- *TRA_AnCoTot* - Total annual energy related costs per vehicle
- *TRA_AnCoY* - Annual energy related costs
- *TRA_AnCoTotY* - Total annual energy related costs

PowerGeneration folder files

Central_2018_<*Country*>_pg_yearly.xlsx / Central_2018_<*Country*>_pg_5years.xlsx

Central_2018_<*Country*>_pg_det_yearly.xlsx / Central_2018_<*Country*>_pg_det_5years.xlsx

Contain the scenario results of the power sector on the following sheets, with the latter file providing data at a more detailed technology level:

Power plants:

- *Gross Capacities* - Gross capacities installed (MW)
- *Net Capacities* - Net capacities installed (MW)
- *Number of Units* - Number of units Installed
- *Unit Size* - Average unit size of installed capacities (MW net)
- *Gross Capacities Decommissioned* - Gross capacities decommissioned (MW)
- *Net Capacities Decommissioned* - Net capacities decommissioned (MW)
- *Number of Units Decommissioned* - Number of units decommissioned
- *Unit Size Decommissioned* - Average unit size of decommissioned capacities (MW net)
- *Gross Capacities Investment* - Gross capacities investment (MW)
- *Net Capacities Investment* - Net capacities investment (MW)
- *Number of Units Investment* - Number of units invested
- *Unit Size Investment* - Average unit size of new investments (MW net)

Annual operating characteristics:

- *Electricity Balance* - Electricity balance (GWh)
- *Steam Balance* - Steam balance (GWh)
- *Net Generation load* - Net generation load (GW) on an hourly basis for the representative day
- *Gross Electricity Generation* - Gross electricity generation (GWh)
- *Net Electricity Generation* - Net electricity generation (GWh)
- *Operating Hours* - Average operating hours
- *Rate of Use* - Rate of use
- *Steam Generation* - Steam generation (GWh)
- *Steam to Electricity ratio* - Steam to electricity ratio (net generation) - includes CHP plants operating in electricity generation mode
- *Gross Generation Efficiency* - Gross electricity generation efficiencies
- *Net Generation Efficiency* - Net electricity generation efficiencies
- *Transformation input Total* - Transformation input / Exchanges and transfers (ktoe) -Incl. dispatching inoptimalities effects
- *CO2 emissions* - CO2 emissions (kt CO2)
- *CO2 emissions captured* - CO2 emissions captured (kt CO2)
- *System Costs* - System costs (in million € 2010)
- *Unit Costs* - Unit costs (in € 2010 per MWh net)

Representative day operating characteristics:

- *Net Capacities in Operation* - Net capacities in operation - representative day (MW)
- *Number of Units in Operation* - Number of units in operation - representative day
- *Idle Capacities* - Idle capacities - representative day (MW)
- *Number of Idle Units* - Number of idle units - representative day
- *Operating Hours RD* - Effective operating hours - representative day

EnergyBalances folder file

Central_2018_<*Country*>_bal_yearly.xlsx / Central_2018_<*Country*>_bal_5years.xlsx

Contain the detailed energy balances on the following sheets:

- GIC - Gross inland consumption
- *TITOT* - Transformation input
- *tipgn* - Transformation input - Nuclear power stations
- *tipgt* - Transformation input - Conventional thermal power stations
- *tipgtele* - Transformation input - Electricity-only plants
- *tipgtchp* - Transformation input - CHP plants
- *tipgel* - Transformation input - Used for electricity generation
- *tidh* - Transformation input - District heating plants
- *tirf* - Transformation input - Refineries
- *tick* - Transformation input - Coke ovens
- *tibf* - Transformation input - Blast furnaces
- *tigw* - Transformation input - Gas works
- *tipf* - Transformation input - Patent fuel plants
- *tibr* - Transformation input - BKB / PB plants
- *ticl* - Transformation input - Coal liquefaction plants
- *tibg* - Transformation input - For blended natural gas
- *tigl* - Transformation input - Gas-to-liquids (GTL) plants
- *tich* - Transformation input - Charcoal production plants
- *TOTOT* - Transformation output
- *topgn* - Transformation output - Nuclear power stations
- *topgt* - Transformation output - Conventional thermal power stations
- *topgtele* - Transformation output - Electricity-only plants
- *topgtchp* - Transformation output - CHP plants
- *todh* - Transformation output - District heating plants
- *torf* - Transformation output - Refineries
- *tock* - Transformation output - Coke ovens
- *tobf* - Transformation output - Blast furnaces
- *togw* - Transformation output - Gas works
- *topf* - Transformation output - Patent fuel plants
- *tobr* - Transformation output - BKB / PB plants
- *toch* - Transformation output - Charcoal production plants
- *TRANS* - Exchanges, transfers, returns
- *transpg* - Exchanges in electricity generation
- *transos* - Exchanges, transfers, returns of liquid fuels
- *transint* - Interproduct transfers

- *transptr* - Products transferred
- *transret* - Returns from petrochemical industry
- *CEN* - Consumption in Energy sector
- *cenpdel* - Own Use in Electricity, CHP and Heat plants
- *cenpuel* - Pumped storage power stations balance
- *tipuel* - Transformation input - Pumped storage
- *topuel* - Transformation output - Pumped storage
- *cenos* - Consumption in Energy sectors except power generation
- *cenrf* - Consumption in Petroleum refineries
- *cenpren* - Consumption in Primary energy production sectors
- *cenisb* - Consumption in Coke ovens and Blast Furnace
- *cenoth* - Consumption in Other energy branches
- *cenh2* - Consumption in Hydrogen production (energy)
- *LOS* - Distribution losses
- *AVFCO* - Energy Available for Final Consumption
- *CFNEN* - Final Non-energy Consumption
- *nech* - Non-energy use in the Chemical industry
- *neos* - Non-energy uses in Other sectors
- *CFENE* - Final energy consumption
- *CFIND* - Final energy consumption - Industry
- *isi* - Iron and Steel
- *isb* - Iron and Steel - Integrated steelworks
- *ise* - Iron and Steel - Electric arc
- *isd* - Iron and Steel - Direct Reduced Iron (DRI) and Iron ore (EAF)
- *isa* - Iron and Steel - Alkaline electrolysis
- *nfm* - Non-ferrous metals
- *nfa* - Alumina production
- *nfp* - Aluminium production - Primary
- *nfs* - Aluminium production - Secondary
- *nfo* - Other non-ferrous metals
- *chi* - Chemical and Petrochemical
- *bch* - Basic chemicals
- *och* - Other chemicals
- *pha* - Pharmaceutical products
- *nmm* - Non-metallic minerals
- *cem* - Cement
- *cer* - Ceramics & other non-metallic minerals
- *gla* - Glass production
- *ppa* - Paper, Pulp and Print
- *pul* - Pulp production
- *pap* - Paper production
- *prp* - Printing and reproduction of recorded media
- *fbt* - Food, beverages and tobacco
- *tre* - Transport equipment
- *mae* - Machinery equipment

- *tel* - Textile and leather
- *wwp* - Wood and wood products
- *ois* - Other industrial sectors
- *CFDOM* - Final energy consumption - Residential, Services, Agriculture
- *res* - Residential
- *rsh* - Residential: Space heating
- *rsc* - Residential: Space cooling
- *rwh* - Residential: Water heating
- *rco* - Residential: Cooking
- *rch* - Residential: Complementary heating
- *rli* - Residential: Household lighting
- *rrf* - Residential: Refrigerators and freezers
- *rwm* - Residential: Washing machines
- *rdr* - Residential: Clothes dryers
- *rdw* - Residential: Dishwashers
- *rtv* - Residential: TV and multimedia
- *rit* - Residential: ICT equipment
- *roa* - Residential: Other appliances
- *ser* - Services
- *ssh* - Services: Space heating
- *ssc* - Services: Space cooling
- *shw* - Services: Hot water services
- *sca* - Services: Catering
- *svo* - Services: Ventilation and others
- *ssl* - Services: Street lighting
- *sbl* - Services: Building lighting
- *scr* - Services: Commercial refrigeration
- *sbt* - Services: Miscellaneous building technologies
- *sim* - Services: ICT and multimedia
- *agr* - Agriculture, Forestry and Fishing
- *CFTRA* - Final energy consumption - Transport
- *tro* - Road transport
- *p2w* - Road transport - Powered 2-wheelers
- *car* - Road transport - Private cars
- *bus* - Road transport - Buses and coaches
- *lcv* - Road transport - Light commercial vehicles
- *hdd* - Road transport - Heavy duty vehicles - Domestic
- *hdi* - Road transport - Heavy duty vehicles - International
- *tra* - Rail transport
- *rtp* - Rail transport - Conventional passenger transport
- *rth* - Rail transport - High speed
- *rtm* - Rail transport - Metro
- *rtf* - Rail transport - Conventional freight transport
- *tav* - Aviation
- *apd* - Domestic aviation

- *api* - Intra-EU passenger aviation
- *ape* - Extra-EU passenger aviation
- *afi* - Intra-EU freight aviation
- *afe* - Extra-EU freight aviation
- *nav* - Domestic navigation
- *ncs* - Domestic coastal shipping
- *niw* - Inland waterways
- *cpi* - Consumption in Pipeline transport
- *STDIF* - Statistical Difference

Year_spec_reports folder file

Central_2018_<*Country*>_ctsl.xlsx

Contains a snapshot of the representative day for a selectable year

- *Year_Summary* - All charts with direct year selection
- *Demand* - Total electricity demand
- *Generation* - Electricity generation by power plants
- *Supply* - Electricity supply
- *SupplySel* - Electricity supply of selected plant type
- *Costs* - Power generation hourly costs

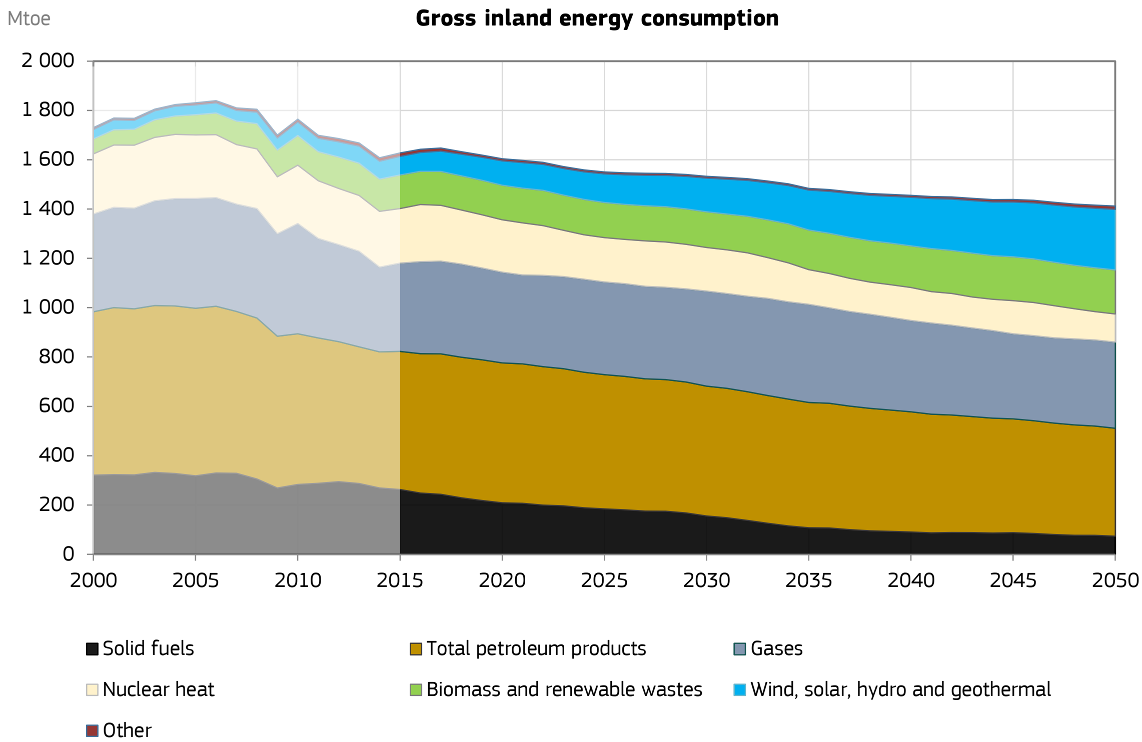
Annex 2. Summary of Central scenario results at EU level and by Member State

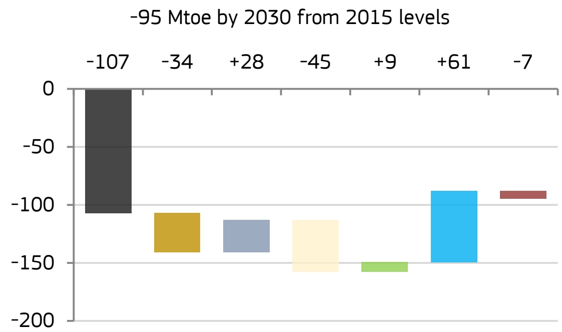
POTEnCIA - Model results overview

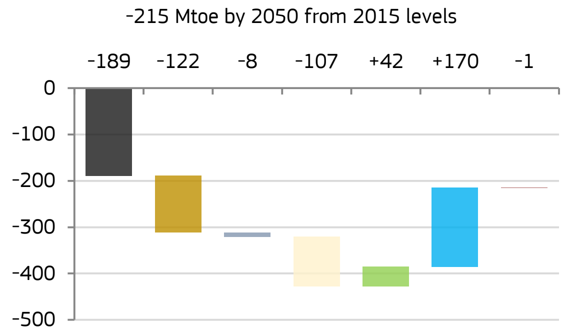
European Union

Central_2018 scenario

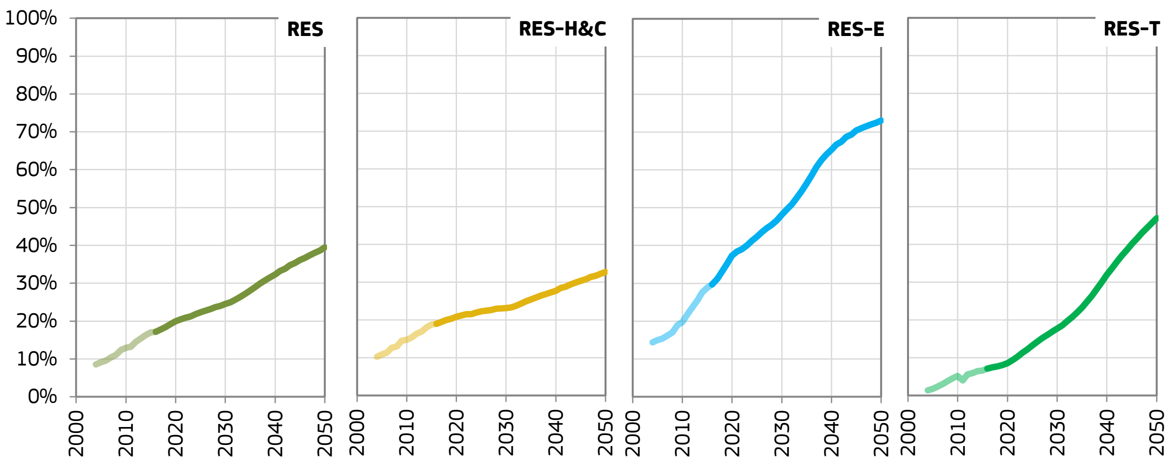
Gross inland energy consumption

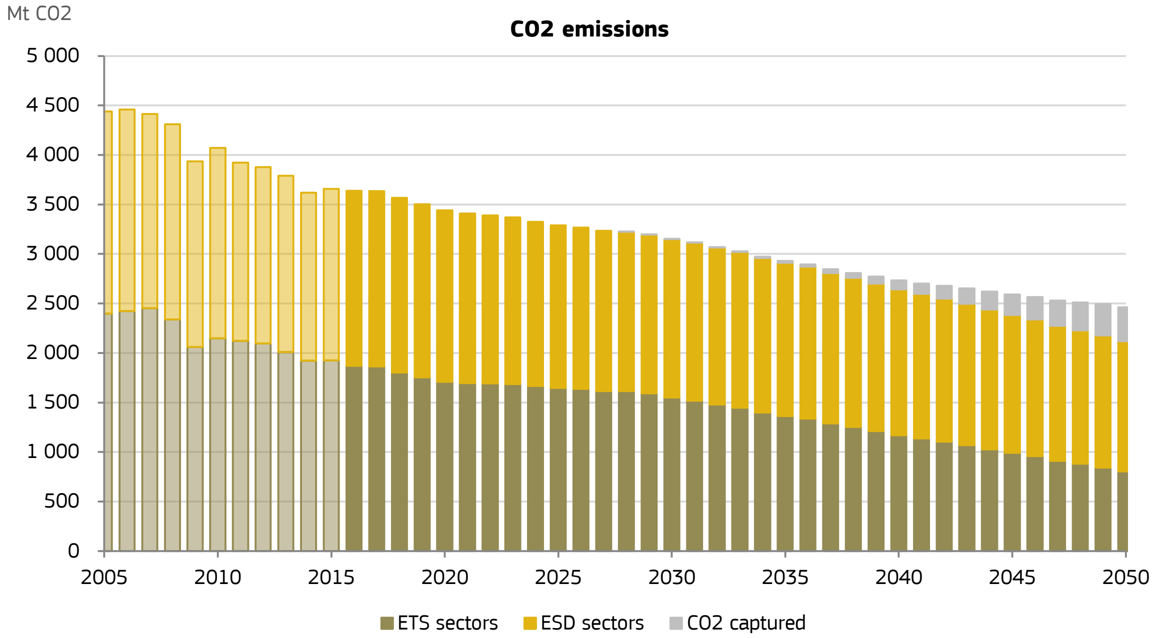


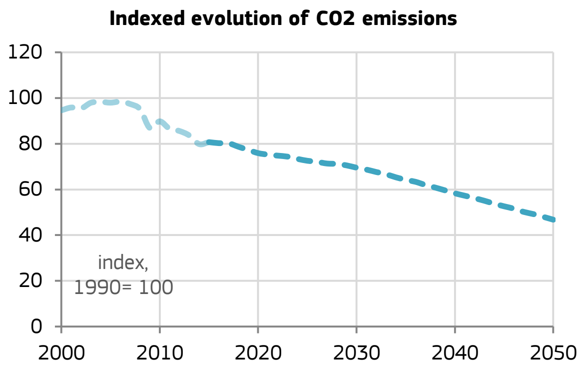


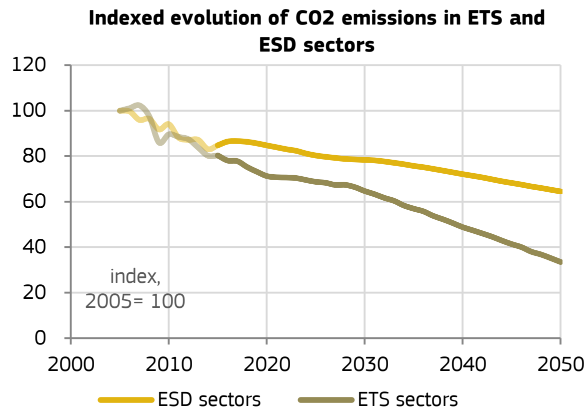


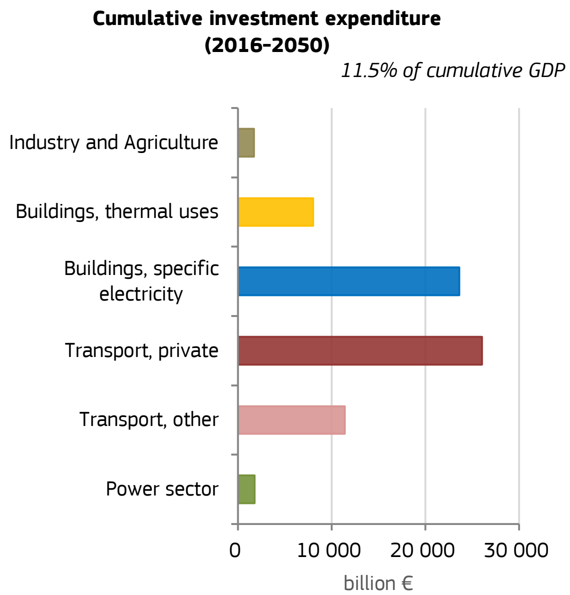
Share of renewable energies

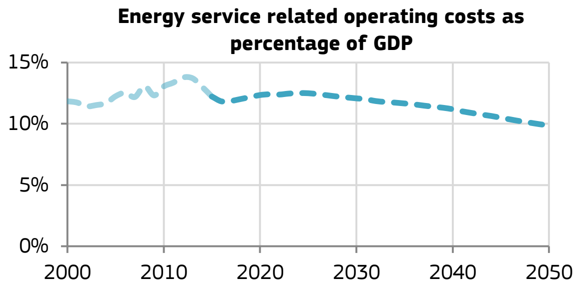


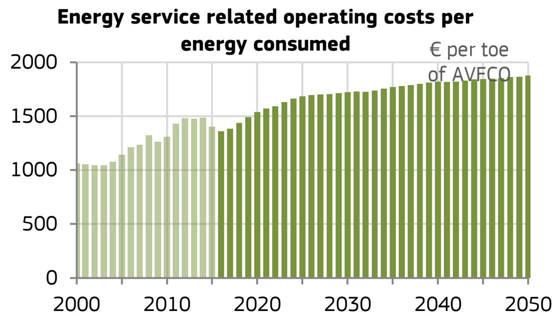

Mt CO2
CO2 emissions
5 000
4 500
4 000
3 500
3 000
2 500
2 000
1 500
1 000
500
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured

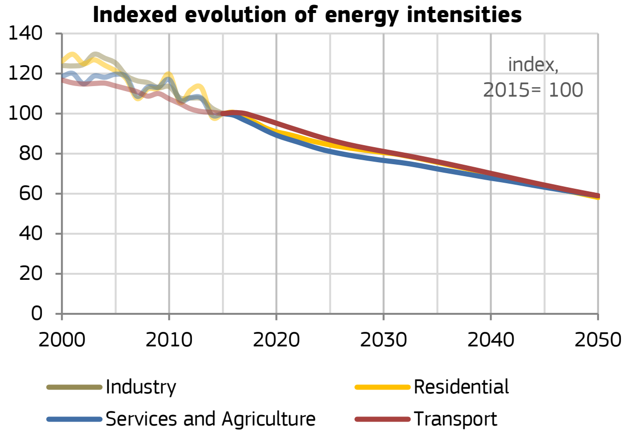

Indexed evolution of CO2 emissions
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

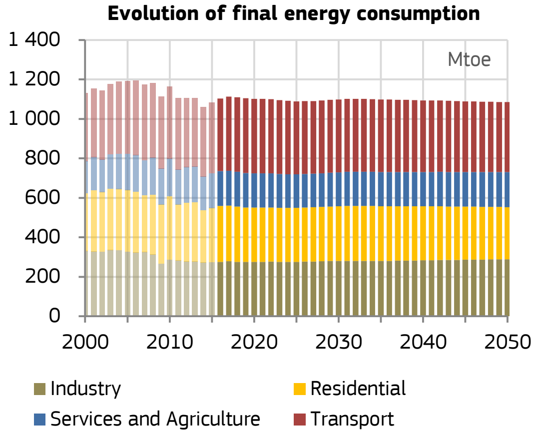

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors

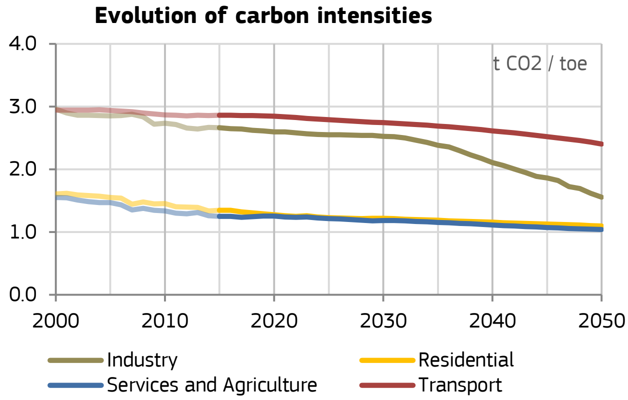

Cumulative investment expenditure (2016-2050)
11.5% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
10 000
20 000
30 000
billion €

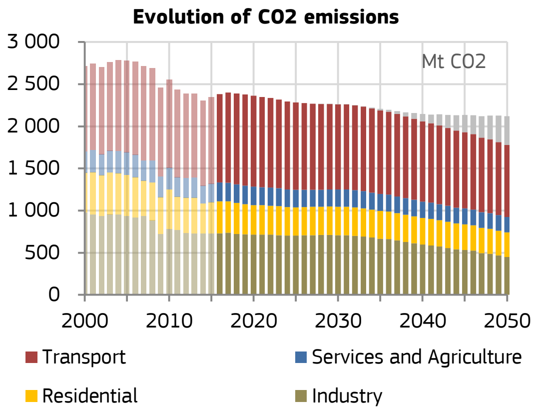

Energy service related operating costs as percentage of GDP
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050

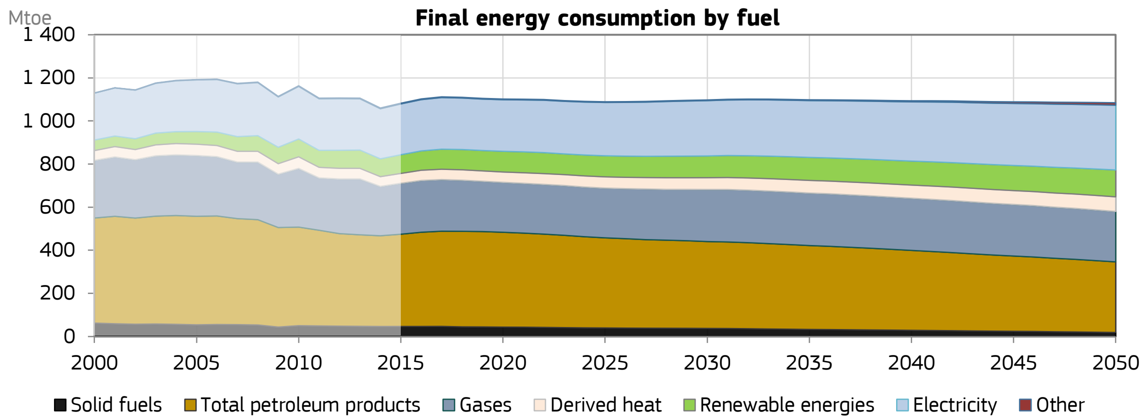

Energy service related operating costs per energy consumed
€ per toe of AVECO
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

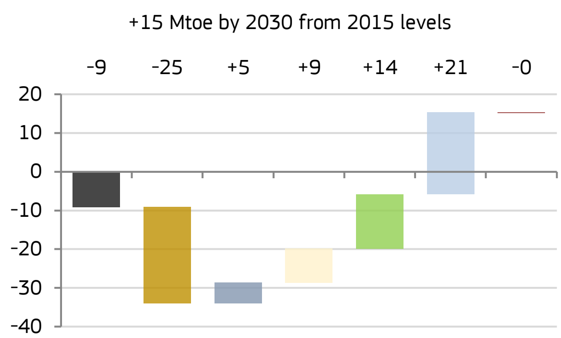

Indexed evolution of energy intensities
index, 2015= 100
140
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

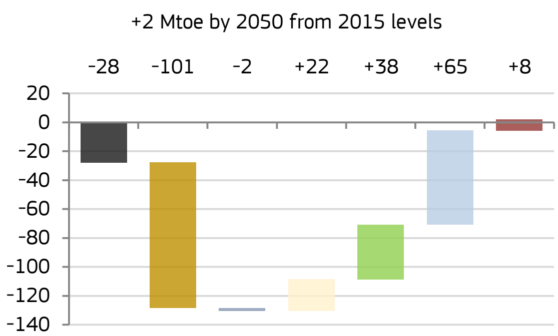

Evolution of final energy consumption
Mtoe
1 400
1 200
1 000
800
600
400
200
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

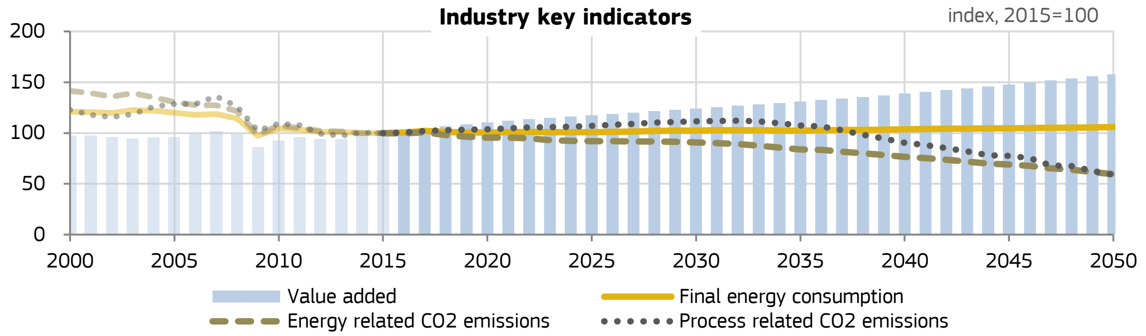

Evolution of carbon intensities
t CO2 / toe
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

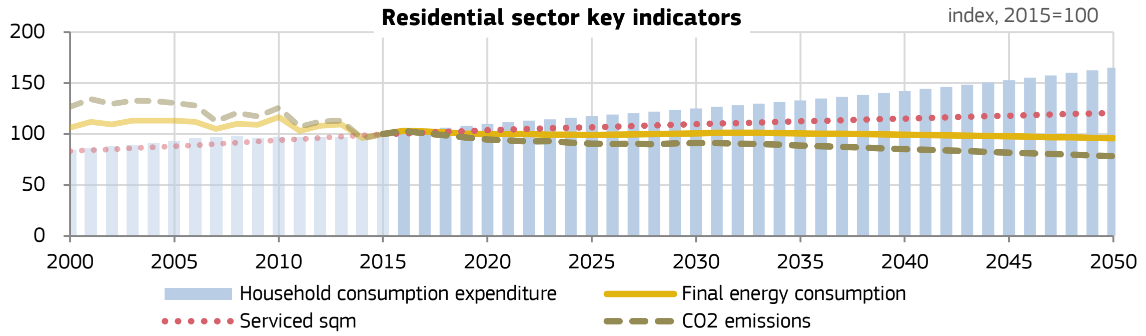

Evolution of CO2 emissions
Mt CO2
3 000
2 500
2 000
1 500
1 000
500
0
2000
2010
2020
2030
2040
2050
Transport
Services and Agriculture
Residential
Industry

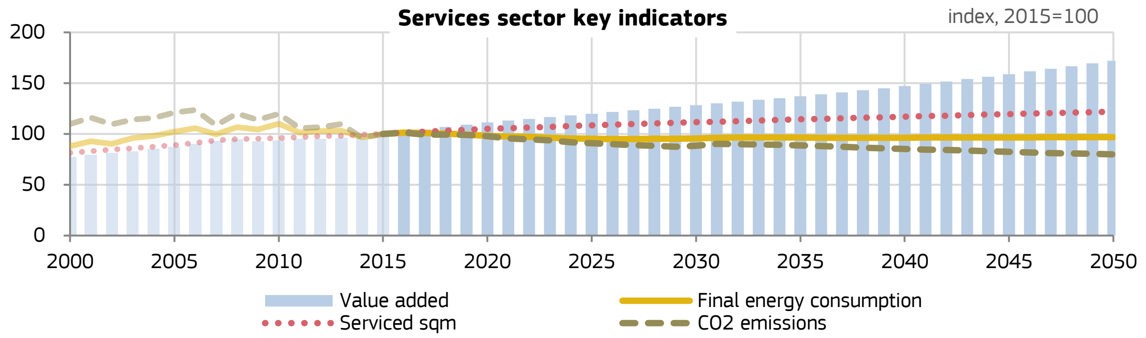

Final energy consumption by fuel
Mtoe
1 400
1 200
1 000
800
600
400
200
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

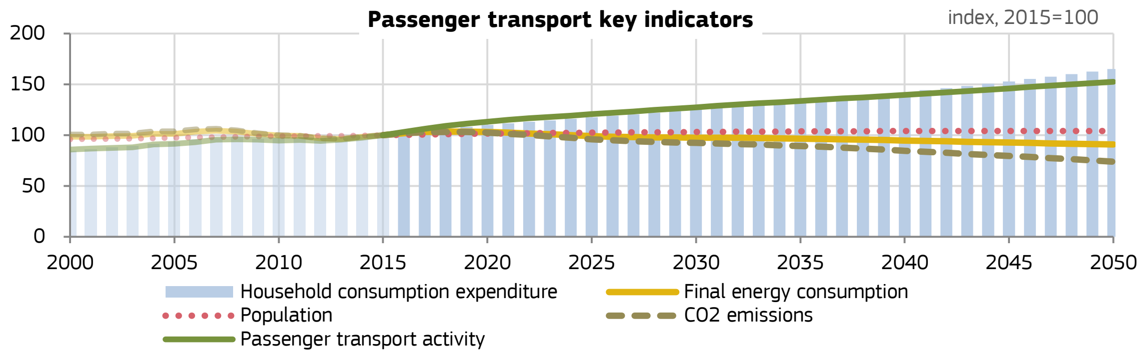

+15 Mtoe by 2030 from 2015 levels
-9
-25
+5
+9
+14
+21
-0
20
10
0
-10
-20
-30
-40

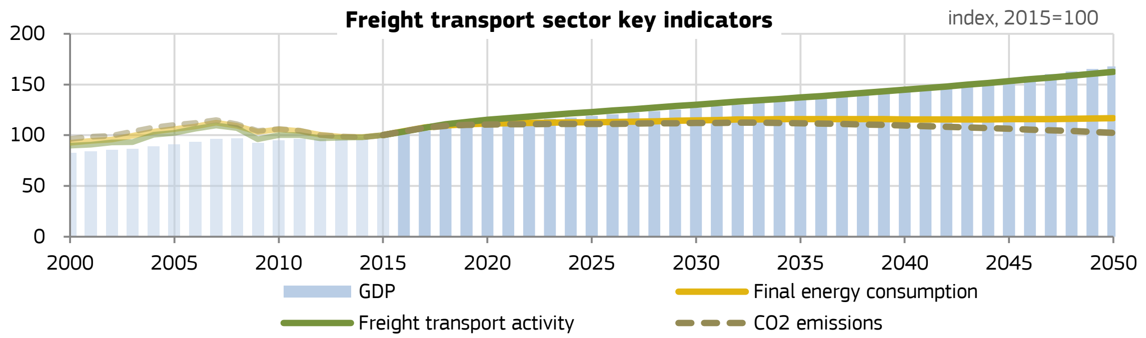

+2 Mtoe by 2050 from 2015 levels
-28
-101
-2
+22
+38
+65
+8
20
0
-20
-40
-60
-80
-100
-120
-140


Industry key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

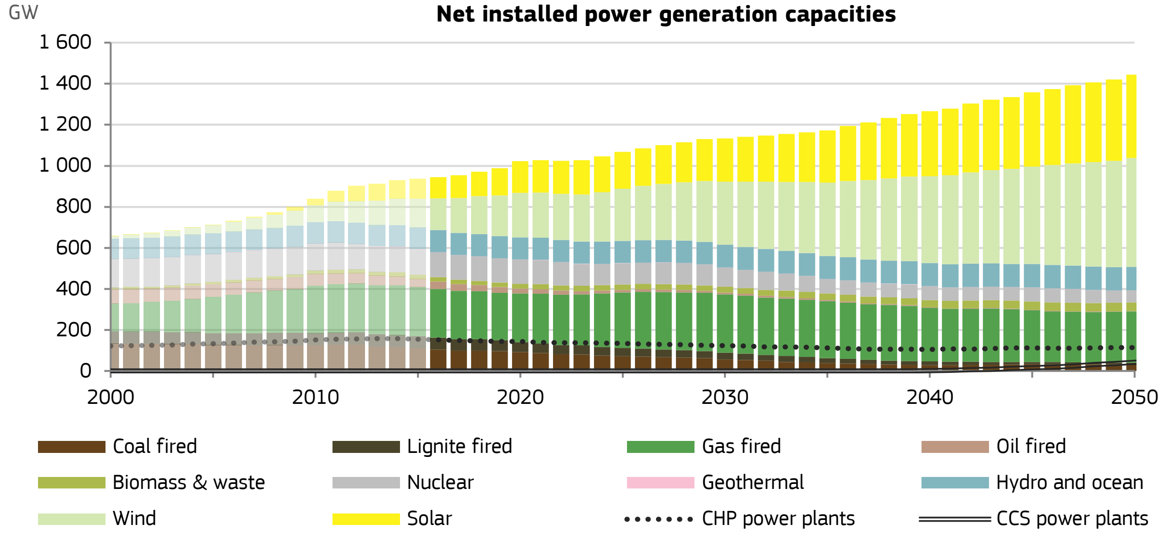

Residential sector key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions


Services sector key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

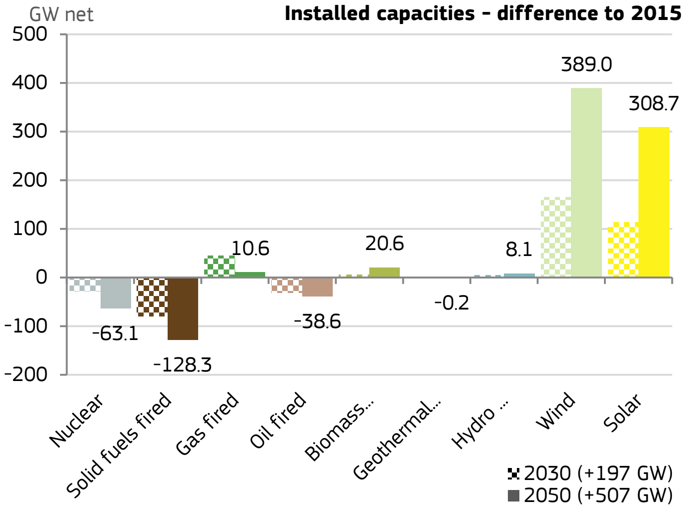

Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity


Freight transport sector key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

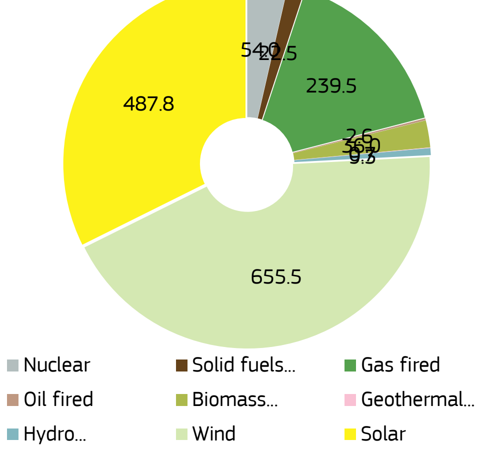
Net installed power generation capacities



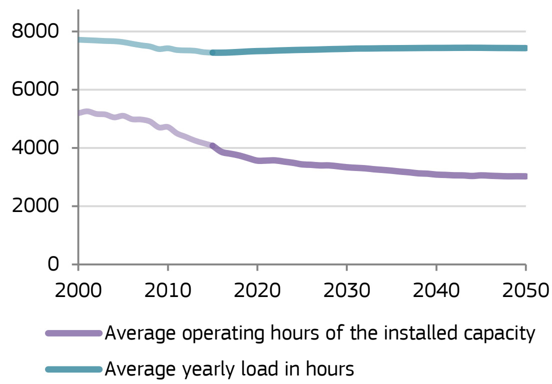
Installed capacities - difference to 2015



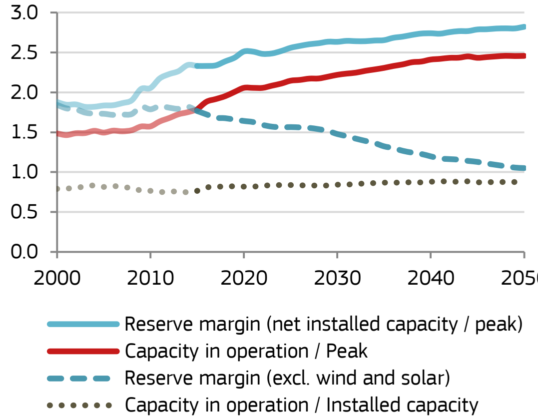
Cumulative investment 2016-2050 GW net



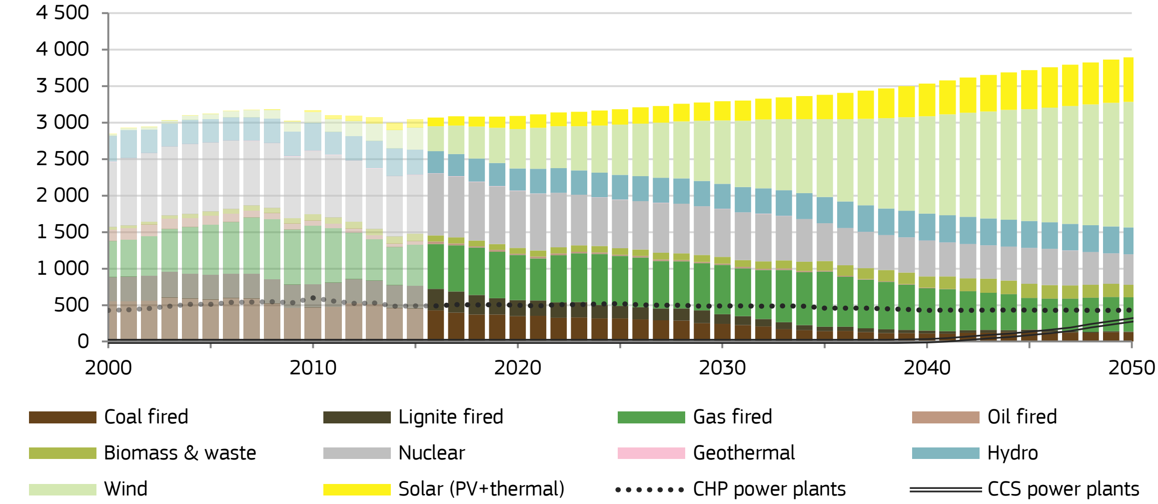
Operational characteristics

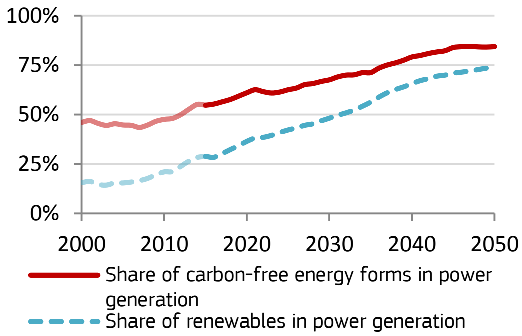


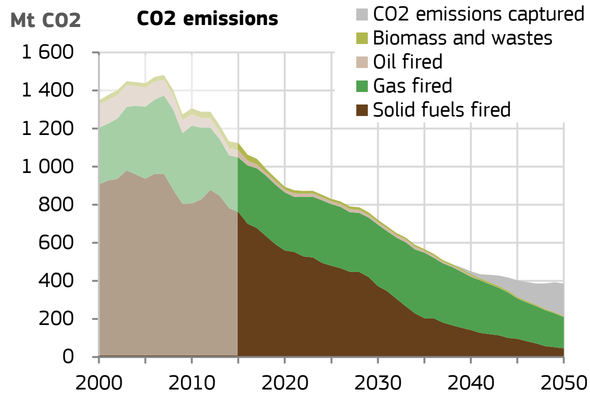
Power system indicators for the representative day

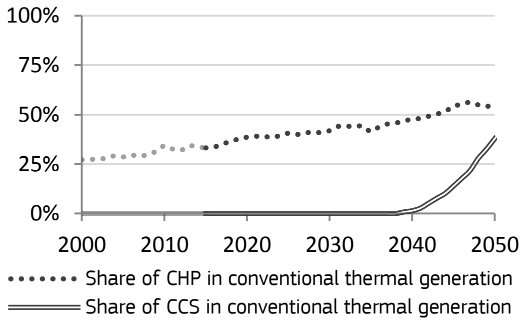


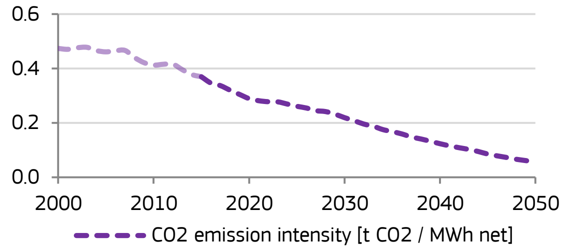
Net electricity generation



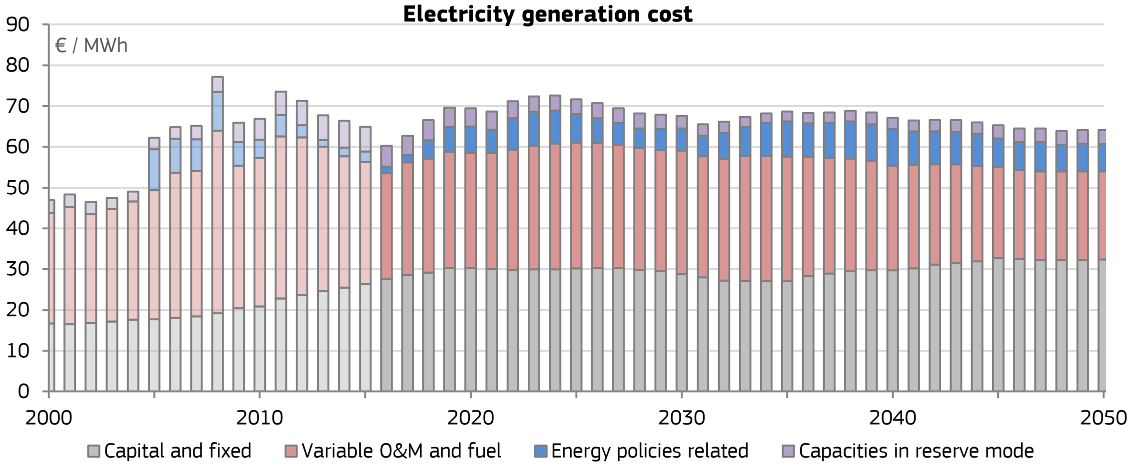


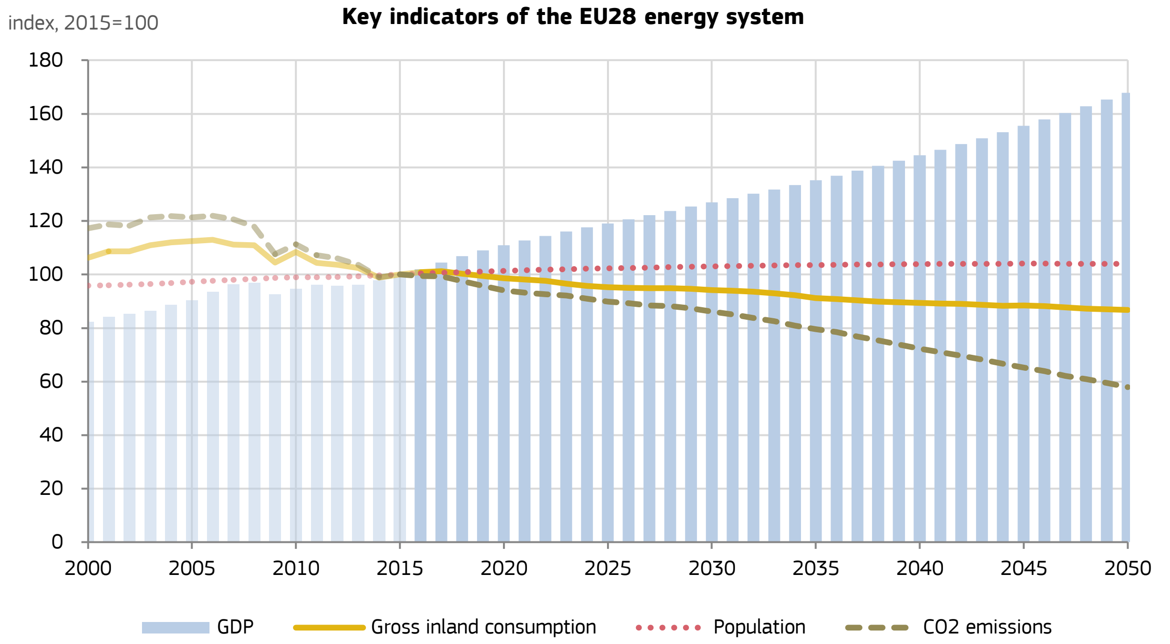




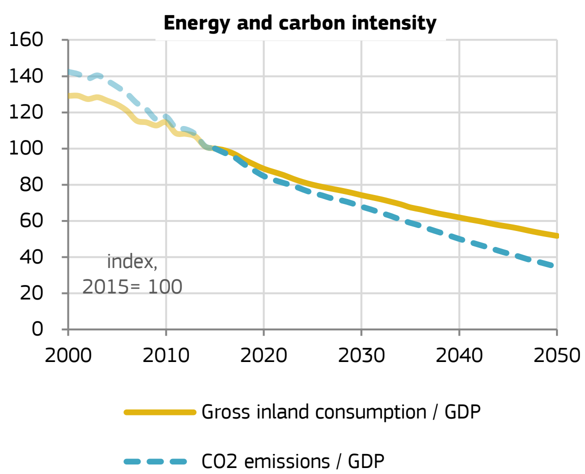


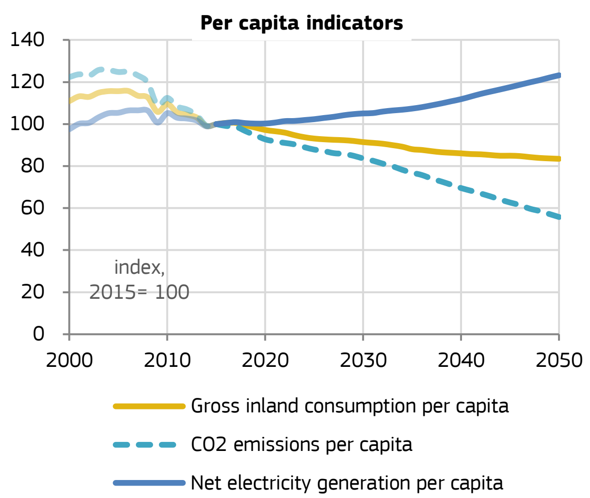
Electricity generation cost





Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	1083	1192	1083	1102	1098	1085
Primary energy consumption [Mtoe]	1569	1713	1529	1499	1424	1303
RES [%] - Share of energy from renewable sources		9.1%	17.0%	20.0%	24.5%	39.5%
RES-E [%] - Share of electricity from renewable sources		15.0%	28.9%	37.4%	48.1%	73.0%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	4534	4440	3658	3440	3151	2121
reduction to 1990		*-2%*	*-19%*	*-24%*	*-30%*	*-53%*
Emissions in current ETS sectors |(EU28) [Mt CO2]		2396	1925	1708	1550	802
reduction to 2005			*-20%*	*-29%*	*-35%*	*-67%*
Emissions in current ESD sectors [Mt CO2]		2044	1733	1732	1602	1318
reduction to 2005			*-15%*	*-15%*	*-22%*	*-35%*

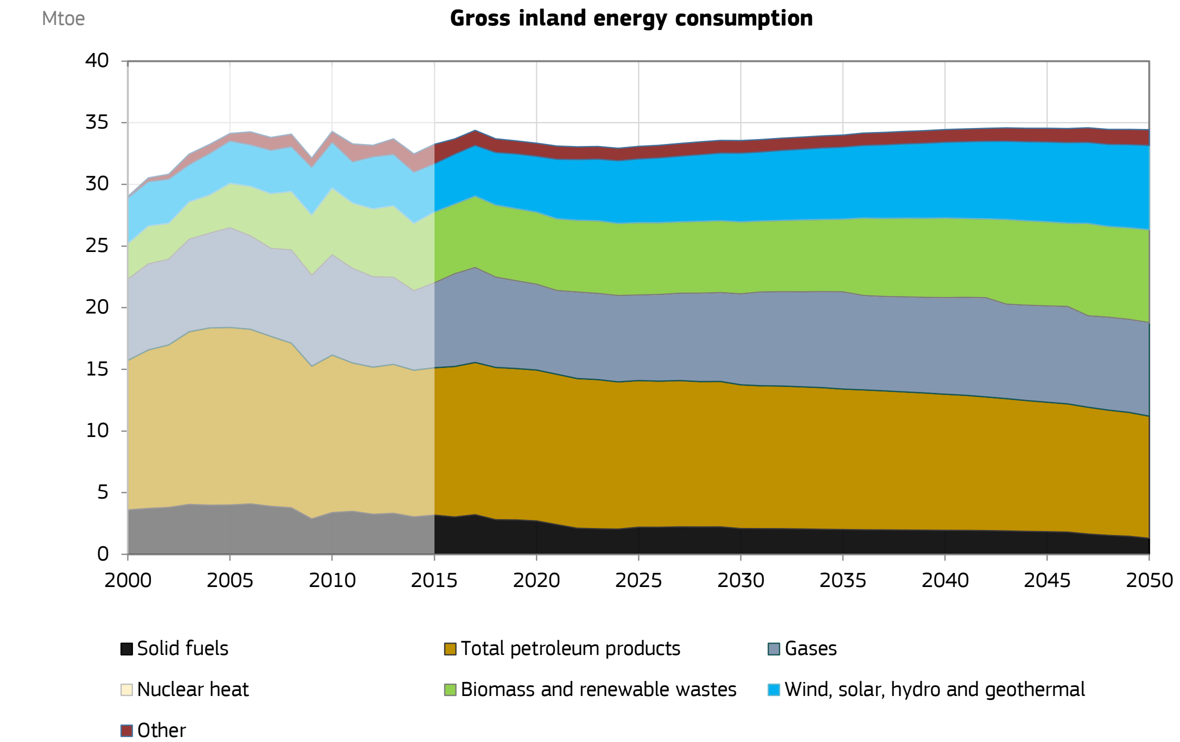


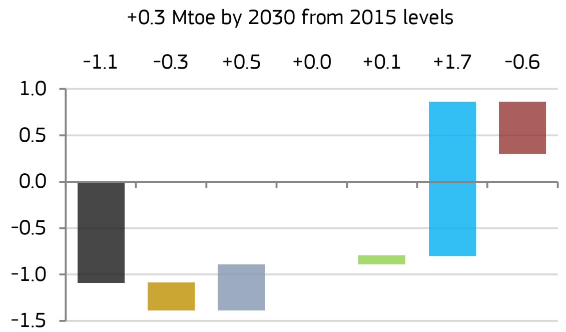


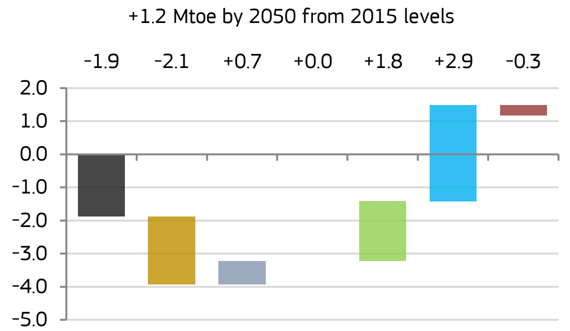
Austria

Central_2018 scenario

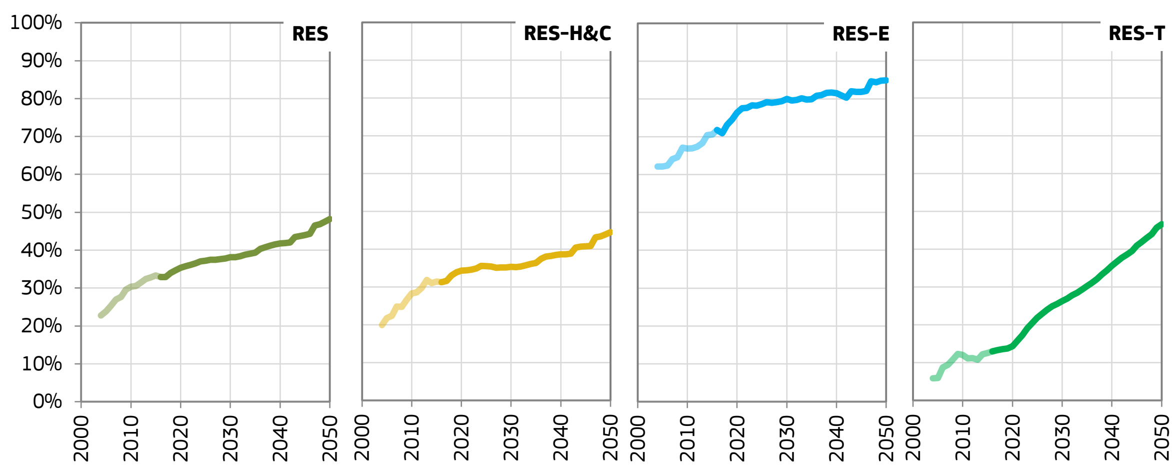
Gross inland energy consumption

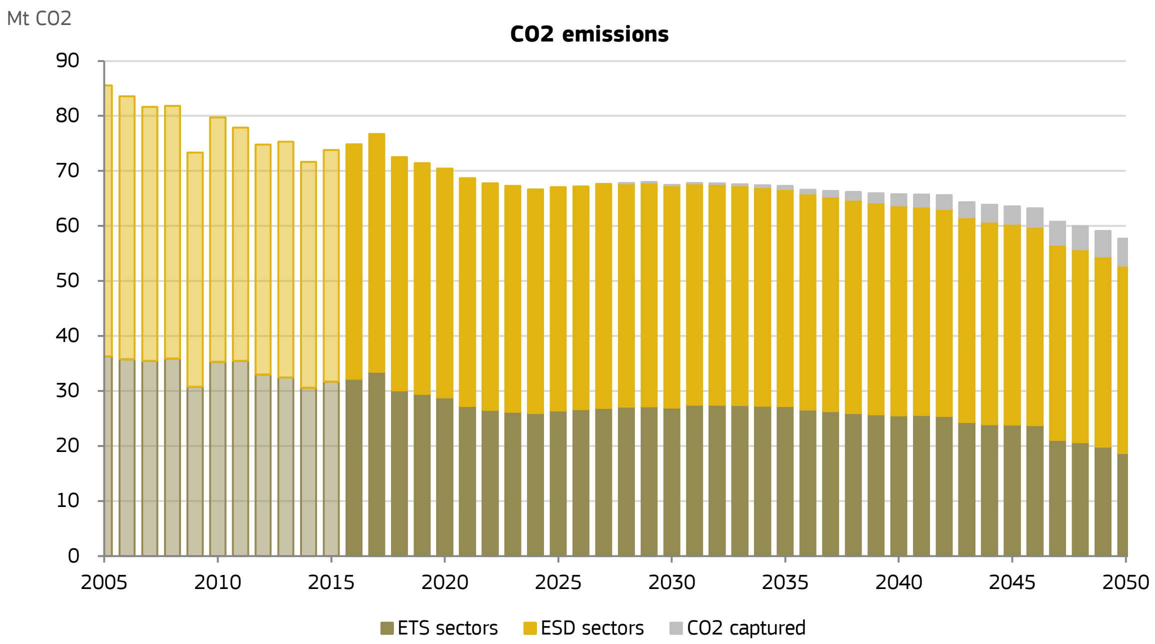


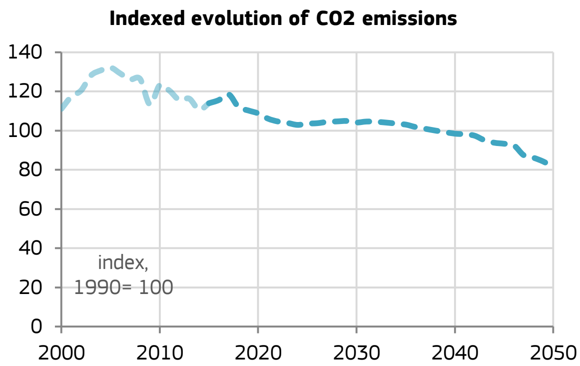


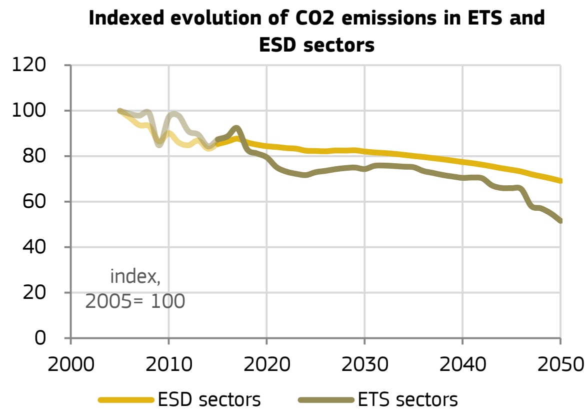


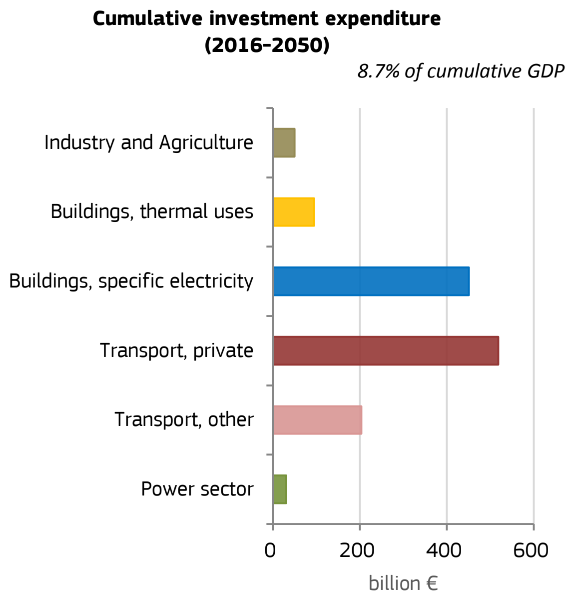
Share of renewable energies

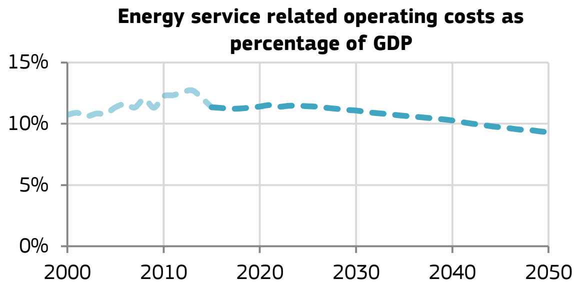


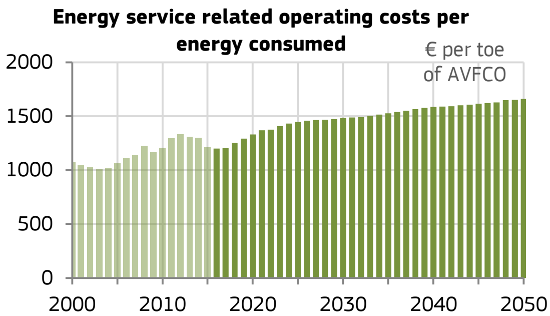

Mt CO2
CO2 emissions
90
80
70
60
50
40
30
20
10
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured

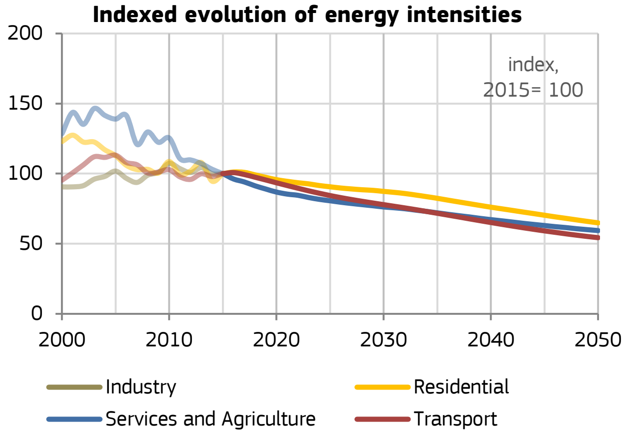

Indexed evolution of CO2 emissions
140
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

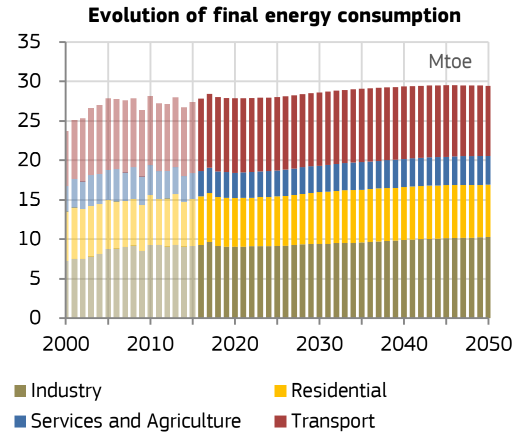

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors

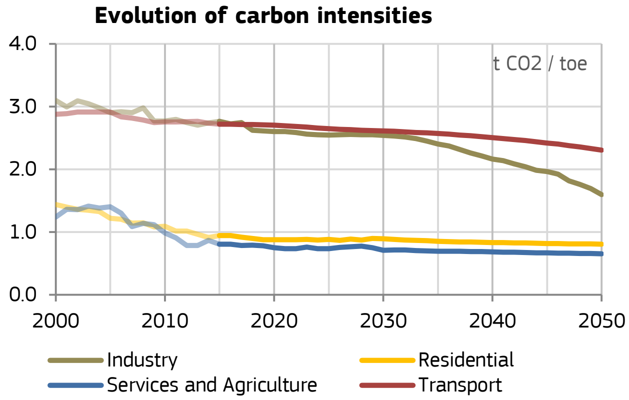

Cumulative investment expenditure (2016-2050)
8.7% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
200
400
600
billion €

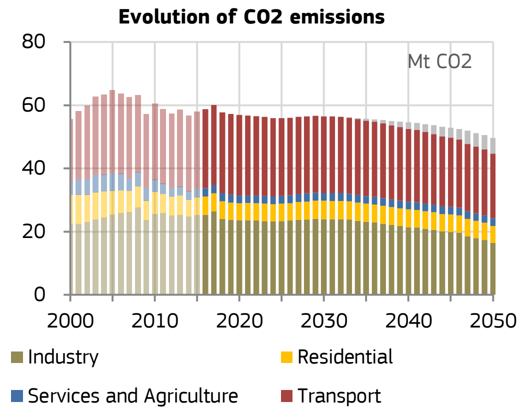

Energy service related operating costs as percentage of GDP
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050

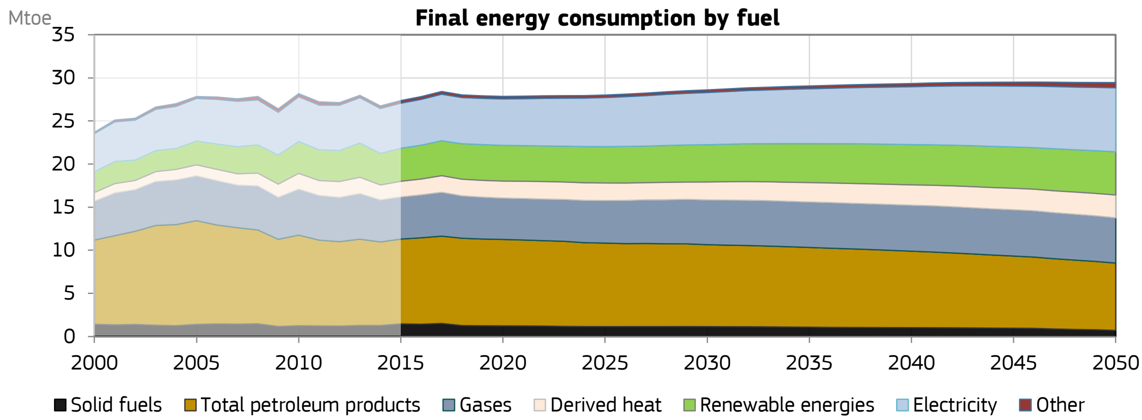

Energy service related operating costs per energy consumed
€ per toe of AVFCO
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

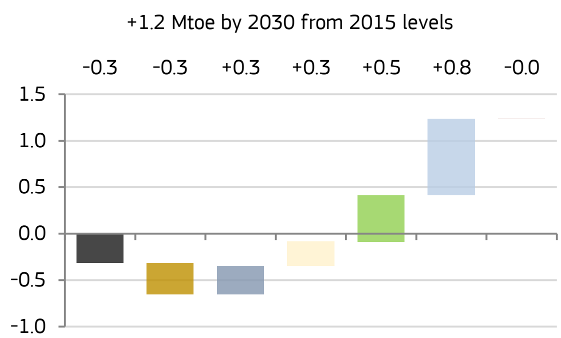

Indexed evolution of energy intensities
index,
2015= 100
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

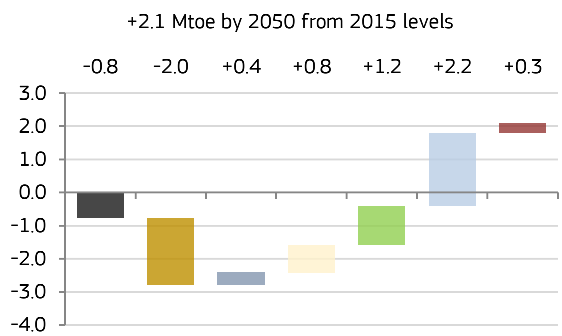

Evolution of final energy consumption
Mtoe
35
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

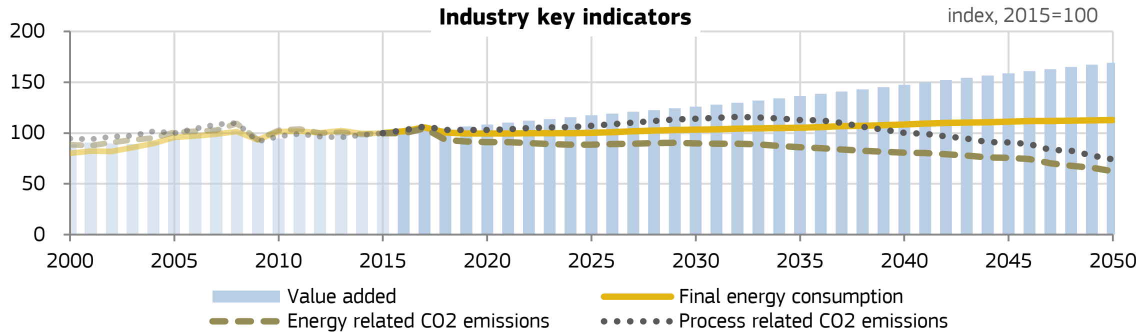

Evolution of carbon intensities
t CO2 / toe
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

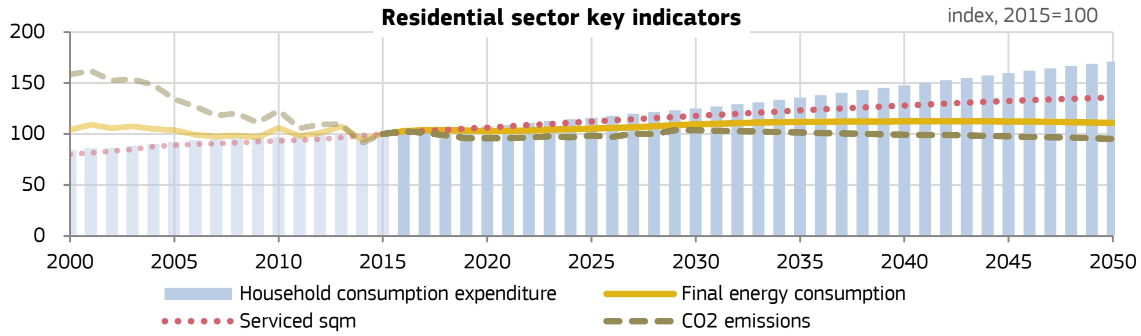

Evolution of CO2 emissions
Mt CO2
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

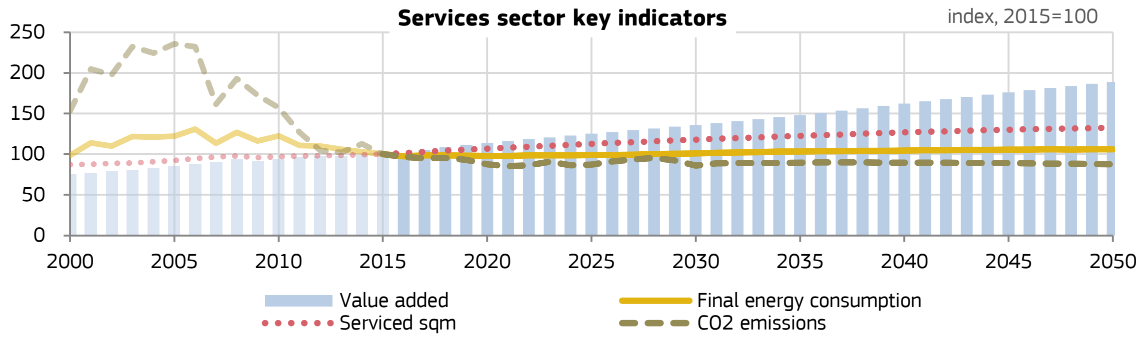

Mtoe
Final energy consumption by fuel
35
30
25
20
15
10
5
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

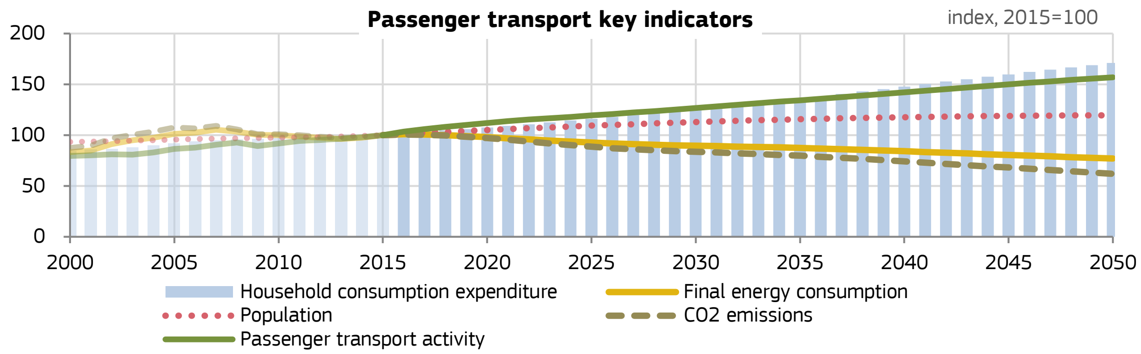

+1.2 Mtoe by 2030 from 2015 levels
-0.3
-0.3
+0.3
+0.3
+0.5
+0.8
-0.0
1.5
1.0
0.5
0.0
-0.5
-1.0

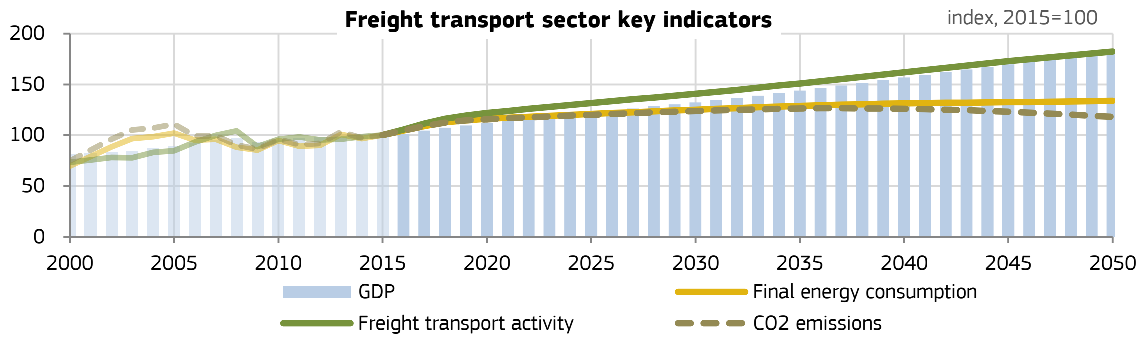

+2.1 Mtoe by 2050 from 2015 levels
-0.8
-2.0
+0.4
+0.8
+1.2
+2.2
+0.3
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0

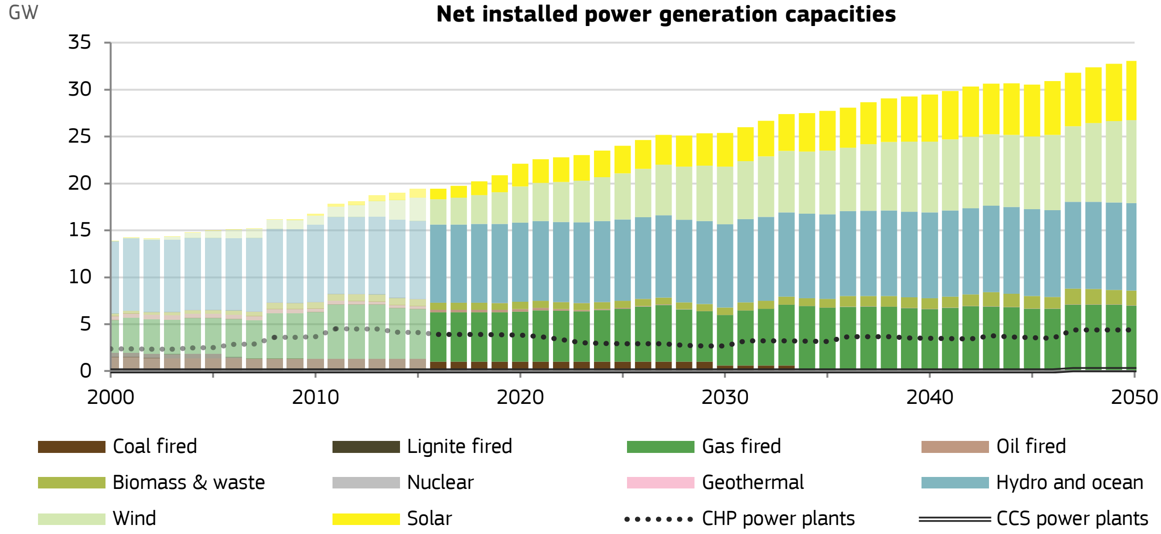

Industry key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

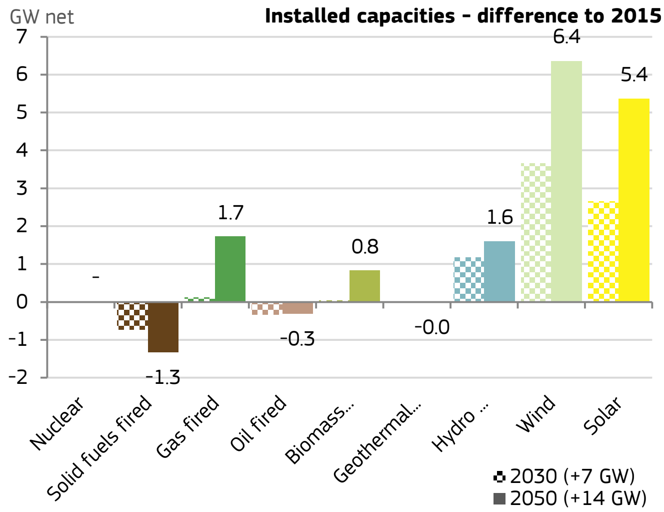

Residential sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

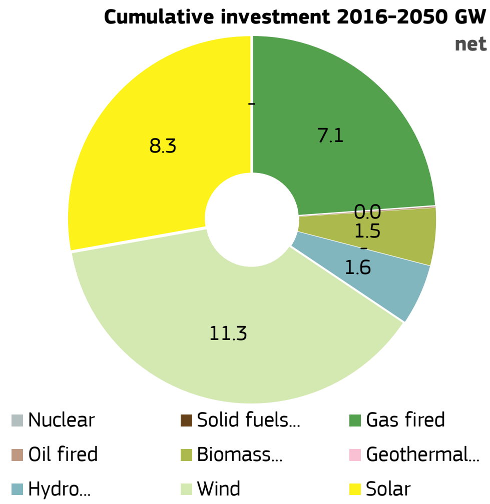

Services sector key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

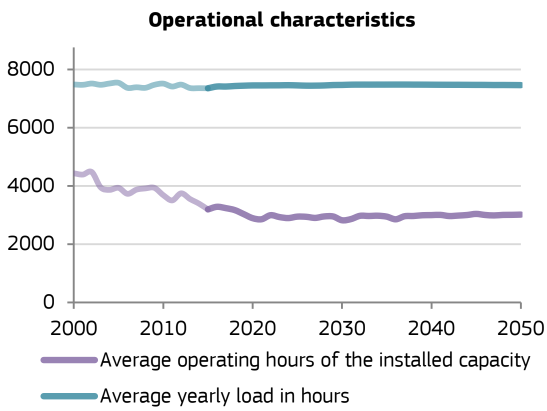

Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

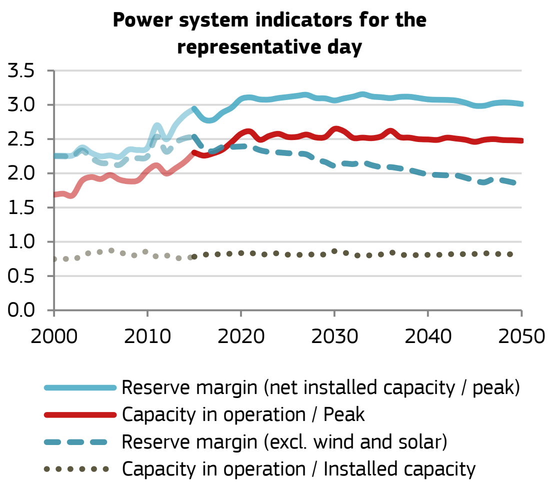

Freight transport sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

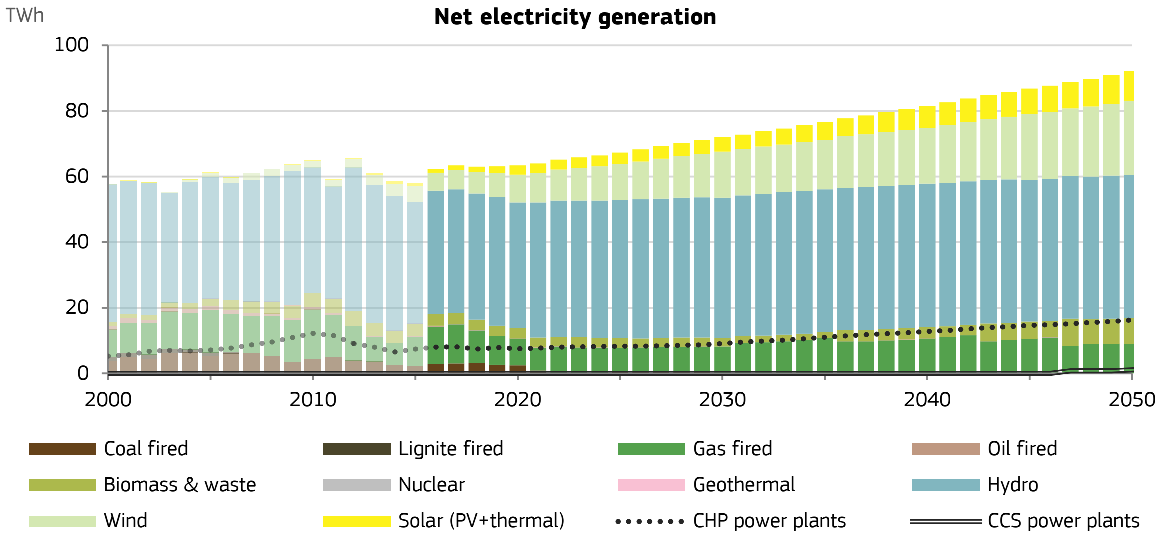

Net installed power generation capacities
GW
35
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

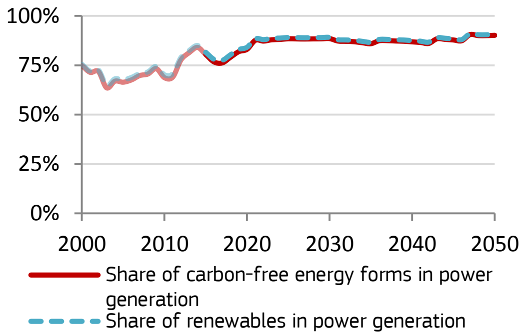

Installed capacities - difference to 2015
GW net
7
6
5
4
3
2
1
0
-1
-2
-
-1.3
1.7
-0.3
0.8
-0.0
1.6
6.4
5.4
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+7 GW)
2050 (+14 GW)

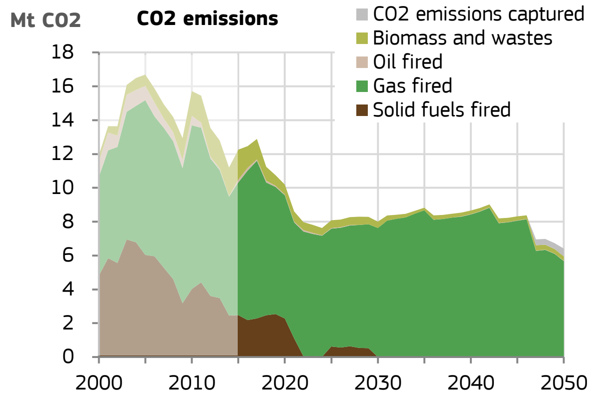

Cumulative investment 2016-2050 GW net
-
7.1
0.0
1.5
-
1.6
11.3
8.3
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

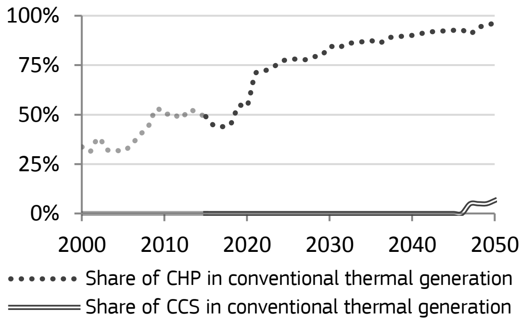

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

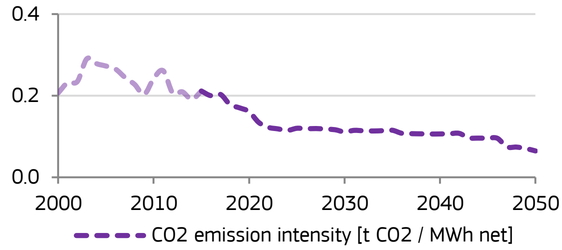

Power system indicators for the representative day
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

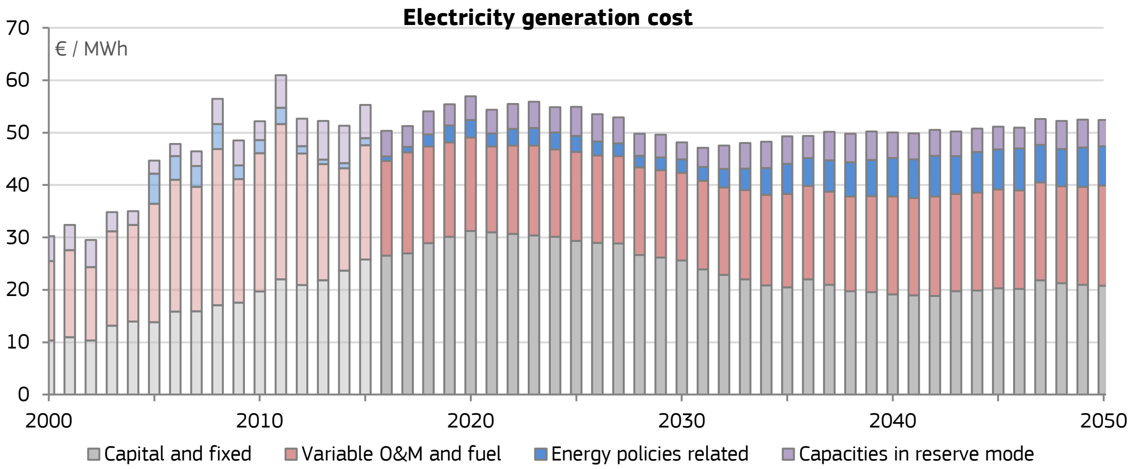

TWh
Net electricity generation
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

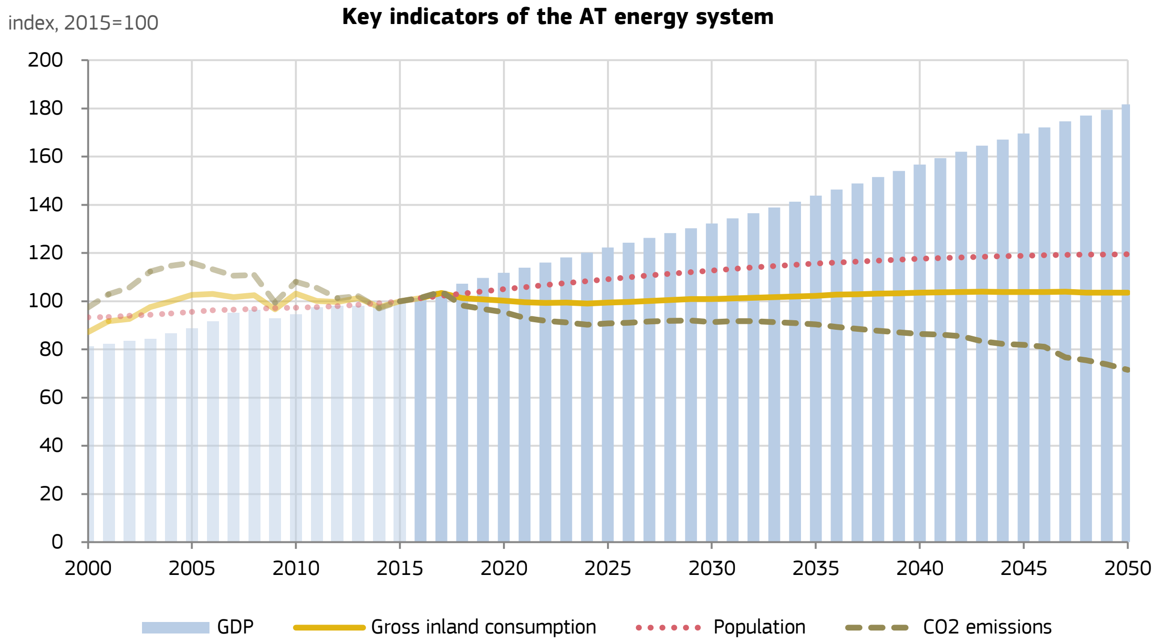

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
18
16
14
12
10
8
6
4
2
0
2000
2010
2020
2030
2040
2050

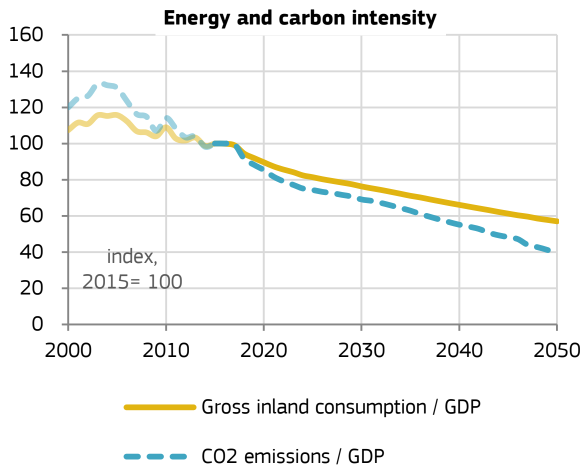

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

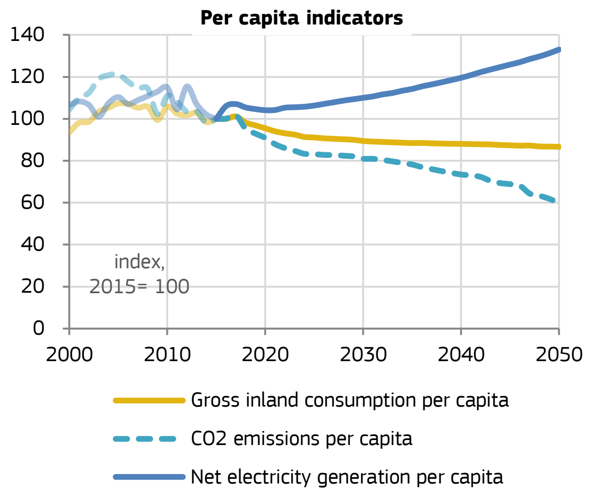

0.4
0.2
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	19.3	27.8	27.4	27.9	28.6	29.5
Primary energy consumption [Mtoe]	23.4	32.4	31.3	31.2	31.3	32.1
RES [%] - Share of energy from renewable sources		23.9%	33.3%	35.4%	38.1%	48.2%
RES-E [%] - Share of electricity from renewable sources		62.1%	70.6%	76.4%	80.0%	84.9%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	64.7	85.6	73.8	70.4	67.4	52.8
reduction to 1990		*32%*	*14%*	*9%*	*4%*	*-18%*
Emissions in current ETS sectors |(AT) [Mt CO2]		36.3	31.7	28.8	27.0	18.7
reduction to 2005			*-13%*	*-20%*	*-26%*	*-48%*
Emissions in current ESD sectors [Mt CO2]		49.3	42.1	41.6	40.5	34.1
reduction to 2005			*-15%*	*-16%*	*-18%*	*-31%*



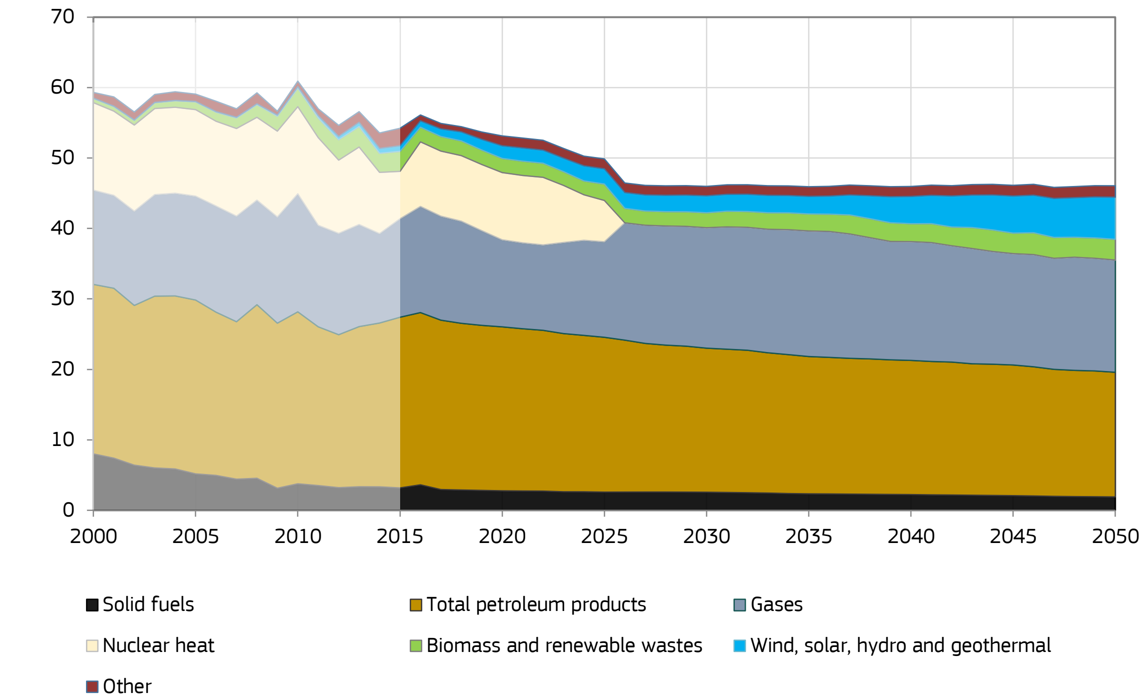


POTEnCIA - Model results overview

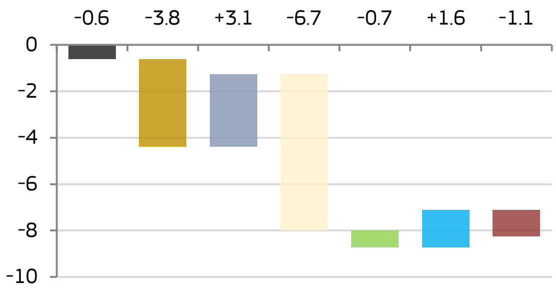
Belgium

Central_2018 scenario

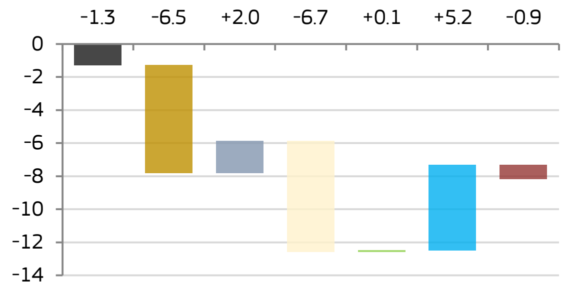
Gross inland energy consumption



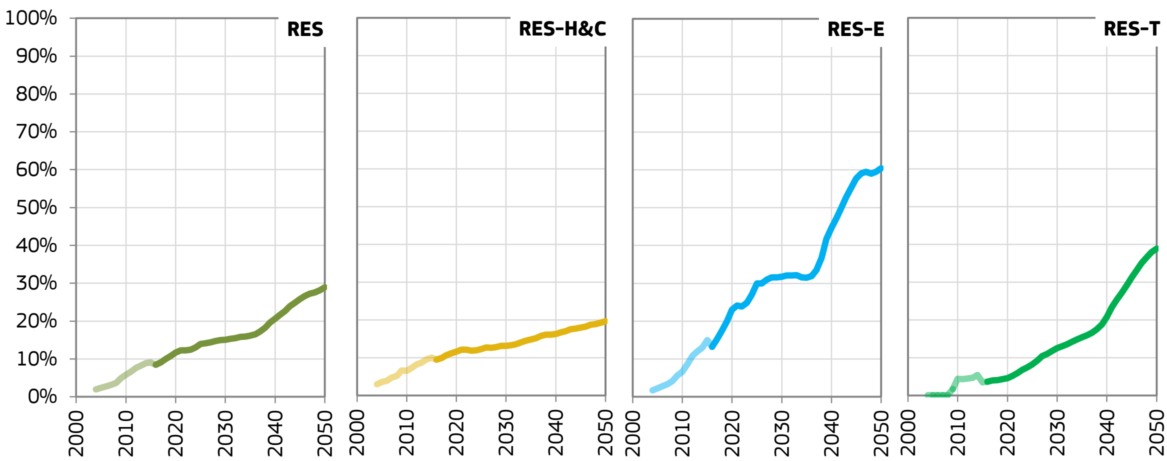
-8.2 Mtoe by 2030 from 2015 levels

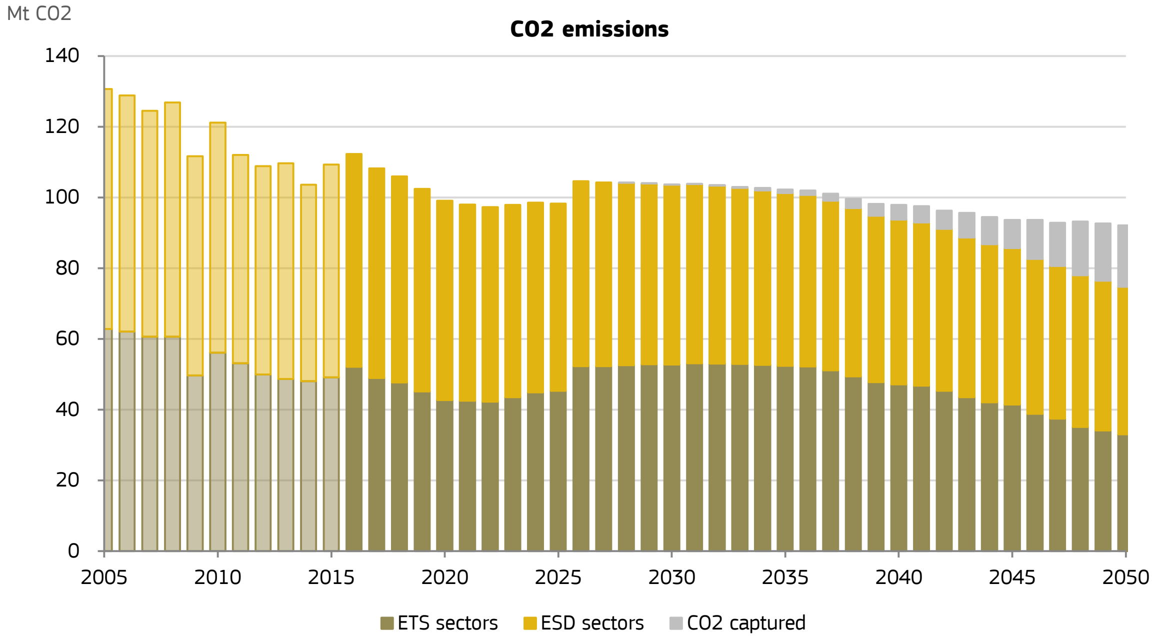


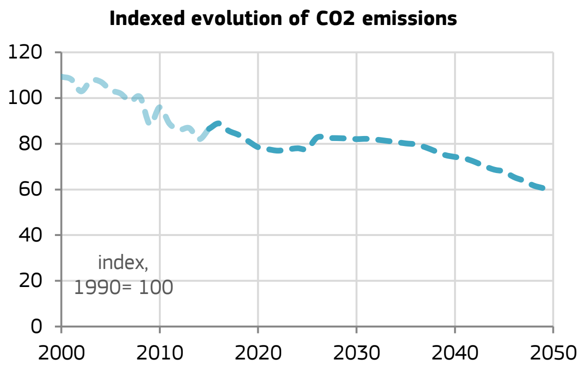
-8.2 Mtoe by 2050 from 2015 levels

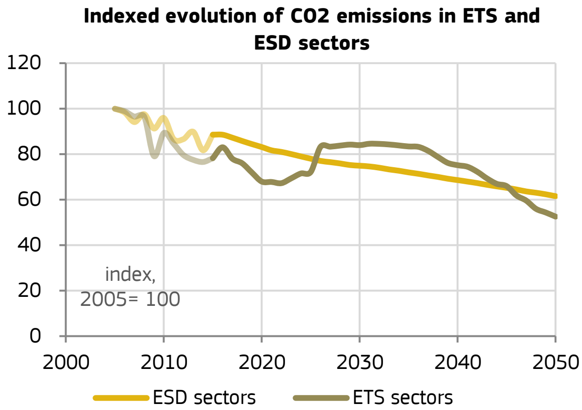


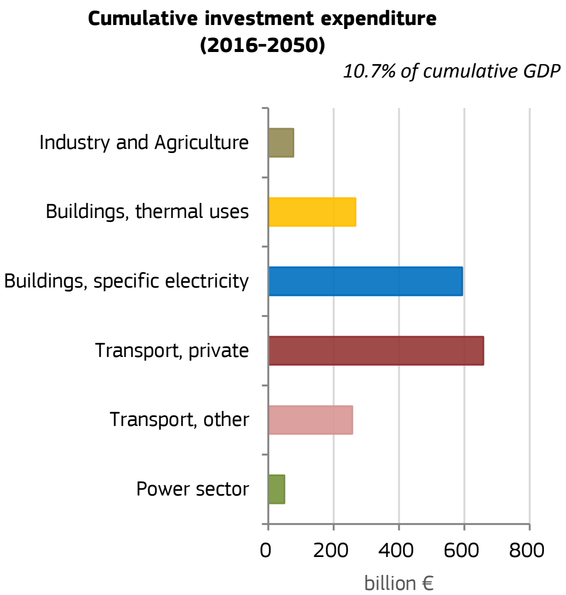
Share of renewable energies

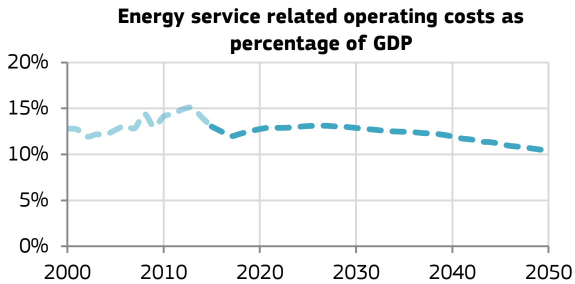


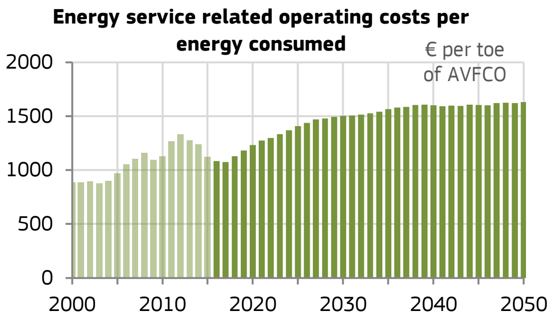

Mt CO2
CO2 emissions
140
120
100
80
60
40
20
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured

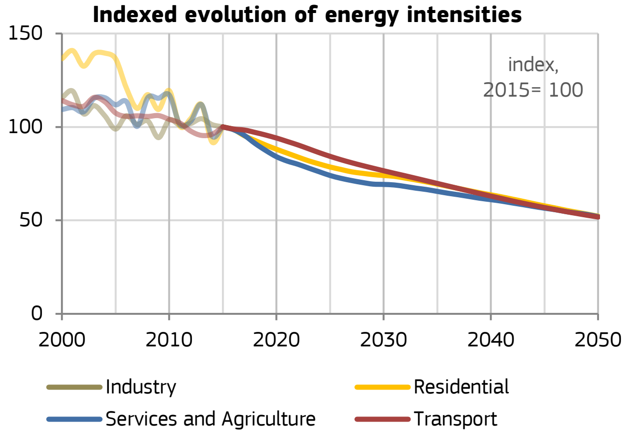

Indexed evolution of CO2 emissions
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

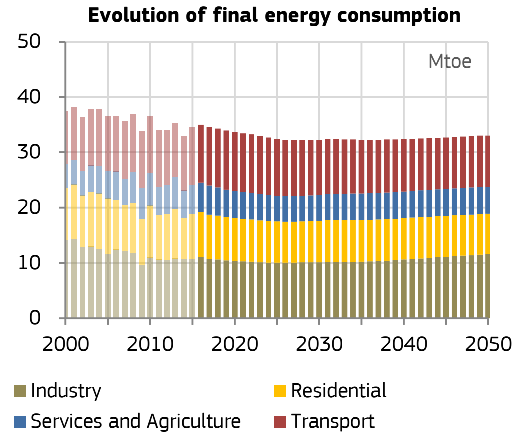

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors

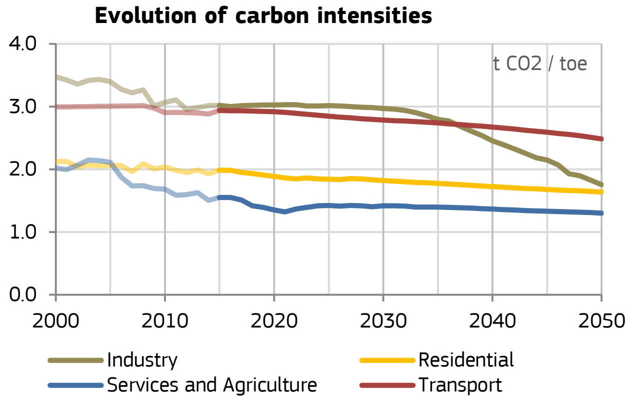

Cumulative investment expenditure (2016-2050)
10.7% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
200
400
600
800
billion €

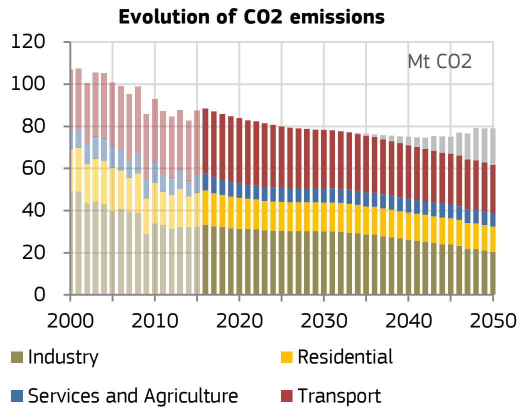

Energy service related operating costs as percentage of GDP
20%
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050

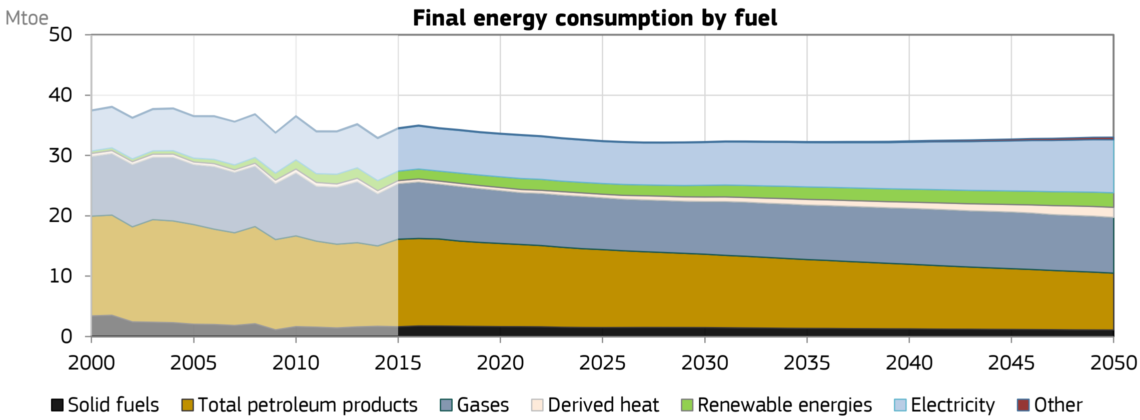

Energy service related operating costs per energy consumed
€ per toe
of AVFCO
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

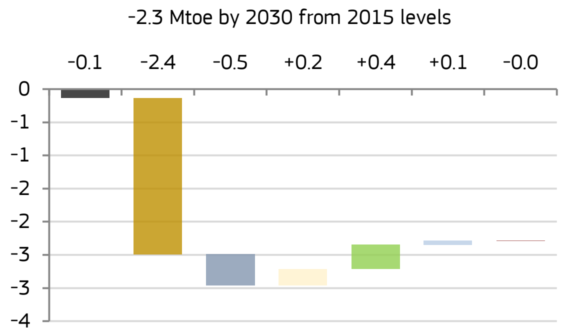

Indexed evolution of energy intensities
index, 2015= 100
150
100
50
0
2000 2010 2020 2030 2040 2050
Industry
Residential
Services and Agriculture
Transport

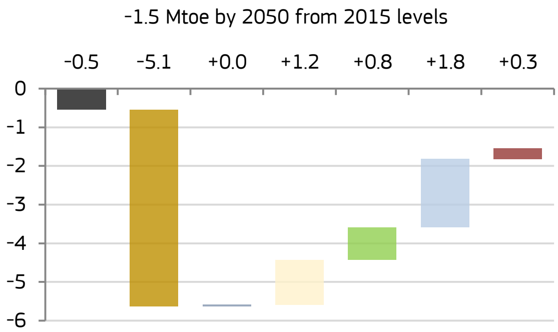

Evolution of final energy consumption
Mtoe
50
40
30
20
10
0
2000 2010 2020 2030 2040 2050
Industry
Residential
Services and Agriculture
Transport

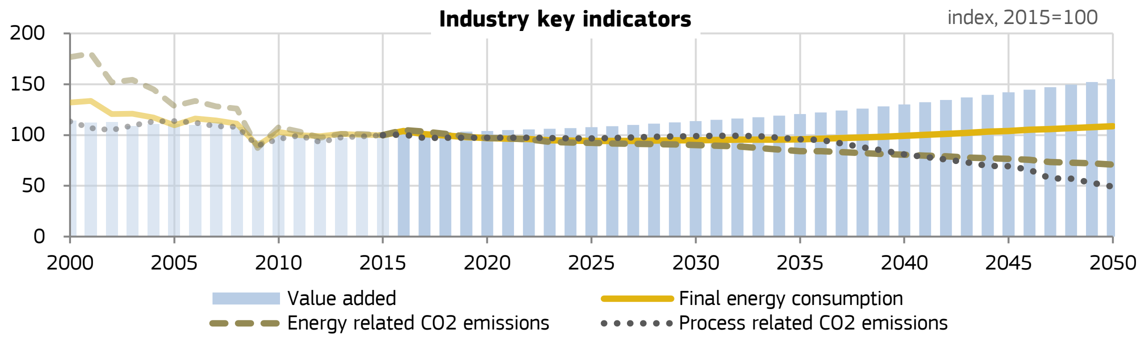

Evolution of carbon intensities
t CO2 / toe
4.0
3.0
2.0
1.0
0.0
2000 2010 2020 2030 2040 2050
Industry
Residential
Services and Agriculture
Transport

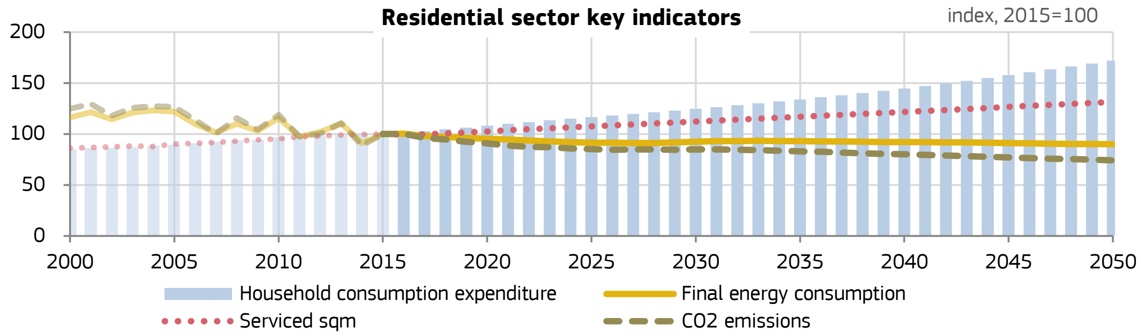

Evolution of CO2 emissions
Mt CO2
120
100
80
60
40
20
0
2000 2010 2020 2030 2040 2050
Industry
Residential
Services and Agriculture
Transport

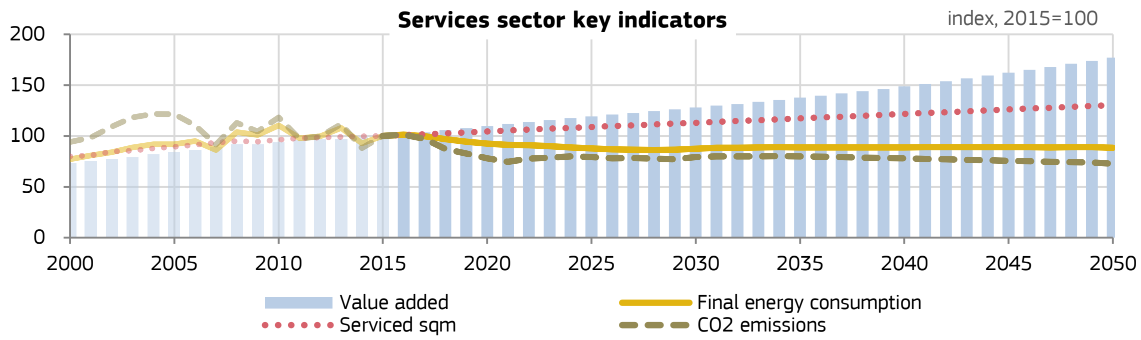

Final energy consumption by fuel
Mtoe
50
40
30
20
10
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

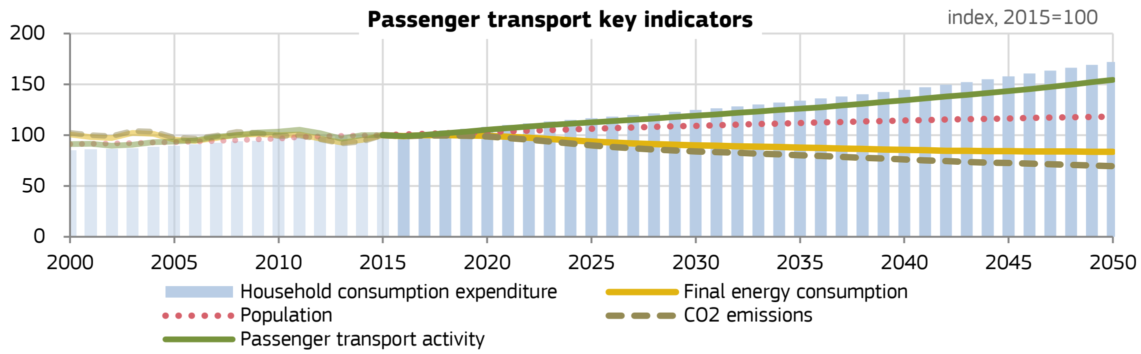

-2.3 Mtoe by 2030 from 2015 levels
-0.1 -2.4 -0.5 +0.2 +0.4 +0.1 -0.0
0
-1
-1
-2
-2
-3
-3
-4

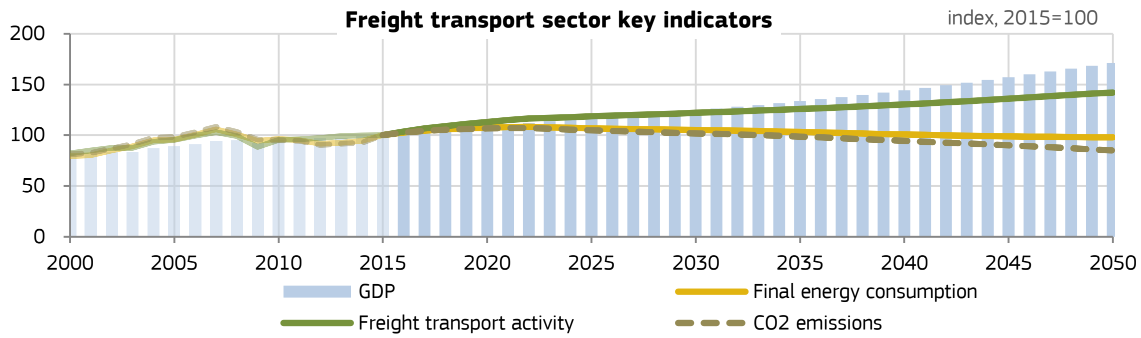

-1.5 Mtoe by 2050 from 2015 levels
-0.5 -5.1 +0.0 +1.2 +0.8 +1.8 +0.3
0
-1
-2
-3
-4
-5
-6

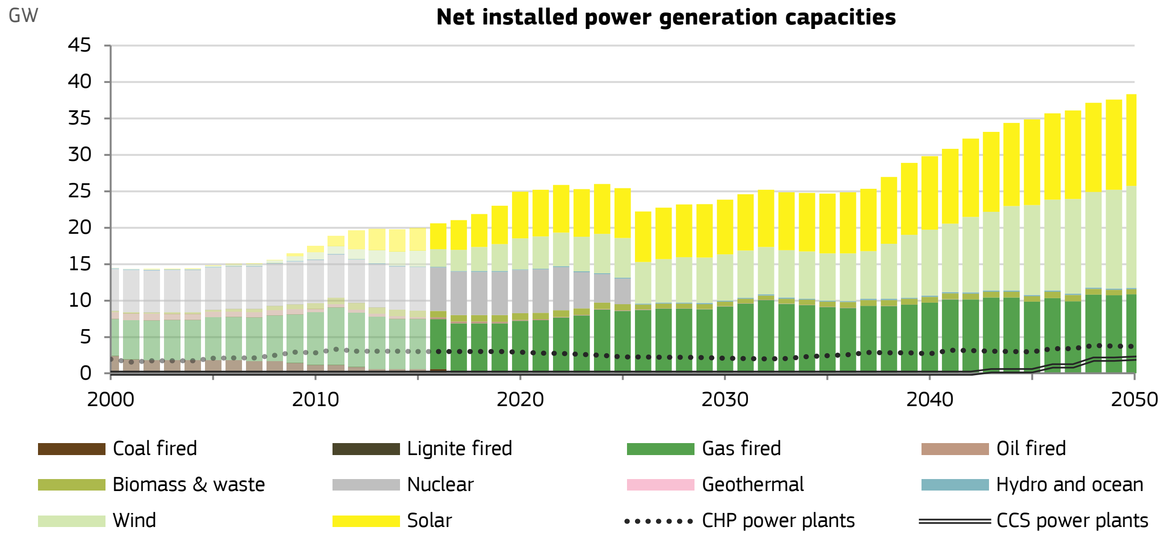

Industry key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions


Residential sector key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

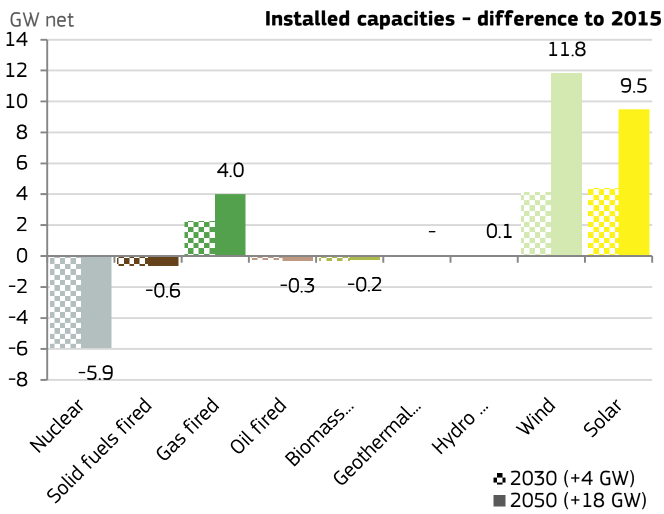

Services sector key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions


Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

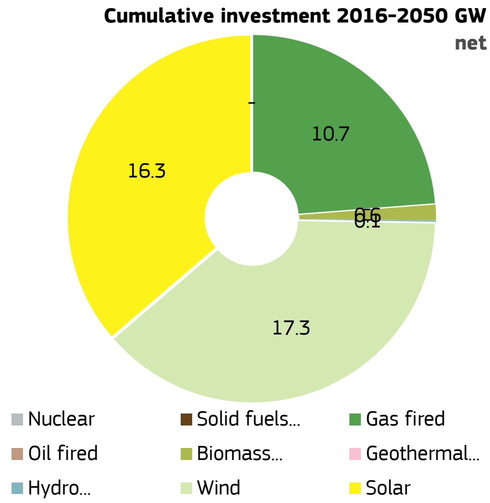

Freight transport sector key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions



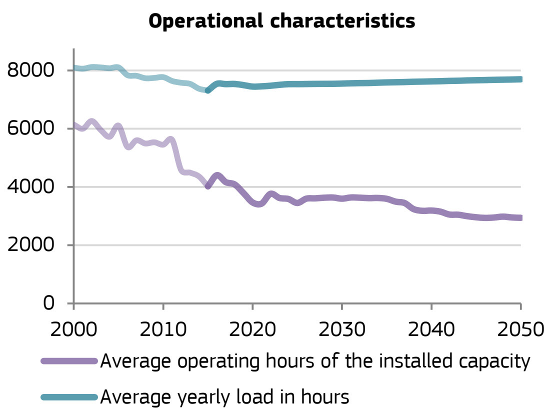
GW
Net installed power generation capacities
45
40
35
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants



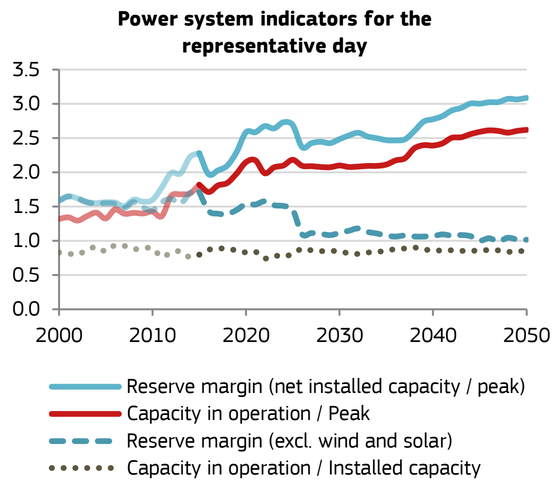
GW net
Installed capacities - difference to 2015
14
12
10
8
6
4
2
0
-2
-4
-6
-8
11.8
9.5
4.0
0.1
-0.6
-0.3
-0.2
-5.9
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+4 GW)
2050 (+18 GW)



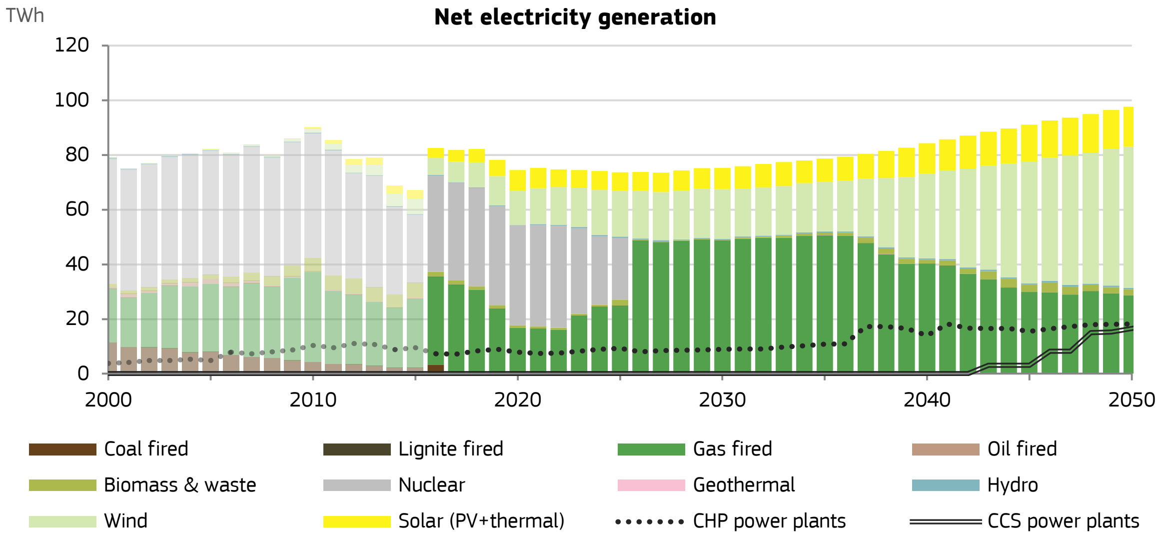
Cumulative investment 2016-2050 GW net
10.7
16.3
0.6
0.1
17.3
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

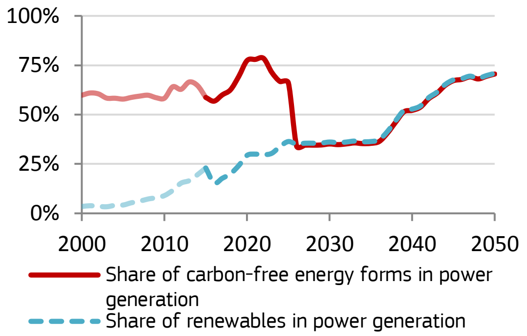


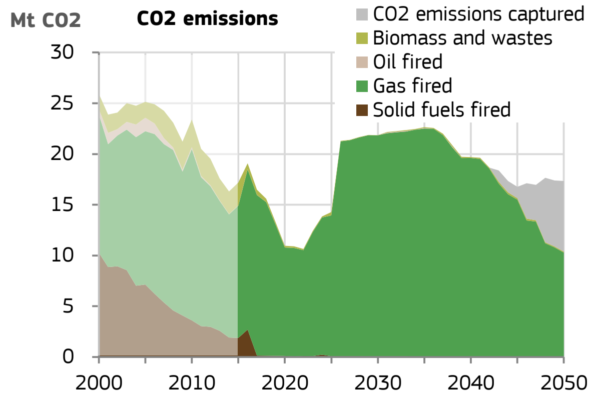
Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

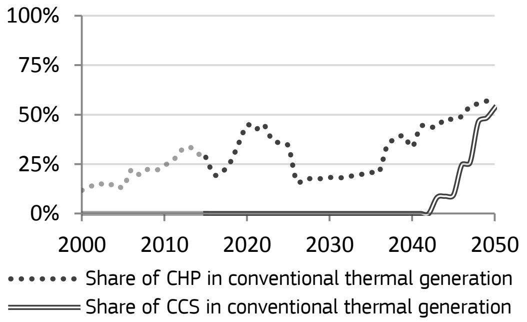


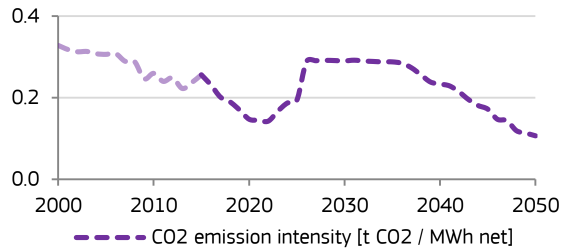
Power system indicators for the representative day
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

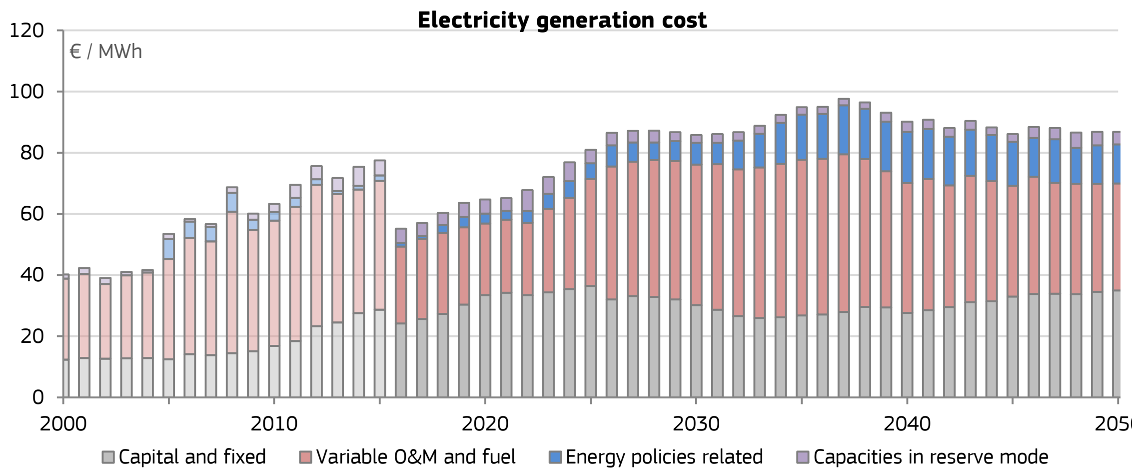

Net electricity generation
TWh
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

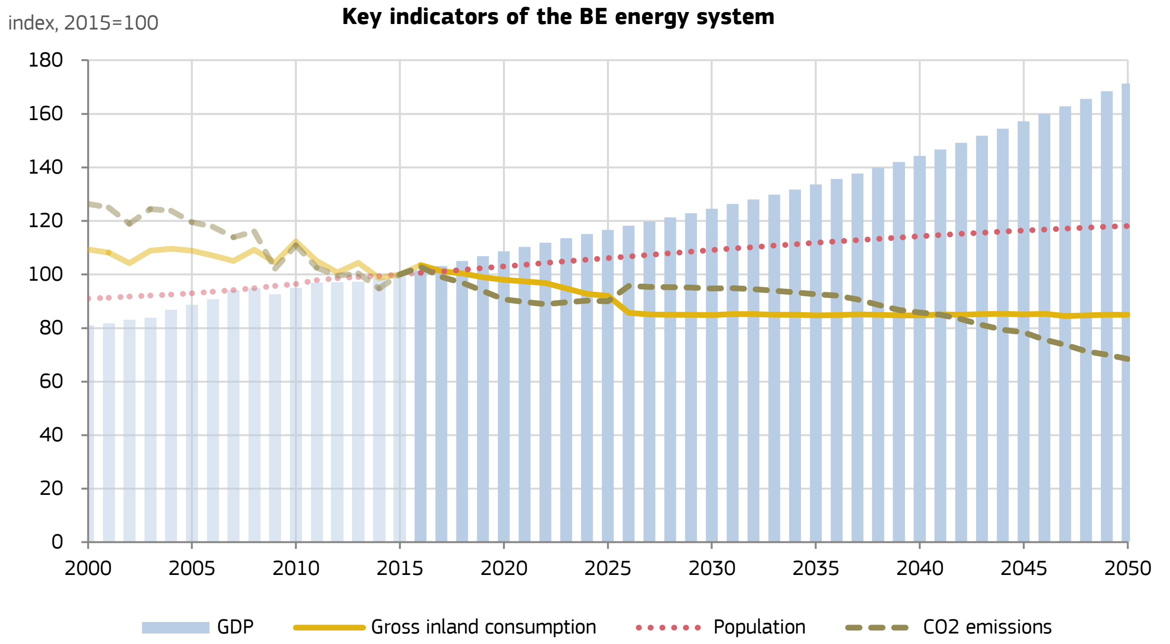

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired

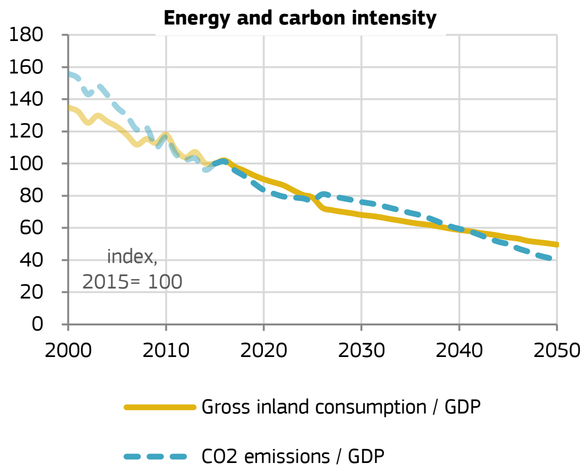

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

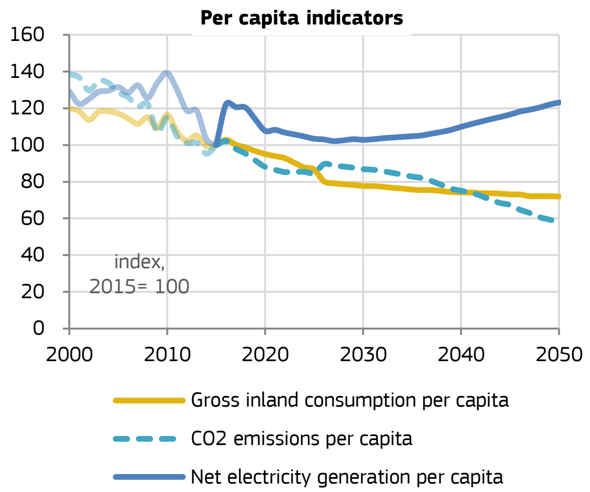

0.4
0.2
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	31.5	36.6	34.6	33.7	32.3	33.0
Primary energy consumption [Mtoe]	45.5	51.3	44.5	43.7	37.3	37.1
RES [%] - Share of energy from renewable sources		2.4%	9.0%	11.7%	15.1%	28.9%
RES-E [%] - Share of electricity from renewable sources		2.2%	15.0%	23.0%	31.7%	60.4%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	126.3	130.6	109.3	99.1	103.6	74.8
reduction to 1990		*3%*	*-14%*	*-22%*	*-18%*	*-41%*
Emissions in current ETS sectors |(BE) [Mt CO2]		62.7	49.1	42.6	52.7	33.0
reduction to 2005			*-22%*	*-32%*	*-16%*	*-47%*
Emissions in current ESD sectors [Mt CO2]		67.9	60.2	56.5	50.9	41.8
reduction to 2005			*-11%*	*-17%*	*-25%*	*-38%*

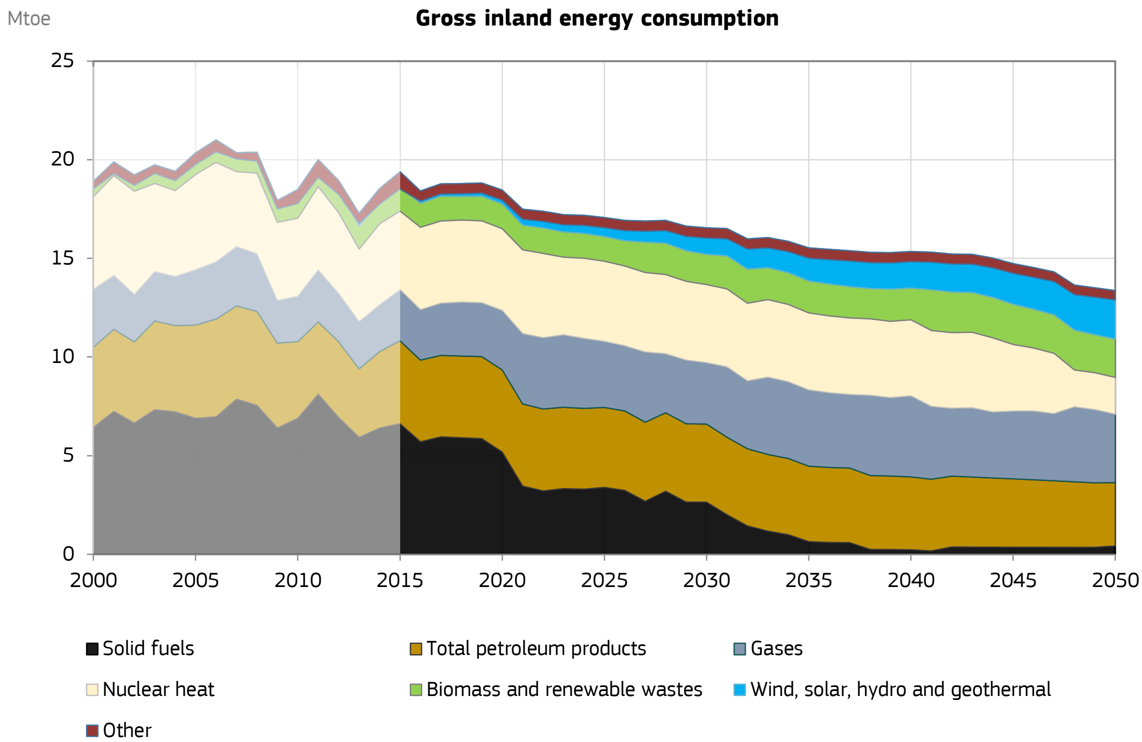


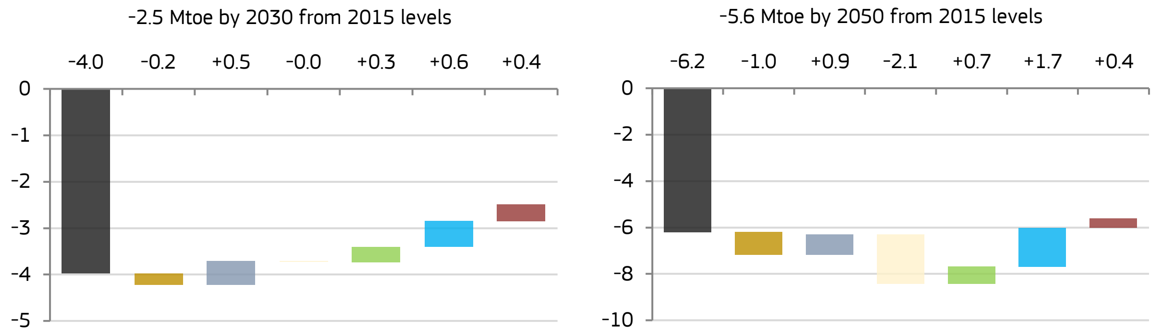


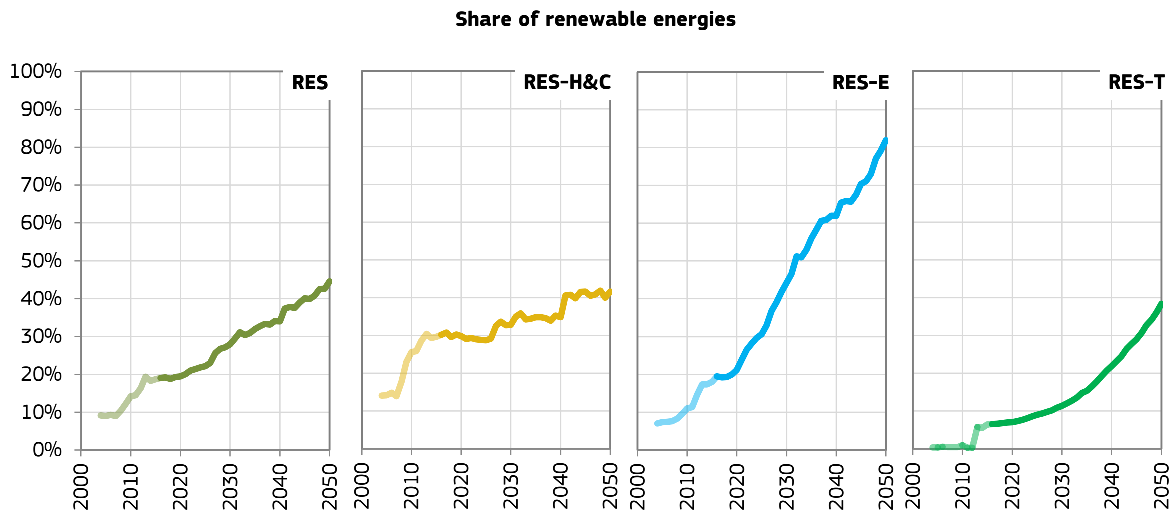
POTEnCIA - Model results overview

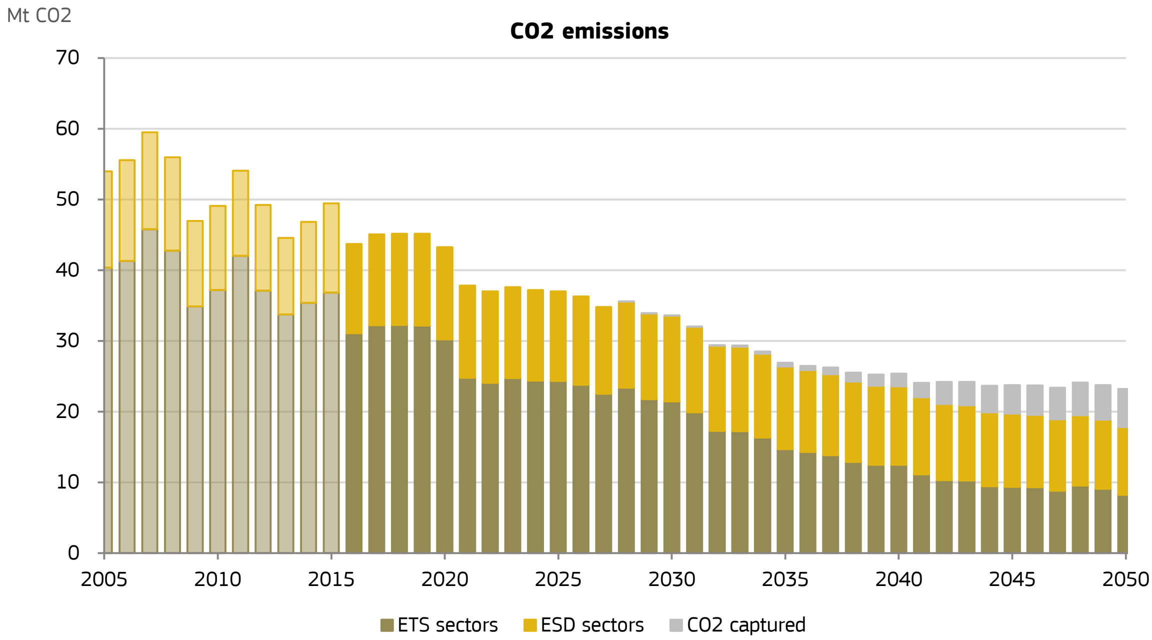
Bulgaria

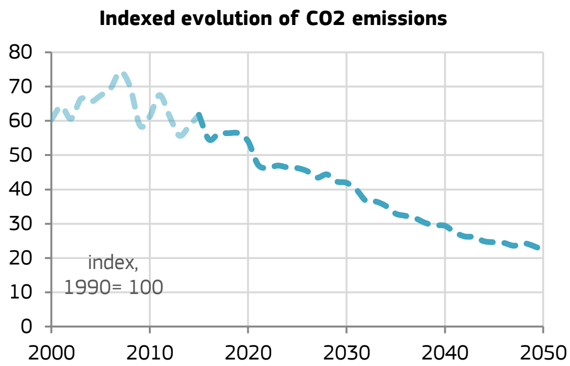
Central_2018 scenario

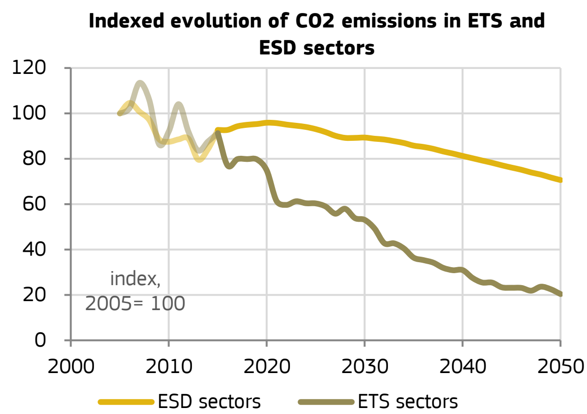

Mtoe
Gross inland energy consumption
25
20
15
10
5
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Nuclear heat
Biomass and renewable wastes
Wind, solar, hydro and geothermal
Other

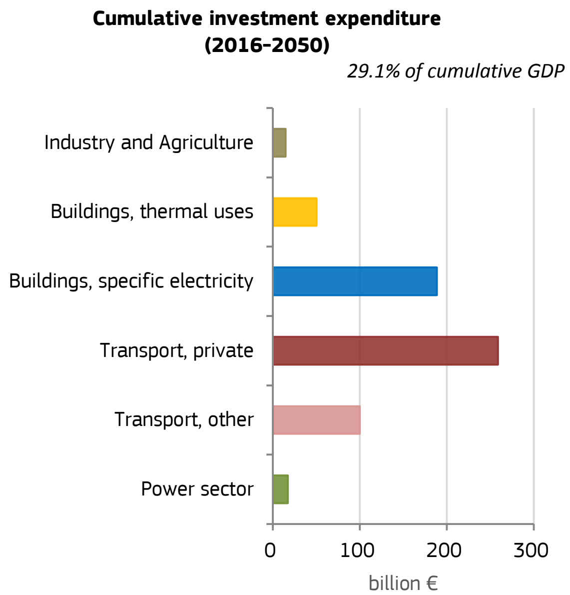

-2.5 Mtoe by 2030 from 2015 levels
-4.0
-0.2
+0.5
-0.0
+0.3
+0.6
+0.4
0
-1
-2
-3
-4
-5
-5.6 Mtoe by 2050 from 2015 levels
-6.2
-1.0
+0.9
-2.1
+0.7
+1.7
+0.4
0
-2
-4
-6
-8
-10

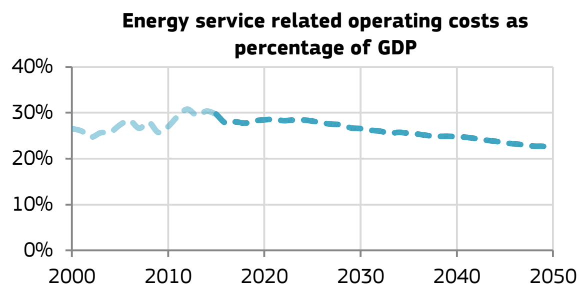

Share of renewable energies
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RES
RES-H&C
RES-E
RES-T
2000
2010
2020
2030
2040
2050

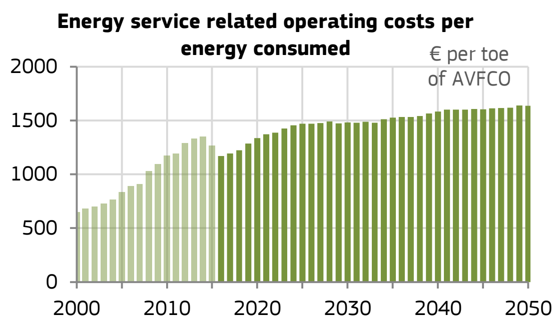

Mt CO2
CO2 emissions
70
60
50
40
30
20
10
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured

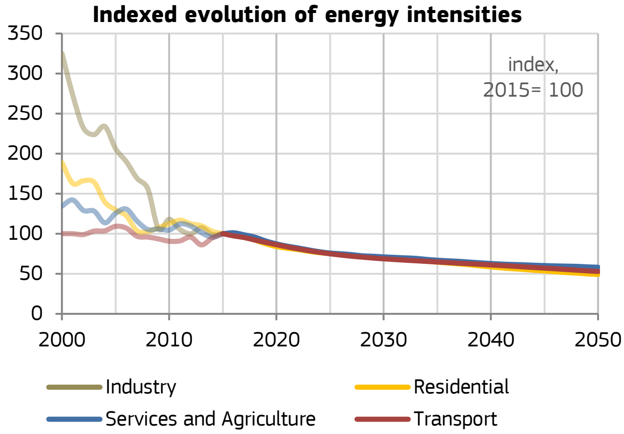

Indexed evolution of CO2 emissions
80
70
60
50
40
30
20
10
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

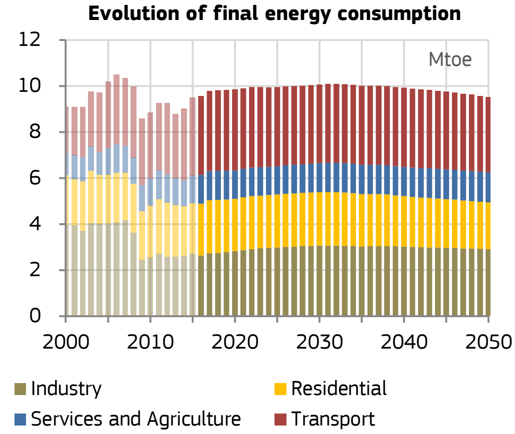

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors

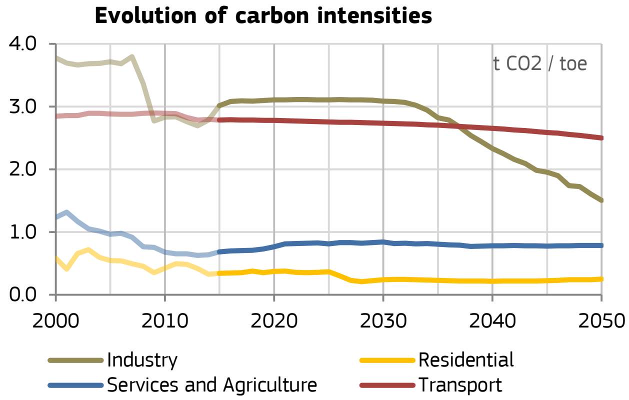

Cumulative investment expenditure (2016-2050)
29.1% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
100
200
300
billion €

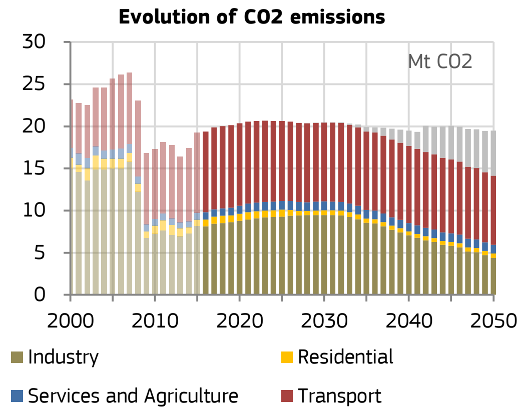

Energy service related operating costs as percentage of GDP
40%
30%
20%
10%
0%
2000
2010
2020
2030
2040
2050

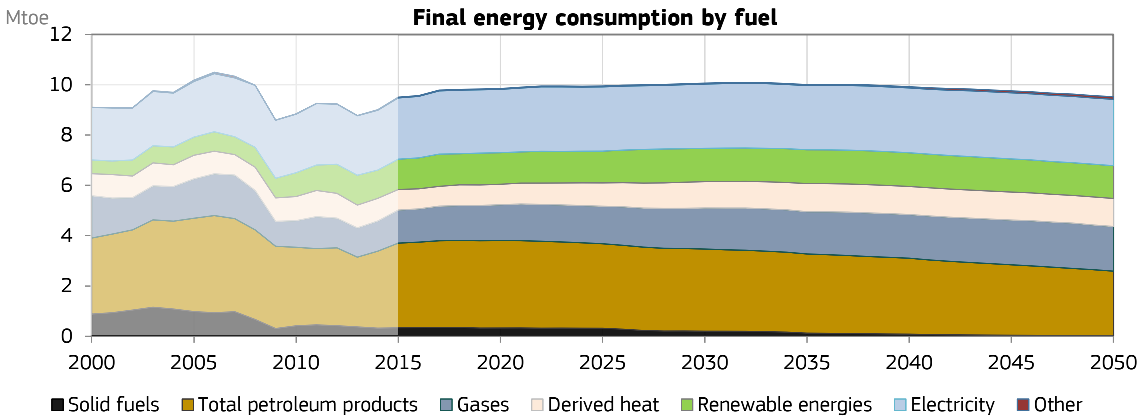

Energy service related operating costs per energy consumed
€ per toe
of AVFCO
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

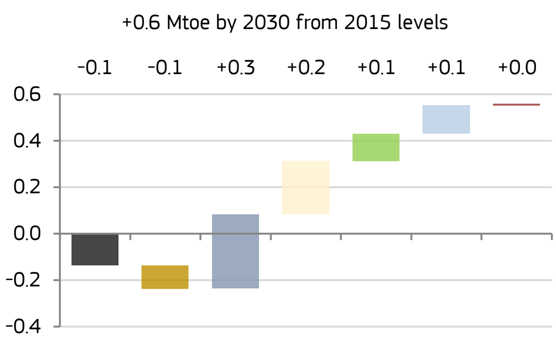

Indexed evolution of energy intensities
index, 2015= 100
350
300
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

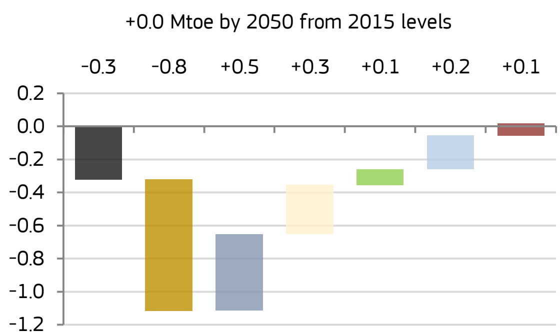

Evolution of final energy consumption
Mtoe
12
10
8
6
4
2
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

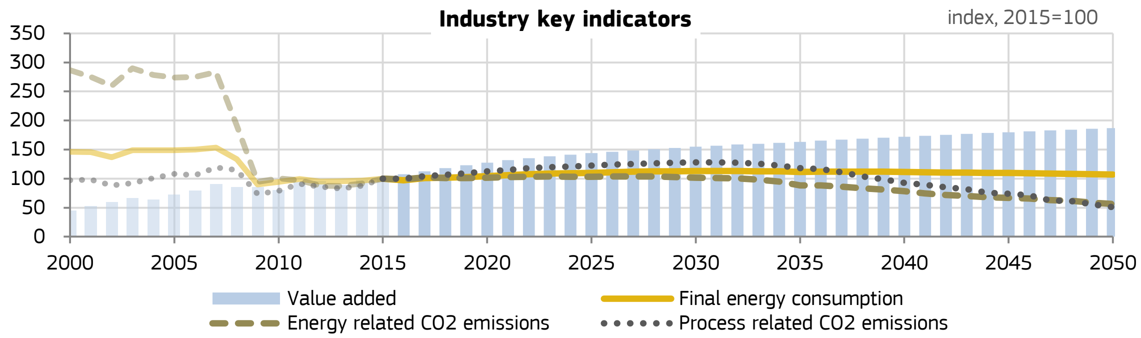

Evolution of carbon intensities
t CO2 / toe
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

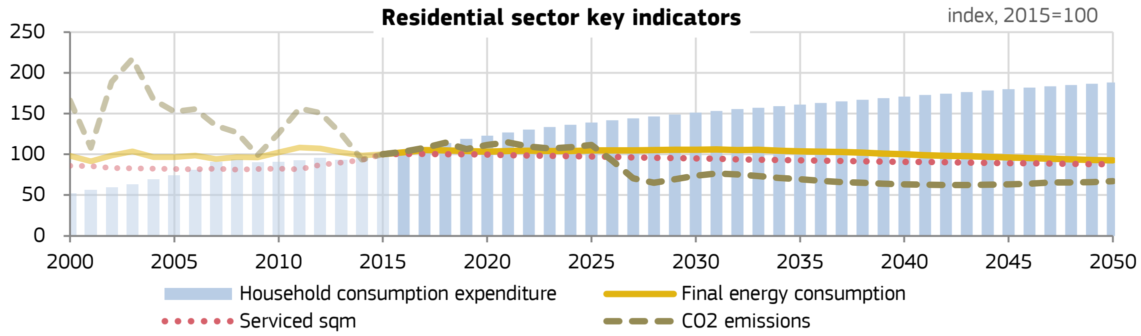

Evolution of CO2 emissions
Mt CO2
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

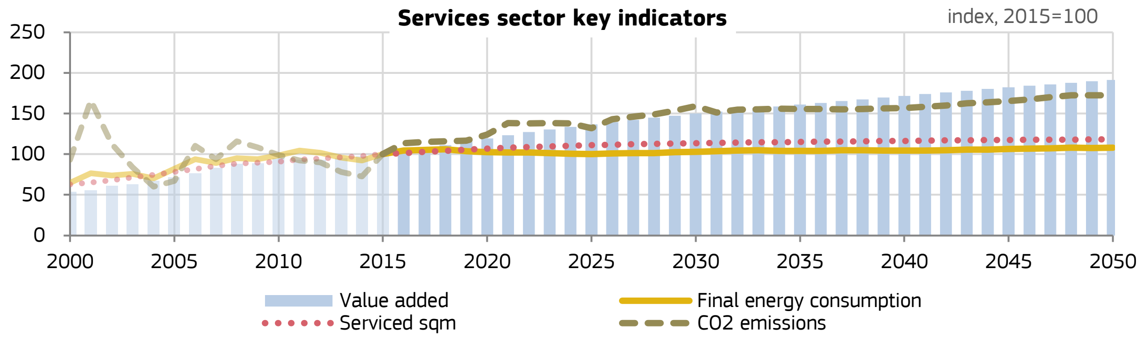

Final energy consumption by fuel
Mtoe
12
10
8
6
4
2
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

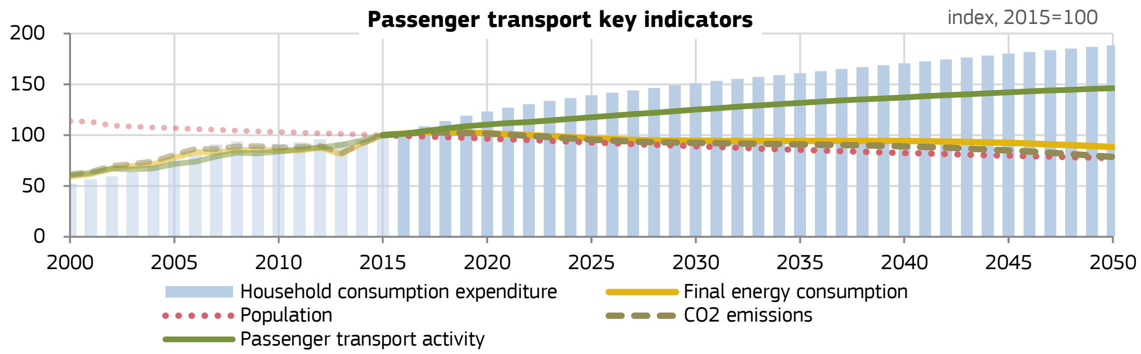

+0.6 Mtoe by 2030 from 2015 levels
-0.1
-0.1
+0.3
+0.2
+0.1
+0.1
+0.0
0.6
0.4
0.2
0.0
-0.2
-0.4

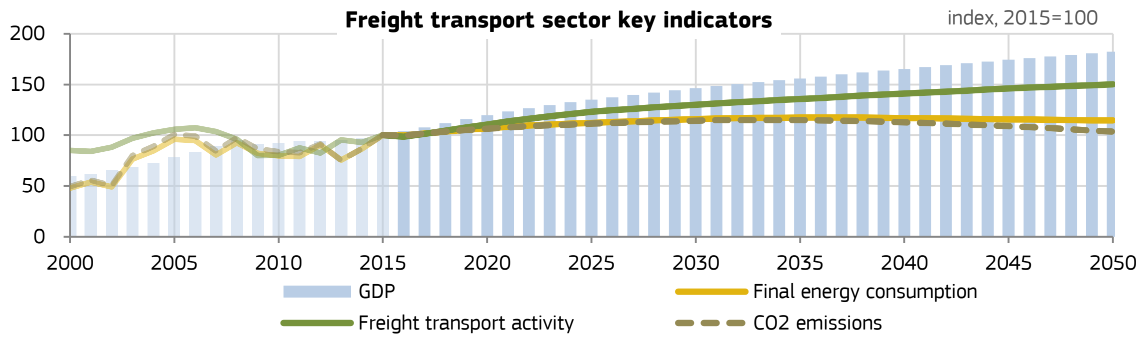

+0.0 Mtoe by 2050 from 2015 levels
-0.3
-0.8
+0.5
+0.3
+0.1
+0.2
+0.1
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2

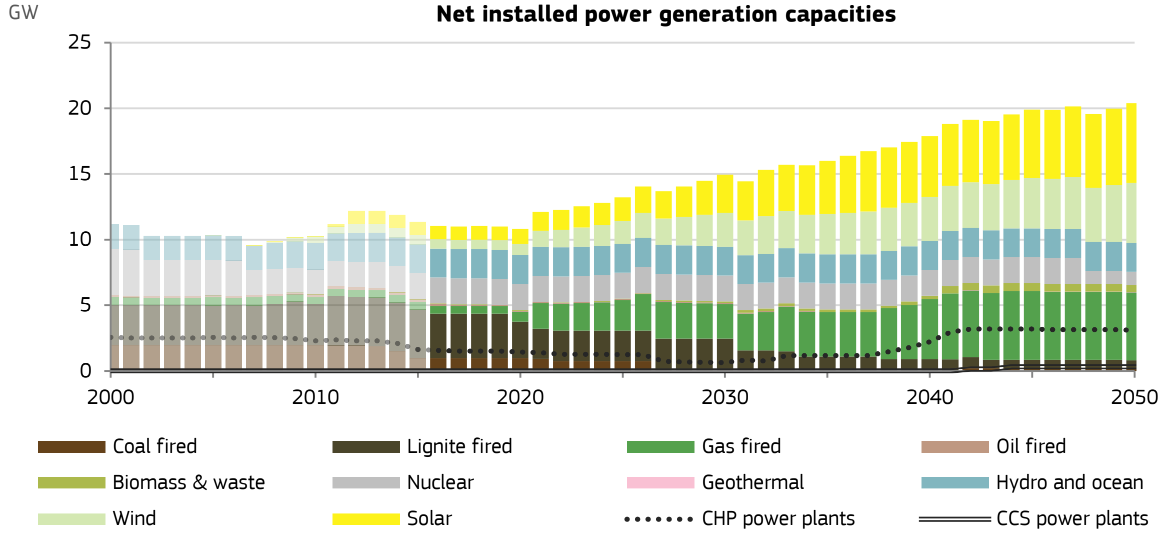

Industry key indicators
index, 2015=100
350
300
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

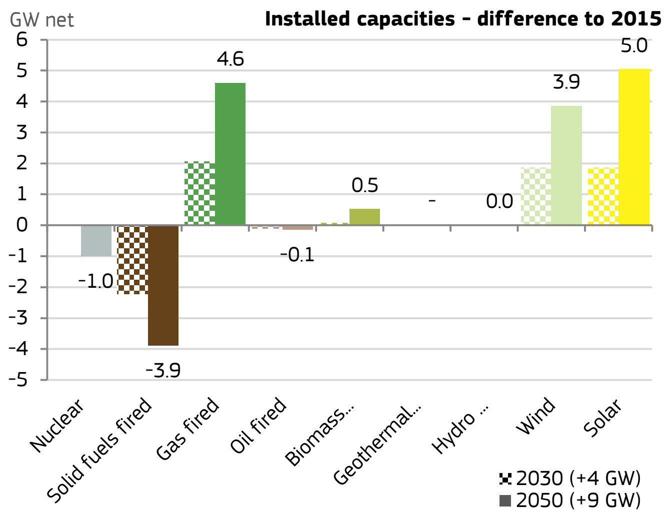

Residential sector key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

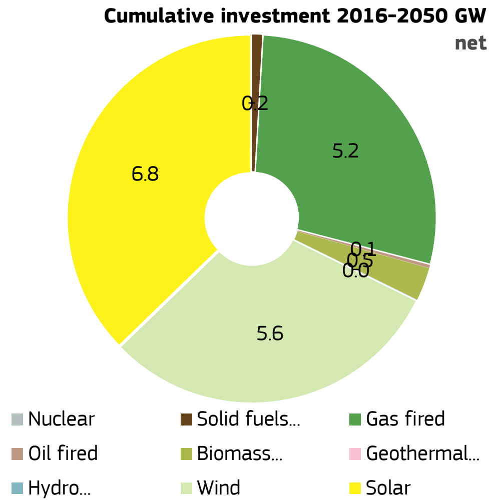

Services sector key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

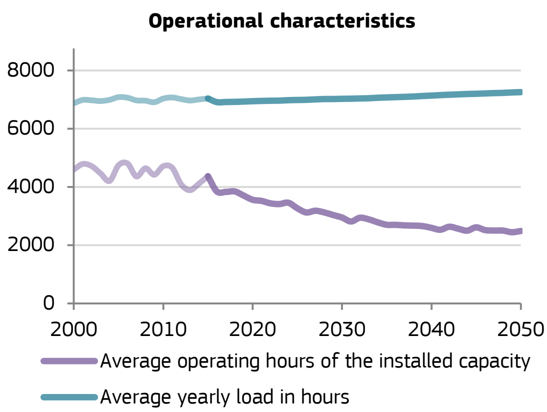

Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

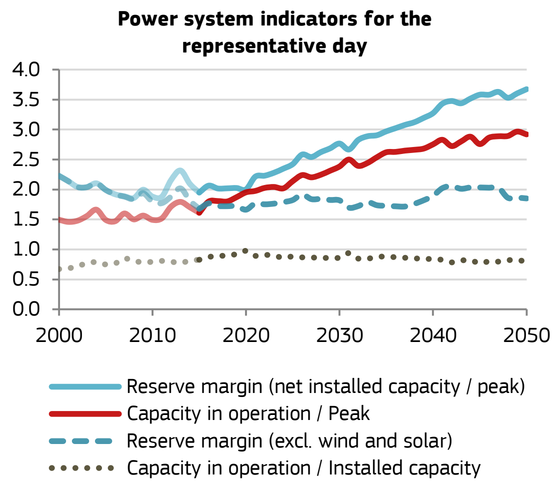

Freight transport sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

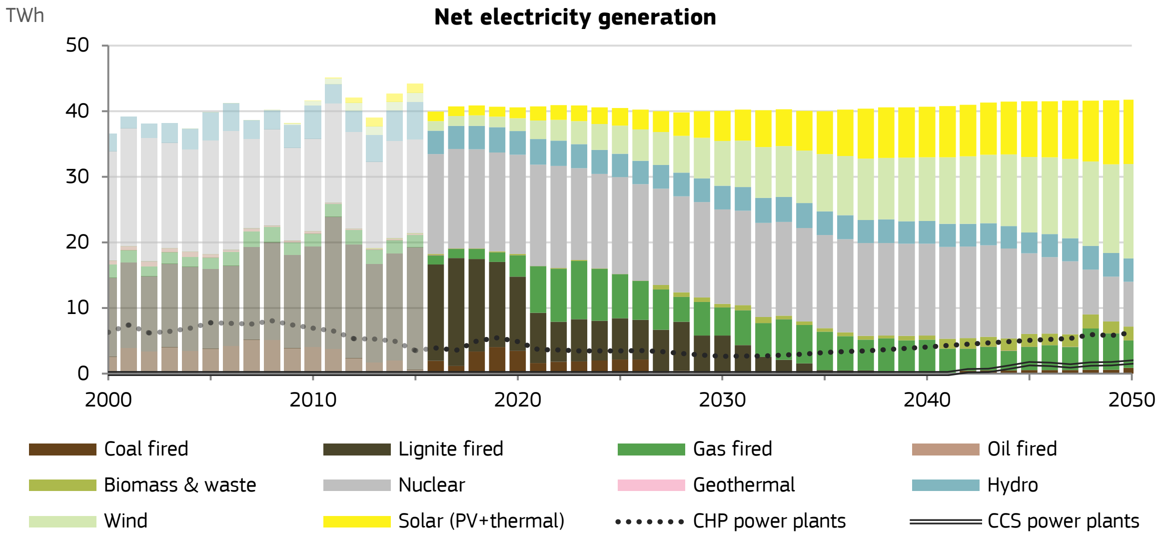

Net installed power generation capacities
GW
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

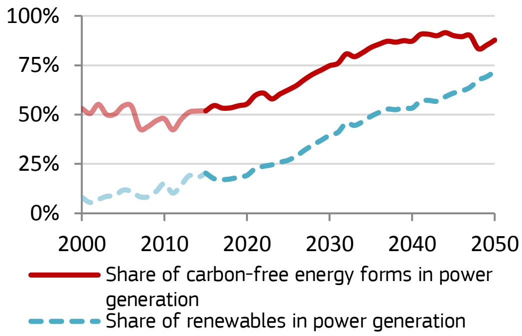

Installed capacities - difference to 2015
GW net
4.6
5.0
3.9
0.5
-
0.0
-1.0
-0.1
-3.9
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+4 GW)
2050 (+9 GW)

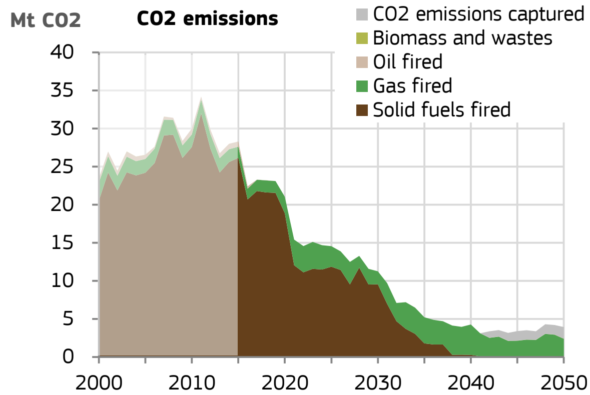

Cumulative investment 2016-2050 GW net
0.2
5.2
6.8
0.1
0.5
0.0
5.6
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

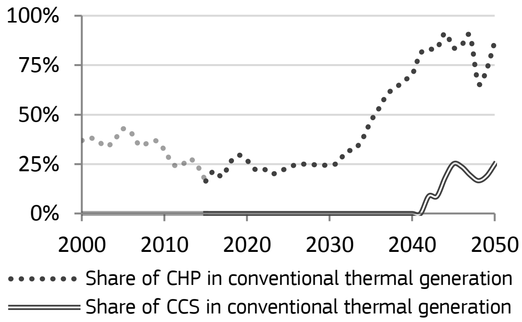

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

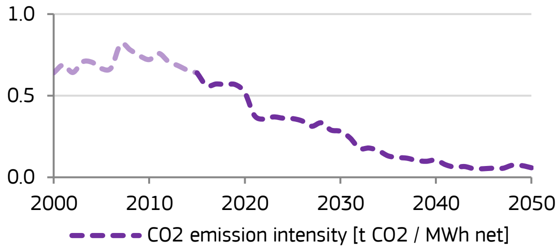

Power system indicators for the representative day
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

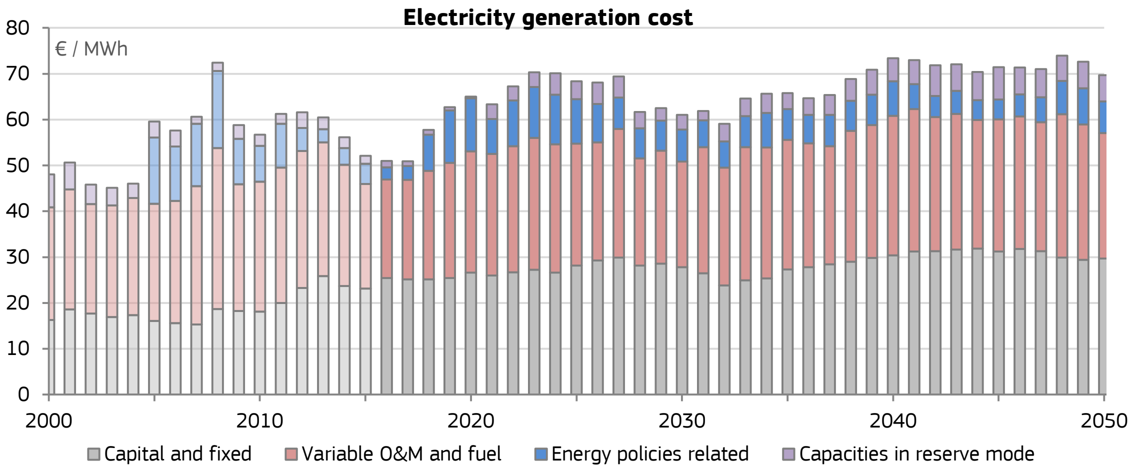

Net electricity generation
TWh
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

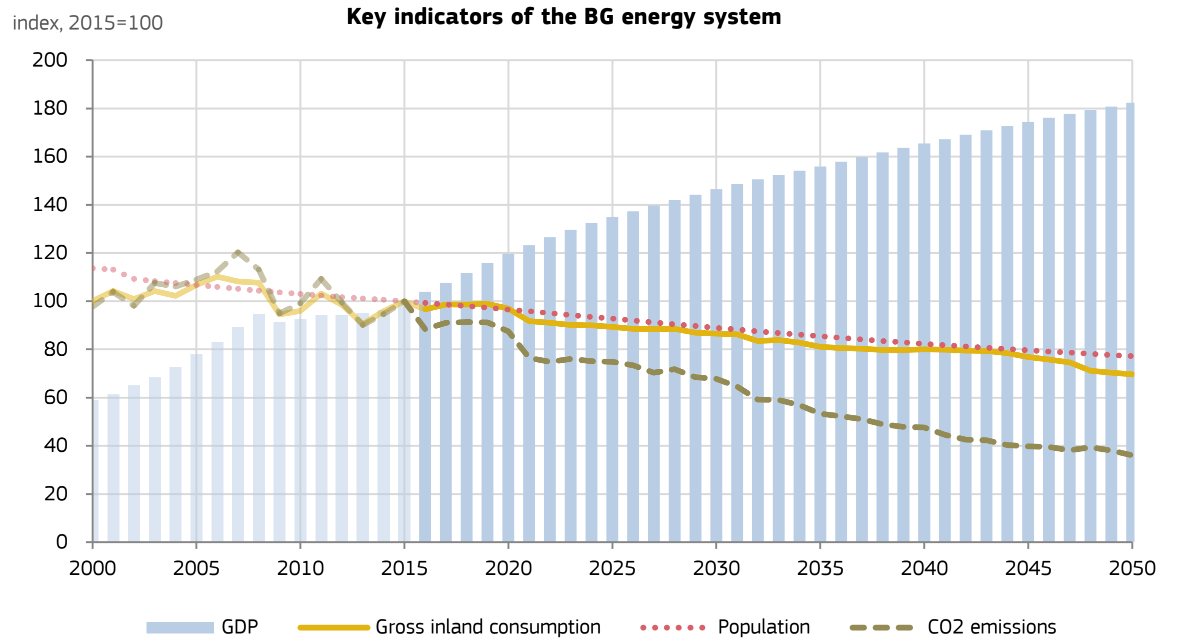

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
40
35
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050

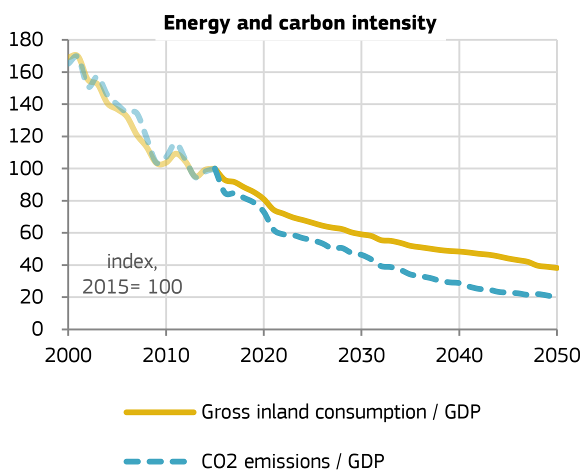

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

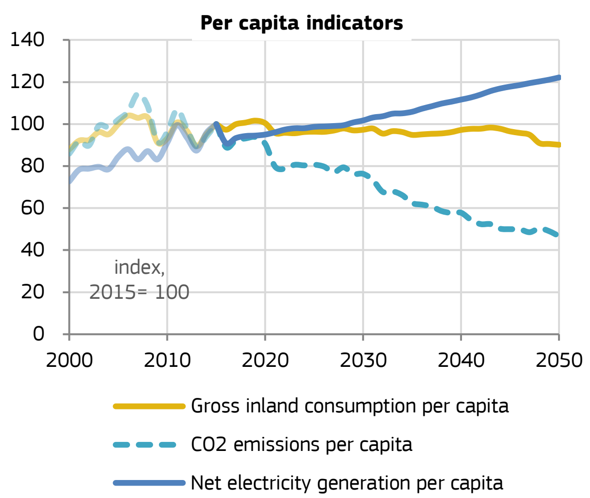

1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
80
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	16.4	10.2	9.5	9.9	10.1	9.5
Primary energy consumption [Mtoe]	26.2	18.9	17.9	17.3	15.3	12.1
RES [%] - Share of energy from renewable sources		9.0%	18.7%	19.4%	27.9%	44.5%
RES-E [%] - Share of electricity from renewable sources		7.3%	18.0%	21.1%	44.2%	82.0%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	80.1	53.9	49.4	43.2	33.6	17.8
reduction to 1990		*-33%*	*-38%*	*-46%*	*-58%*	*-78%*
Emissions in current ETS sectors |(BG) [Mt CO2]		40.3	36.8	30.2	21.4	8.2
reduction to 2005			*-9%*	*-25%*	*-47%*	*-80%*
Emissions in current ESD sectors [Mt CO2]		13.6	12.6	13.0	12.2	9.6
reduction to 2005			*-7%*	*-4%*	*-11%*	*-29%*

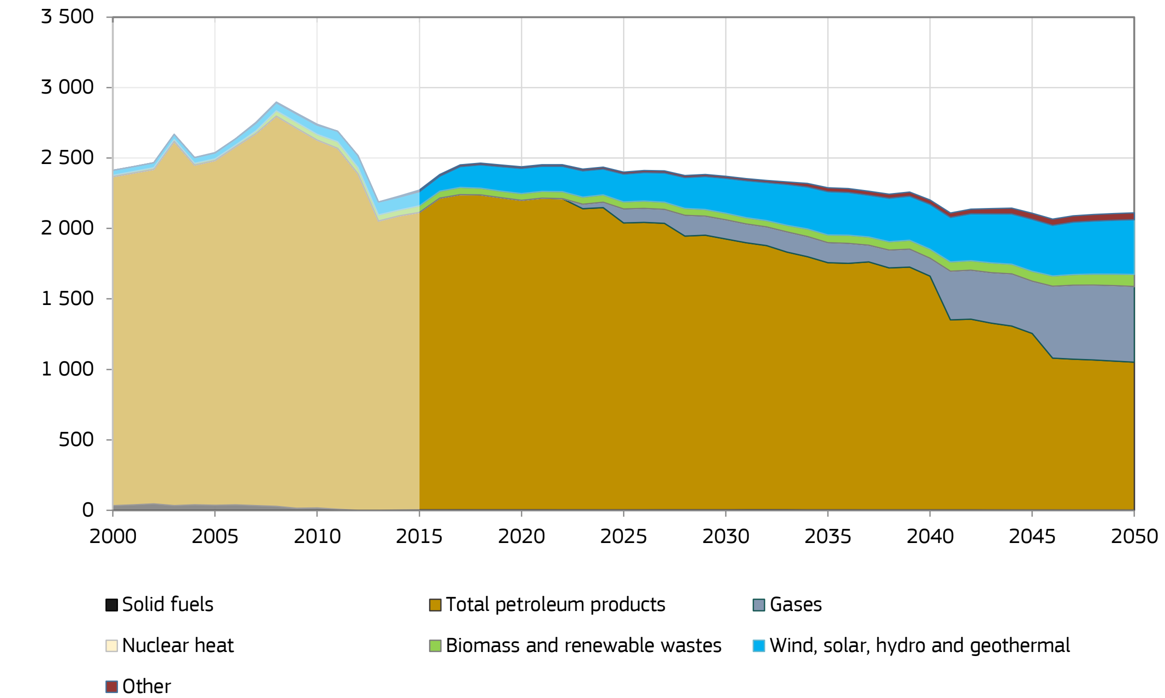


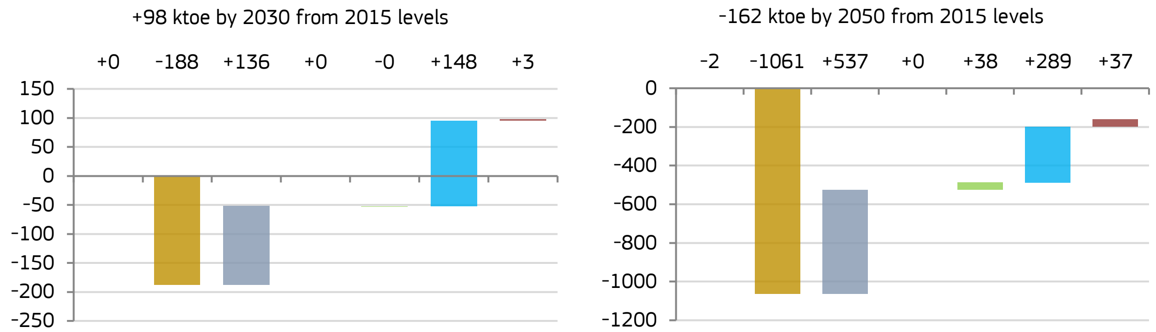


Cyprus

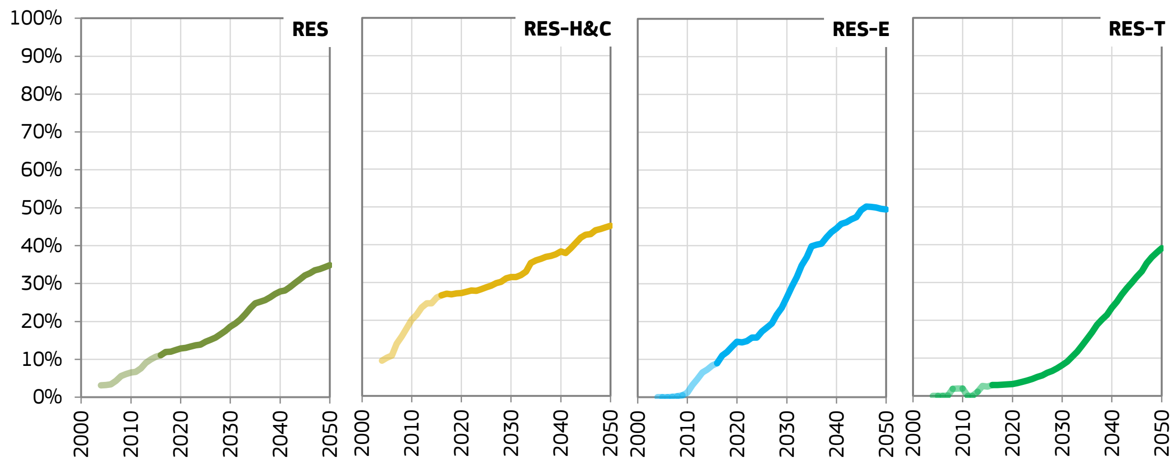
Central_2018 scenario

Gross inland energy consumption

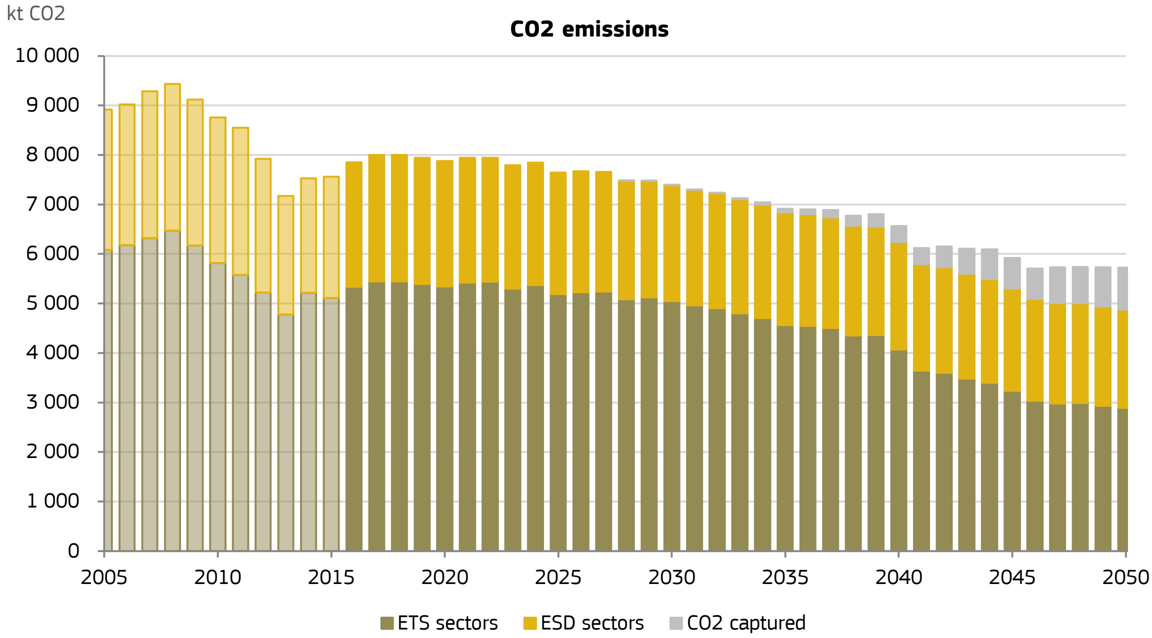




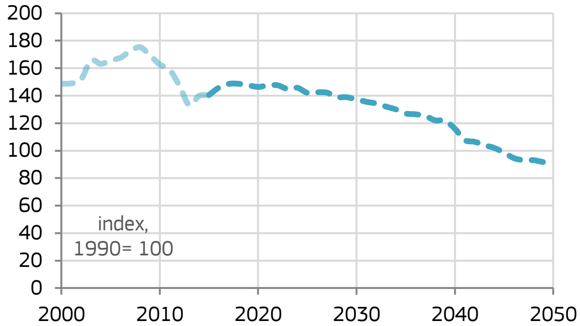
Share of renewable energies



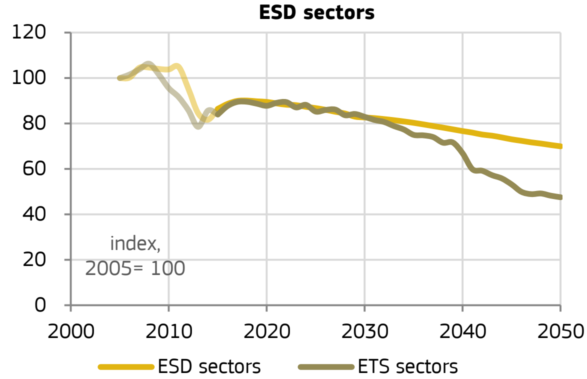
CO2 emissions



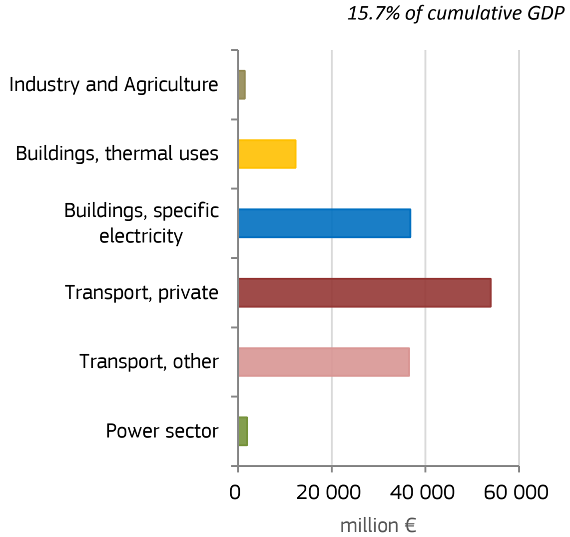
Indexed evolution of CO2 emissions



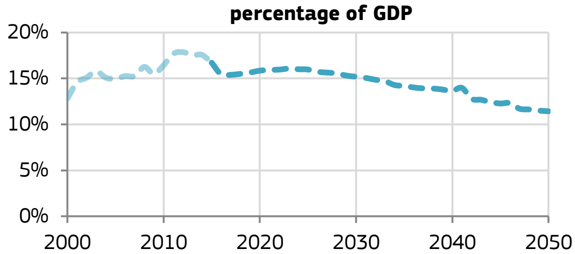
Indexed evolution of CO2 emissions in ETS and ESD sectors



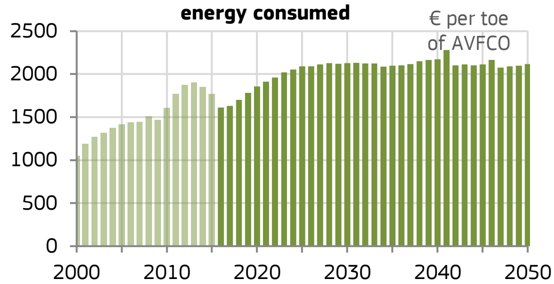
Cumulative investment expenditure (2016-2050)

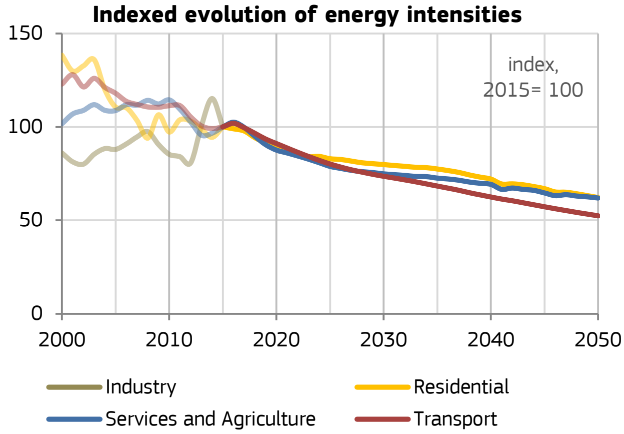


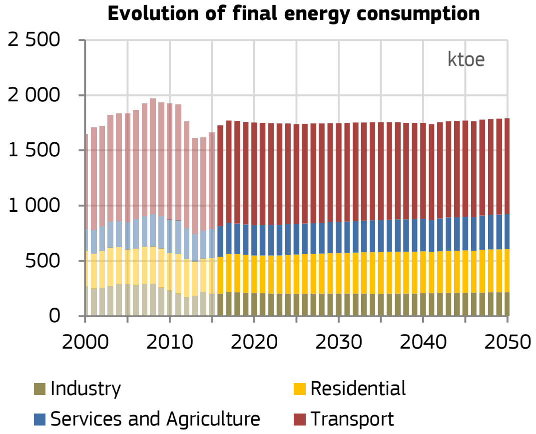
Energy service related operating costs as percentage of GDP

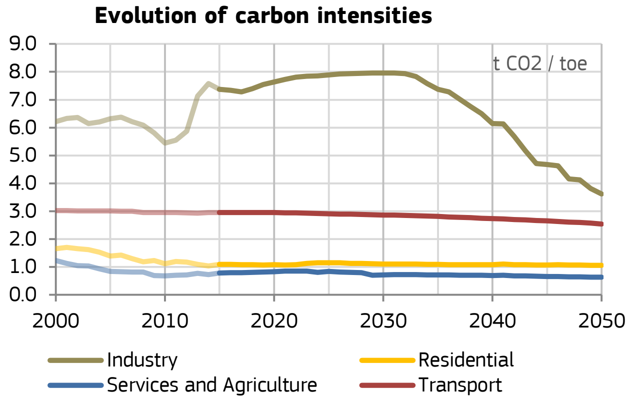


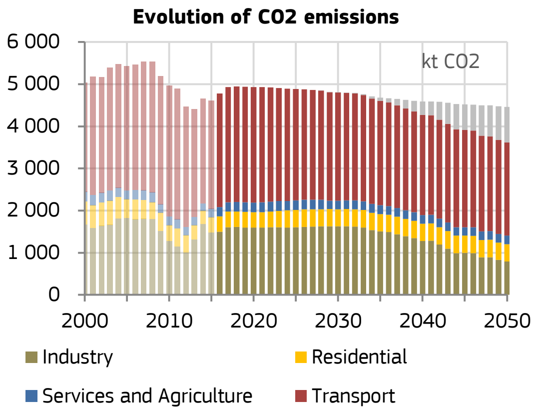
Energy service related operating costs per energy consumed

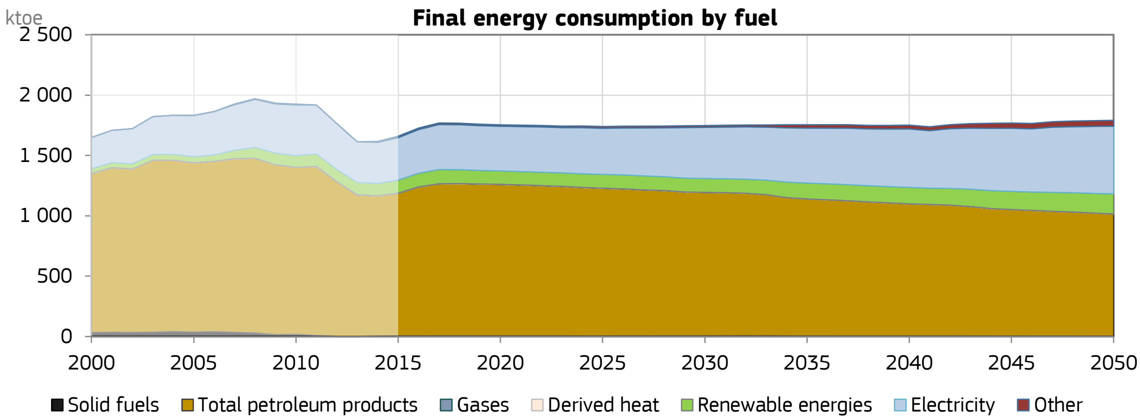


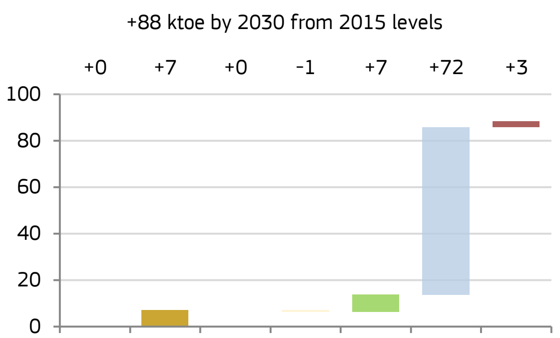

Indexed evolution of energy intensities
index, 2015= 100
150
100
50
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

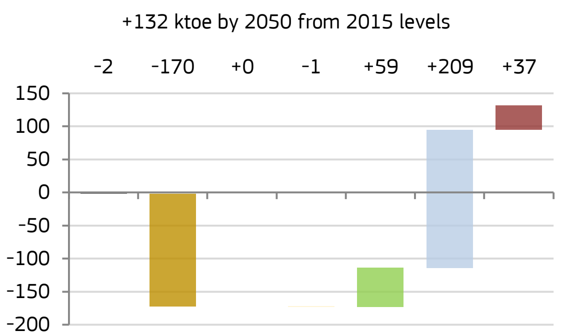

Evolution of final energy consumption
ktoe
2 500
2 000
1 500
1 000
500
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

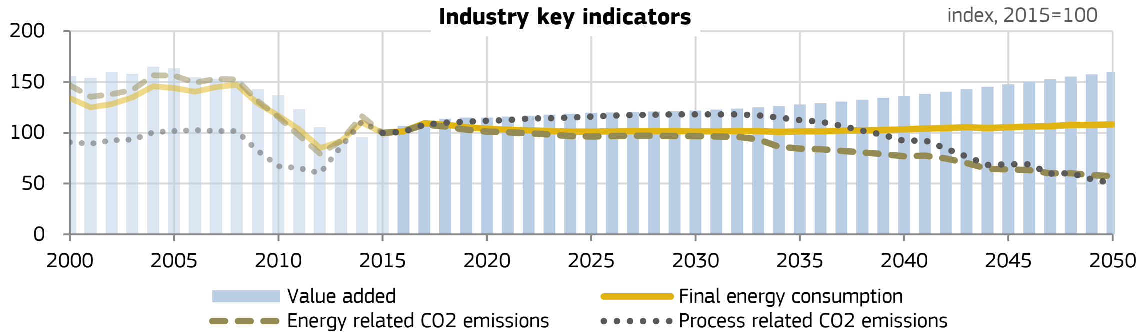

Evolution of carbon intensities
t CO2 / toe
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

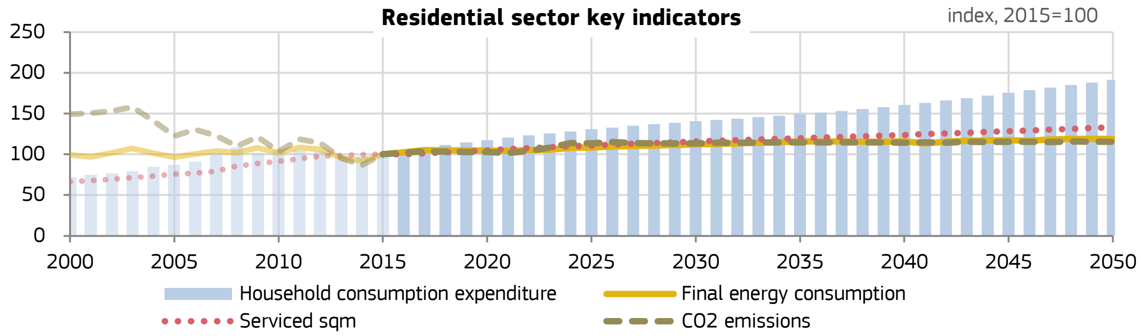

Evolution of CO2 emissions
kt CO2
6 000
5 000
4 000
3 000
2 000
1 000
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

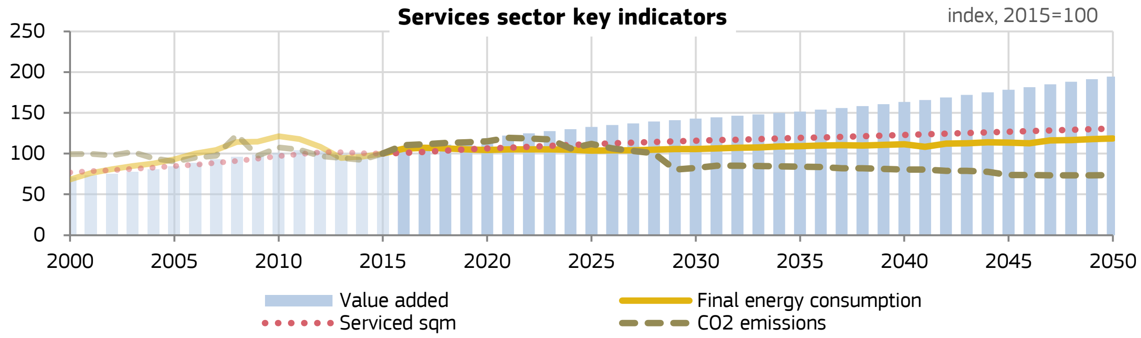

Final energy consumption by fuel
ktoe
2 500
2 000
1 500
1 000
500
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

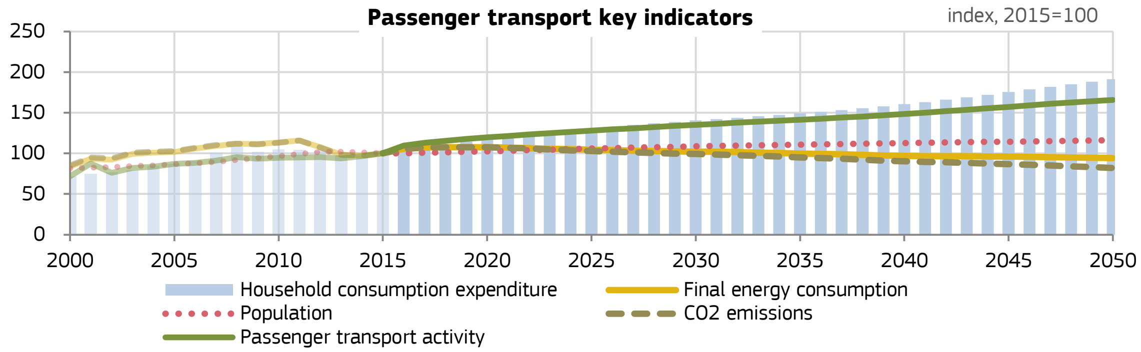

+88 ktoe by 2030 from 2015 levels
+0
+7
+0
-1
+7
+72
+3
100
80
60
40
20
0

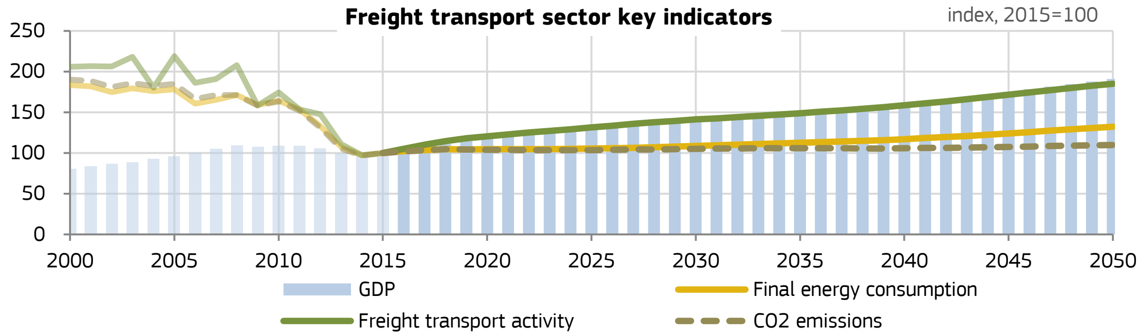

+132 ktoe by 2050 from 2015 levels
-2
-170
+0
-1
+59
+209
+37
150
100
50
0
-50
-100
-150
-200

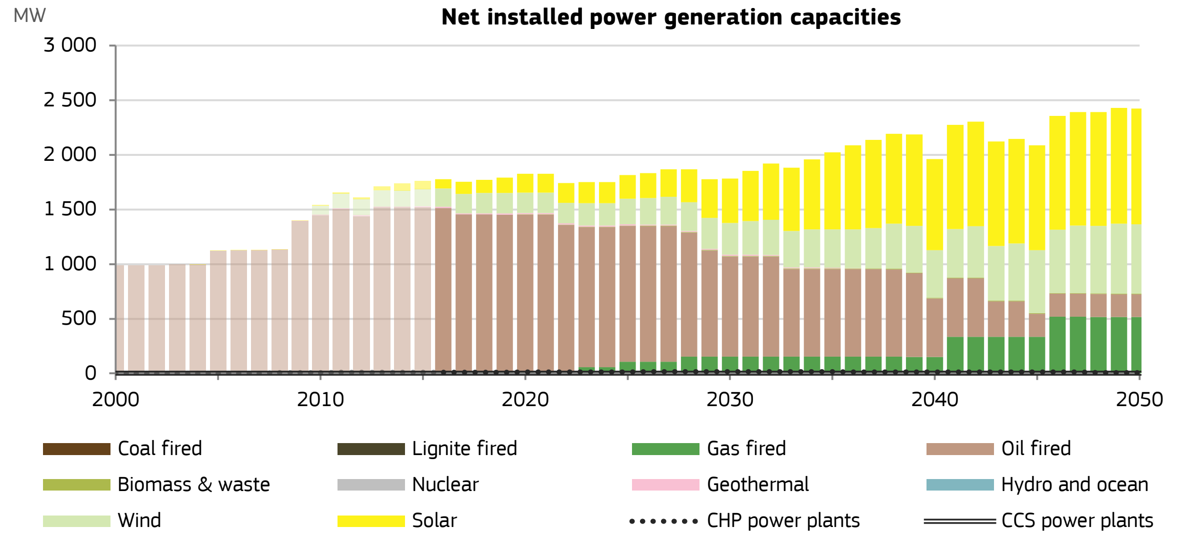

Industry key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

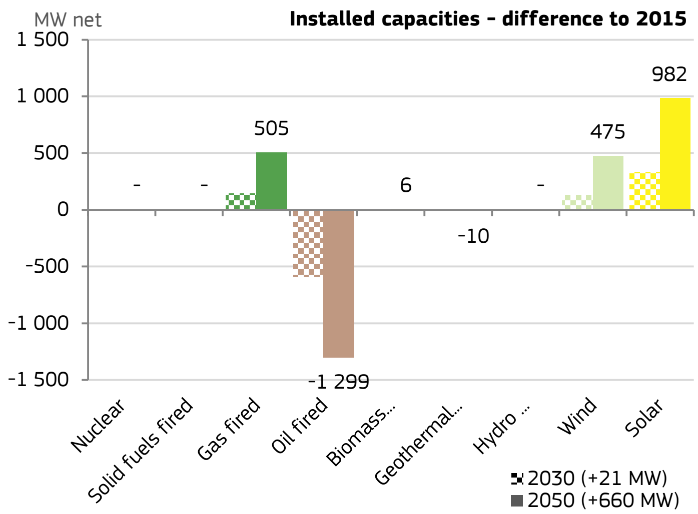

Residential sector key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

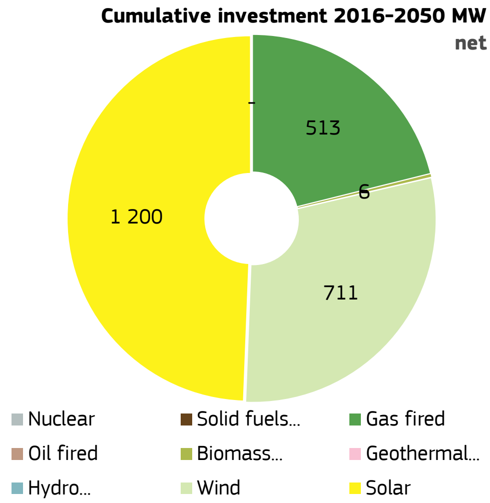

Services sector key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

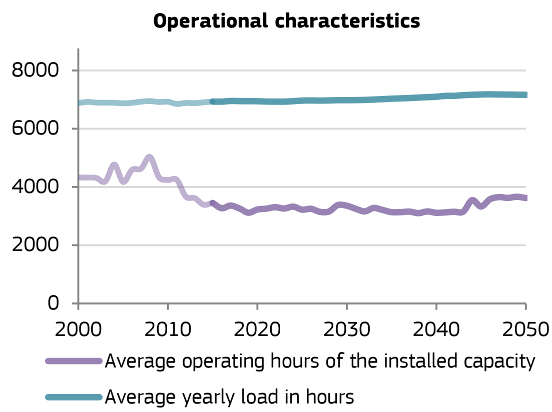

Passenger transport key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

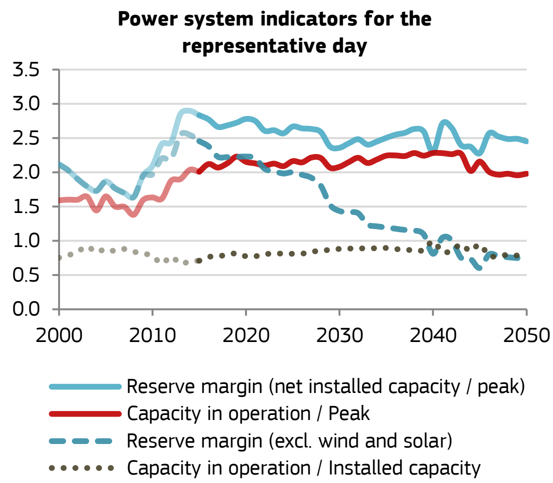

Freight transport sector key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

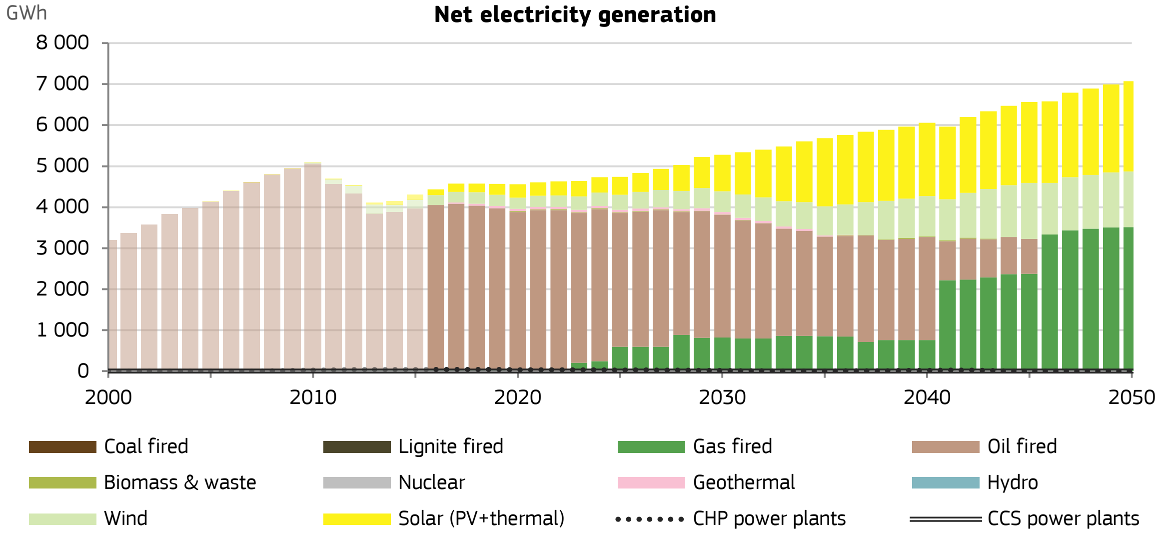

MW
Net installed power generation capacities
3 000
2 500
2 000
1 500
1 000
500
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

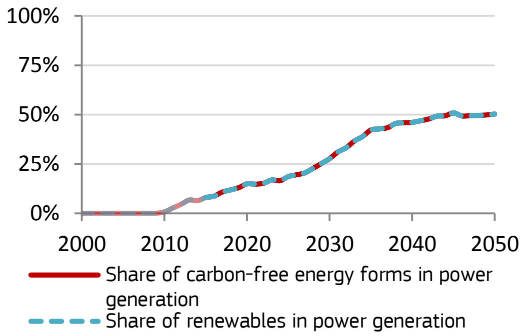

MW net
Installed capacities - difference to 2015
1 500
1 000
500
0
-500
-1 000
-1 500
505
982
475
6
-10
-1 299
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+21 MW)
2050 (+660 MW)

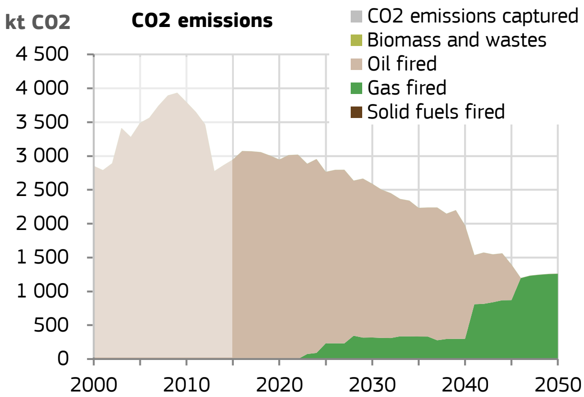

Cumulative investment 2016-2050 MW net
513
6
711
1 200
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

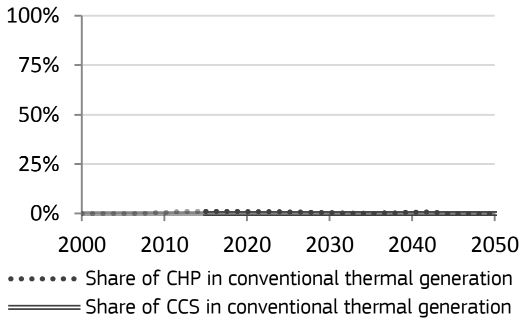

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

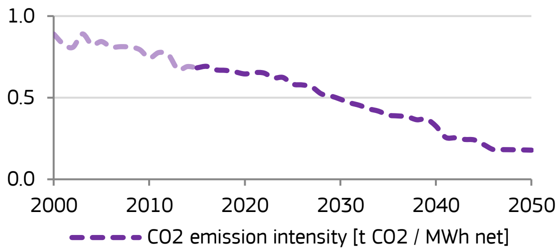

Power system indicators for the representative day
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

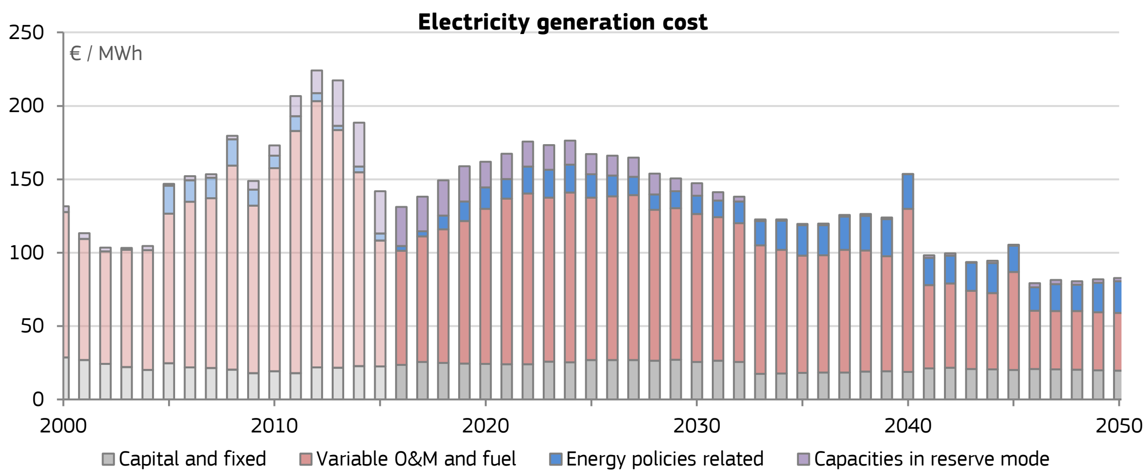

Net electricity generation
GWh
8 000
7 000
6 000
5 000
4 000
3 000
2 000
1 000
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

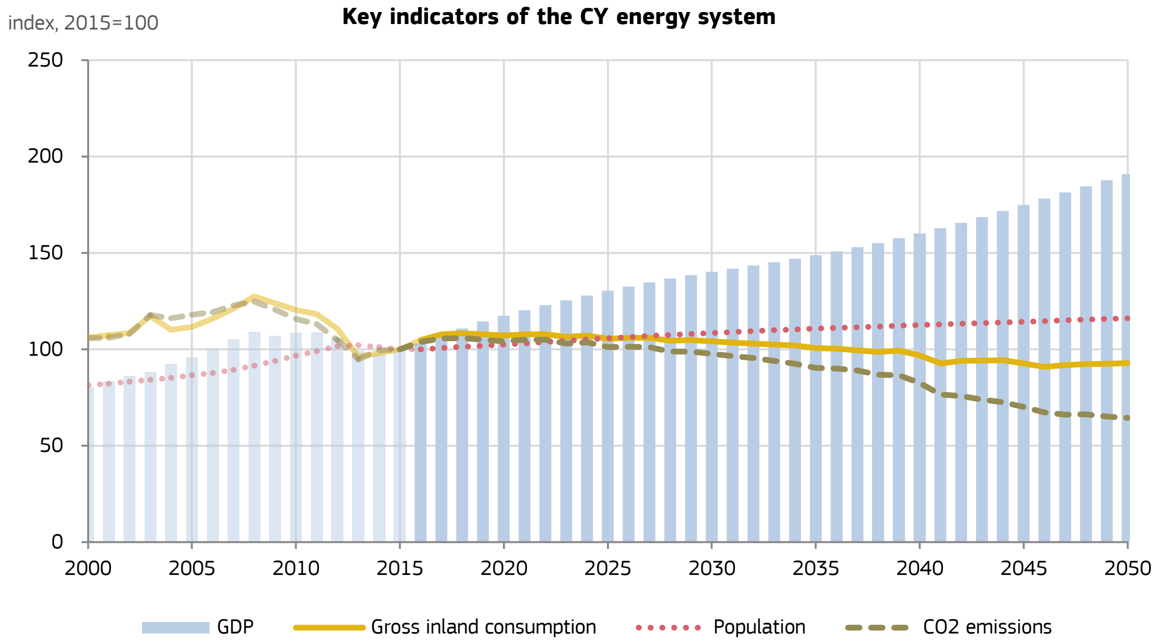

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


kt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
4 500
4 000
3 500
3 000
2 500
2 000
1 500
1 000
500
0
2000
2010
2020
2030
2040
2050

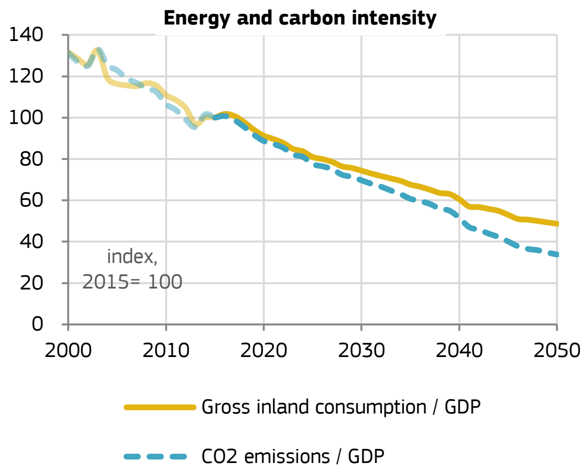

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

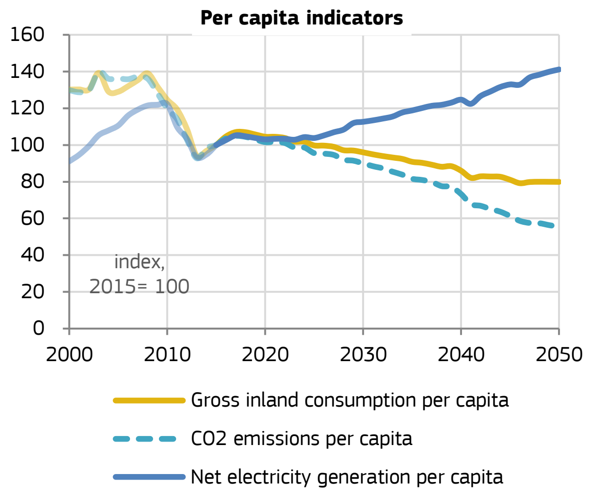

1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [ktoe]	1 101	1 833	1 660	1 754	1 748	1 791
Primary energy consumption [ktoe]	1 579	2 465	2 248	2 411	2 340	2 074
RES [%] - Share of energy from renewable sources		3.2%	10.6%	12.9%	18.6%	34.8%
RES-E [%] - Share of electricity from renewable sources		0.0%	8.4%	14.6%	26.4%	49.6%
Total CO2 emissions [kt CO2] (with intern. aviation, without LULUCF)	5 382	8 918	7 559	7 880	7 390	4 875
reduction to 1990		*66%*	*40%*	*46%*	*37%*	*-9%*
Emissions in current ETS sectors |(CY) [kt CO2]		6 083	5 108	5 342	5 045	2 892
reduction to 2005			*-16%*	*-12%*	*-17%*	*-52%*
Emissions in current ESD sectors [kt CO2]		2 835	2 452	2 538	2 344	1 984
reduction to 2005			*-14%*	*-10%*	*-17%*	*-30%*



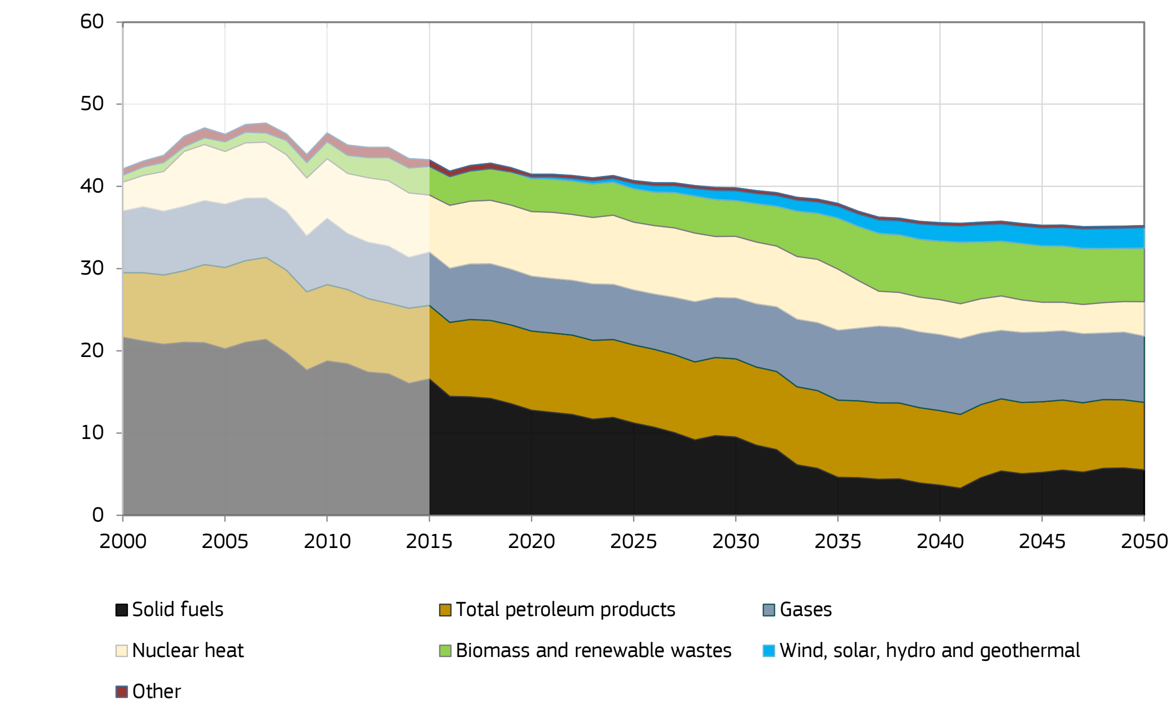


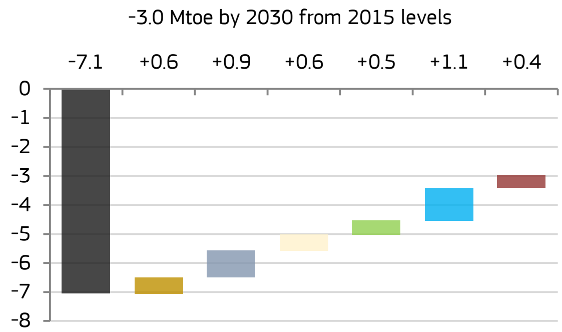
POTEnCIA - Model results overview

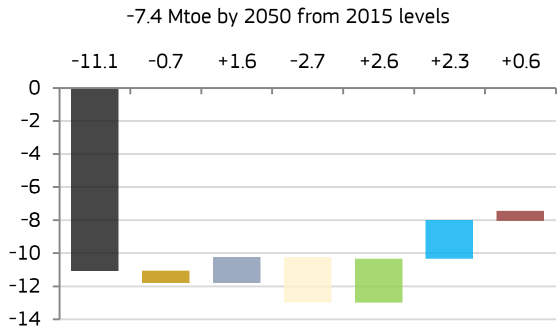
Czechia

Central_2018 scenario

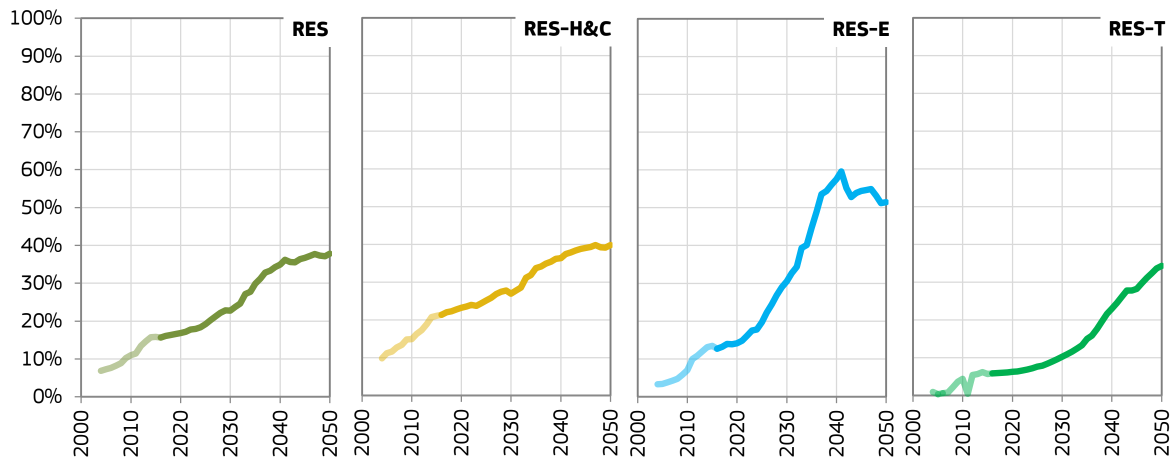
Gross inland energy consumption

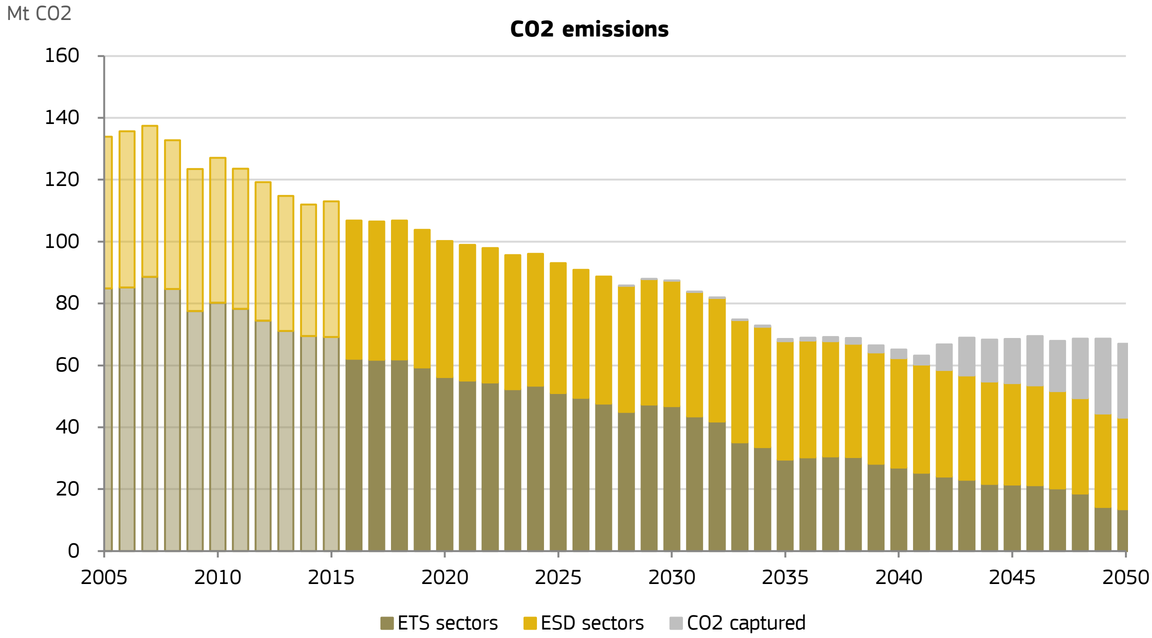


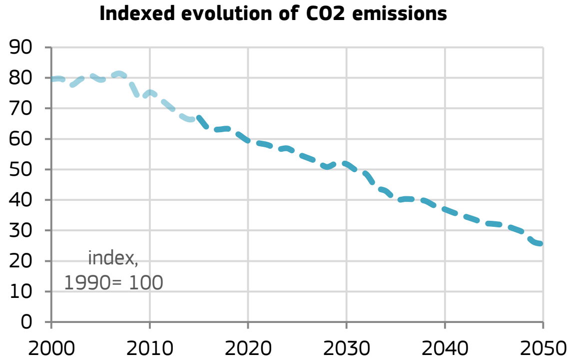


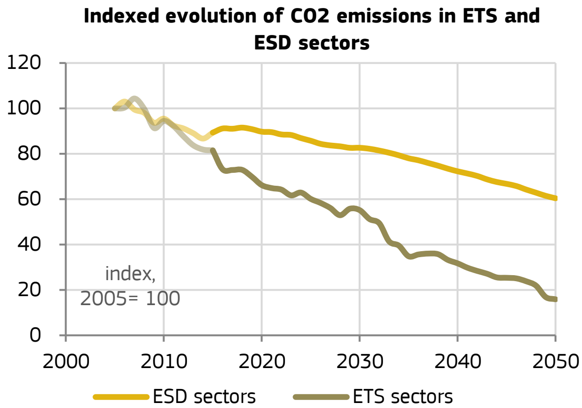


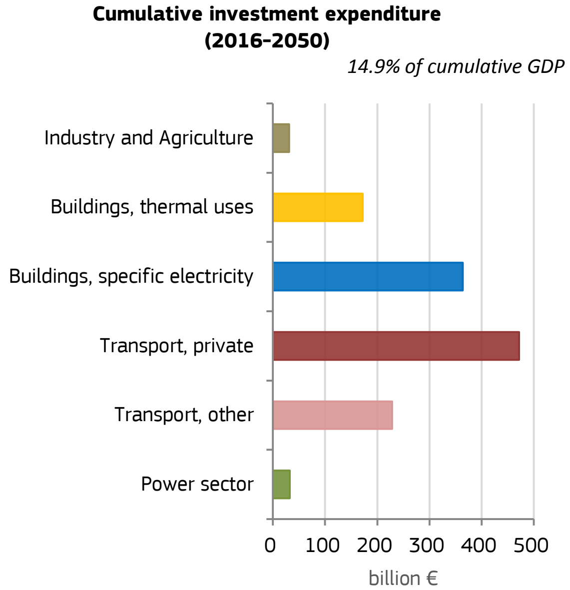
Share of renewable energies

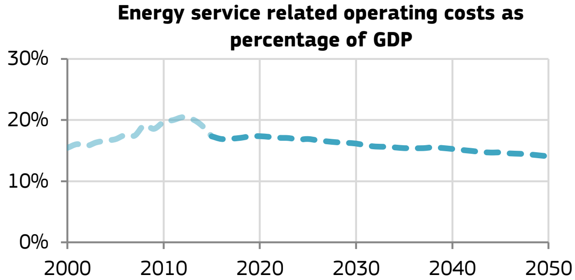


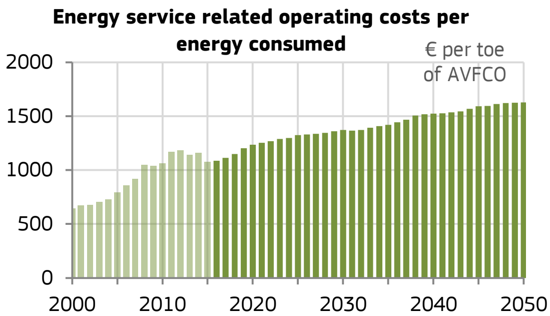

Mt CO2
CO2 emissions
160
140
120
100
80
60
40
20
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured

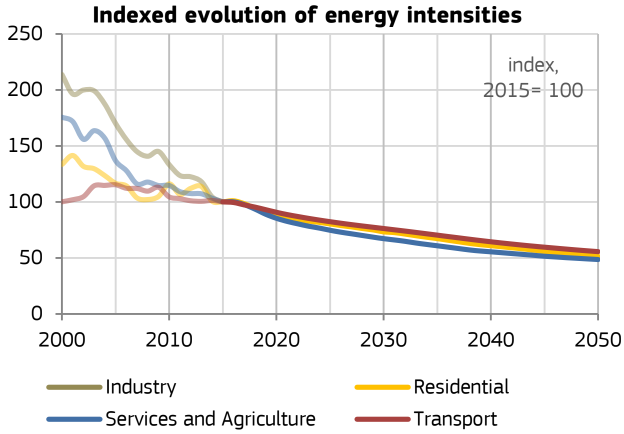

Indexed evolution of CO2 emissions
90
80
70
60
50
40
30
20
10
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

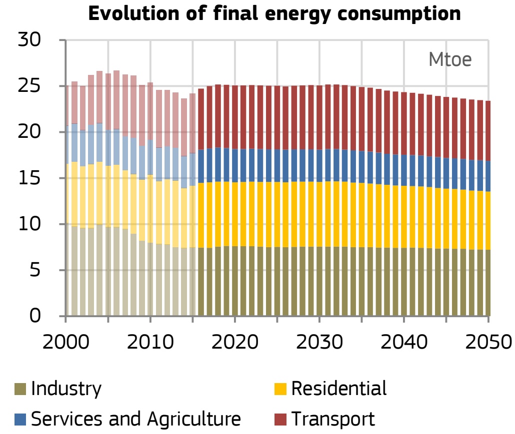

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors

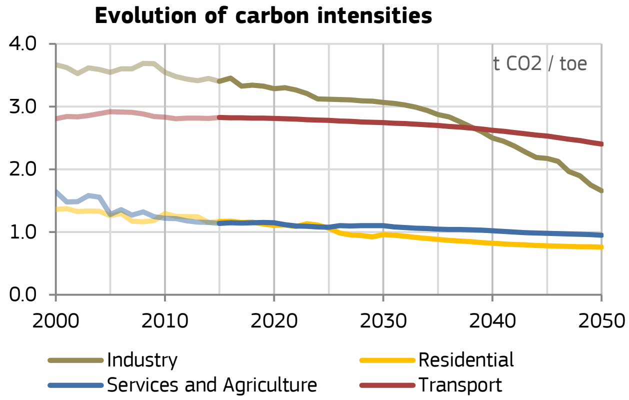

Cumulative investment expenditure (2016-2050)
14.9% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
100
200
300
400
500
billion €

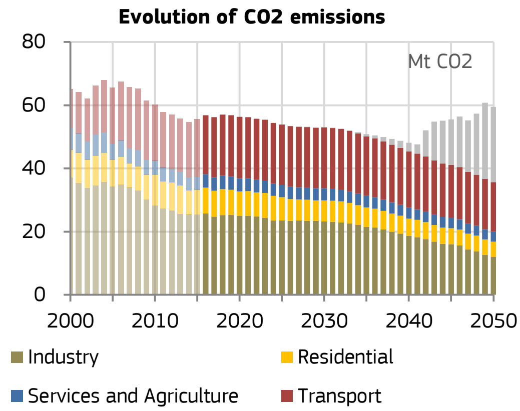

Energy service related operating costs as percentage of GDP
30%
20%
10%
0%
2000
2010
2020
2030
2040
2050

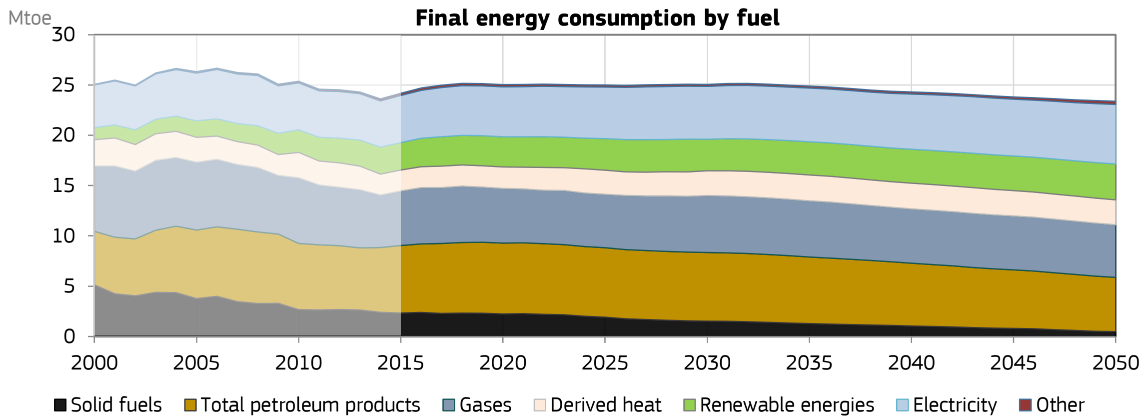

Energy service related operating costs per energy consumed
€ per toe
of AVFCO
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

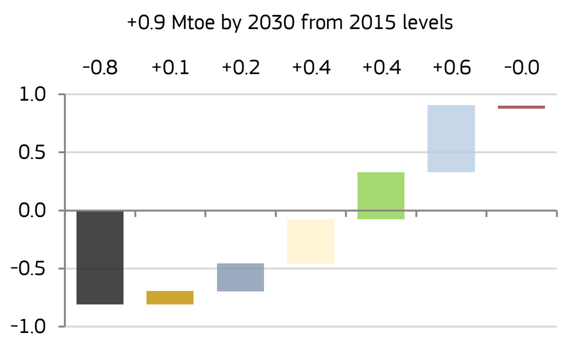

Indexed evolution of energy intensities
index, 2015= 100
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

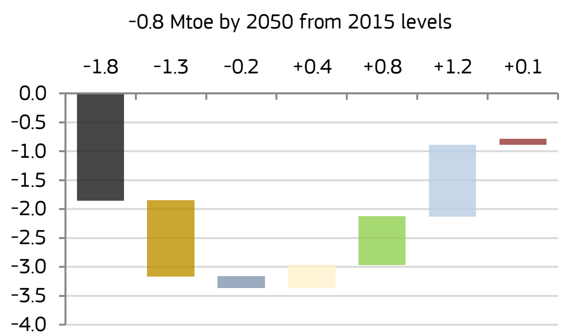

Evolution of final energy consumption
Mtoe
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

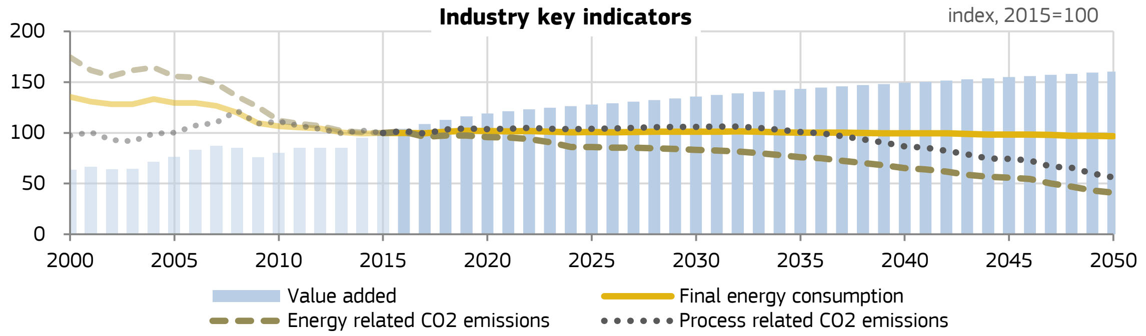

Evolution of carbon intensities
t CO2 / toe
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

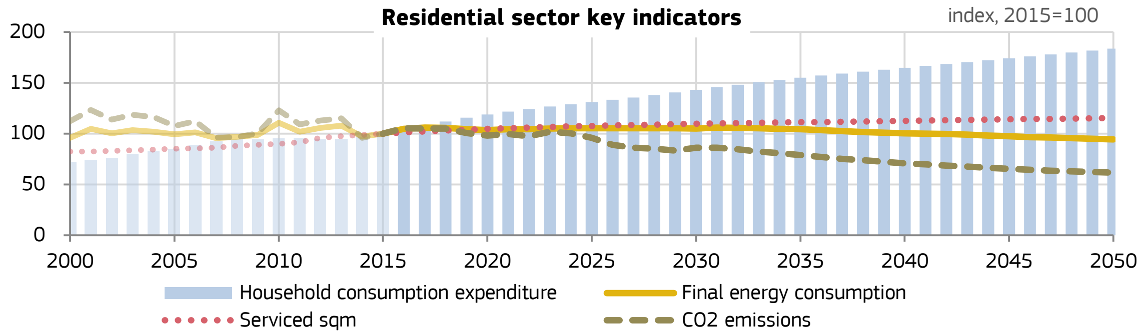

Evolution of CO2 emissions
Mt CO2
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

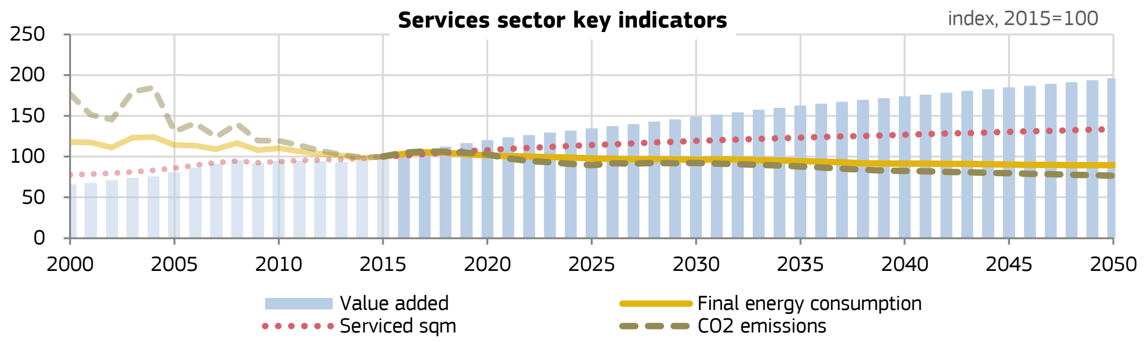

Final energy consumption by fuel
Mtoe
30
25
20
15
10
5
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

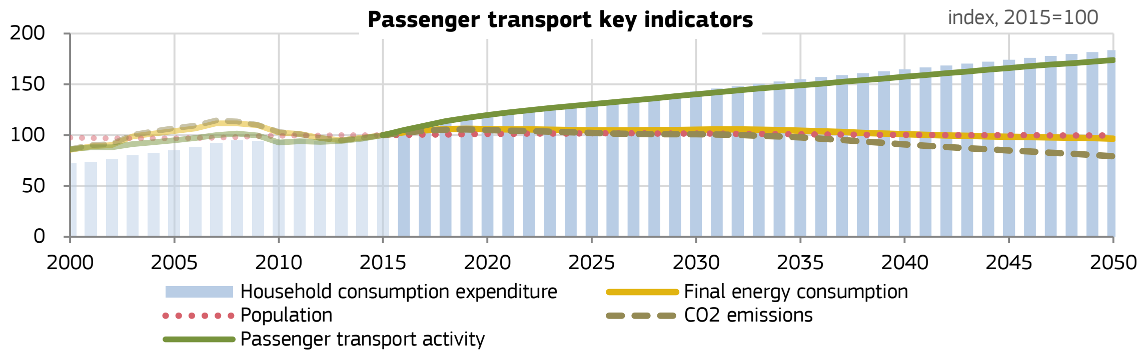

+0.9 Mtoe by 2030 from 2015 levels
-0.8
+0.1
+0.2
+0.4
+0.4
+0.6
-0.0
1.0
0.5
0.0
-0.5
-1.0

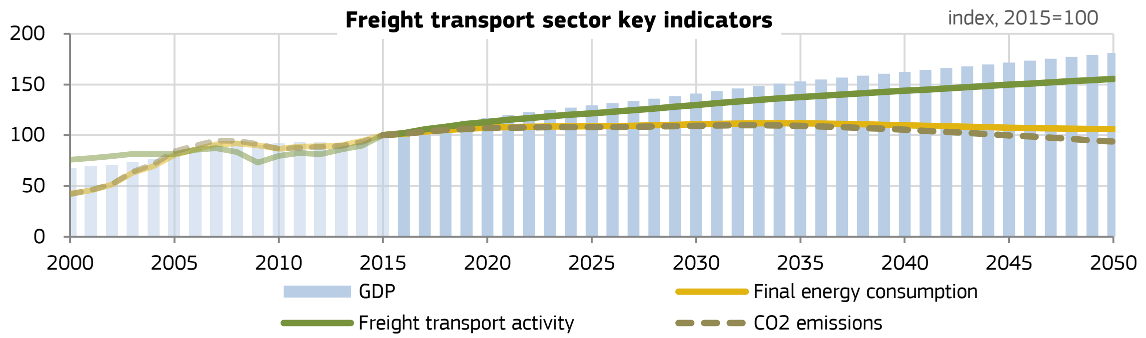

-0.8 Mtoe by 2050 from 2015 levels
-1.8
-1.3
-0.2
+0.4
+0.8
+1.2
+0.1
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0

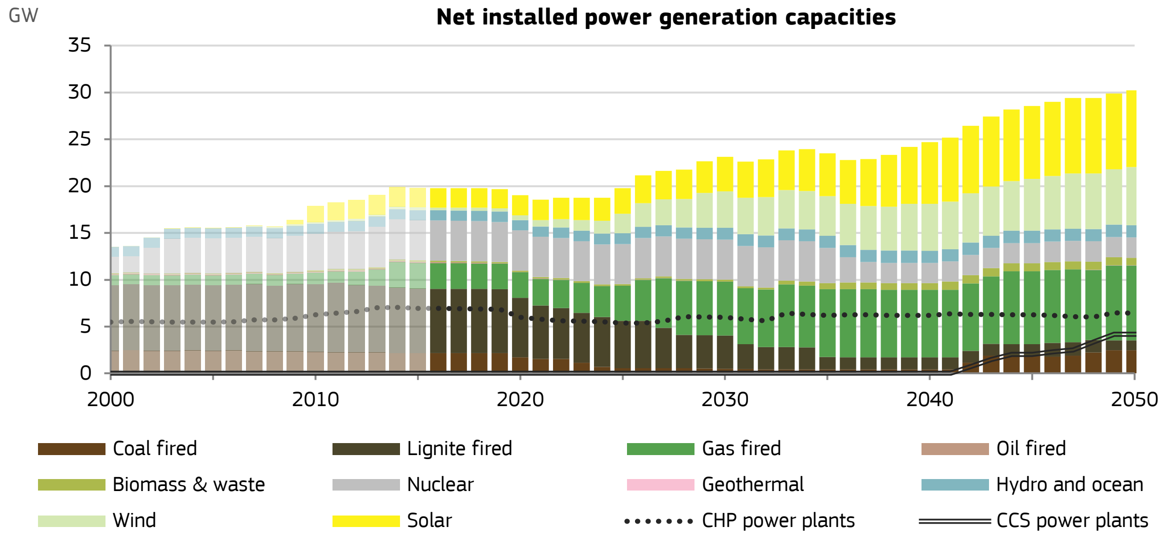

Industry key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

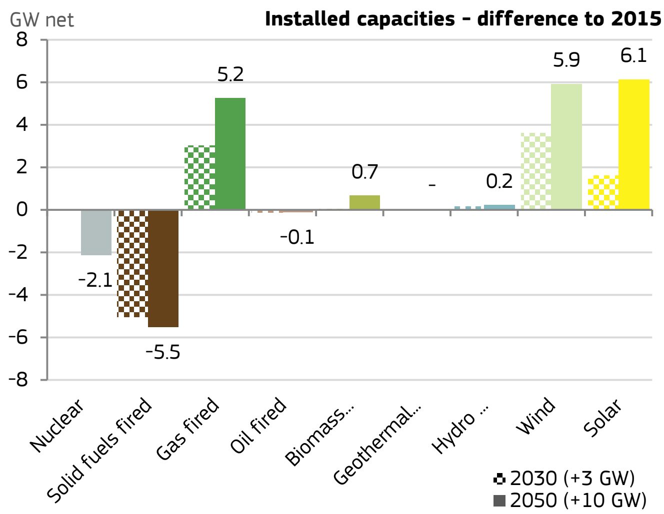

Residential sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

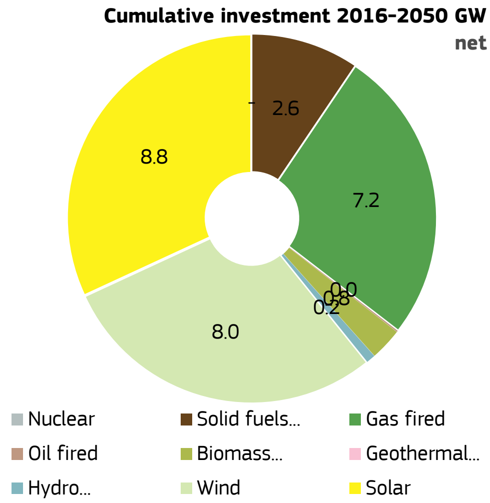

Services sector key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

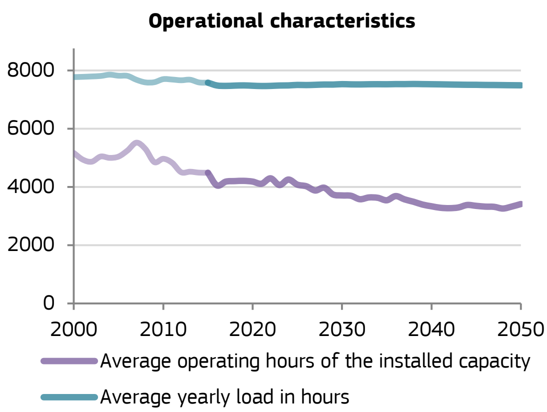

Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

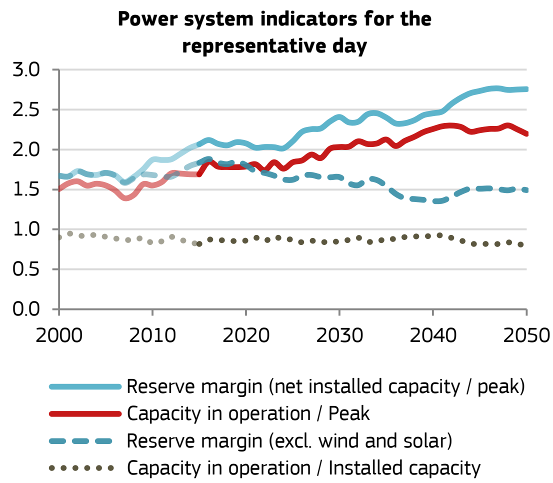

Freight transport sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

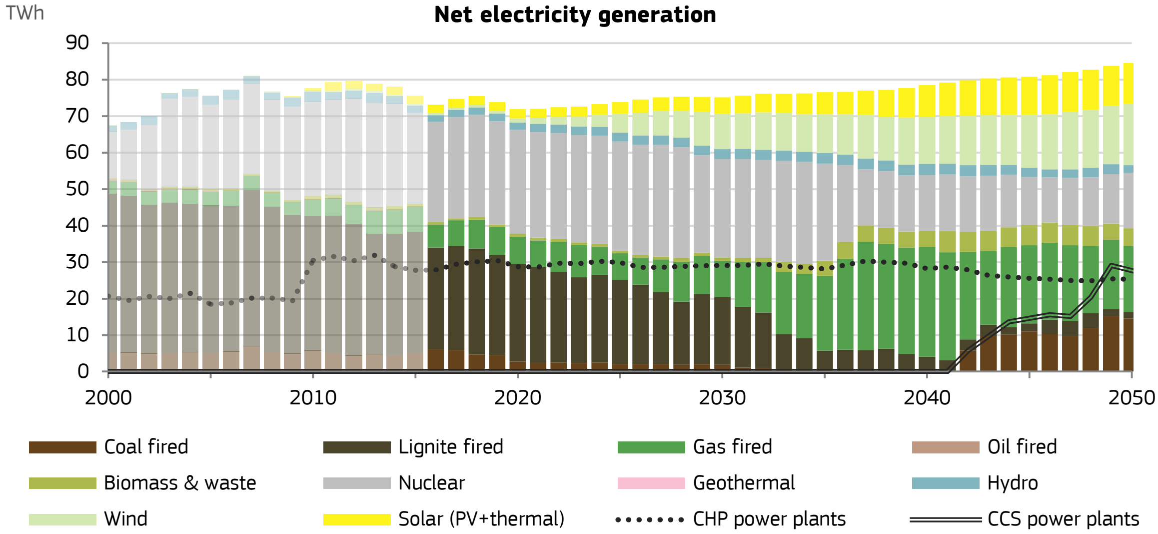

Net installed power generation capacities
GW
35
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

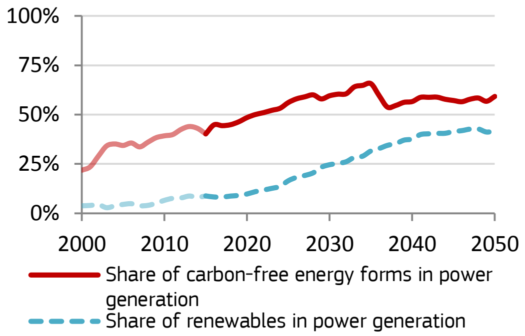

Installed capacities - difference to 2015
GW net
8
6
4
2
0
-2
-4
-6
-8
5.2
5.9
6.1
0.7
0.2
-0.1
-2.1
-5.5
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+3 GW)
2050 (+10 GW)

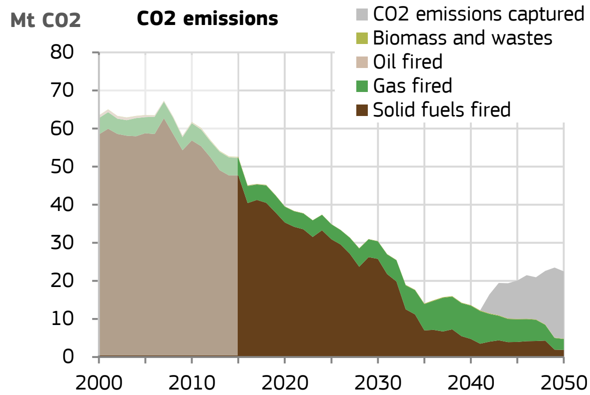

Cumulative investment 2016-2050 GW net
2.6
7.2
8.8
8.0
0.0
0.8
0.2
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

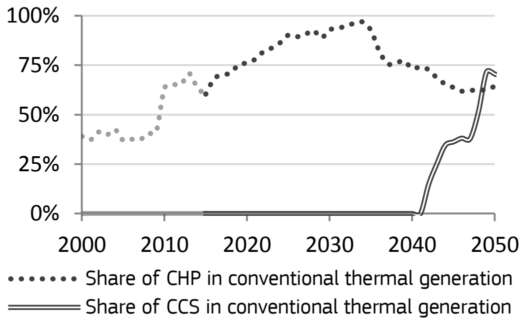

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

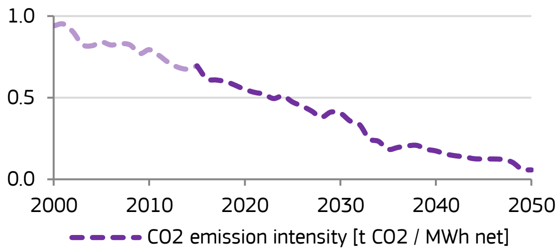

Power system indicators for the representative day
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

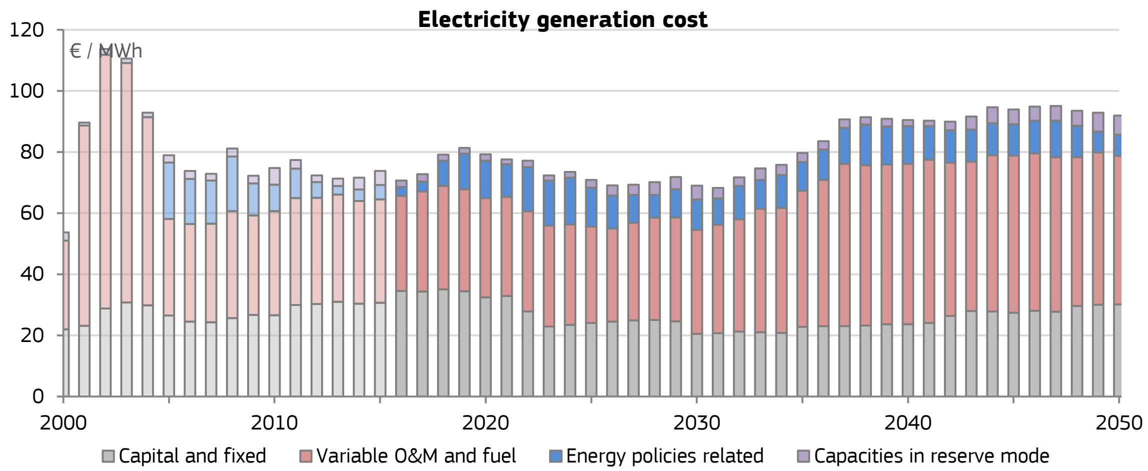

TWh
Net electricity generation
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

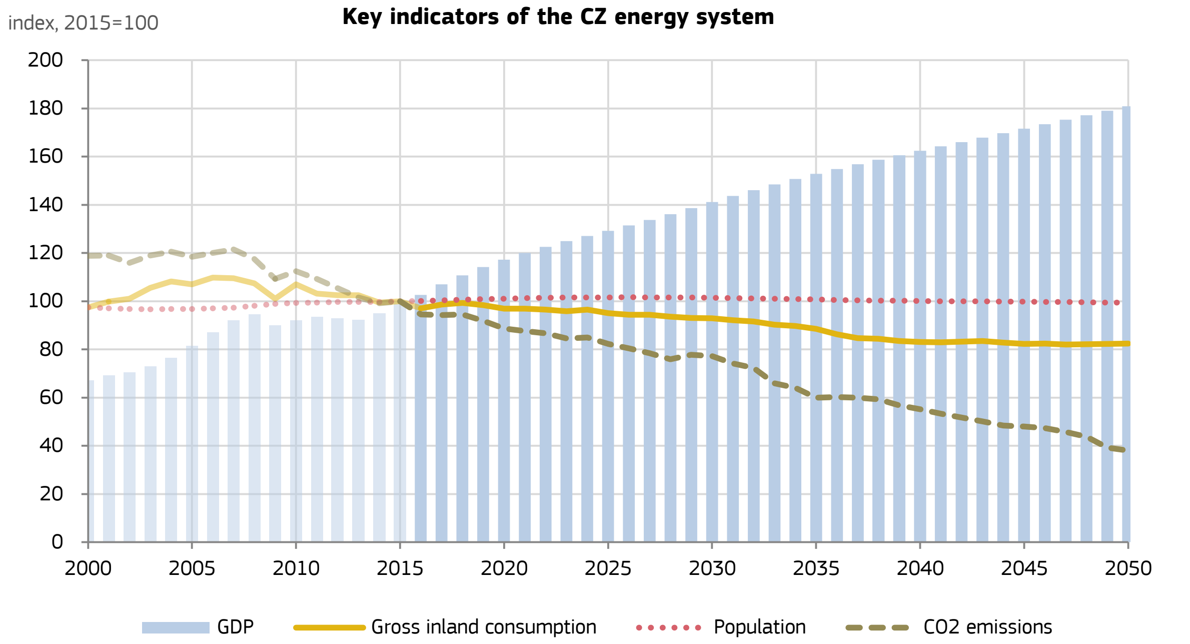

Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired

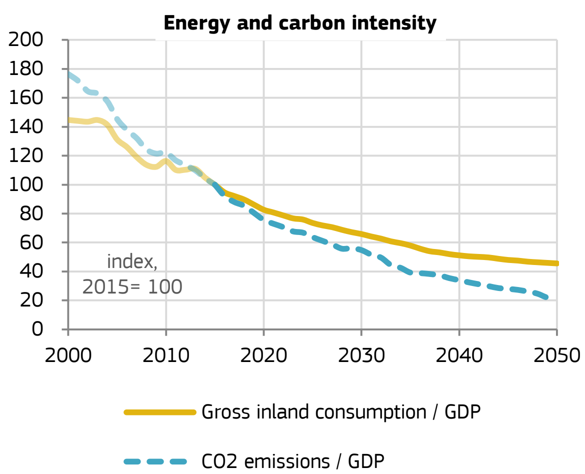

Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

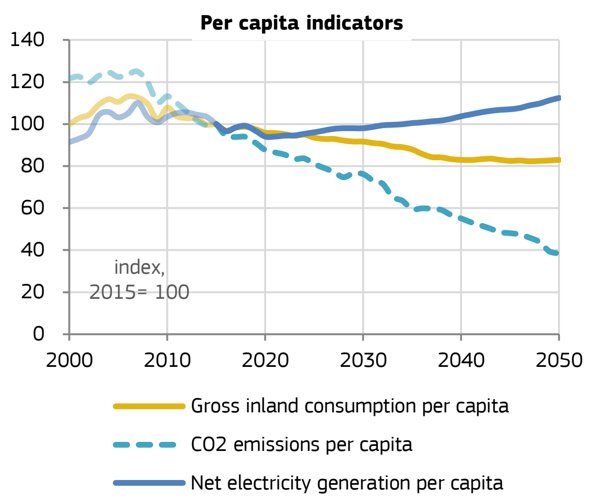

CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	32.7	26.3	24.2	25.0	25.1	23.4
Primary energy consumption [Mtoe]	48.4	42.5	39.9	38.1	36.3	31.8
RES [%] - Share of energy from renewable sources		7.3%	15.8%	16.8%	22.8%	37.8%
RES-E [%] - Share of electricity from renewable sources		3.4%	13.4%	14.2%	30.6%	51.5%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	168.8	133.9	113.0	100.2	87.3	43.1
reduction to 1990		*-21%*	*-33%*	*-41%*	*-48%*	*-74%*
Emissions in current ETS sectors |(CZ) [Mt CO2]		84.9	69.2	56.2	46.8	13.5
reduction to 2005			*-18%*	*-34%*	*-45%*	*-84%*
Emissions in current ESD sectors [Mt CO2]		49.0	43.8	44.0	40.5	29.6
reduction to 2005			*-11%*	*-10%*	*-17%*	*-40%*

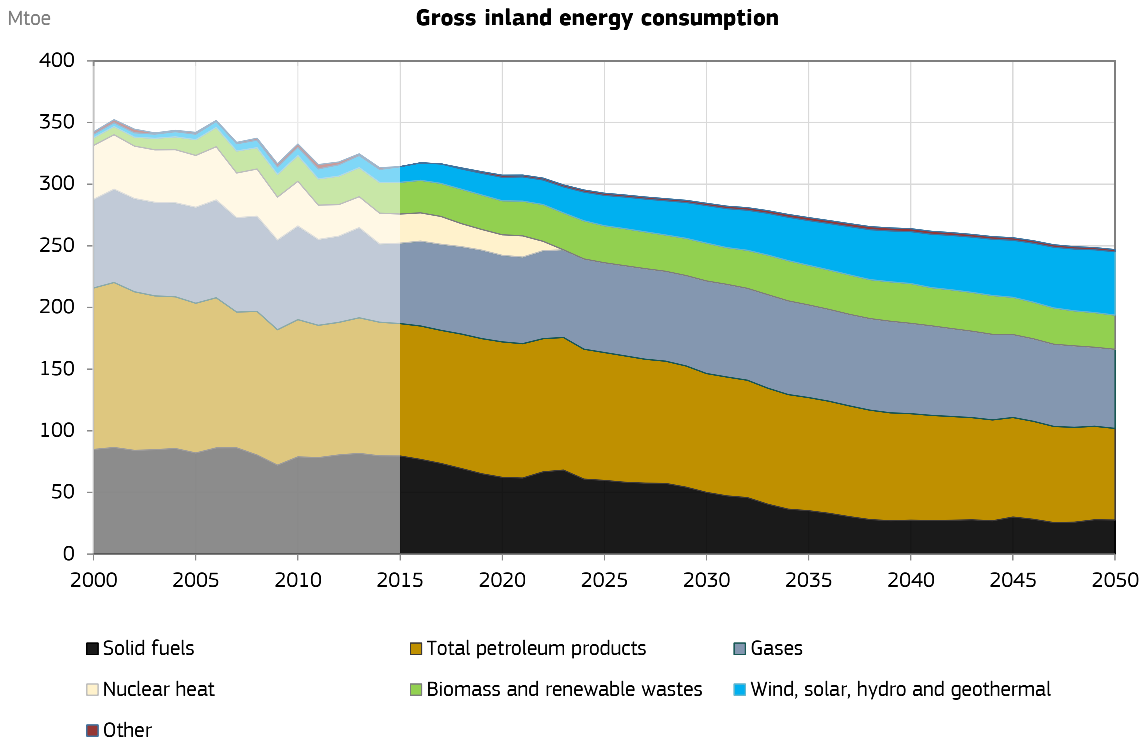


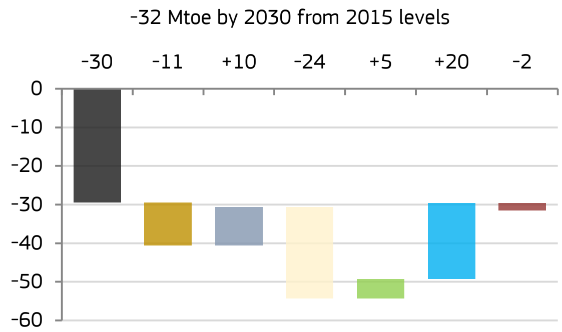


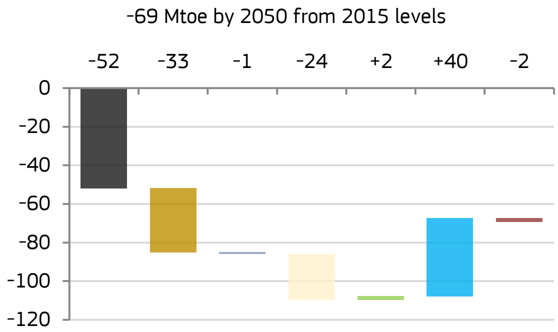
POTEnCIA - Model results overview

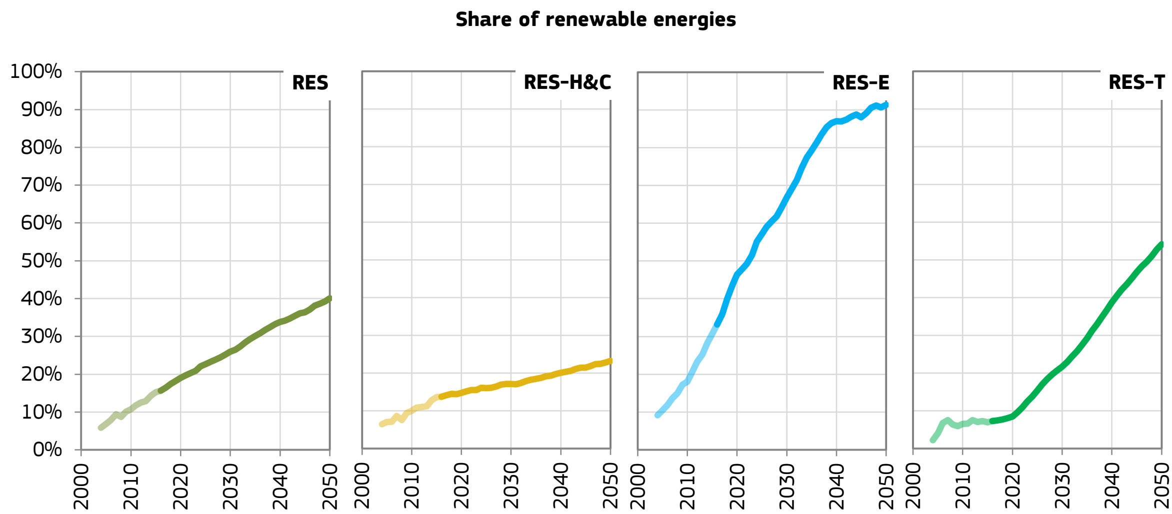
Germany

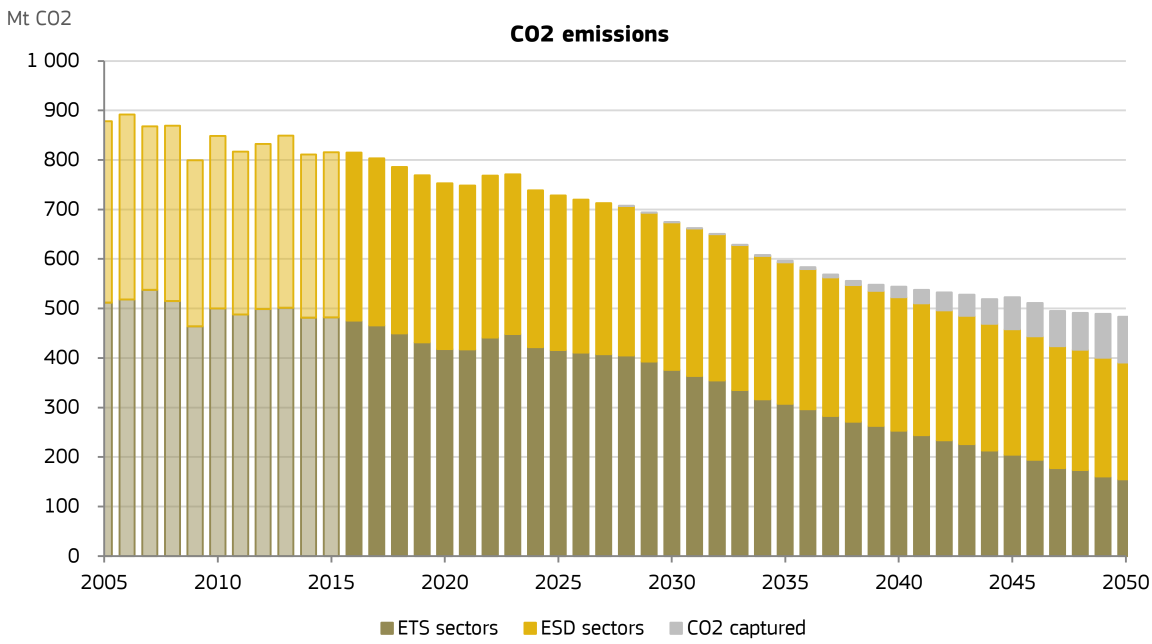
Central_2018 scenario


Mtoe
Gross inland energy consumption
400
350
300
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Nuclear heat
Biomass and renewable wastes
Wind, solar, hydro and geothermal
Other

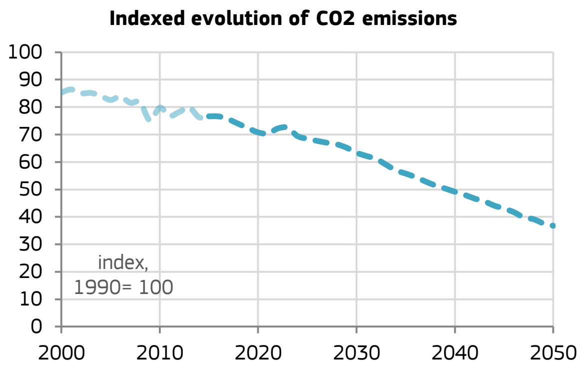

-32 Mtoe by 2030 from 2015 levels
-30
-11
+10
-24
+5
+20
-2
0
-10
-20
-30
-40
-50
-60


-69 Mtoe by 2050 from 2015 levels
-52
-33
-1
-24
+2
+40
-2
0
-20
-40
-60
-80
-100
-120

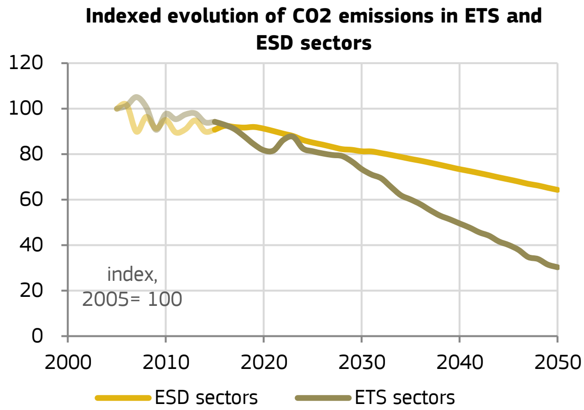

Share of renewable energies
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RES
RES-H&C
RES-E
RES-T
2000
2010
2020
2030
2040
2050



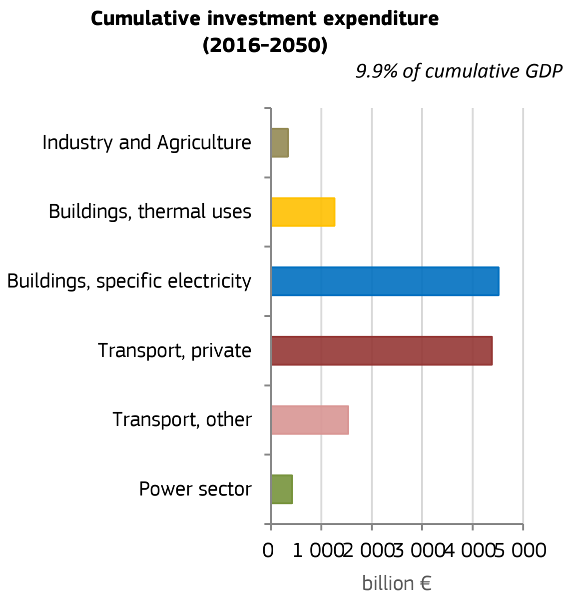
Mt CO2
CO2 emissions
1 000
900
800
700
600
500
400
300
200
100
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured



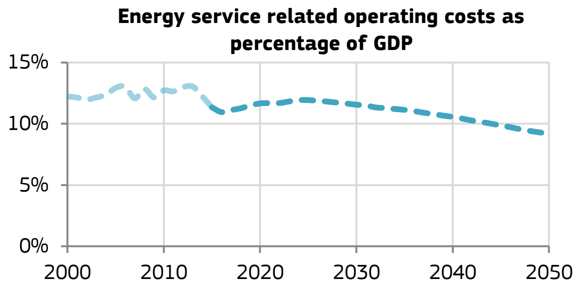
Indexed evolution of CO2 emissions
100
90
80
70
60
50
40
30
20
10
0
index,
1990= 100
2000
2010
2020
2030
2040
2050



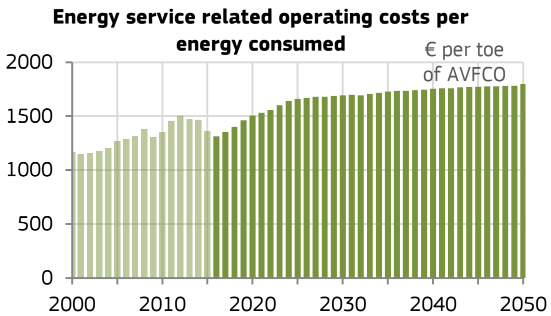
Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors



Cumulative investment expenditure (2016-2050)
9.9% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
1 000
2 000
3 000
4 000
5 000
billion €

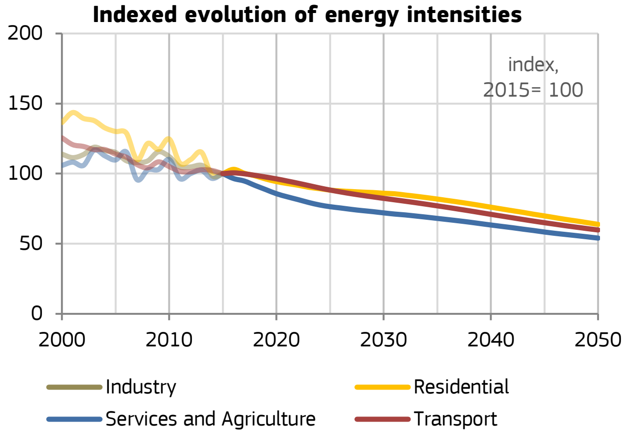


Energy service related operating costs as percentage of GDP
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050

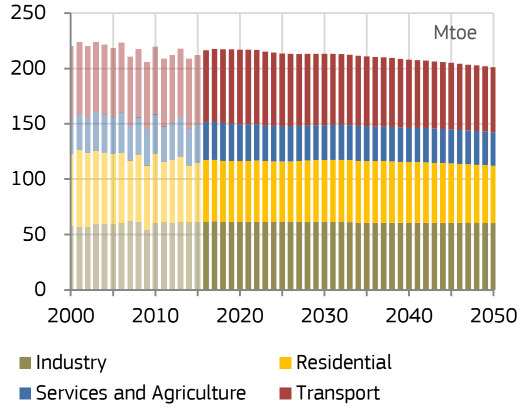


Energy service related operating costs per energy consumed
€ per toe
of AVFCO
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

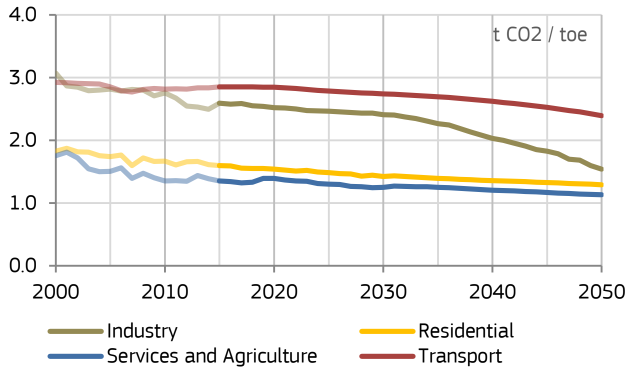
Indexed evolution of energy intensities



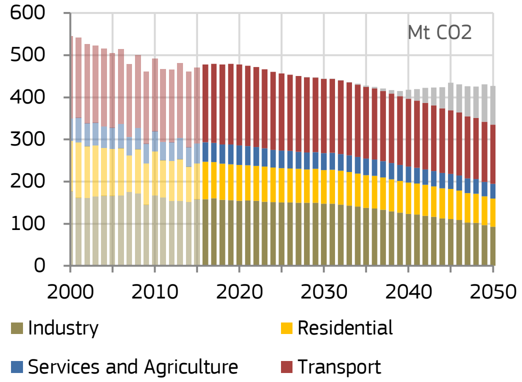
Evolution of final energy consumption



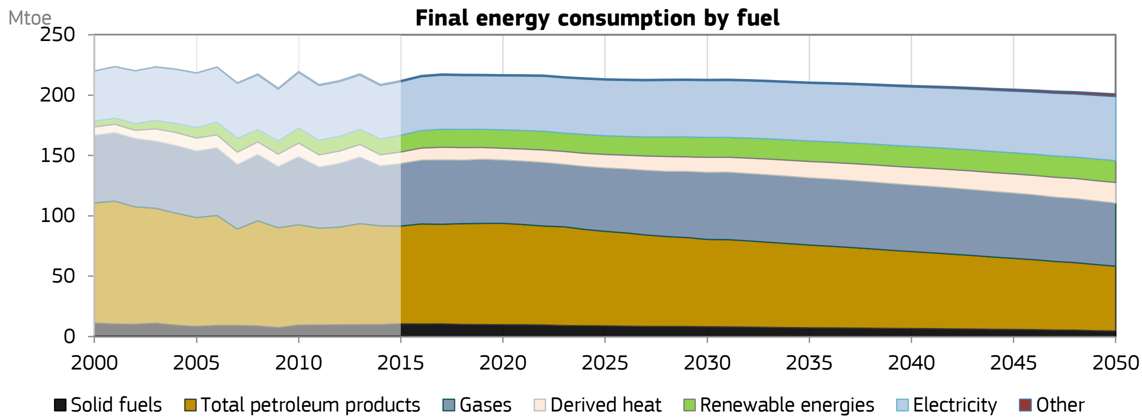
Evolution of carbon intensities



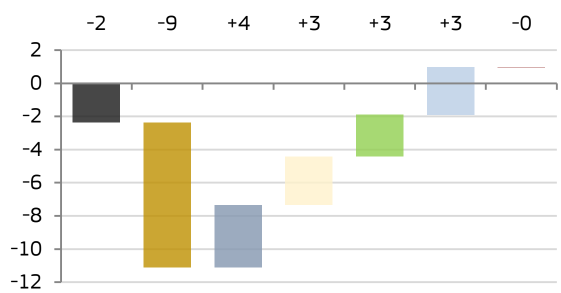
Evolution of CO2 emissions



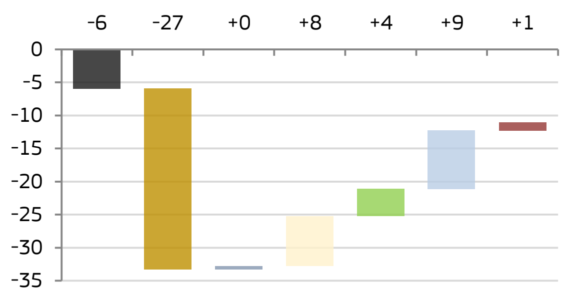
Final energy consumption by fuel

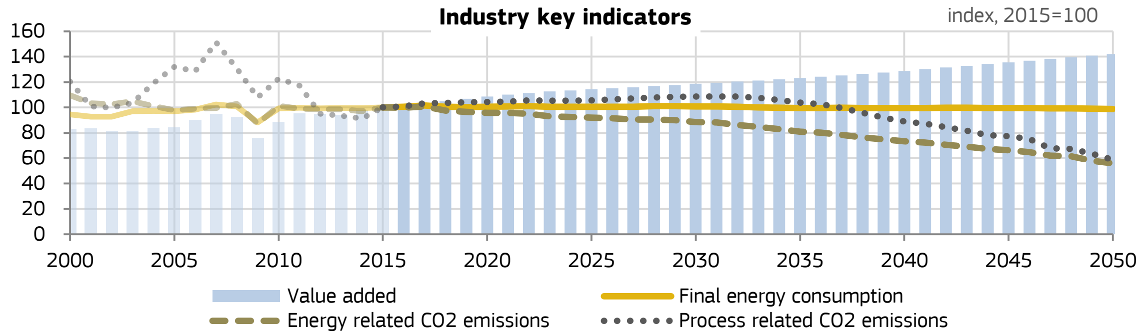


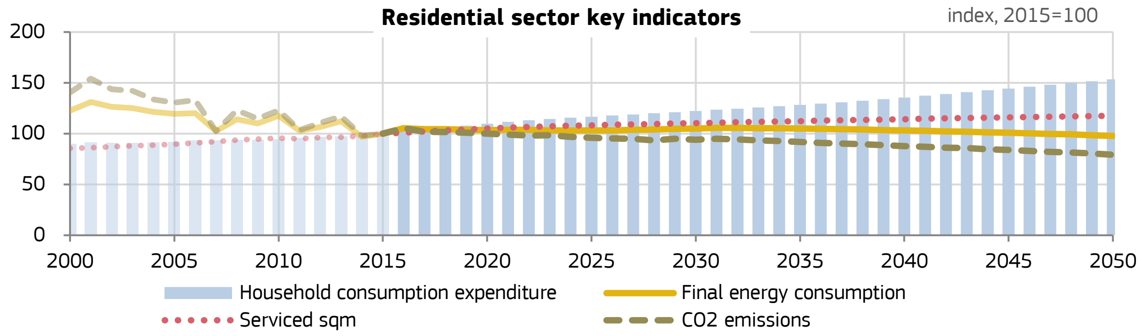
+1 Mtoe by 2030 from 2015 levels

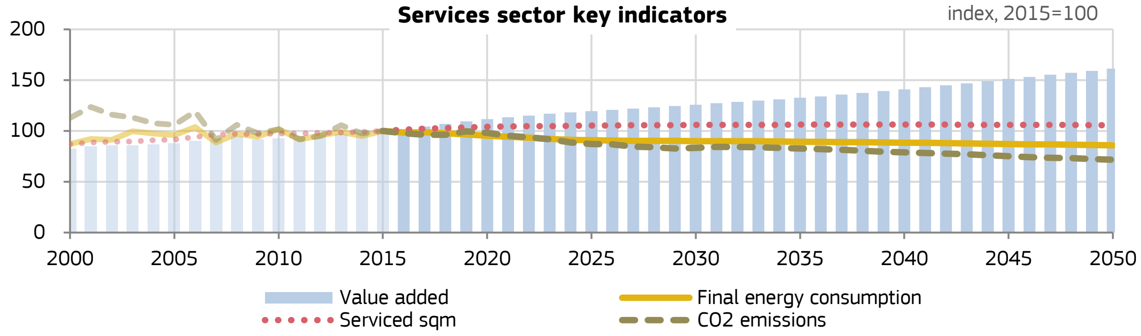


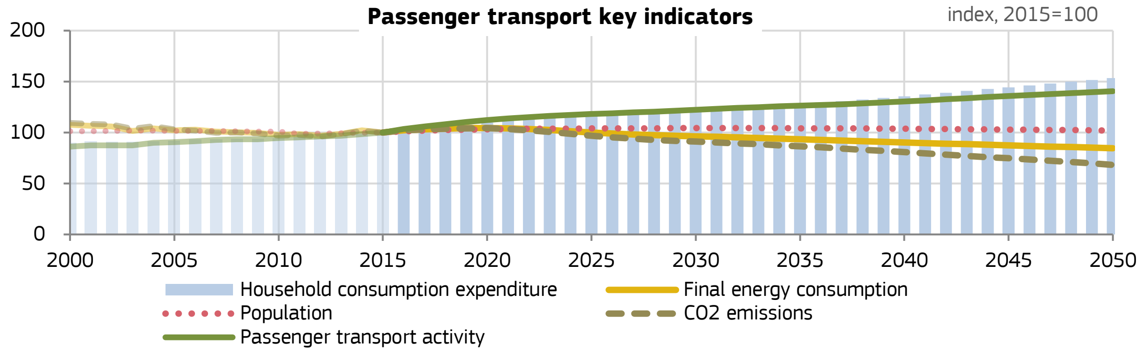
-11 Mtoe by 2050 from 2015 levels

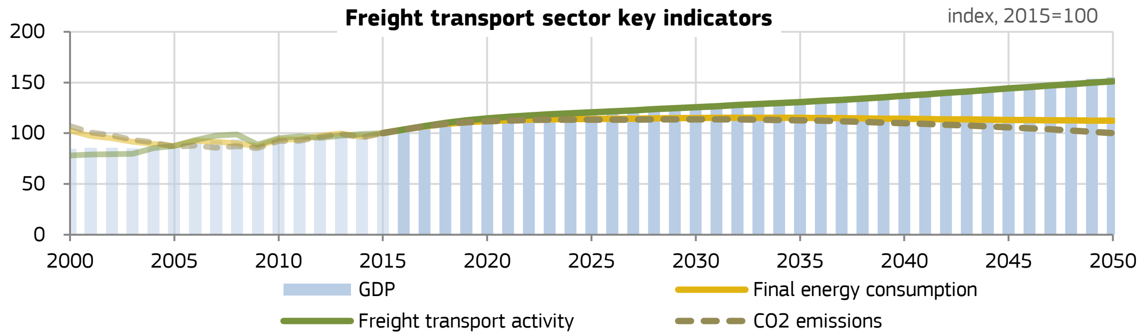


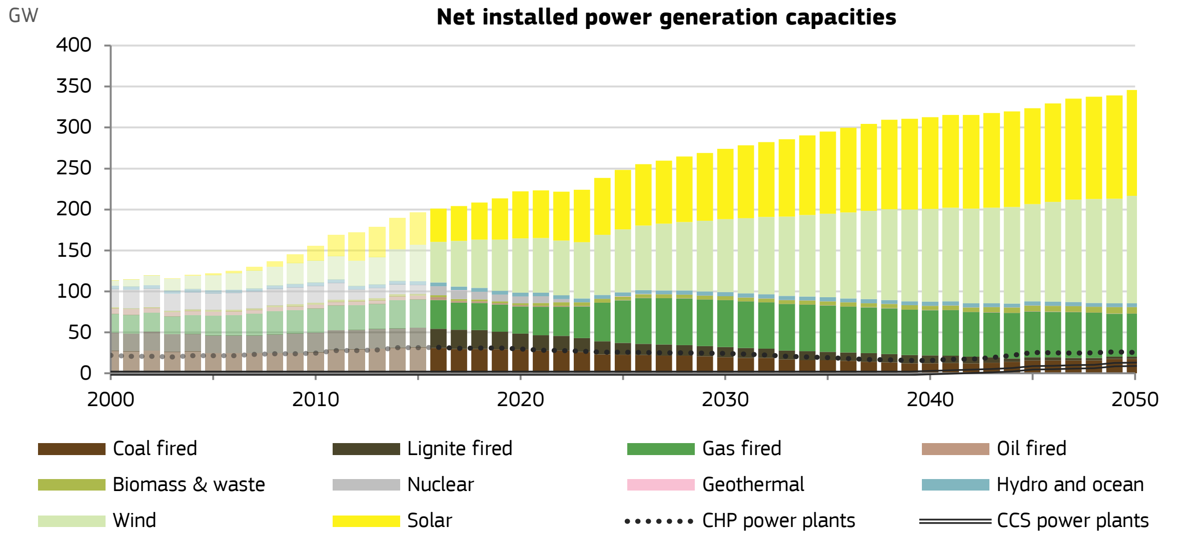

Industry key indicators
index, 2015=100
160
140
120
100
80
60
40
20
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

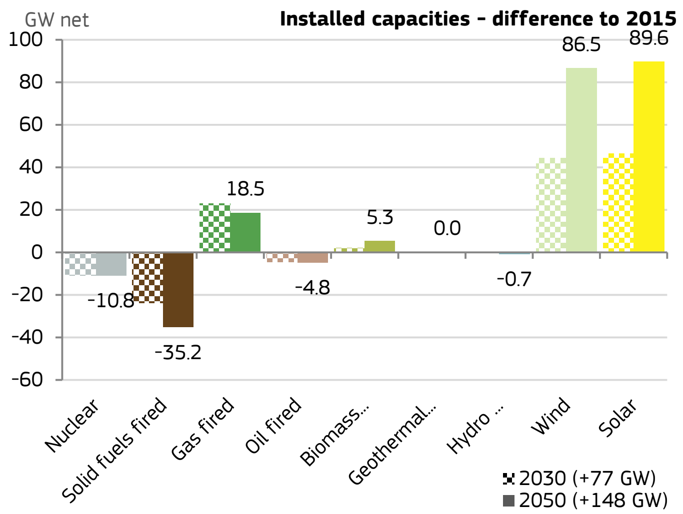

Residential sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

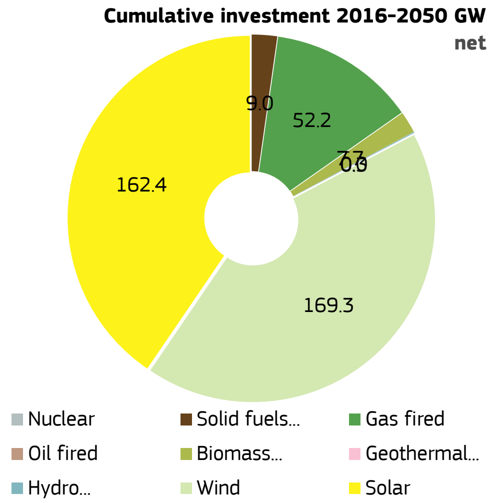

Services sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

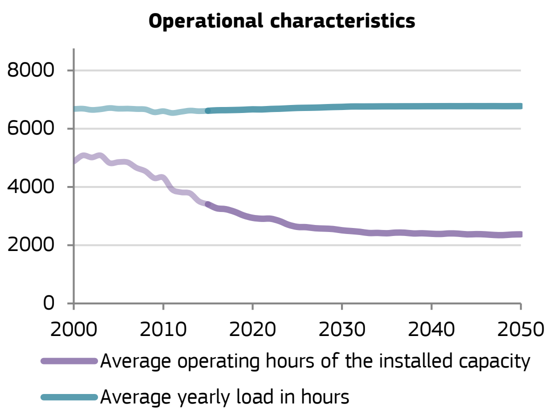

Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

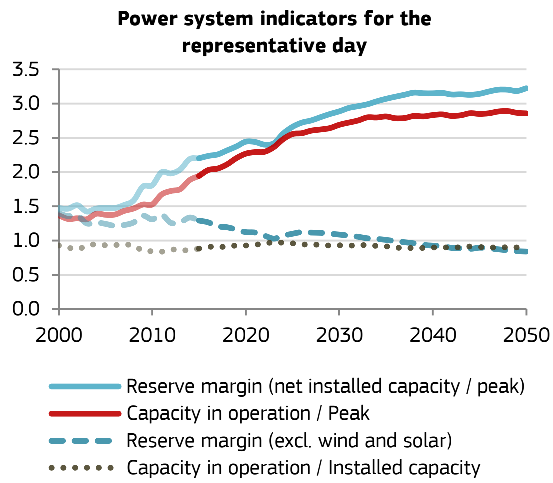

Freight transport sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

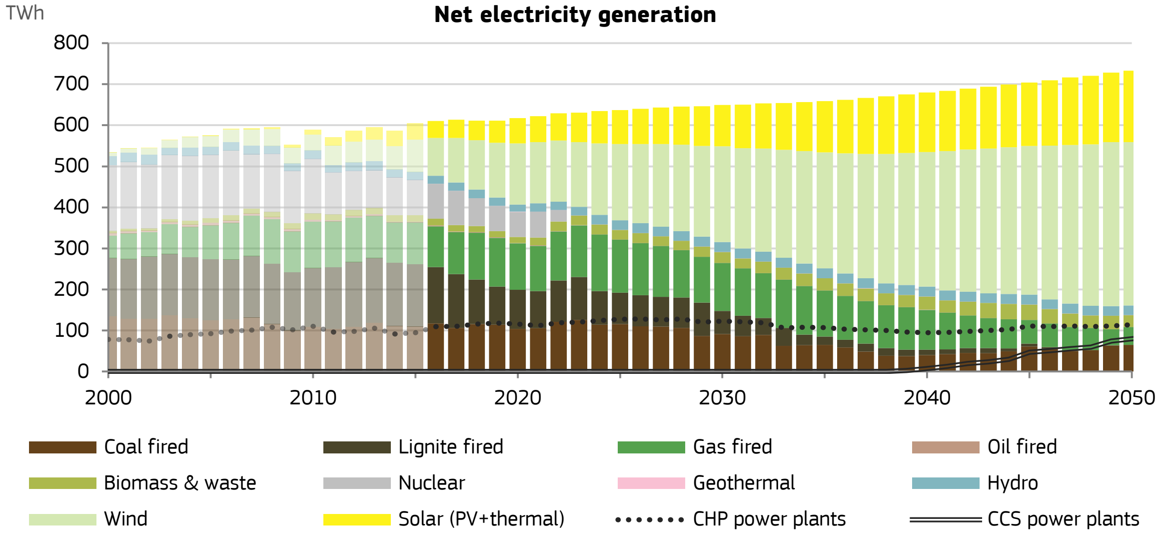

Net installed power generation capacities
GW
400
350
300
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

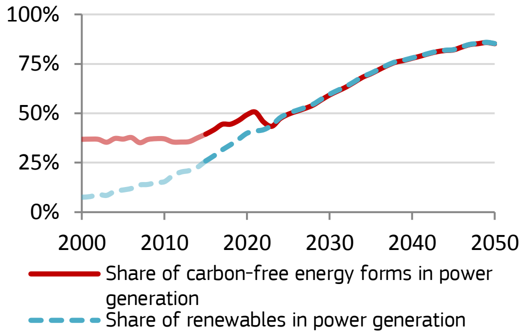

Installed capacities - difference to 2015
GW net
100
80
60
40
20
0
-20
-40
-60
86.5
89.6
18.5
5.3
0.0
-10.8
-35.2
-4.8
-0.7
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+77 GW)
2050 (+148 GW)

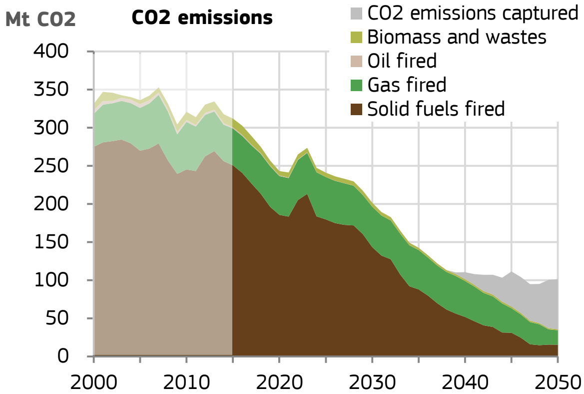

Cumulative investment 2016-2050 GW net
9.0
52.2
7.3
0.0
162.4
169.3
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

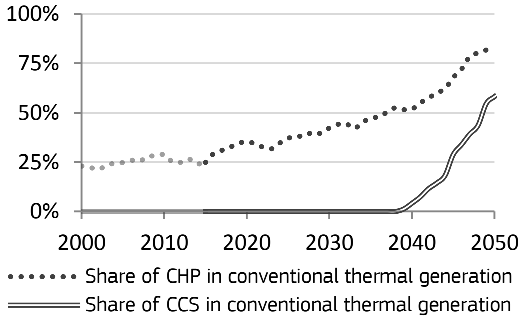

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

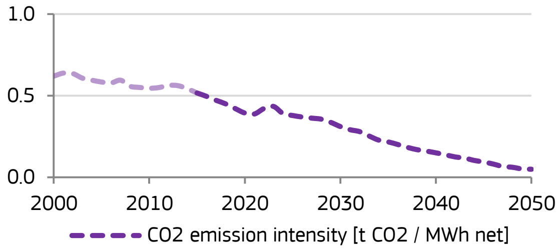

Power system indicators for the representative day
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

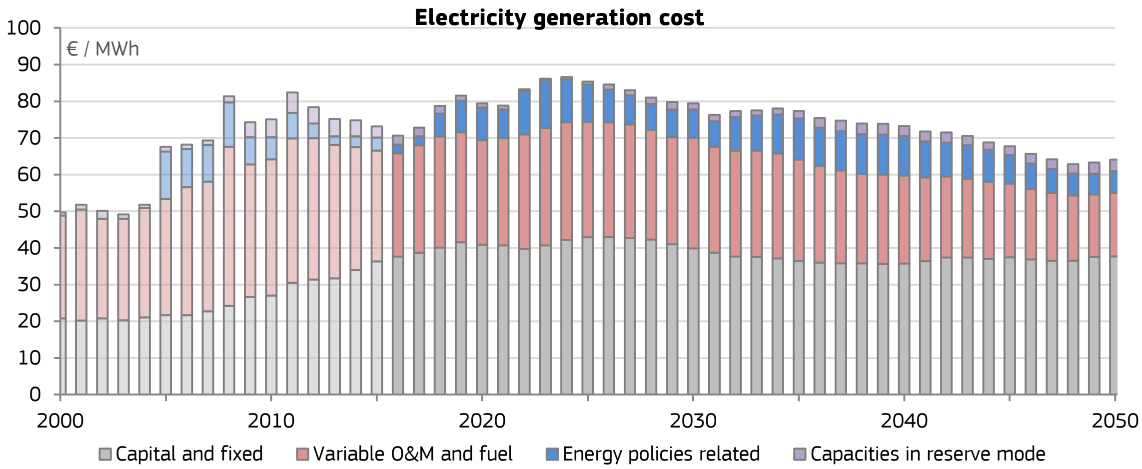

Net electricity generation
TWh
800
700
600
500
400
300
200
100
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

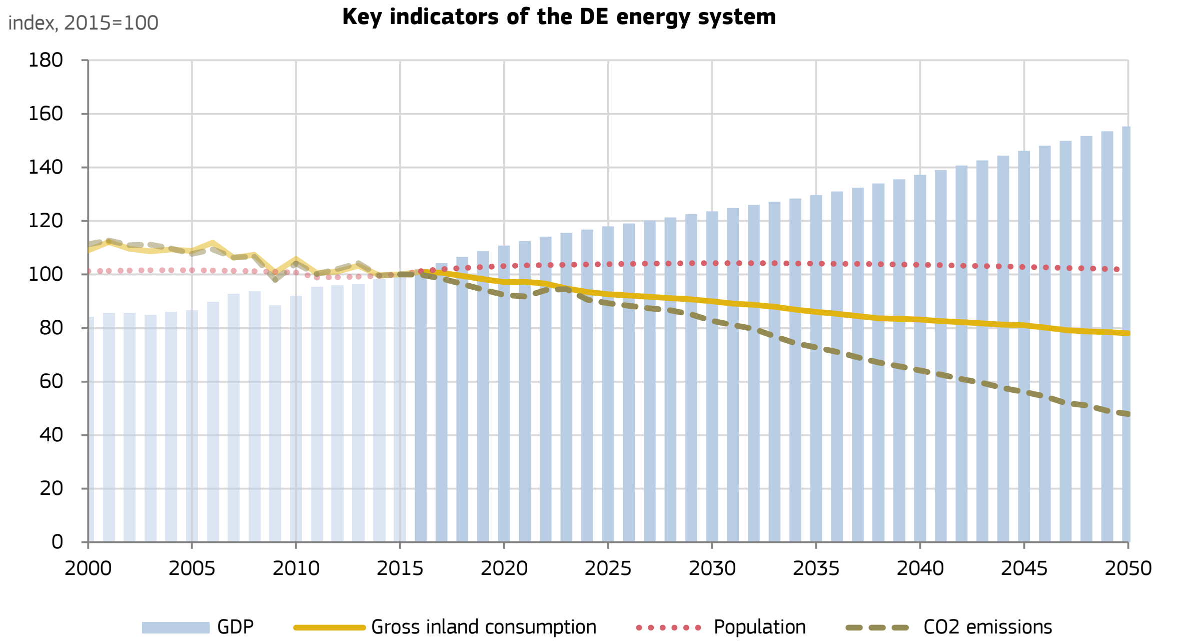

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
400
350
300
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050

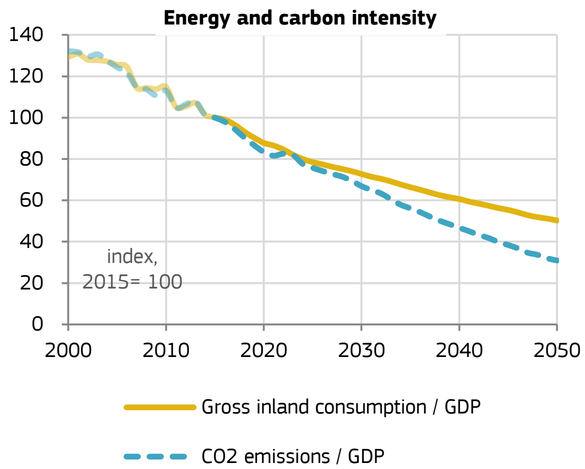

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

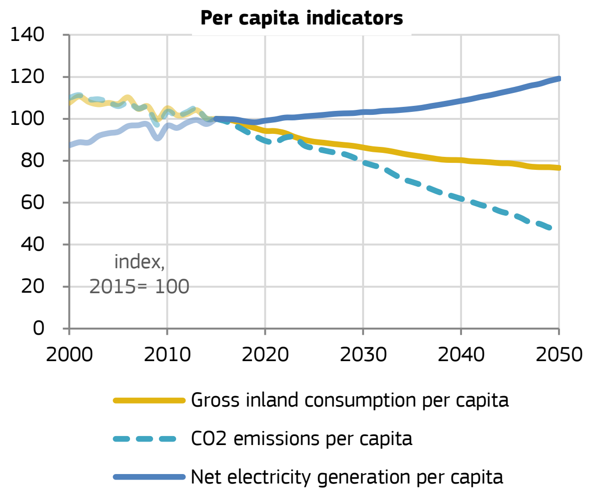

1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
100
90
80
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	229	218	212	217	213	201
Primary energy consumption [Mtoe]	333	317	293	282	259	223
RES [%] - Share of energy from renewable sources		6.9%	15.2%	19.0%	26.0%	40.1%
RES-E [%] - Share of electricity from renewable sources		10.4%	30.8%	46.4%	66.9%	91.4%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	1 064	878	815	753	674	391
reduction to 1990		*-17%*	*-23%*	*-29%*	*-37%*	*-63%*
Emissions in current ETS sectors |(DE) [Mt CO2]		512	482	418	376	155
reduction to 2005			*-6%*	*-18%*	*-27%*	*-70%*
Emissions in current ESD sectors [Mt CO2]		367	333	335	298	236
reduction to 2005			*-9%*	*-9%*	*-19%*	*-36%*

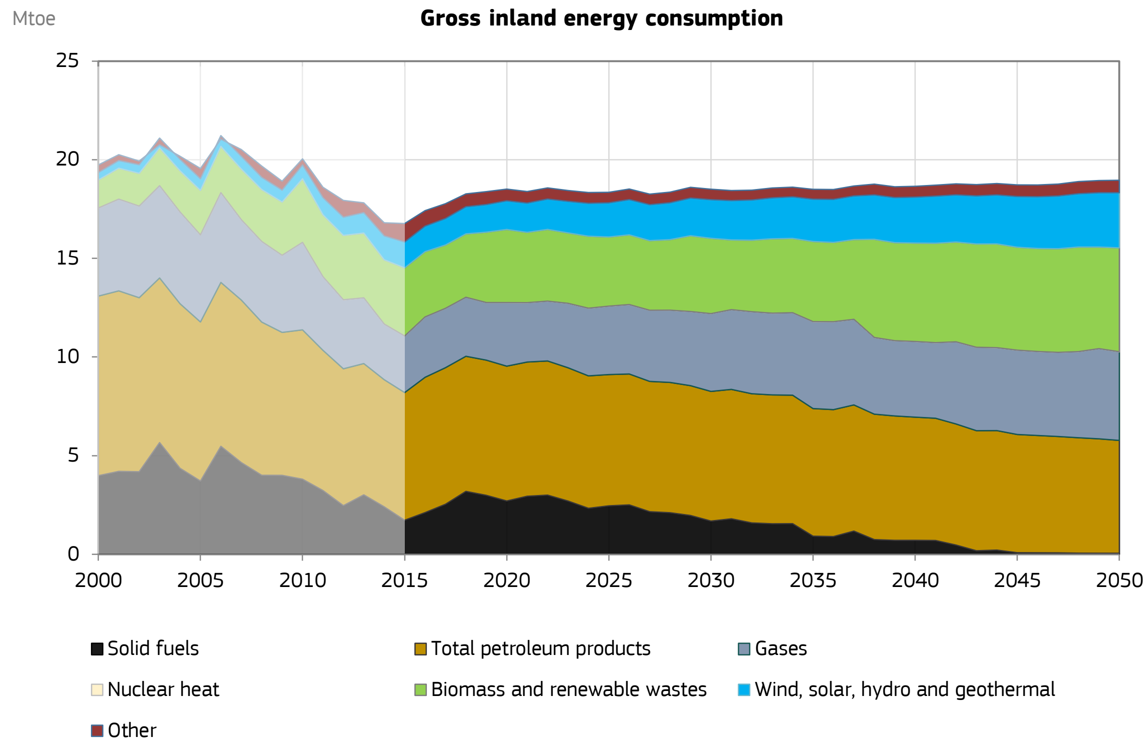


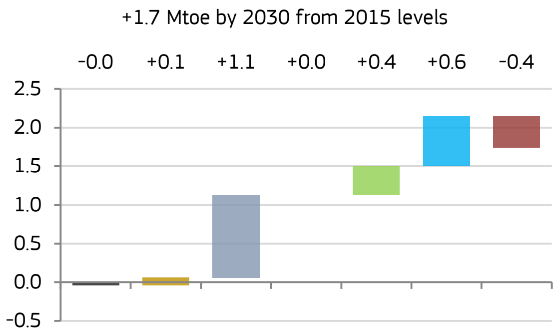


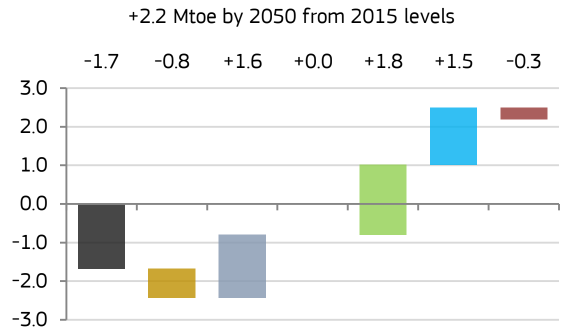
Denmark

Central_2018 scenario

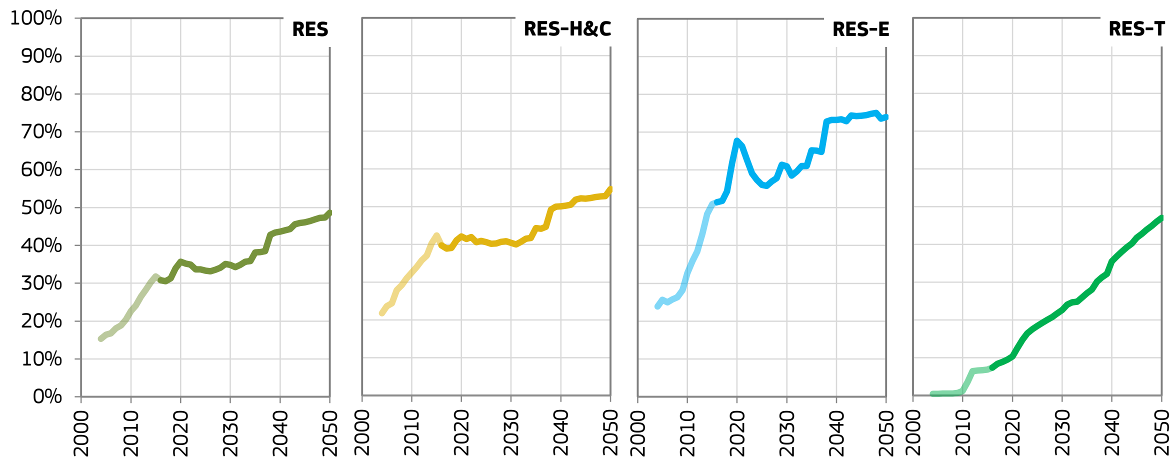
Gross inland energy consumption

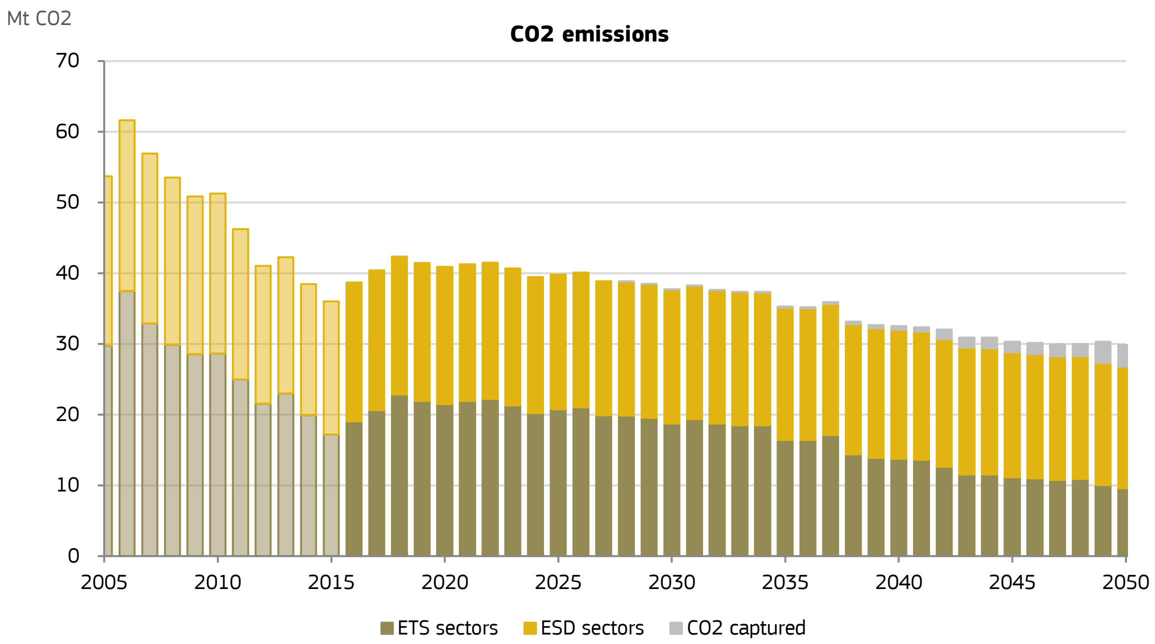


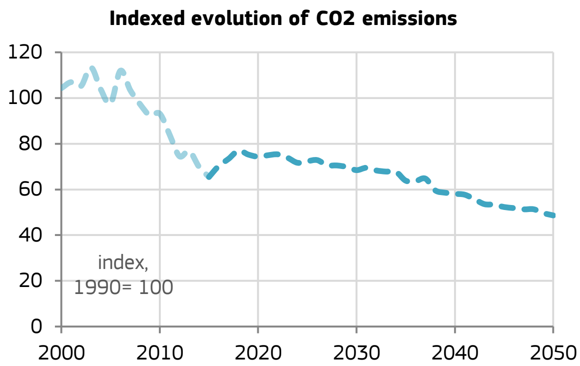


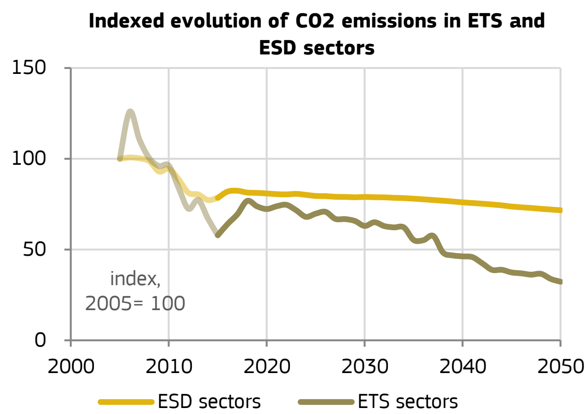


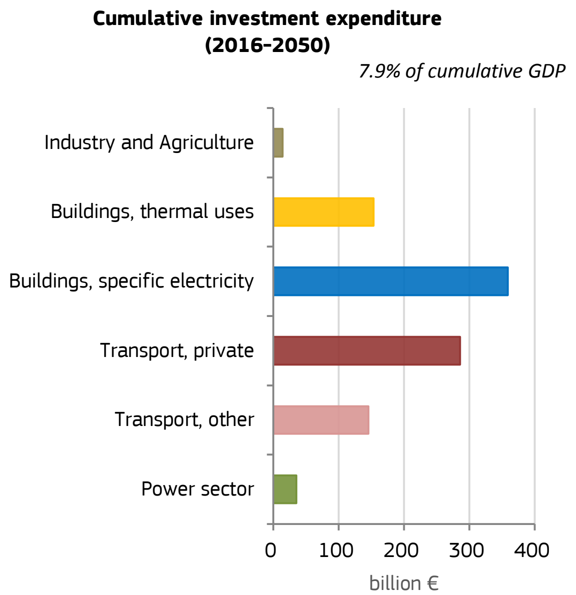
Share of renewable energies

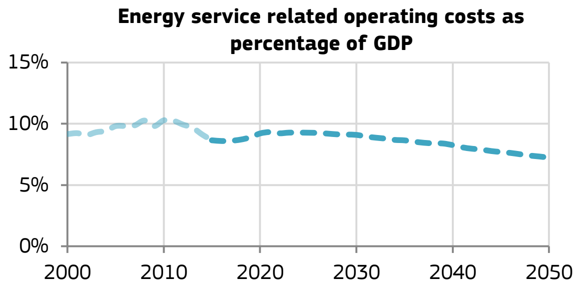


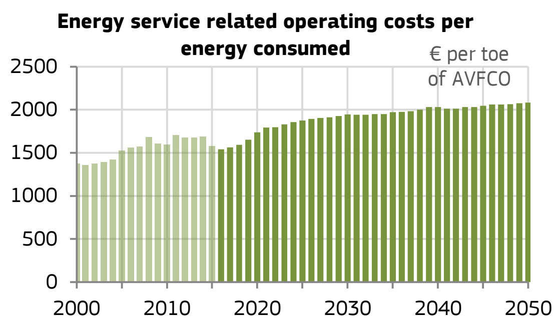

Mt CO2
CO2 emissions
70
60
50
40
30
20
10
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured

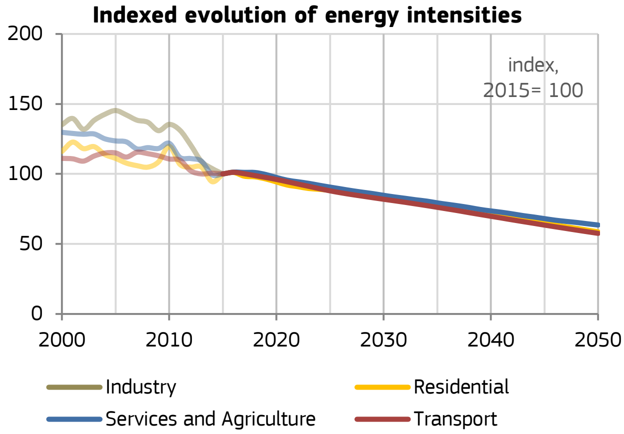

Indexed evolution of CO2 emissions
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

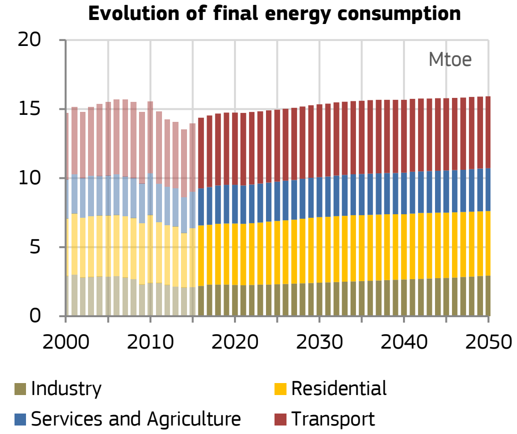

Indexed evolution of CO2 emissions in ETS and ESD sectors
150
100
50
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors

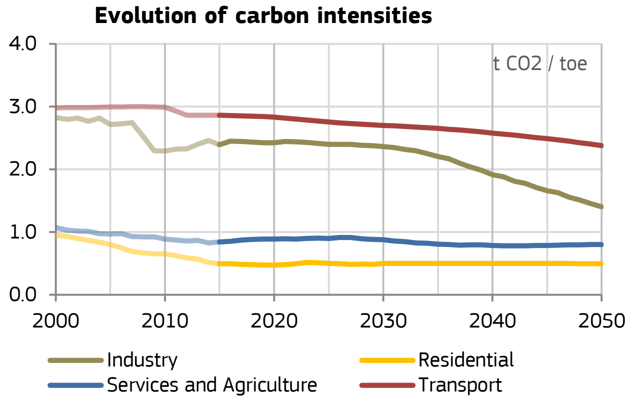

Cumulative investment expenditure (2016-2050)
7.9% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
100
200
300
400
billion €

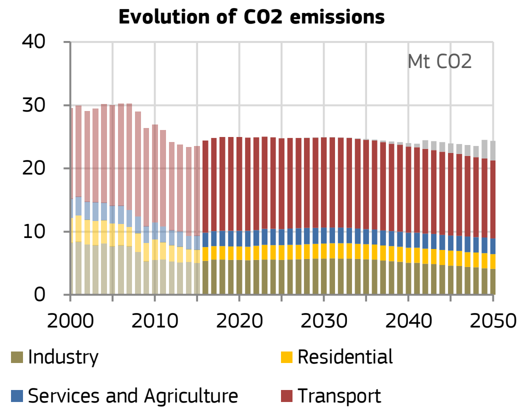

Energy service related operating costs as percentage of GDP
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050

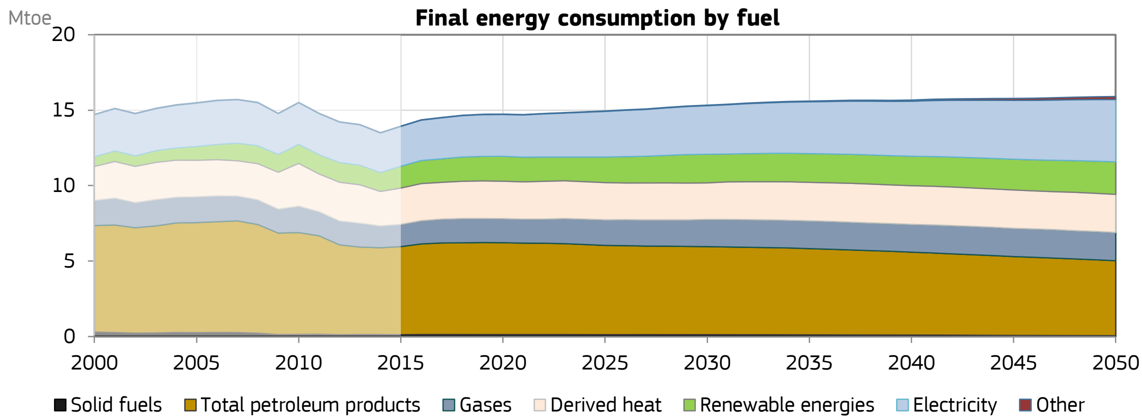

Energy service related operating costs per energy consumed
€ per toe
of AVFCO
2500
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

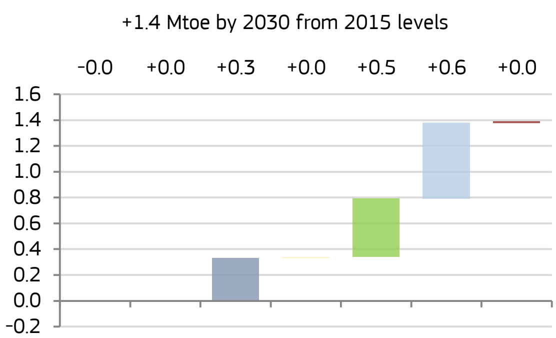

Indexed evolution of energy intensities
index, 2015= 100
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

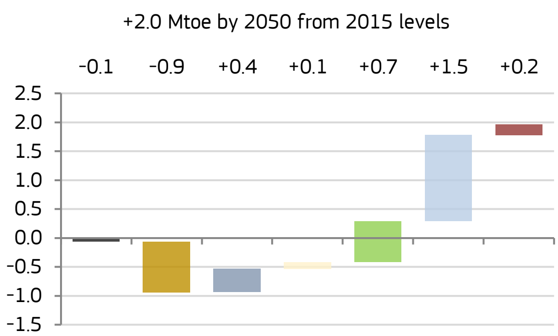

Evolution of final energy consumption
Mtoe
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

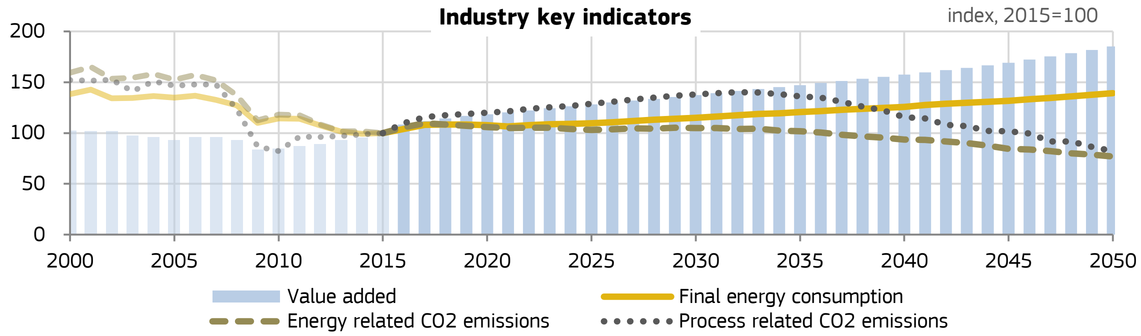

Evolution of carbon intensities
t CO2 / toe
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

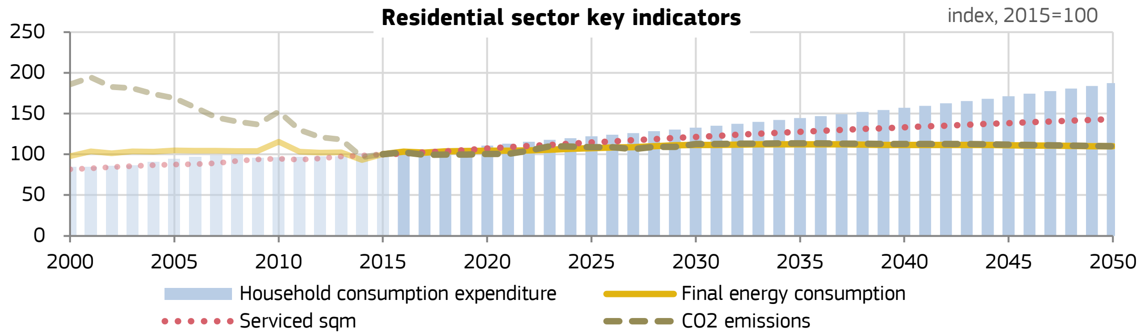

Evolution of CO2 emissions
Mt CO2
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

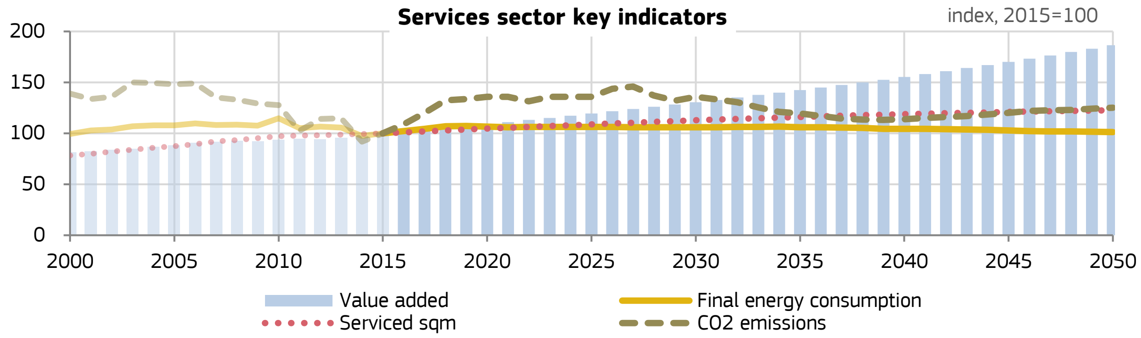

Final energy consumption by fuel
Mtoe
20
15
10
5
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

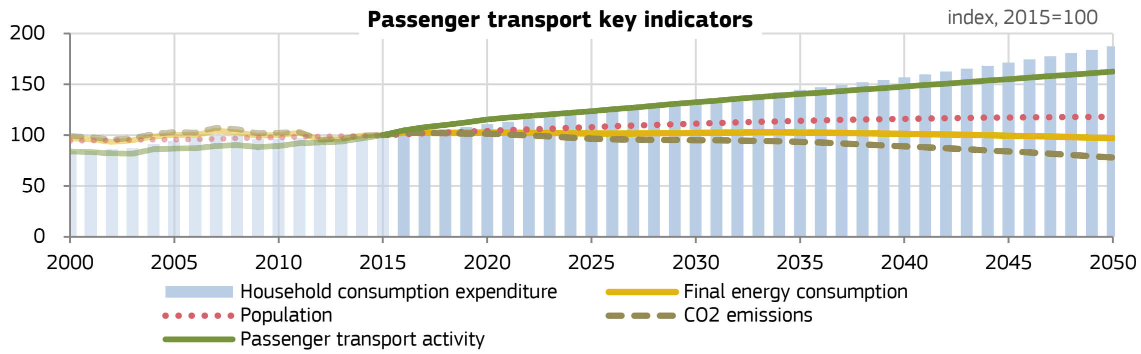

+1.4 Mtoe by 2030 from 2015 levels
-0.0
+0.0
+0.3
+0.0
+0.5
+0.6
+0.0
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2

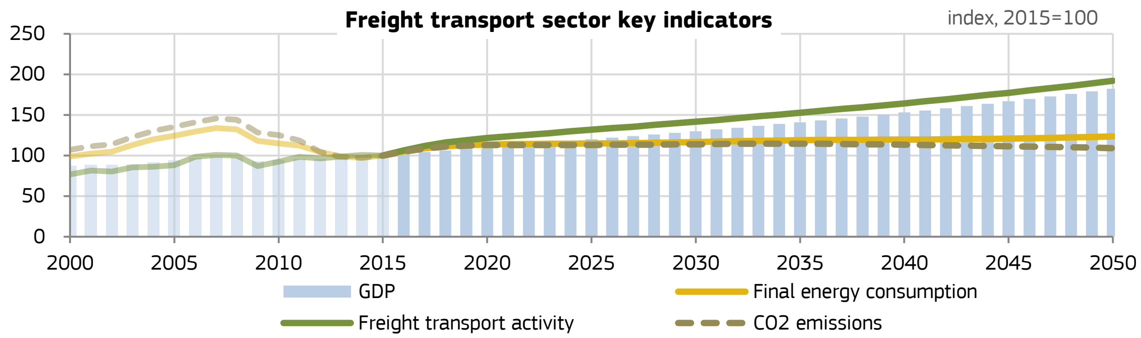

+2.0 Mtoe by 2050 from 2015 levels
-0.1
-0.9
+0.4
+0.1
+0.7
+1.5
+0.2
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5


Industry key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

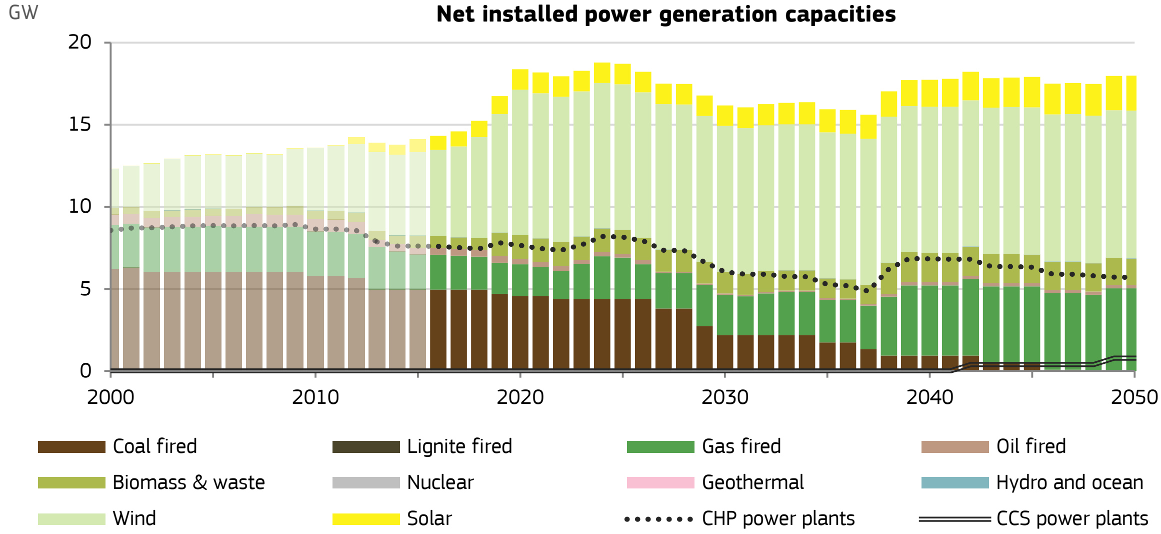

Residential sector key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions


Services sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

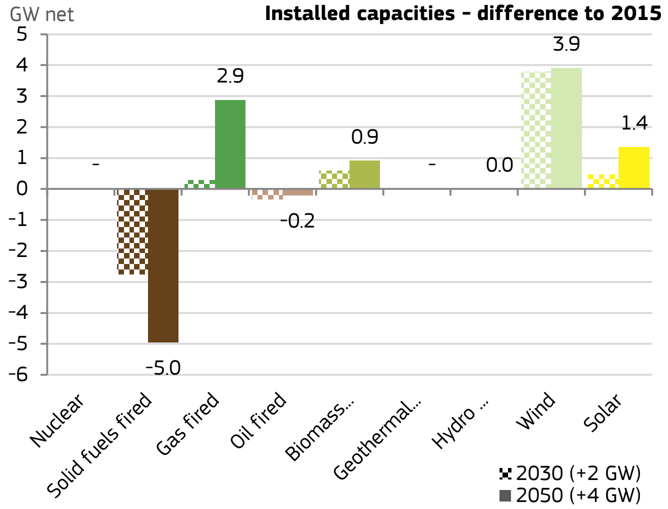

Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity


Freight transport sector key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

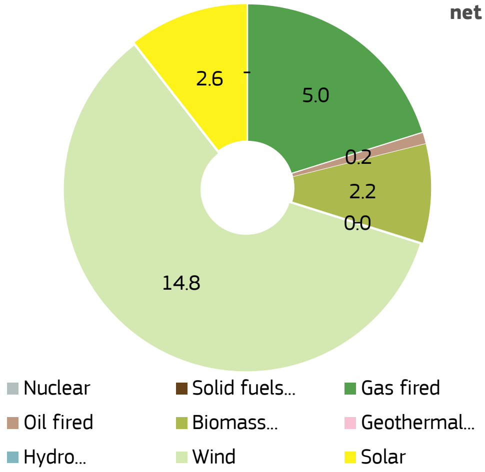
Net installed power generation capacities



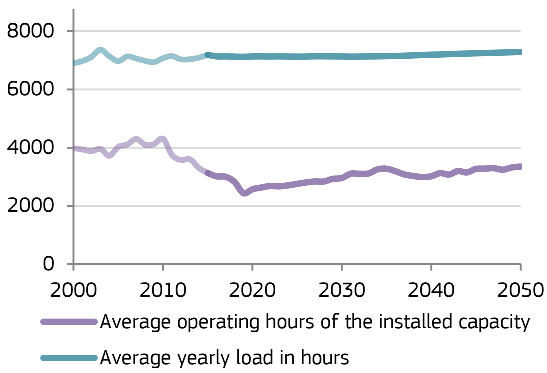
Installed capacities - difference to 2015



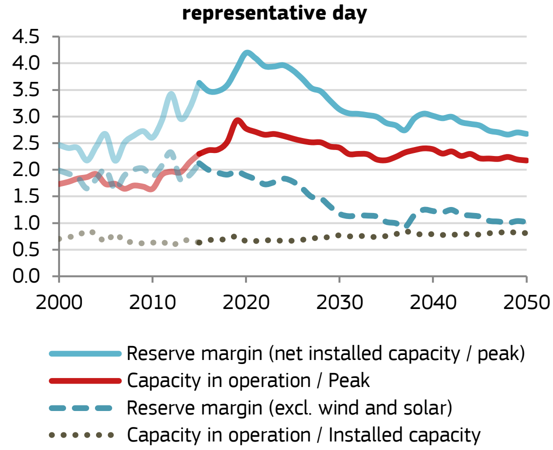
Cumulative investment 2016-2050 GW net

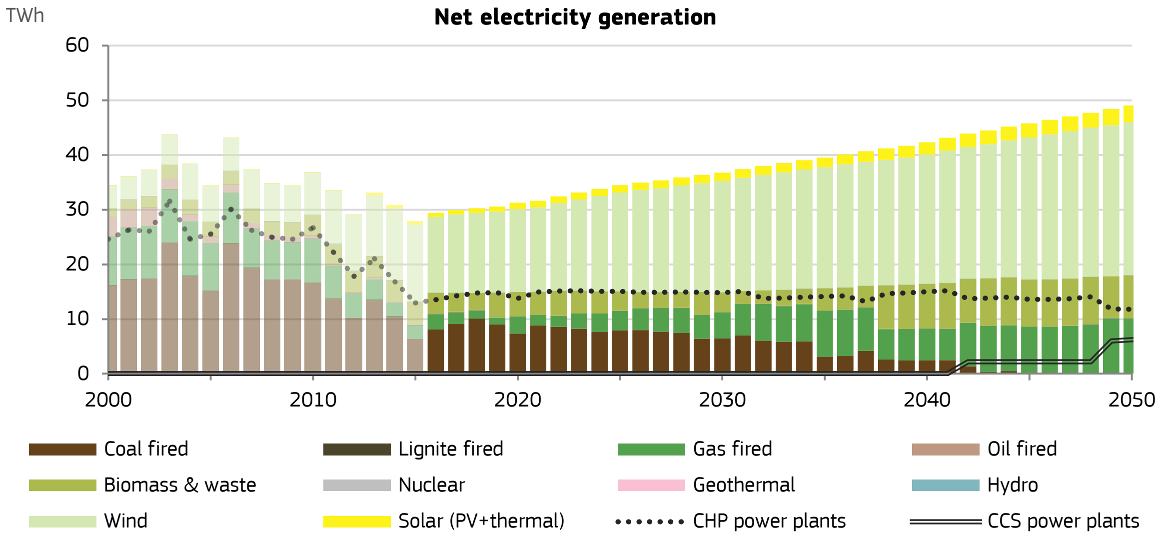


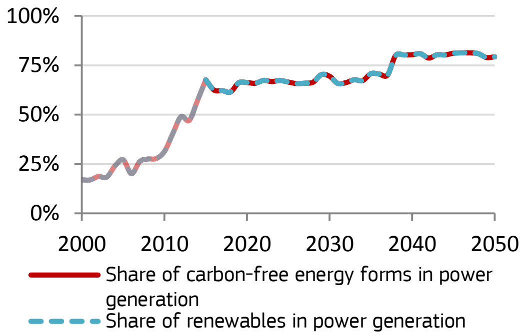
Operational characteristics

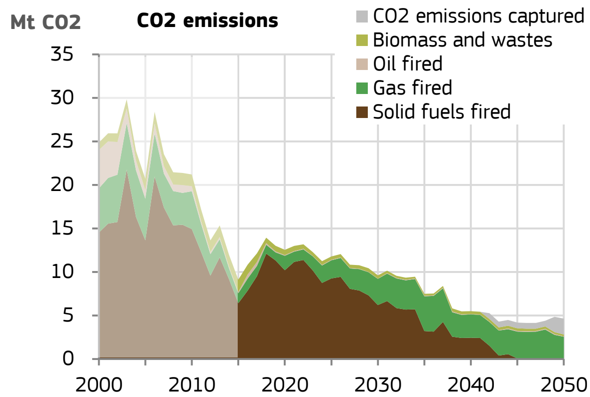


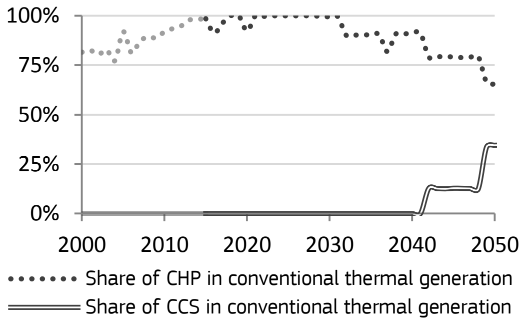
Power system indicators for the representative day

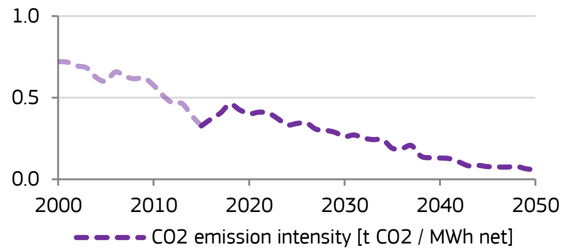


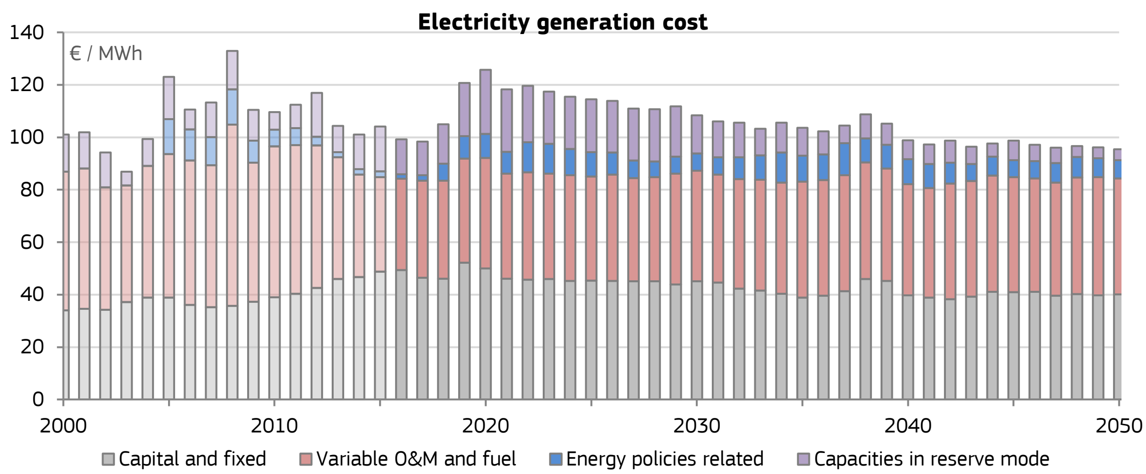

TWh
Net electricity generation
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

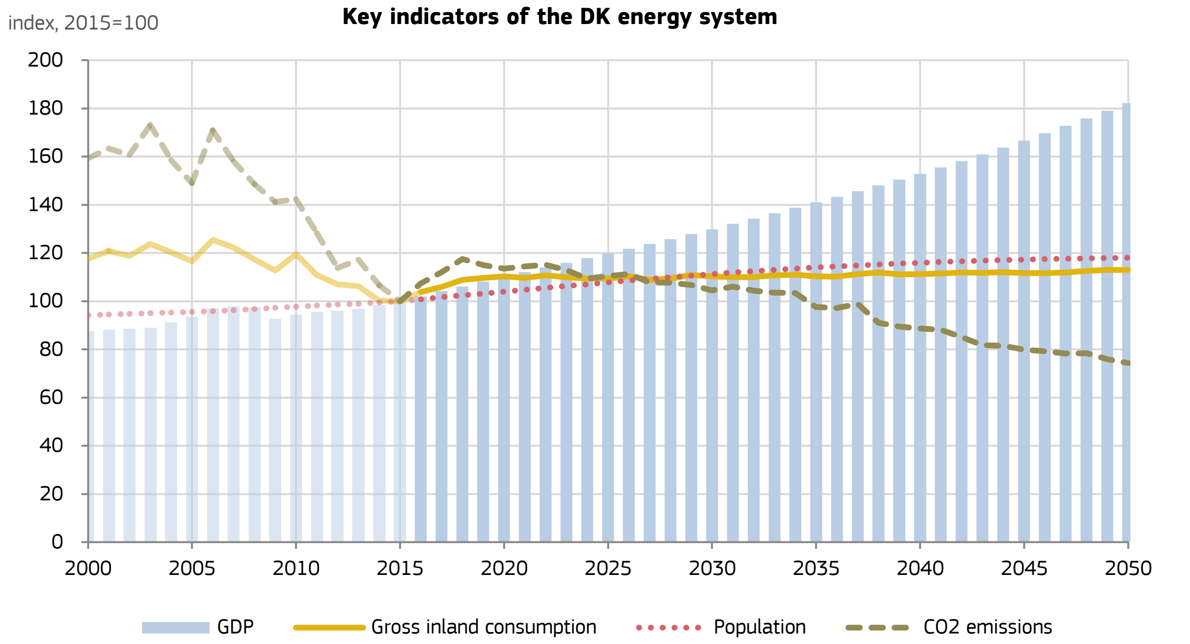

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
35
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050

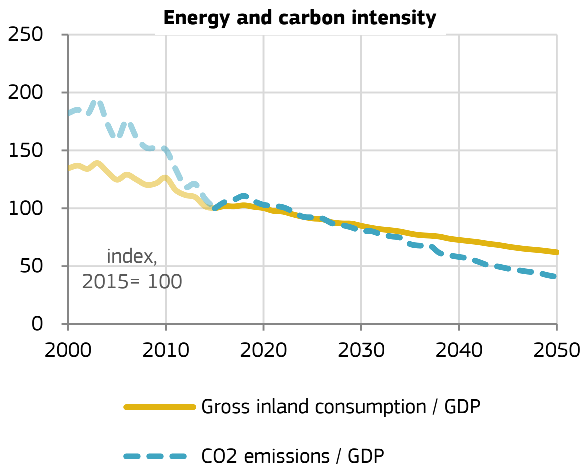

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

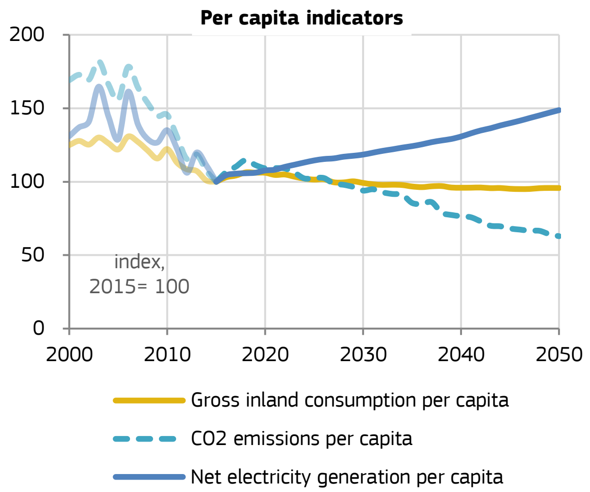

1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
140
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	13.5	15.5	13.9	14.7	15.3	15.9
Primary energy consumption [Mtoe]	17.6	19.3	16.5	18.2	18.2	18.6
RES [%] - Share of energy from renewable sources		16.4%	31.8%	35.7%	34.9%	48.6%
RES-E [%] - Share of electricity from renewable sources		25.7%	51.0%	67.7%	60.9%	74.0%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	55.0	53.7	36.0	40.9	37.7	26.8
reduction to 1990		*-2%*	*-35%*	*-26%*	*-32%*	*-51%*
Emissions in current ETS sectors |(DK) [Mt CO2]		29.7	17.2	21.5	18.7	9.6
reduction to 2005			*-42%*	*-28%*	*-37%*	*-68%*
Emissions in current ESD sectors [Mt CO2]		24.0	18.8	19.4	18.9	17.2
reduction to 2005			*-22%*	*-19%*	*-21%*	*-28%*

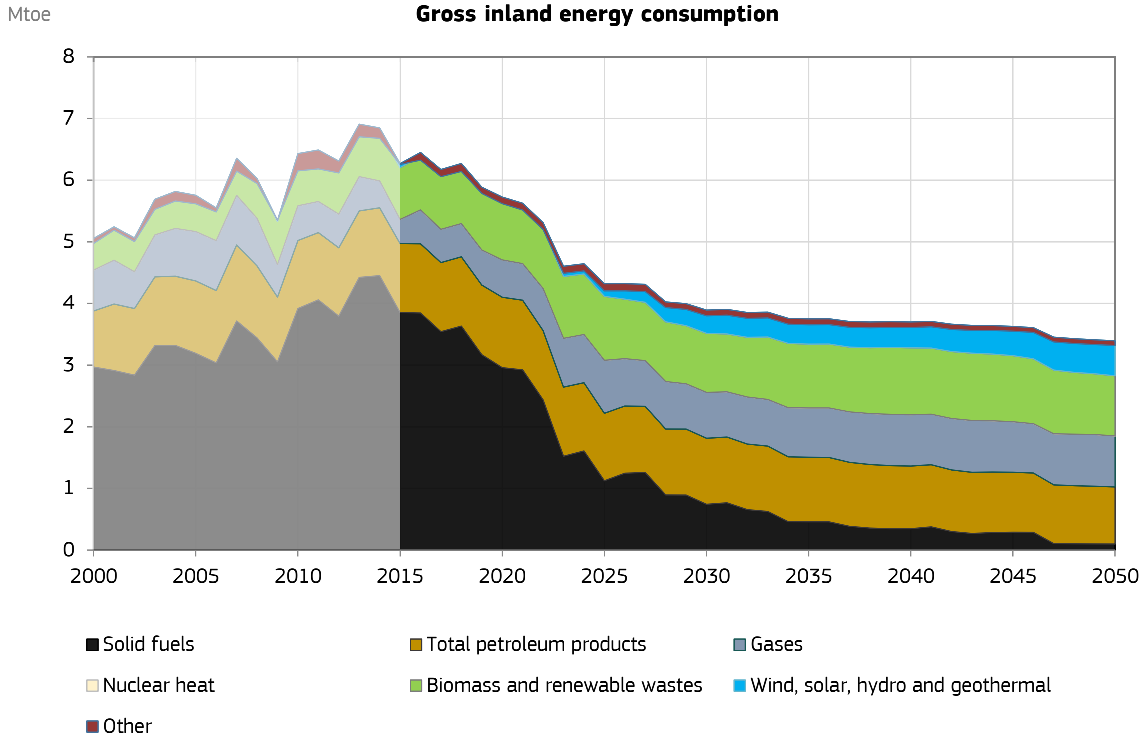




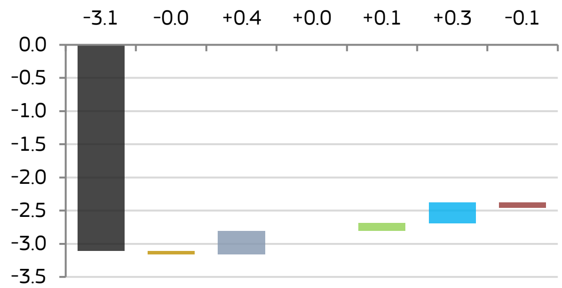
Estonia

Central_2018 scenario

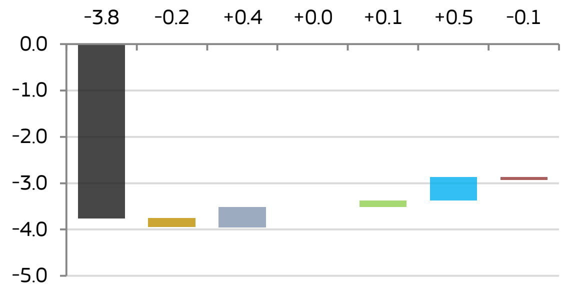
Gross inland energy consumption



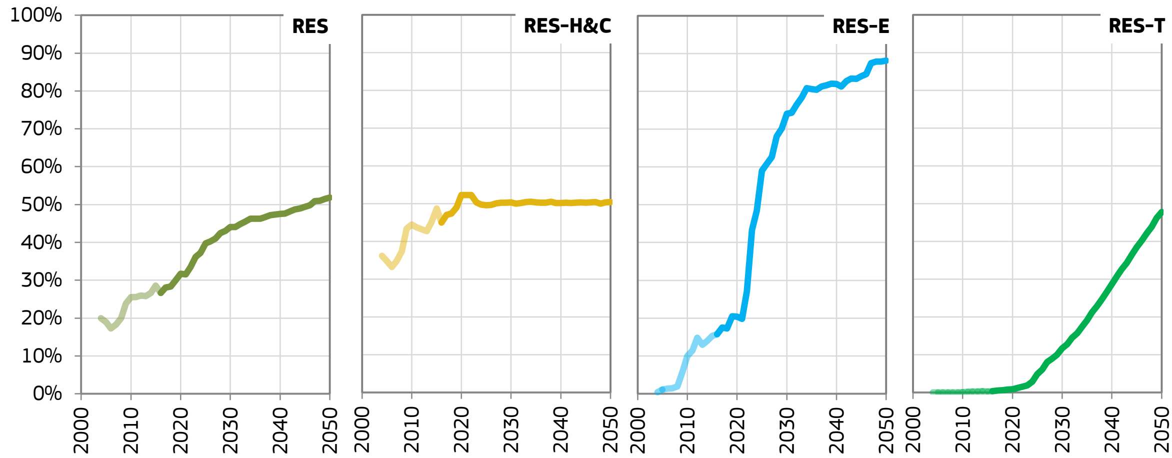
-2.5 Mtoe by 2030 from 2015 levels

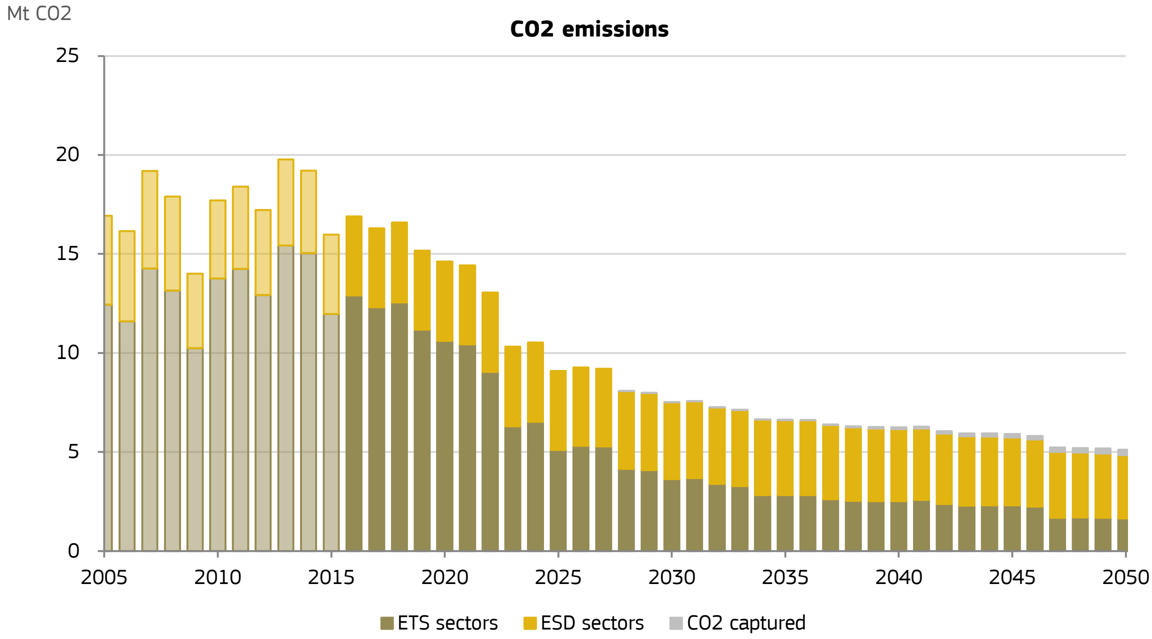


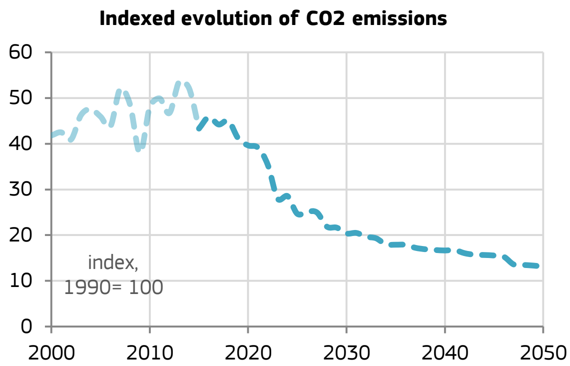
-2.9 Mtoe by 2050 from 2015 levels

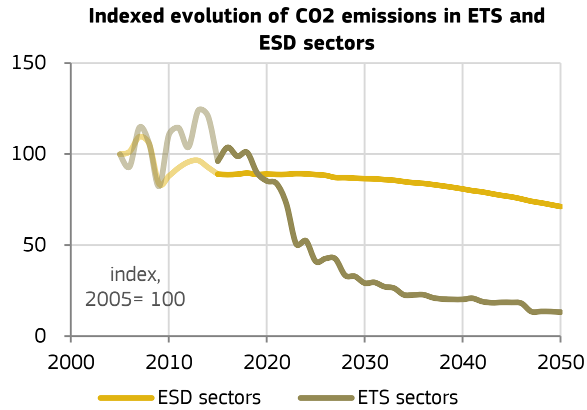


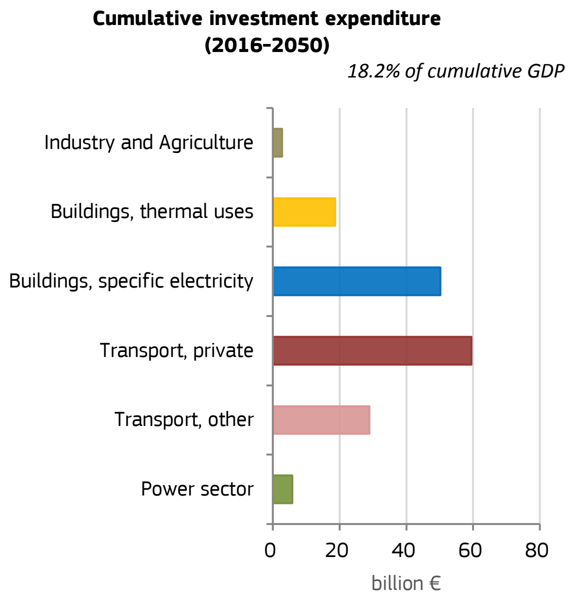
Share of renewable energies

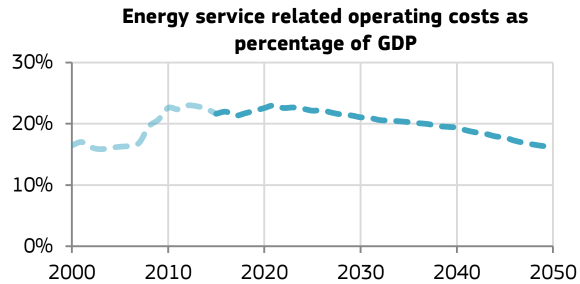


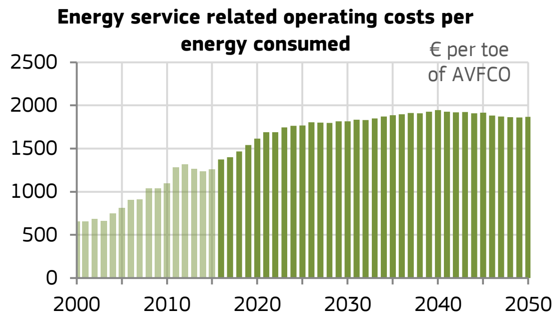

CO2 emissions
Mt CO2
25
20
15
10
5
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured

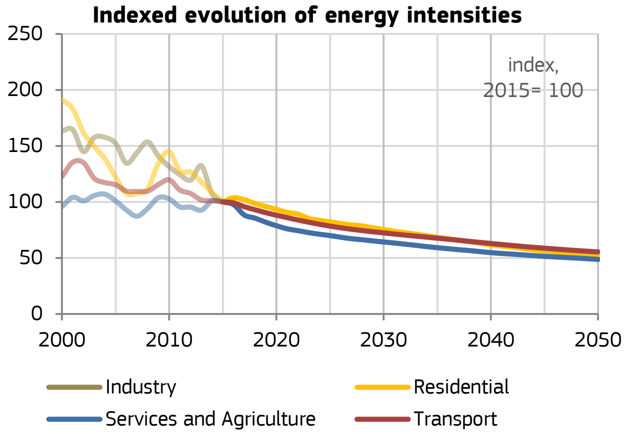

Indexed evolution of CO2 emissions
60
50
40
30
20
10
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

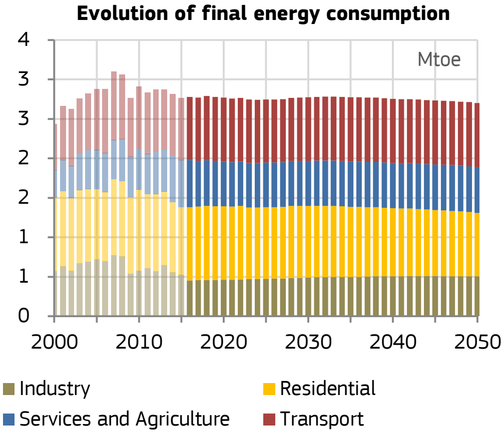

Indexed evolution of CO2 emissions in ETS and ESD sectors
150
100
50
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors

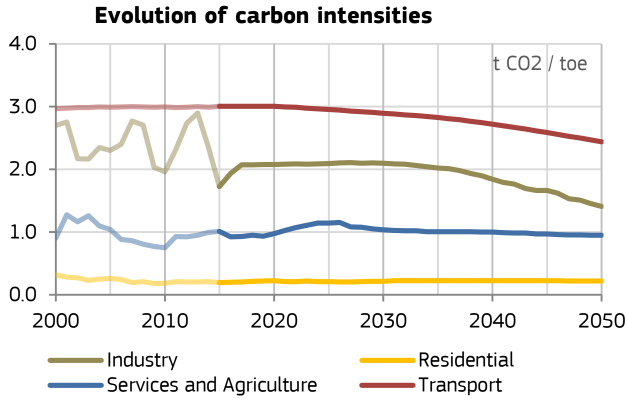

Cumulative investment expenditure (2016-2050)
18.2% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
20
40
60
80
billion €

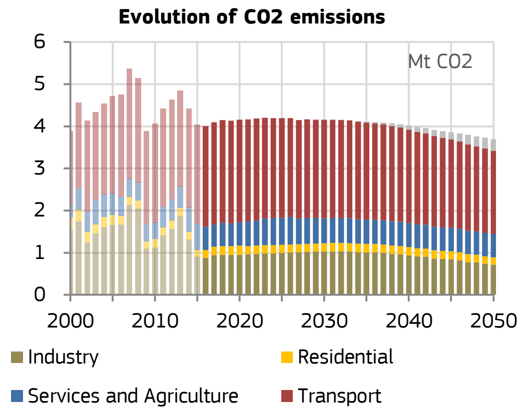

Energy service related operating costs as percentage of GDP
30%
20%
10%
0%
2000
2010
2020
2030
2040
2050

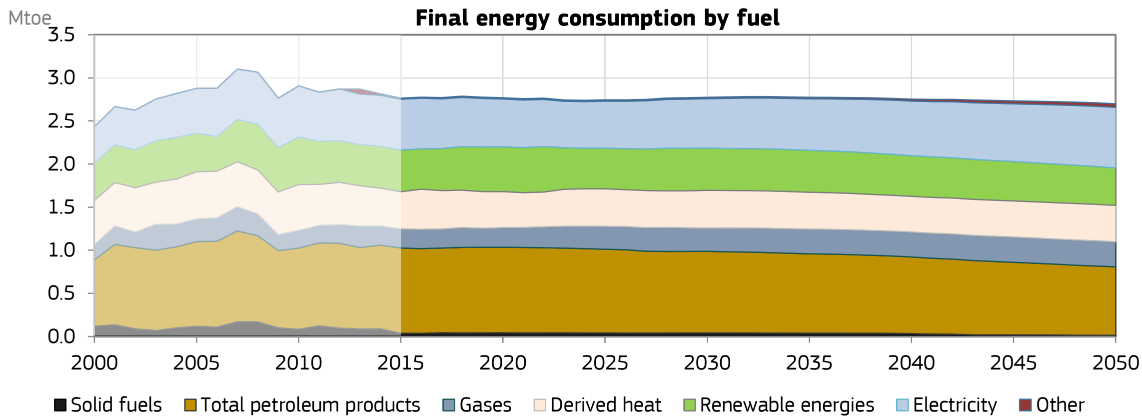

Energy service related operating costs per energy consumed
€ per toe of AVFCO
2500
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

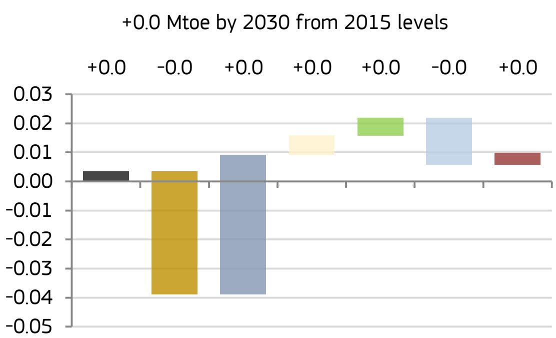

Indexed evolution of energy intensities
index, 2015= 100
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

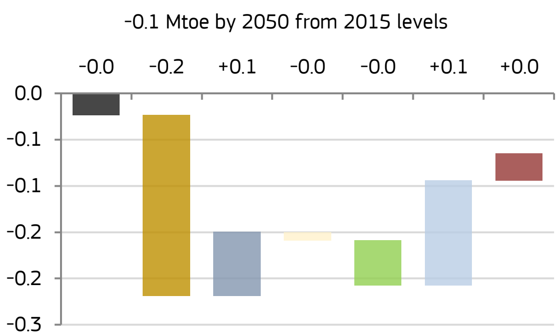

Evolution of final energy consumption
Mtoe
4
3
3
2
2
1
1
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

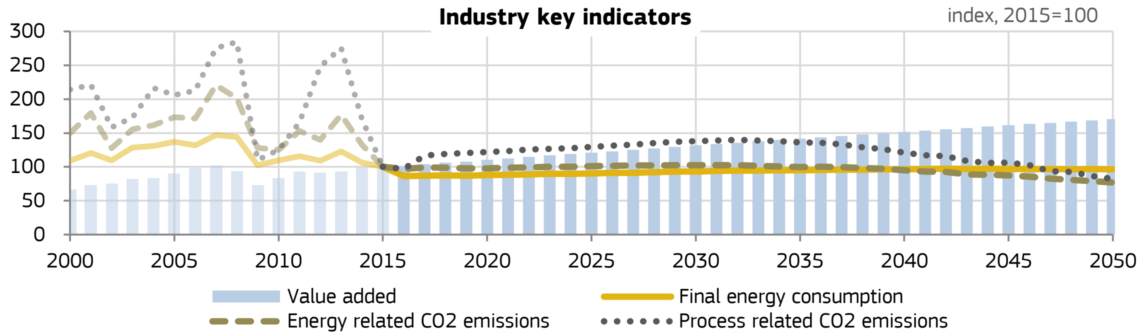

Evolution of carbon intensities
t CO2 / toe
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

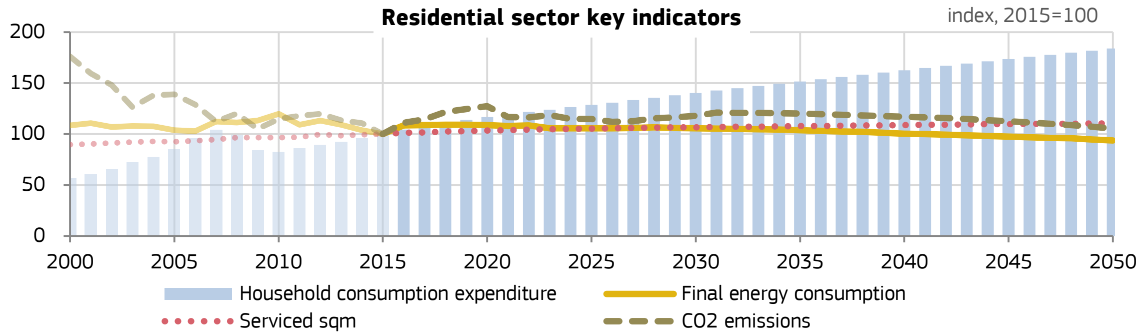

Evolution of CO2 emissions
Mt CO2
6
5
4
3
2
1
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

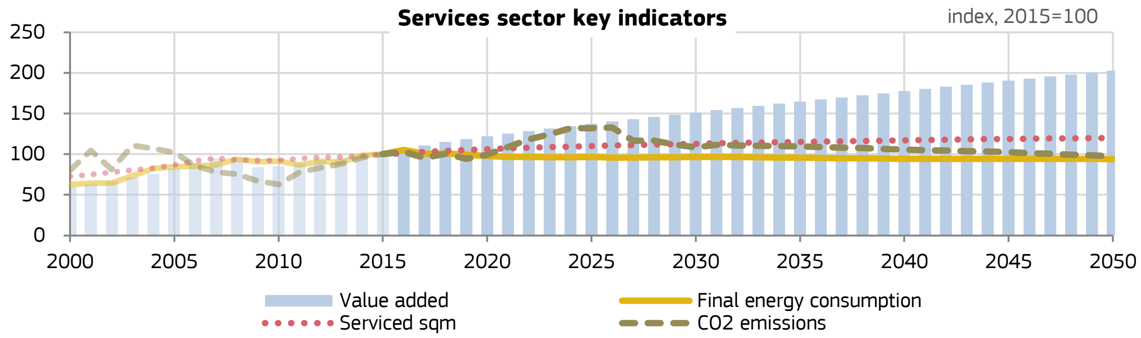

Final energy consumption by fuel
Mtoe
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

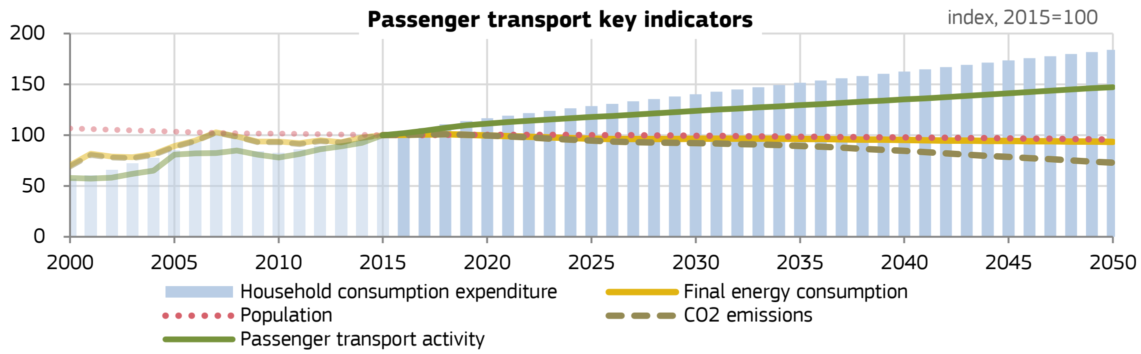

+0.0 Mtoe by 2030 from 2015 levels
+0.0
-0.0
+0.0
+0.0
+0.0
-0.0
+0.0
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05

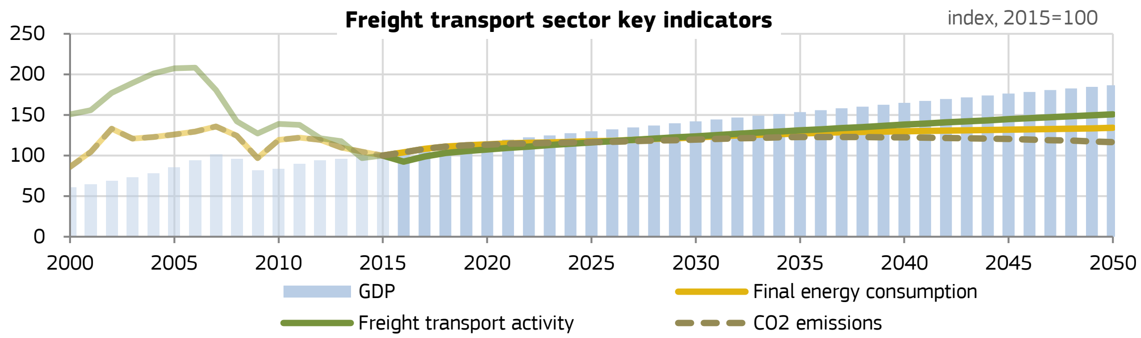

-0.1 Mtoe by 2050 from 2015 levels
-0.0
-0.2
+0.1
-0.0
-0.0
+0.1
+0.0
0.0
-0.1
-0.1
-0.2
-0.2
-0.3

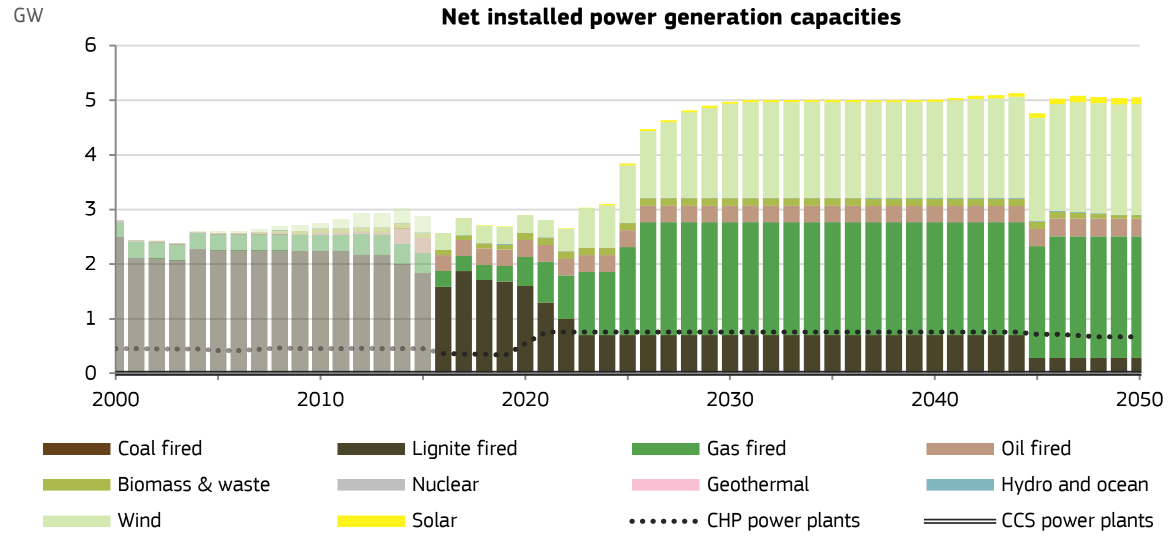

Industry key indicators
index, 2015=100
300
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

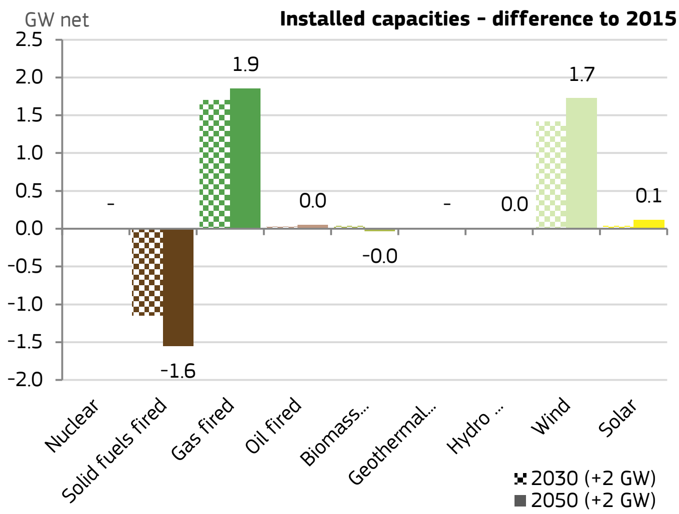

Residential sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

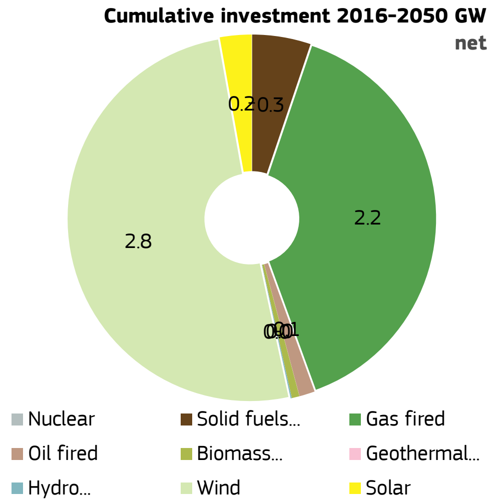

Services sector key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

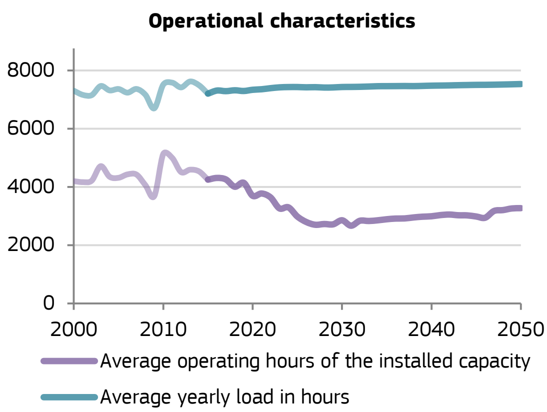

Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

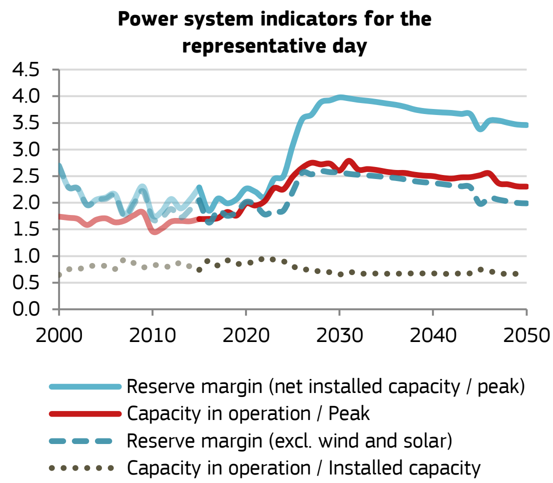

Freight transport sector key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

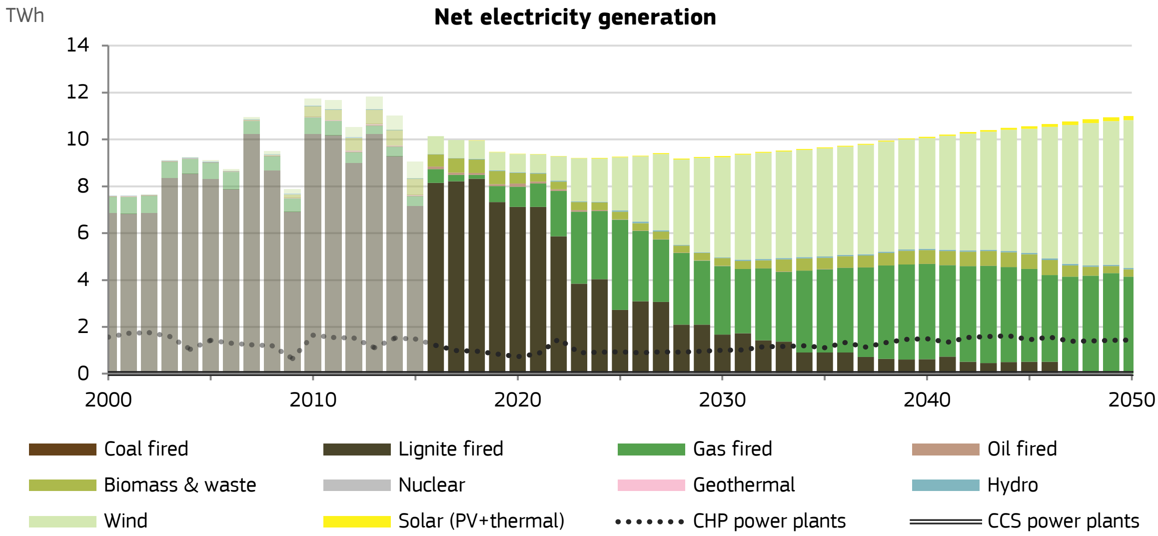

Net installed power generation capacities
GW
6
5
4
3
2
1
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

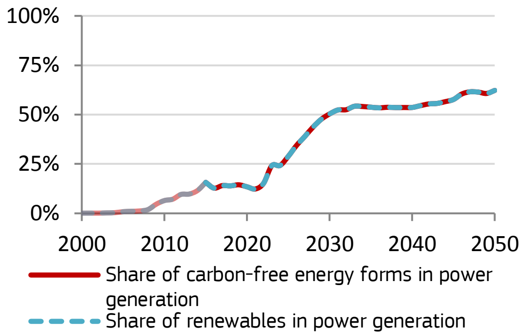

Installed capacities - difference to 2015
GW net
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-
1.9
0.0
-0.0
-
0.0
1.7
0.1
-1.6
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+2 GW)
2050 (+2 GW)

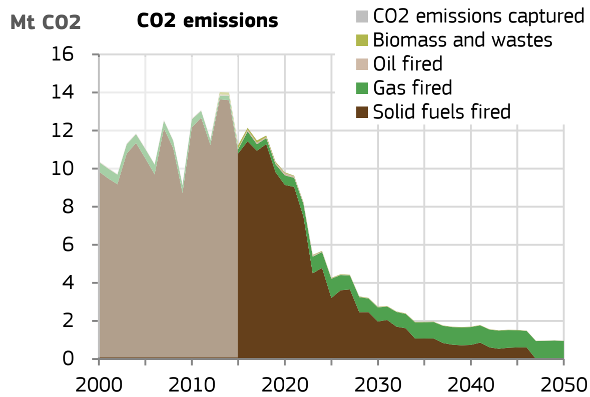

Cumulative investment 2016-2050 GW net
0.2
0.3
2.2
2.8
0.0
0.1
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

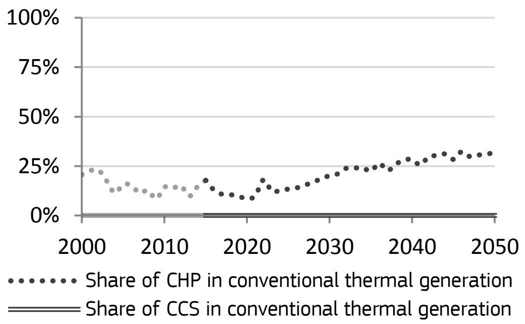

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

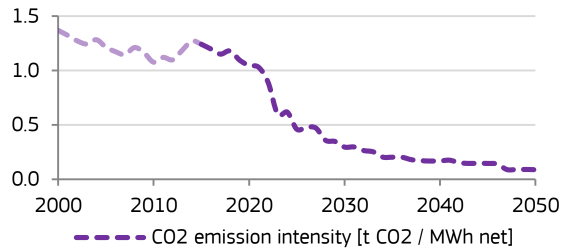

Power system indicators for the representative day
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

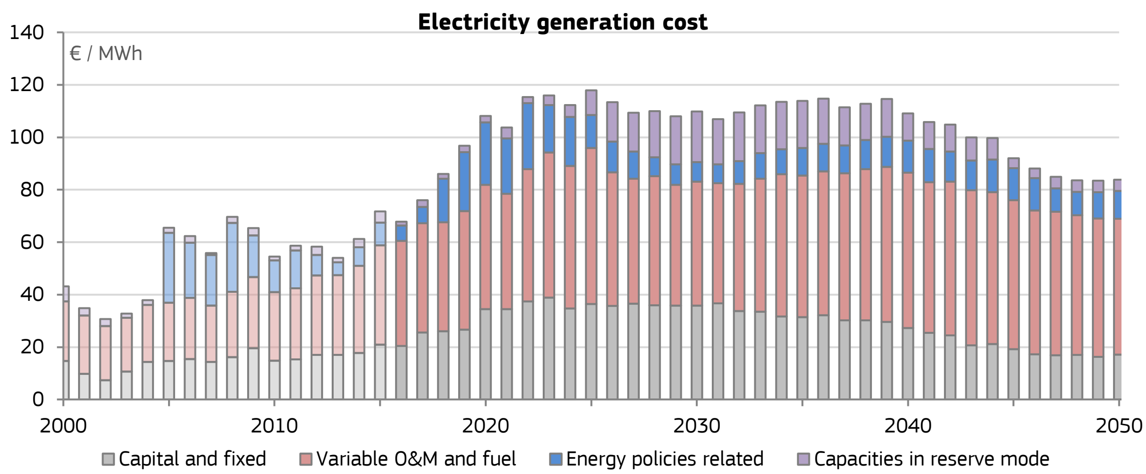

Net electricity generation
TWh
14
12
10
8
6
4
2
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

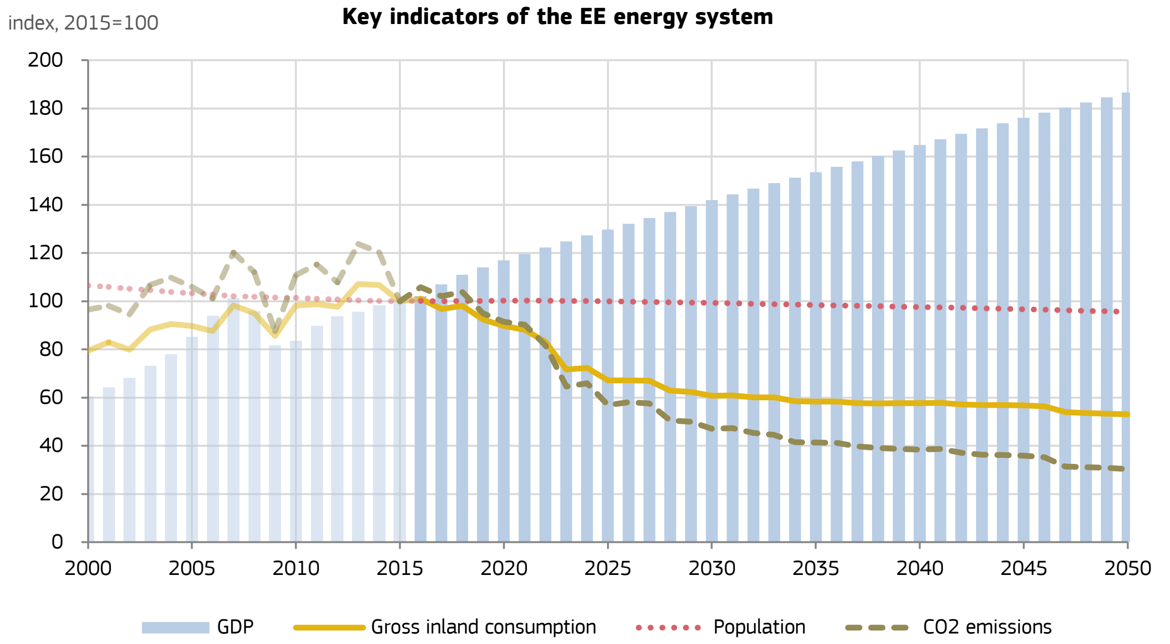

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
16
14
12
10
8
6
4
2
0
2000
2010
2020
2030
2040
2050

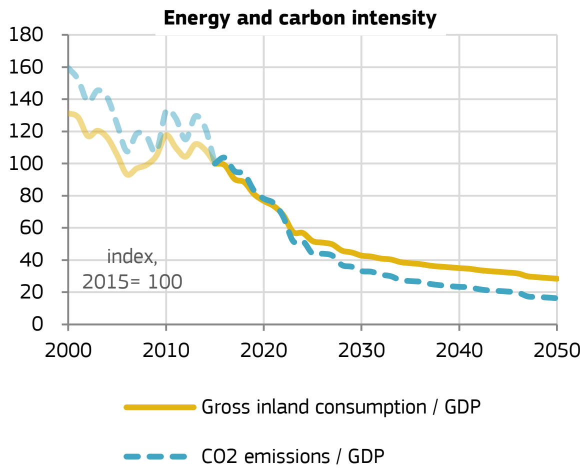

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

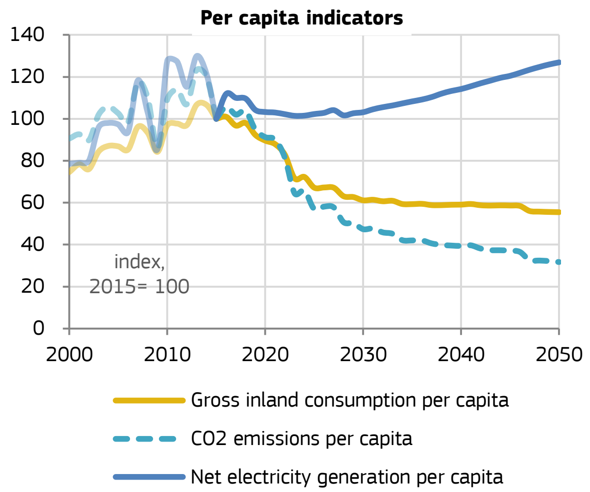

1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
140
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	5.7	2.9	2.8	2.8	2.8	2.7
Primary energy consumption [Mtoe]	9.7	5.4	6.2	5.5	3.7	3.2
RES [%] - Share of energy from renewable sources		18.9%	28.5%	31.7%	44.1%	51.8%
RES-E [%] - Share of electricity from renewable sources		1.1%	15.3%	20.4%	74.1%	88.1%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	36.9	16.9	16.0	14.6	7.5	4.8
reduction to 1990		*-54%*	*-57%*	*-60%*	*-80%*	*-87%*
Emissions in current ETS sectors |(EE) [Mt CO2]		12.4	12.0	10.6	3.6	1.6
reduction to 2005			*-4%*	*-15%*	*-71%*	*-87%*
Emissions in current ESD sectors [Mt CO2]		4.5	4.0	4.0	3.9	3.2
reduction to 2005			*-11%*	*-11%*	*-13%*	*-29%*

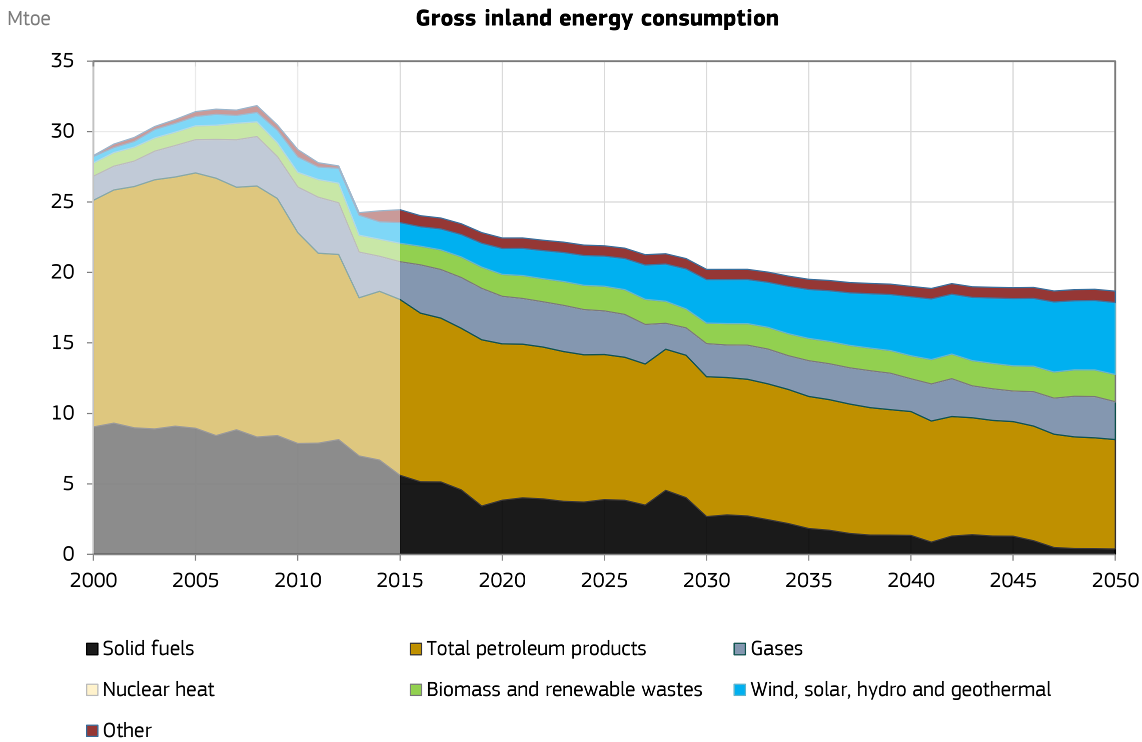


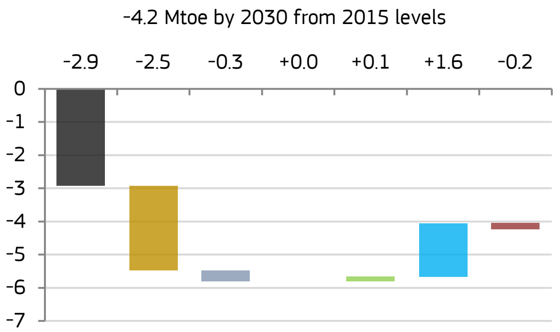


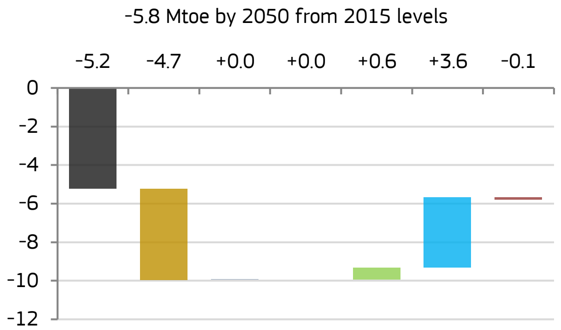
POTEnCIA - Model results overview

Greece

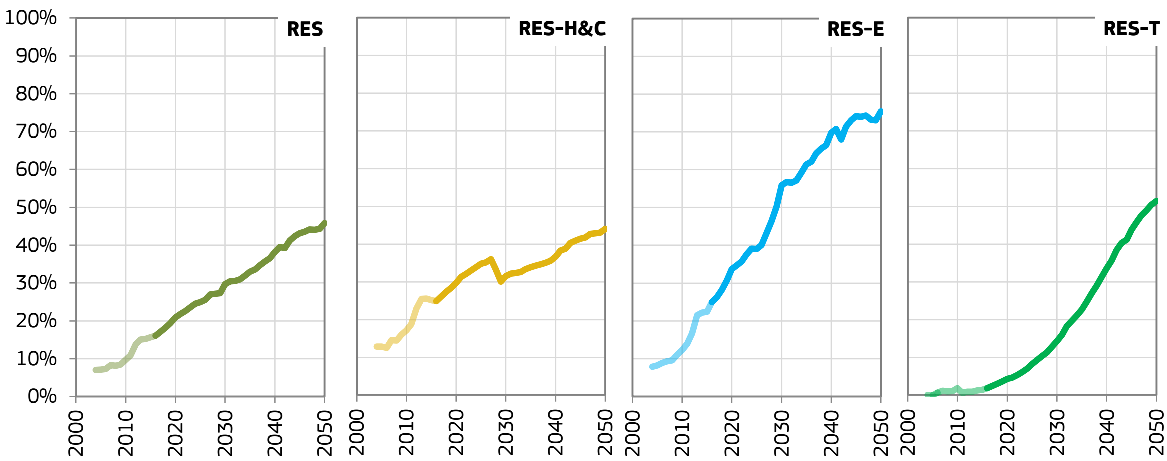
Central_2018 scenario

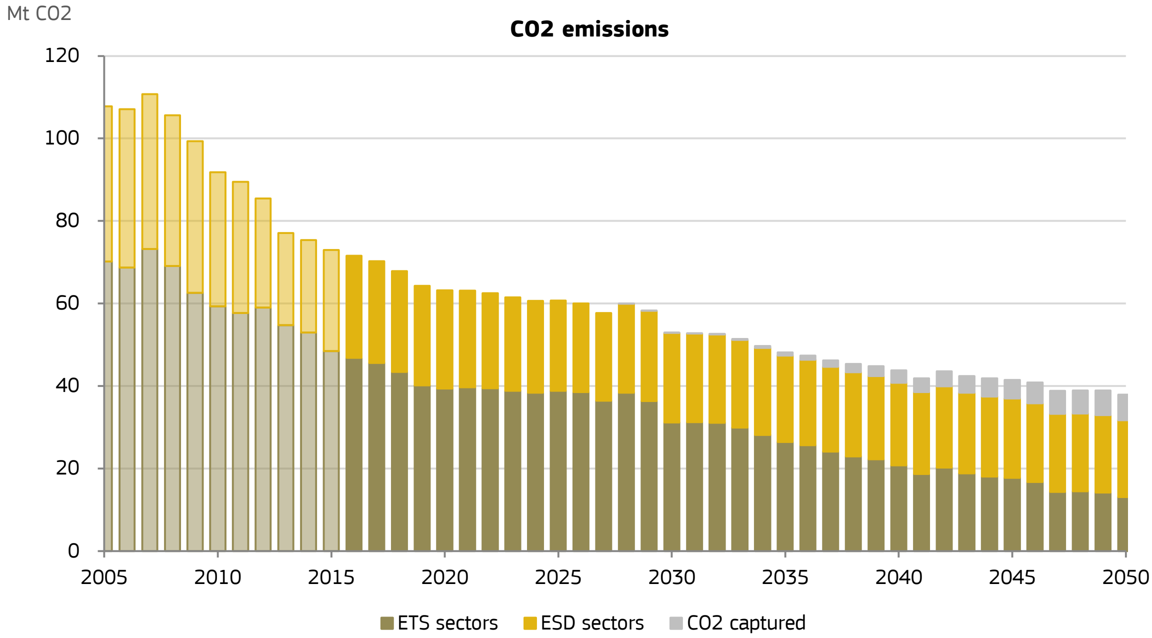


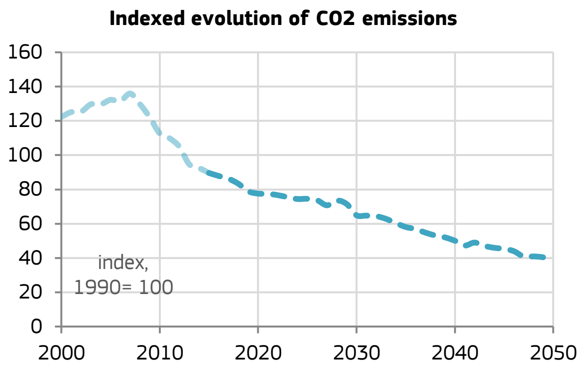


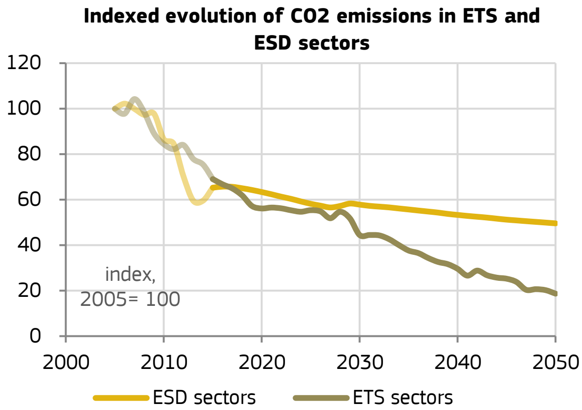


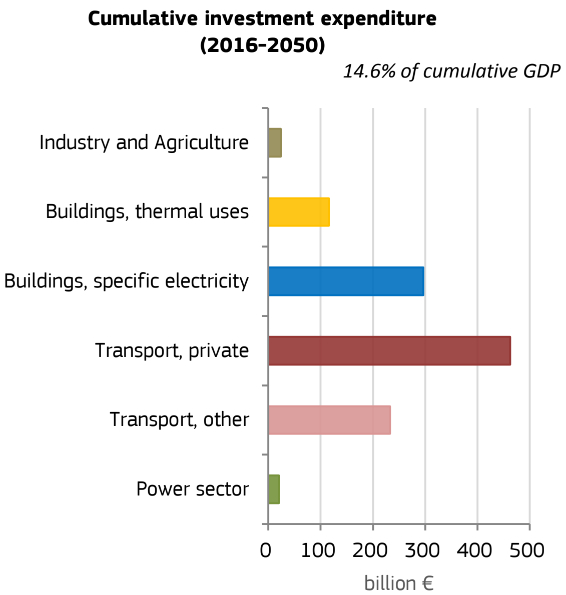
Share of renewable energies

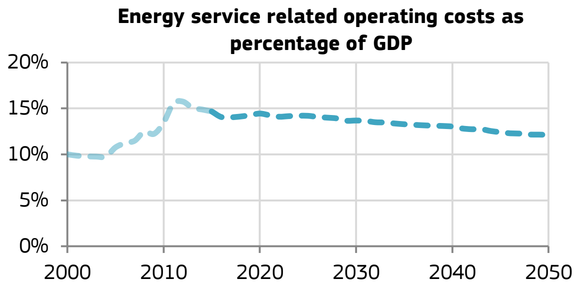


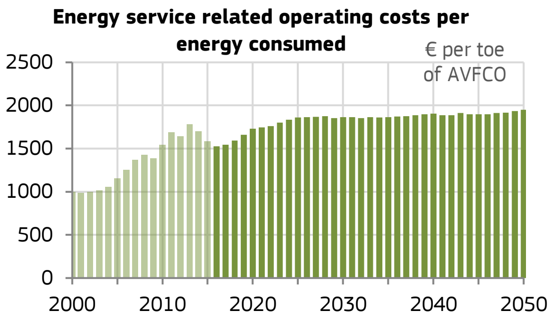

Mt CO2
CO2 emissions
120
100
80
60
40
20
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured


Indexed evolution of CO2 emissions
160
140
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

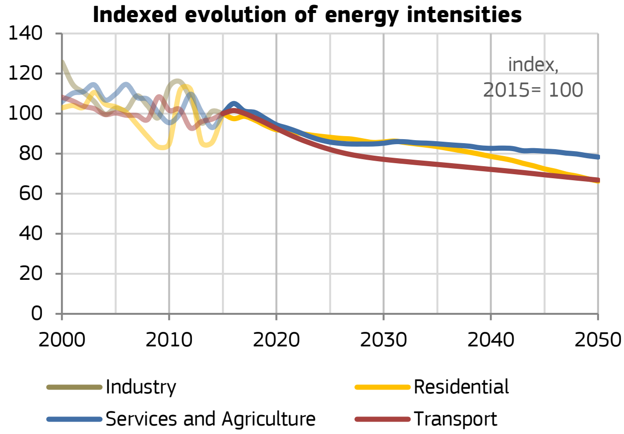

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors


Cumulative investment expenditure (2016-2050)
14.6% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
100
200
300
400
500
billion €

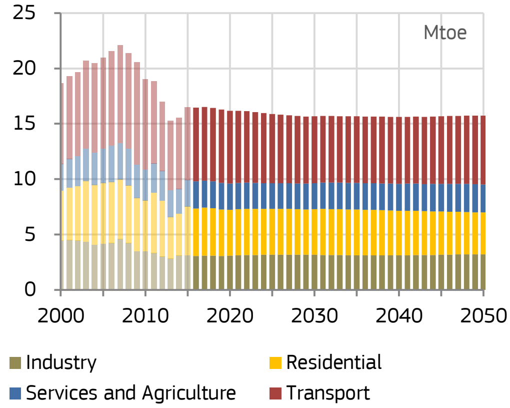

Energy service related operating costs as percentage of GDP
20%
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050


Energy service related operating costs per energy consumed
€ per toe of AVFCO
2500
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

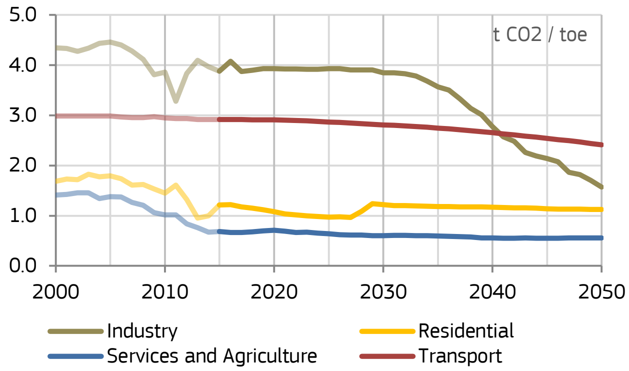
Indexed evolution of energy intensities



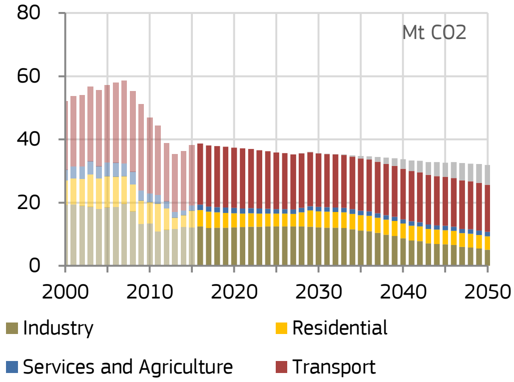
Evolution of final energy consumption



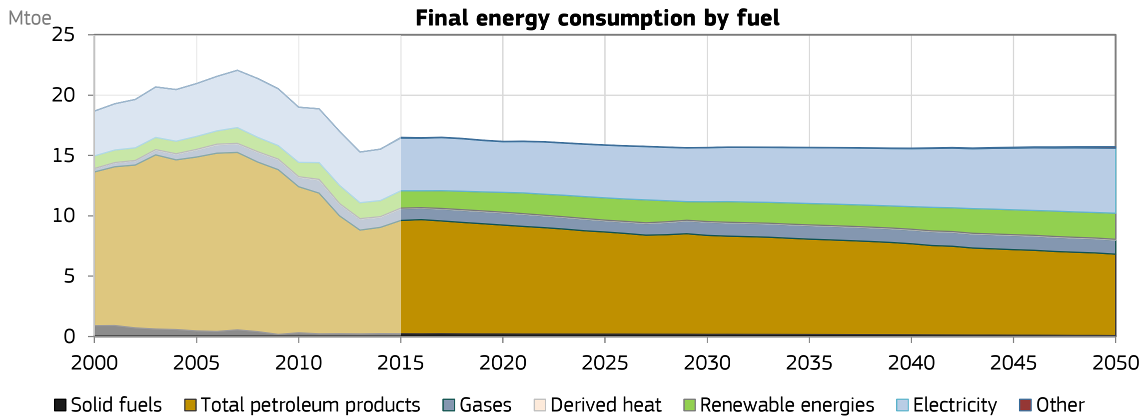
Evolution of carbon intensities



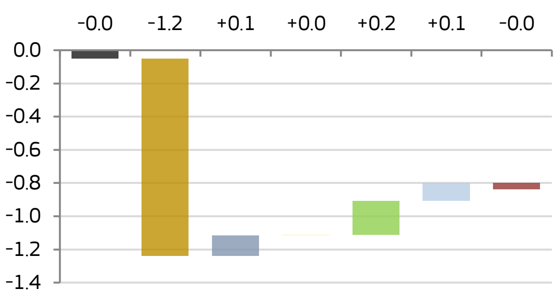
Evolution of CO2 emissions



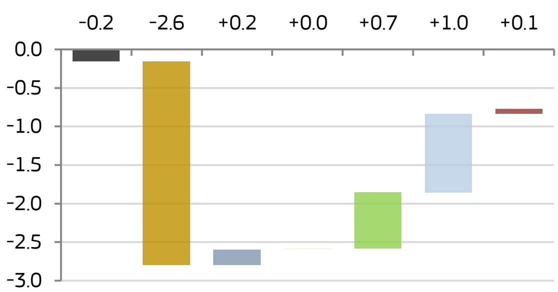
Final energy consumption by fuel

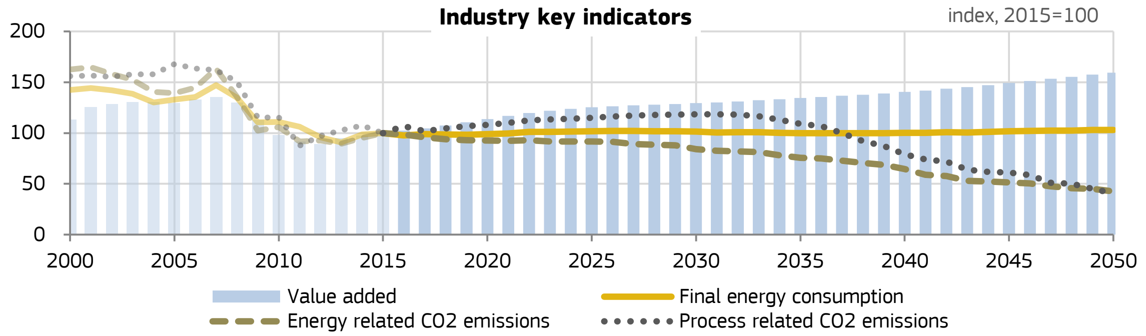


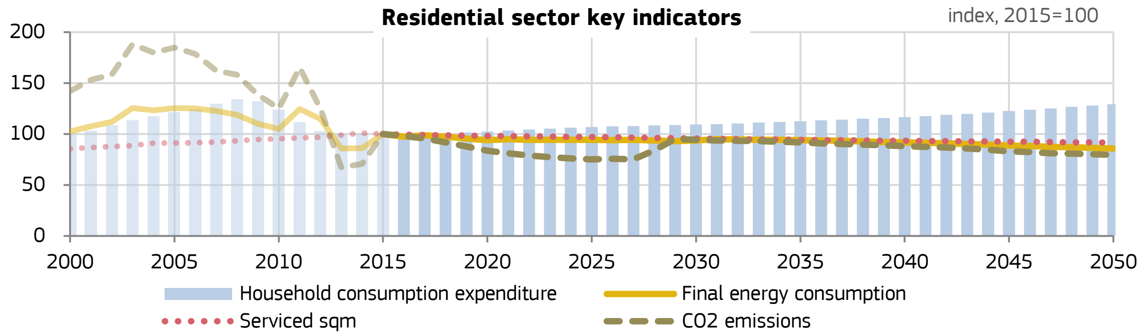
-0.8 Mtoe by 2030 from 2015 levels

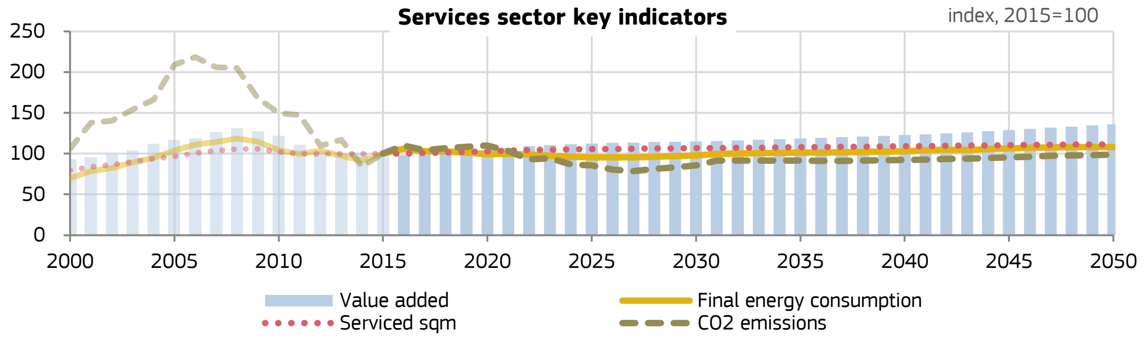


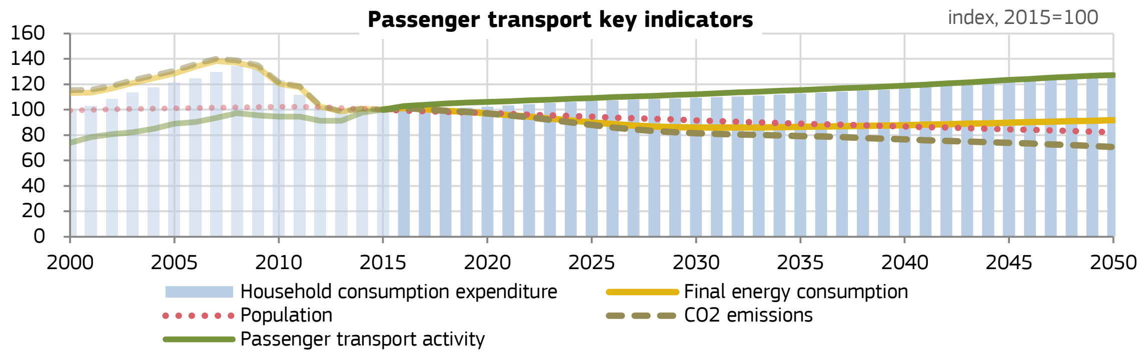
-0.8 Mtoe by 2050 from 2015 levels

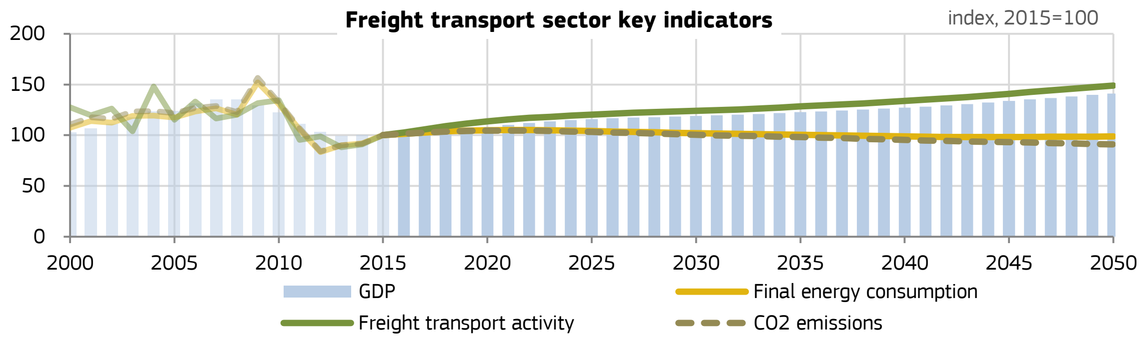


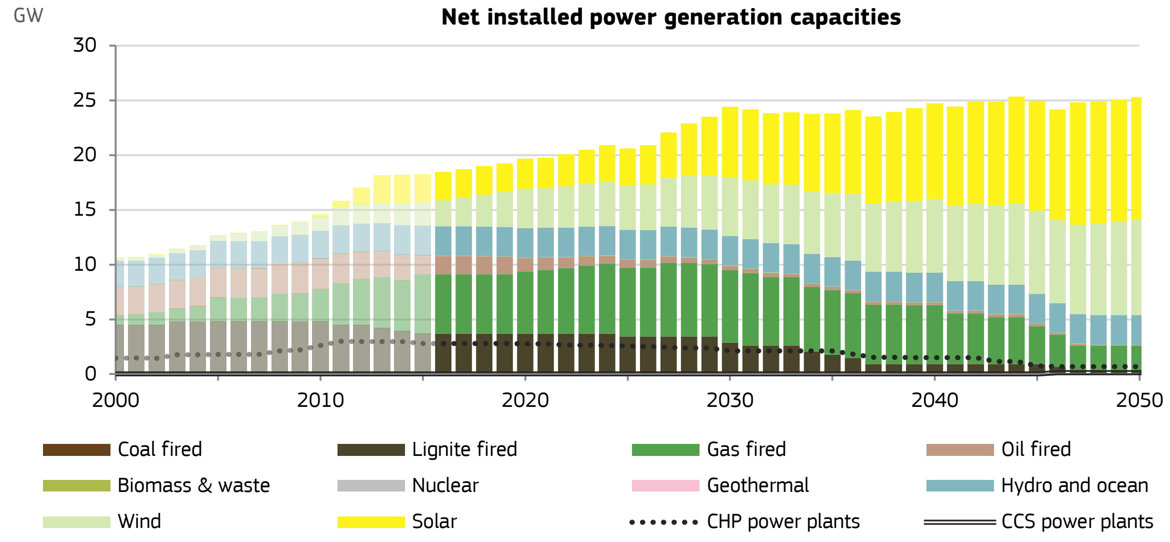

Industry key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

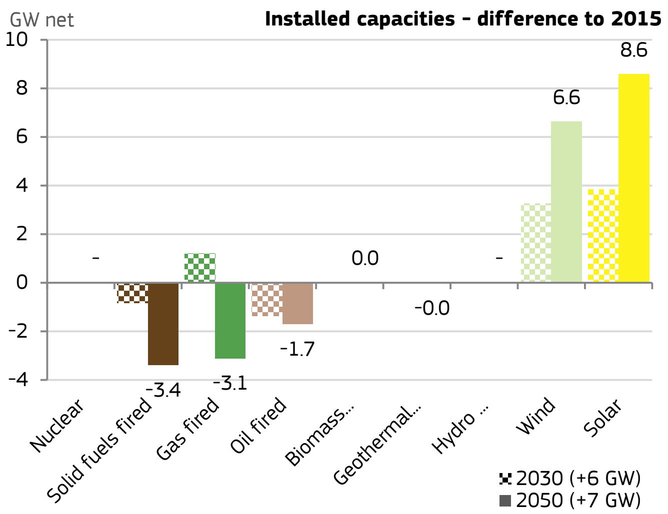

Residential sector key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

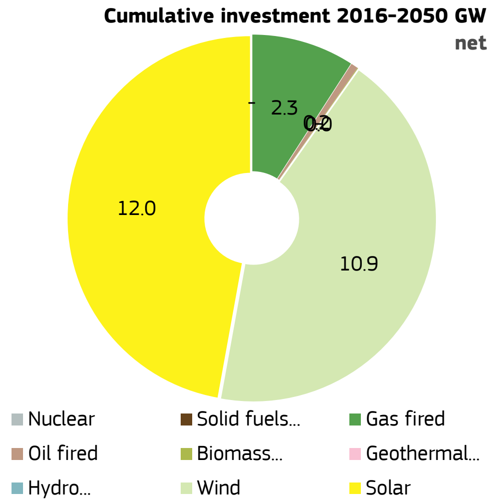

Services sector key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

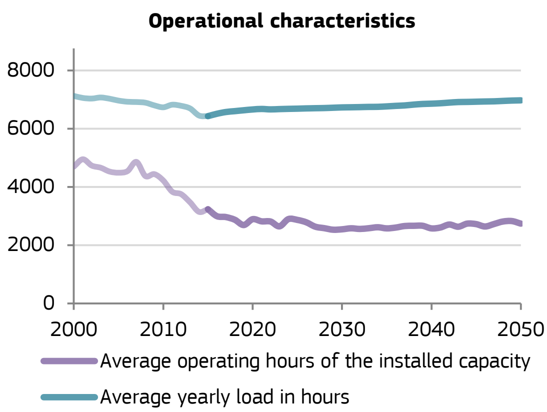

Passenger transport key indicators
index, 2015=100
160
140
120
100
80
60
40
20
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

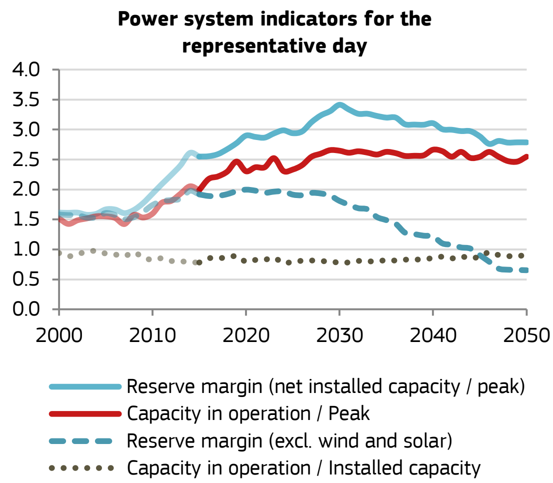

Freight transport sector key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

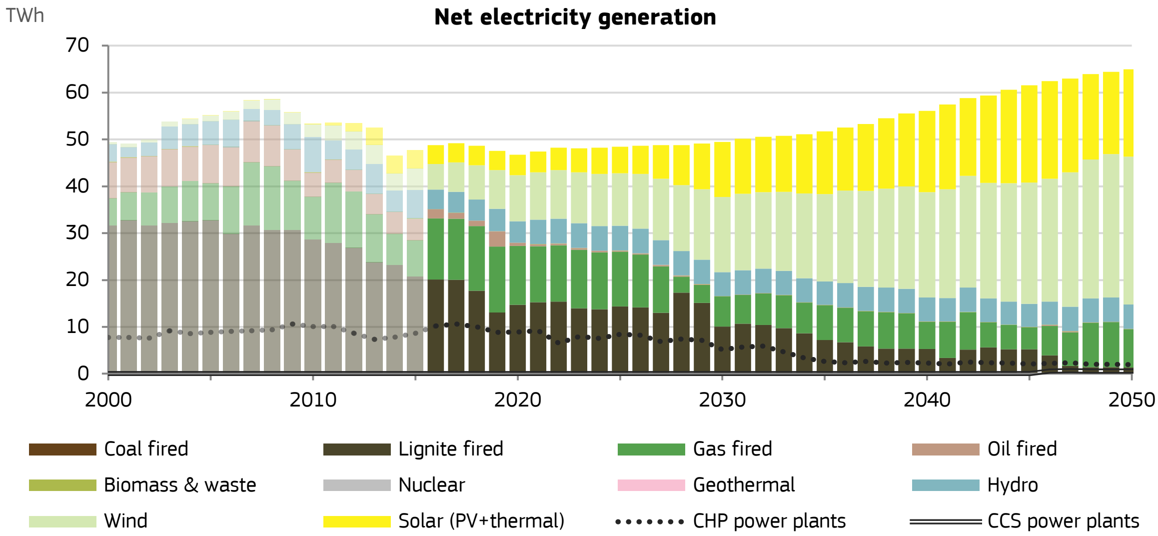

GW
Net installed power generation capacities
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants


GW net
Installed capacities - difference to 2015
10
8
6
4
2
0
-2
-4
-
-3.4
-3.1
-1.7
0.0
-0.0
-
6.6
8.6
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+6 GW)
2050 (+7 GW)

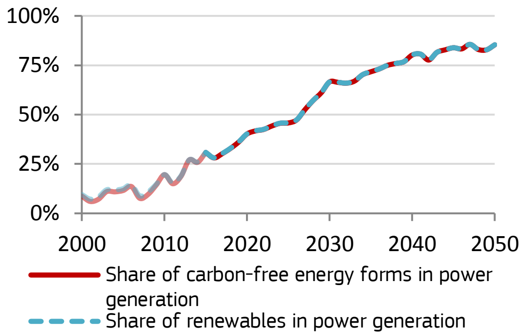

Cumulative investment 2016-2050 GW net
2.3
0.2
12.0
10.9
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar


Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

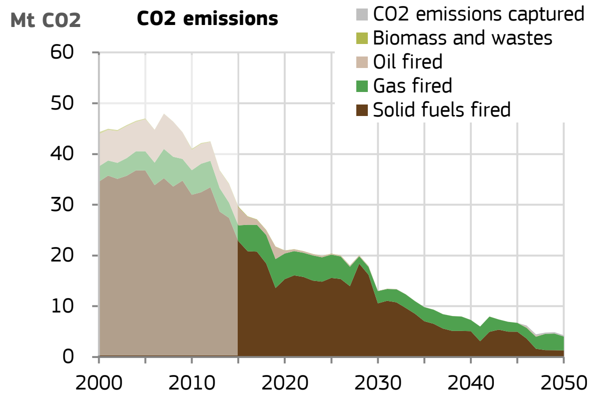

Power system indicators for the representative day
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity



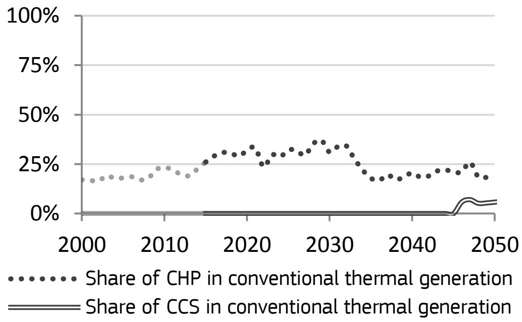
Net electricity generation
TWh
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants



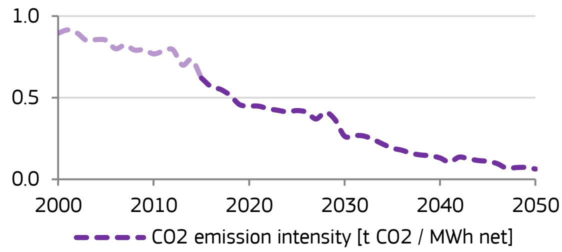
100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation



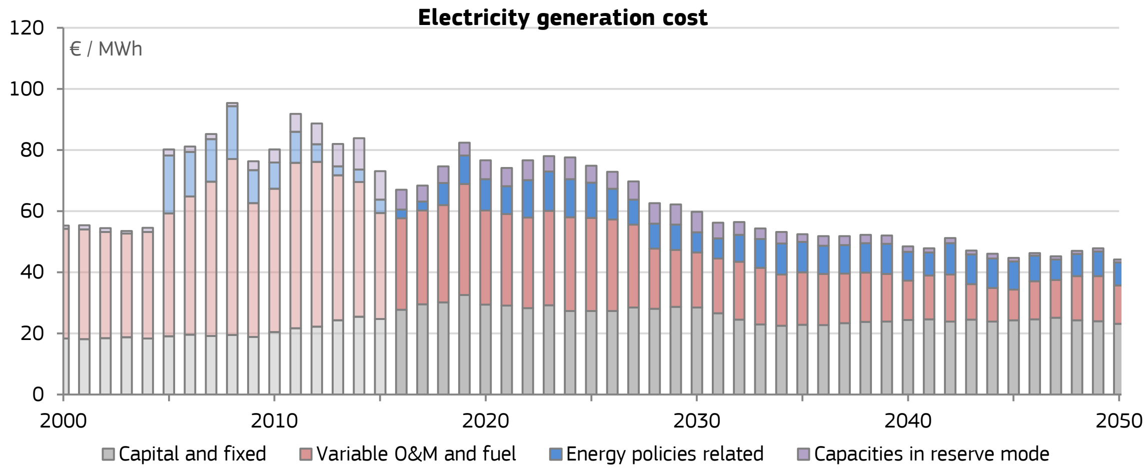
Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050



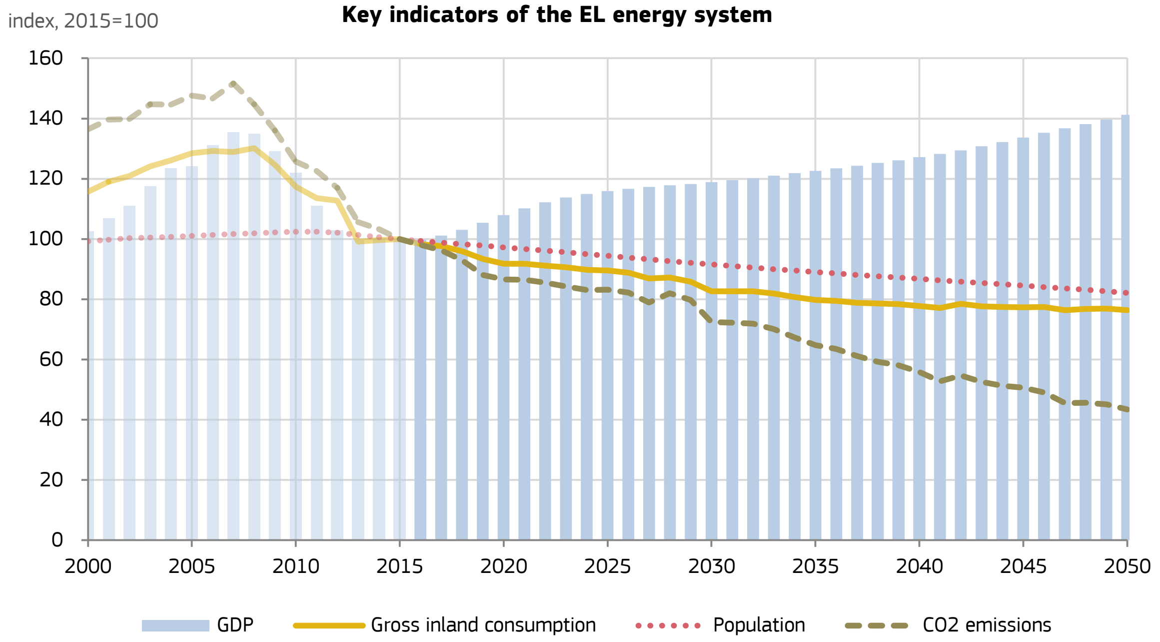
100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation



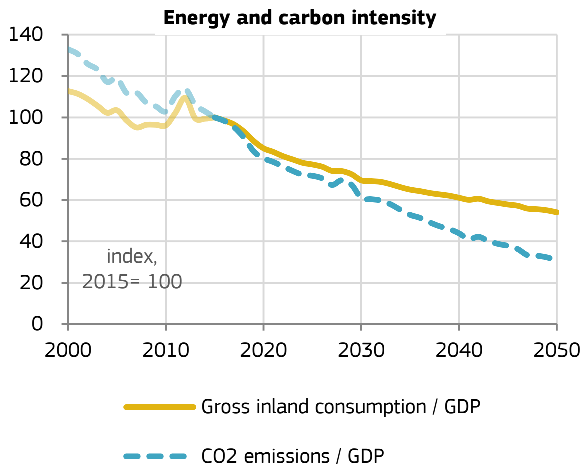
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]

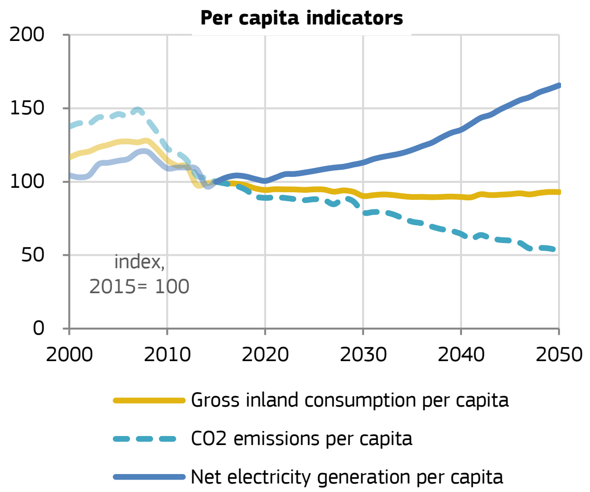


Electricity generation cost
€ / MWh
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	14.7	21.0	16.5	16.2	15.7	15.7
Primary energy consumption [Mtoe]	21.6	30.6	23.7	22.0	19.7	18.2
RES [%] - Share of energy from renewable sources		7.1%	15.6%	20.9%	29.7%	45.8%
RES-E [%] - Share of electricity from renewable sources		8.2%	22.5%	33.7%	55.8%	75.5%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	81.5	107.8	73.0	63.2	52.9	31.7
reduction to 1990		*32%*	*-10%*	*-22%*	*-35%*	*-61%*
Emissions in current ETS sectors |(EL) [Mt CO2]		70.2	48.5	39.4	31.2	13.1
reduction to 2005			*-31%*	*-44%*	*-56%*	*-81%*
Emissions in current ESD sectors [Mt CO2]		37.6	24.5	23.8	21.7	18.6
reduction to 2005			*-35%*	*-37%*	*-42%*	*-50%*



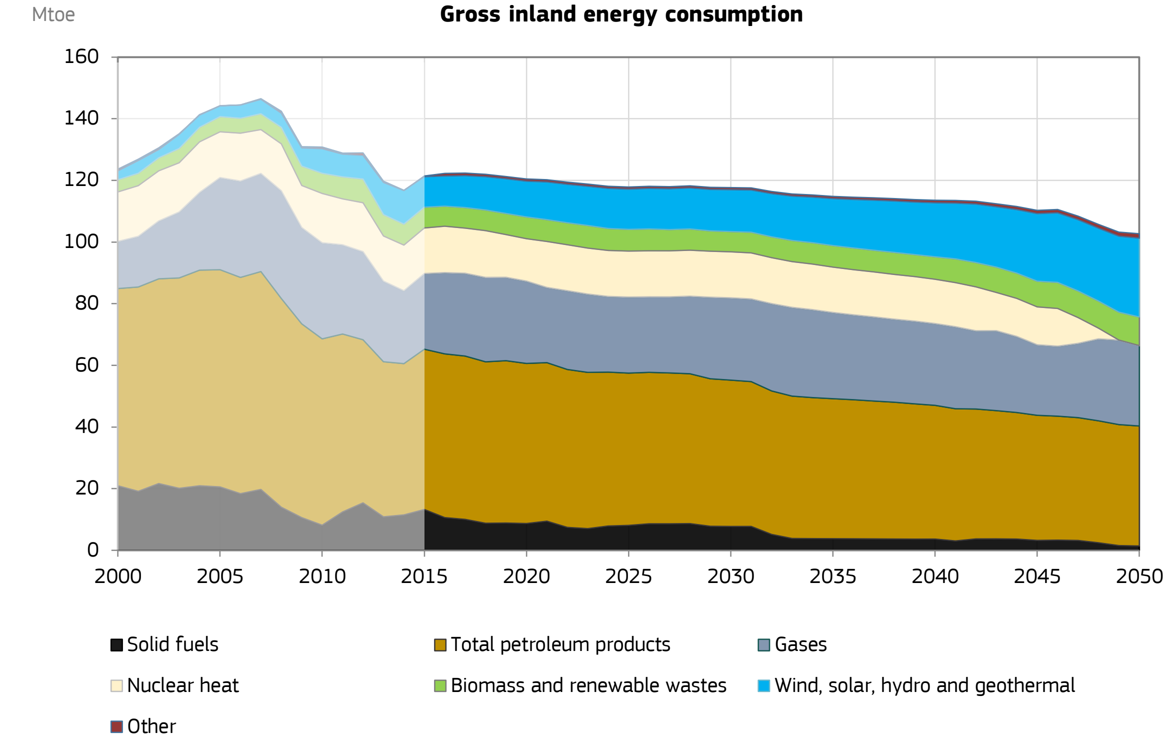


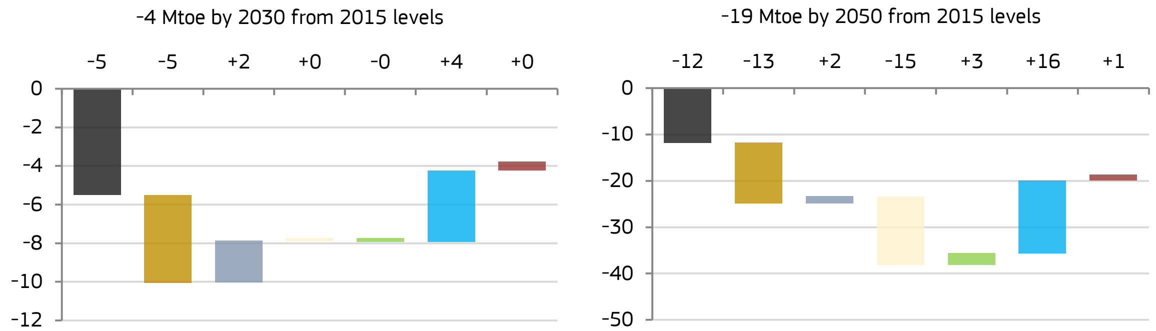
POTEnCIA - Model results overview

Spain

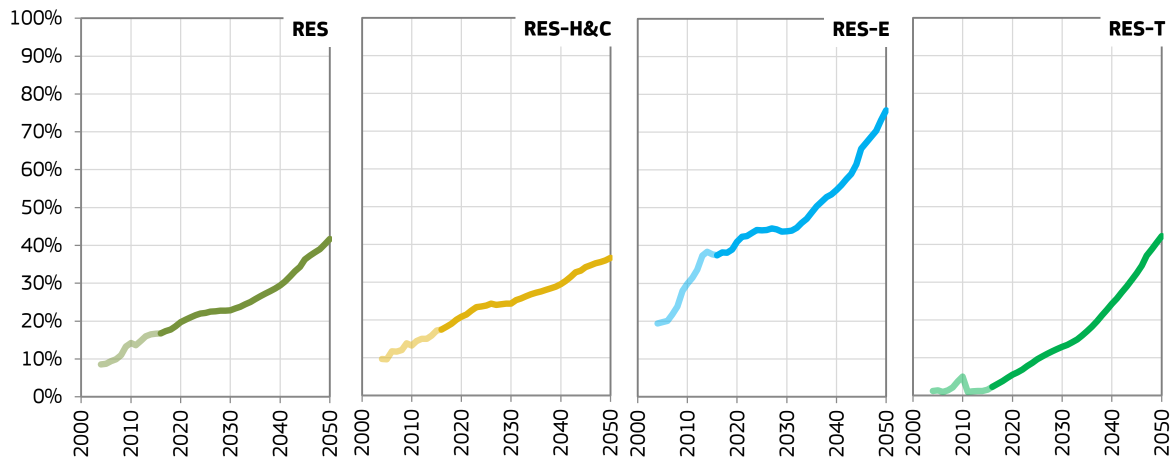
Central_2018 scenario

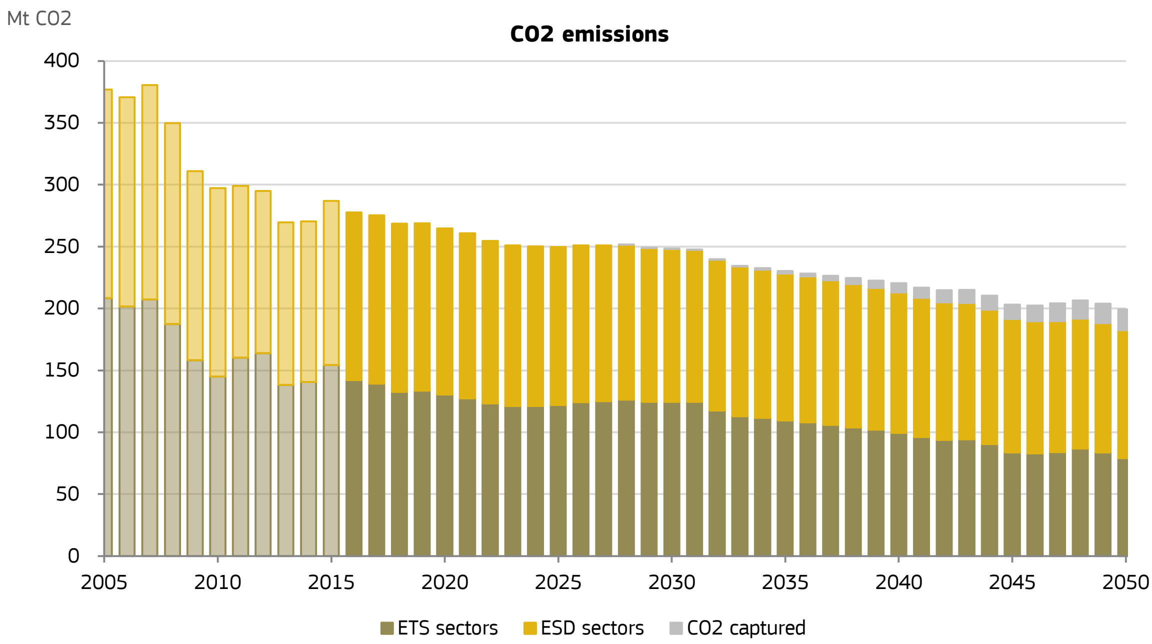
Gross inland energy consumption

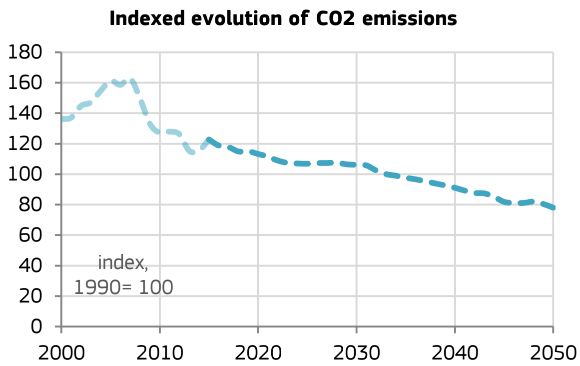


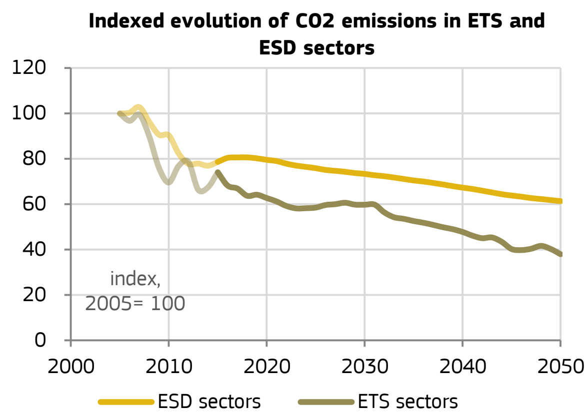


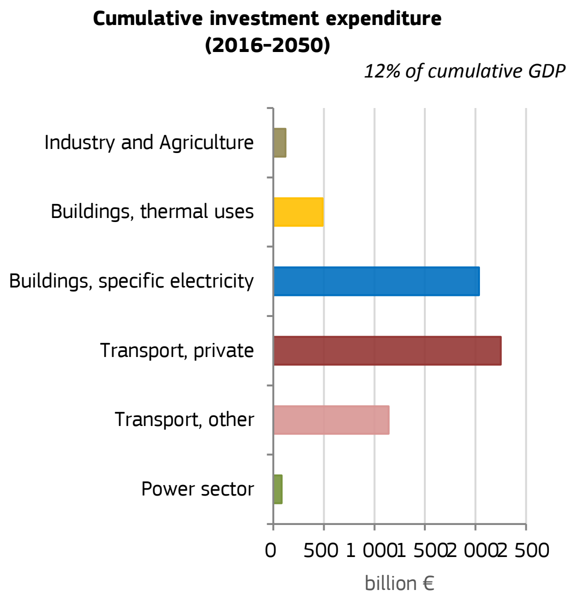
Share of renewable energies

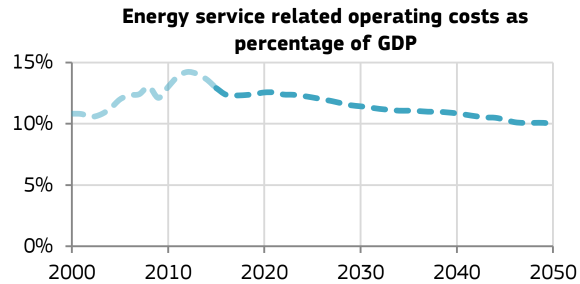


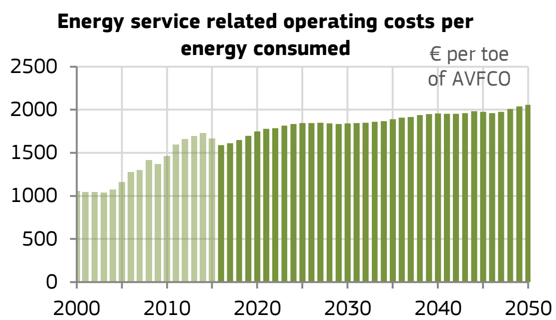

Mt CO2
CO2 emissions
400
350
300
250
200
150
100
50
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured

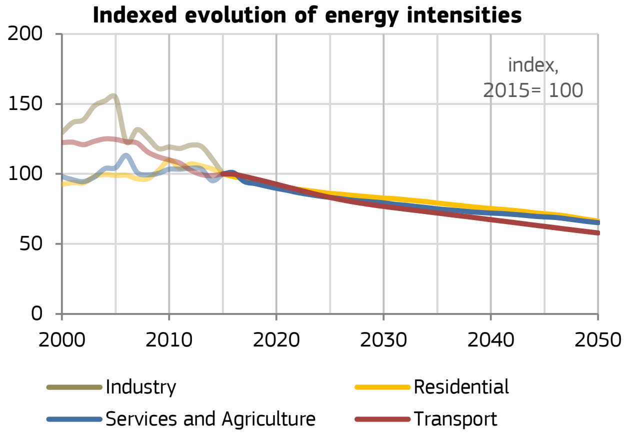

Indexed evolution of CO2 emissions
180
160
140
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

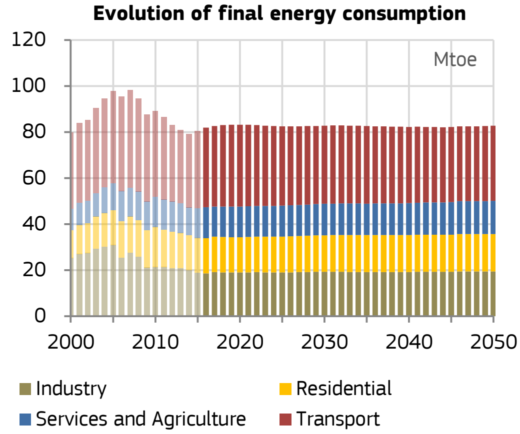

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors

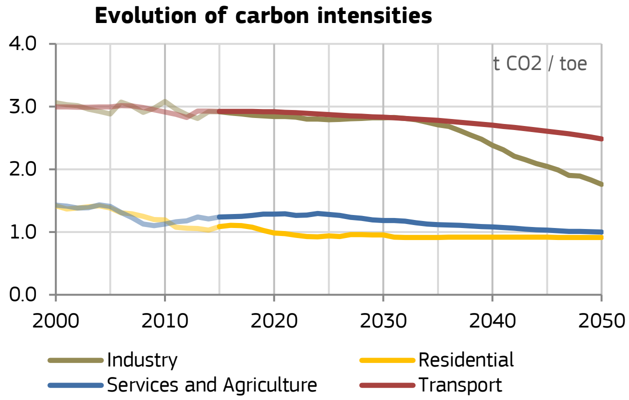

Cumulative investment expenditure (2016-2050)
12% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
500
1 000
1 500
2 000
2 500
billion €

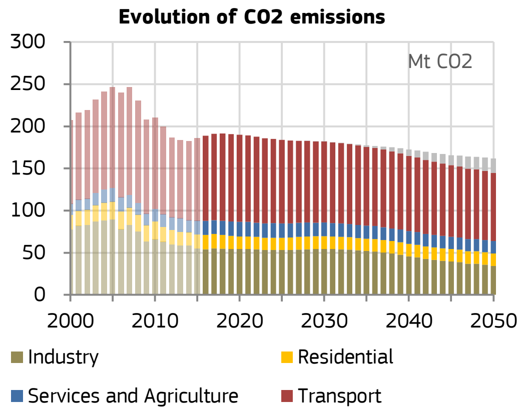

Energy service related operating costs as percentage of GDP
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050

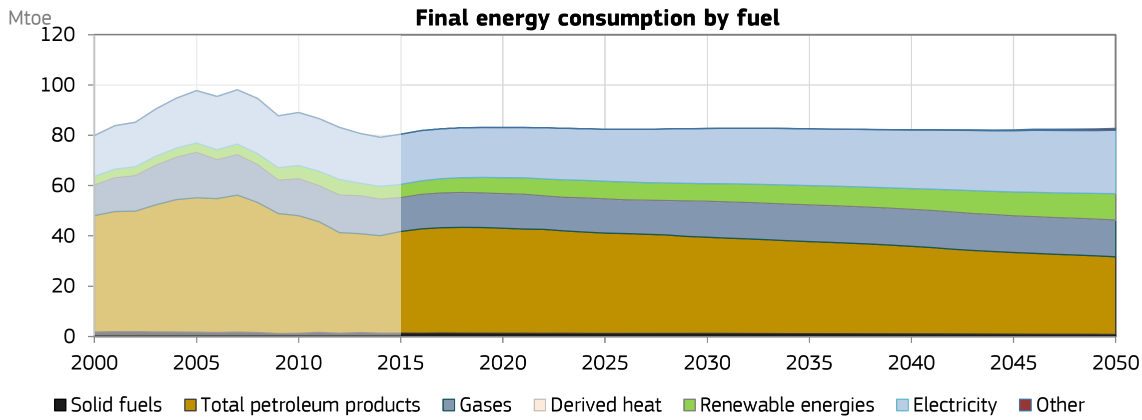

Energy service related operating costs per energy consumed
€ per toe of AVFCO
2500
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

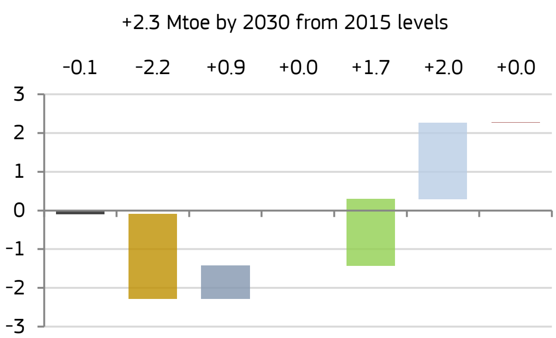

Indexed evolution of energy intensities
index, 2015= 100
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

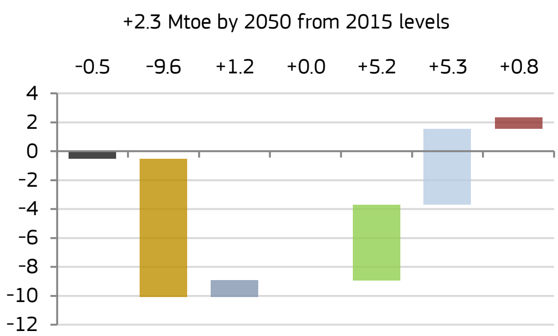

Evolution of final energy consumption
Mtoe
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

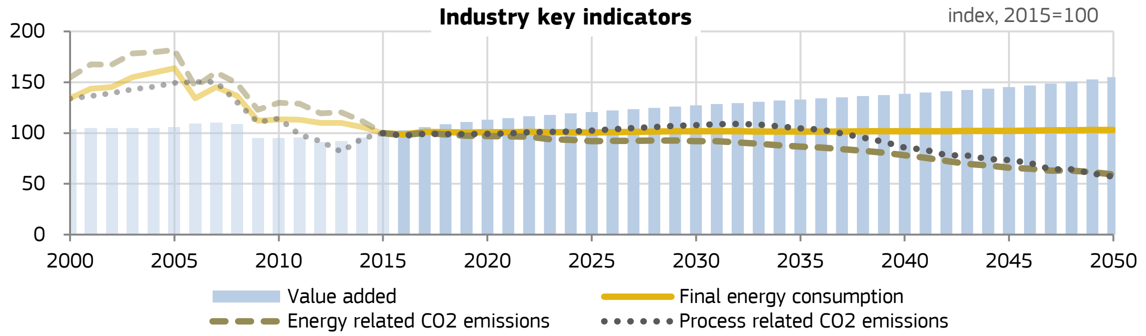

Evolution of carbon intensities
t CO2 / toe
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

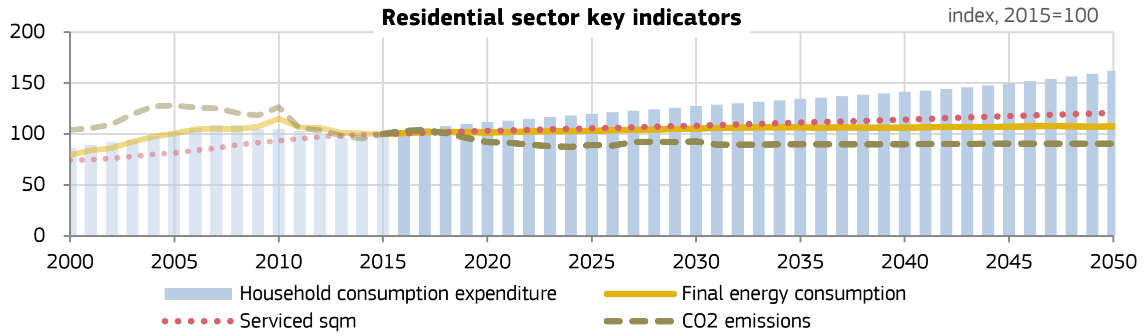

Evolution of CO2 emissions
Mt CO2
300
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

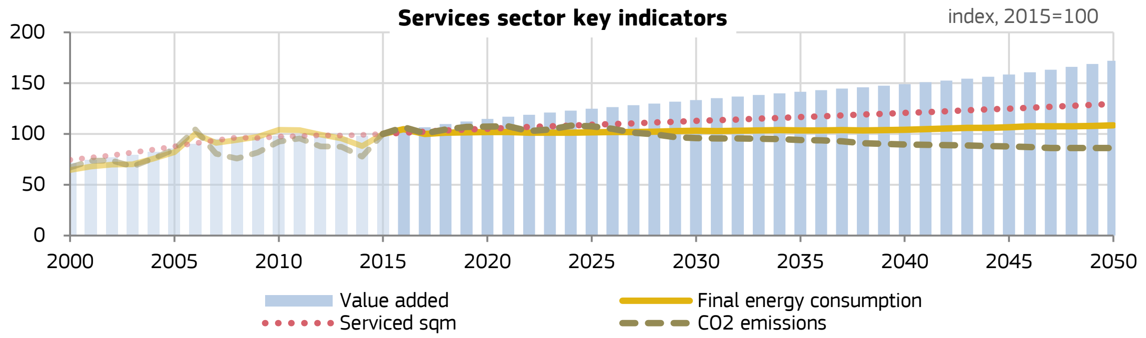

Final energy consumption by fuel
Mtoe
120
100
80
60
40
20
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

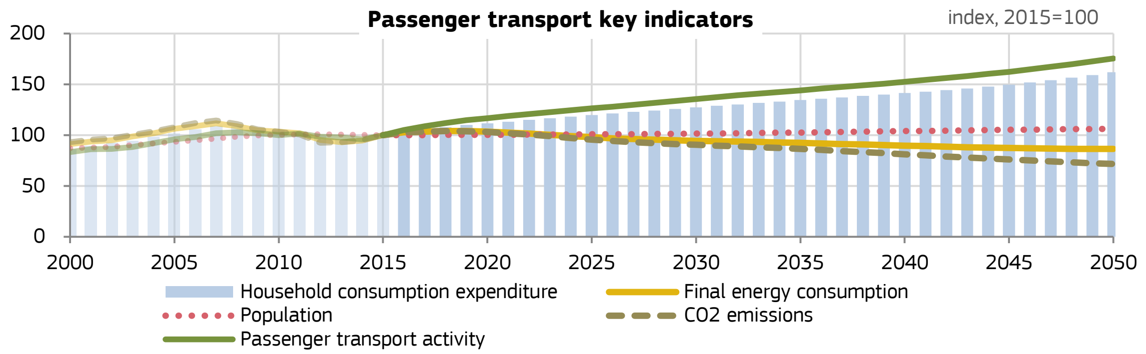

+2.3 Mtoe by 2030 from 2015 levels
-0.1
-2.2
+0.9
+0.0
+1.7
+2.0
+0.0
3
2
1
0
-1
-2
-3

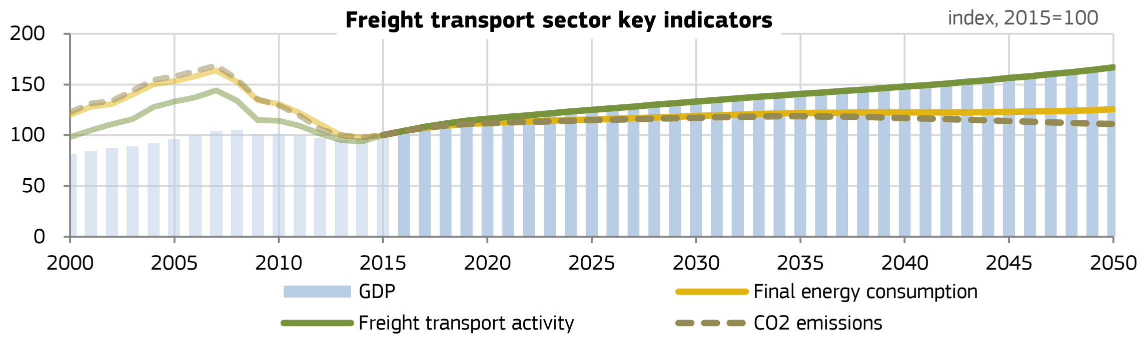

+2.3 Mtoe by 2050 from 2015 levels
-0.5
-9.6
+1.2
+0.0
+5.2
+5.3
+0.8
4
2
0
-2
-4
-6
-8
-10
-12


Industry key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

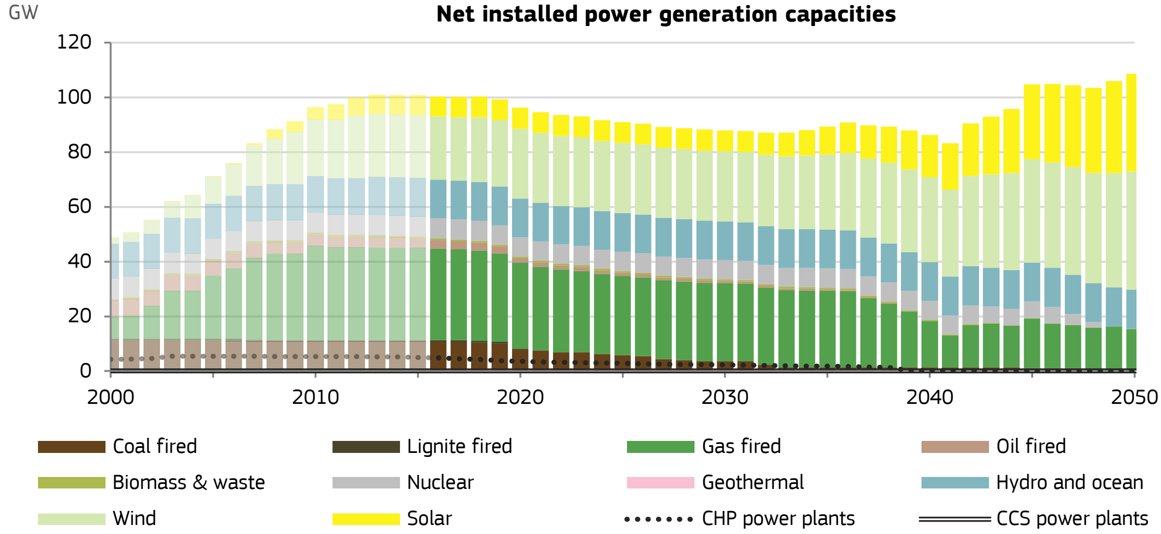

Residential sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions


Services sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

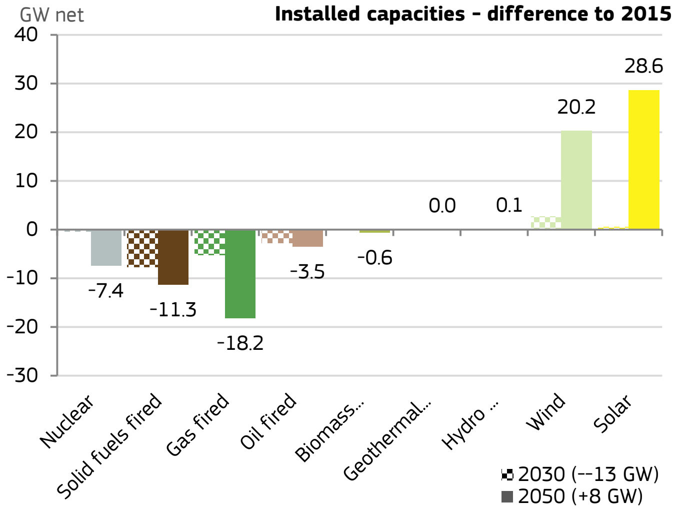

Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity


Freight transport sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

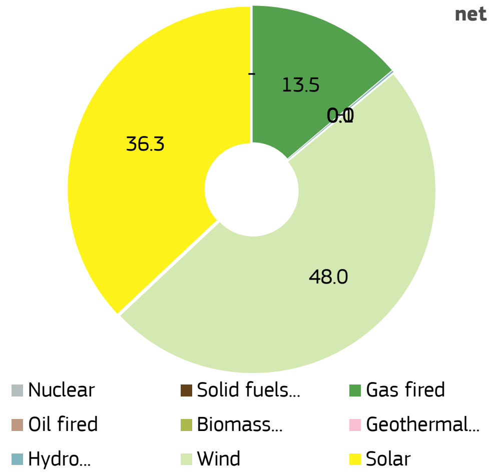
Net installed power generation capacities



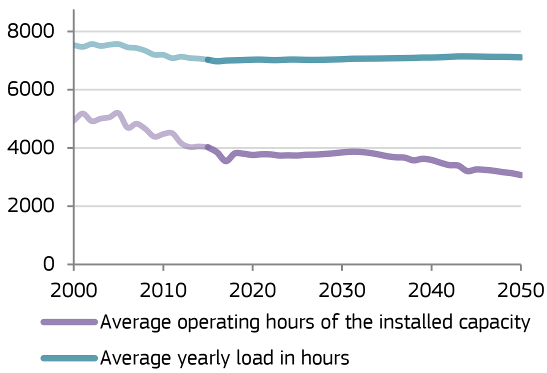
Installed capacities - difference to 2015



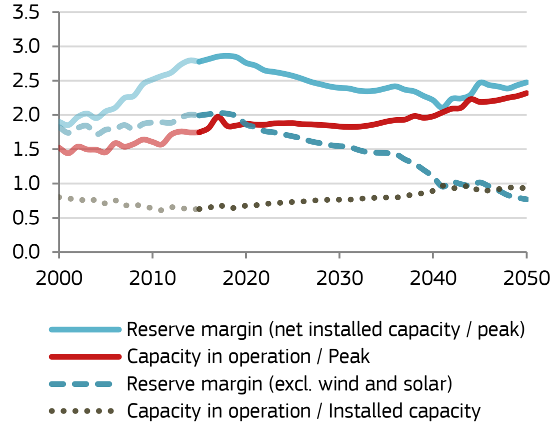
Cumulative investment 2016-2050 GW net

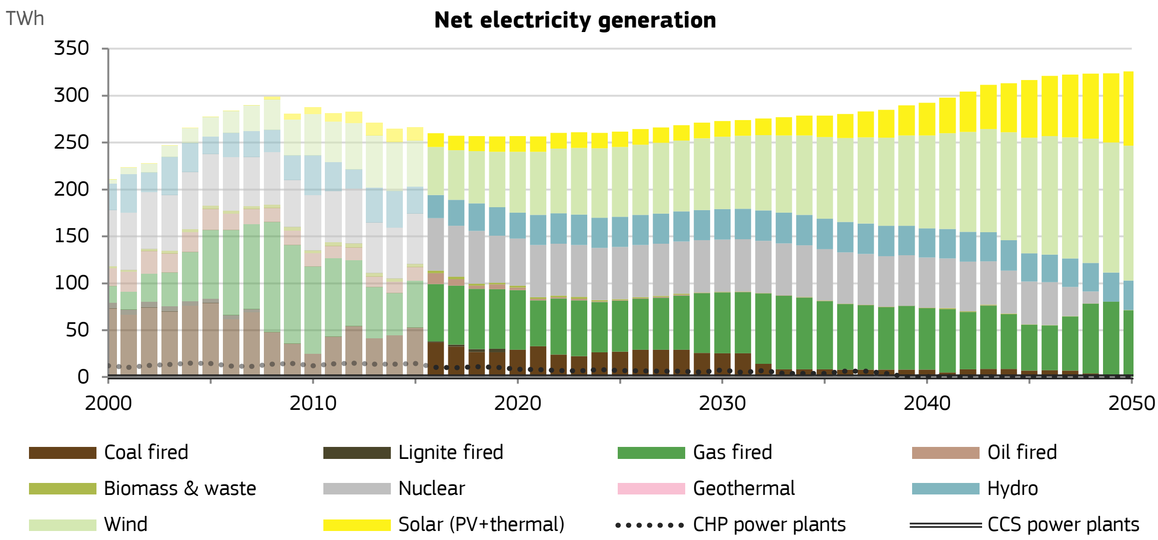


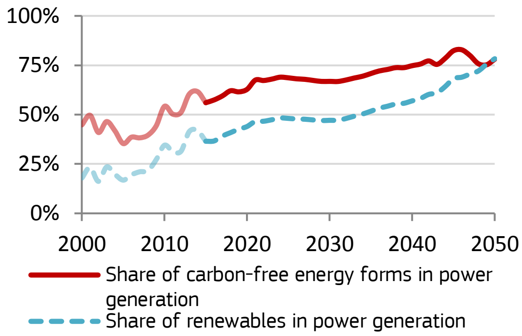
Operational characteristics

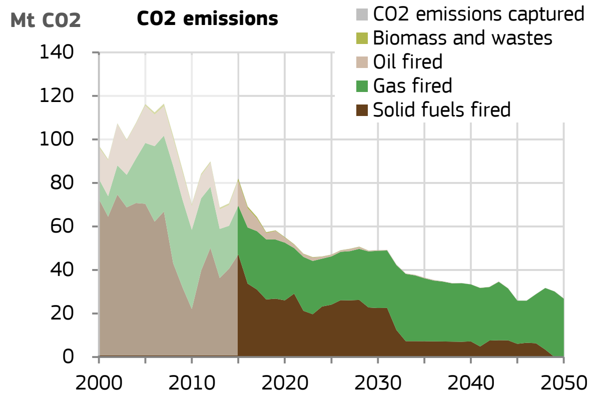


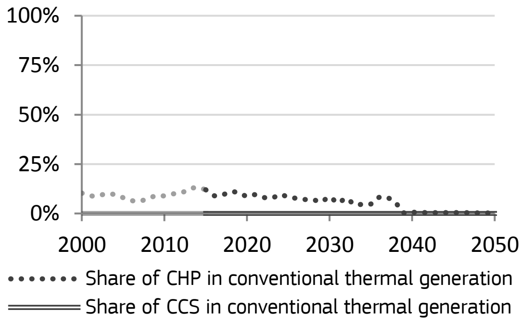
Power system indicators for the representative day

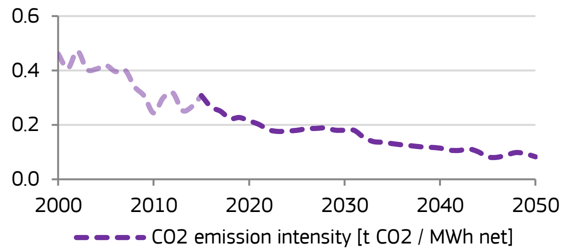


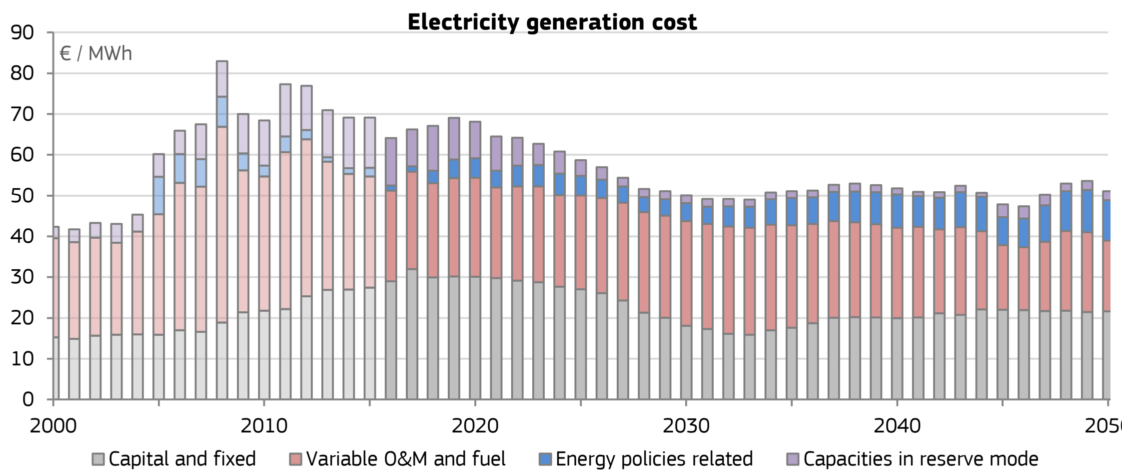

Net electricity generation
TWh
350
300
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

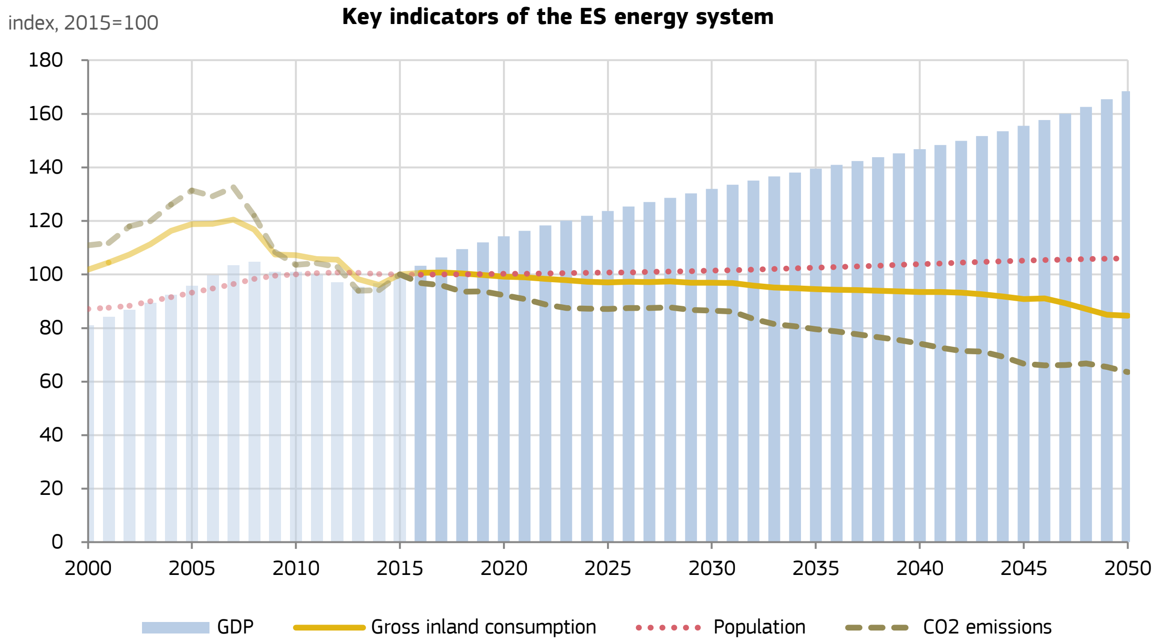

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
140
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050

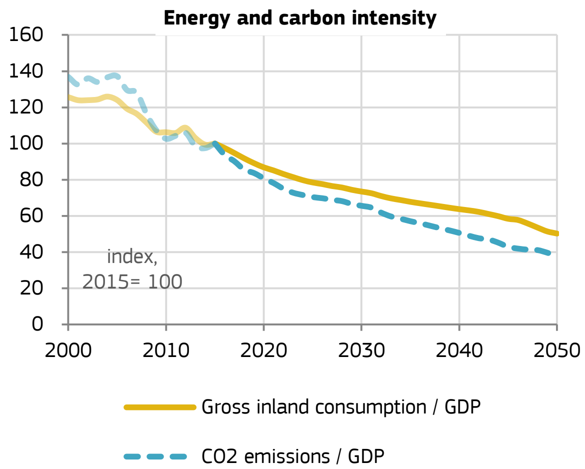

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

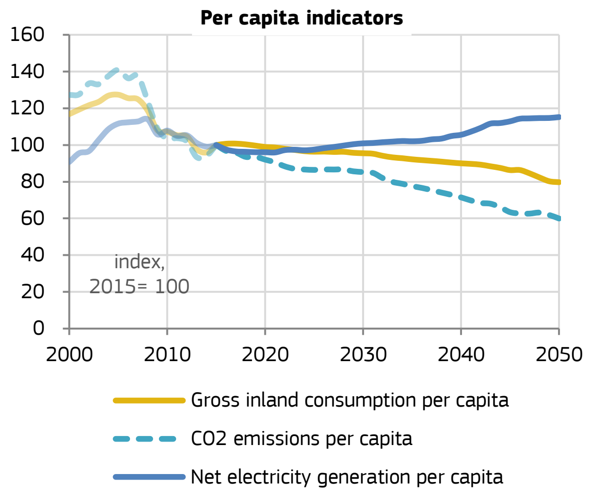

0.6
0.4
0.2
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
90
80
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	57.1	97.8	80.5	83.1	82.7	82.8
Primary energy consumption [Mtoe]	84.2	135.9	117.1	115.8	112.8	97.8
RES [%] - Share of energy from renewable sources		8.7%	16.7%	19.7%	22.8%	41.7%
RES-E [%] - Share of electricity from renewable sources		19.7%	37.7%	41.0%	43.7%	75.8%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	233.8	376.9	286.9	264.7	248.2	182.4
reduction to 1990		*61%*	*23%*	*13%*	*6%*	*-22%*
Emissions in current ETS sectors |(ES) [Mt CO2]		208.3	154.3	130.6	124.5	79.0
reduction to 2005			*-26%*	*-37%*	*-40%*	*-62%*
Emissions in current ESD sectors [Mt CO2]		168.6	132.6	134.1	123.7	103.4
reduction to 2005			*-21%*	*-20%*	*-27%*	*-39%*



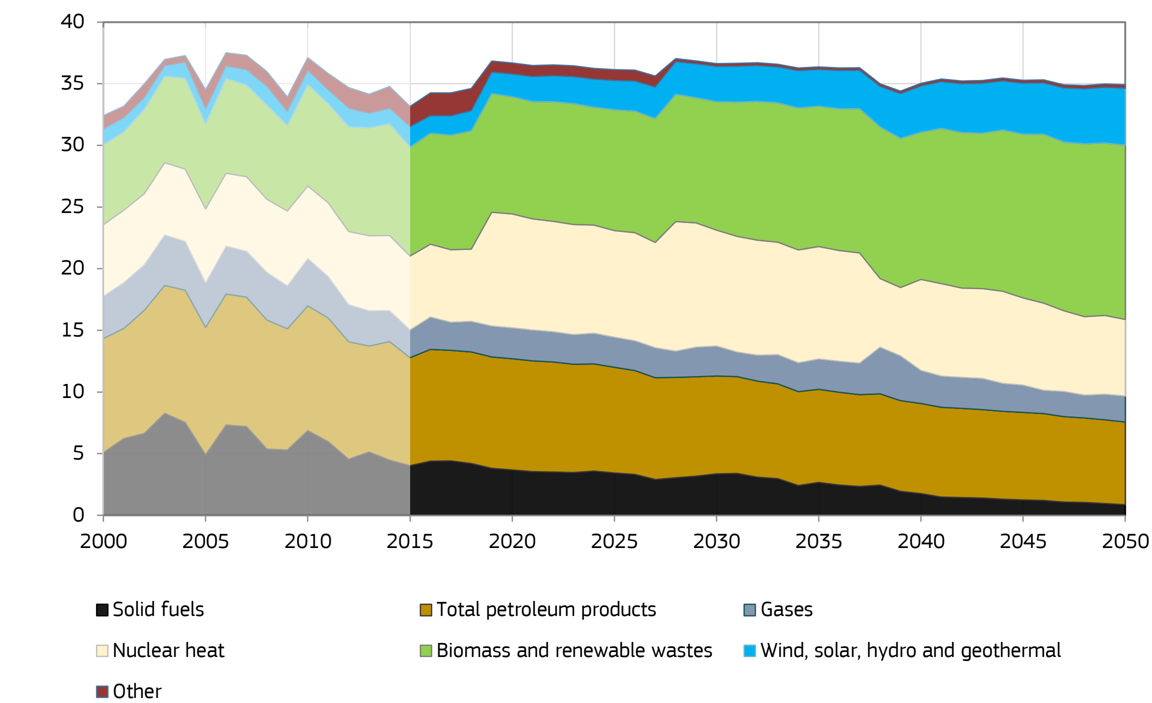


Finland

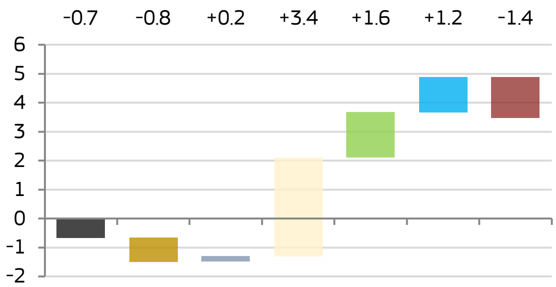
Central_2018 scenario

Gross inland energy consumption

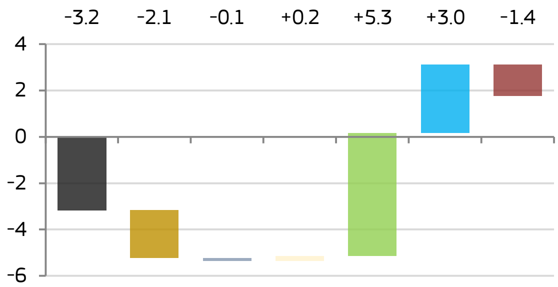
Mtoe



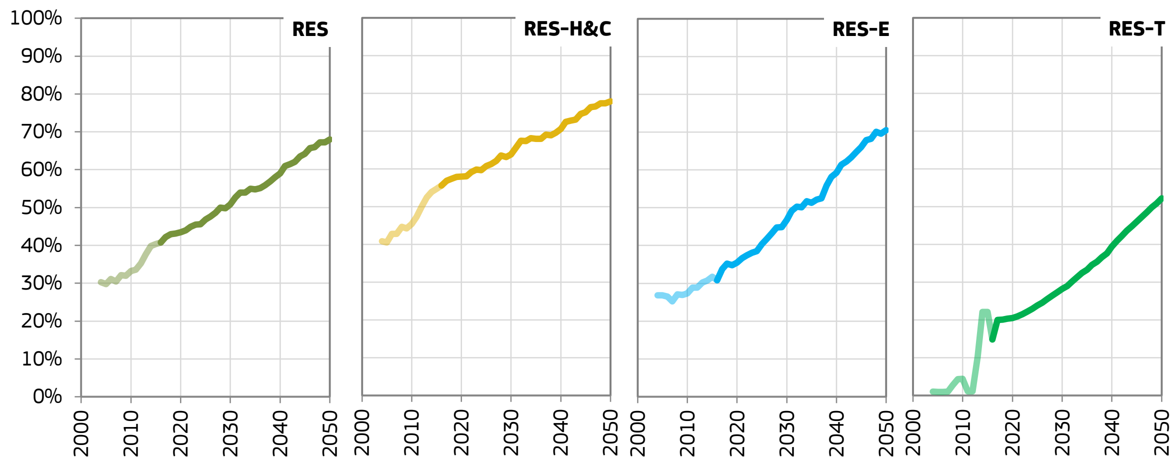
+3.5 Mtoe by 2030 from 2015 levels

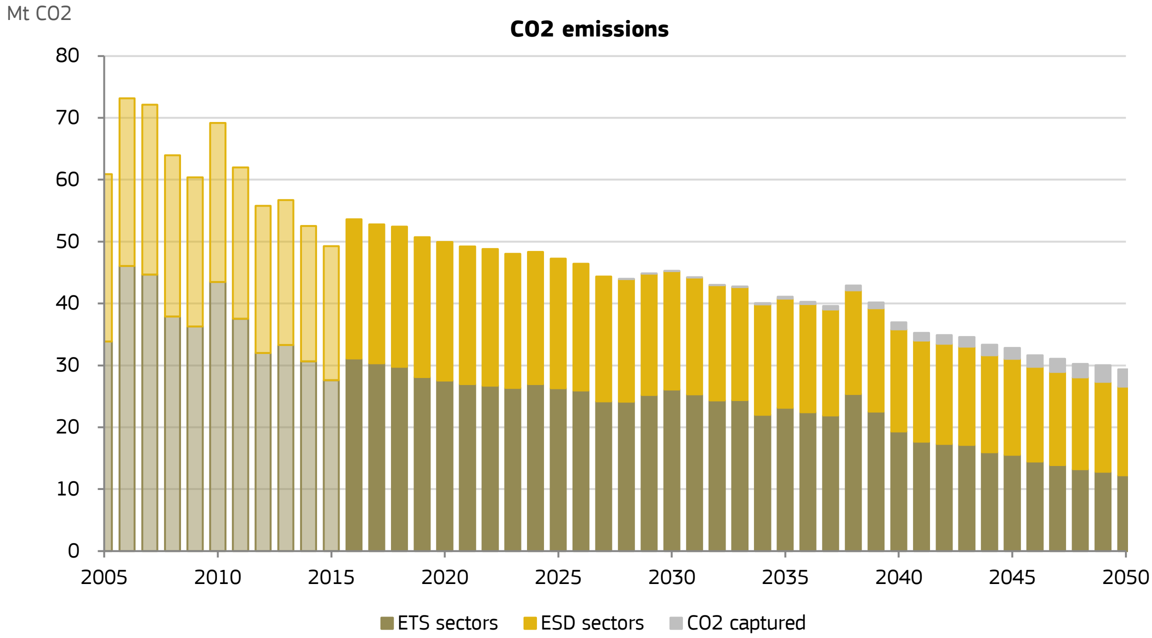


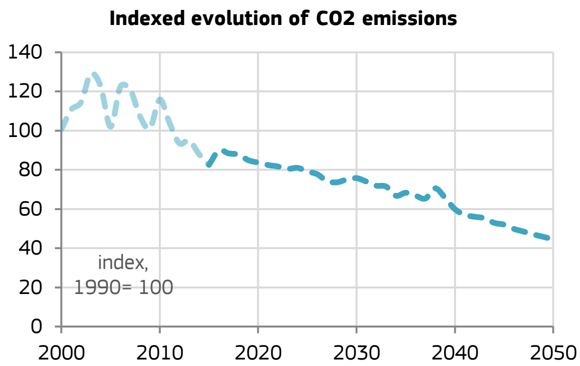
+1.8 Mtoe by 2050 from 2015 levels

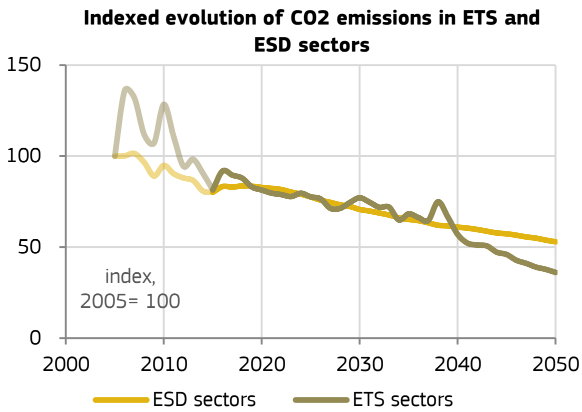


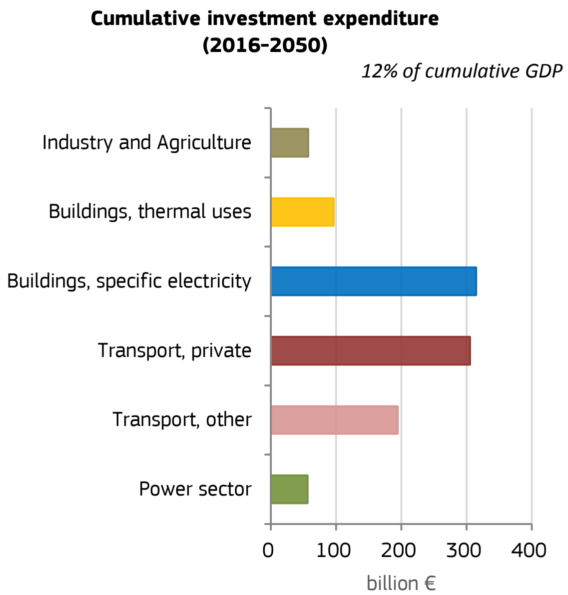
Share of renewable energies

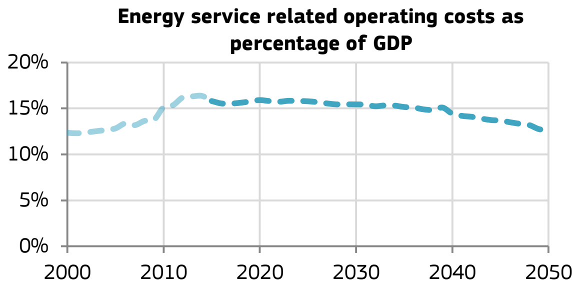


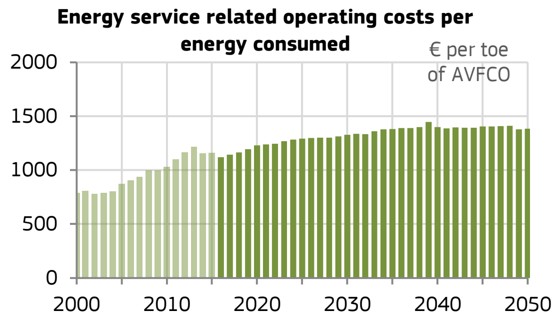

Mt CO2
CO2 emissions
80
70
60
50
40
30
20
10
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured


Indexed evolution of CO2 emissions
140
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

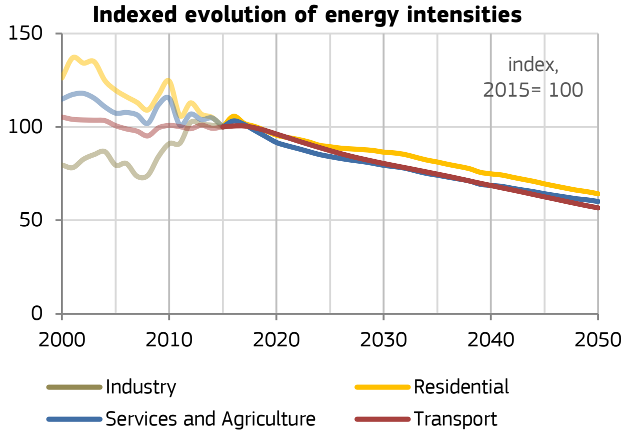

Indexed evolution of CO2 emissions in ETS and ESD sectors
150
100
50
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors


Cumulative investment expenditure (2016-2050)
12% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
100
200
300
400
billion €

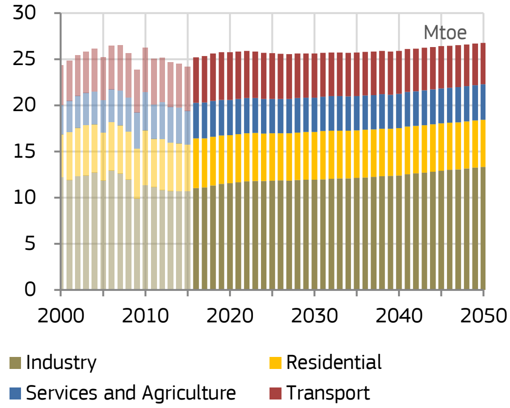

Energy service related operating costs as percentage of GDP
20%
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050


Energy service related operating costs per energy consumed
€ per toe of AVFCO
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

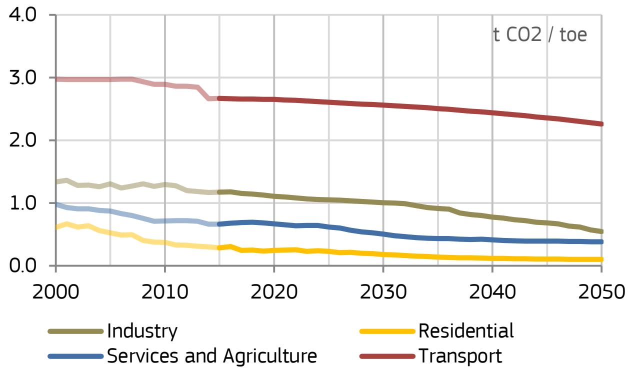
Indexed evolution of energy intensities



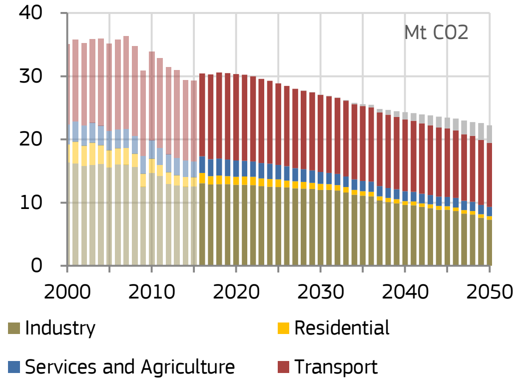
Evolution of final energy consumption



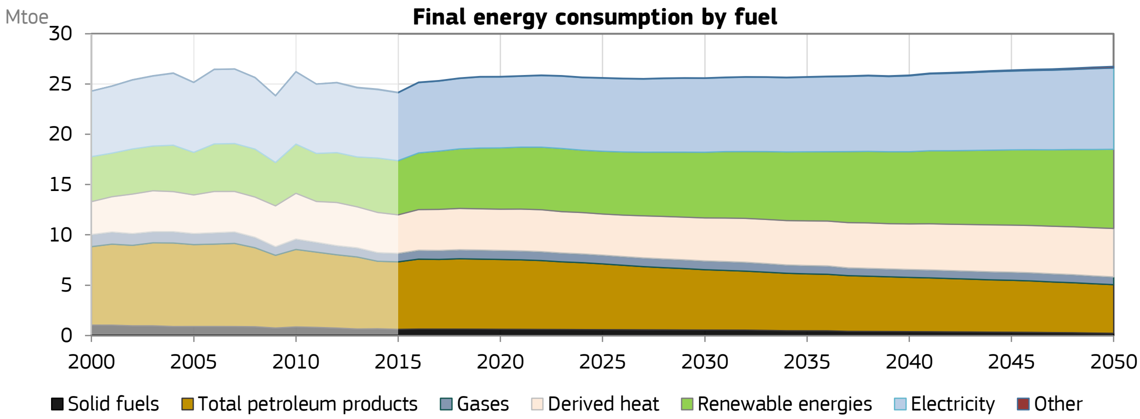
Evolution of carbon intensities



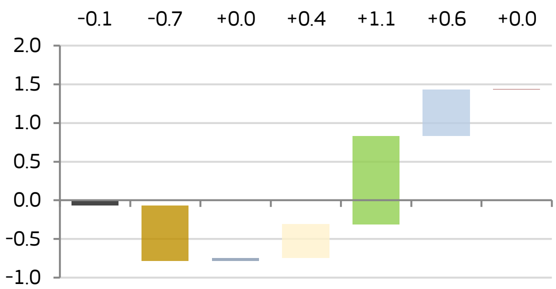
Evolution of CO2 emissions



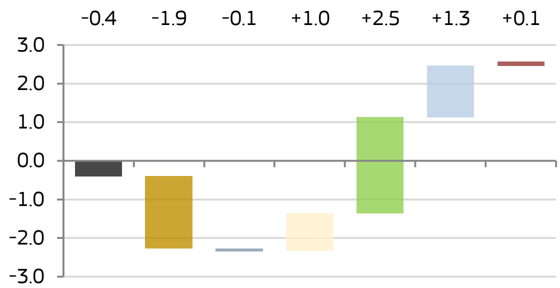
Final energy consumption by fuel

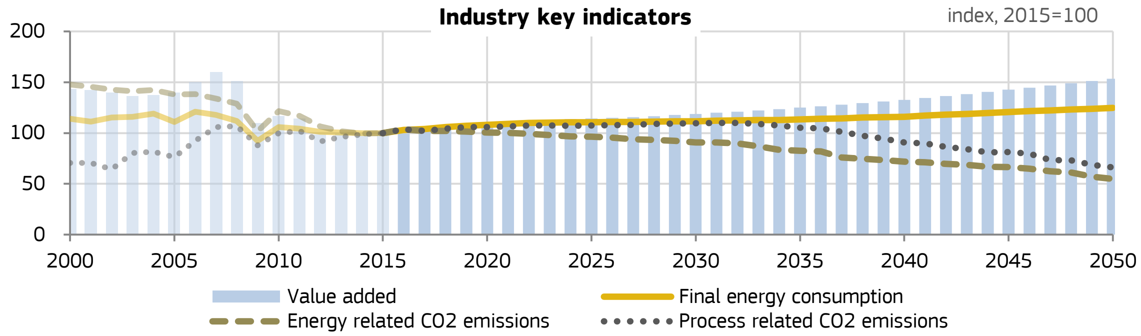


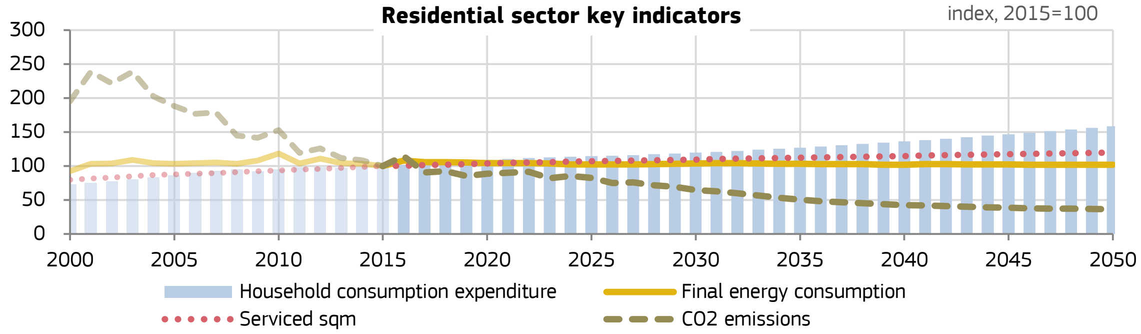
+1.4 Mtoe by 2030 from 2015 levels

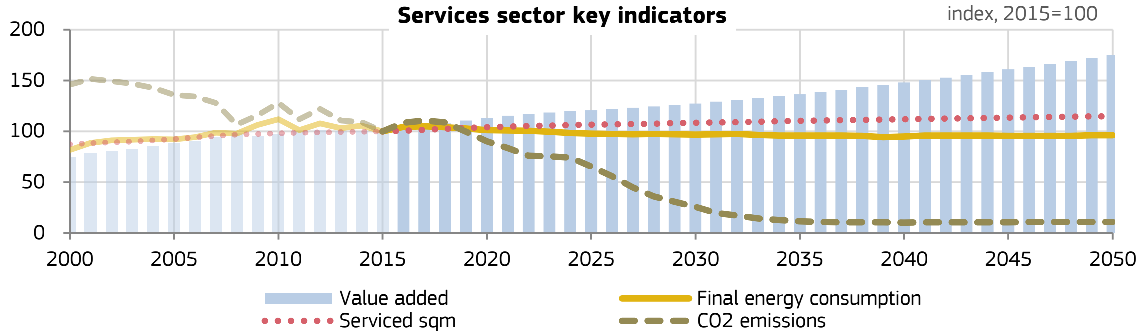


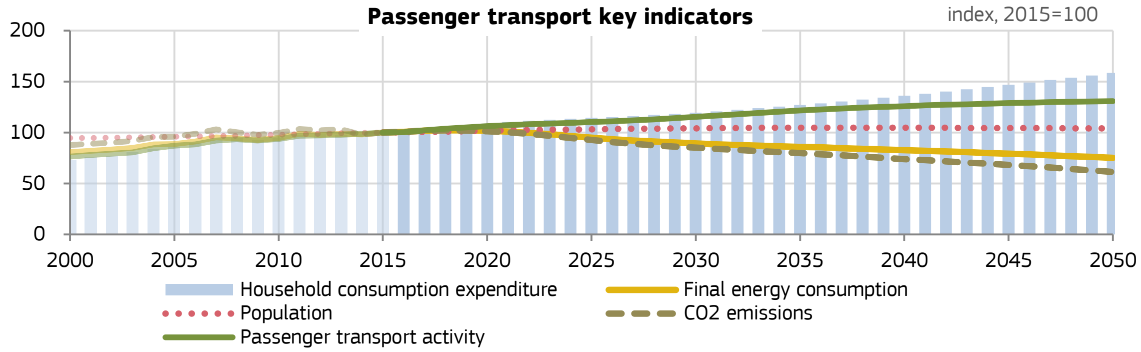
+2.6 Mtoe by 2050 from 2015 levels

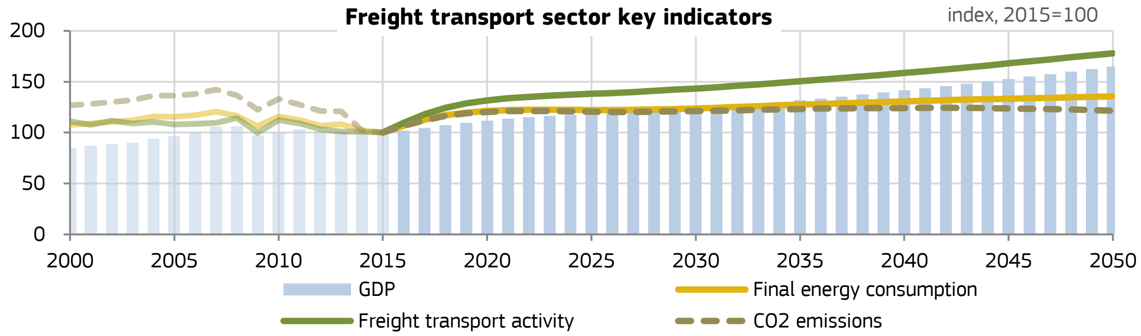


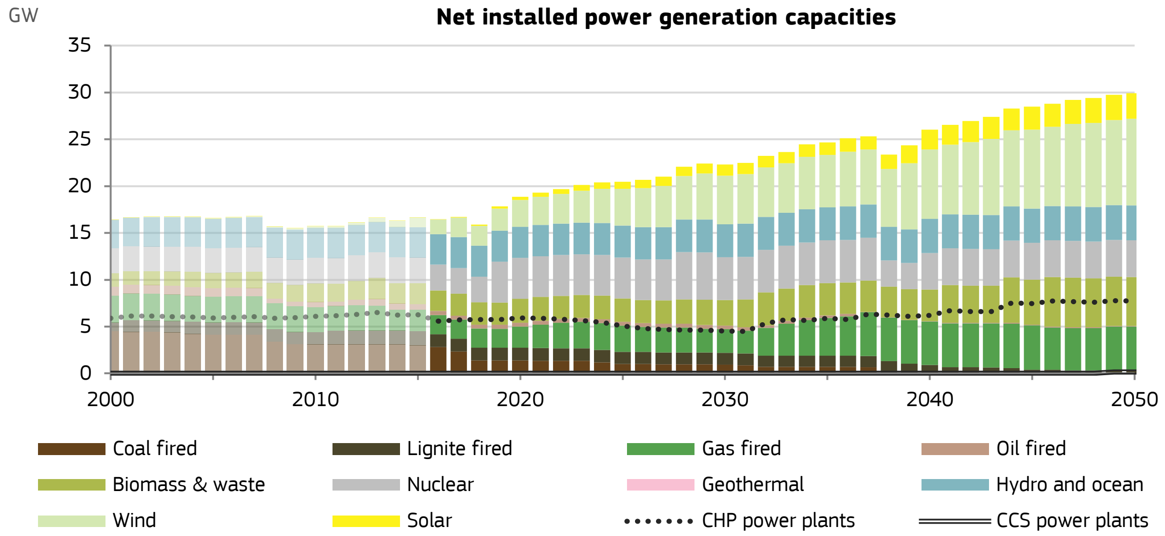

Industry key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

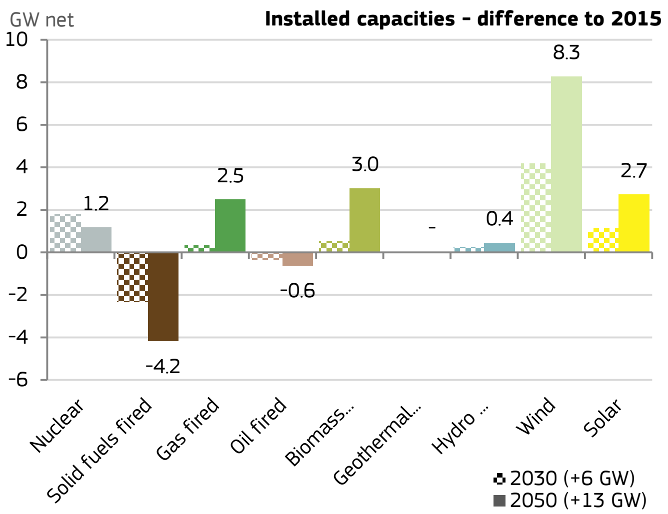

Residential sector key indicators
index, 2015=100
300
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

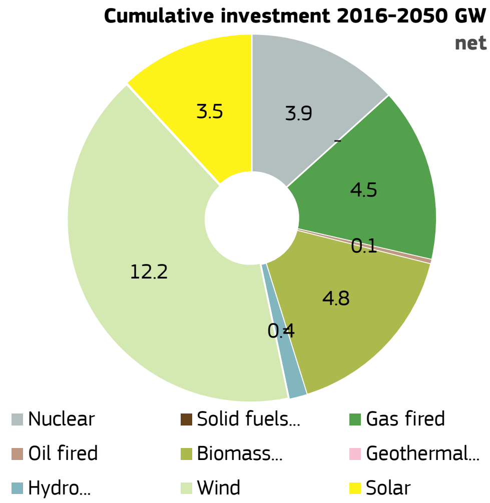

Services sector key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

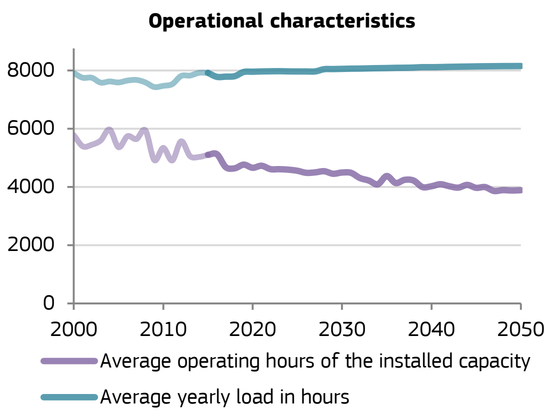

Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

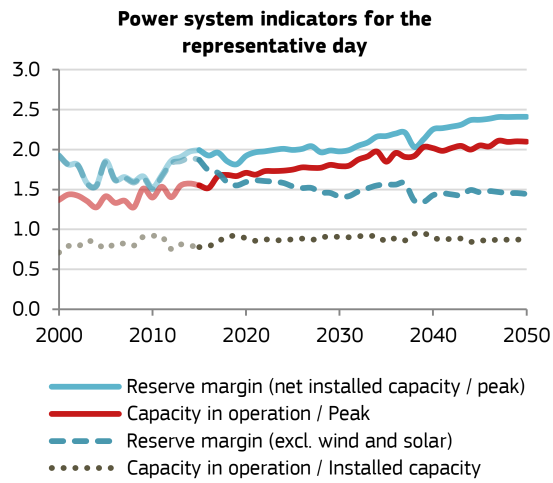

Freight transport sector key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

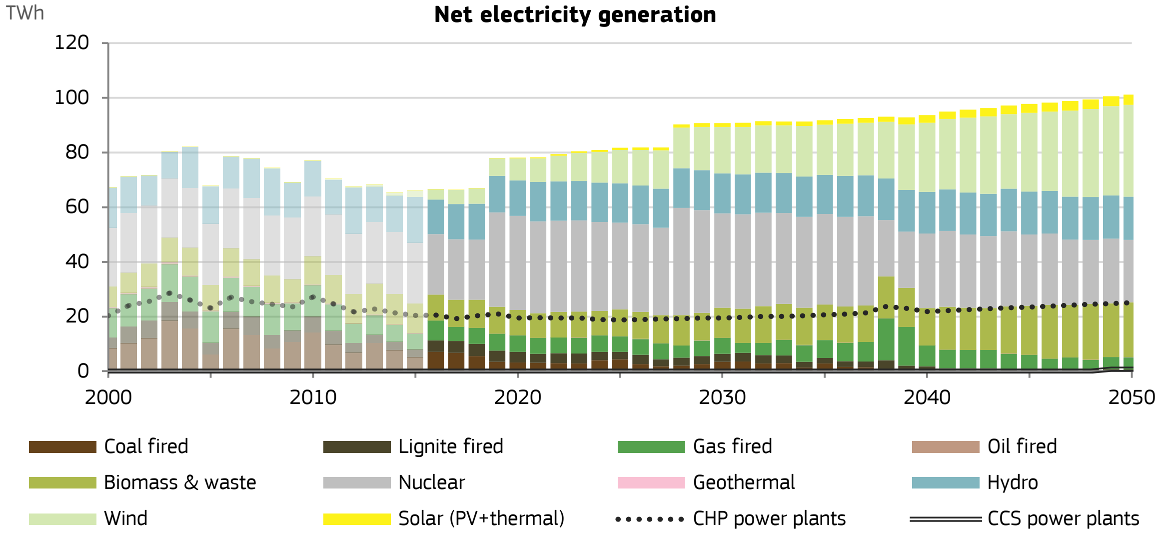

Net installed power generation capacities
GW
35
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

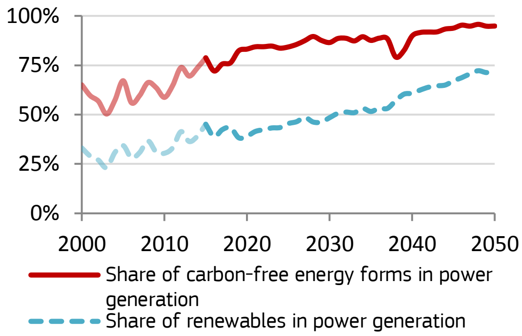

Installed capacities - difference to 2015
GW net
10
8
6
4
2
0
-2
-4
-6
1.2
-4.2
2.5
-0.6
3.0
-
0.4
8.3
2.7
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+6 GW)
2050 (+13 GW)

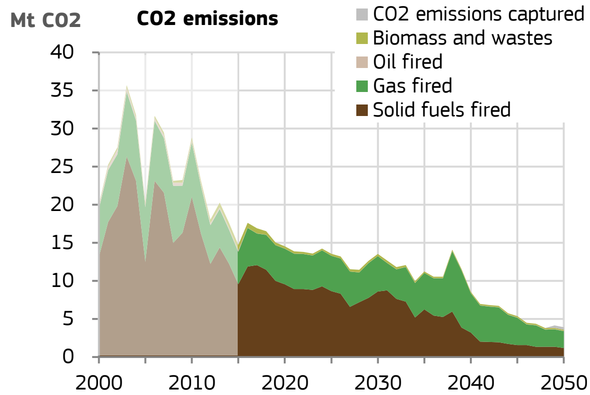

Cumulative investment 2016-2050 GW net
3.5
3.9
4.5
0.1
4.8
0.4
12.2
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

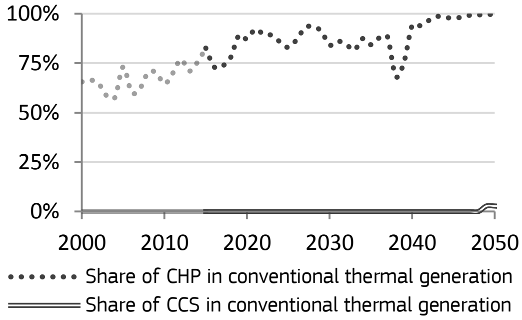

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

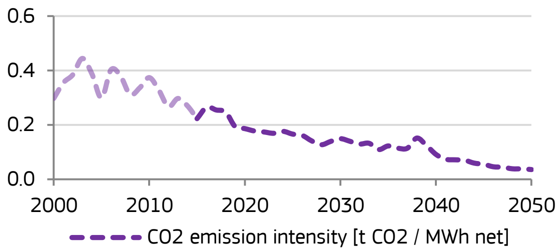

Power system indicators for the representative day
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

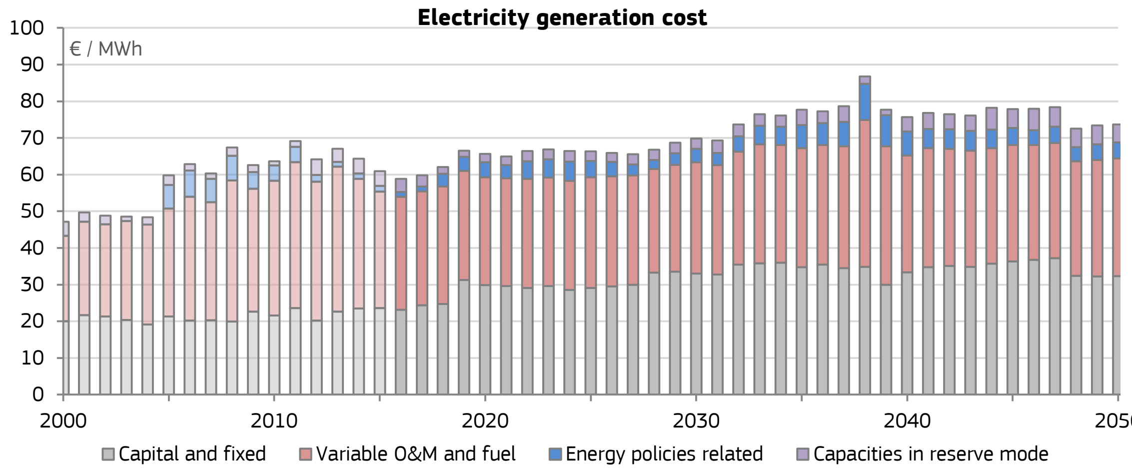

Net electricity generation
TWh
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

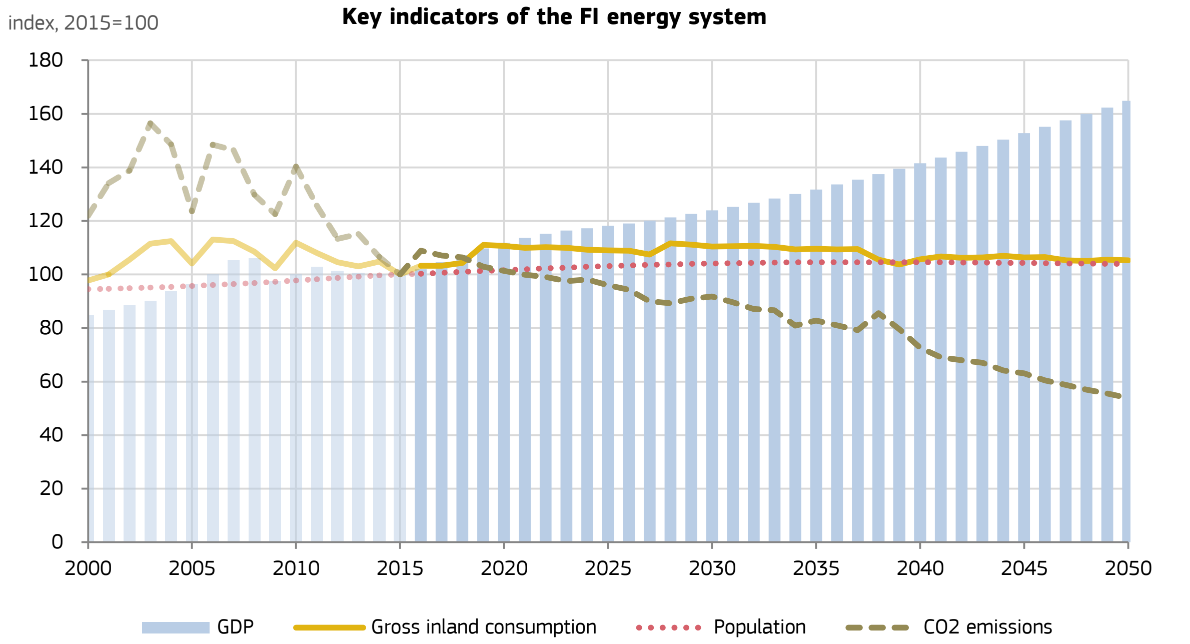

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
40
35
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050

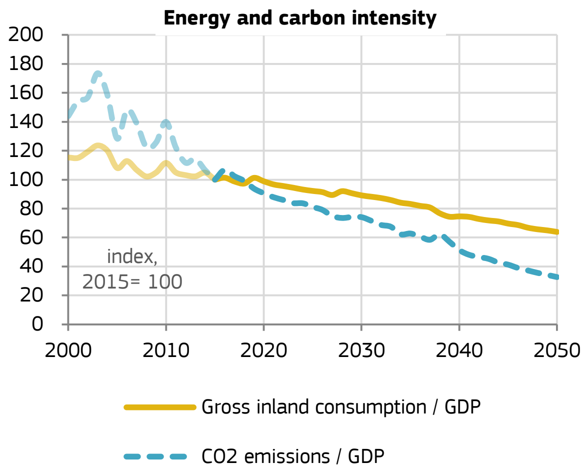

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

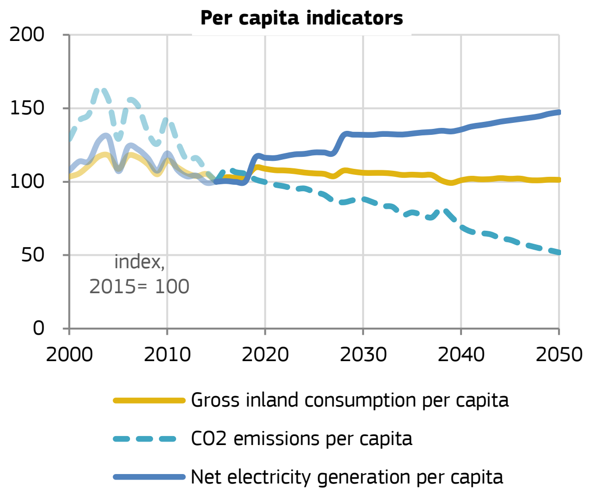

0.6
0.4
0.2
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
100
90
80
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	21.7	25.2	24.2	25.8	25.6	26.8
Primary energy consumption [Mtoe]	27.4	33.3	31.9	35.4	35.4	33.6
RES [%] - Share of energy from renewable sources		29.7%	40.4%	43.4%	50.8%	68.0%
RES-E [%] - Share of electricity from renewable sources		26.8%	31.7%	35.5%	46.8%	70.5%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	59.7	60.9	49.3	49.9	45.2	26.5
reduction to 1990		*2%*	*-17%*	*-16%*	*-24%*	*-56%*
Emissions in current ETS sectors |(FI) [Mt CO2]		33.8	27.6	27.6	26.1	12.2
reduction to 2005			*-18%*	*-19%*	*-23%*	*-64%*
Emissions in current ESD sectors [Mt CO2]		27.0	21.7	22.4	19.1	14.3
reduction to 2005			*-20%*	*-17%*	*-29%*	*-47%*

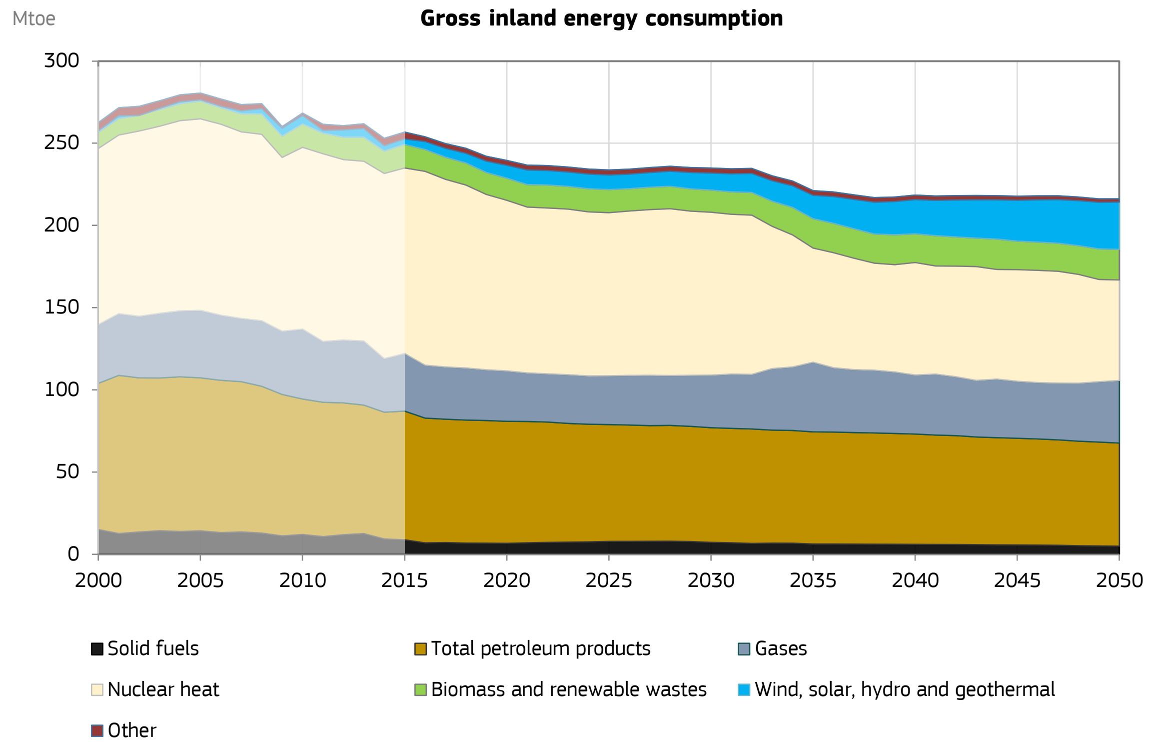


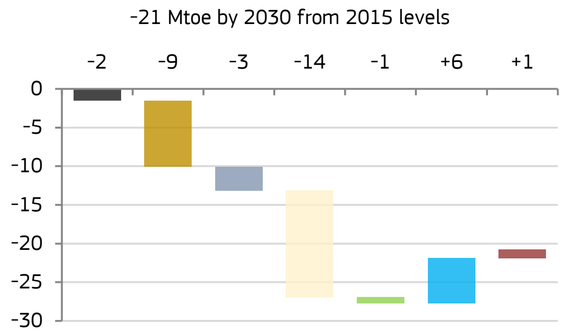


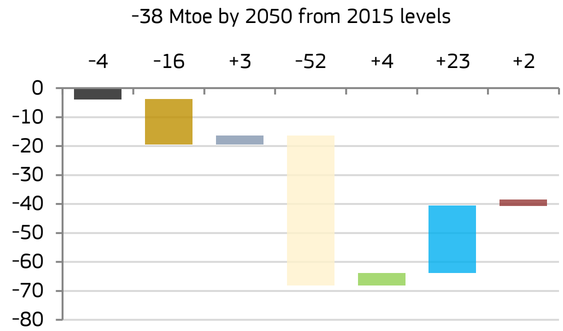
POTEnCIA - Model results overview

France

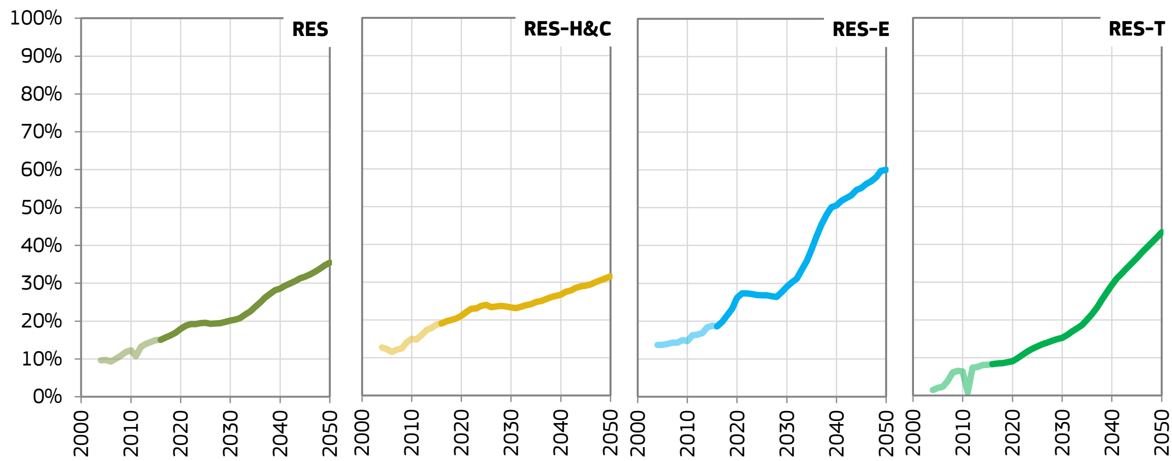
Central_2018 scenario

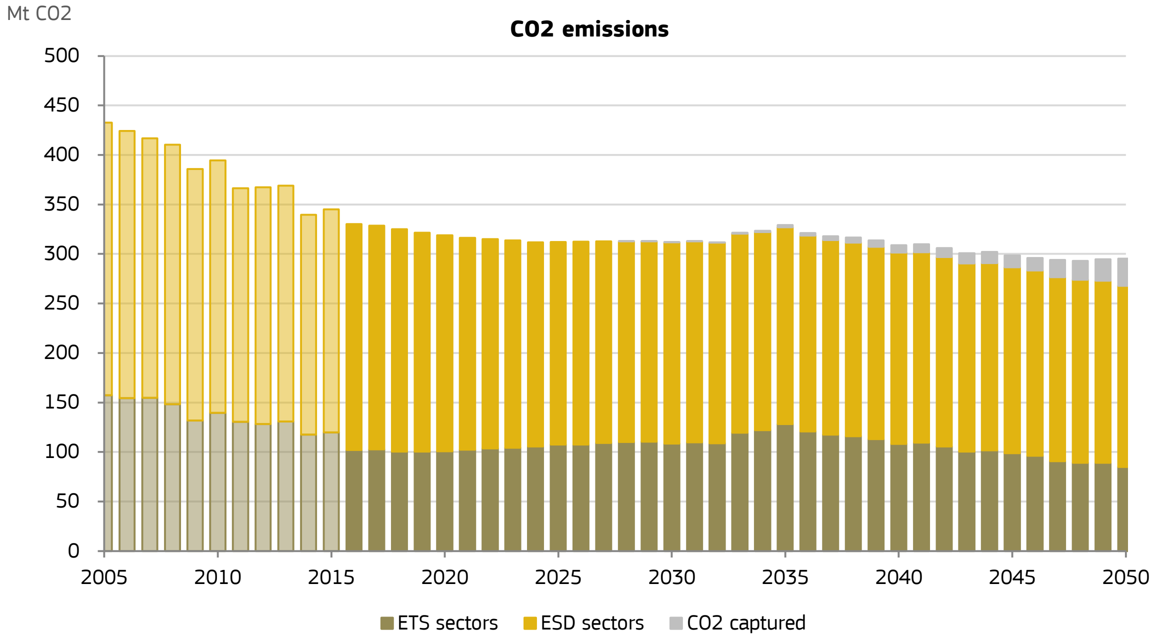


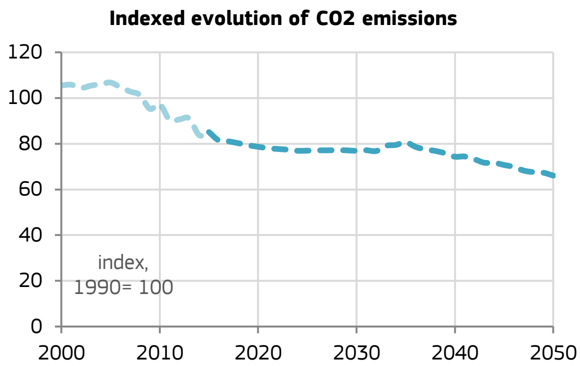


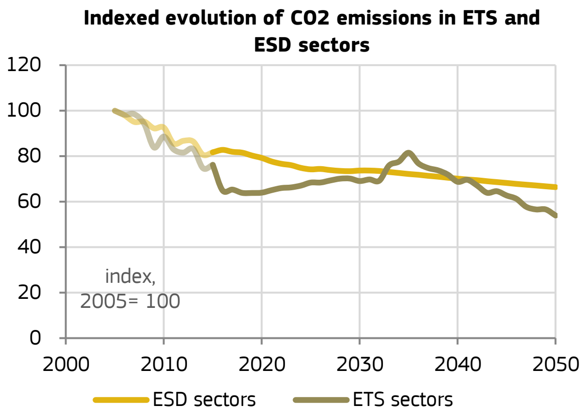


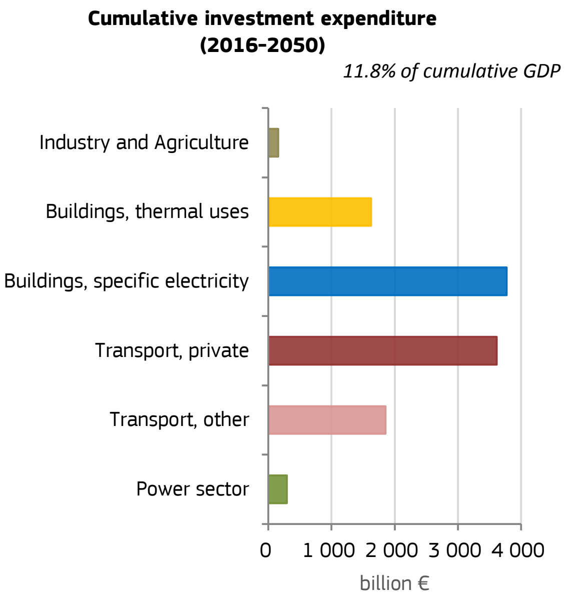
Share of renewable energies

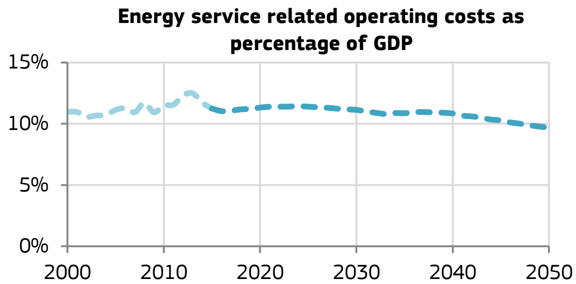


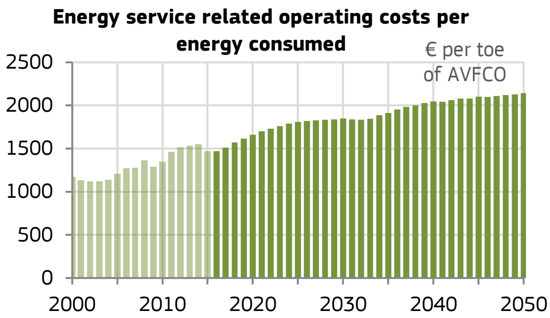

Mt CO2
CO2 emissions
500
450
400
350
300
250
200
150
100
50
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured


Indexed evolution of CO2 emissions
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

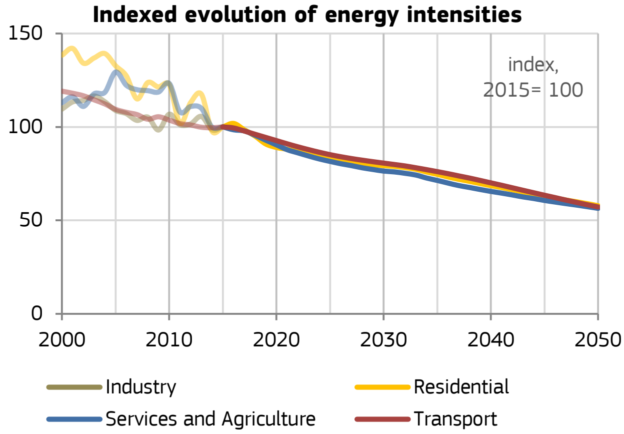

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors


Cumulative investment expenditure (2016-2050)
11.8% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
1 000
2 000
3 000
4 000
billion €

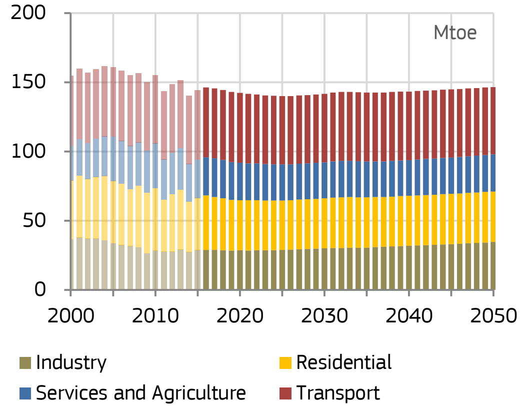

Energy service related operating costs as percentage of GDP
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050


Energy service related operating costs per energy consumed
€ per toe of AVFCO
2500
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

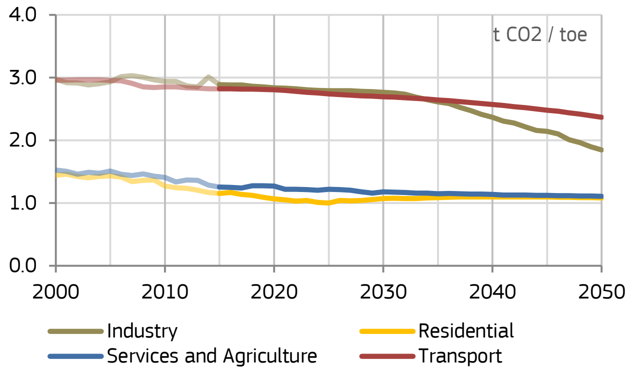
Indexed evolution of energy intensities



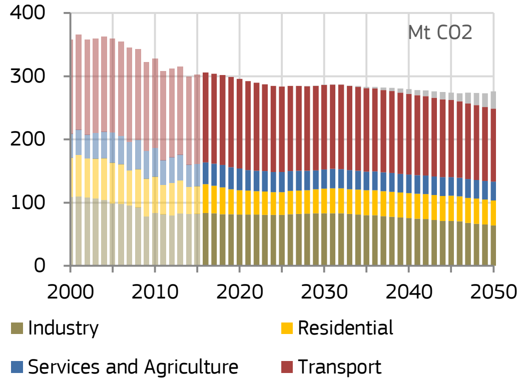
Evolution of final energy consumption



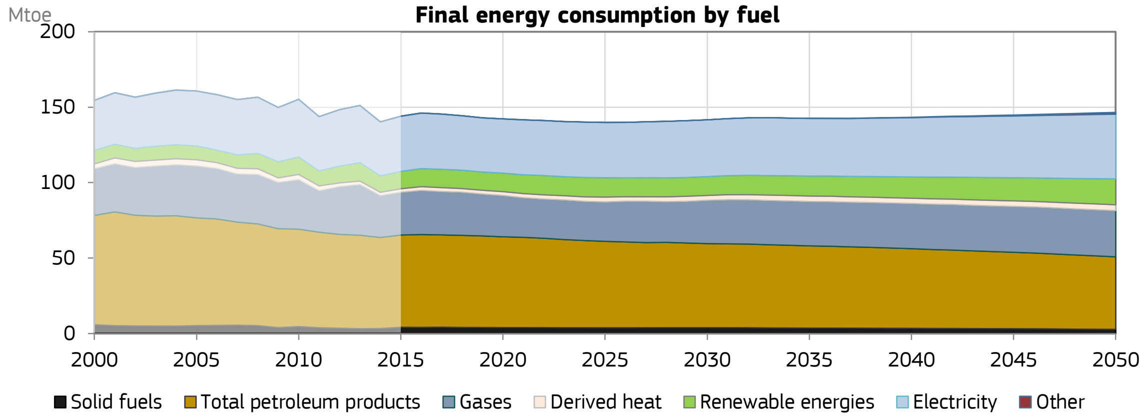
Evolution of carbon intensities



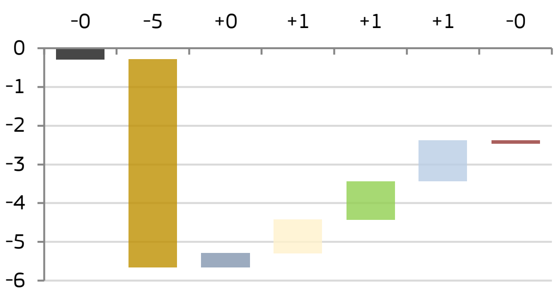
Evolution of CO2 emissions



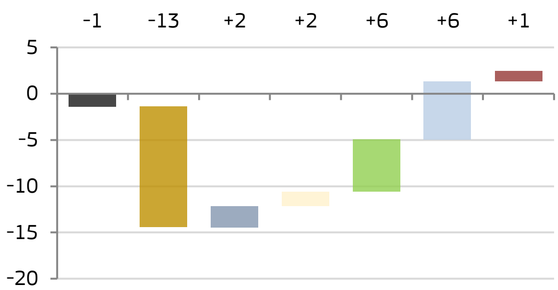
Final energy consumption by fuel

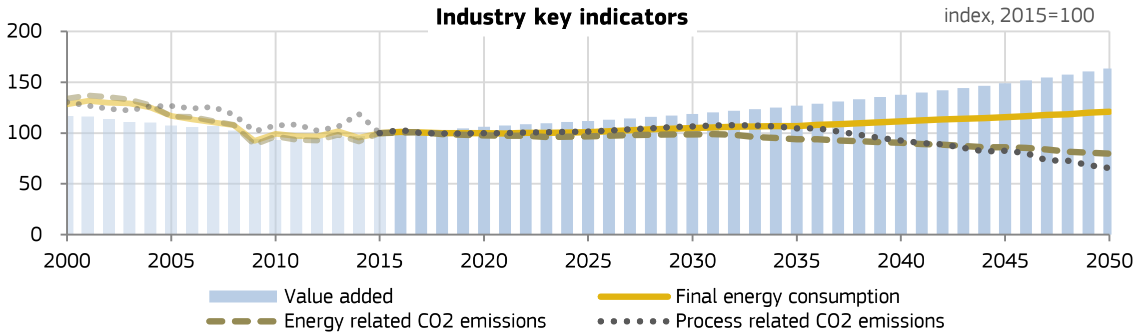


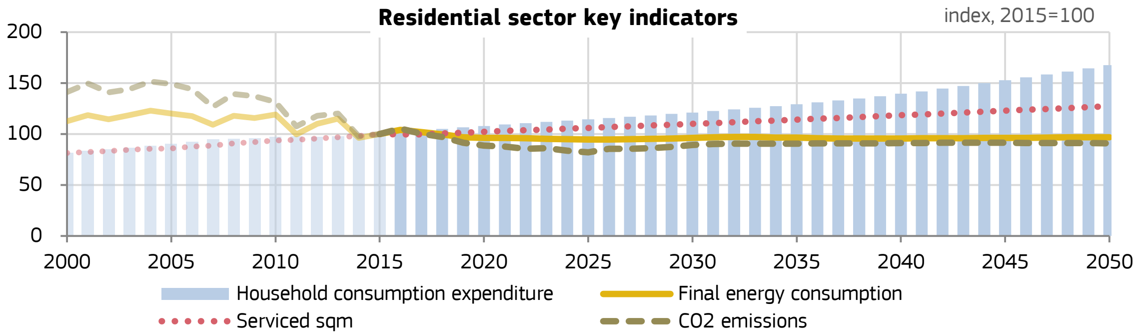
-2 Mtoe by 2030 from 2015 levels

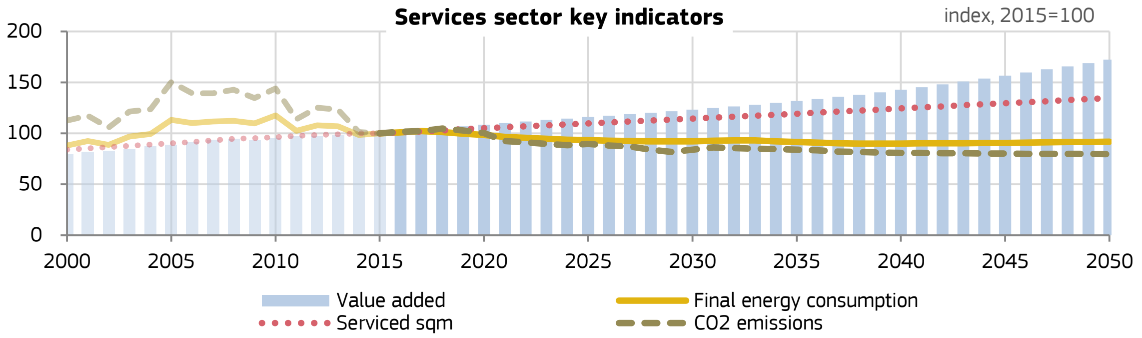


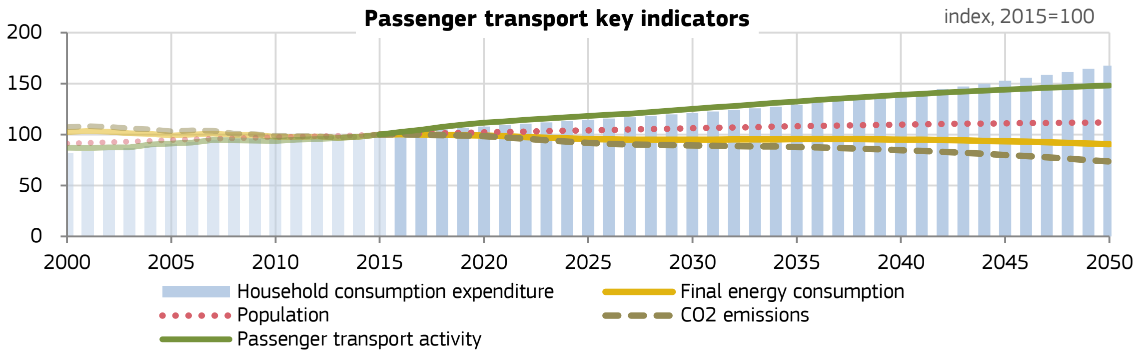
+2 Mtoe by 2050 from 2015 levels

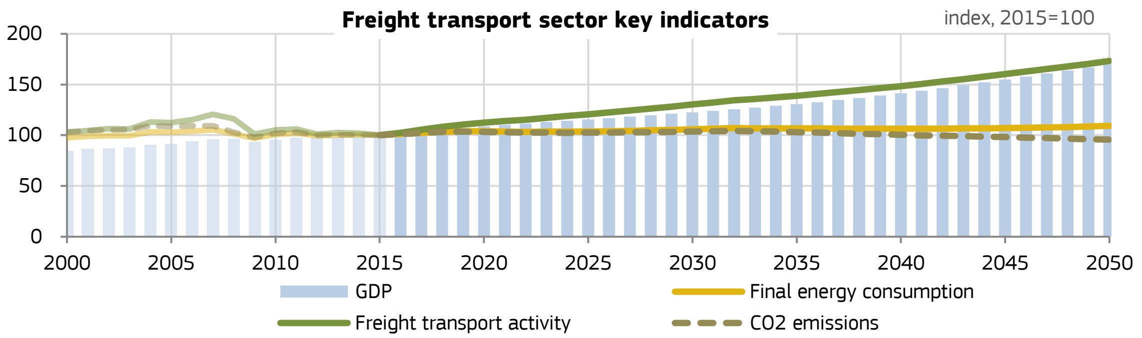


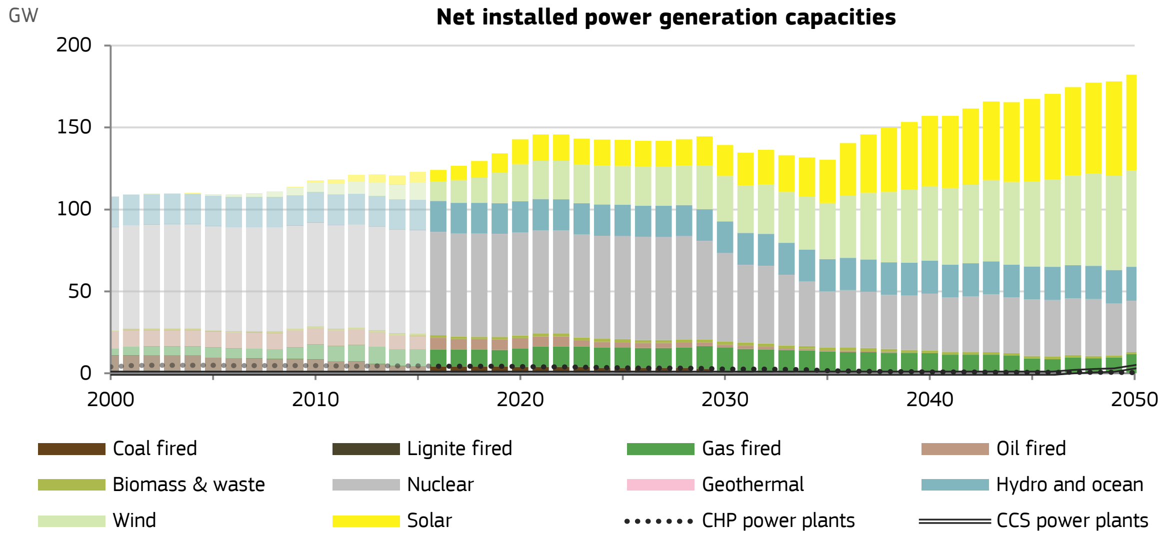

Industry key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

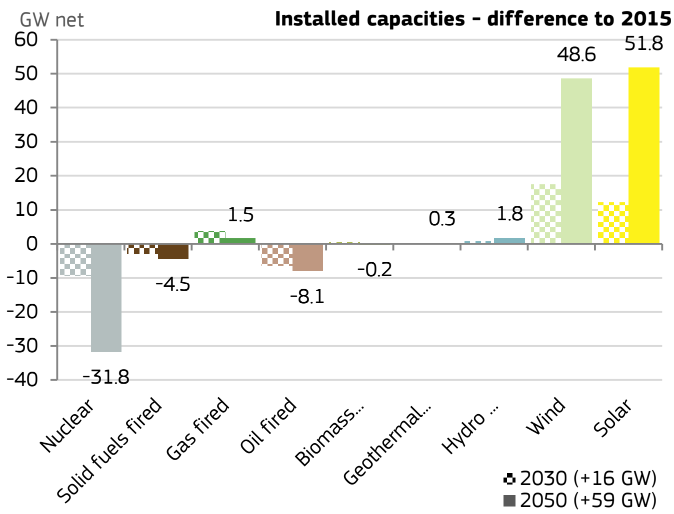

Residential sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

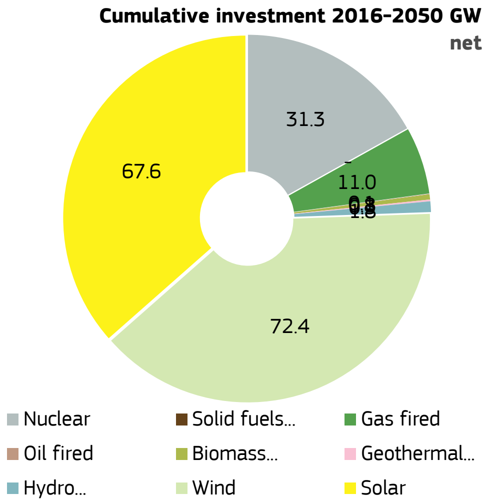

Services sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

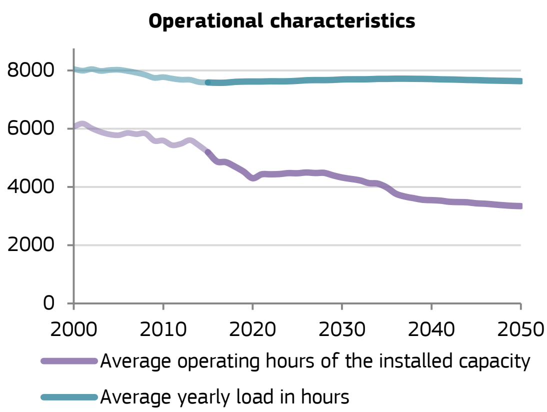

Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

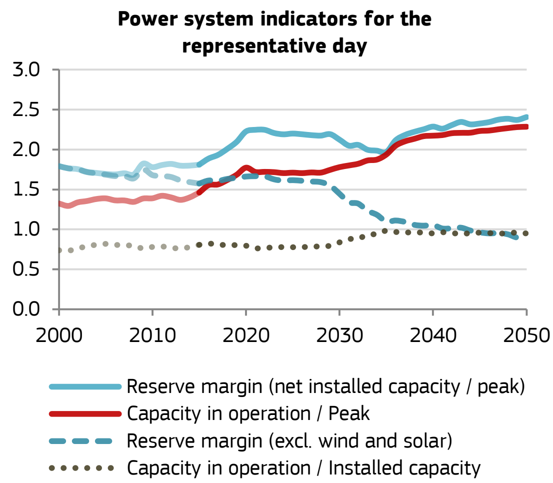

Freight transport sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

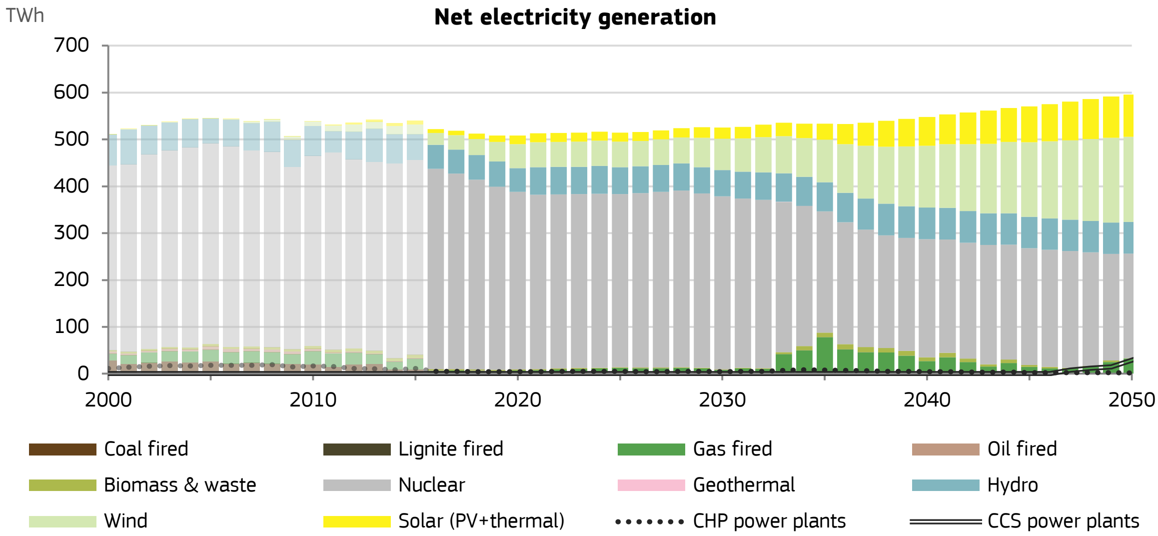

Net installed power generation capacities
GW
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

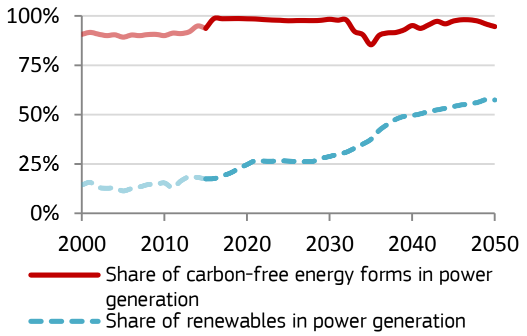

Installed capacities - difference to 2015
GW net
60
50
40
30
20
10
0
-10
-20
-30
-40
-31.8
-4.5
1.5
-8.1
-0.2
0.3
1.8
48.6
51.8
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+16 GW)
2050 (+59 GW)

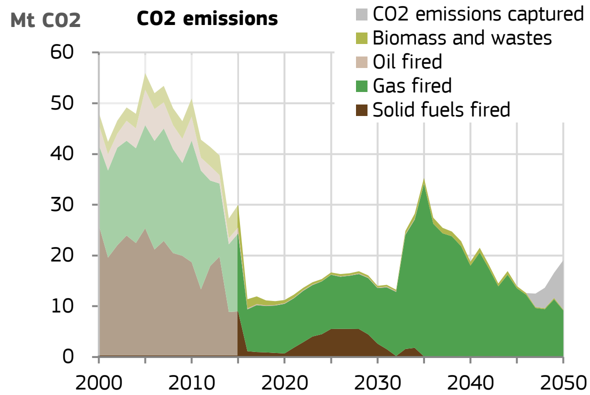

Cumulative investment 2016-2050 GW net
31.3
11.0
67.6
72.4
1.8
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

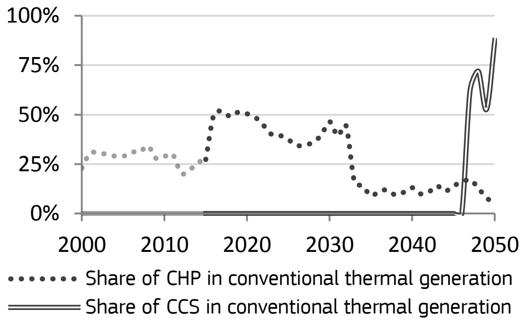

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

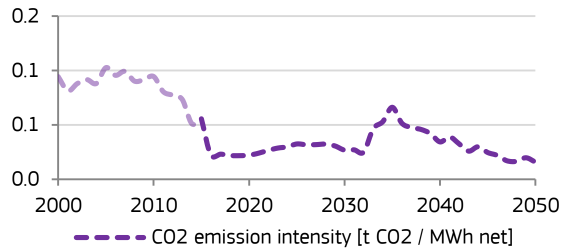

Power system indicators for the representative day
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

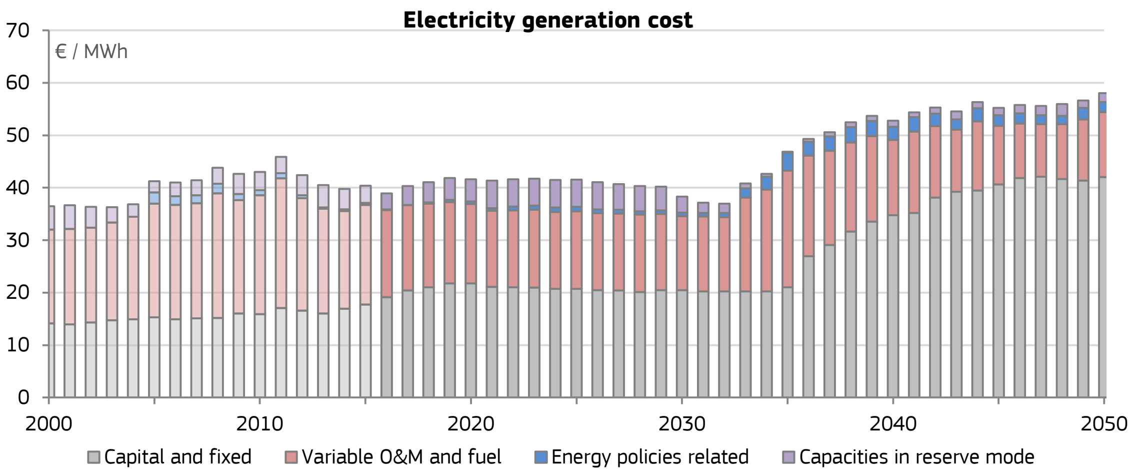

Net electricity generation
TWh
700
600
500
400
300
200
100
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

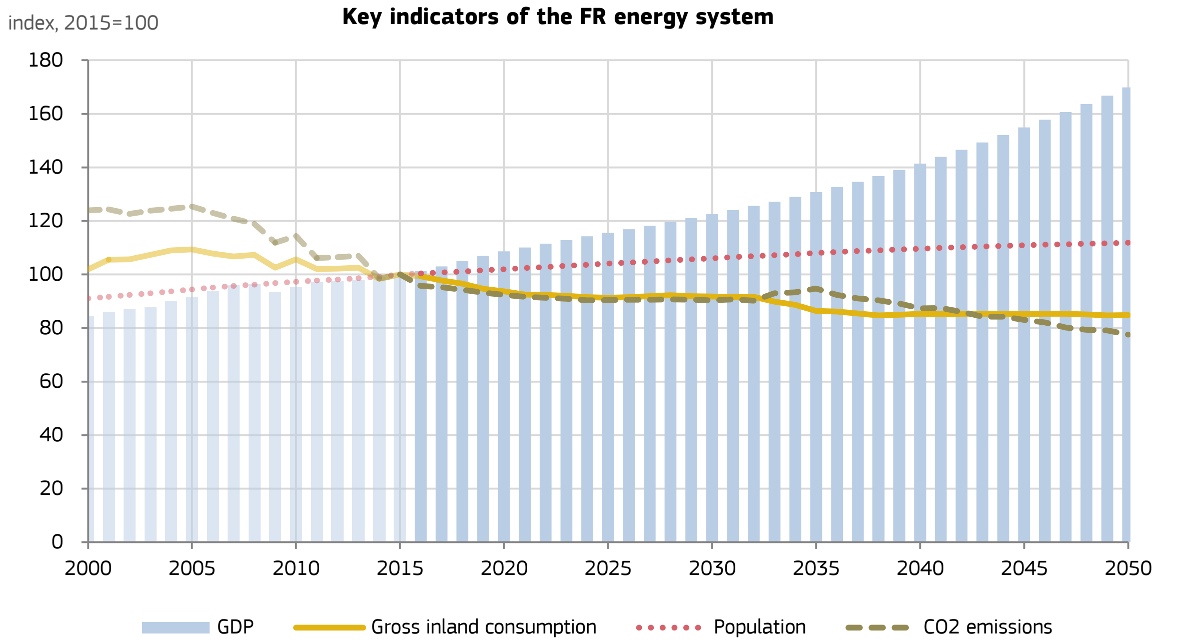

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050

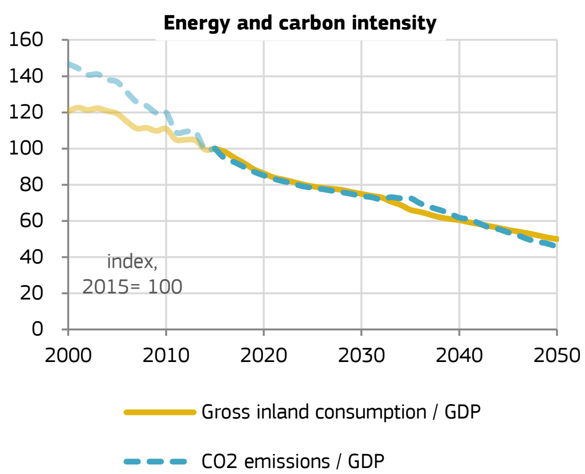

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

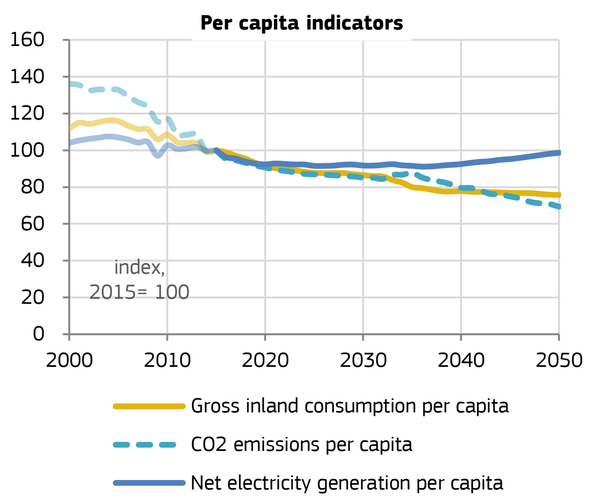

0.2
0.1
0.1
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	136	161	144	142	142	147
Primary energy consumption [Mtoe]	214	260	239	224	219	200
RES [%] - Share of energy from renewable sources		9.7%	15.0%	18.0%	20.1%	35.4%
RES-E [%] - Share of electricity from renewable sources		13.7%	18.8%	26.2%	29.1%	60.0%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	405	433	345	319	312	268
reduction to 1990		*7%*	*-15%*	*-21%*	*-23%*	*-34%*
Emissions in current ETS sectors |(FR) [Mt CO2]		157	120	101	109	85
reduction to 2005			*-24%*	*-36%*	*-31%*	*-46%*
Emissions in current ESD sectors [Mt CO2]		275	225	218	203	183
reduction to 2005			*-18%*	*-21%*	*-26%*	*-34%*

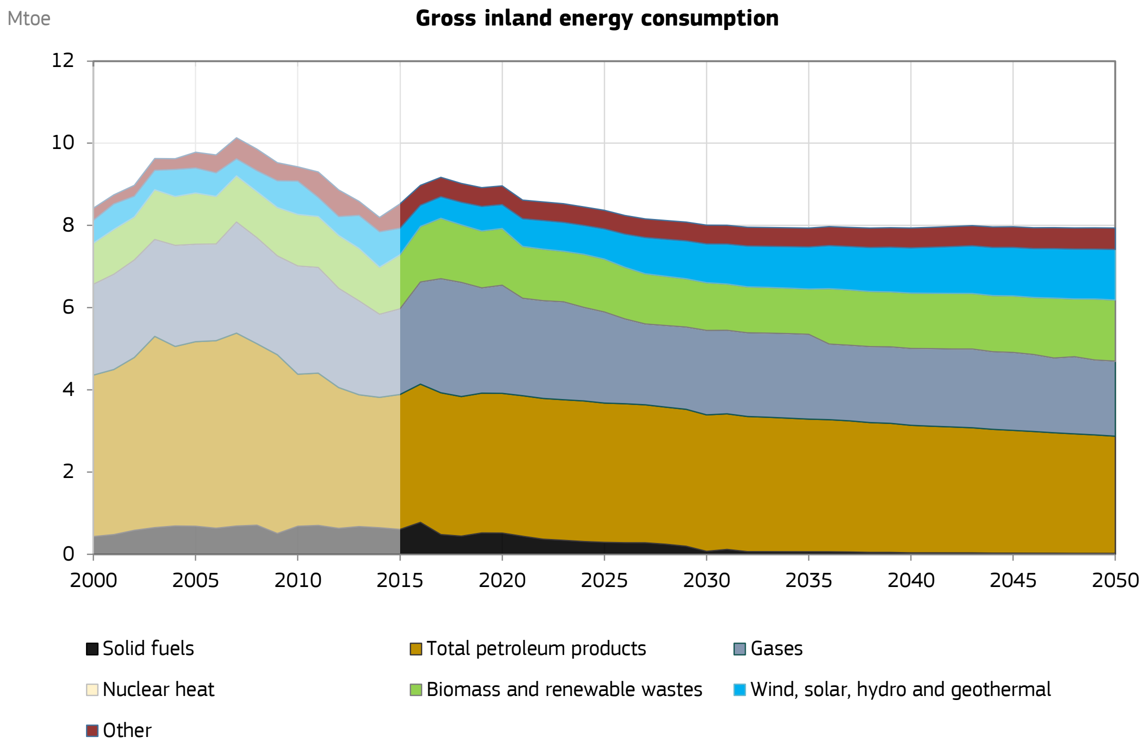




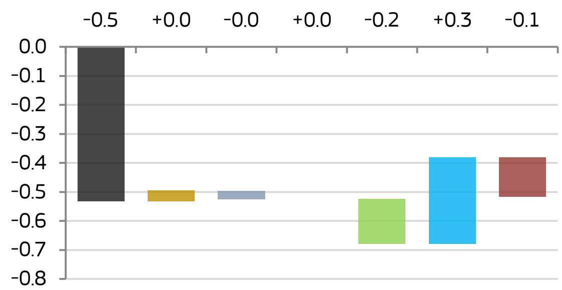
Croatia

Central_2018 scenario

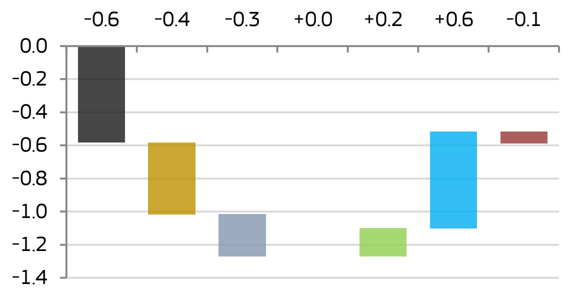
Gross inland energy consumption



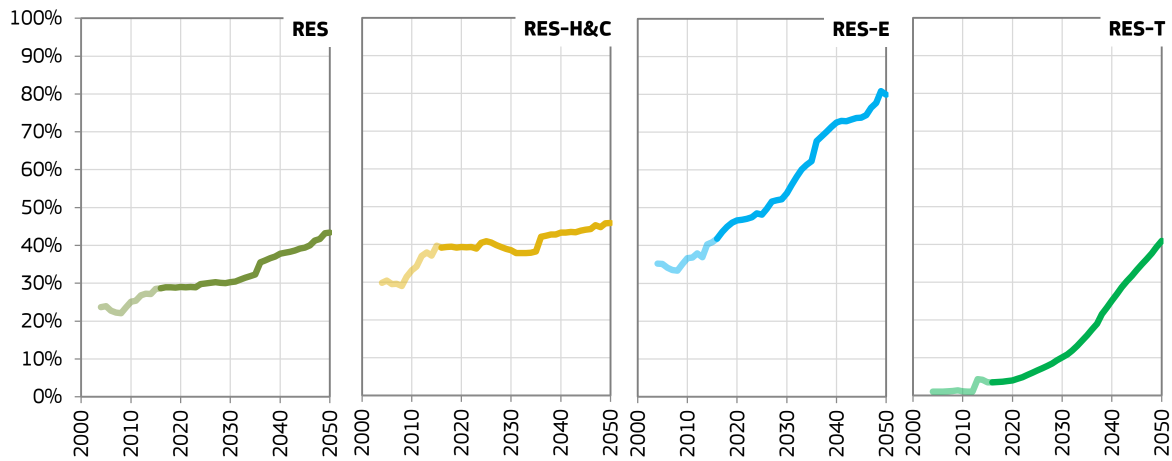
-0.5 Mtoe by 2030 from 2015 levels

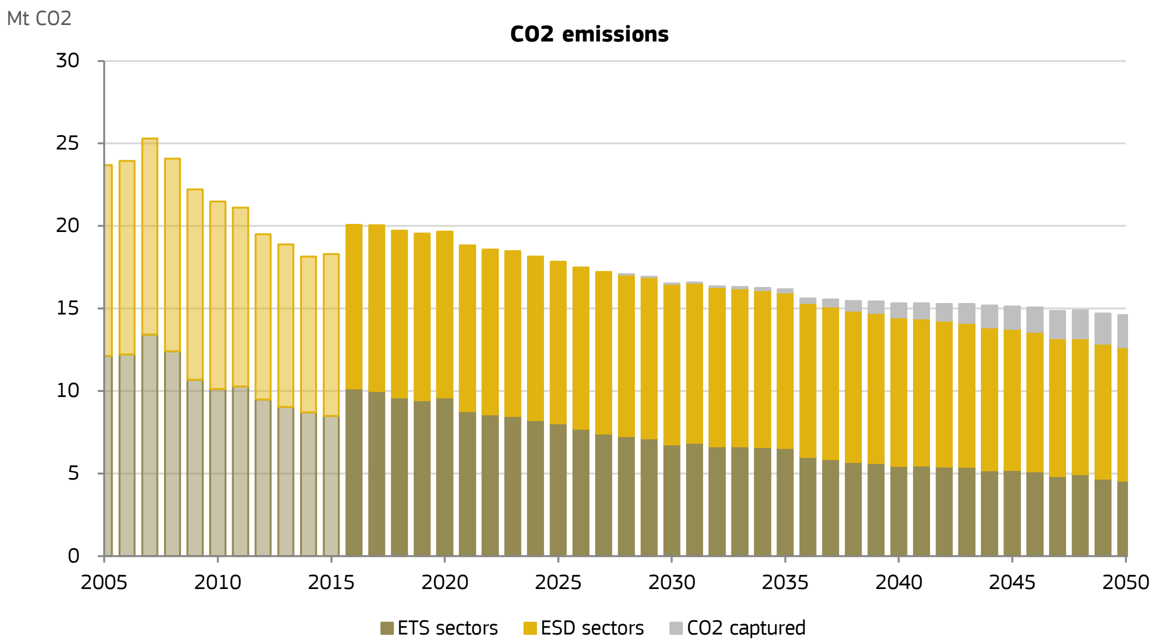


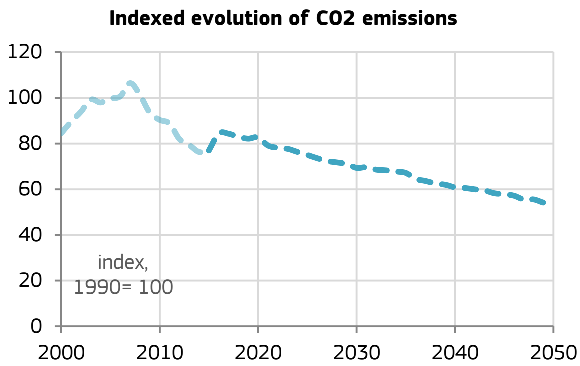
-0.6 Mtoe by 2050 from 2015 levels

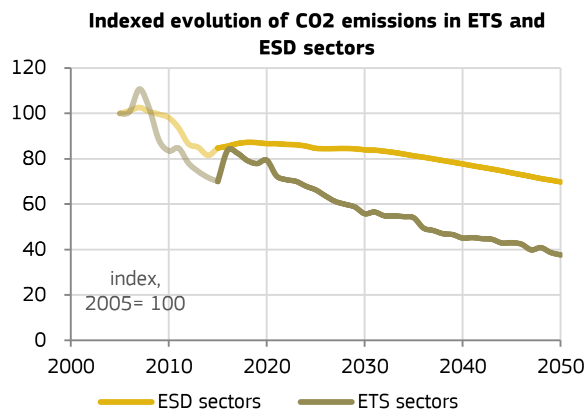


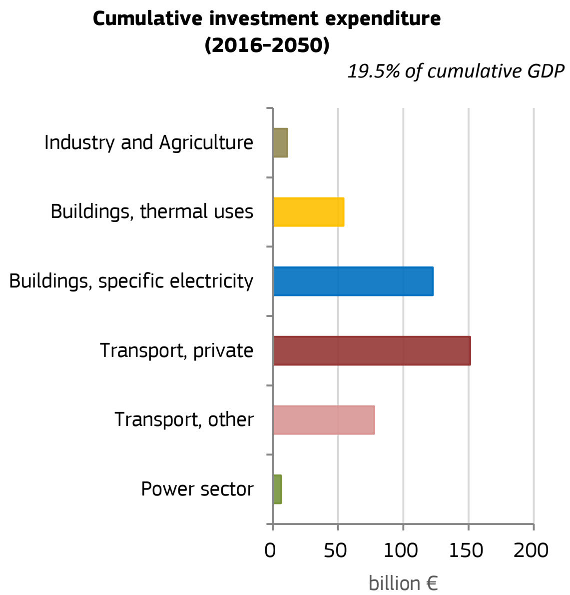
Share of renewable energies

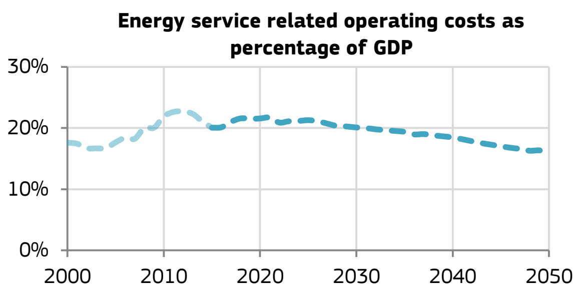


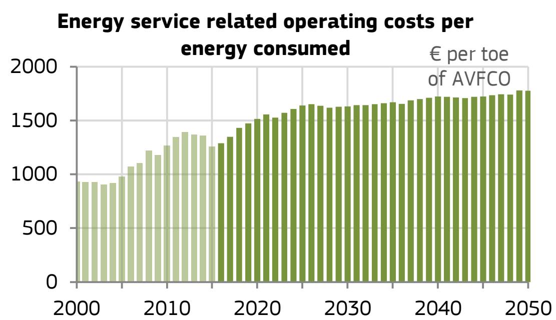

Mt CO2
CO2 emissions
30
25
20
15
10
5
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured

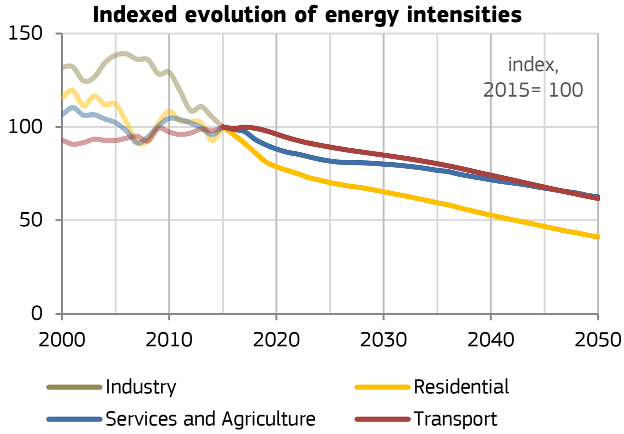

Indexed evolution of CO2 emissions
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

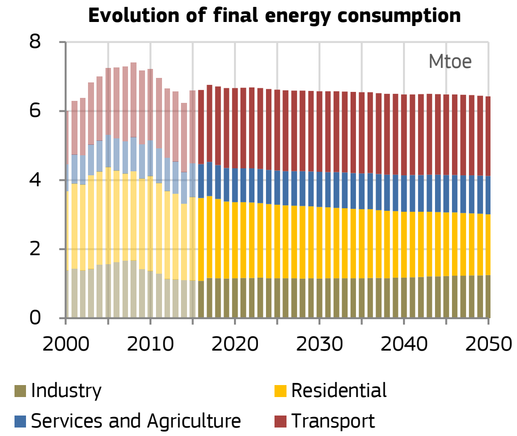

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors

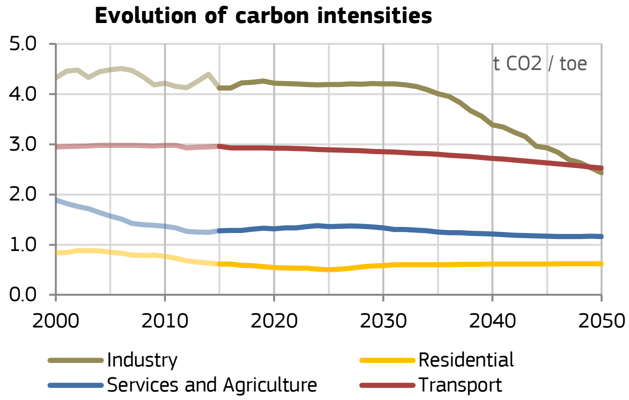

Cumulative investment expenditure (2016-2050)
19.5% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
50
100
150
200
billion €

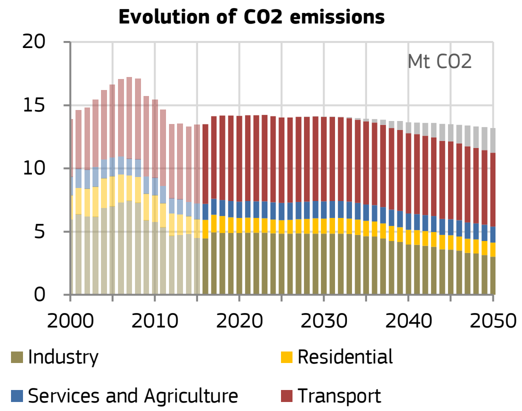

Energy service related operating costs as percentage of GDP
30%
20%
10%
0%
2000
2010
2020
2030
2040
2050

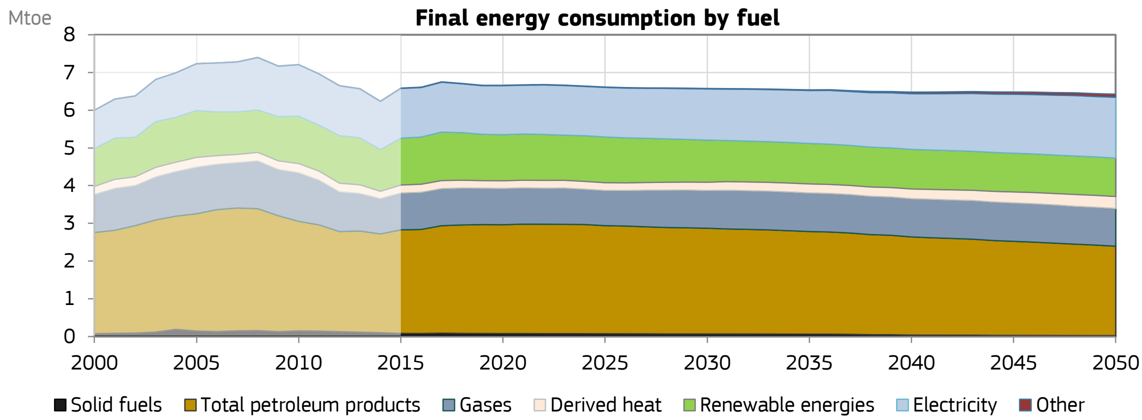

Energy service related operating costs per energy consumed
€ per toe
of AVFCO
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

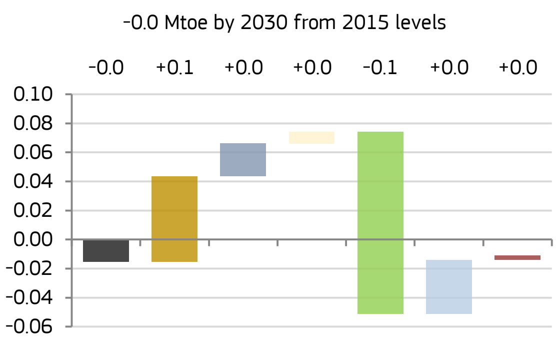

Indexed evolution of energy intensities
index, 2015= 100
150
100
50
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

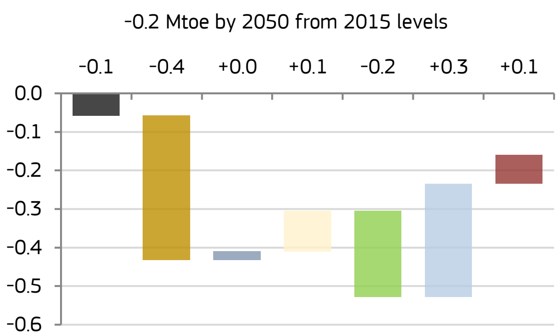

Evolution of final energy consumption
Mtoe
8
6
4
2
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

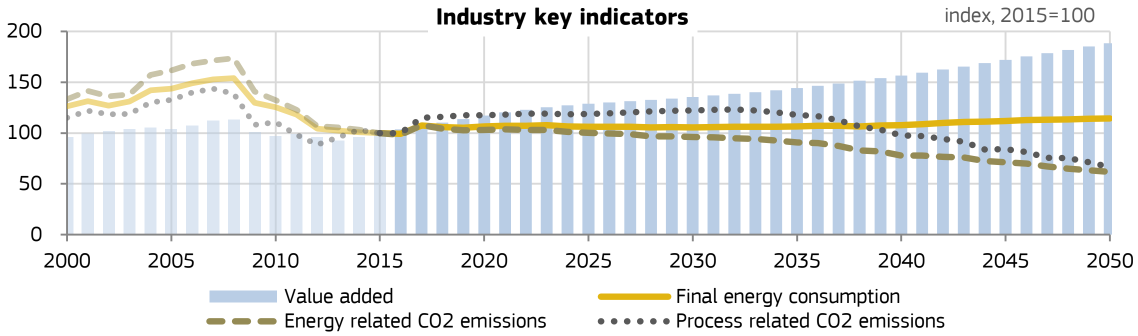

Evolution of carbon intensities
t CO2 / toe
5.0
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

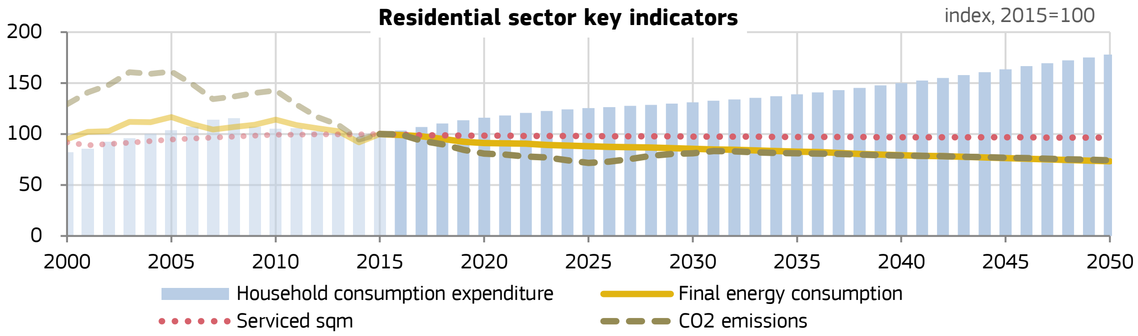

Evolution of CO2 emissions
Mt CO2
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

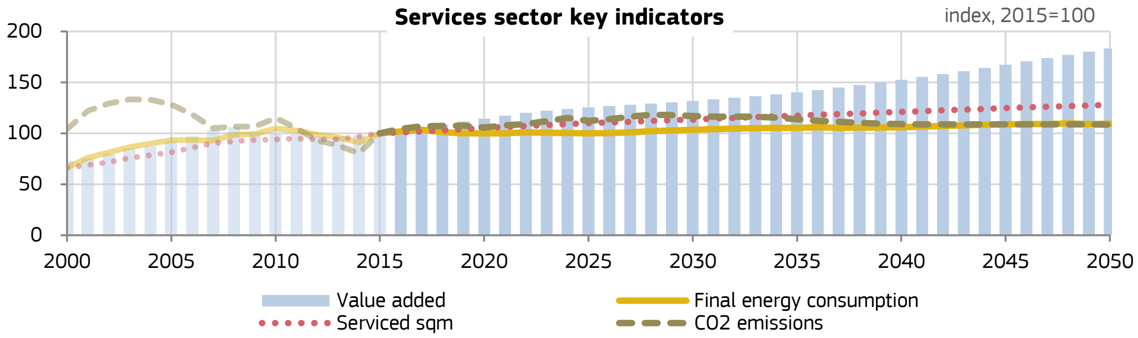

Mtoe
Final energy consumption by fuel
8
7
6
5
4
3
2
1
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

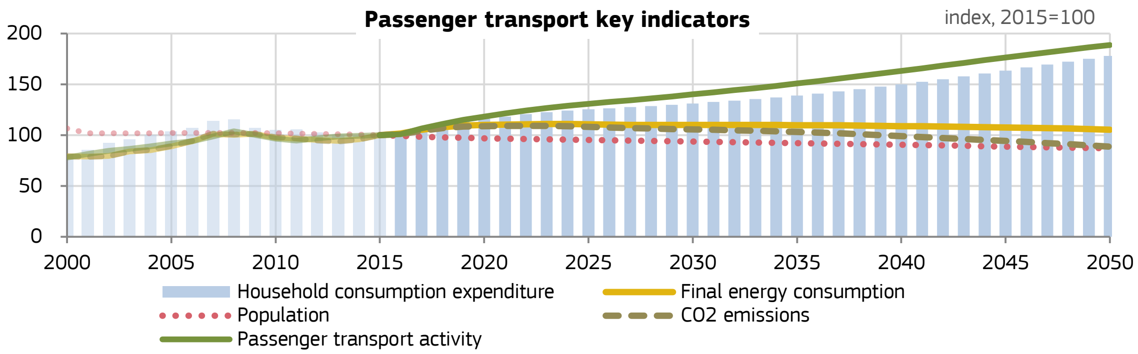

-0.0 Mtoe by 2030 from 2015 levels
-0.0
+0.1
+0.0
+0.0
-0.1
+0.0
+0.0
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06

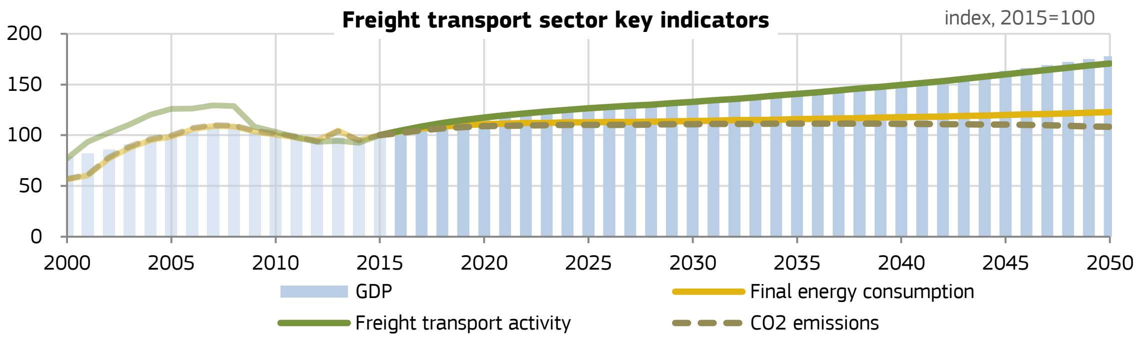

-0.2 Mtoe by 2050 from 2015 levels
-0.1
-0.4
+0.0
+0.1
-0.2
+0.3
+0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6


Industry key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

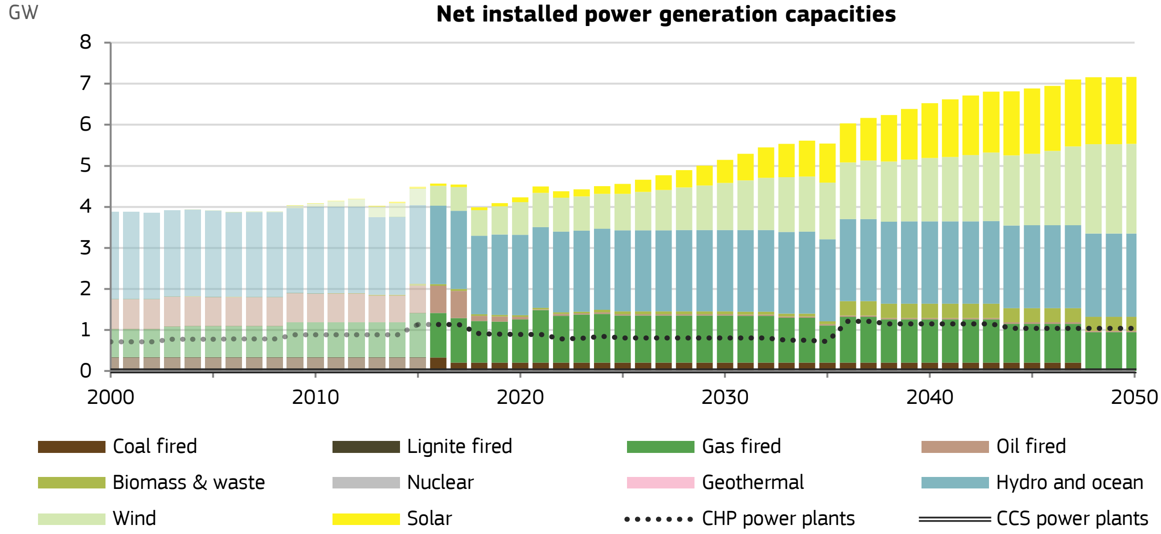

Residential sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions


Services sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

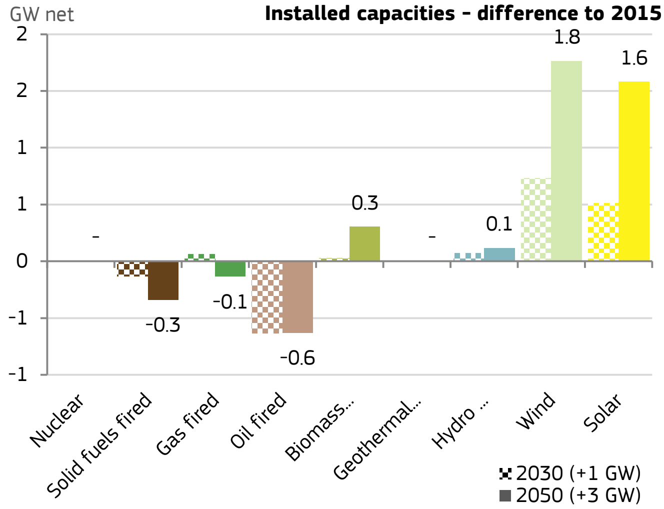

Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity


Freight transport sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

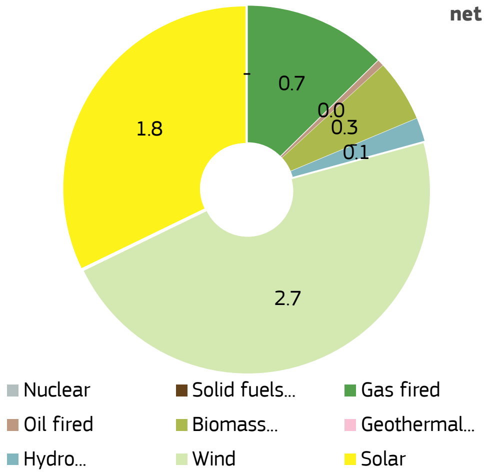
Net installed power generation capacities



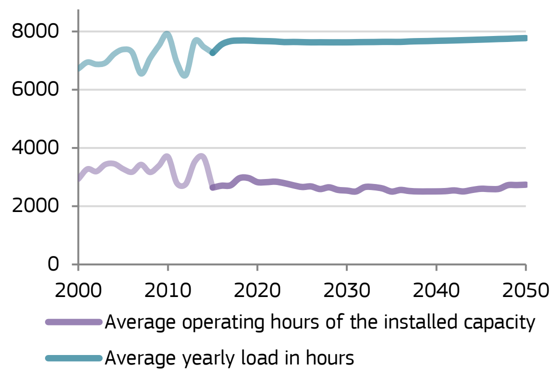
Installed capacities - difference to 2015



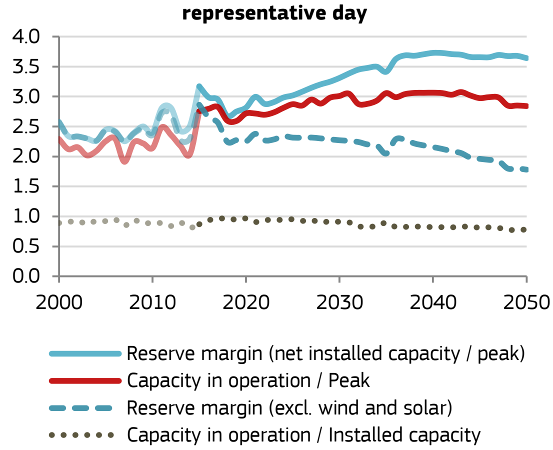
Cumulative investment 2016-2050 GW net

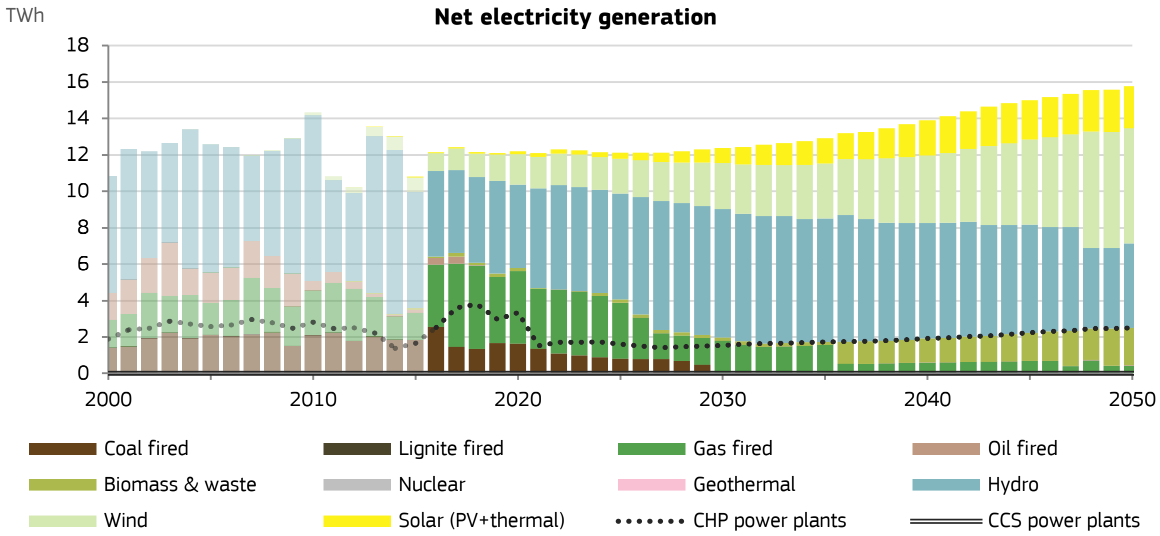


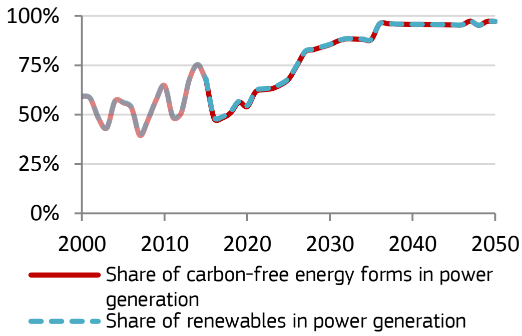
Operational characteristics

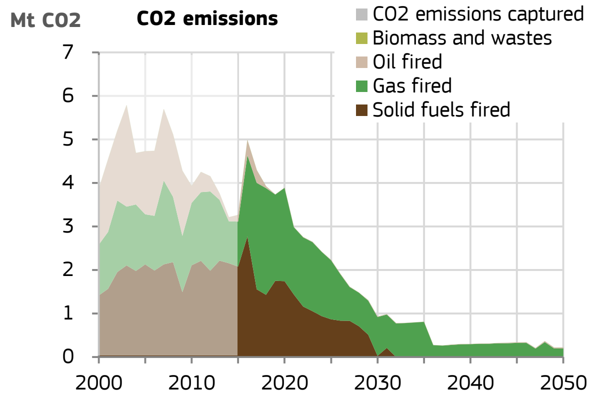


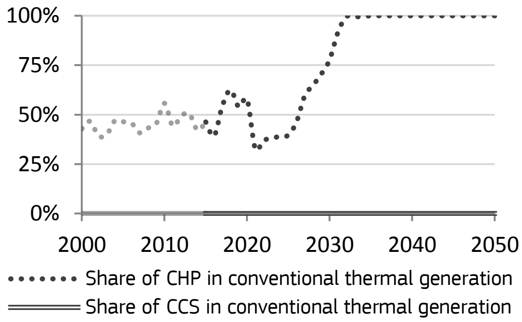
Power system indicators for the representative day

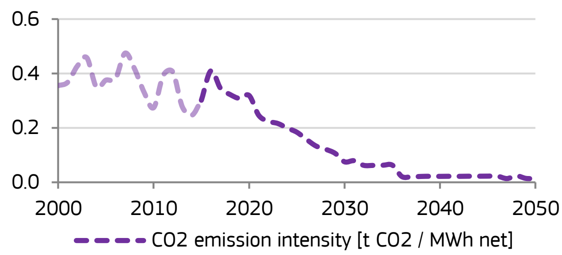


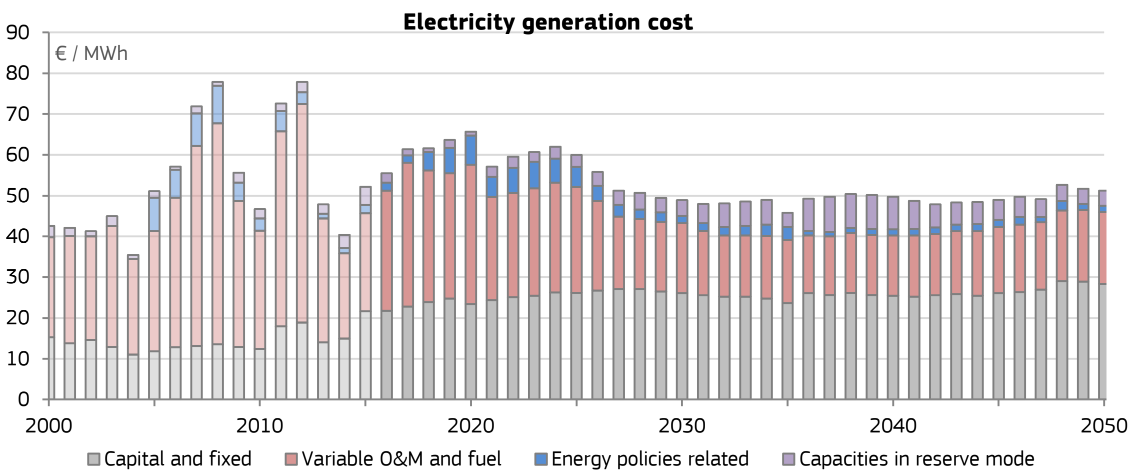

Net electricity generation
TWh
18
16
14
12
10
8
6
4
2
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

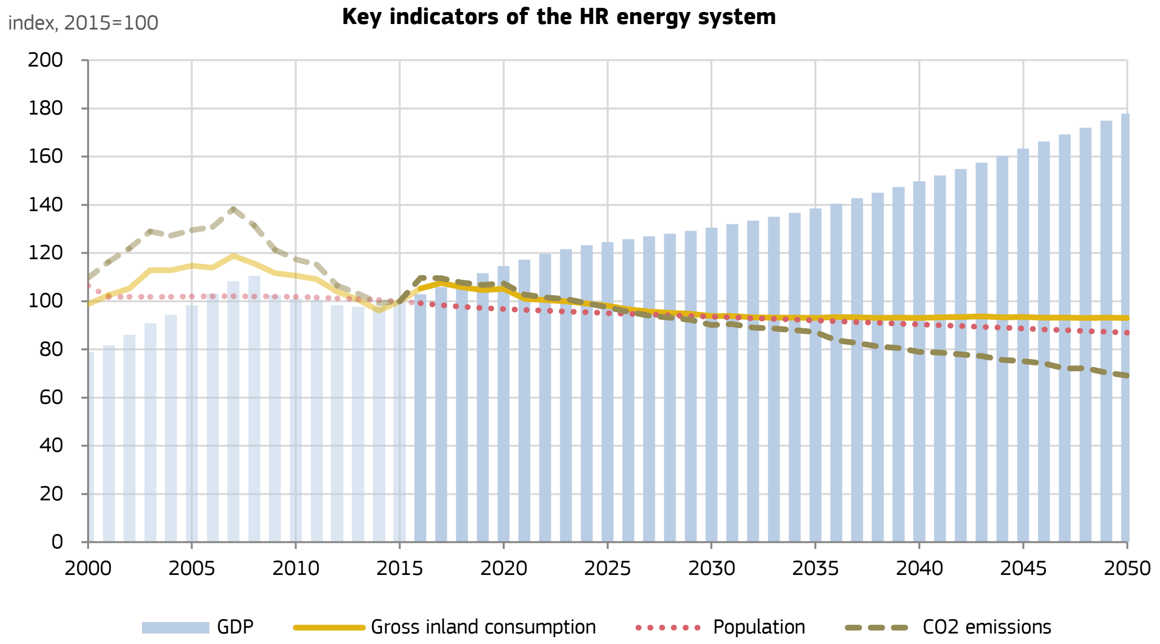

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
7
6
5
4
3
2
1
0
2000
2010
2020
2030
2040
2050

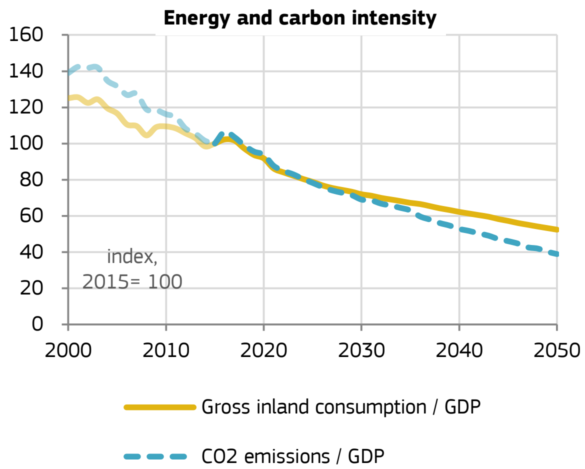

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

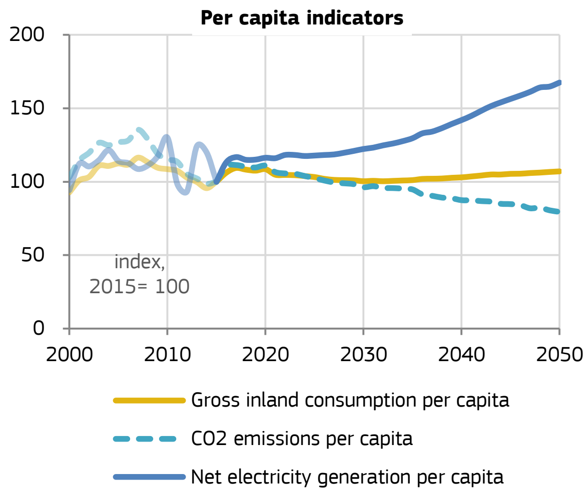

0.6
0.4
0.2
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
90
80
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	6.5	7.2	6.6	6.7	6.6	6.4
Primary energy consumption [Mtoe]	8.8	9.1	8.0	8.3	7.4	7.2
RES [%] - Share of energy from renewable sources		23.9%	28.5%	29.0%	30.3%	43.4%
RES-E [%] - Share of electricity from renewable sources		35.2%	40.9%	46.6%	53.9%	79.9%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	23.8	23.7	18.3	19.7	16.5	12.6
reduction to 1990		*0%*	*-23%*	*-17%*	*-31%*	*-47%*
Emissions in current ETS sectors |(HR) [Mt CO2]		12.1	8.5	9.6	6.8	4.6
reduction to 2005			*-30%*	*-21%*	*-44%*	*-62%*
Emissions in current ESD sectors [Mt CO2]		11.6	9.8	10.0	9.7	8.1
reduction to 2005			*-15%*	*-13%*	*-16%*	*-30%*

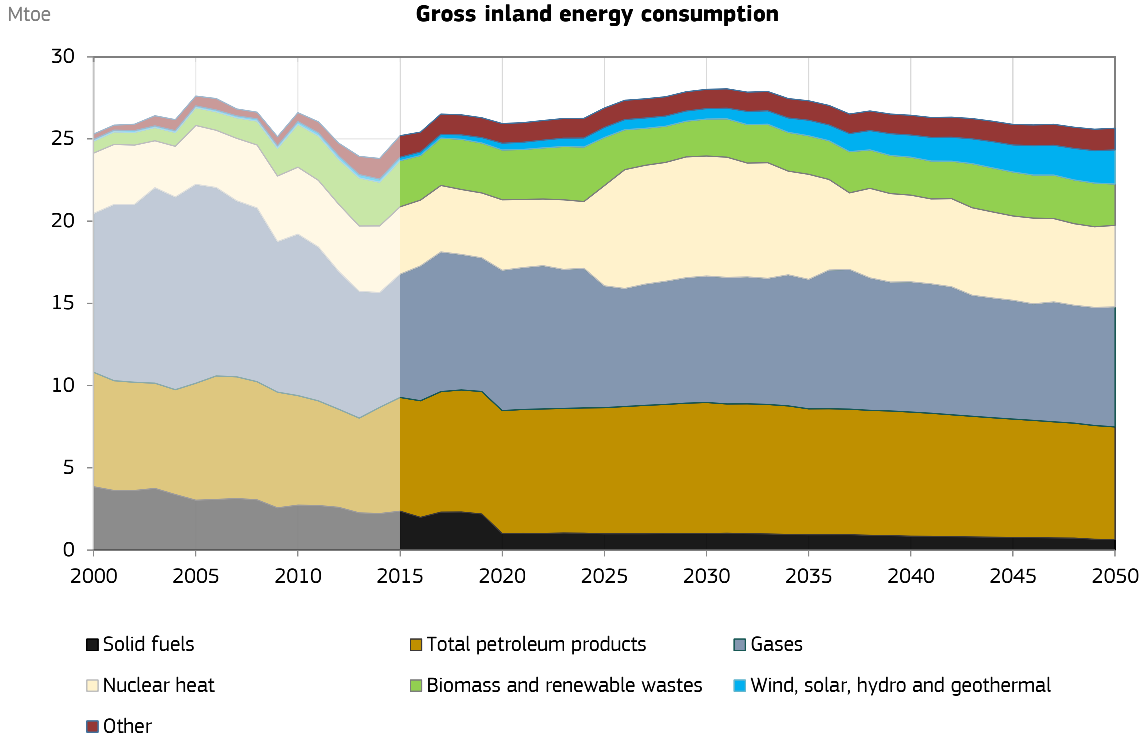




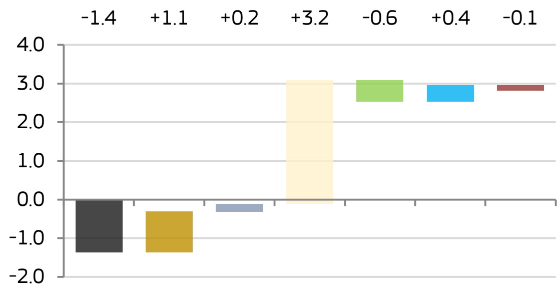
Hungary

Central_2018 scenario

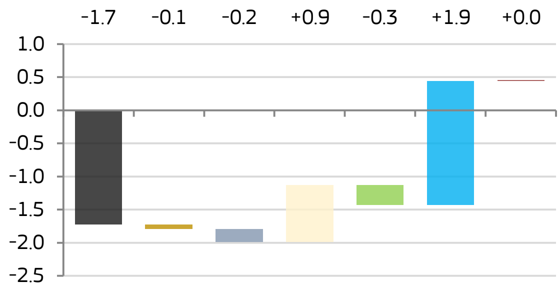
Gross inland energy consumption



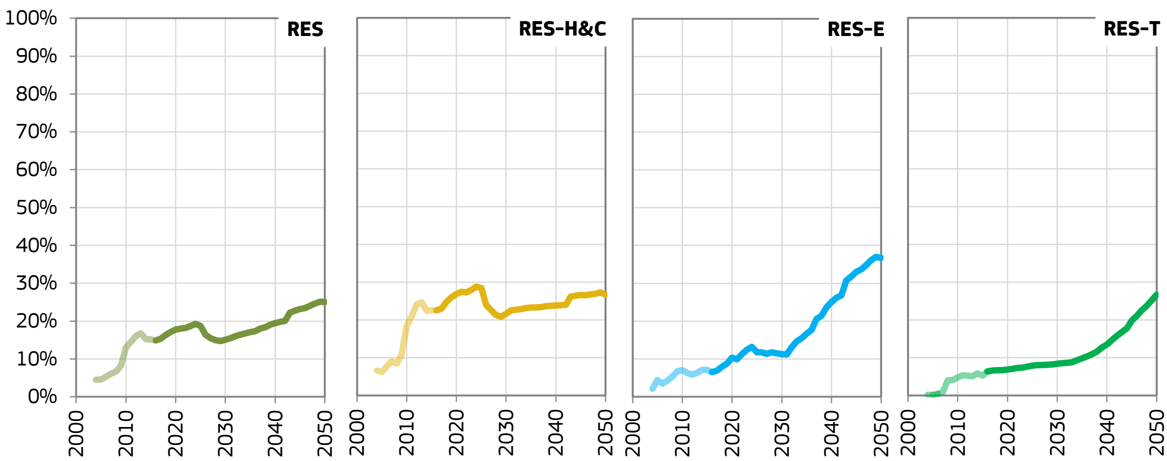
+2.8 Mtoe by 2030 from 2015 levels

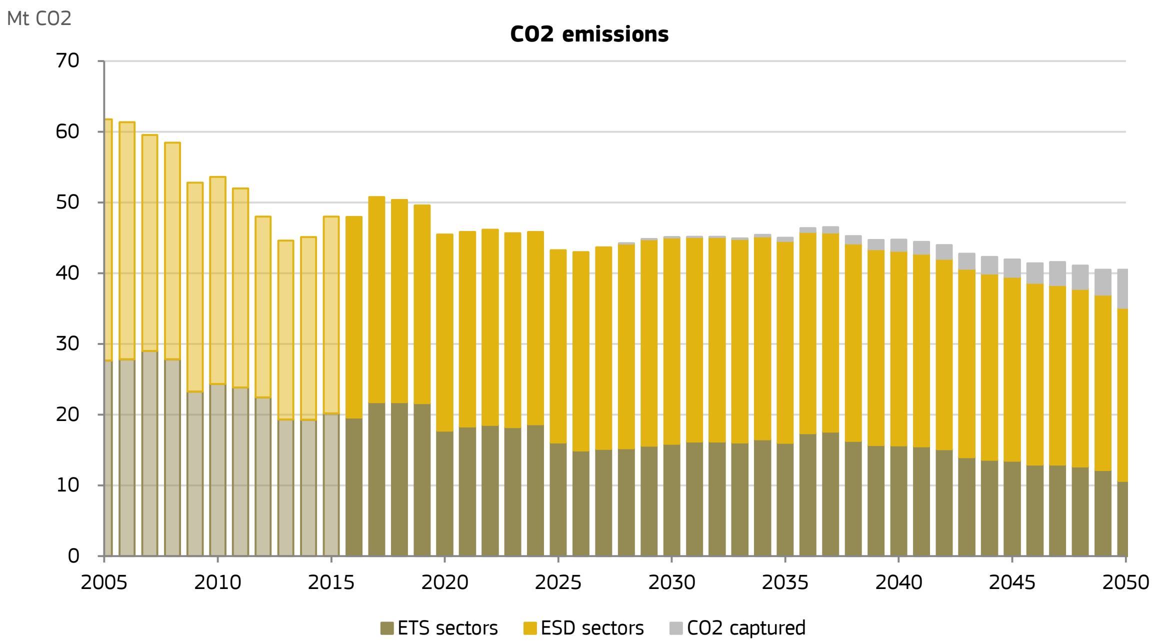


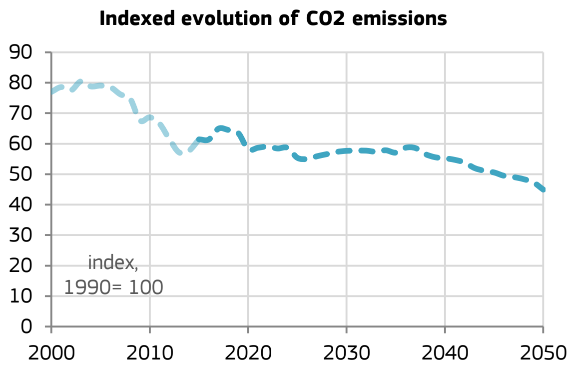
+0.5 Mtoe by 2050 from 2015 levels

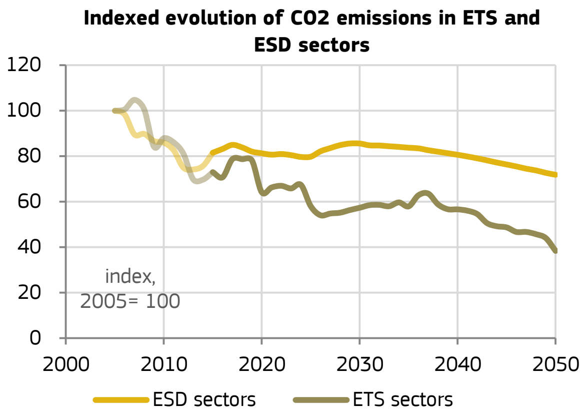


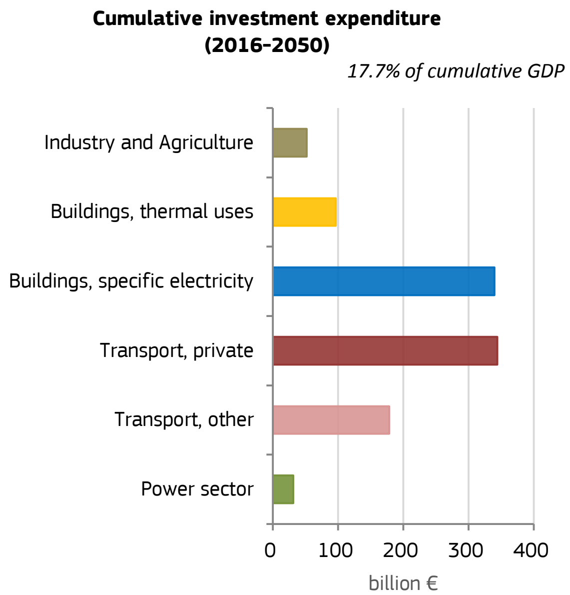
Share of renewable energies

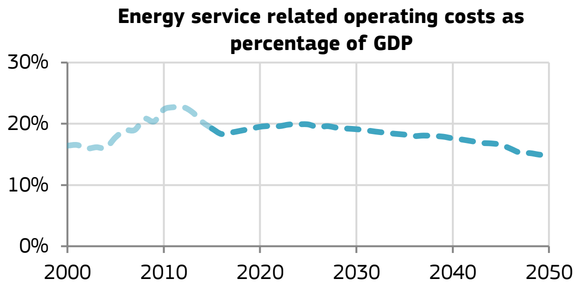


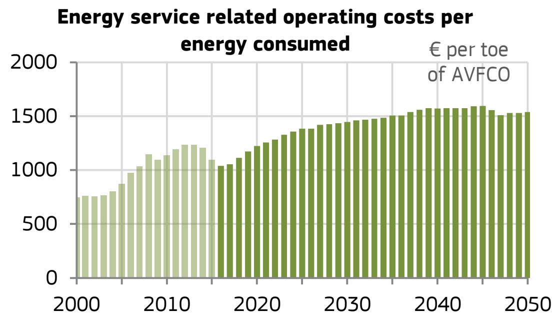

Mt CO2
CO2 emissions
70
60
50
40
30
20
10
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured


Indexed evolution of CO2 emissions
90
80
70
60
50
40
30
20
10
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

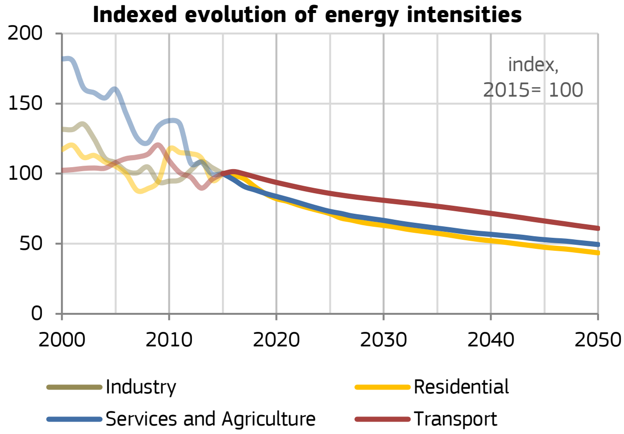

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors


Cumulative investment expenditure (2016-2050)
17.7% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
100
200
300
400
billion €

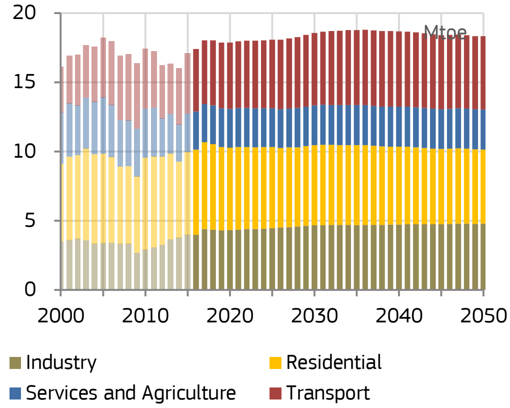

Energy service related operating costs as percentage of GDP
30%
20%
10%
0%
2000
2010
2020
2030
2040
2050


Energy service related operating costs per energy consumed
€ per toe of AVFCO
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

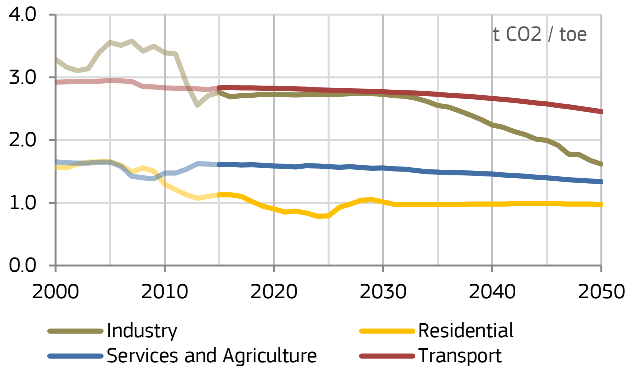
Indexed evolution of energy intensities



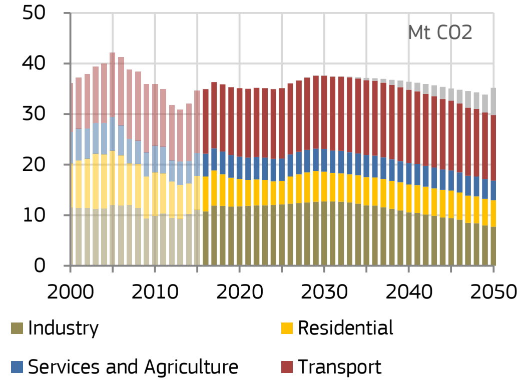
Evolution of final energy consumption



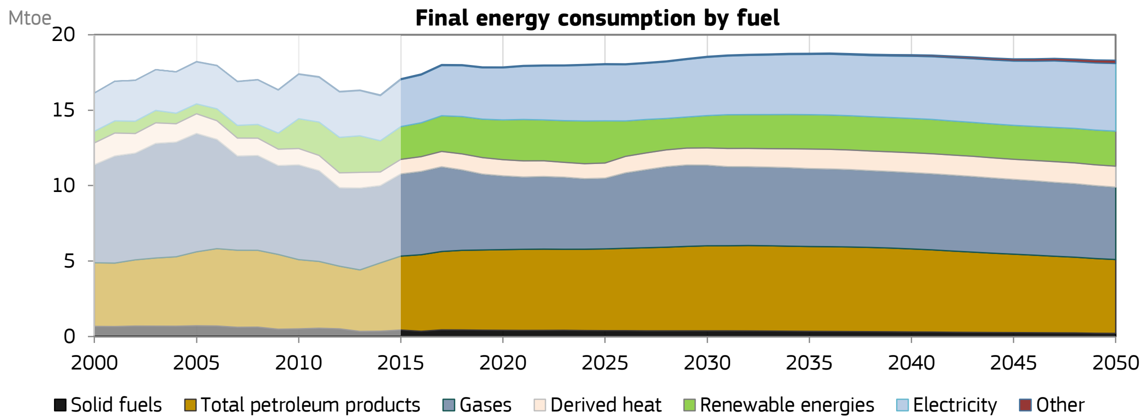
Evolution of carbon intensities



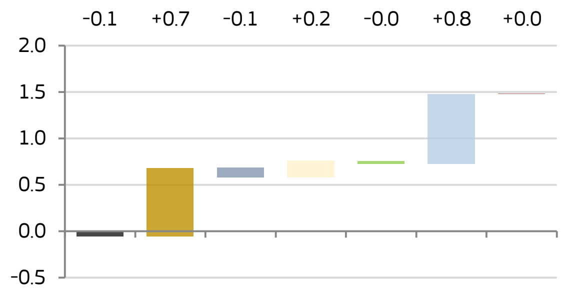
Evolution of CO2 emissions



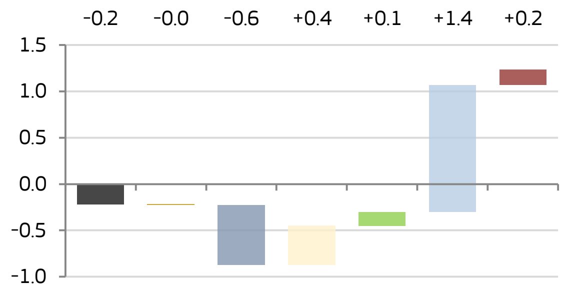
Final energy consumption by fuel

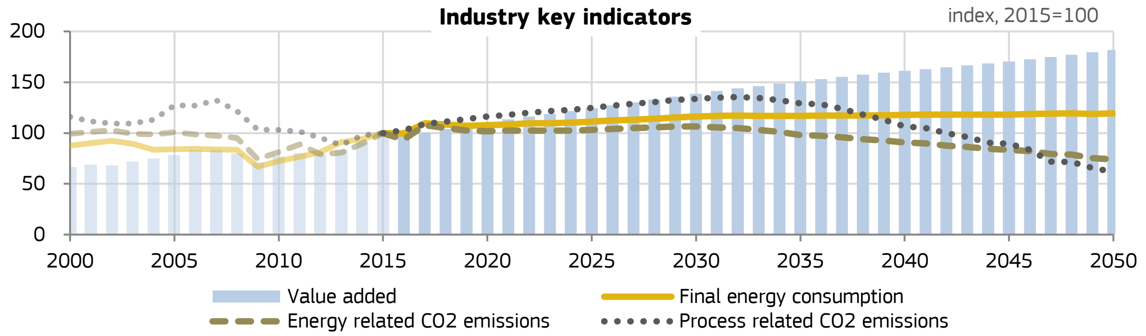


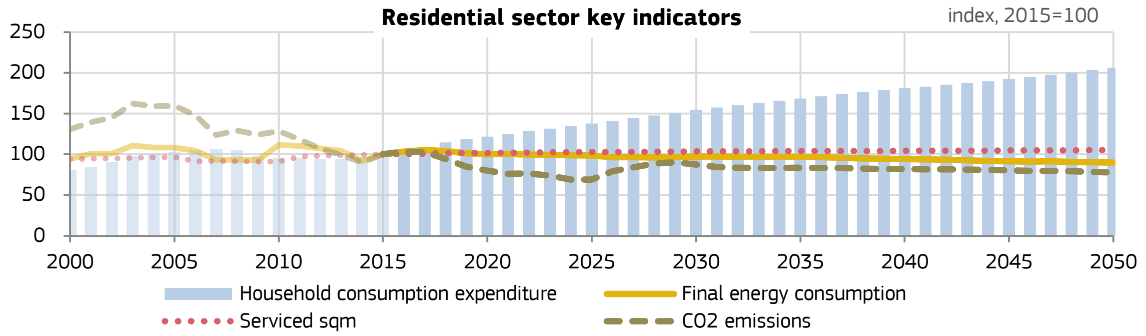
+1.5 Mtoe by 2030 from 2015 levels

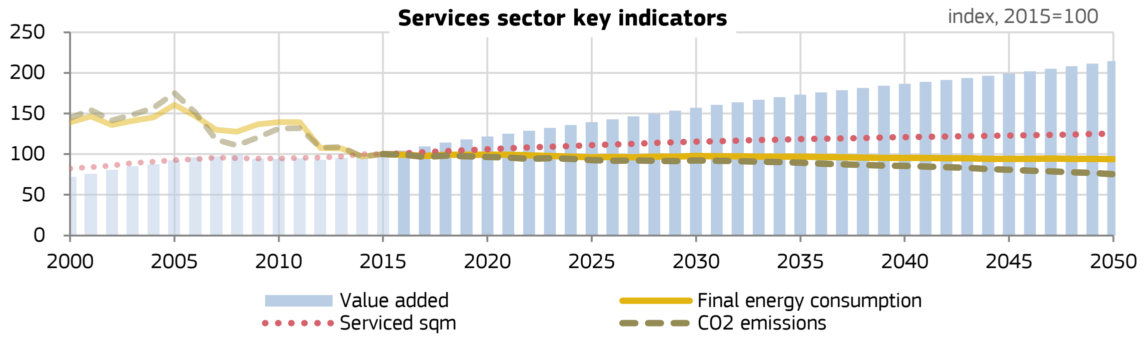


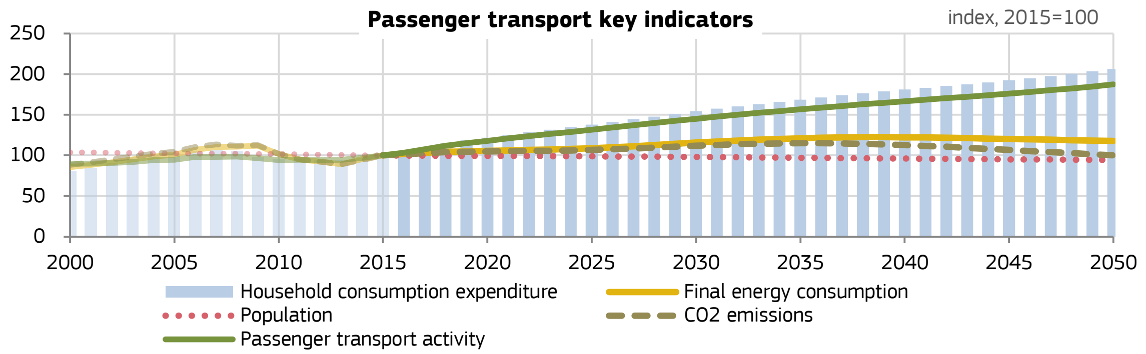
+1.2 Mtoe by 2050 from 2015 levels

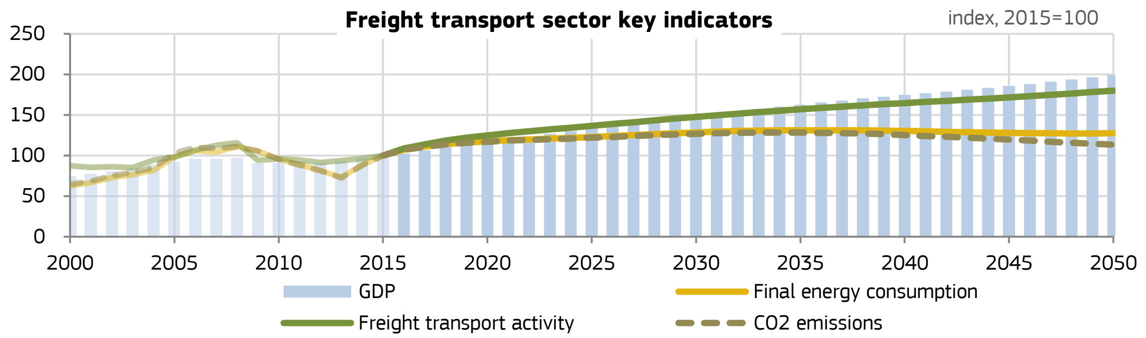


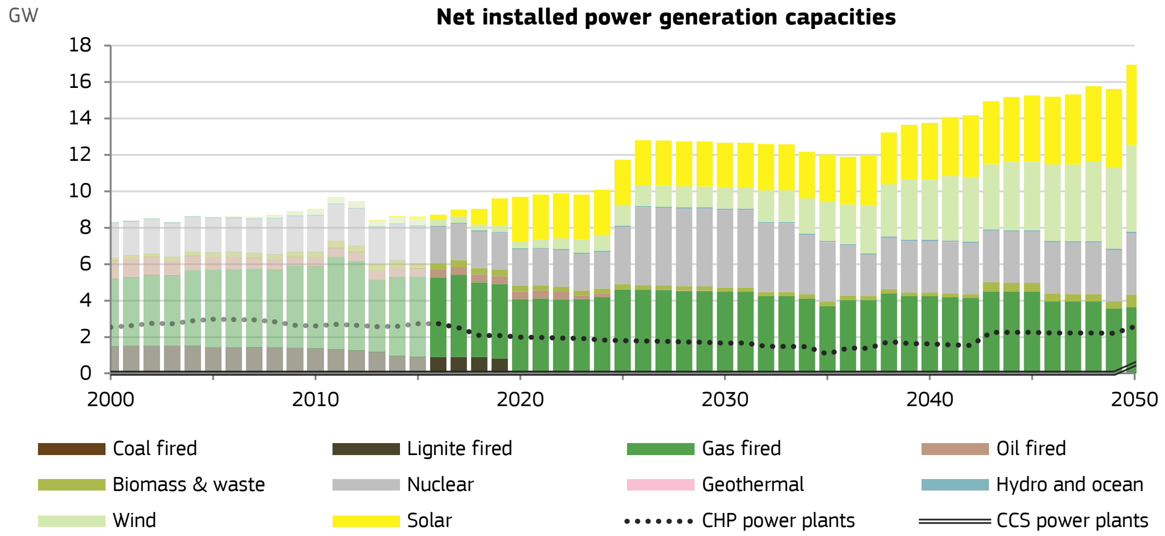

Industry key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

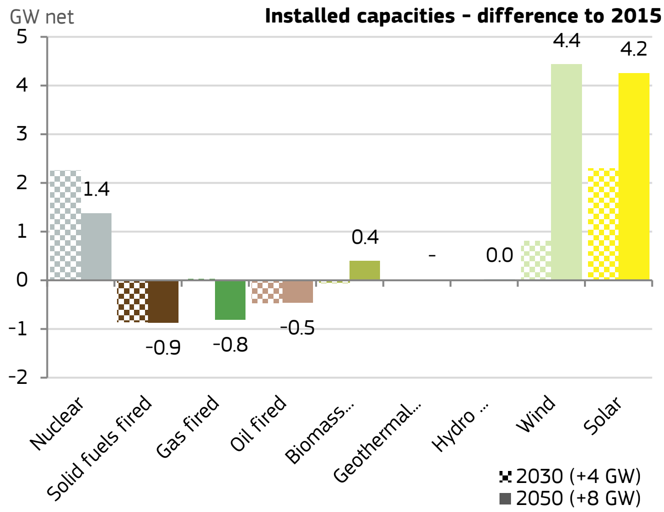

Residential sector key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

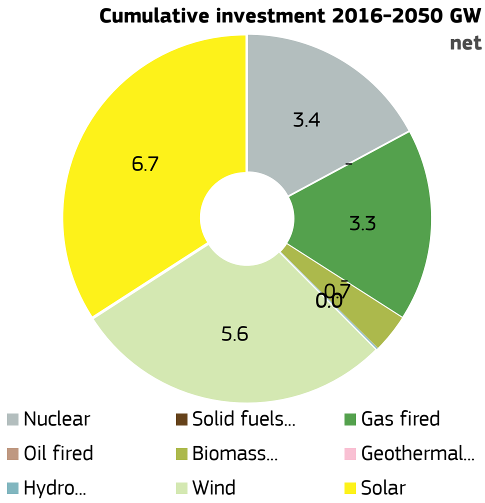

Services sector key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

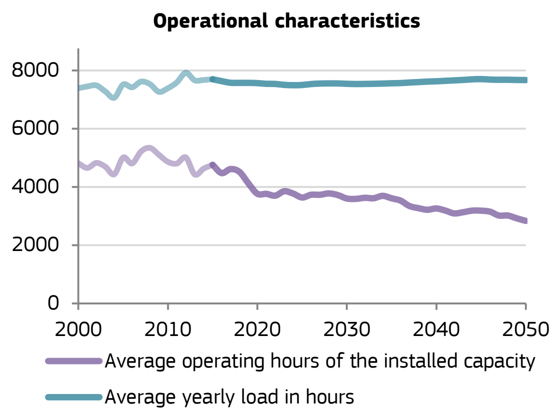

Passenger transport key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

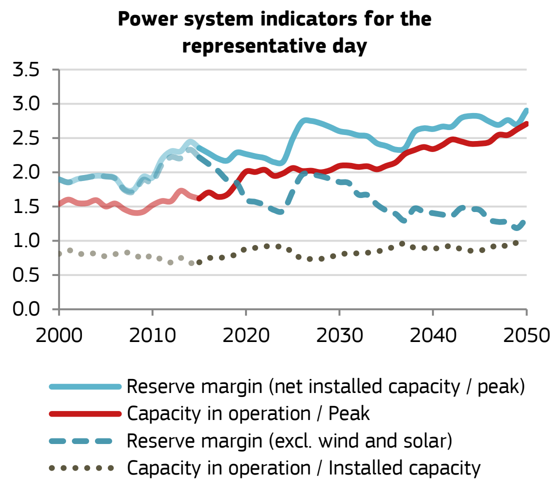

Freight transport sector key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

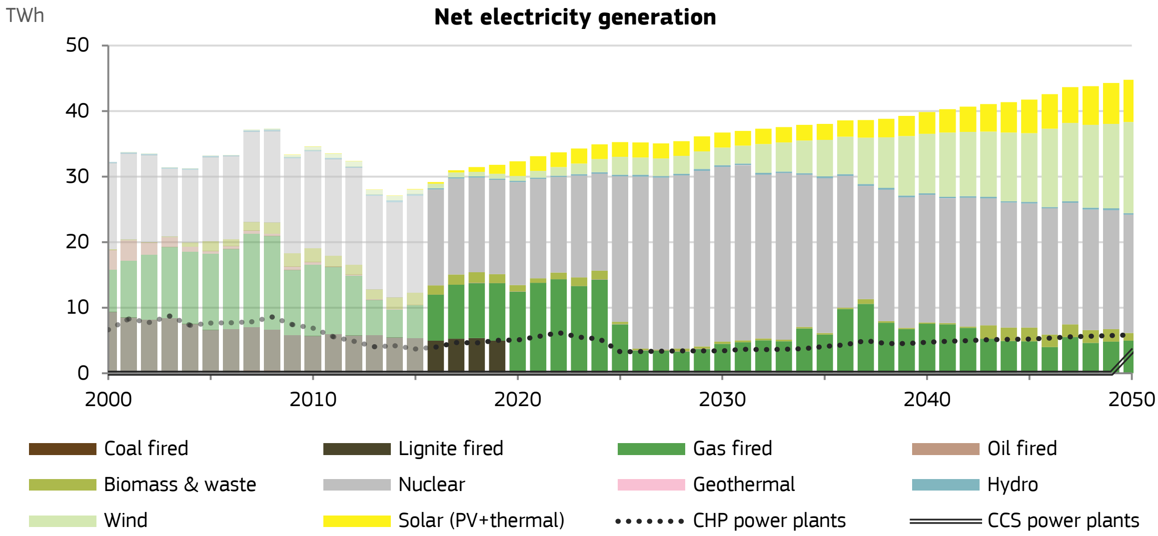

Net installed power generation capacities
GW
18
16
14
12
10
8
6
4
2
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

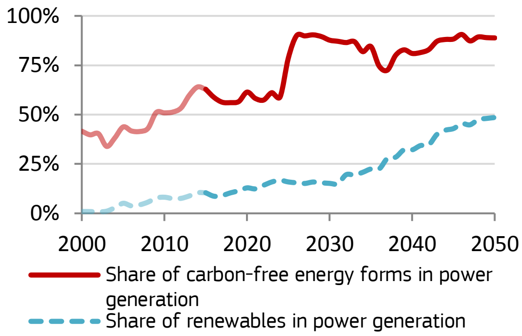

Installed capacities - difference to 2015
GW net
1.4
-0.9
-0.8
-0.5
0.4
-
0.0
4.4
4.2
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+4 GW)
2050 (+8 GW)

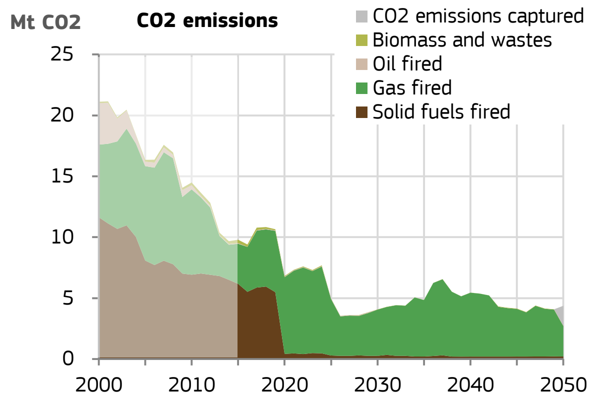

Cumulative investment 2016-2050 GW net
3.4
3.3
0.7
0.0
5.6
6.7
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

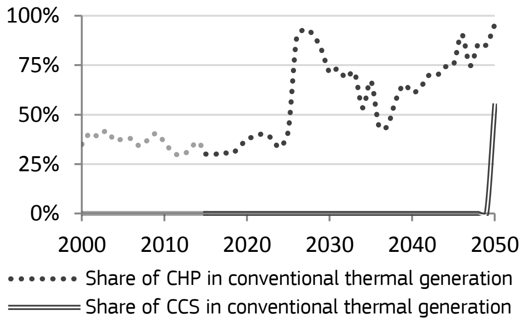

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

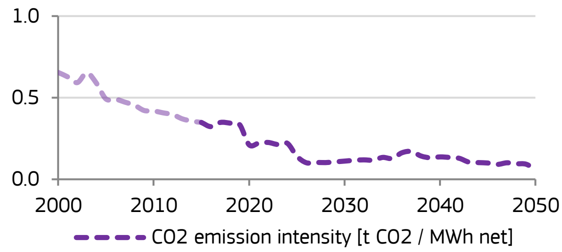

Power system indicators for the representative day
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

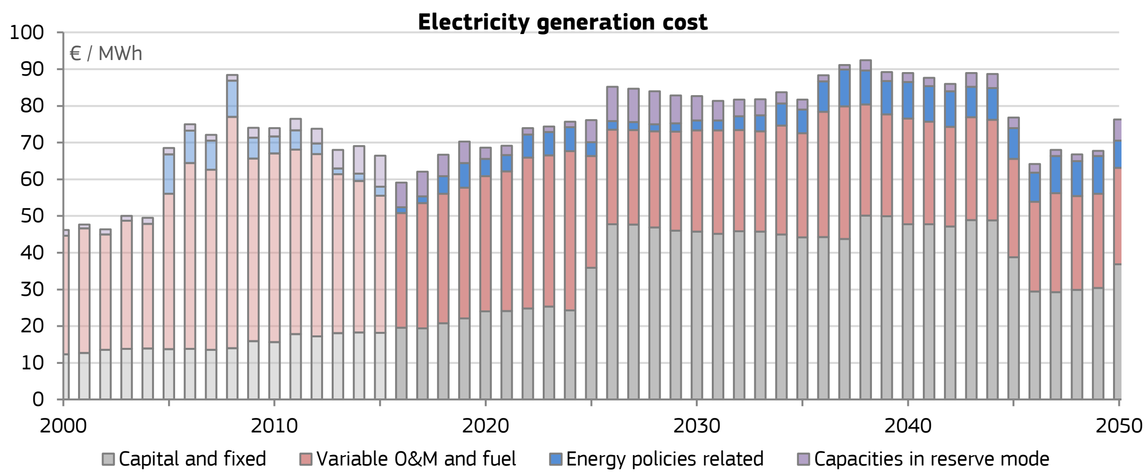

TWh
Net electricity generation
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

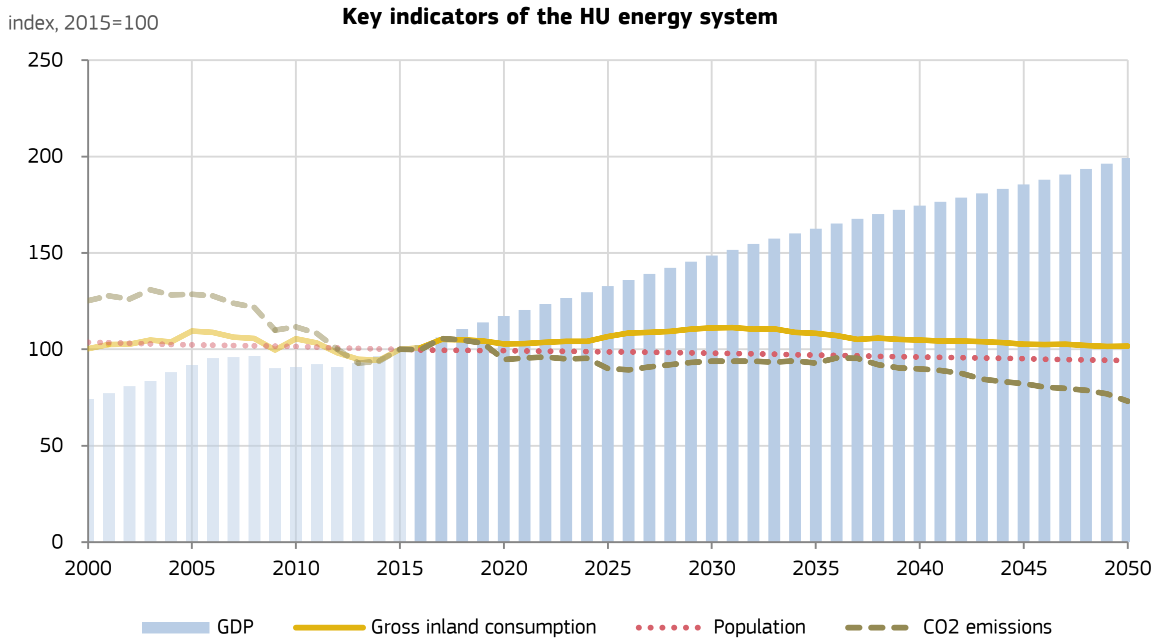

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050

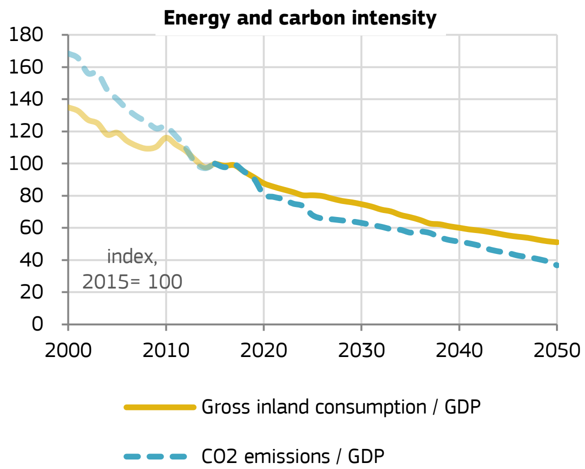

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

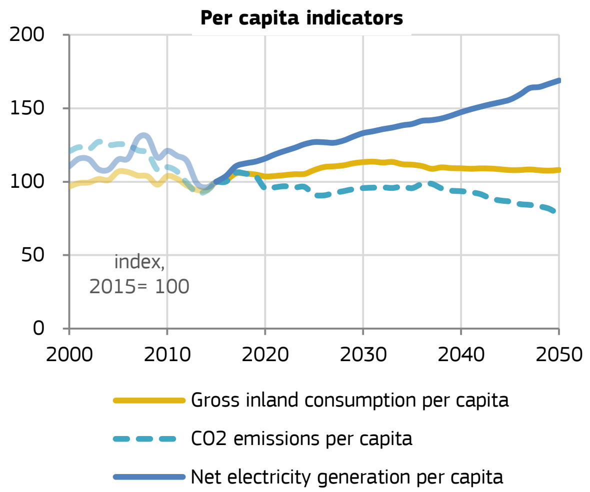

1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
100
90
80
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	19.9	18.2	17.1	17.9	18.6	18.3
Primary energy consumption [Mtoe]	27.1	25.4	23.1	23.5	25.2	23.1
RES [%] - Share of energy from renewable sources		4.6%	15.2%	17.8%	15.0%	25.1%
RES-E [%] - Share of electricity from renewable sources		4.4%	7.1%	10.3%	11.2%	36.7%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	78.1	61.7	48.0	45.4	45.0	35.1
reduction to 1990		*-21%*	*-39%*	*-42%*	*-42%*	*-55%*
Emissions in current ETS sectors |(HU) [Mt CO2]		27.6	20.2	17.7	15.9	10.6
reduction to 2005			*-27%*	*-36%*	*-43%*	*-62%*
Emissions in current ESD sectors [Mt CO2]		34.1	27.8	27.7	29.2	24.5
reduction to 2005			*-18%*	*-19%*	*-14%*	*-28%*



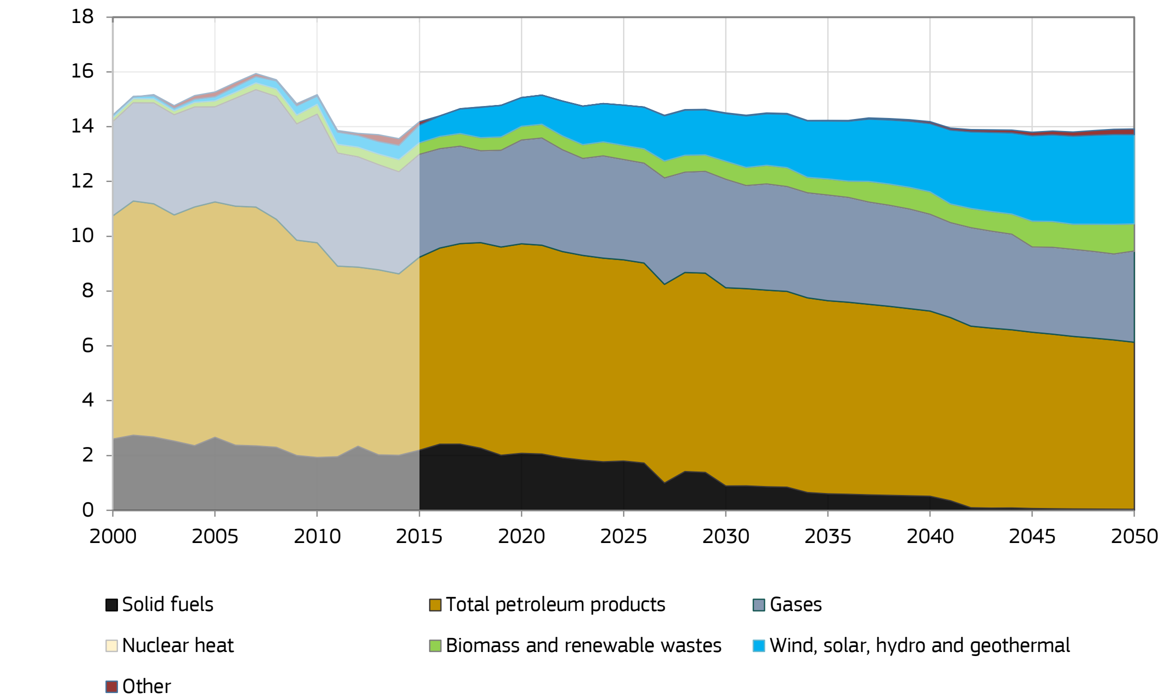


Ireland

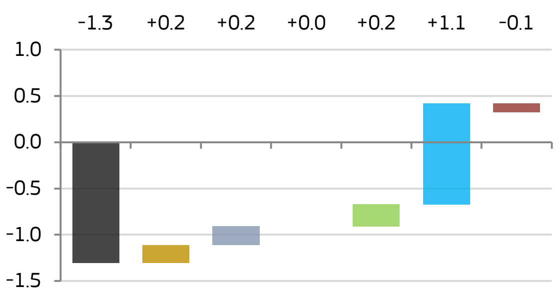
Central_2018 scenario

Mtoe

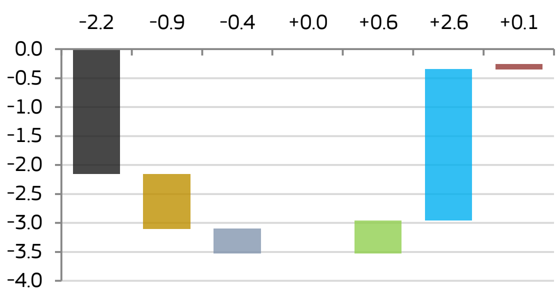
Gross inland energy consumption



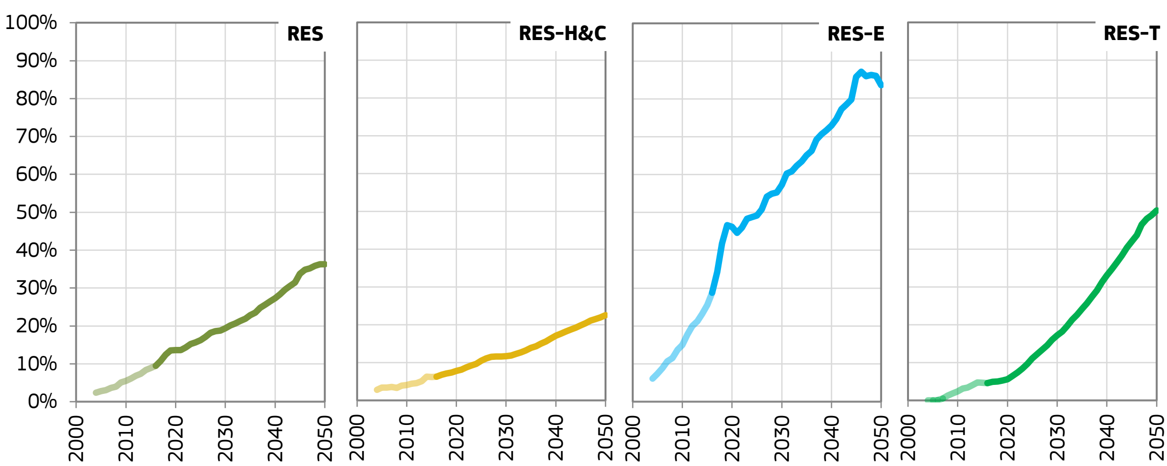
+0.3 Mtoe by 2030 from 2015 levels

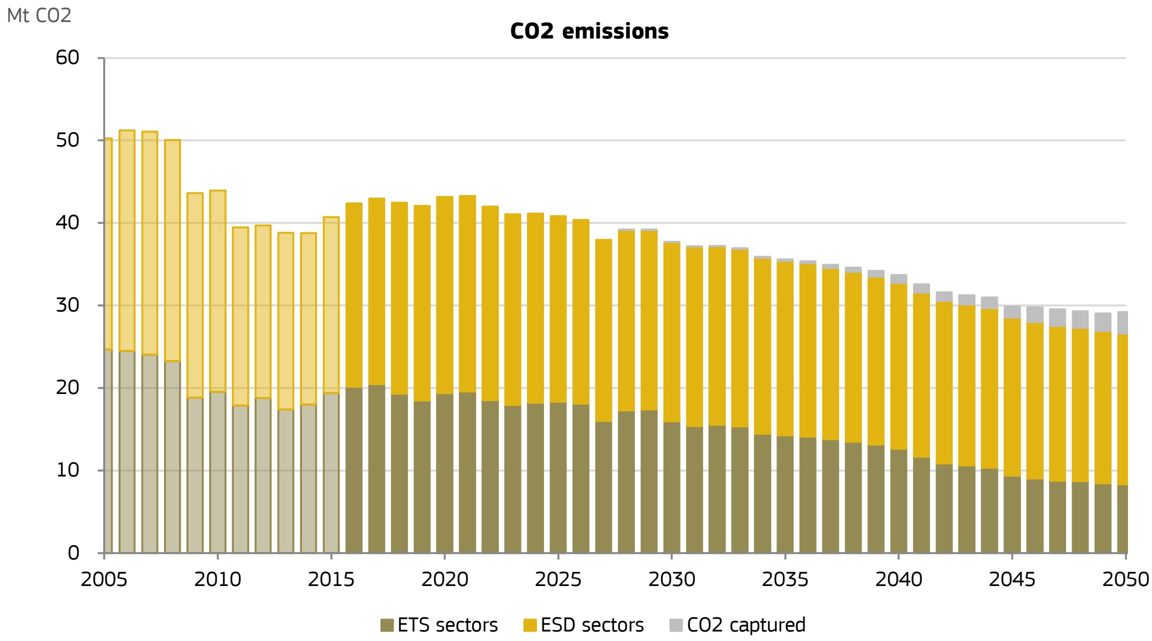


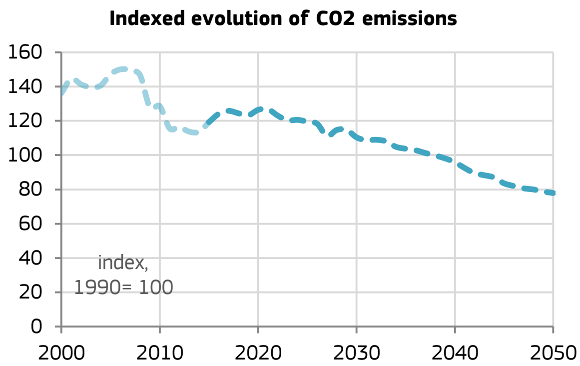
-0.3 Mtoe by 2050 from 2015 levels

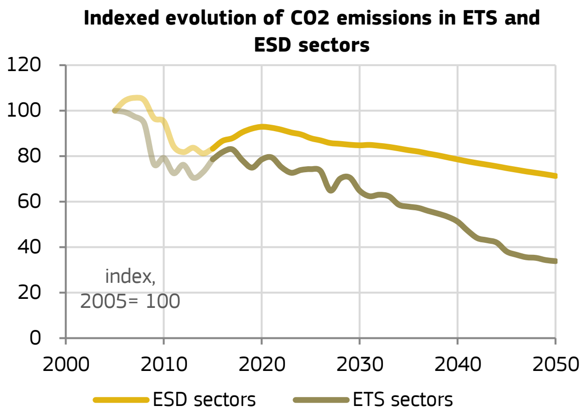


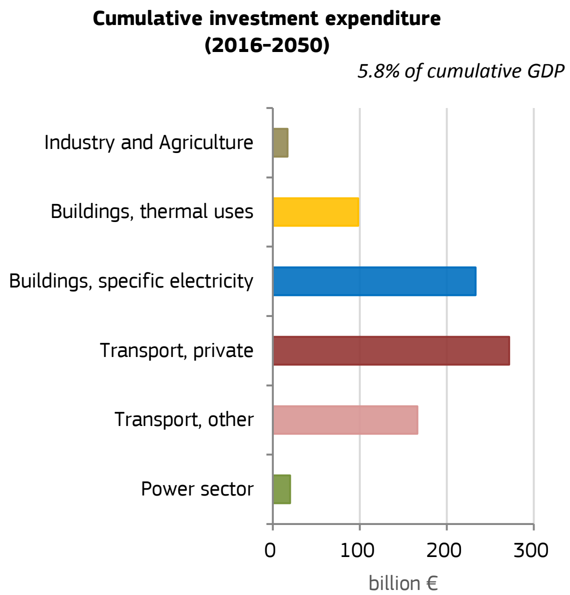
Share of renewable energies

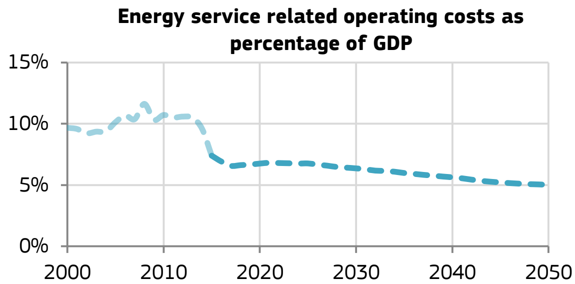


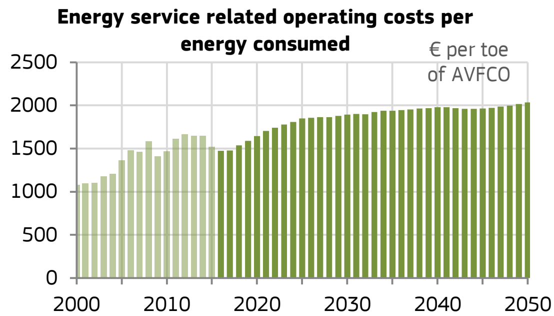

Mt CO2
CO2 emissions
60
50
40
30
20
10
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured

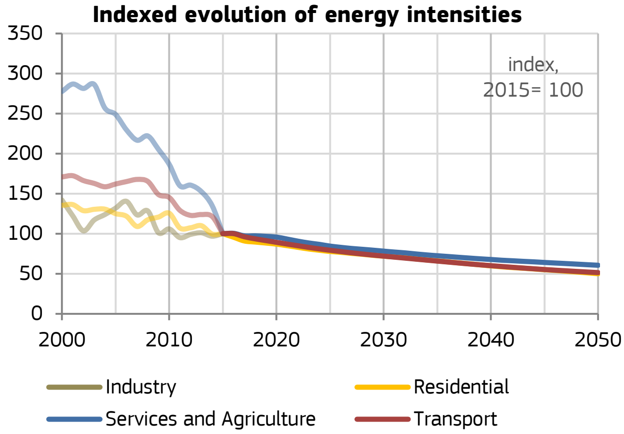

Indexed evolution of CO2 emissions
160
140
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

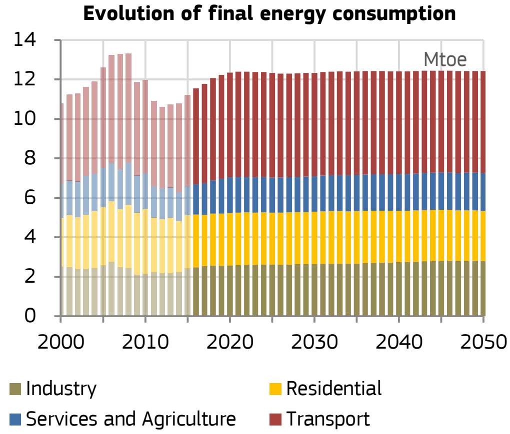

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors

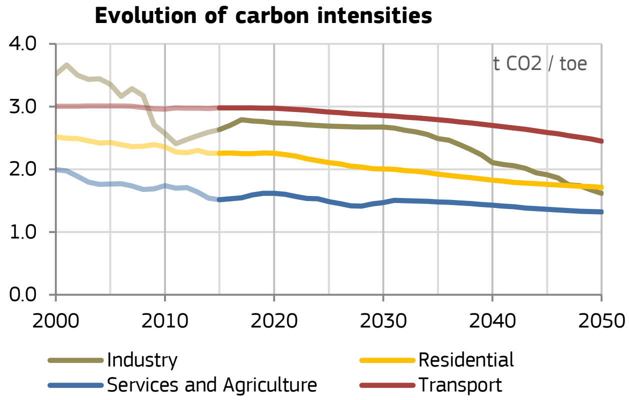

Cumulative investment expenditure (2016-2050)
5.8% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
100
200
300
billion €

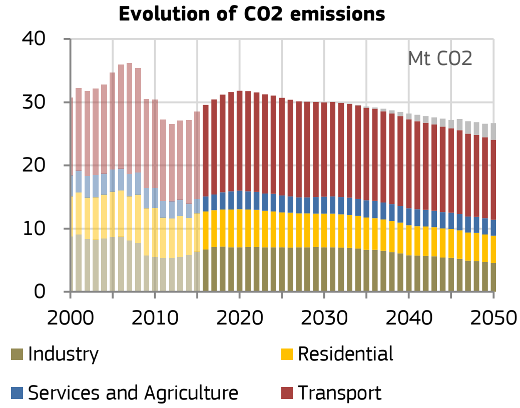

Energy service related operating costs as percentage of GDP
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050

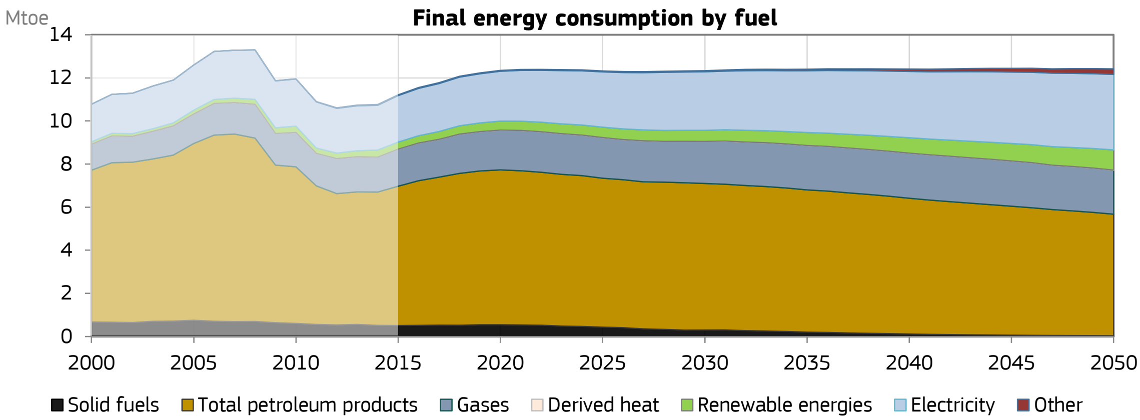

Energy service related operating costs per energy consumed
€ per toe of AVFCO
2500
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

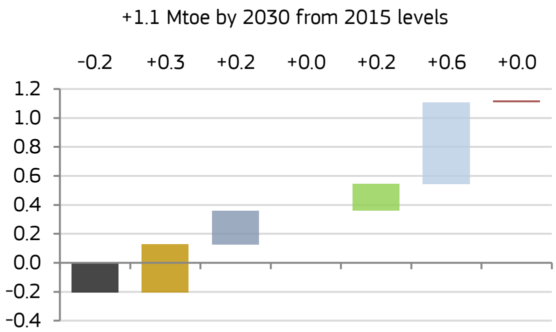

Indexed evolution of energy intensities
index, 2015= 100
350
300
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

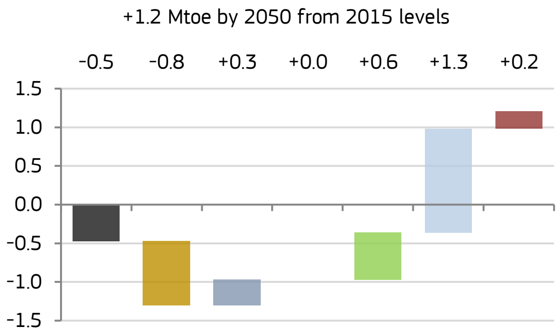

Evolution of final energy consumption
Mtoe
14
12
10
8
6
4
2
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

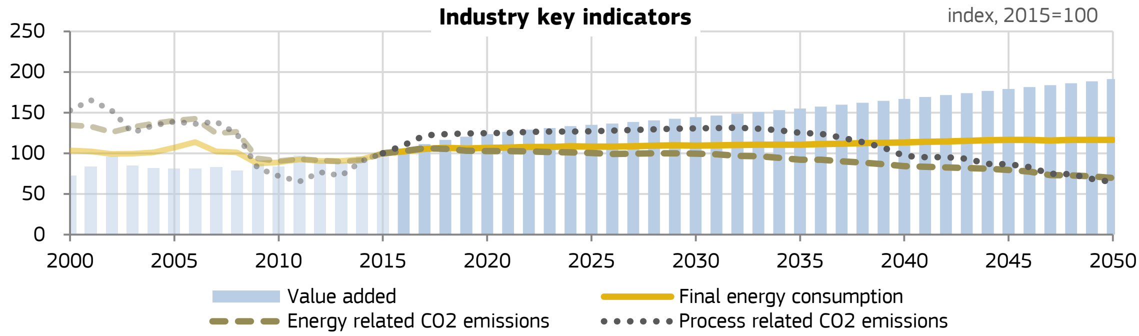

Evolution of carbon intensities
t CO2 / toe
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

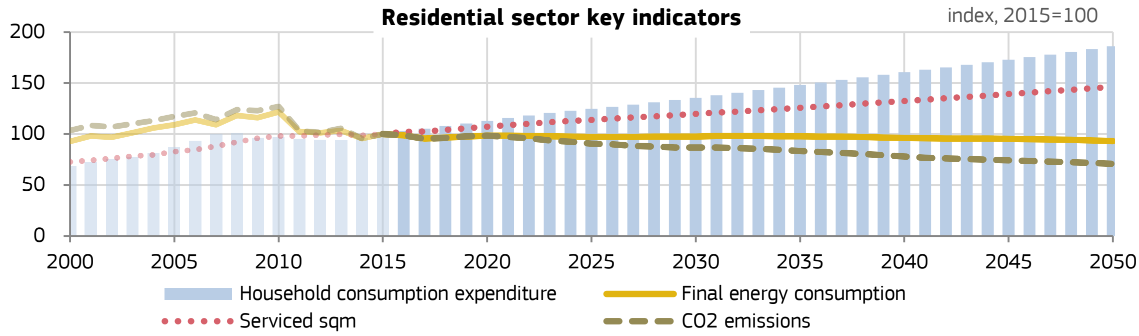

Evolution of CO2 emissions
Mt CO2
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

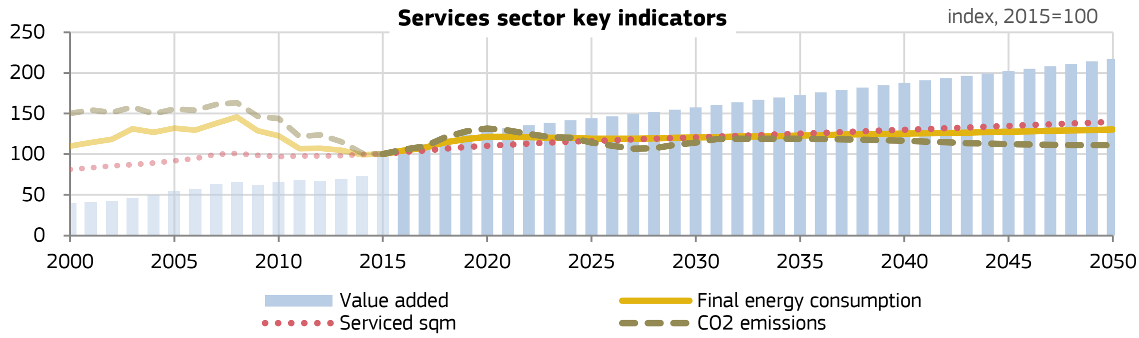

Final energy consumption by fuel
Mtoe
14
12
10
8
6
4
2
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

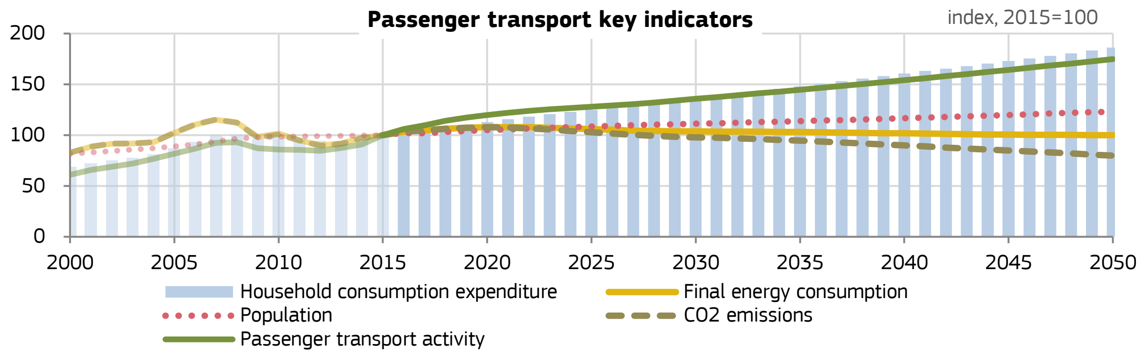

+1.1 Mtoe by 2030 from 2015 levels
-0.2
+0.3
+0.2
+0.0
+0.2
+0.6
+0.0
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4

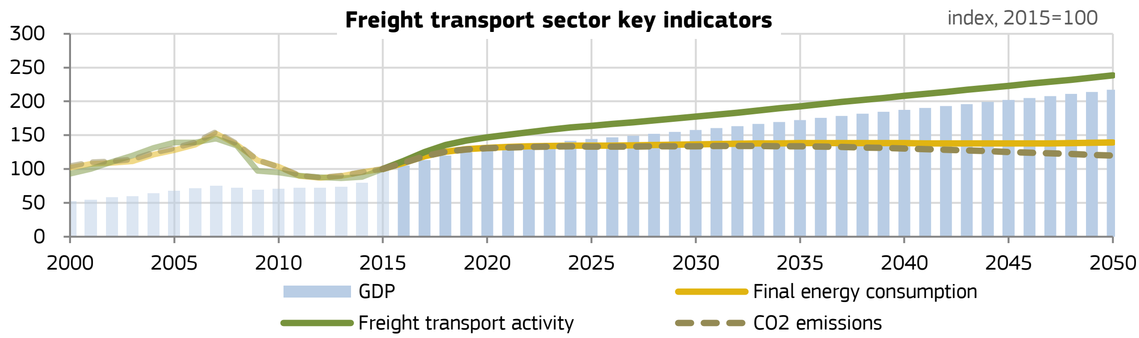

+1.2 Mtoe by 2050 from 2015 levels
-0.5
-0.8
+0.3
+0.0
+0.6
+1.3
+0.2
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5

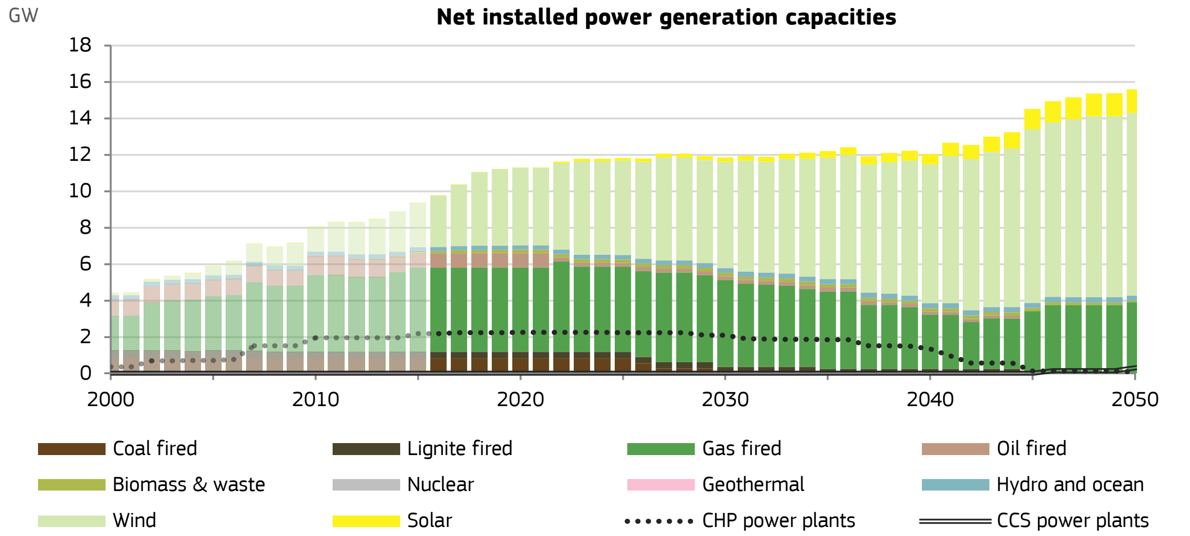

Industry key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

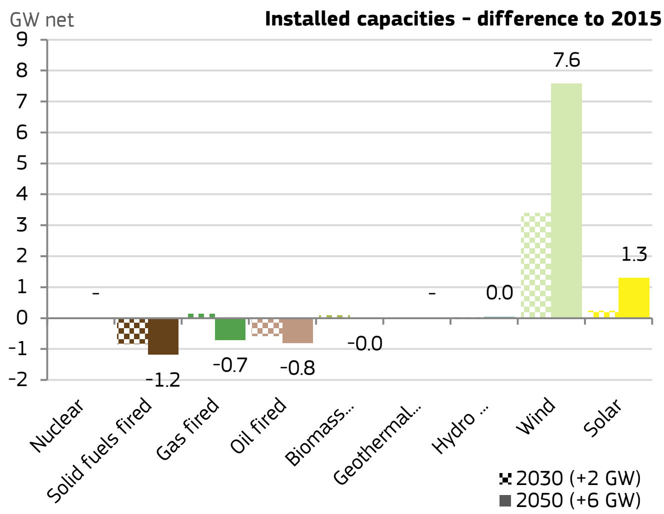

Residential sector key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

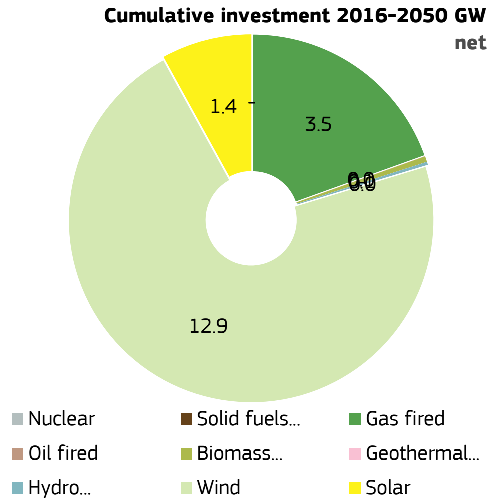

Services sector key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

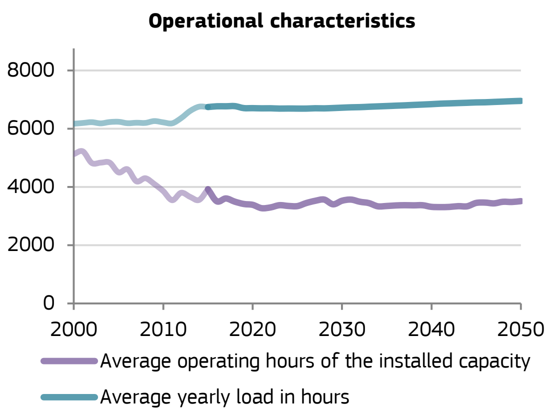

Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

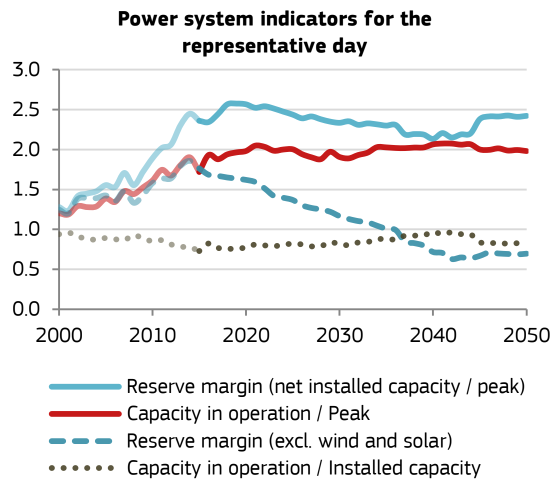

Freight transport sector key indicators
index, 2015=100
300
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

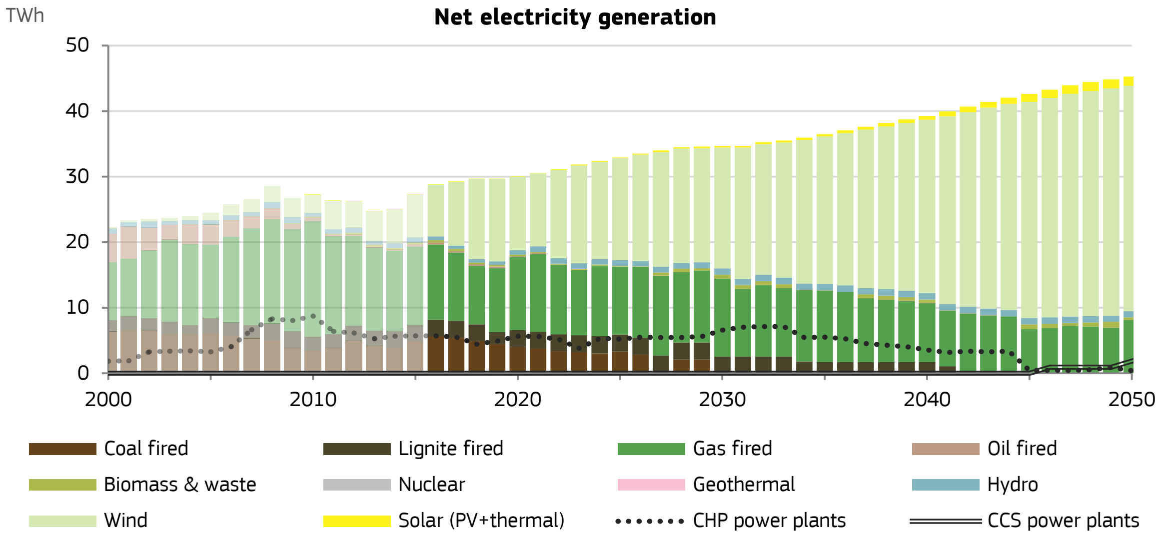

GW
Net installed power generation capacities
18
16
14
12
10
8
6
4
2
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

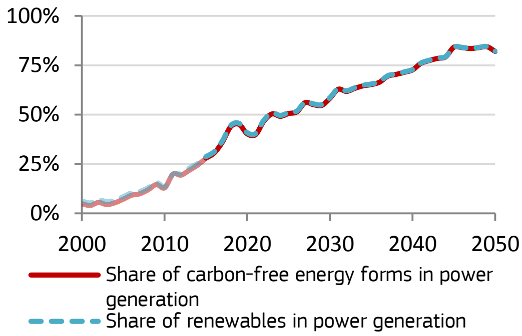

GW net
Installed capacities - difference to 2015
7.6
1.3
0.0
-1.2
-0.7
-0.8
-0.0
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+2 GW)
2050 (+6 GW)

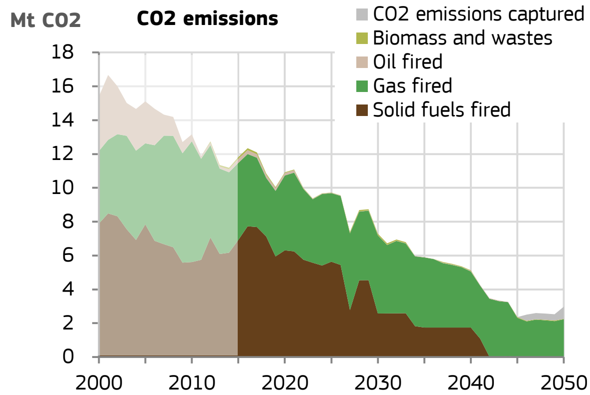

Cumulative investment 2016-2050 GW net
1.4
3.5
0.0
12.9
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

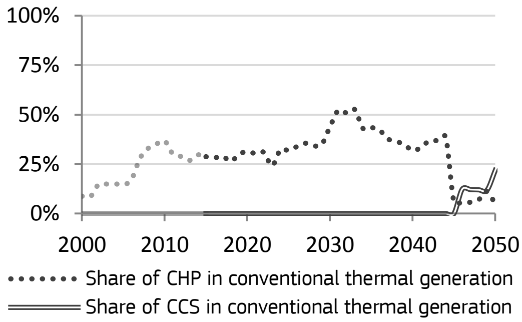

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

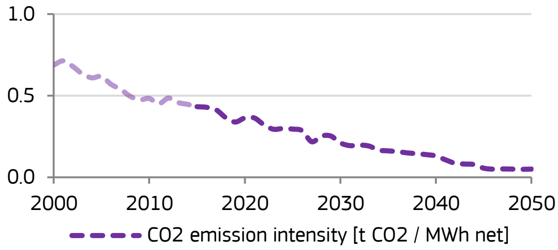

Power system indicators for the representative day
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

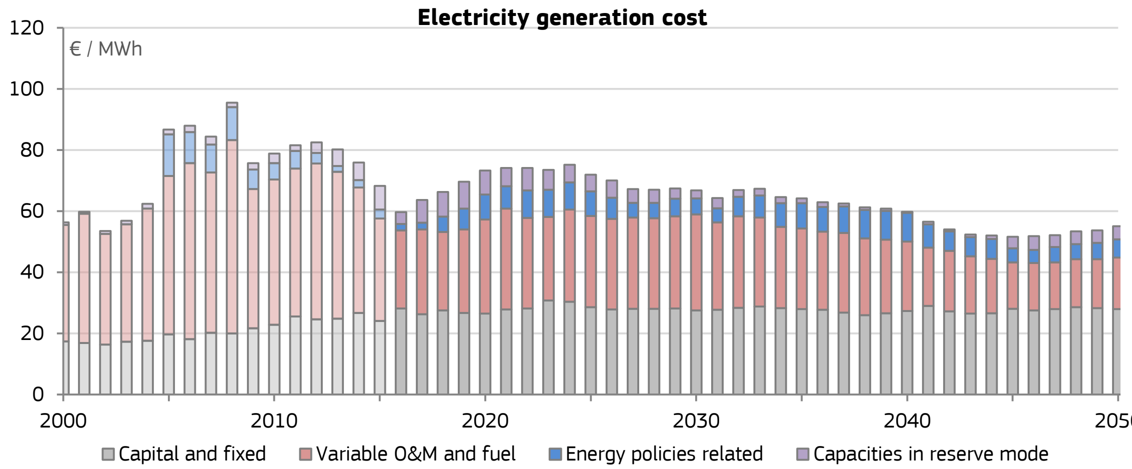

Net electricity generation
TWh
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

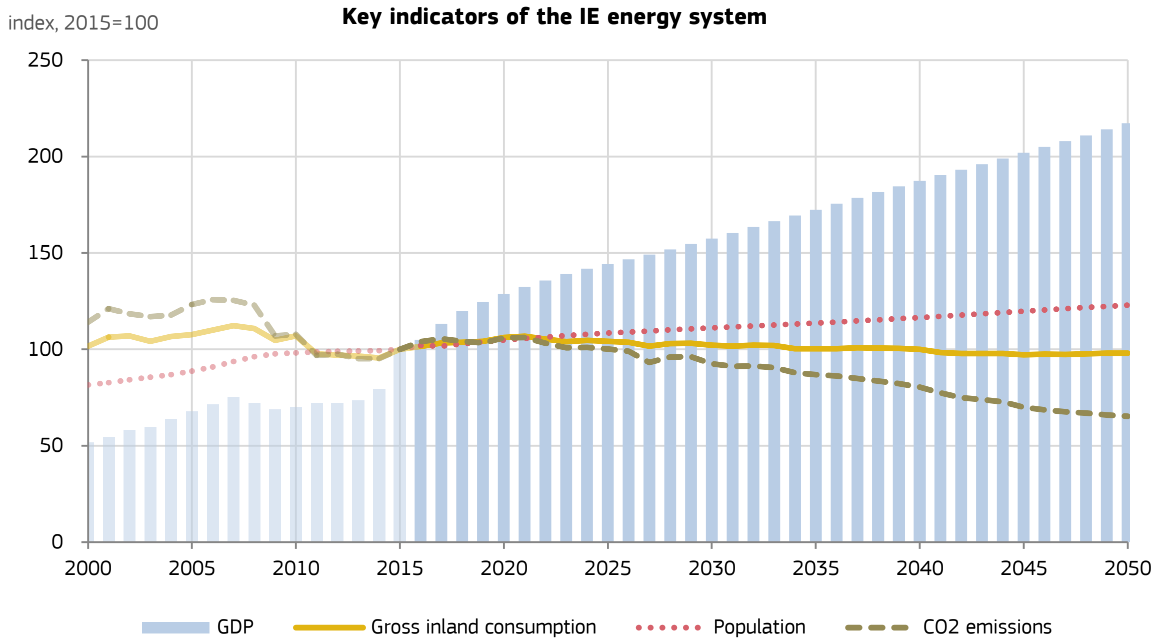

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
18
16
14
12
10
8
6
4
2
0
2000
2010
2020
2030
2040
2050

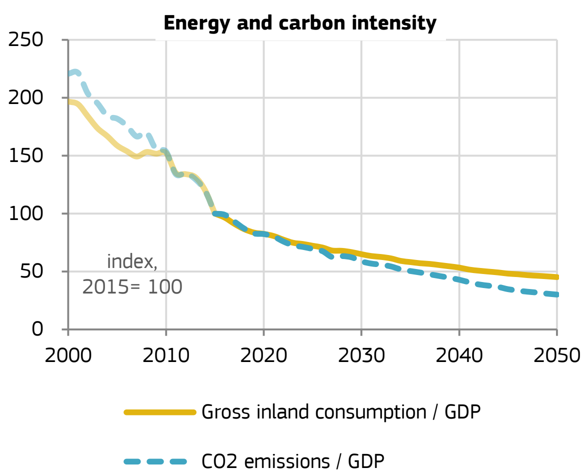

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

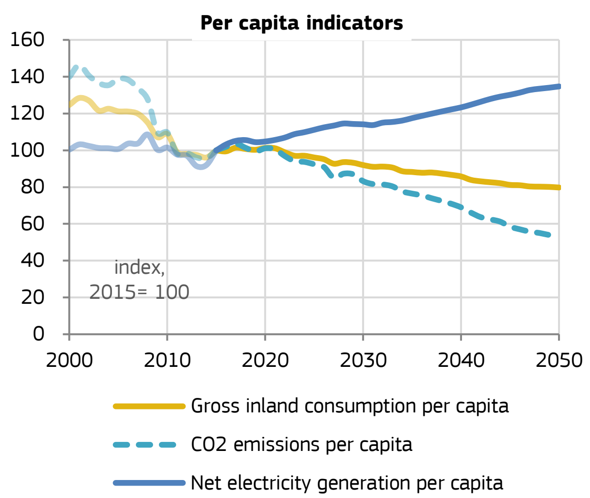

1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	7.3	12.6	11.2	12.3	12.3	12.4
Primary energy consumption [Mtoe]	9.6	14.7	14.0	14.8	14.2	13.6
RES [%] - Share of energy from renewable sources		2.8%	8.8%	13.6%	19.3%	36.3%
RES-E [%] - Share of electricity from renewable sources		7.4%	25.6%	46.2%	57.3%	83.6%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	34.1	50.2	40.7	43.2	37.7	26.6
reduction to 1990		*47%*	*19%*	*26%*	*10%*	*-22%*
Emissions in current ETS sectors |(IE) [Mt CO2]		24.6	19.4	19.4	16.0	8.3
reduction to 2005			*-21%*	*-21%*	*-35%*	*-66%*
Emissions in current ESD sectors [Mt CO2]		25.6	21.3	23.8	21.7	18.2
reduction to 2005			*-17%*	*-7%*	*-15%*	*-29%*



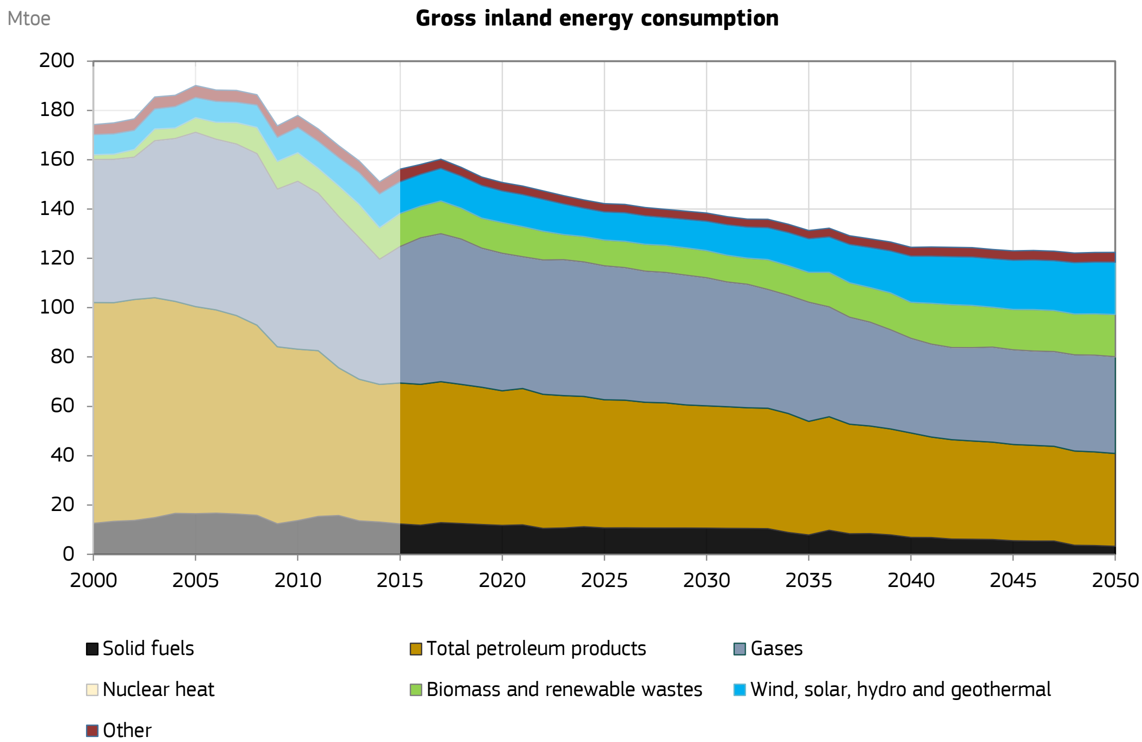


POTEnCIA - Model results overview

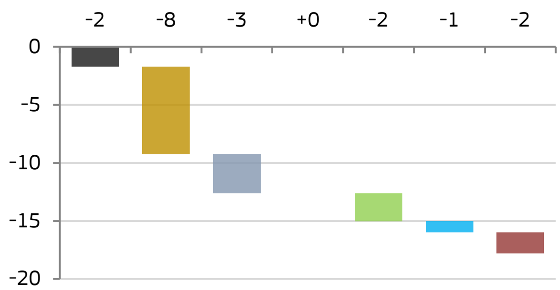
Italy

Central_2018 scenario

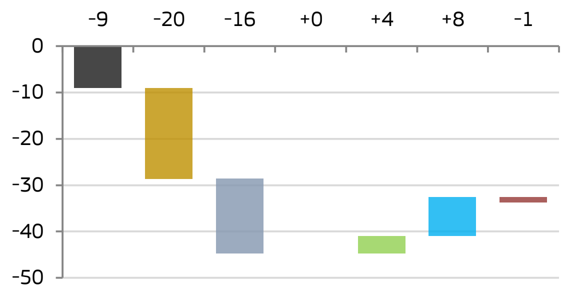
Gross inland energy consumption



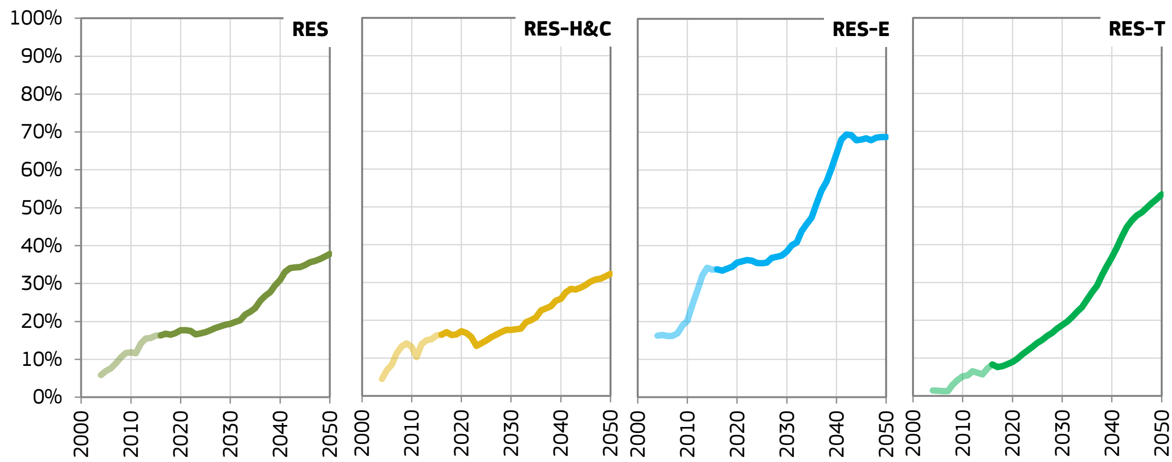
-18 Mtoe by 2030 from 2015 levels



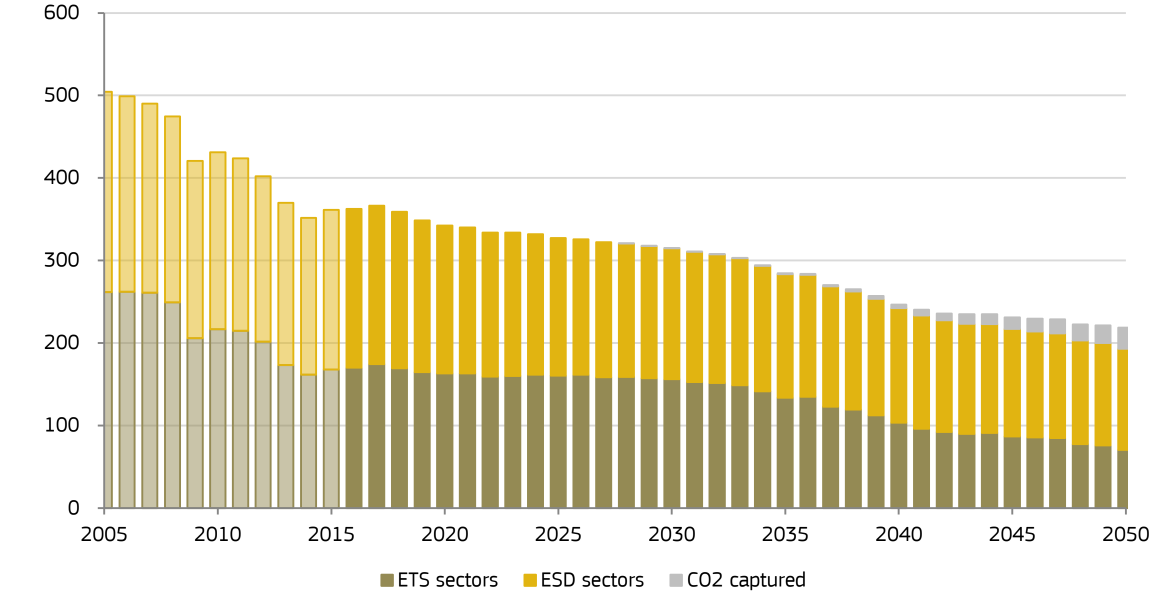
-34 Mtoe by 2050 from 2015 levels



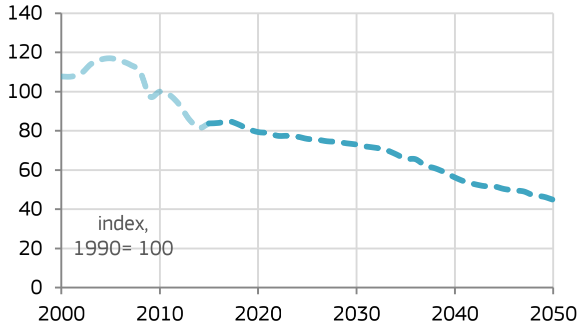
Share of renewable energies



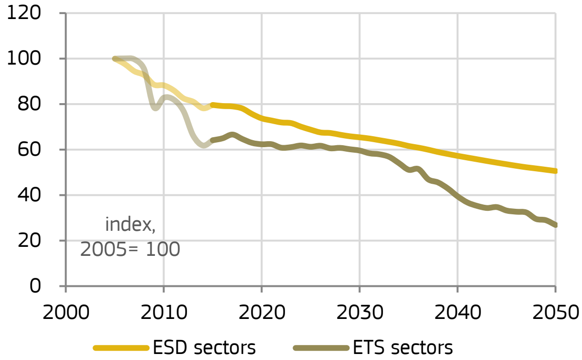
CO2 emissions



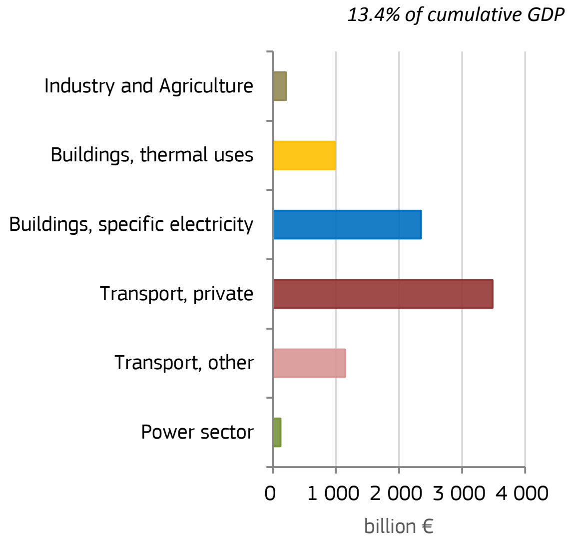
Indexed evolution of CO2 emissions



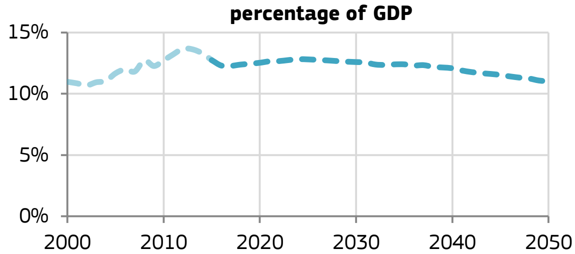
Indexed evolution of CO2 emissions in ETS and ESD sectors



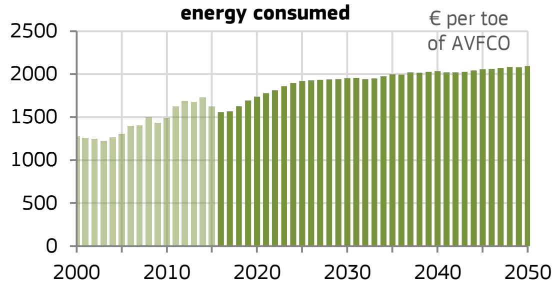
Cumulative investment expenditure (2016-2050)



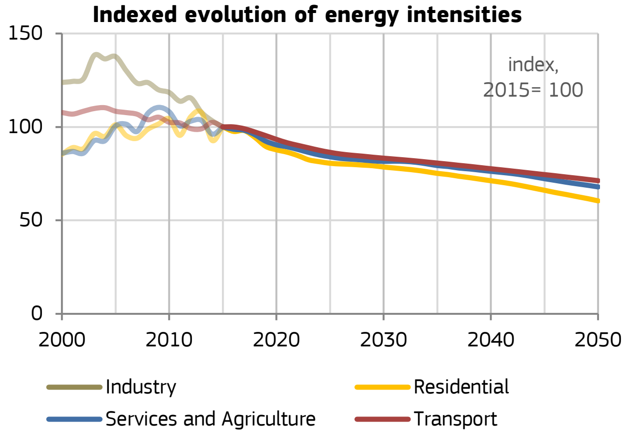
Energy service related operating costs as percentage of GDP



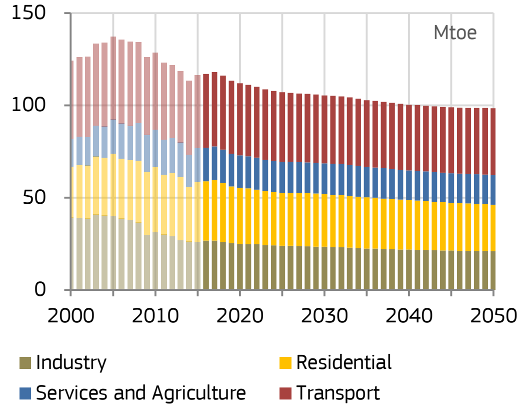
Energy service related operating costs per energy consumed



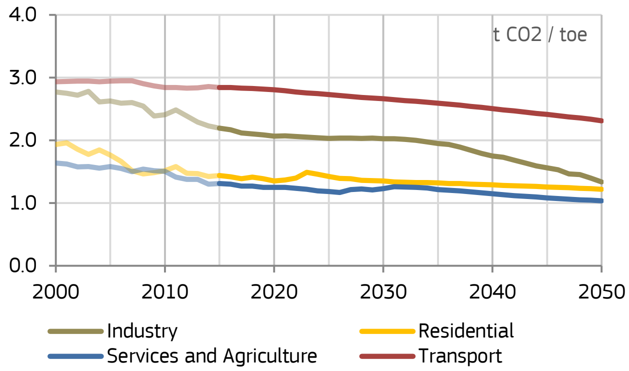
Indexed evolution of energy intensities



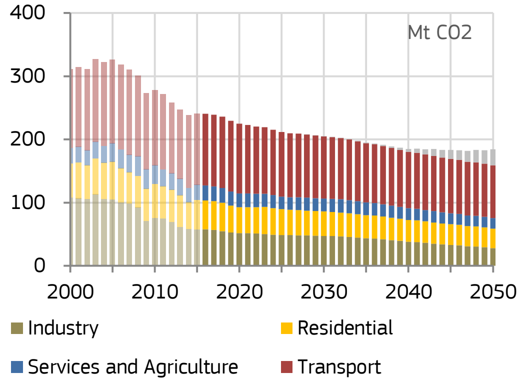
Evolution of final energy consumption



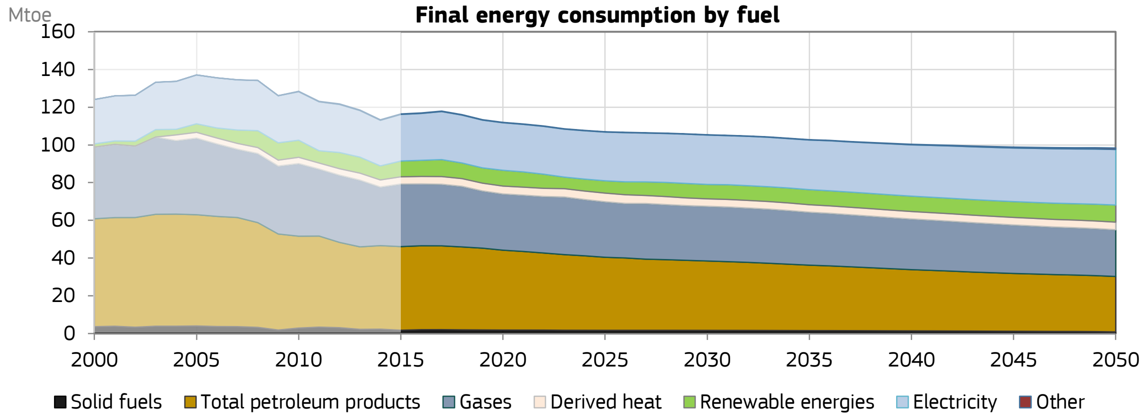
Evolution of carbon intensities



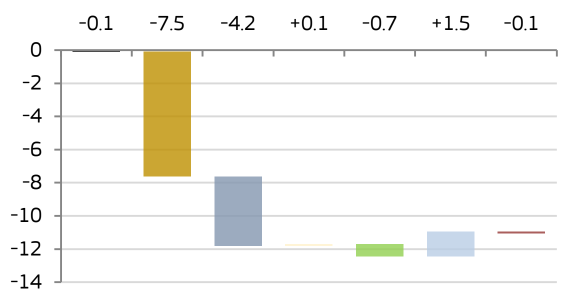
Evolution of CO2 emissions



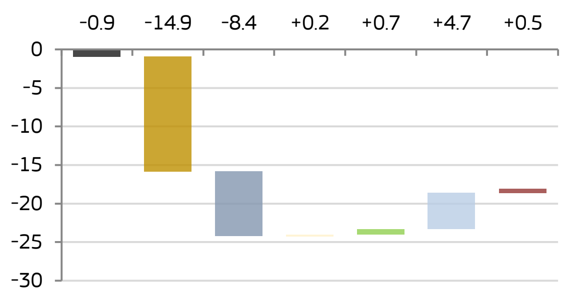
Final energy consumption by fuel

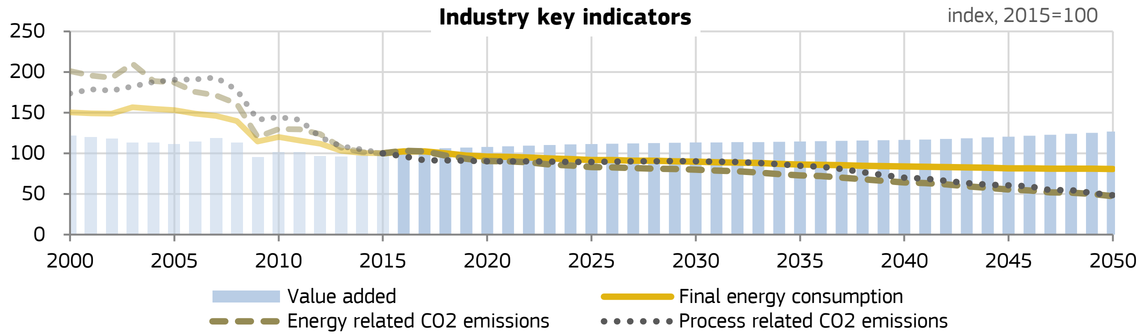


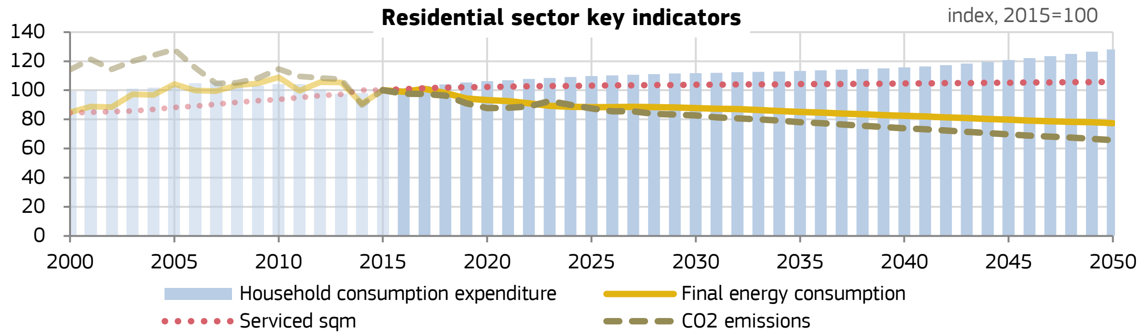
-11.0 Mtoe by 2030 from 2015 levels

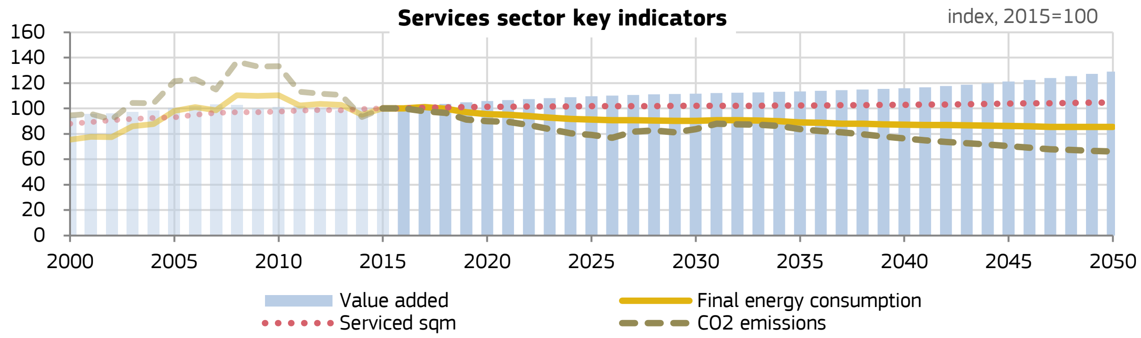


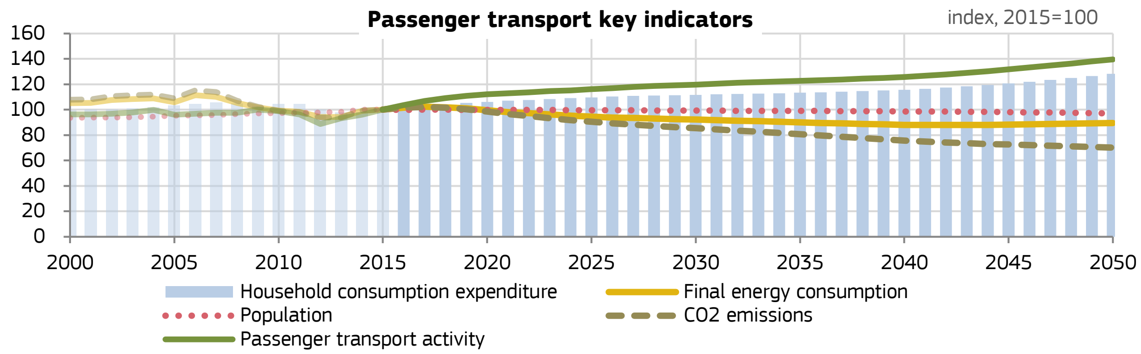
-18.1 Mtoe by 2050 from 2015 levels

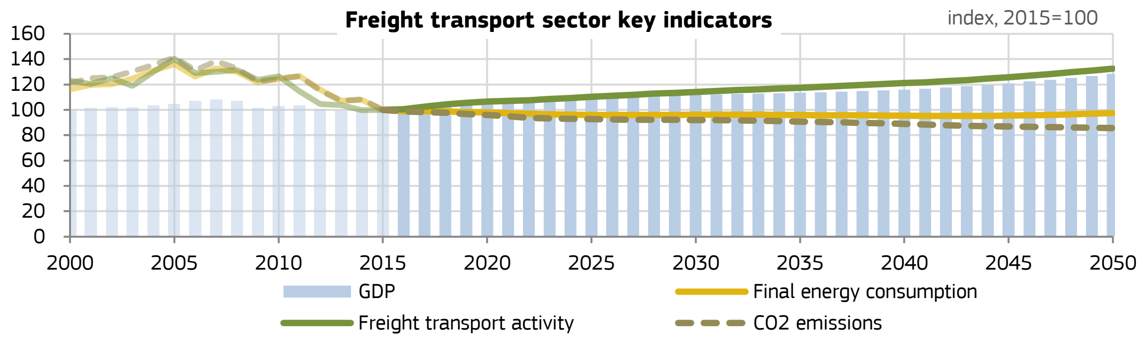


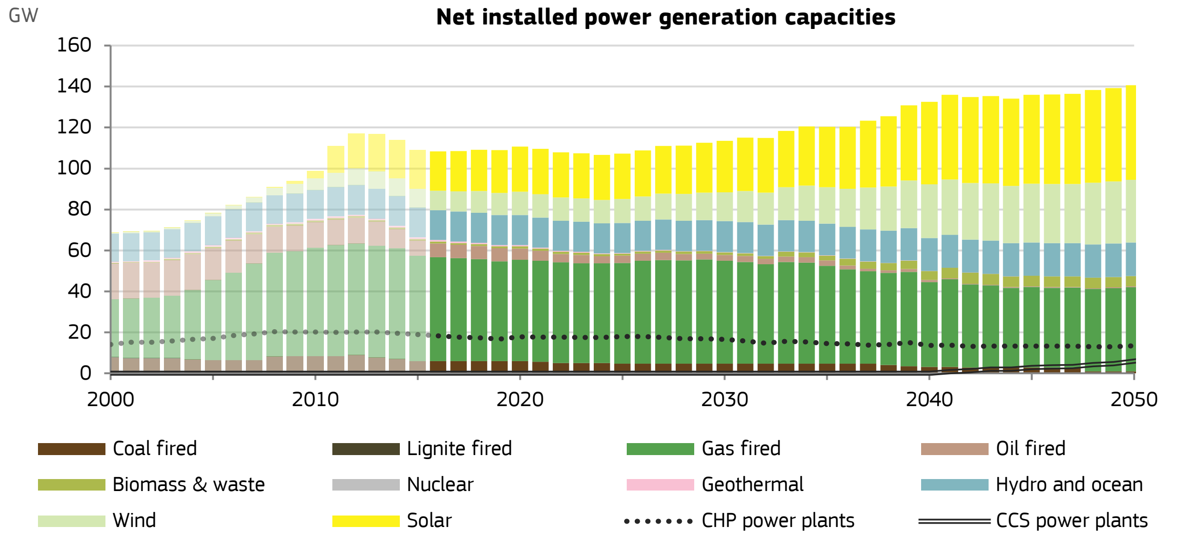

Industry key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

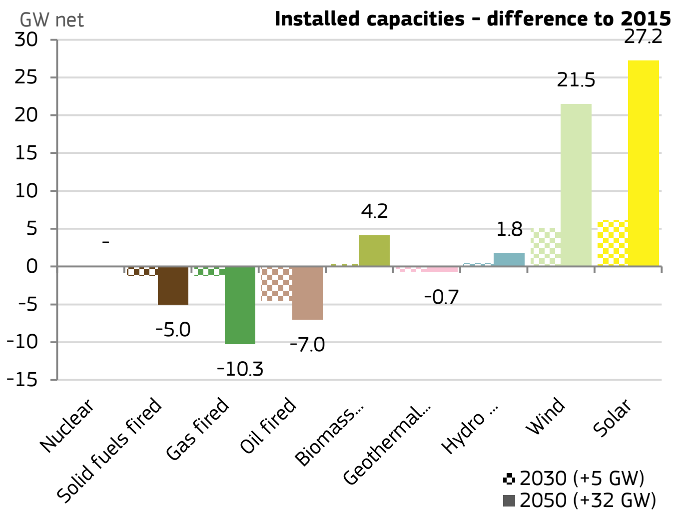

Residential sector key indicators
index, 2015=100
140
120
100
80
60
40
20
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

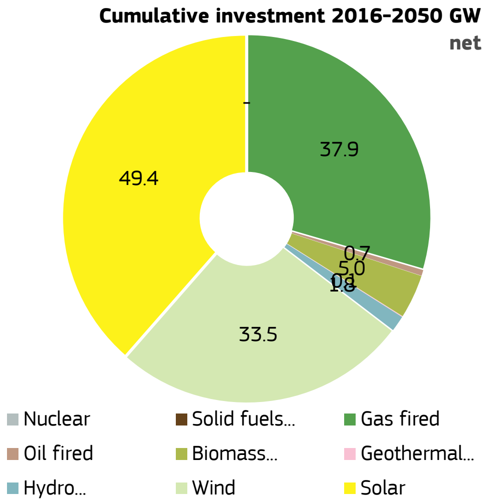

Services sector key indicators
index, 2015=100
160
140
120
100
80
60
40
20
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

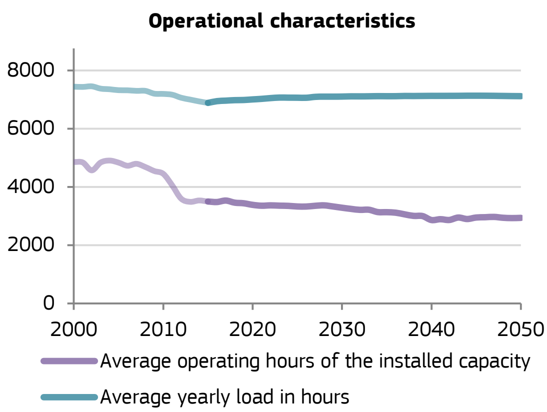

Passenger transport key indicators
index, 2015=100
160
140
120
100
80
60
40
20
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

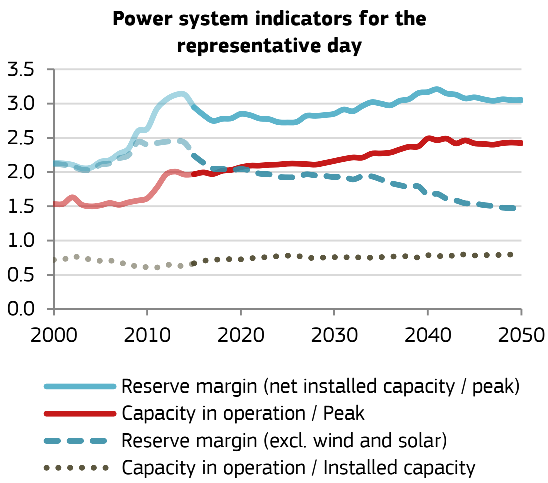

Freight transport sector key indicators
index, 2015=100
160
140
120
100
80
60
40
20
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

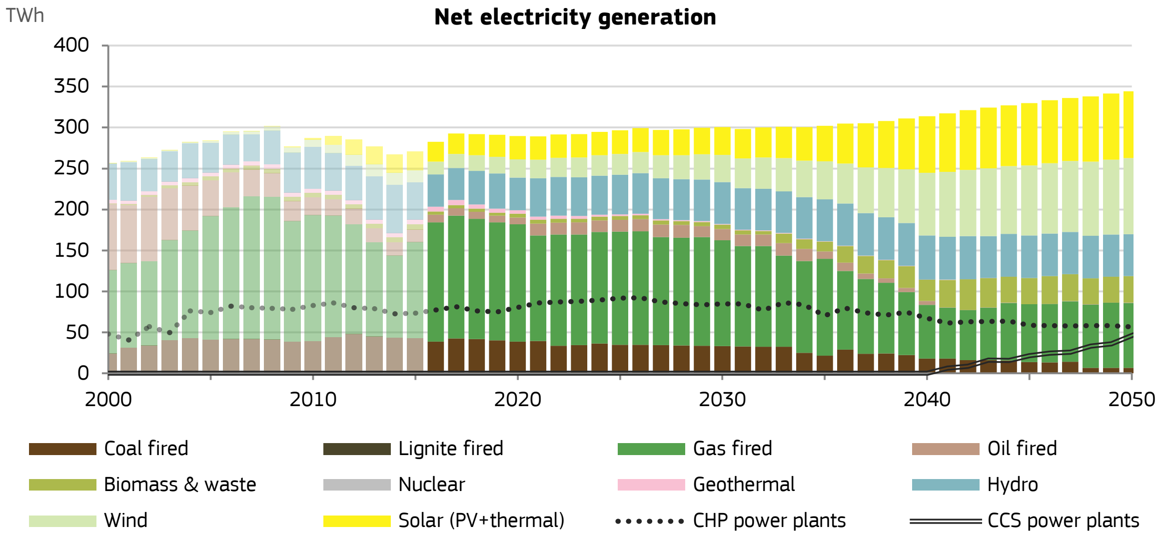

Net installed power generation capacities
GW
160
140
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

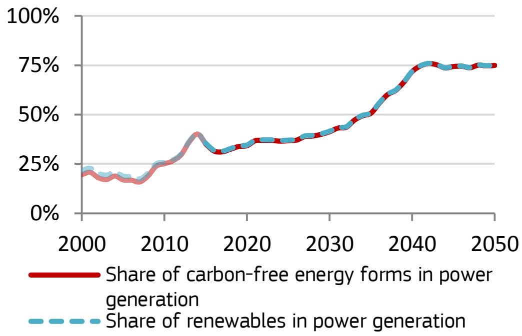

Installed capacities - difference to 2015
GW net
30
25
20
15
10
5
0
-5
-10
-15
-
-5.0
-10.3
-7.0
4.2
-0.7
1.8
21.5
27.2
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+5 GW)
2050 (+32 GW)

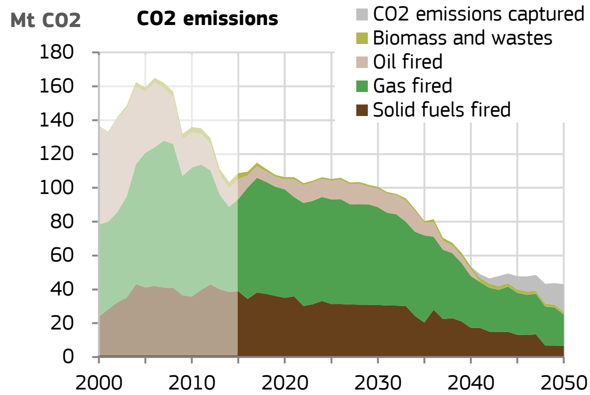

Cumulative investment 2016-2050 GW net
-
37.9
0.7
5.0
0.1
1.8
33.5
49.4
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

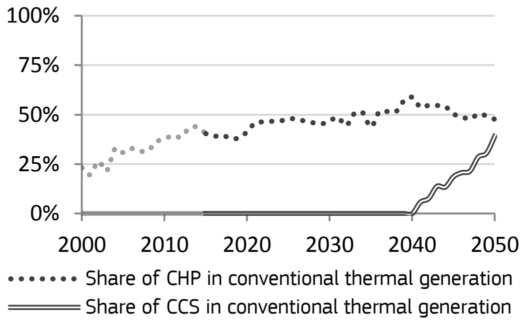

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

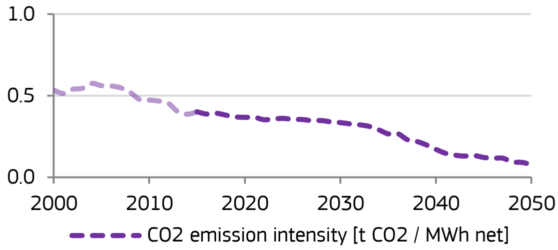

Power system indicators for the representative day
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

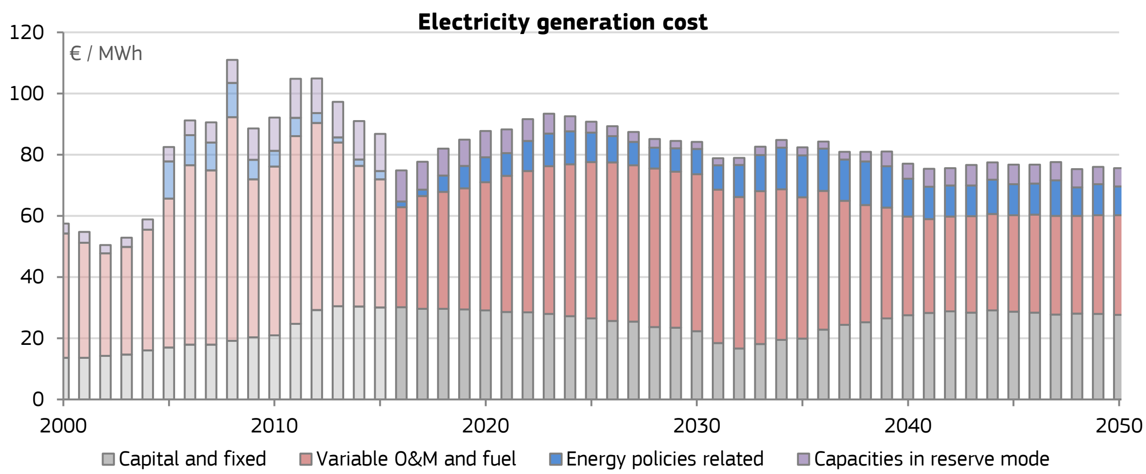

Net electricity generation
TWh
400
350
300
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

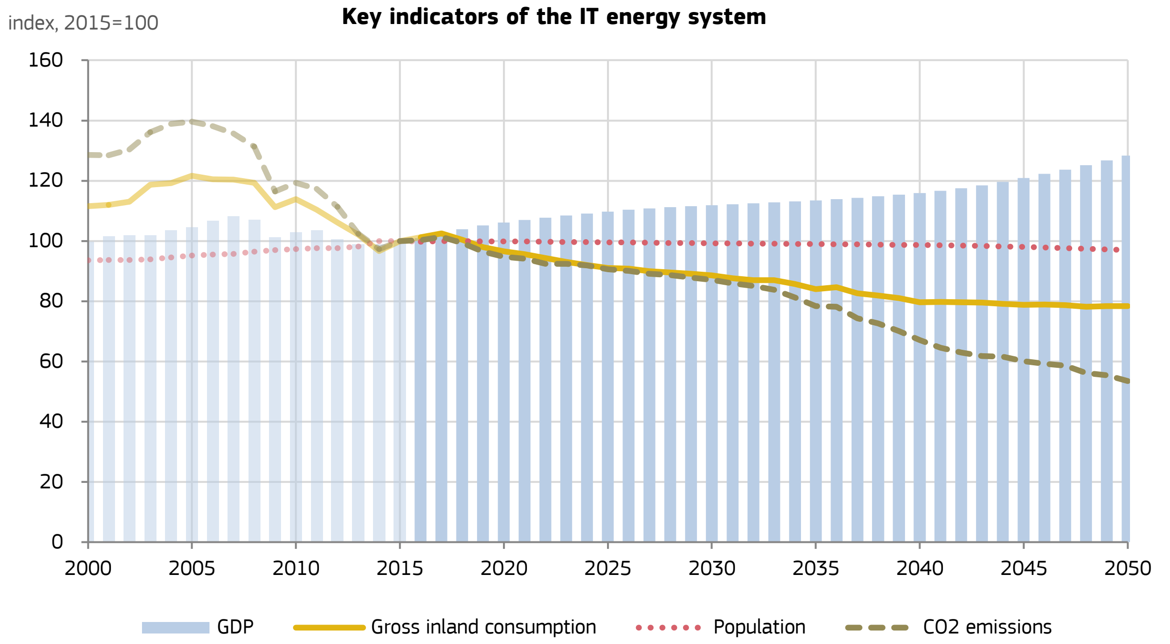

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
180
160
140
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050

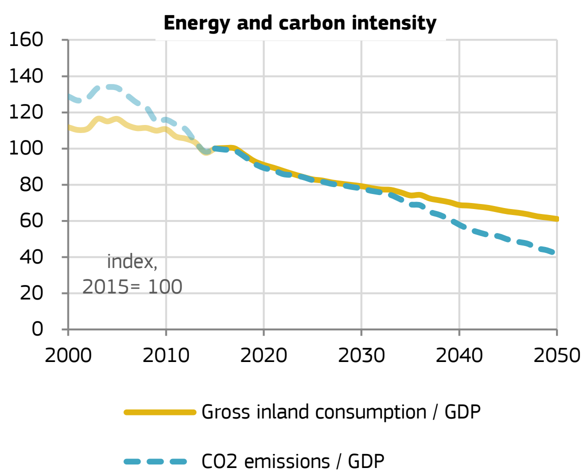

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

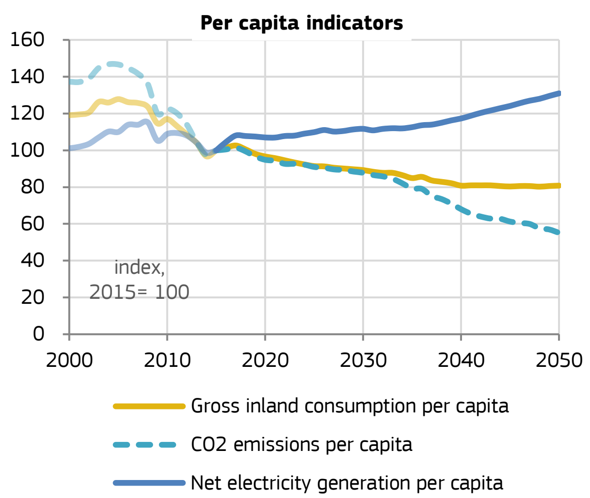

1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	106	137	116	112	105	98
Primary energy consumption [Mtoe]	142	181	150	144	131	116
RES [%] - Share of energy from renewable sources		6.9%	16.2%	17.7%	19.4%	37.8%
RES-E [%] - Share of electricity from renewable sources		16.4%	33.7%	35.6%	38.5%	68.7%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	431	504	361	342	315	193
reduction to 1990		*17%*	*-16%*	*-21%*	*-27%*	*-55%*
Emissions in current ETS sectors |(IT) [Mt CO2]		262	168	163	156	70
reduction to 2005			*-36%*	*-38%*	*-40%*	*-73%*
Emissions in current ESD sectors [Mt CO2]		243	193	179	159	123
reduction to 2005			*-20%*	*-26%*	*-35%*	*-49%*

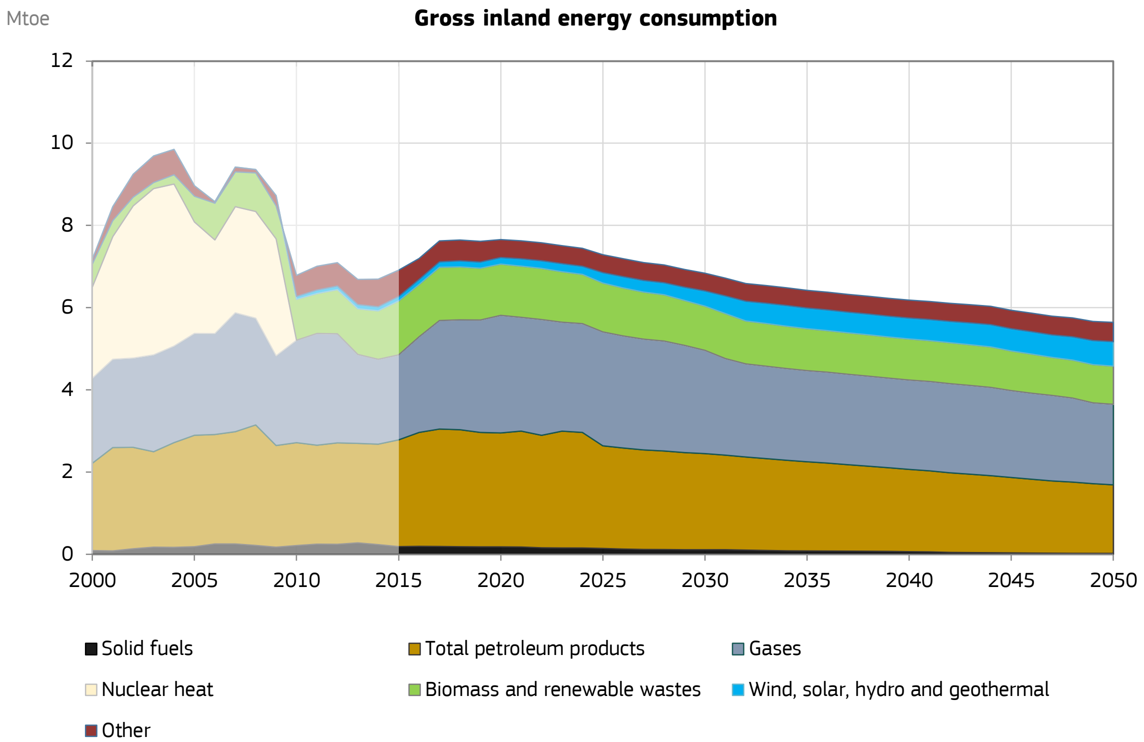


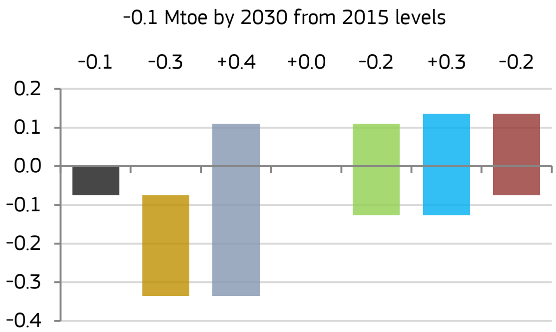


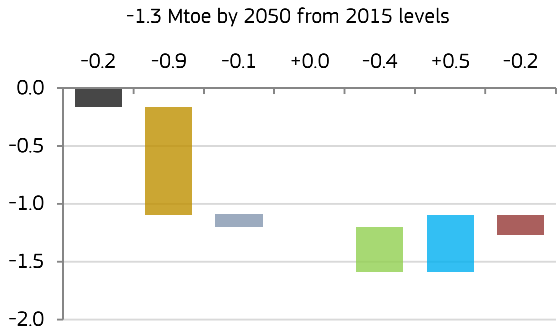
POTEnCIA - Model results overview

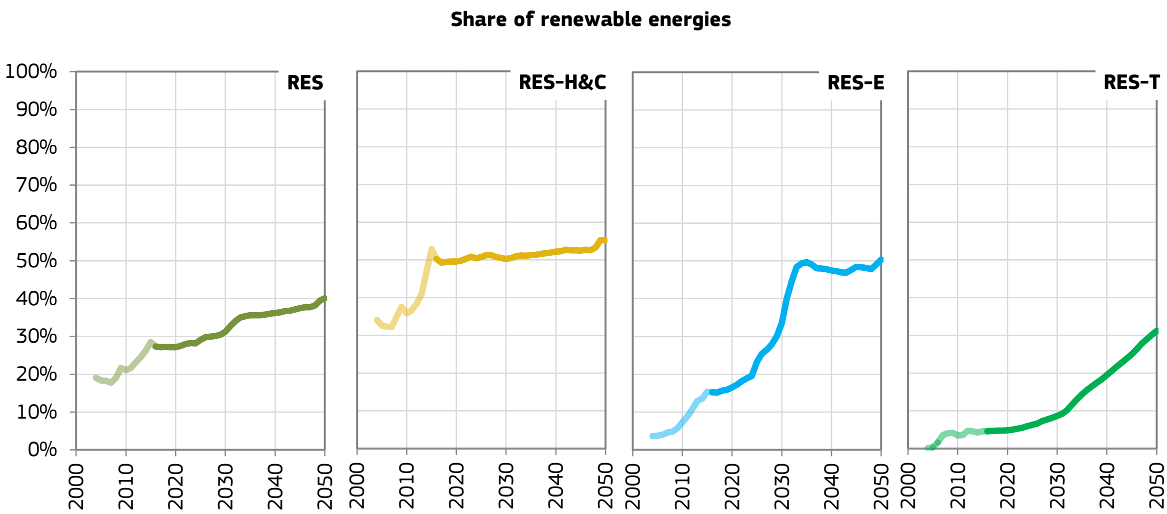
Lithuania

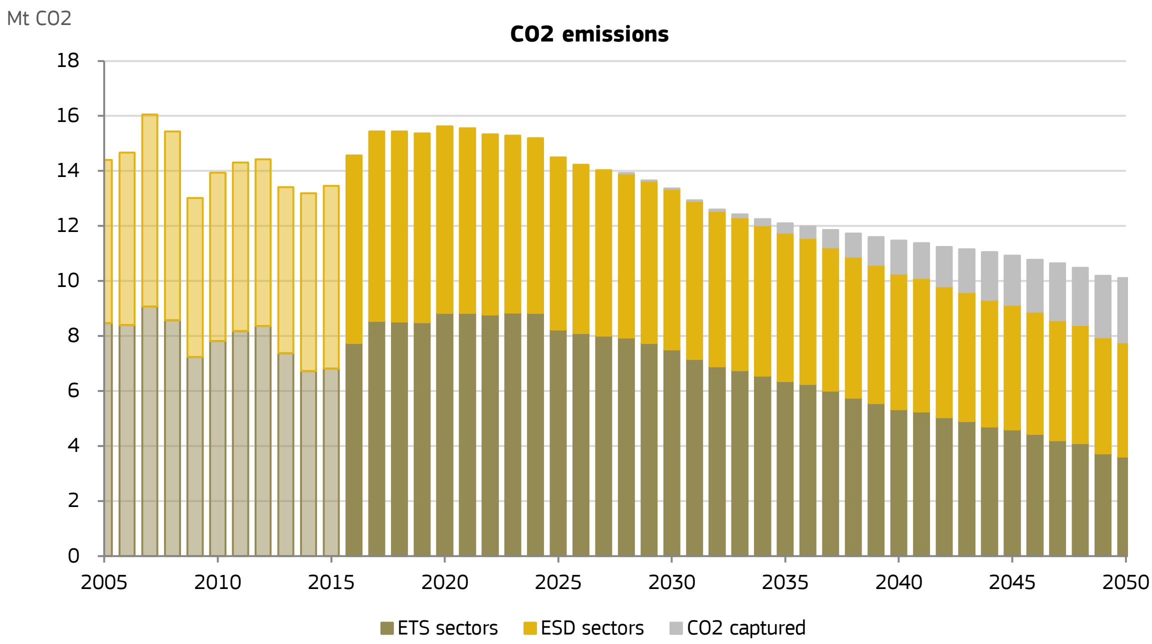
Central_2018 scenario

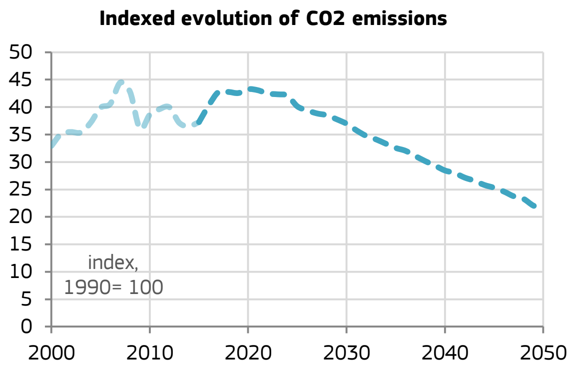

Mtoe
Gross inland energy consumption
12
10
8
6
4
2
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Nuclear heat
Biomass and renewable wastes
Wind, solar, hydro and geothermal
Other

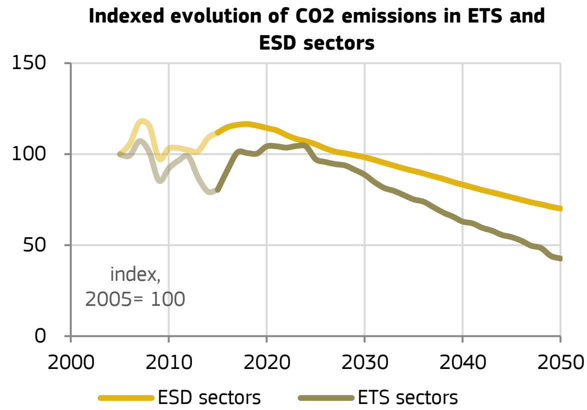

-0.1 Mtoe by 2030 from 2015 levels
-0.1
-0.3
+0.4
+0.0
-0.2
+0.3
-0.2
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4

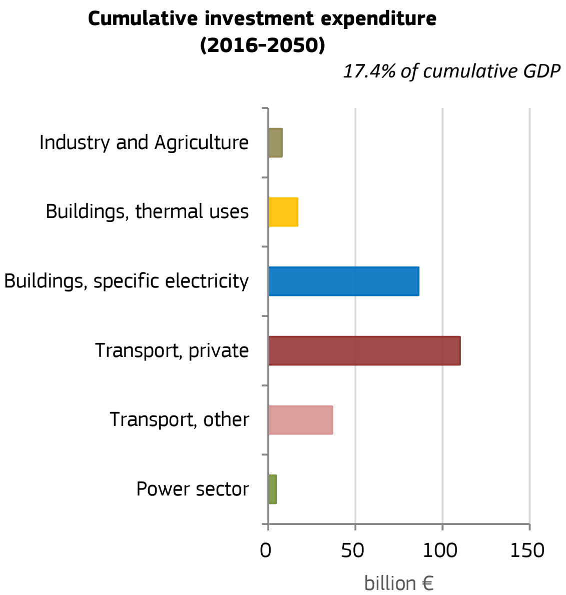

-1.3 Mtoe by 2050 from 2015 levels
-0.2
-0.9
-0.1
+0.0
-0.4
+0.5
-0.2
0.0
-0.5
-1.0
-1.5
-2.0

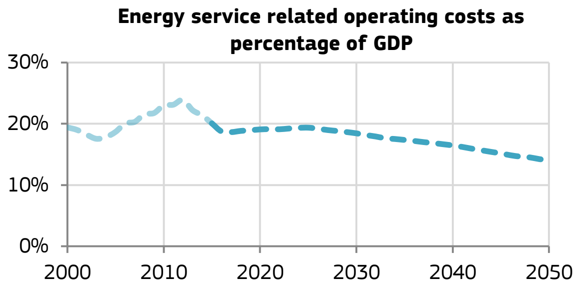

Share of renewable energies
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RES
RES-H&C
RES-E
RES-T
2000
2010
2020
2030
2040
2050

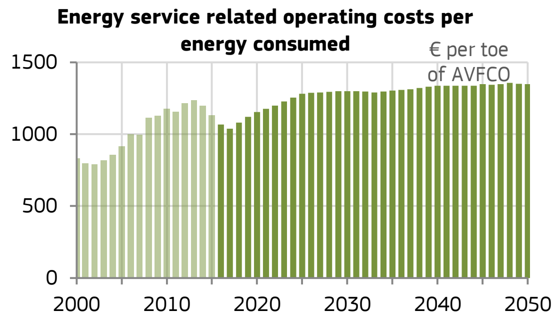

Mt CO2
CO2 emissions
ETS sectors
ESD sectors
CO2 captured


Indexed evolution of CO2 emissions
index,
1990= 100

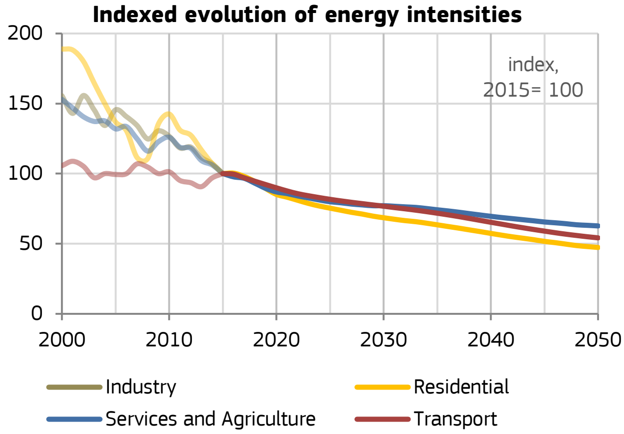

Indexed evolution of CO2 emissions in ETS and ESD sectors
index,
2005= 100
ESD sectors
ETS sectors


Cumulative investment expenditure (2016-2050)
17.4% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
billion €

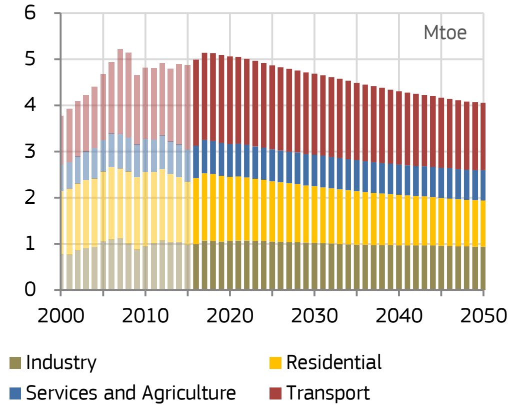

Energy service related operating costs as percentage of GDP


Energy service related operating costs per energy consumed
€ per toe
of AVFCO

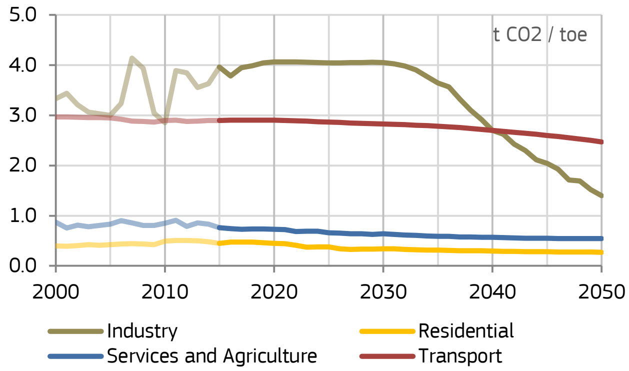
Indexed evolution of energy intensities



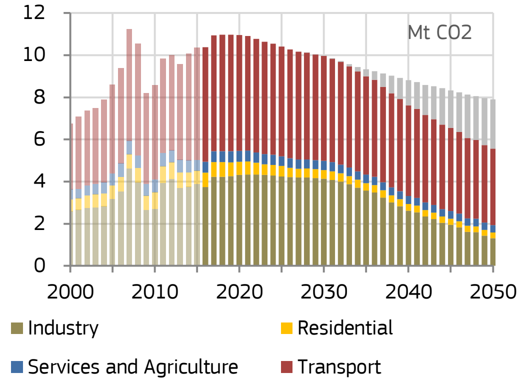
Evolution of final energy consumption



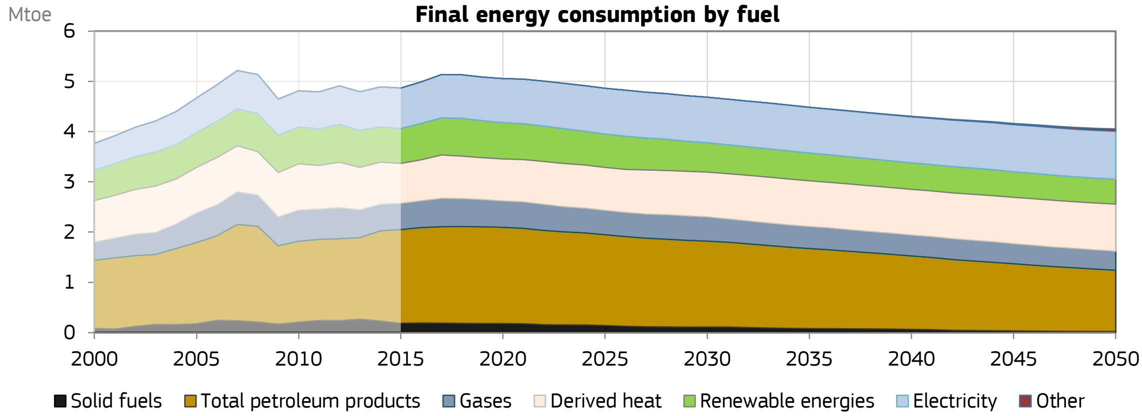
Evolution of carbon intensities



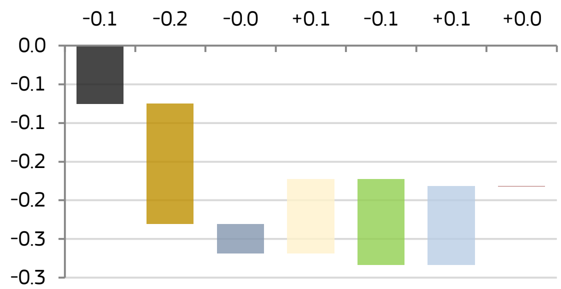
Evolution of CO2 emissions



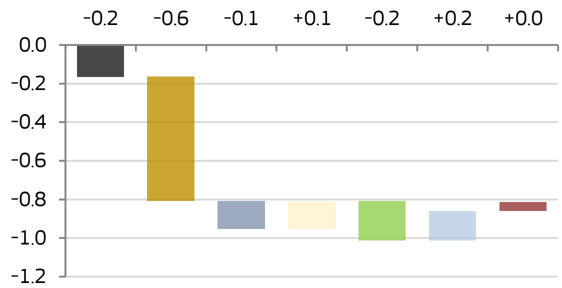
Final energy consumption by fuel

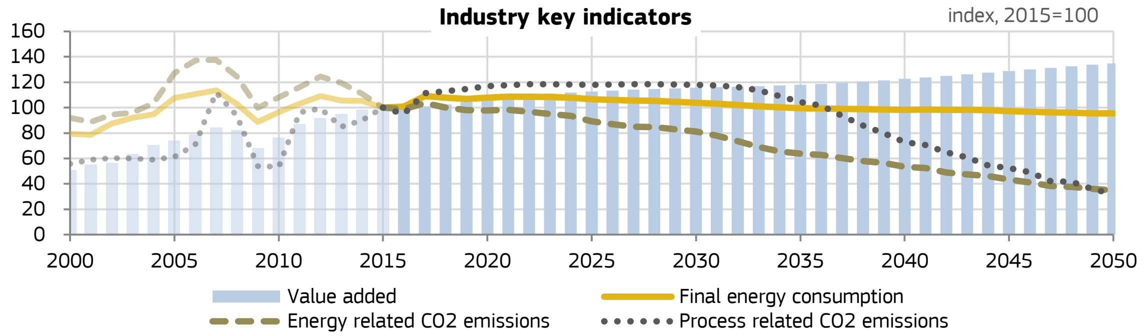


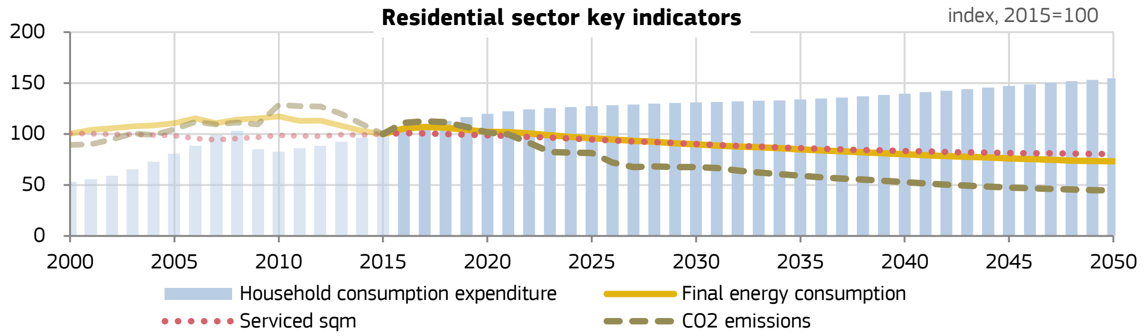
-0.2 Mtoe by 2030 from 2015 levels

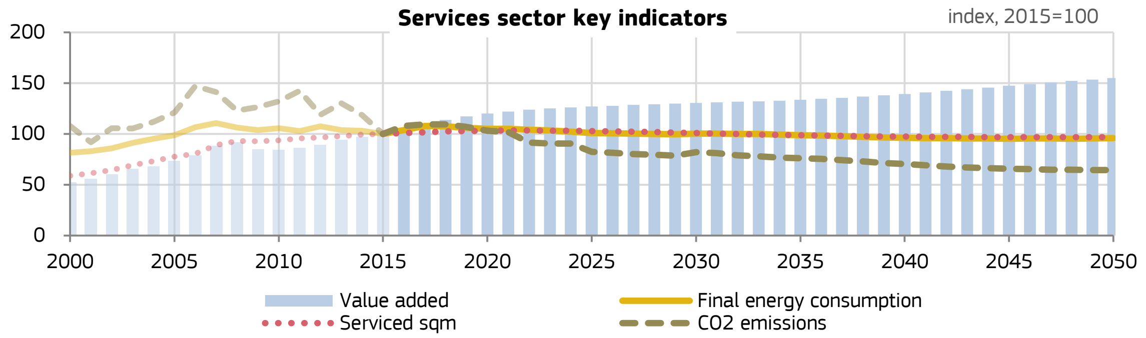


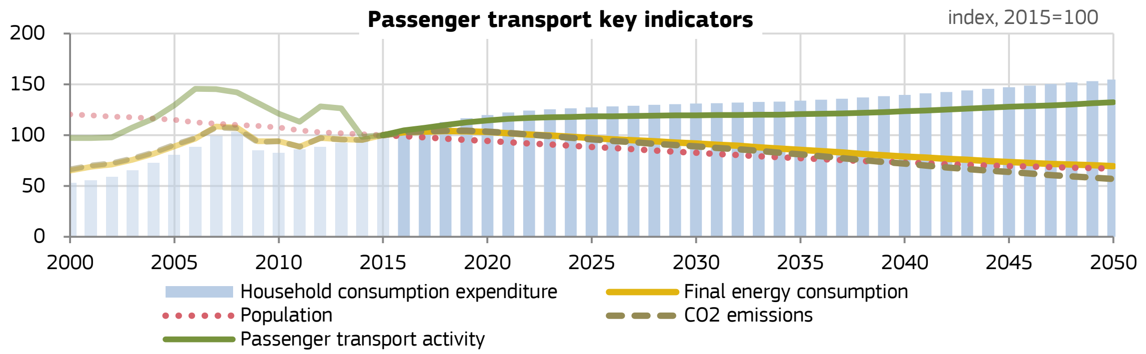
-0.8 Mtoe by 2050 from 2015 levels

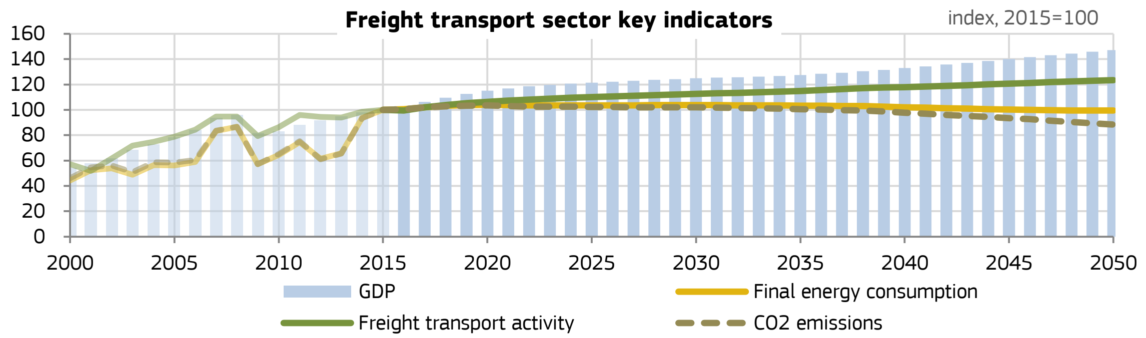


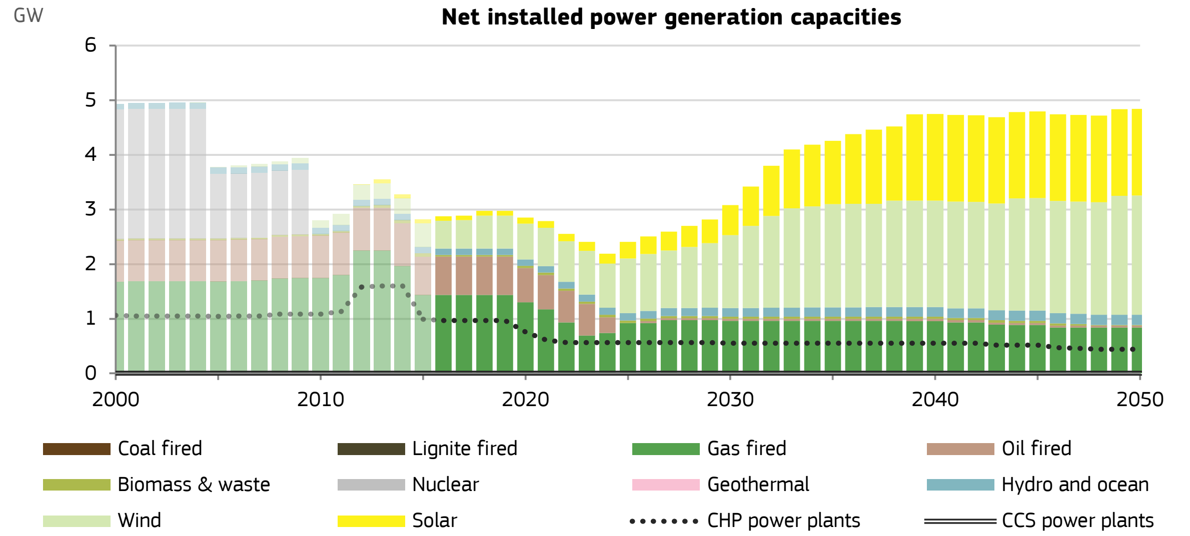

Industry key indicators
index, 2015=100
160
140
120
100
80
60
40
20
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

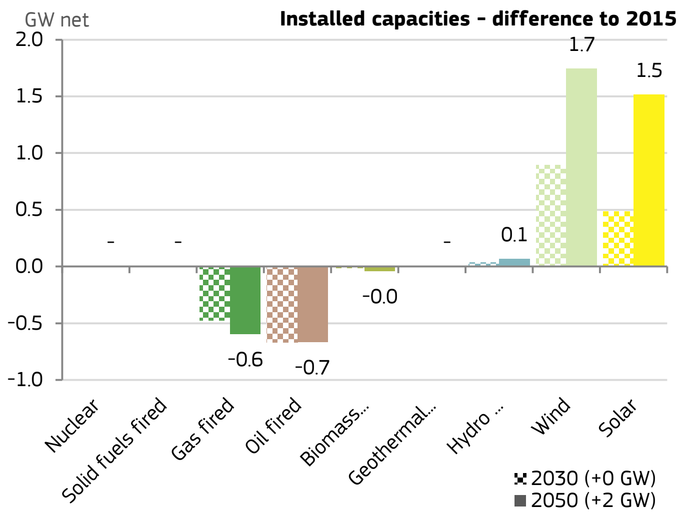

Residential sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

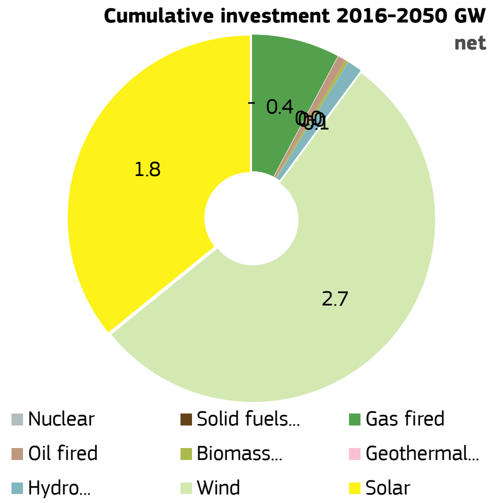

Services sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

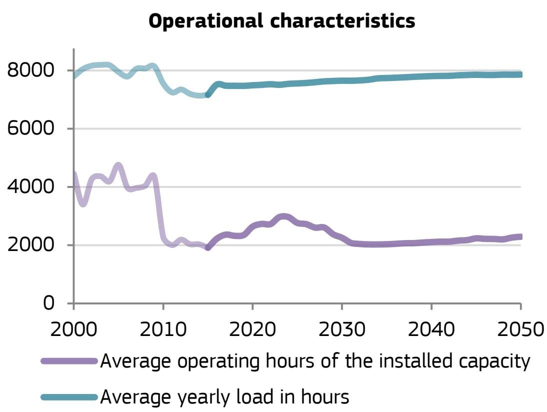

Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

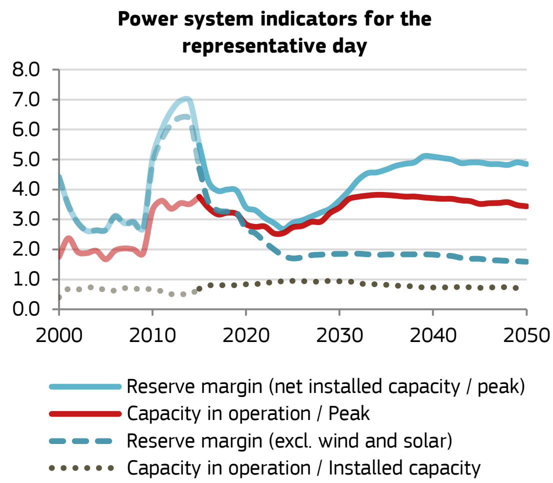

Freight transport sector key indicators
index, 2015=100
160
140
120
100
80
60
40
20
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

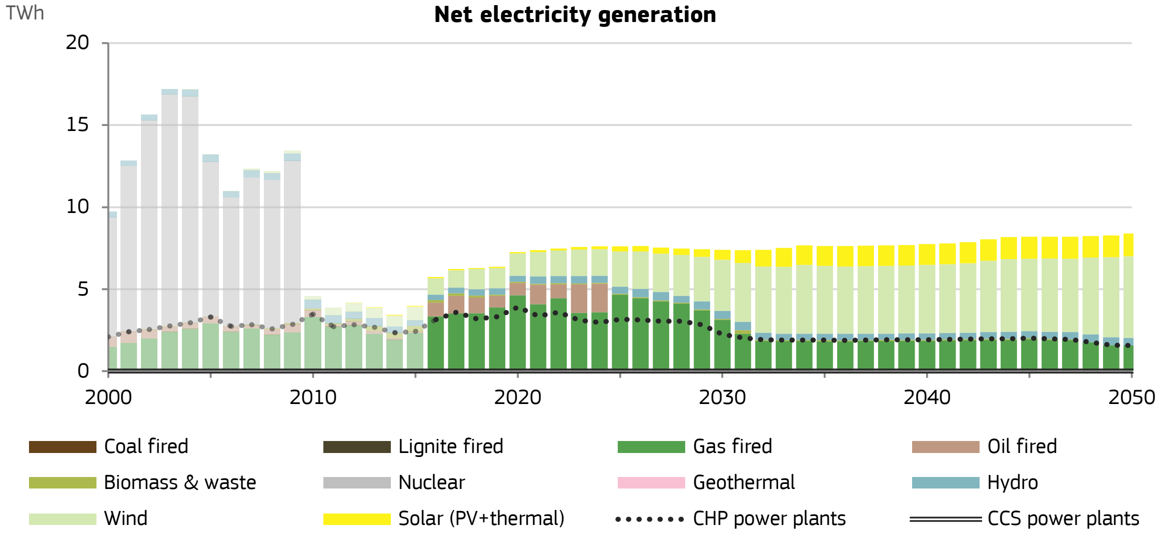

GW
Net installed power generation capacities
6
5
4
3
2
1
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants


GW net
Installed capacities - difference to 2015
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
1.7
1.5
0.1
-0.0
-0.6
-0.7
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+0 GW)
2050 (+2 GW)

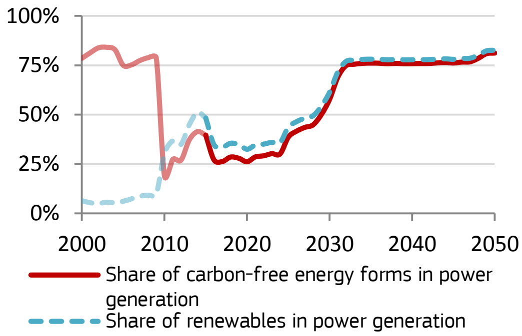

Cumulative investment 2016-2050 GW net
0.4
1.8
2.7
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar


Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

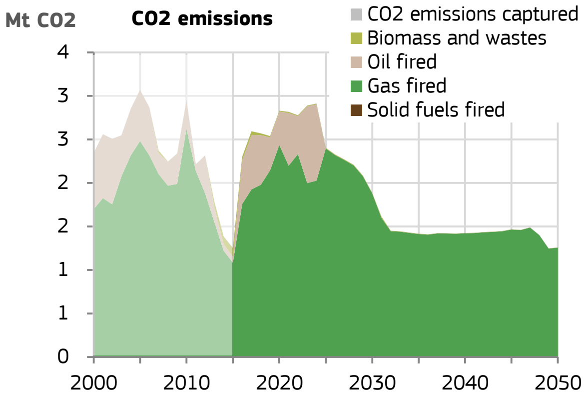

Power system indicators for the representative day
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity



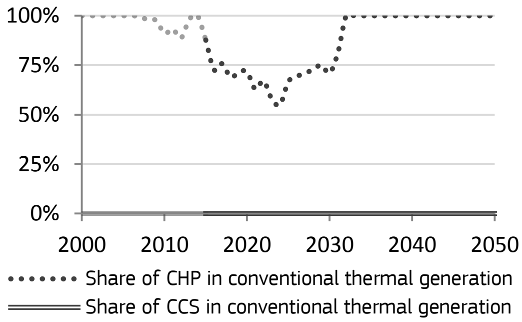
TWh
Net electricity generation
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants



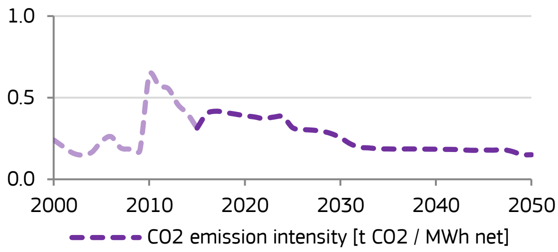
100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation



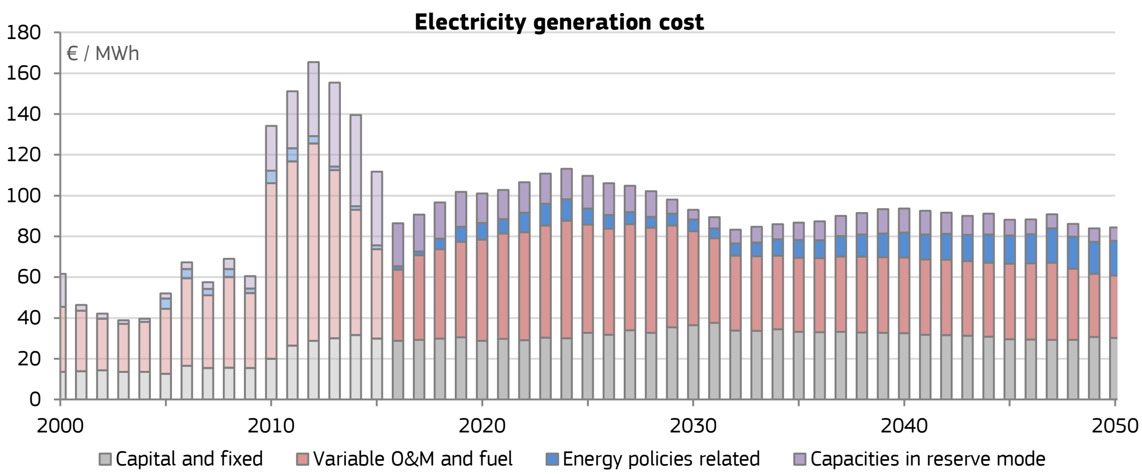
Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
4
3
3
2
2
1
1
0
2000
2010
2020
2030
2040
2050



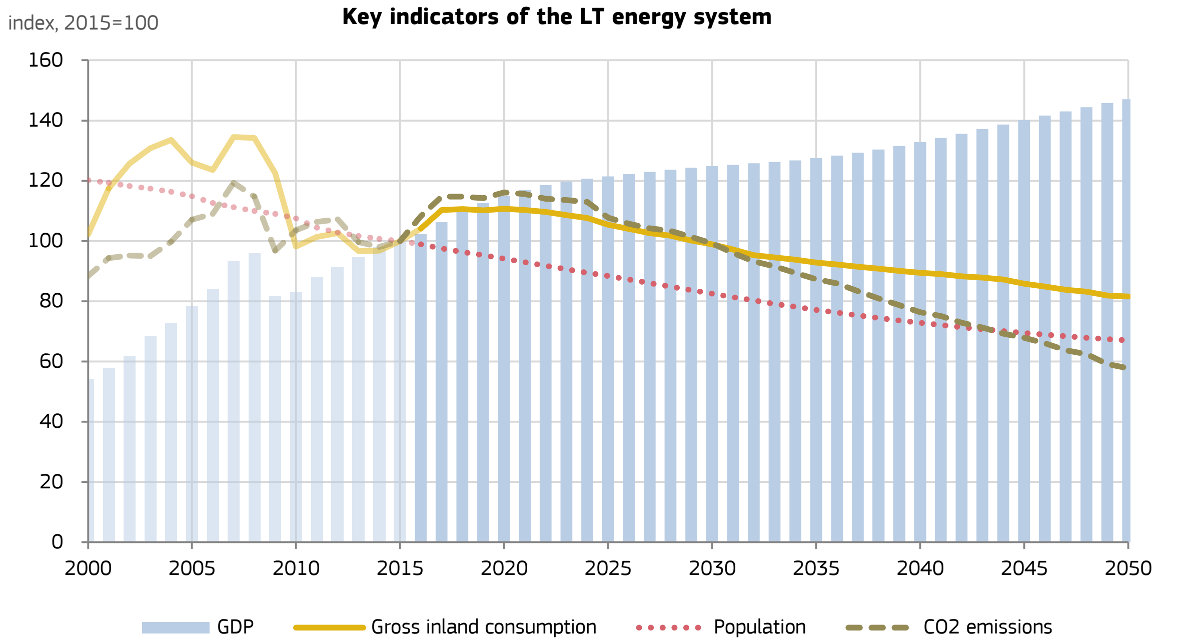
100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation



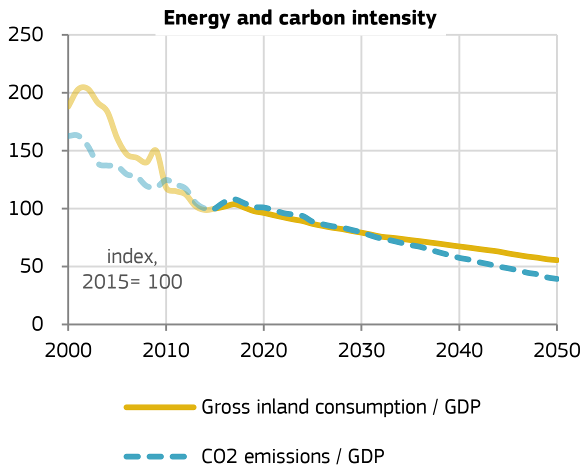
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]

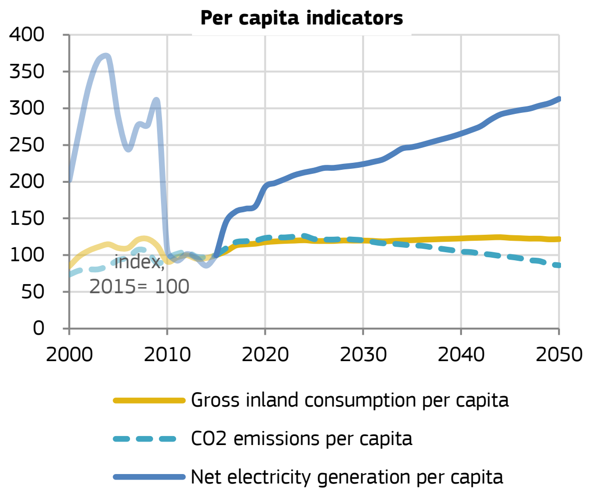


Electricity generation cost
€ / MWh
180
160
140
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



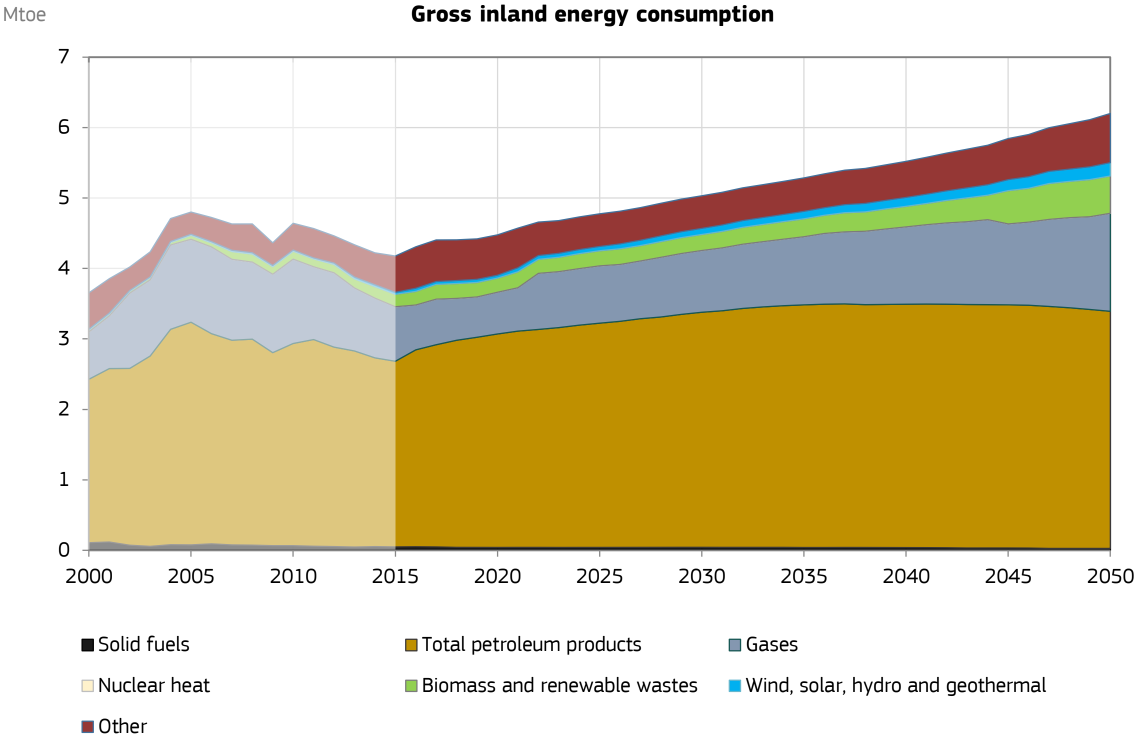
Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	9.7	4.7	4.9	5.1	4.7	4.1
Primary energy consumption [Mtoe]	15.1	8.0	5.8	6.3	5.5	4.5
RES [%] - Share of energy from renewable sources		18.3%	28.5%	27.1%	31.2%	40.1%
RES-E [%] - Share of electricity from renewable sources		3.7%	15.4%	16.5%	33.6%	50.4%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	36.1	14.4	13.5	15.6	13.3	7.8
reduction to 1990		*-60%*	*-63%*	*-57%*	*-63%*	*-78%*
Emissions in current ETS sectors |(LT) [Mt CO2]		8.5	6.8	8.8	7.5	3.6
reduction to 2005			*-20%*	*4%*	*-11%*	*-57%*
Emissions in current ESD sectors [Mt CO2]		5.9	6.6	6.8	5.8	4.2
reduction to 2005			*12%*	*14%*	*-2%*	*-30%*

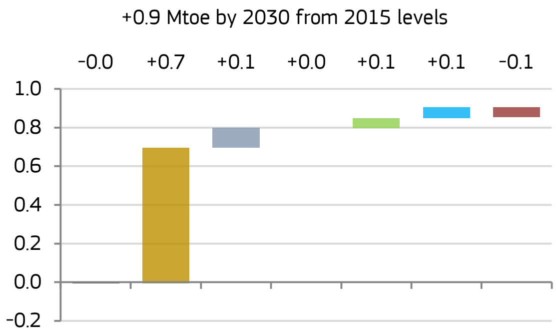


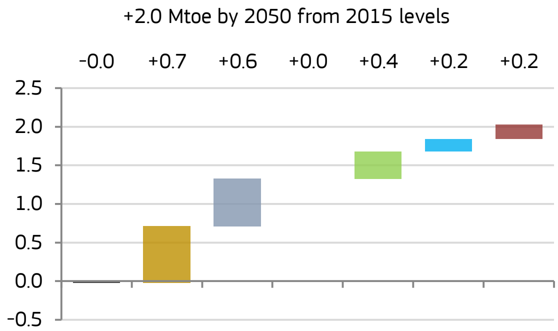


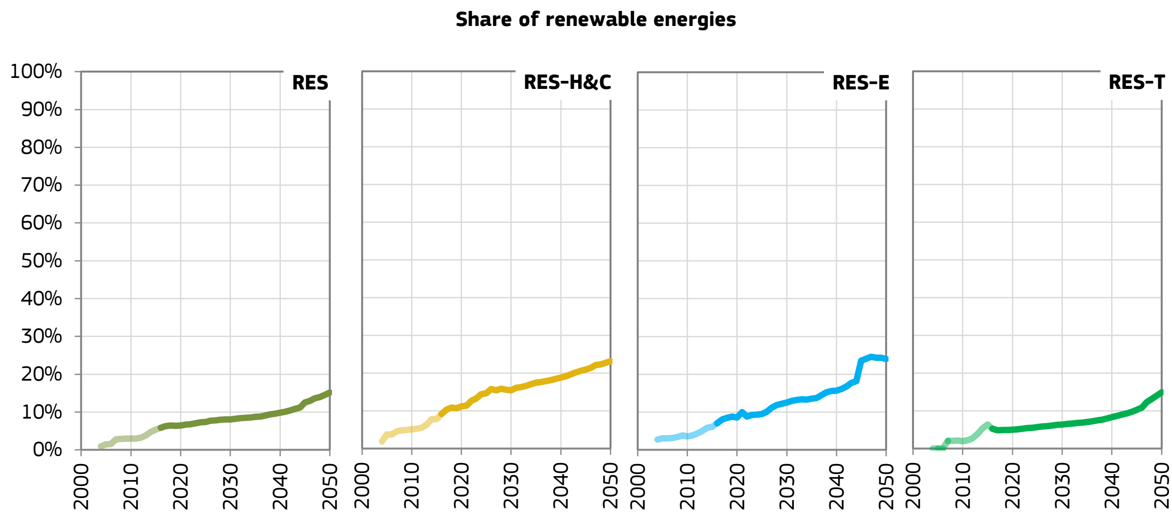
Luxembourg

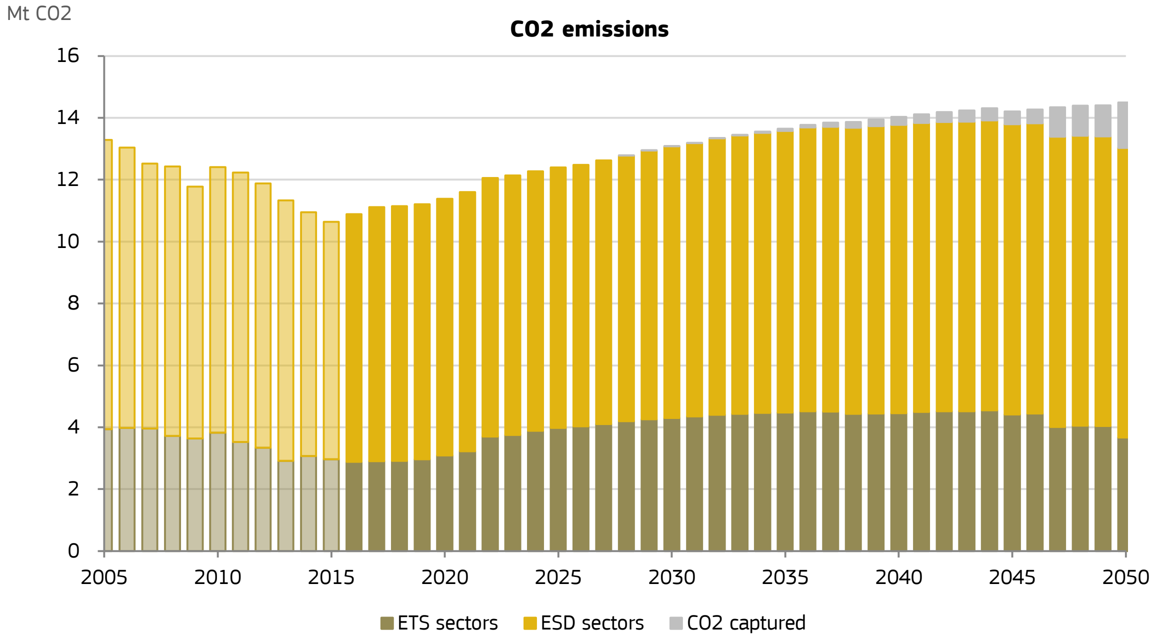
Central_2018 scenario

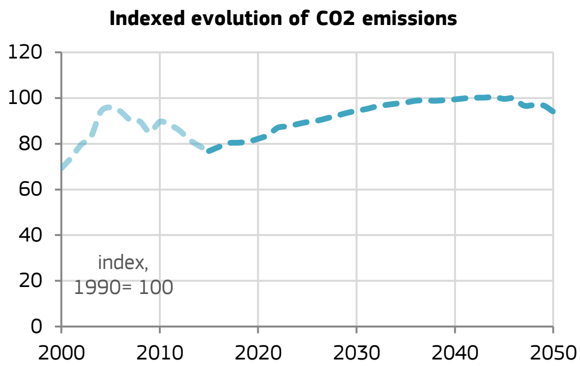

Mtoe
Gross inland energy consumption
7
6
5
4
3
2
1
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Nuclear heat
Biomass and renewable wastes
Wind, solar, hydro and geothermal
Other

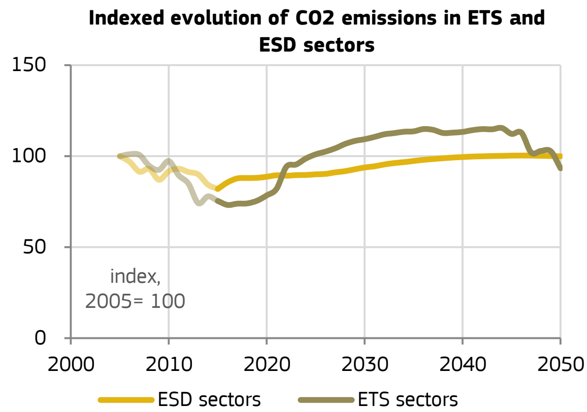

+0.9 Mtoe by 2030 from 2015 levels
-0.0
+0.7
+0.1
+0.0
+0.1
+0.1
-0.1
1.0
0.8
0.6
0.4
0.2
0.0
-0.2

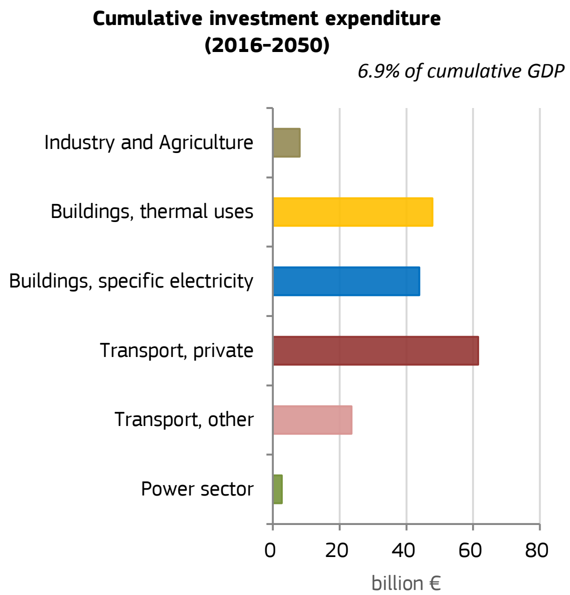

+2.0 Mtoe by 2050 from 2015 levels
-0.0
+0.7
+0.6
+0.0
+0.4
+0.2
+0.2
2.5
2.0
1.5
1.0
0.5
0.0
-0.5

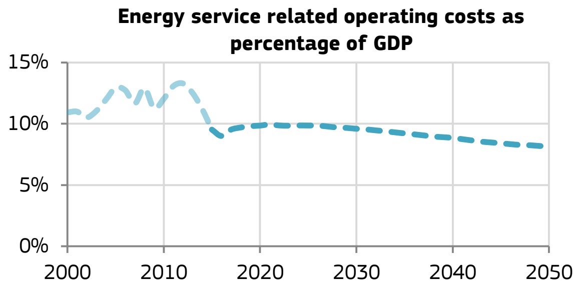

Share of renewable energies
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RES
RES-H&C
RES-E
RES-T
2000
2010
2020
2030
2040
2050

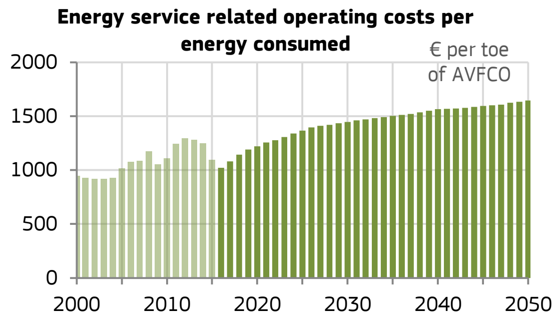

CO2 emissions
Mt CO2
16
14
12
10
8
6
4
2
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured

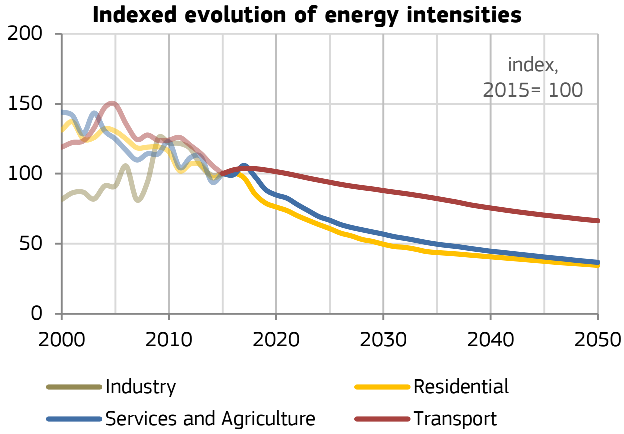

Indexed evolution of CO2 emissions
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

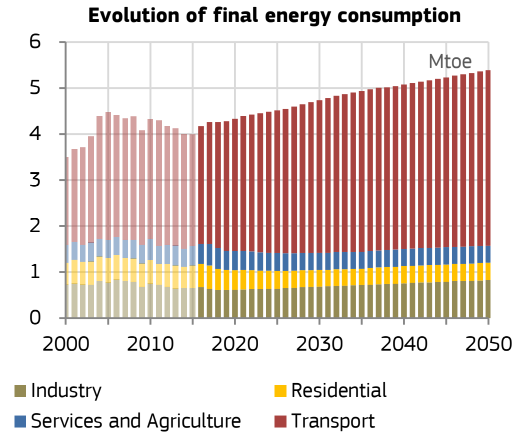

Indexed evolution of CO2 emissions in ETS and ESD sectors
150
100
50
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors

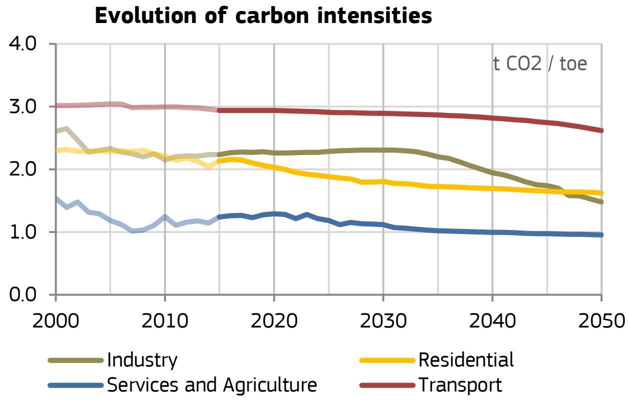

Cumulative investment expenditure (2016-2050)
6.9% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
20
40
60
80
billion €

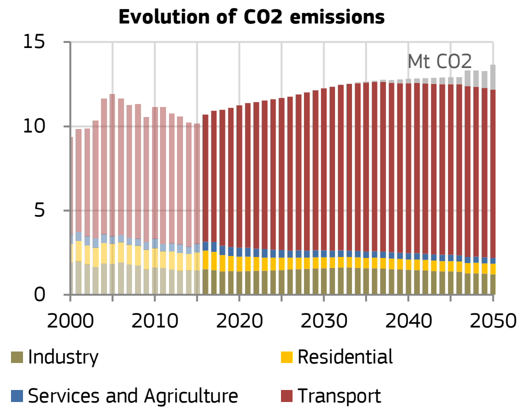

Energy service related operating costs as percentage of GDP
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050

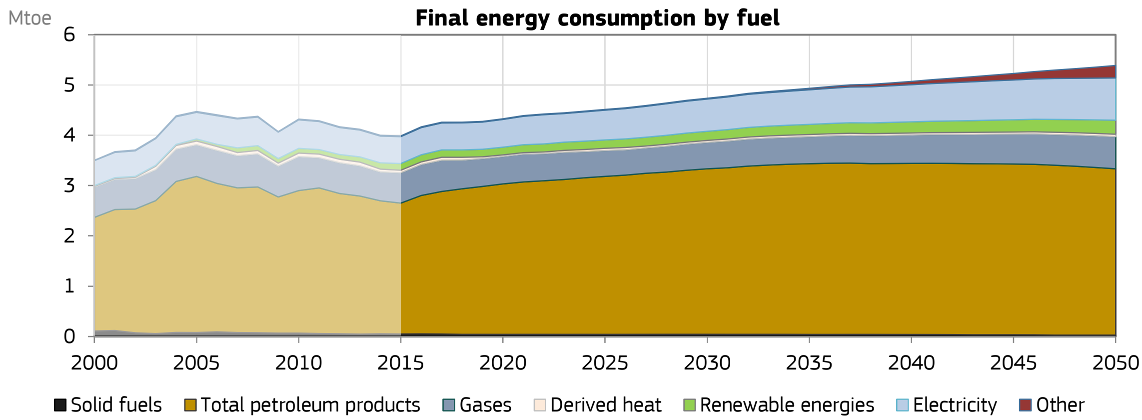

Energy service related operating costs per energy consumed
€ per toe of AVFCO
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

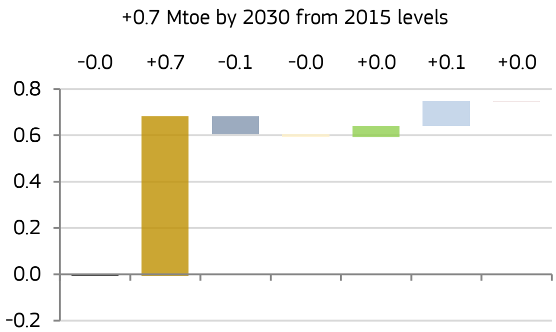

Indexed evolution of energy intensities
index, 2015= 100
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

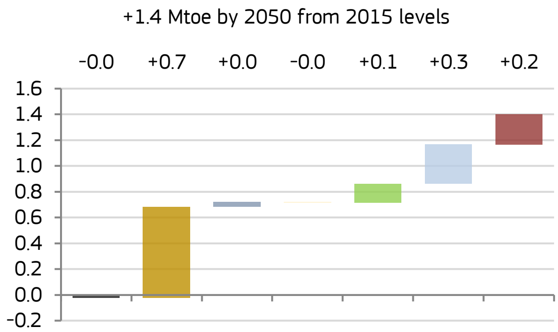

Evolution of final energy consumption
Mtoe
6
5
4
3
2
1
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

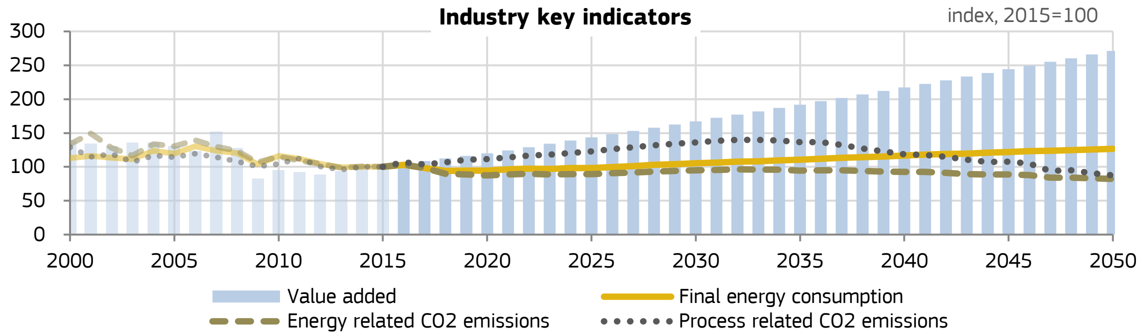

Evolution of carbon intensities
t CO2 / toe
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

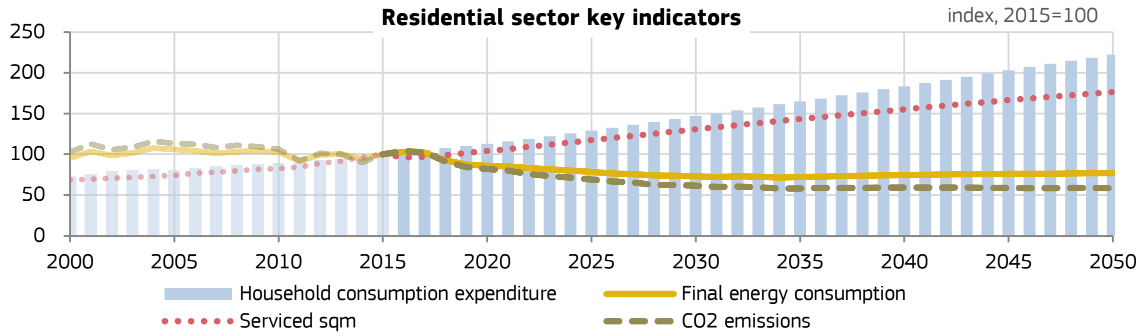

Evolution of CO2 emissions
Mt CO2
15
10
5
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

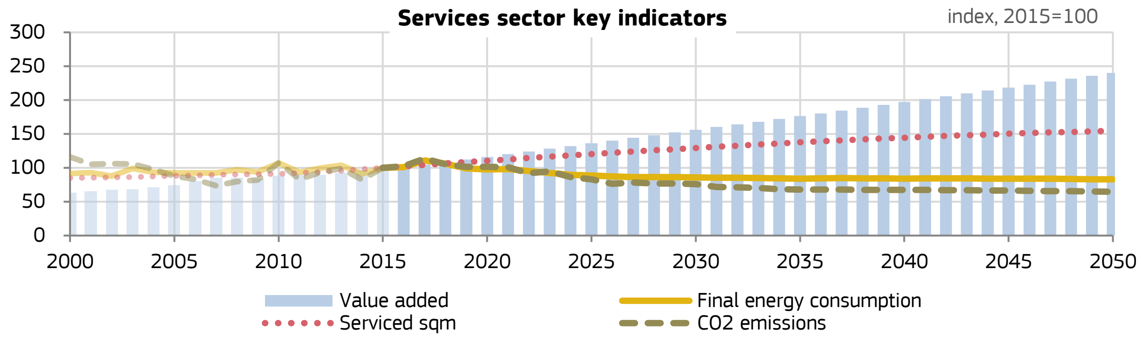

Final energy consumption by fuel
Mtoe
6
5
4
3
2
1
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

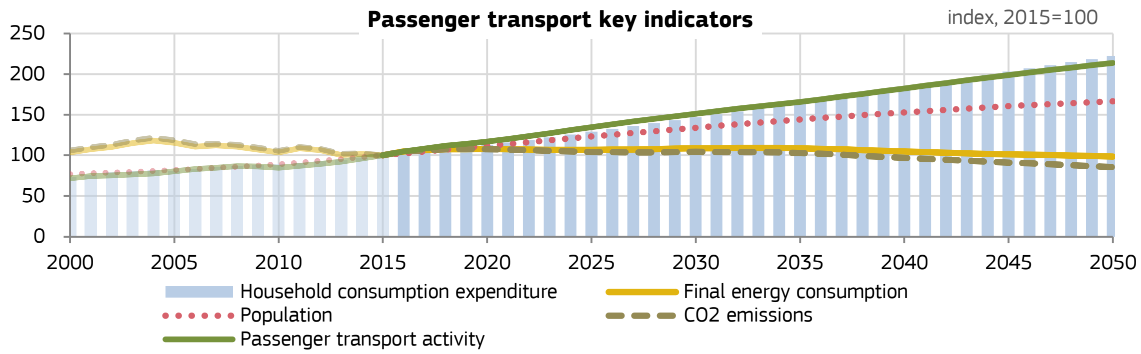

+0.7 Mtoe by 2030 from 2015 levels
-0.0
+0.7
-0.1
-0.0
+0.0
+0.1
+0.0
0.8
0.6
0.4
0.2
0.0
-0.2

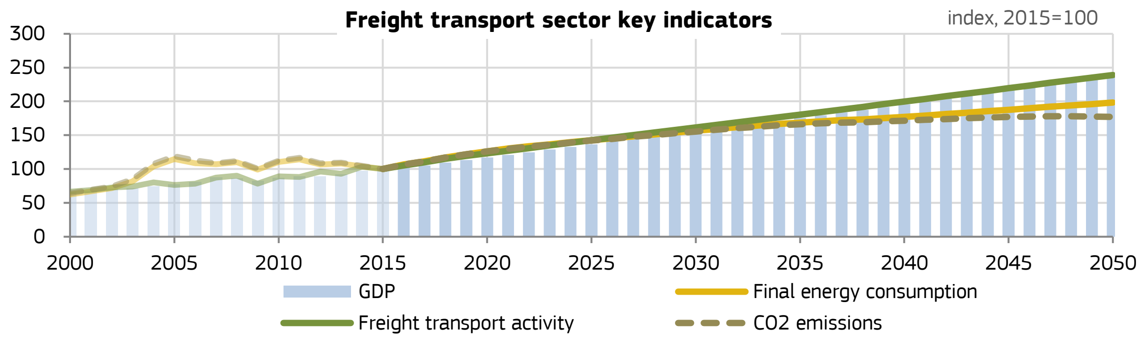

+1.4 Mtoe by 2050 from 2015 levels
-0.0
+0.7
+0.0
-0.0
+0.1
+0.3
+0.2
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2

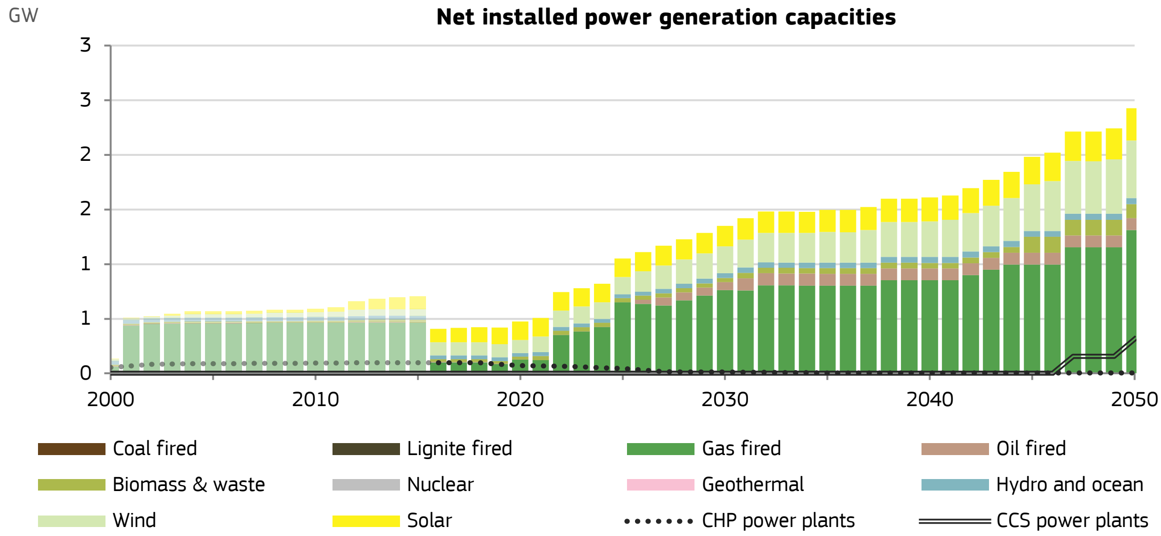

Industry key indicators
index, 2015=100
300
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

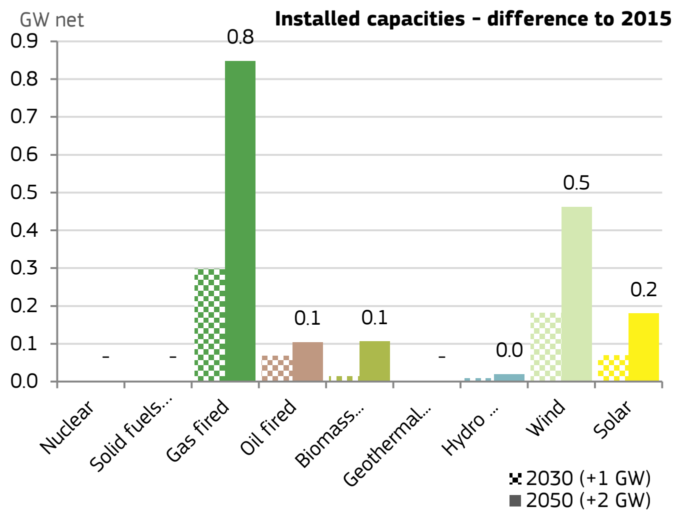

Residential sector key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

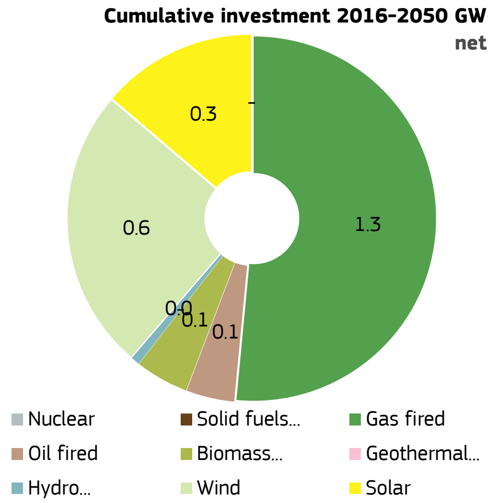

Services sector key indicators
index, 2015=100
300
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

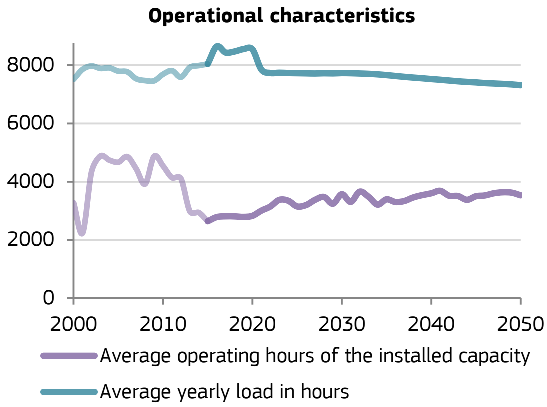

Passenger transport key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

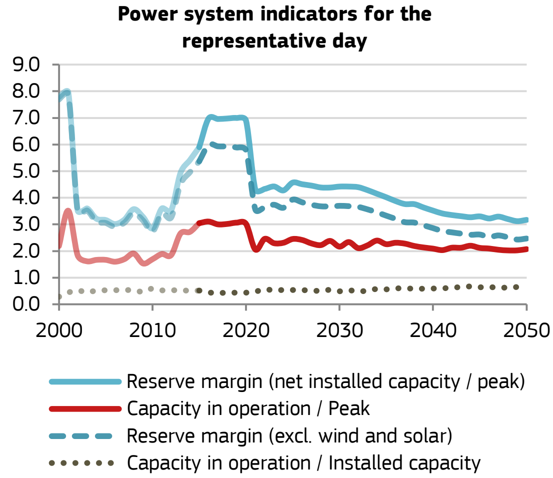

Freight transport sector key indicators
index, 2015=100
300
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

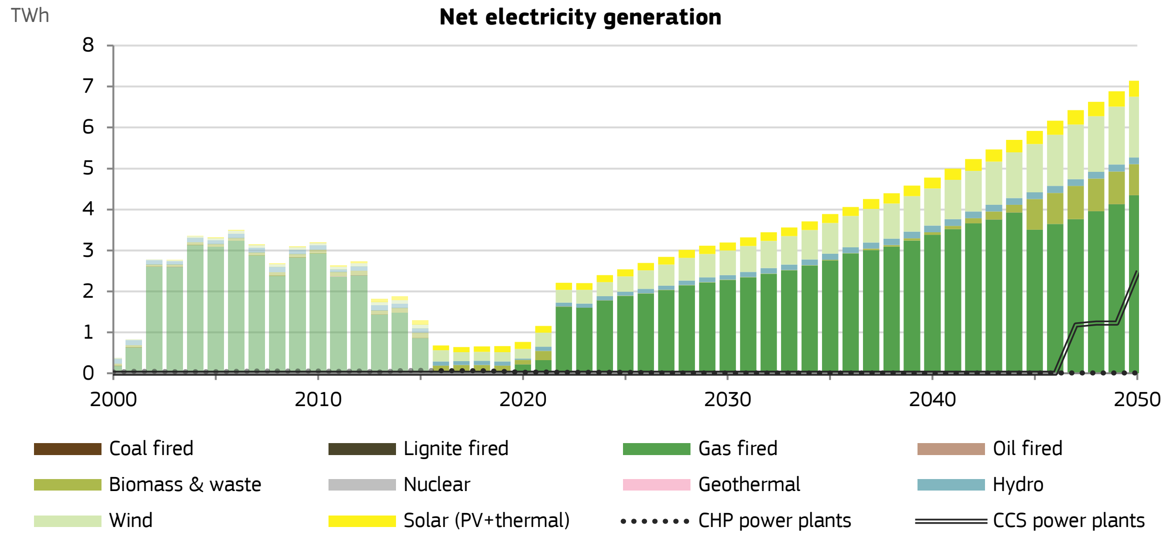

GW
Net installed power generation capacities
3
3
2
2
1
1
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants


GW net
Installed capacities - difference to 2015
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.8
0.1
0.1
0.0
0.5
0.2
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+1 GW)
2050 (+2 GW)

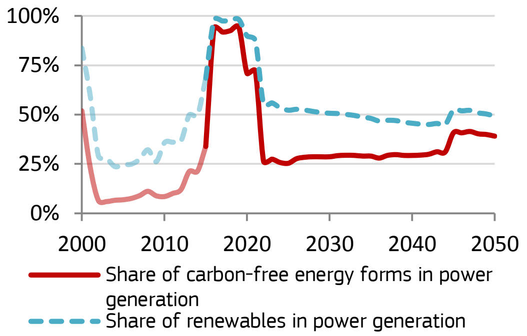

Cumulative investment 2016-2050 GW net
0.3
0.6
1.3
0.0
0.1
0.1
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar


Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

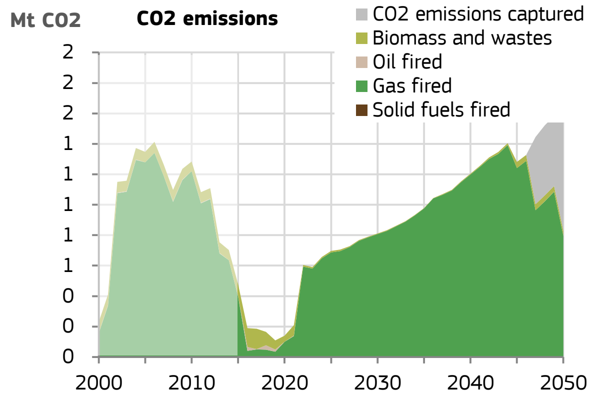

Power system indicators for the representative day
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity



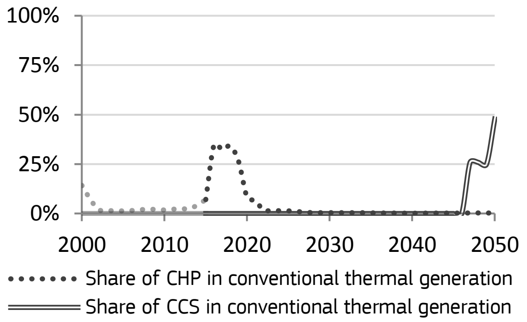
TWh
Net electricity generation
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants



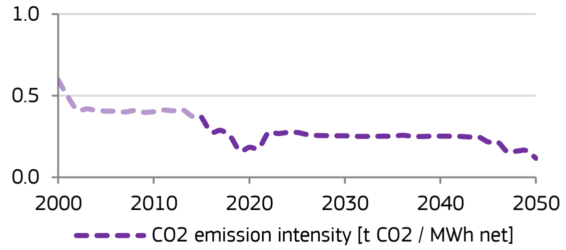
Share of carbon-free energy forms in power generation
Share of renewables in power generation



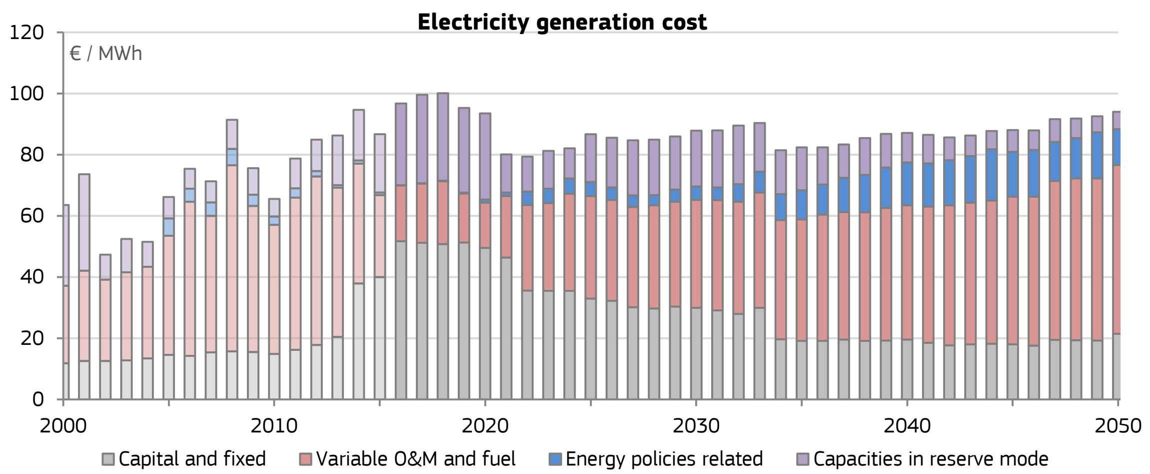
Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired



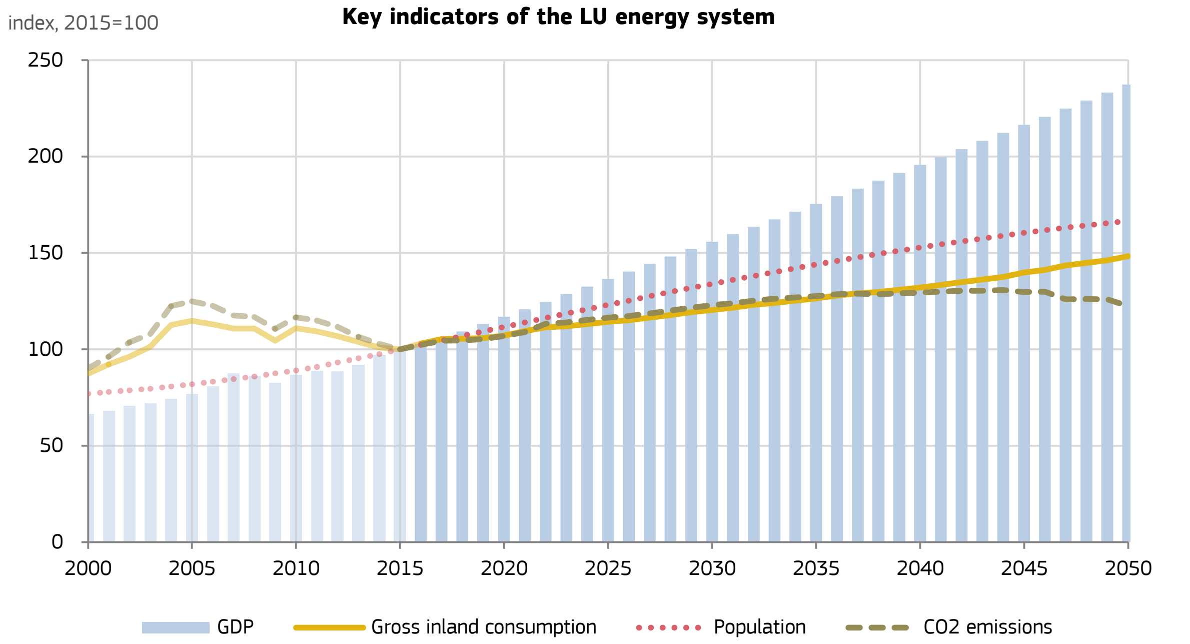
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation



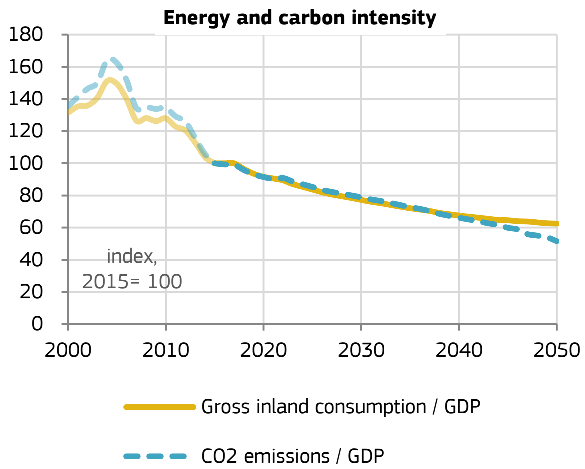
CO2 emission intensity [t CO2 / MWh net]

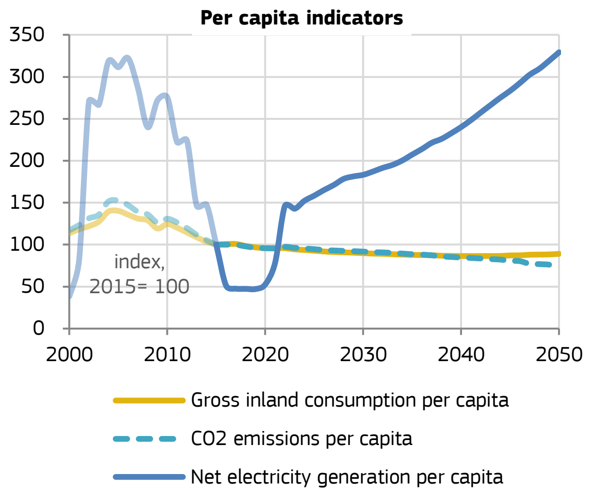


Electricity generation cost
€ / MWh
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	3.3	4.5	4.0	4.3	4.7	5.4
Primary energy consumption [Mtoe]	3.5	4.8	4.1	4.4	5.0	6.1
RES [%] - Share of energy from renewable sources		1.4%	5.3%	6.4%	8.0%	15.1%
RES-E [%] - Share of electricity from renewable sources		3.0%	6.1%	8.5%	12.5%	24.0%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	13.9	13.3	10.6	11.4	13.1	13.0
reduction to 1990		*-4%*	*-23%*	*-18%*	*-6%*	*-6%*
Emissions in current ETS sectors |(LU) [Mt CO2]		3.9	3.0	3.1	4.3	3.7
reduction to 2005			*-25%*	*-22%*	*9%*	*-7%*
Emissions in current ESD sectors [Mt CO2]		9.4	7.7	8.3	8.8	9.4
reduction to 2005			*-18%*	*-11%*	*-6%*	*0%*

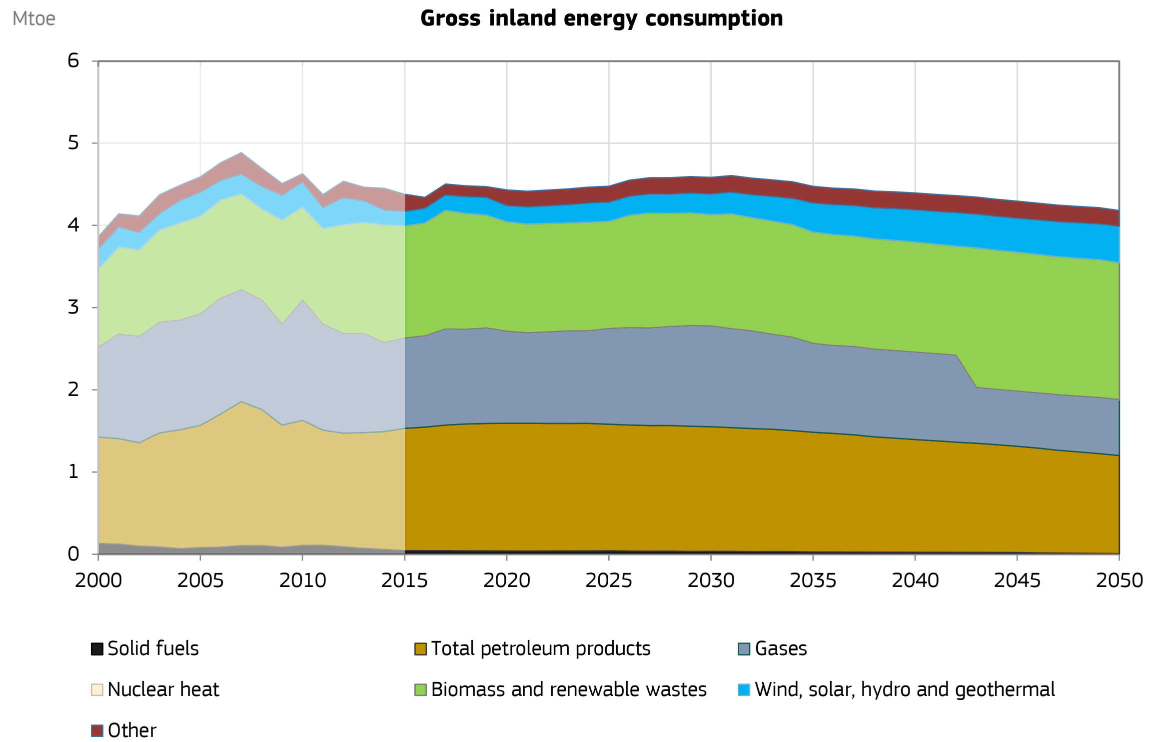


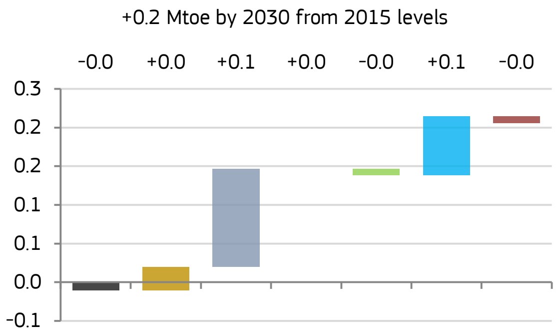


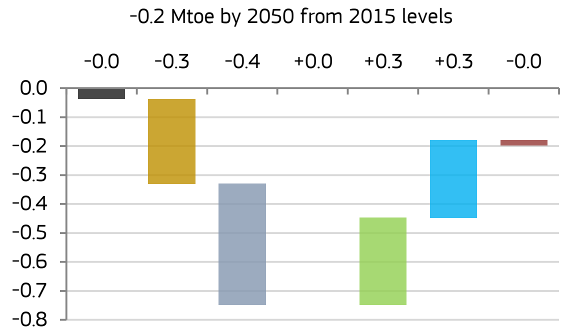
POTEnCIA - Model results overview

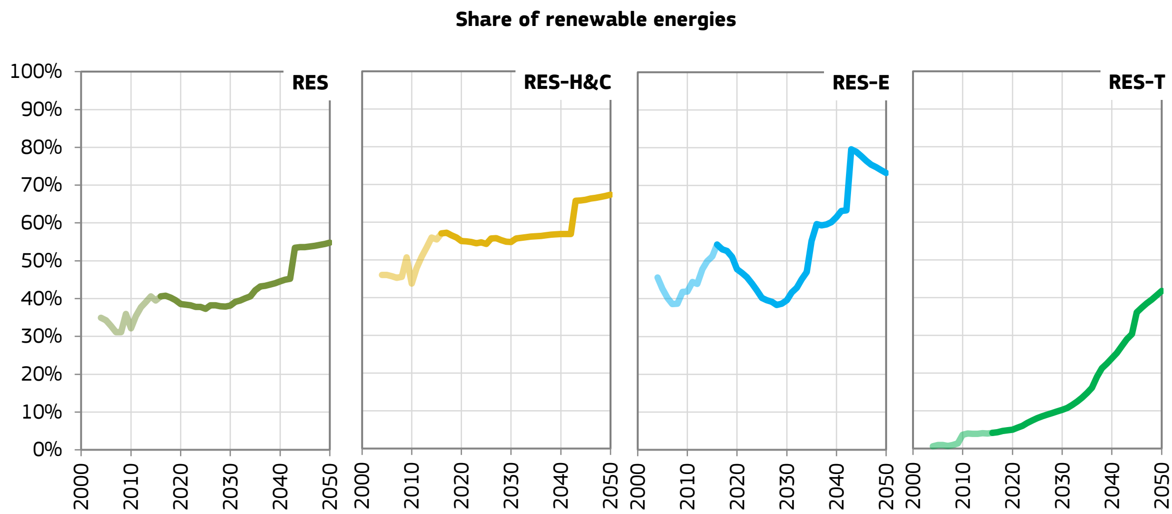
Latvia

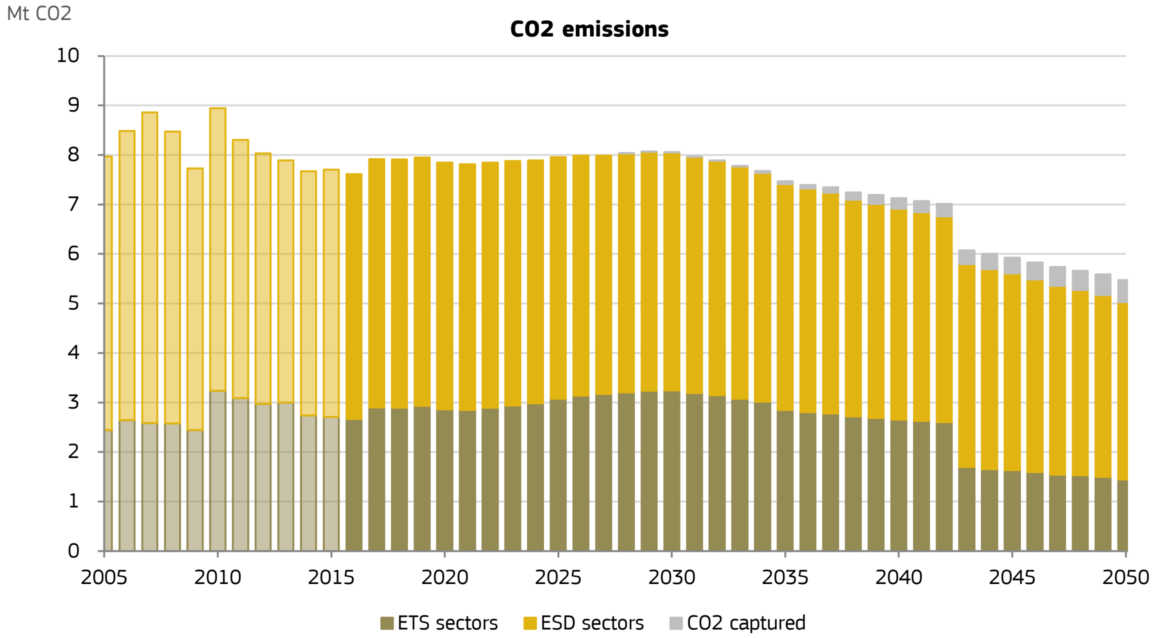
Central_2018 scenario

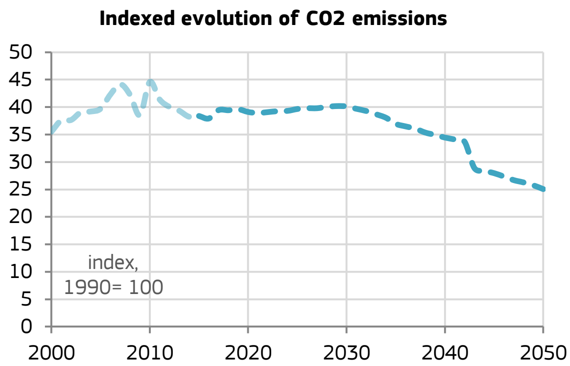

Mtoe
Gross inland energy consumption
6
5
4
3
2
1
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Nuclear heat
Biomass and renewable wastes
Wind, solar, hydro and geothermal
Other

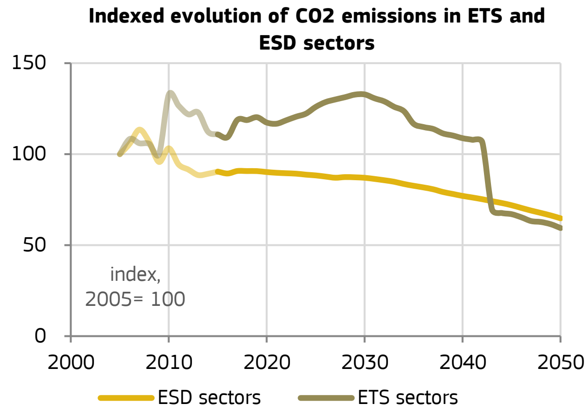

+0.2 Mtoe by 2030 from 2015 levels
-0.0
+0.0
+0.1
+0.0
-0.0
+0.1
-0.0
0.3
0.2
0.2
0.1
0.1
0.0
-0.1

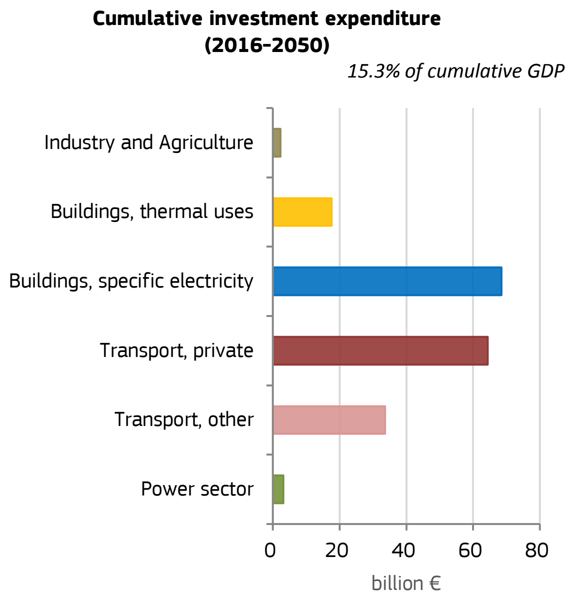

-0.2 Mtoe by 2050 from 2015 levels
-0.0
-0.3
-0.4
+0.0
+0.3
+0.3
-0.0
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8

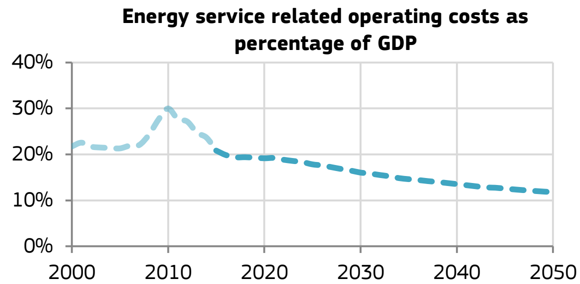

Share of renewable energies
RES
RES-H&C
RES-E
RES-T
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2000
2010
2020
2030
2040
2050

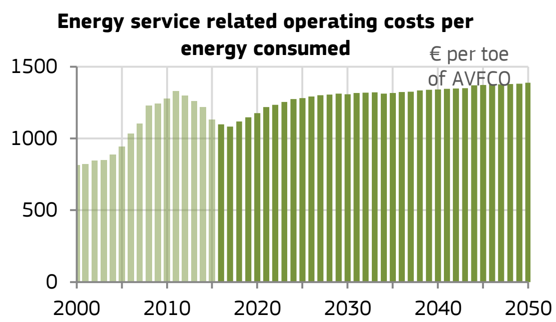

CO2 emissions
Mt CO2
10
9
8
7
6
5
4
3
2
1
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured

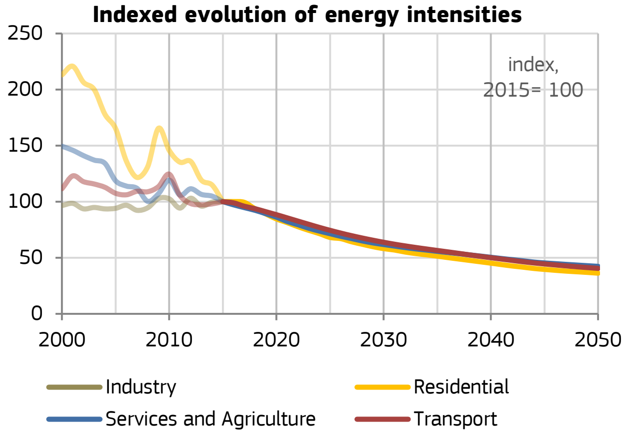

Indexed evolution of CO2 emissions
50
45
40
35
30
25
20
15
10
5
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

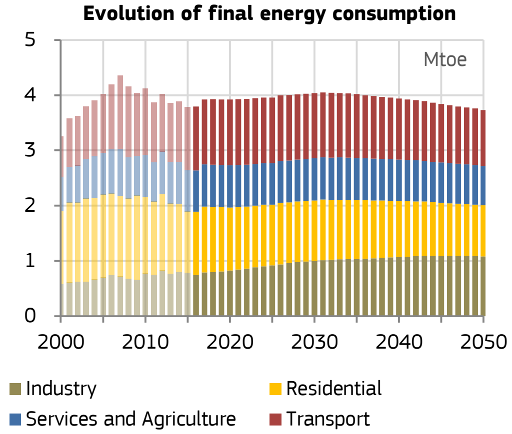

Indexed evolution of CO2 emissions in ETS and ESD sectors
150
100
50
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors

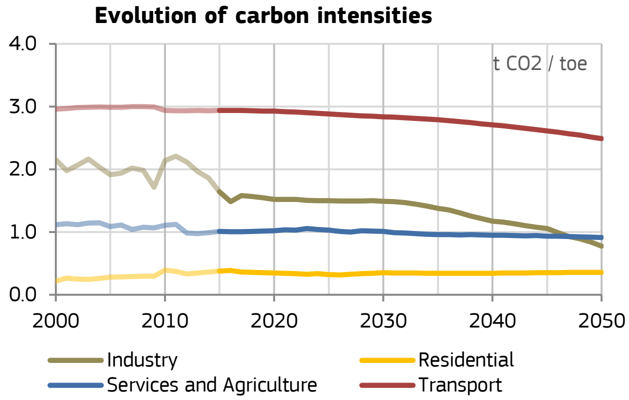

Cumulative investment expenditure (2016-2050)
15.3% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
20
40
60
80
billion €

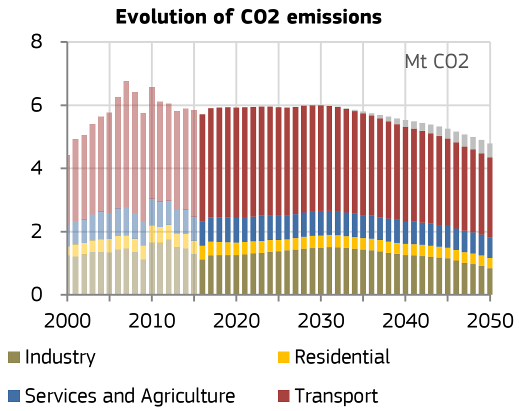

Energy service related operating costs as percentage of GDP
40%
30%
20%
10%
0%
2000
2010
2020
2030
2040
2050

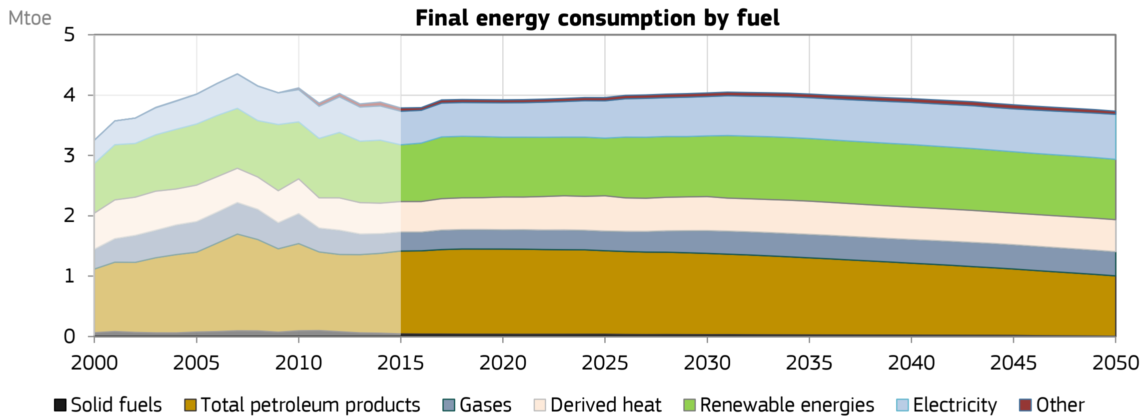

Energy service related operating costs per energy consumed
€ per toe of AVFECO
1500
1000
500
0
2000
2010
2020
2030
2040
2050

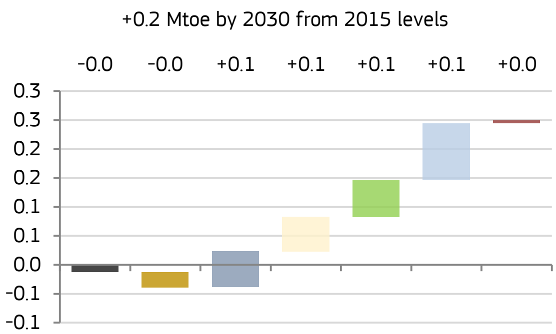

Indexed evolution of energy intensities
index,
2015= 100
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

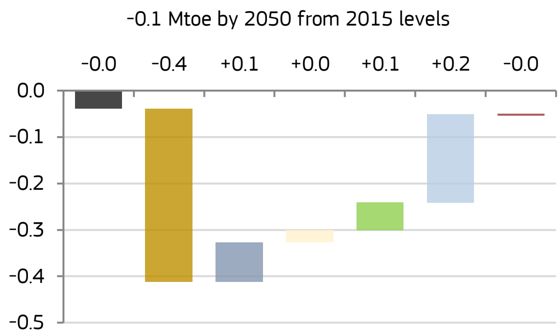

Evolution of final energy consumption
Mtoe
5
4
3
2
1
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

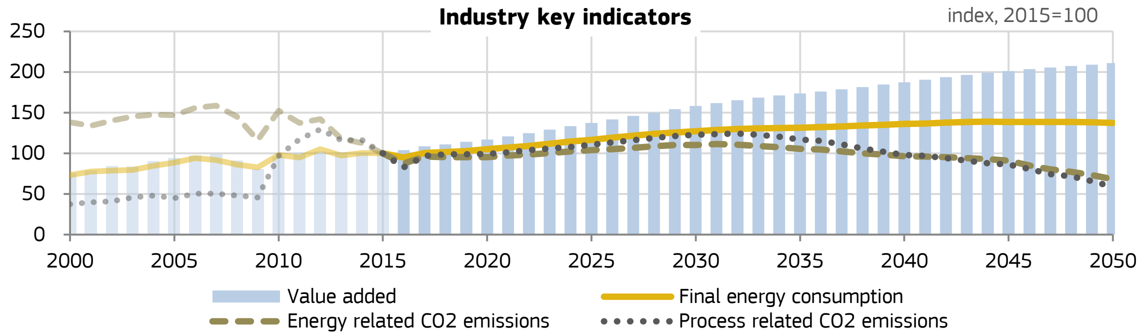

Evolution of carbon intensities
t CO2 / toe
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

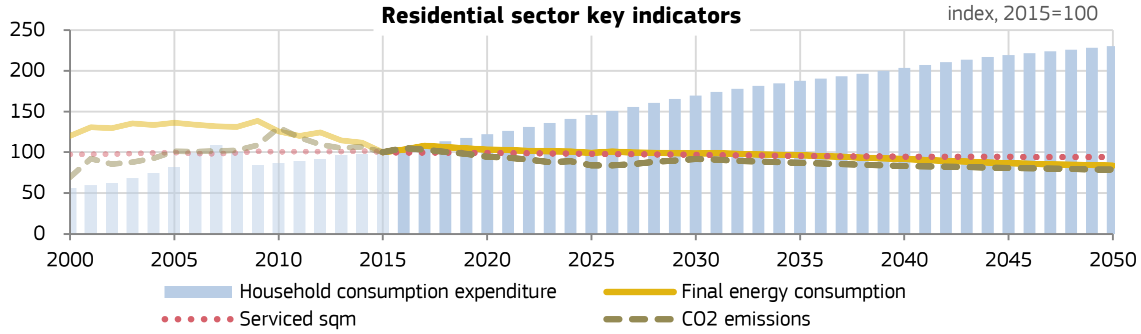

Evolution of CO2 emissions
Mt CO2
8
6
4
2
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

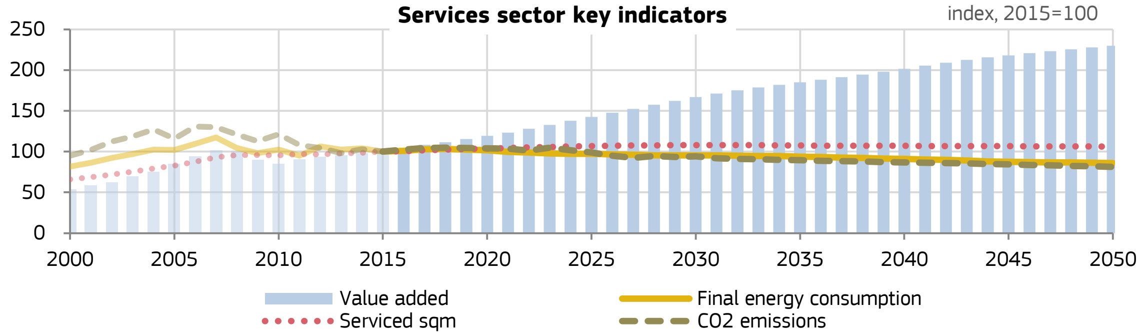

Mtoe
Final energy consumption by fuel
5
4
3
2
1
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

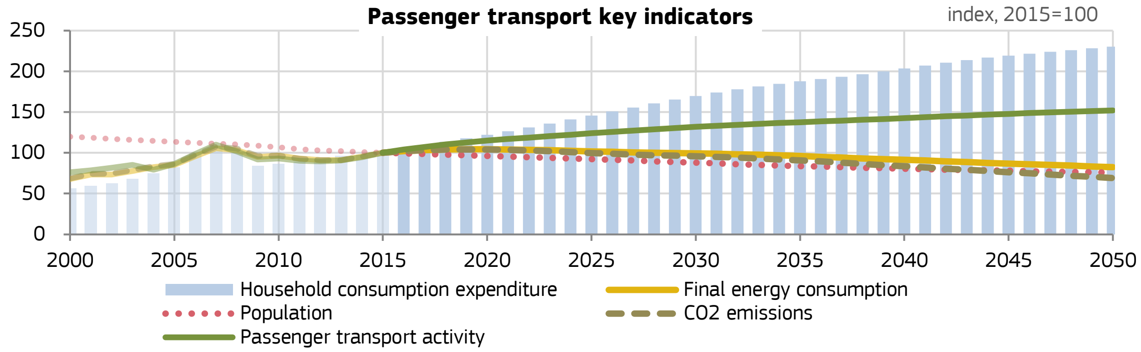

+0.2 Mtoe by 2030 from 2015 levels
-0.0
-0.0
+0.1
+0.1
+0.1
+0.1
+0.0
0.3
0.3
0.2
0.2
0.1
0.1
0.0
-0.1
-0.1

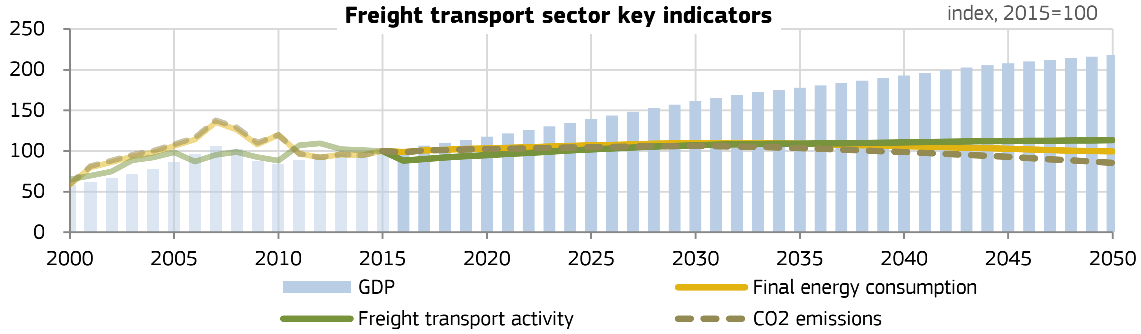

-0.1 Mtoe by 2050 from 2015 levels
-0.0
-0.4
+0.1
+0.0
+0.1
+0.2
-0.0
0.0
-0.1
-0.2
-0.3
-0.4
-0.5

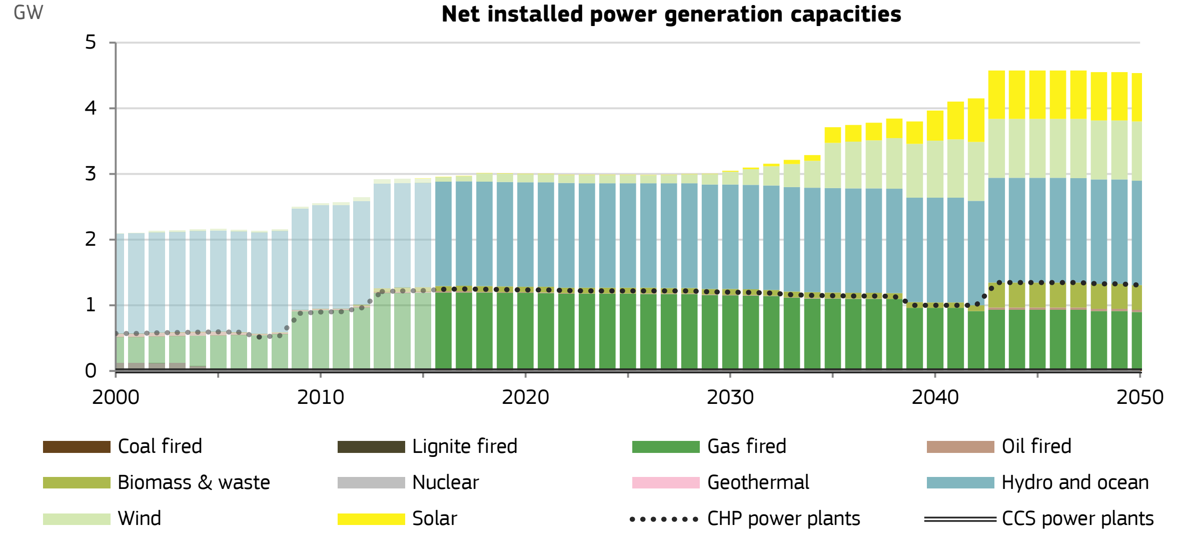

Industry key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

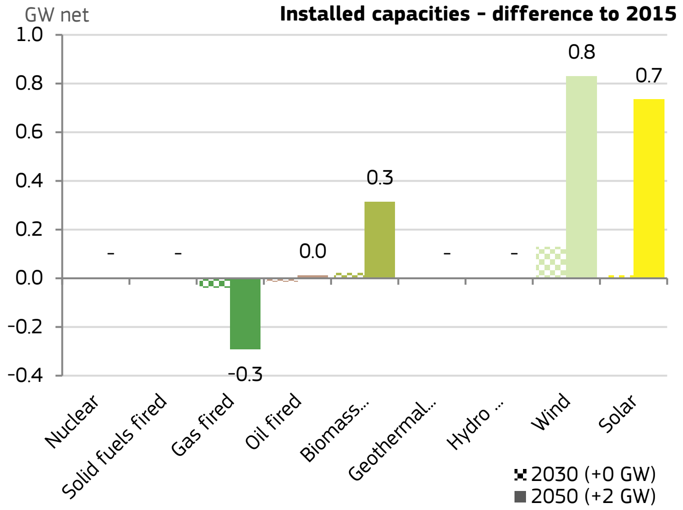

Residential sector key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

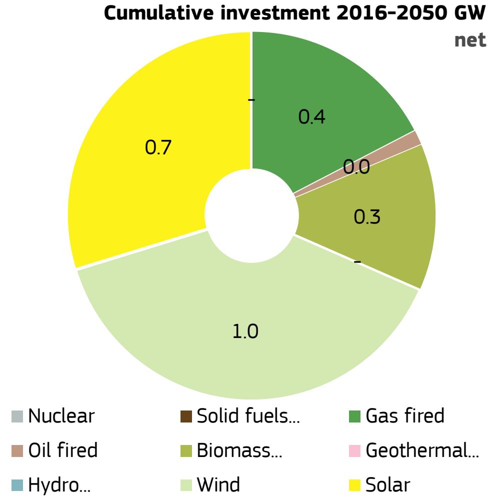

Services sector key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

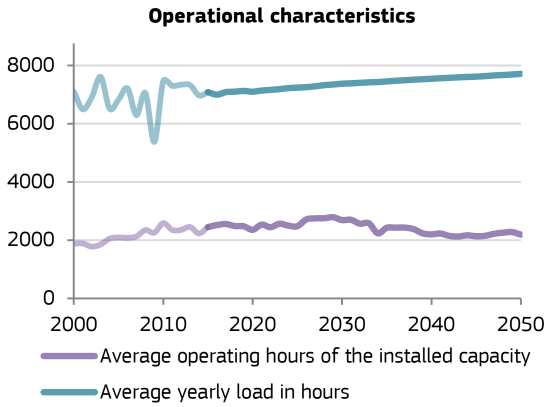

Passenger transport key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

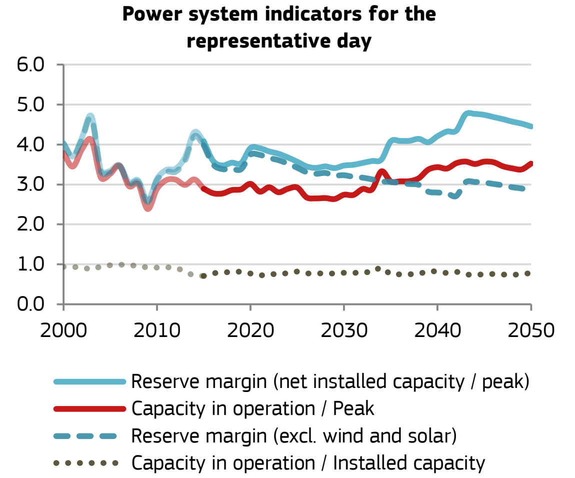

Freight transport sector key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

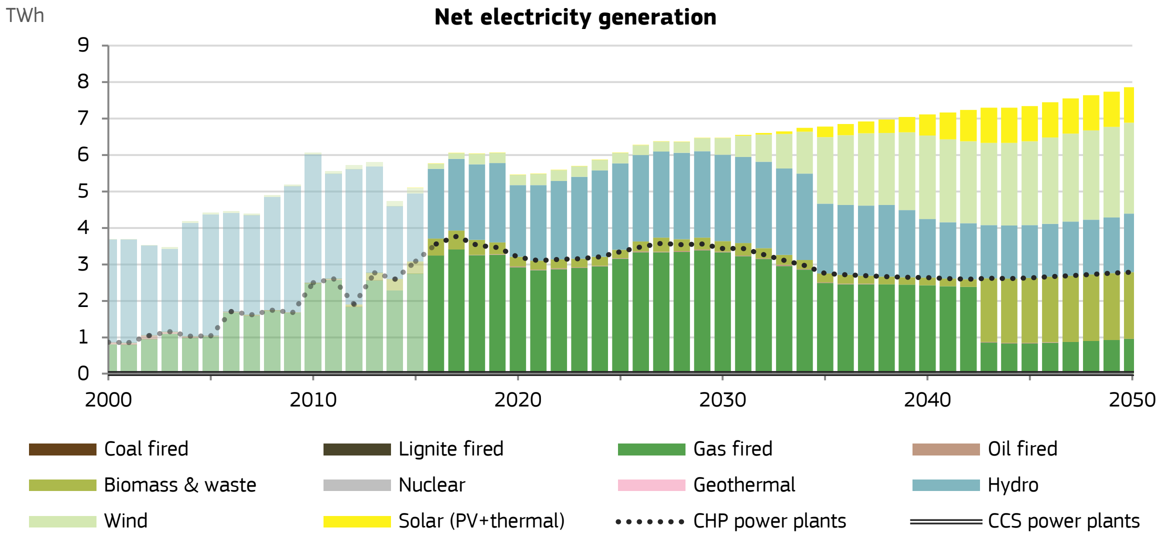

Net installed power generation capacities
GW
5
4
3
2
1
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

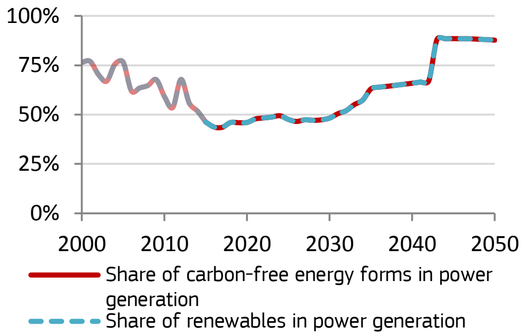

Installed capacities - difference to 2015
GW net
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
0.8
0.7
0.3
0.0
-0.3
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+0 GW)
2050 (+2 GW)

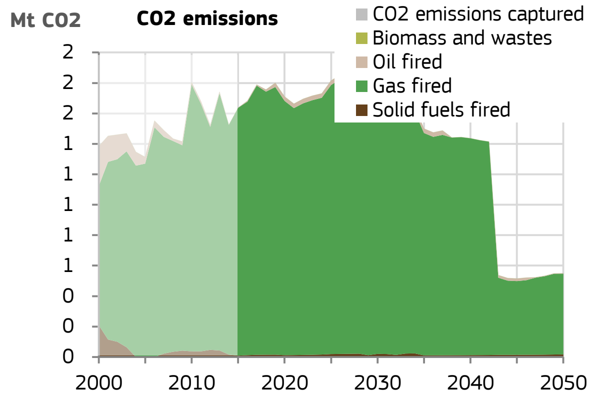

Cumulative investment 2016-2050 GW net
0.4
0.0
0.3
1.0
0.7
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

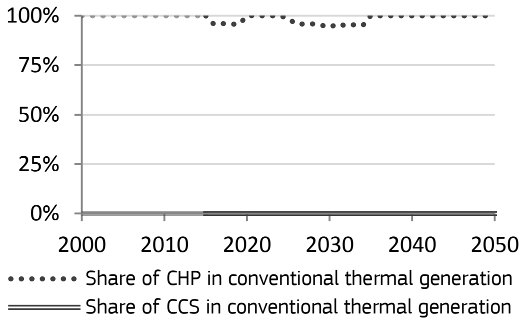

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

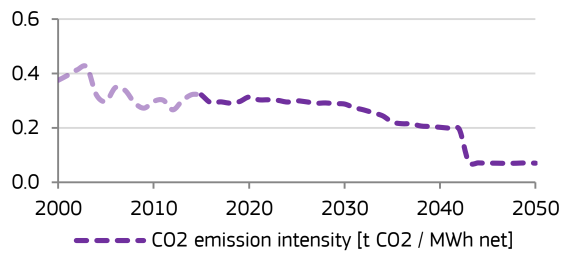

Power system indicators for the representative day
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

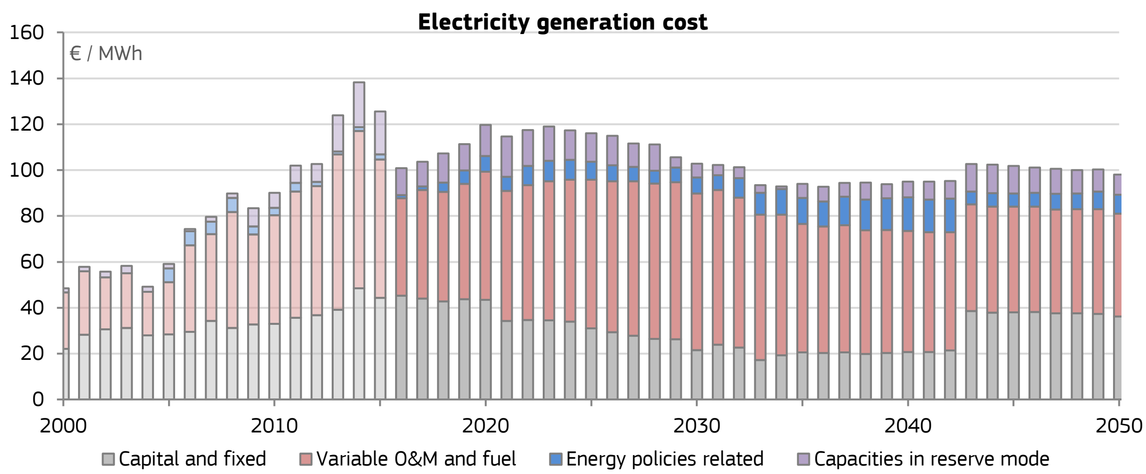

TWh
Net electricity generation
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

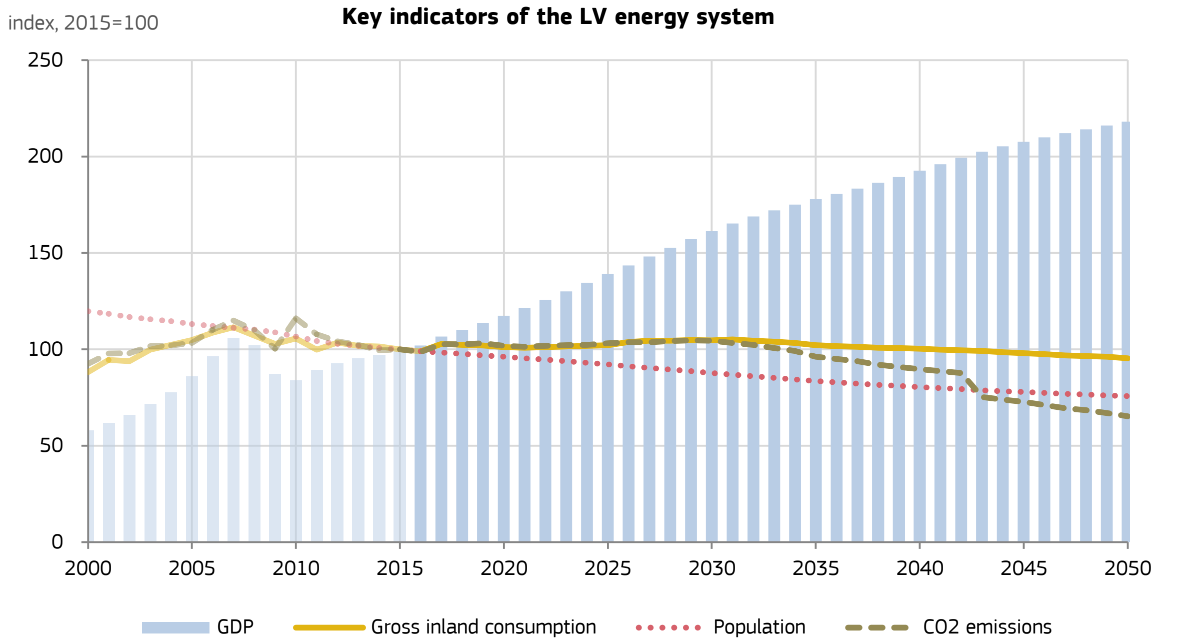

Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired

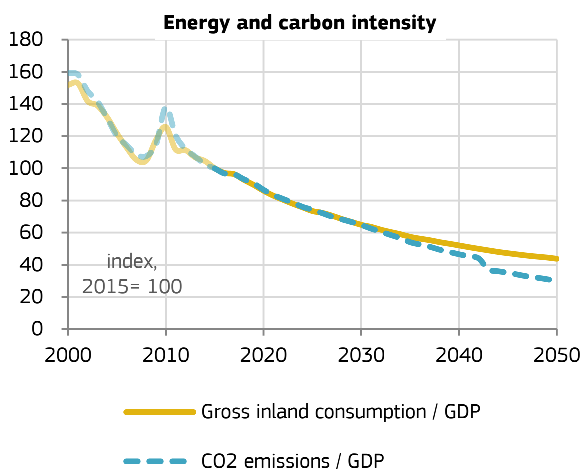

Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

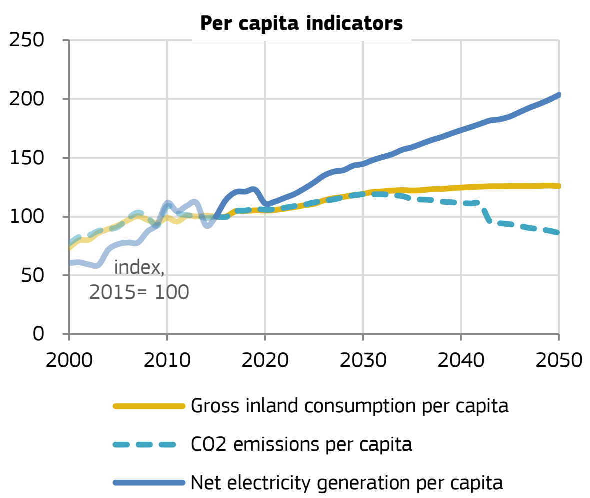

CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	6.4	4.0	3.8	3.9	4.0	3.7
Primary energy consumption [Mtoe]	7.9	4.5	4.3	4.3	4.4	4.0
RES [%] - Share of energy from renewable sources		34.2%	39.5%	38.6%	38.1%	54.8%
RES-E [%] - Share of electricity from renewable sources		42.7%	51.2%	47.9%	39.6%	73.3%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	20.1	8.0	7.7	7.8	8.1	5.0
reduction to 1990		*-60%*	*-62%*	*-61%*	*-60%*	*-75%*
Emissions in current ETS sectors |(LV) [Mt CO2]		2.4	2.7	2.9	3.2	1.4
reduction to 2005			*11%*	*17%*	*33%*	*-41%*
Emissions in current ESD sectors [Mt CO2]		5.5	5.0	5.0	4.8	3.6
reduction to 2005			*-10%*	*-10%*	*-13%*	*-35%*

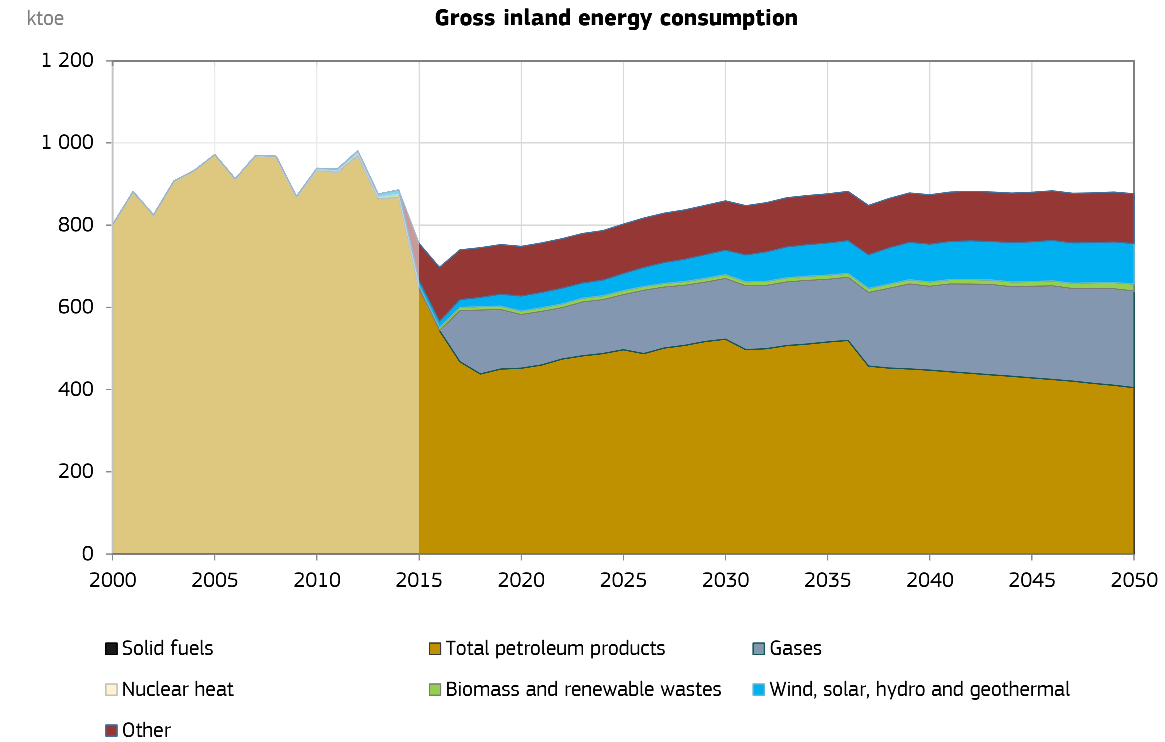


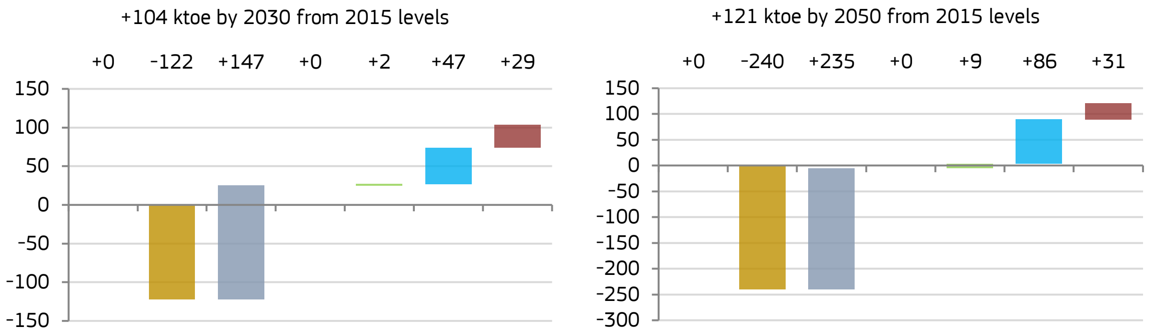


Malta

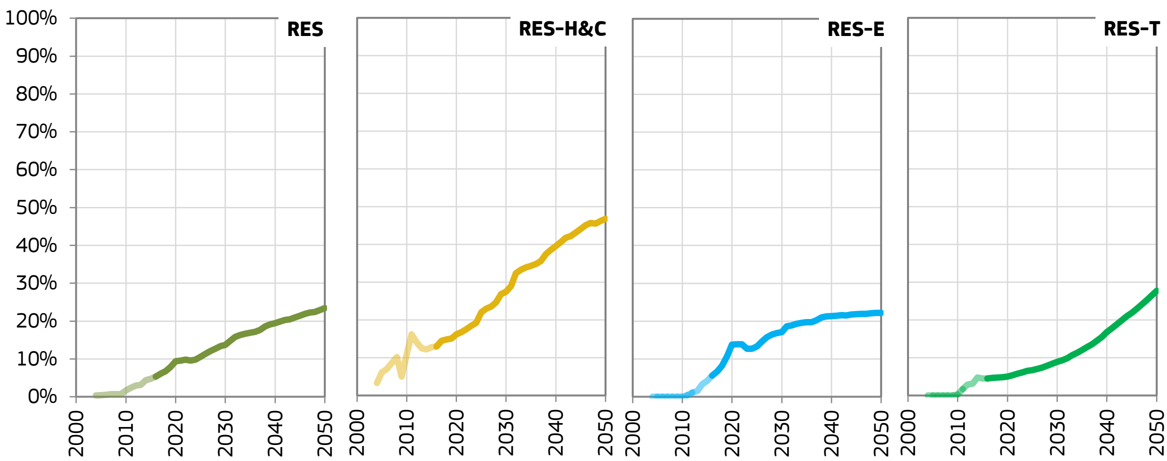
Central_2018 scenario

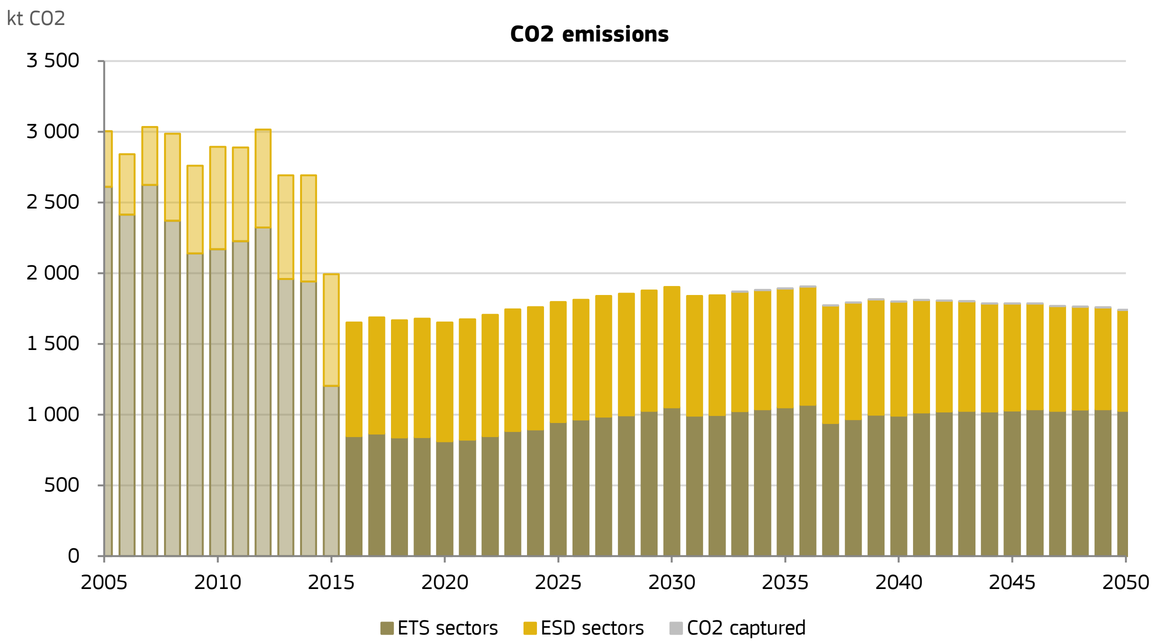
Gross inland energy consumption

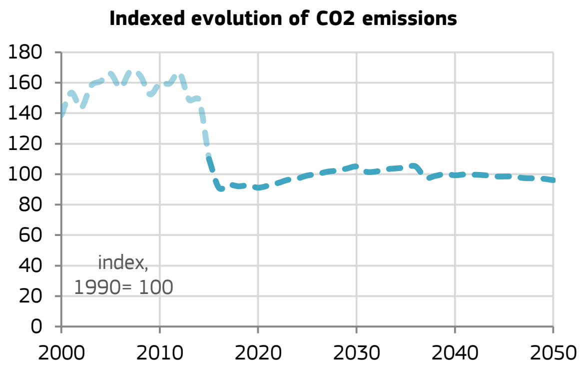


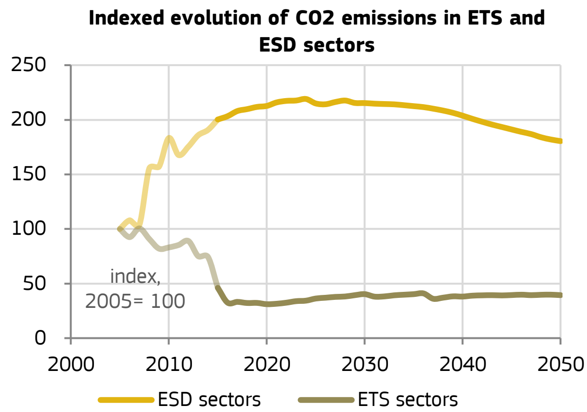


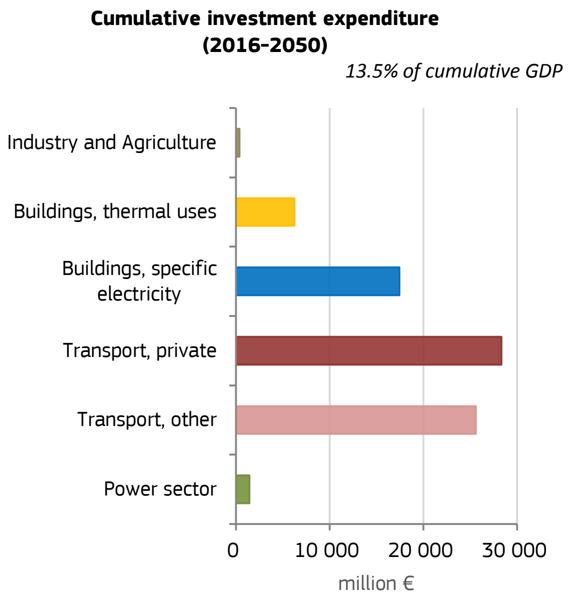
Share of renewable energies

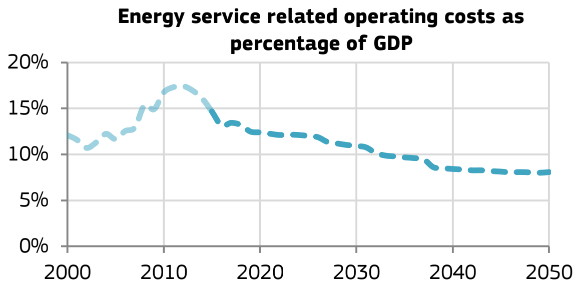


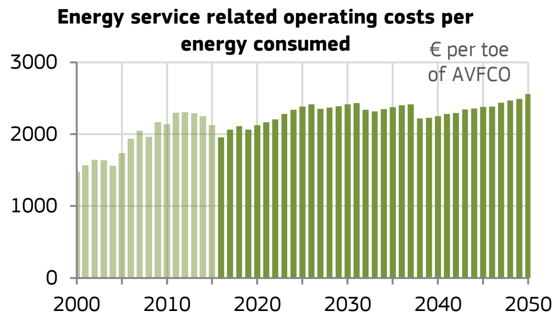

kt CO2
CO2 emissions
3 500
3 000
2 500
2 000
1 500
1 000
500
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured


Indexed evolution of CO2 emissions
180
160
140
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

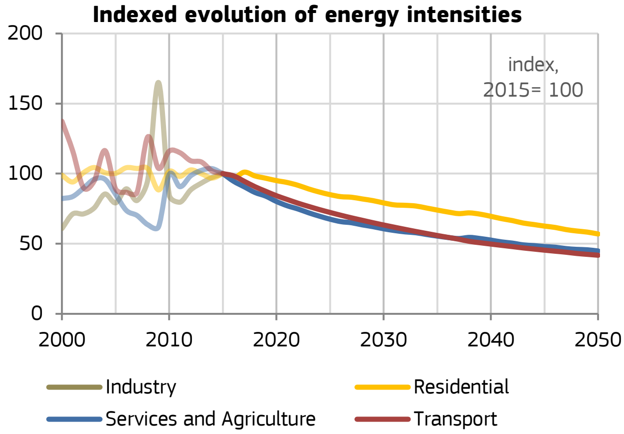

Indexed evolution of CO2 emissions in ETS and ESD sectors
250
200
150
100
50
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors


Cumulative investment expenditure (2016-2050)
13.5% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
10 000
20 000
30 000
million €

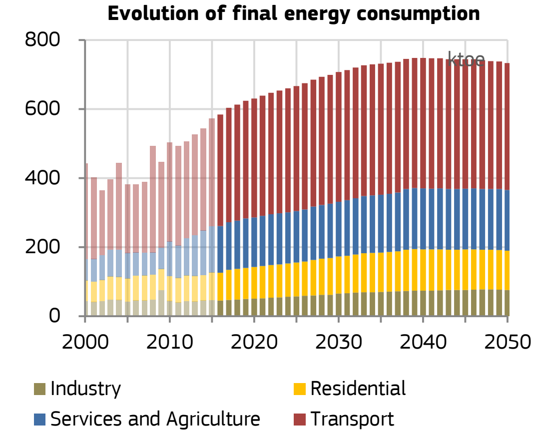

Energy service related operating costs as percentage of GDP
20%
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050


Energy service related operating costs per energy consumed
€ per toe
of AVFCO
3000
2000
1000
0
2000
2010
2020
2030
2040
2050

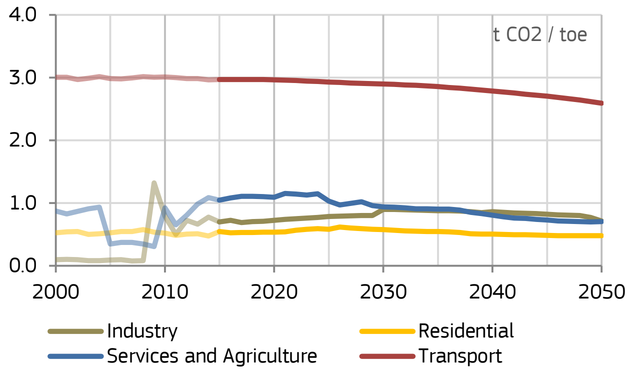
Indexed evolution of energy intensities



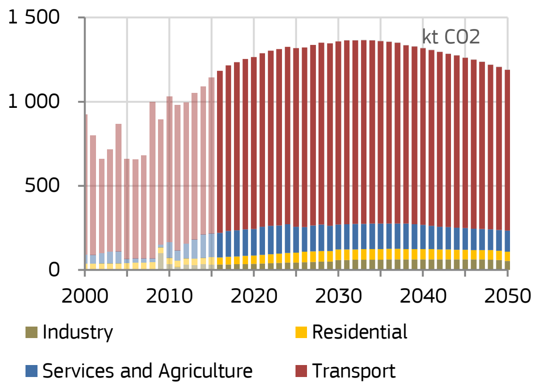
Evolution of final energy consumption



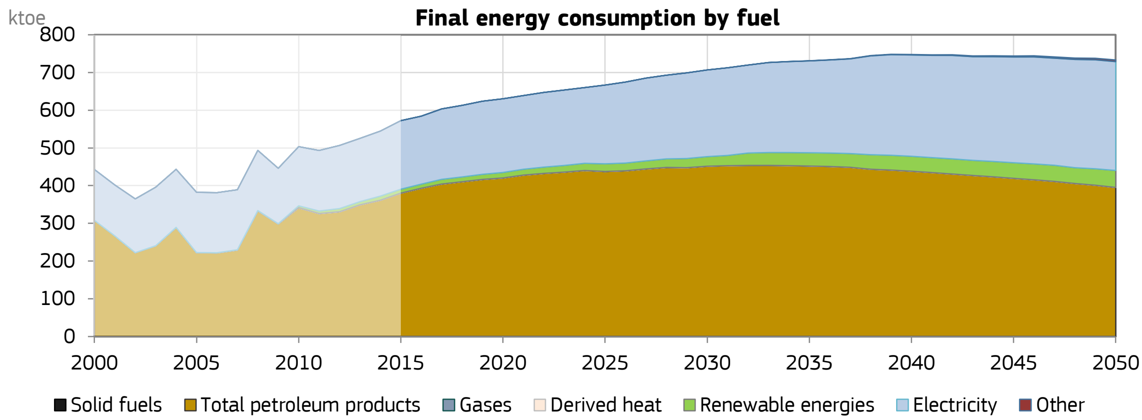
Evolution of carbon intensities



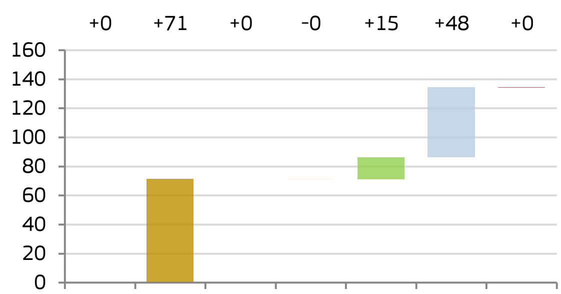
Evolution of CO2 emissions



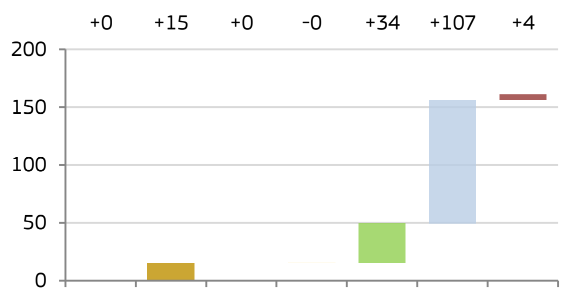
Final energy consumption by fuel

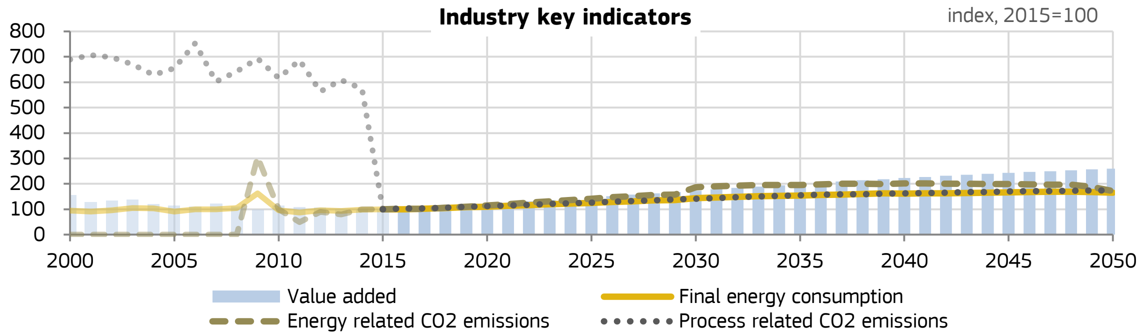


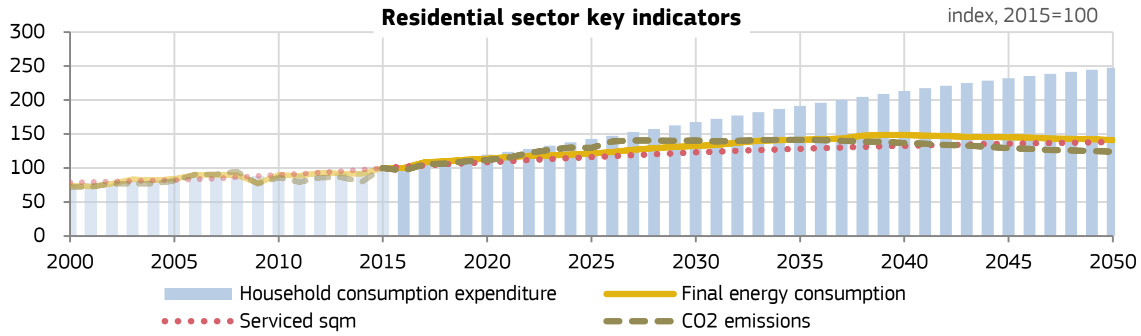
+134 ktoe by 2030 from 2015 levels

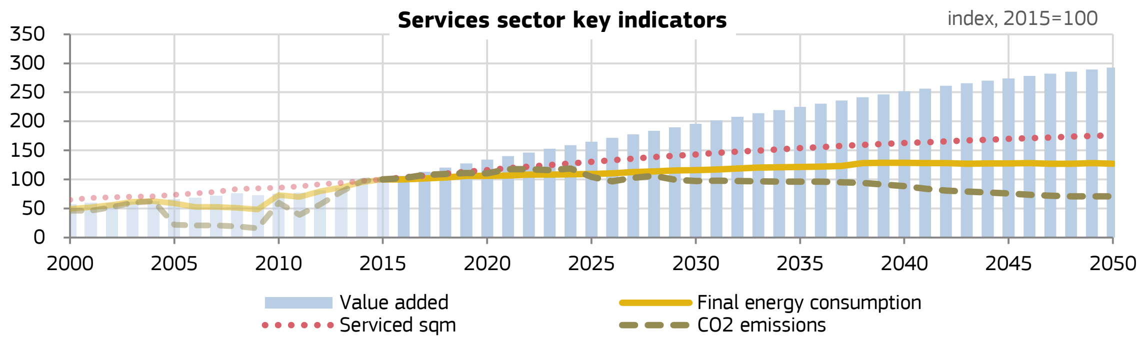


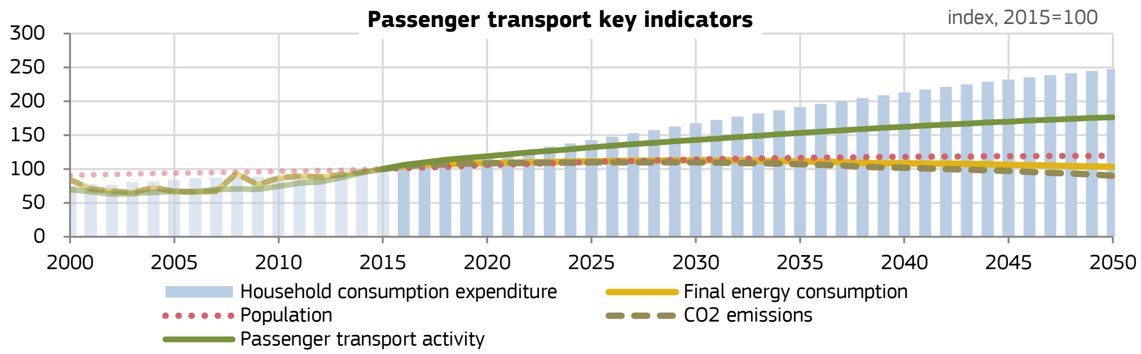
+161 ktoe by 2050 from 2015 levels

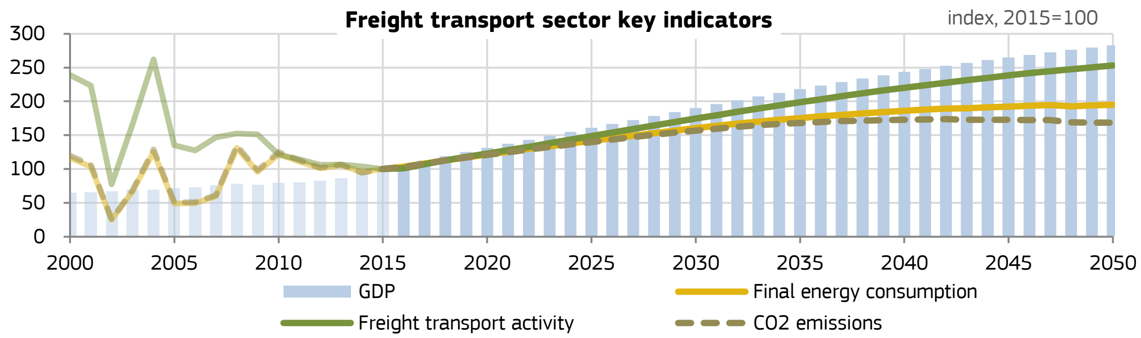


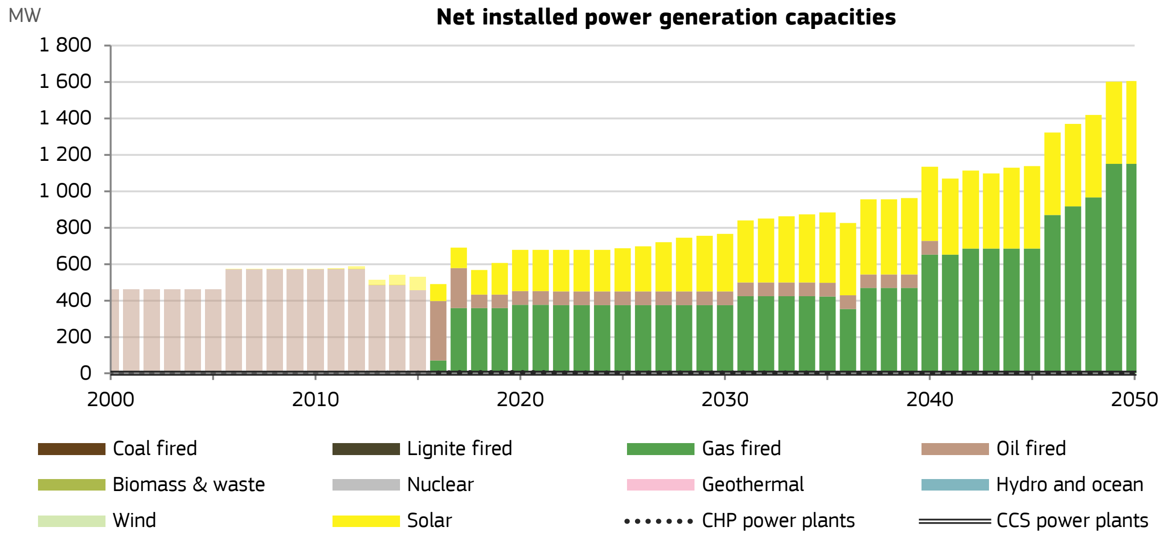

Industry key indicators
index, 2015=100
800
700
600
500
400
300
200
100
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

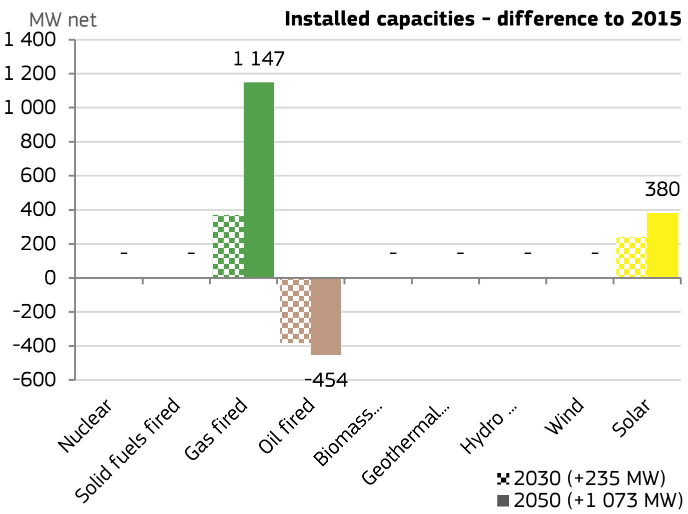

Residential sector key indicators
index, 2015=100
300
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

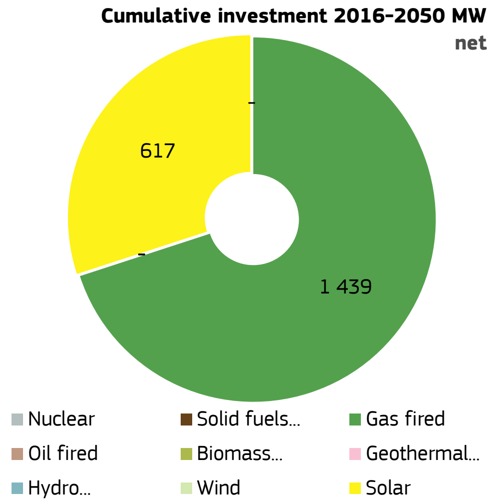

Services sector key indicators
index, 2015=100
350
300
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

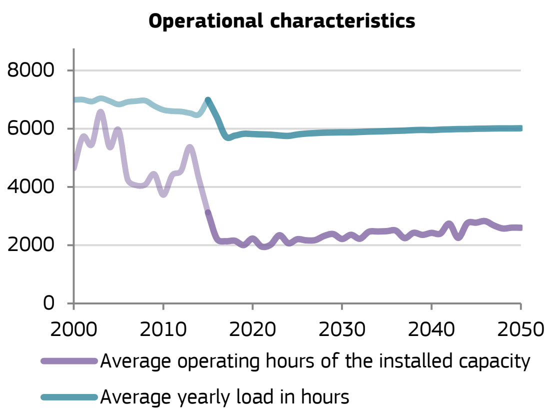

Passenger transport key indicators
index, 2015=100
300
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

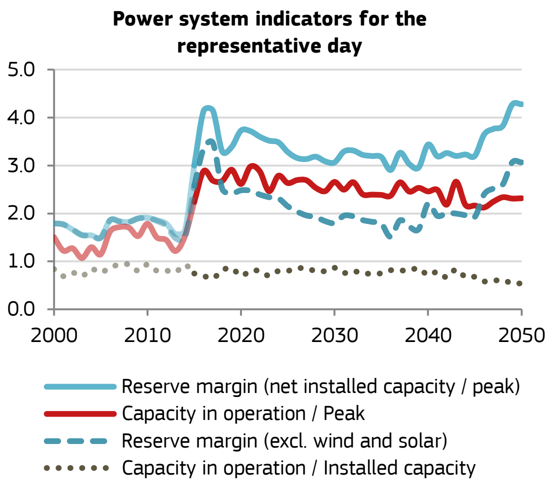

Freight transport sector key indicators
index, 2015=100
300
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

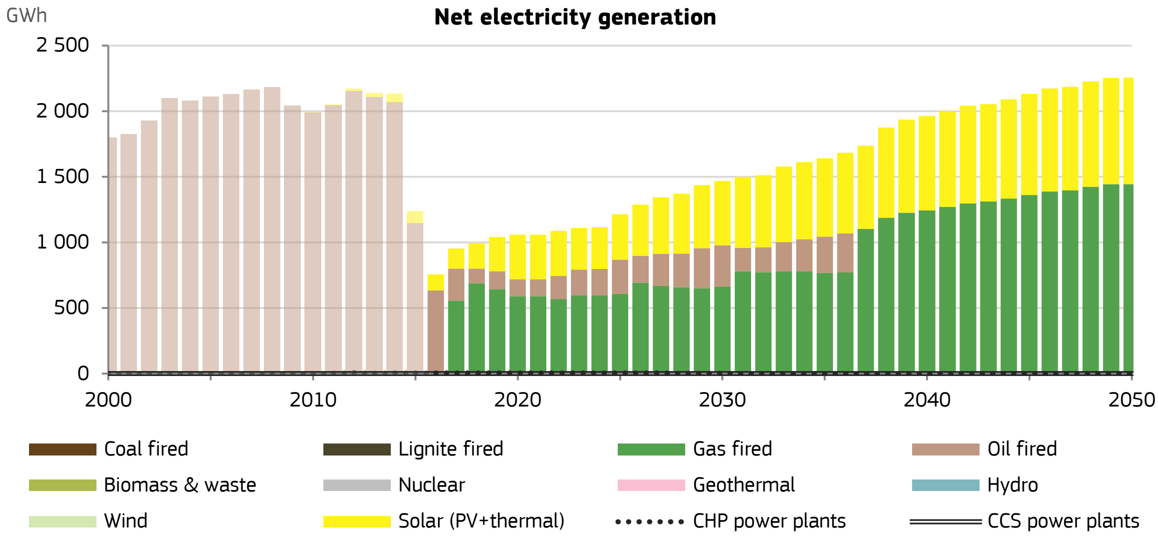

Net installed power generation capacities
MW
1 800
1 600
1 400
1 200
1 000
800
600
400
200
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

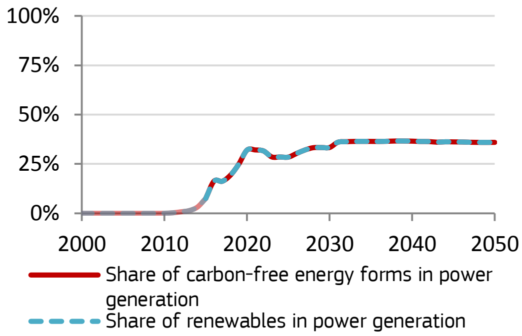

Installed capacities - difference to 2015
MW net
1 147
380
-454
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+235 MW)
2050 (+1 073 MW)

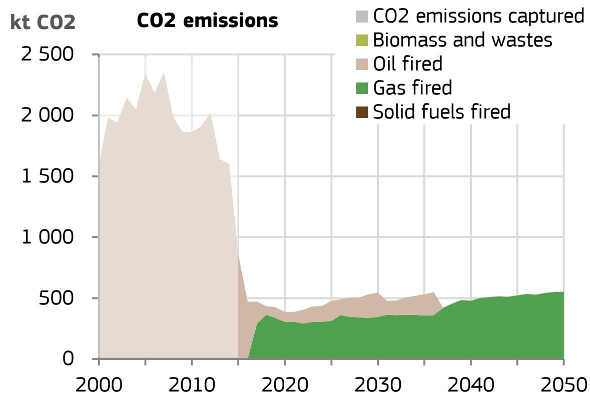

Cumulative investment 2016-2050 MW net
617
1 439
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

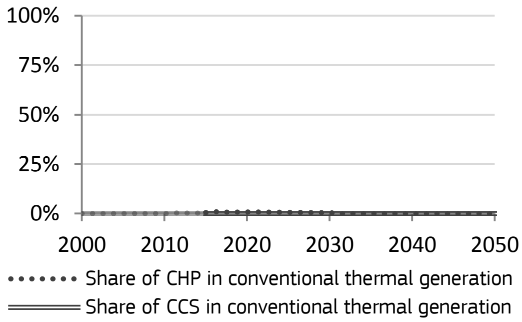

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

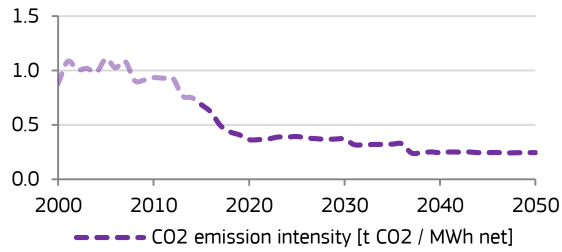

Power system indicators for the representative day
5.0
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

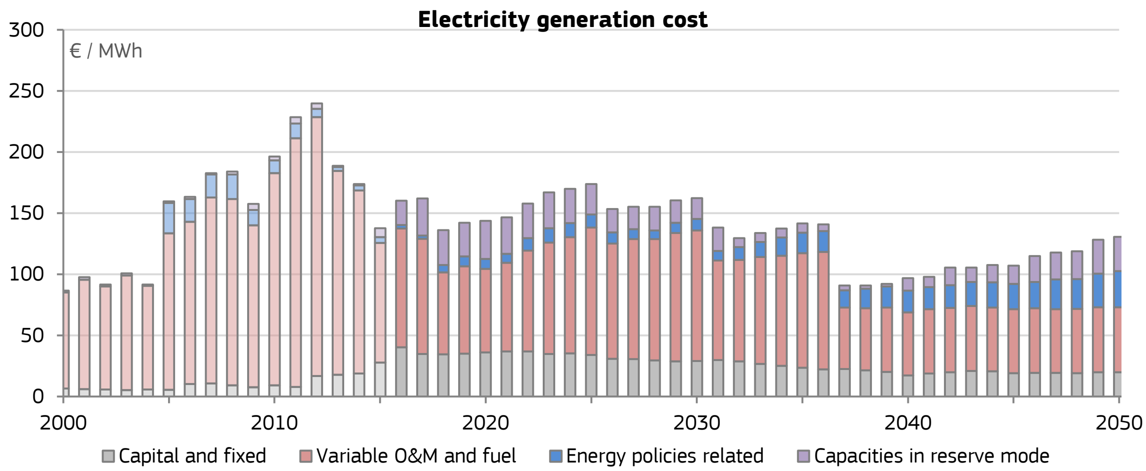

Net electricity generation
GWh
2 500
2 000
1 500
1 000
500
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

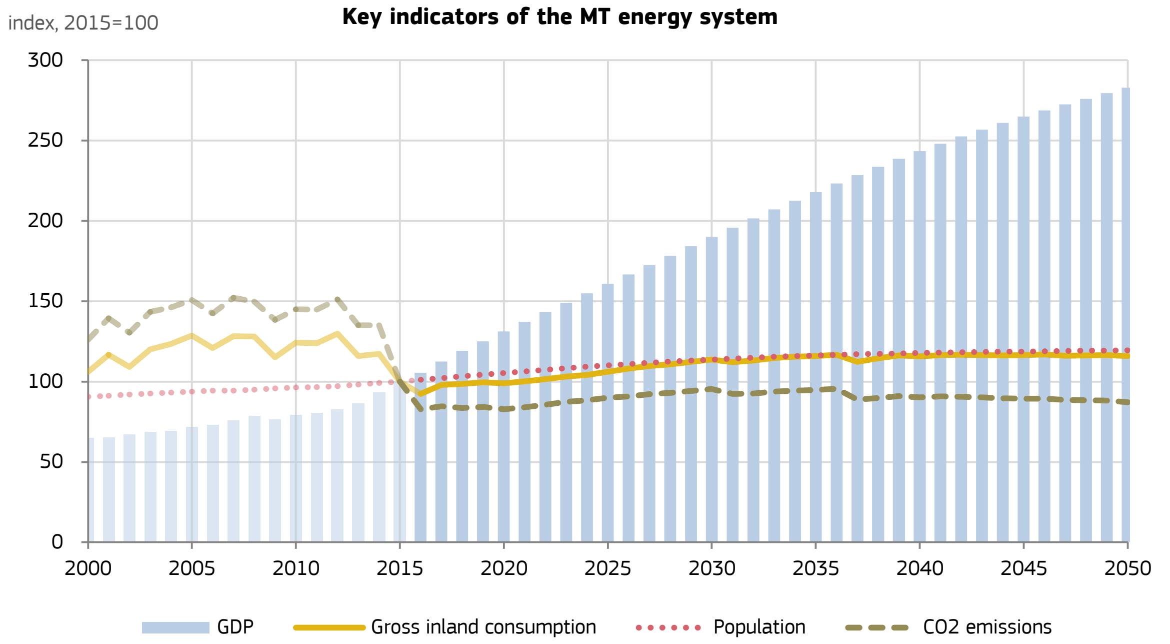

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


kt CO2
CO2 emissions
2 500
2 000
1 500
1 000
500
0
2000
2010
2020
2030
2040
2050
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired

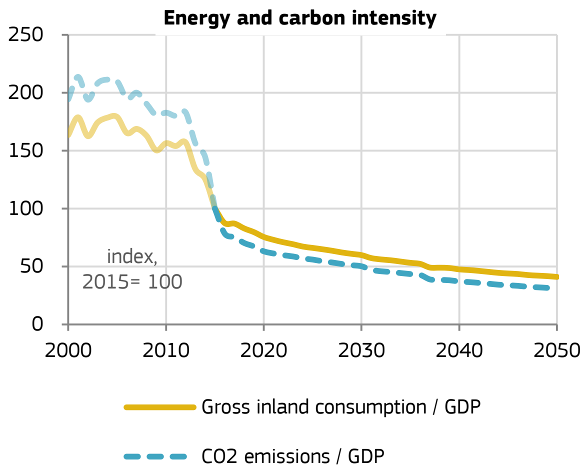

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

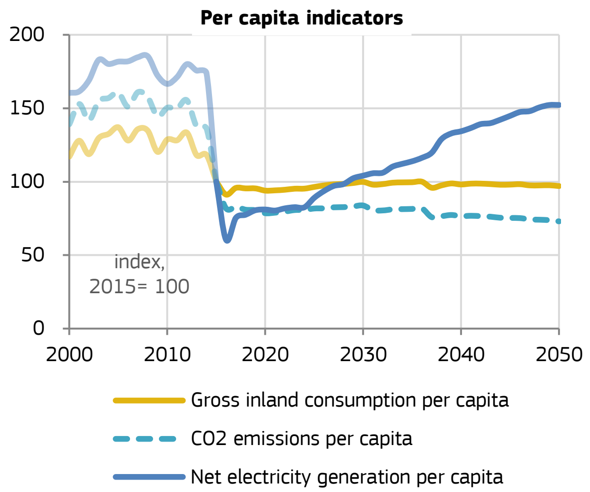

1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
300
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [ktoe]	335	382	572	630	707	733
Primary energy consumption [ktoe]	578	952	751	743	852	867
RES [%] - Share of energy from renewable sources		0.4%	4.7%	9.4%	13.7%	23.4%
RES-E [%] - Share of electricity from renewable sources		0.0%	4.2%	13.8%	17.1%	22.2%
Total CO2 emissions [kt CO2] (with intern. aviation, without LULUCF)	1 811	3 004	1 993	1 651	1 902	1 739
reduction to 1990		*66%*	*10%*	*-9%*	*5%*	*-4%*
Emissions in current ETS sectors |(MT) [kt CO2]		2 609	1 203	811	1 052	1 027
reduction to 2005			*-54%*	*-69%*	*-60%*	*-61%*
Emissions in current ESD sectors [kt CO2]		395	791	840	850	712
reduction to 2005			*100%*	*113%*	*115%*	*81%*

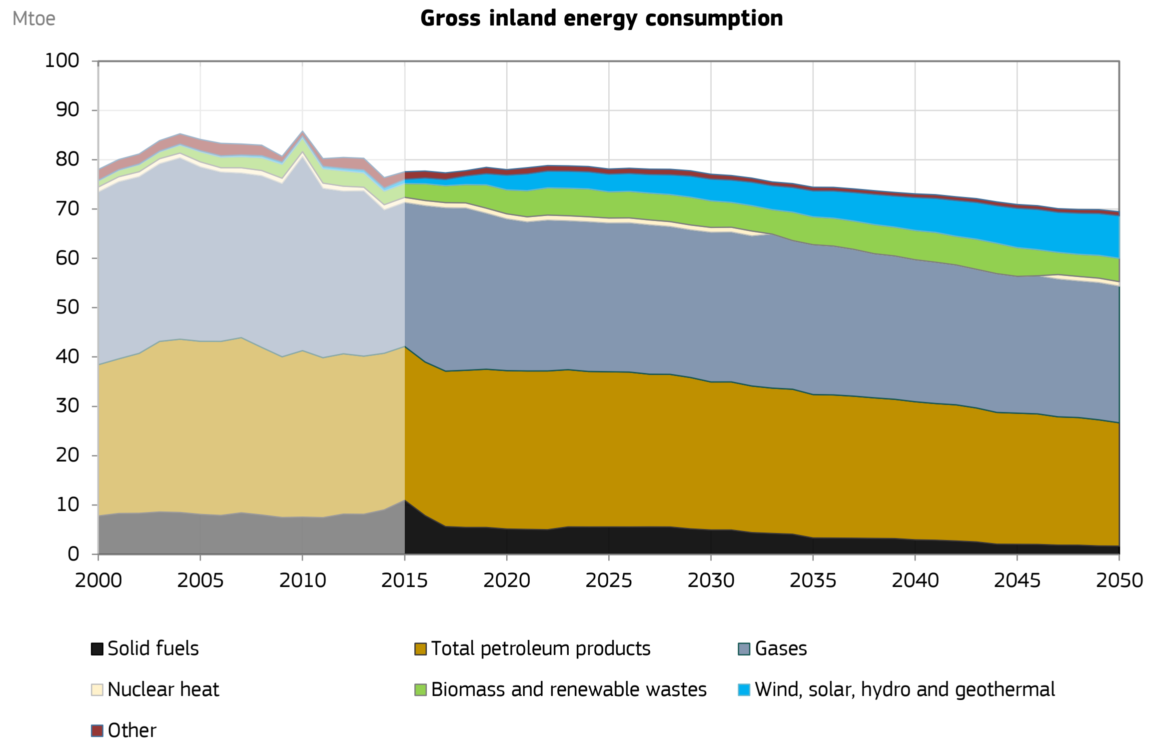


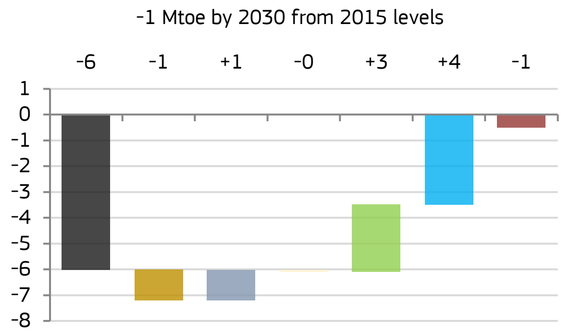


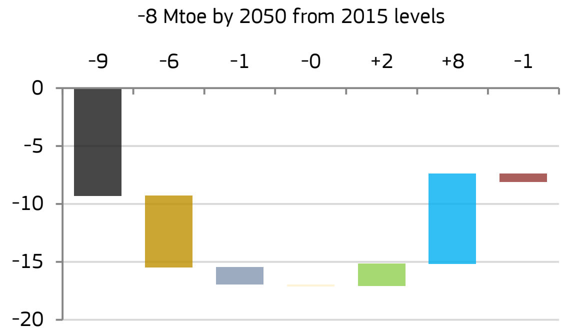
POTEnCIA - Model results overview

Netherlands

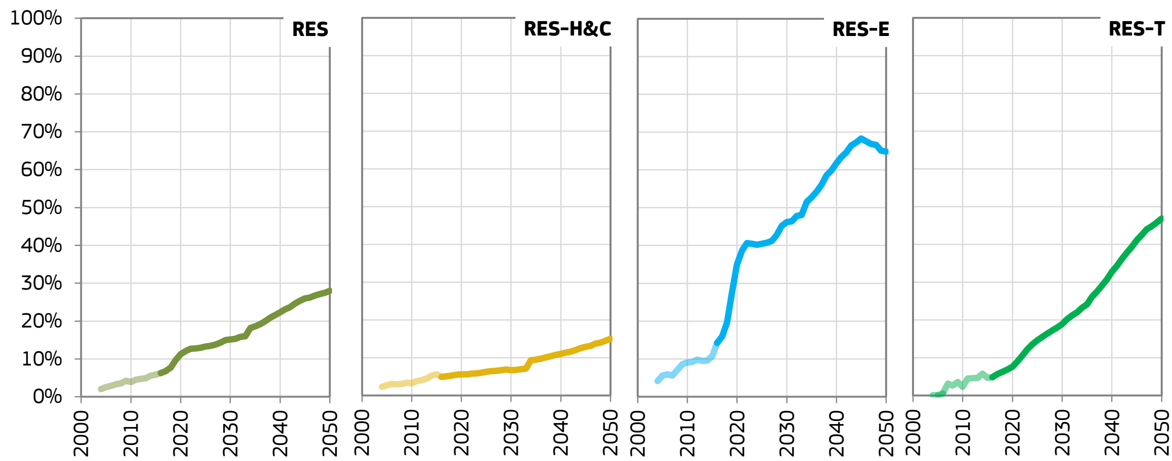
Central_2018 scenario

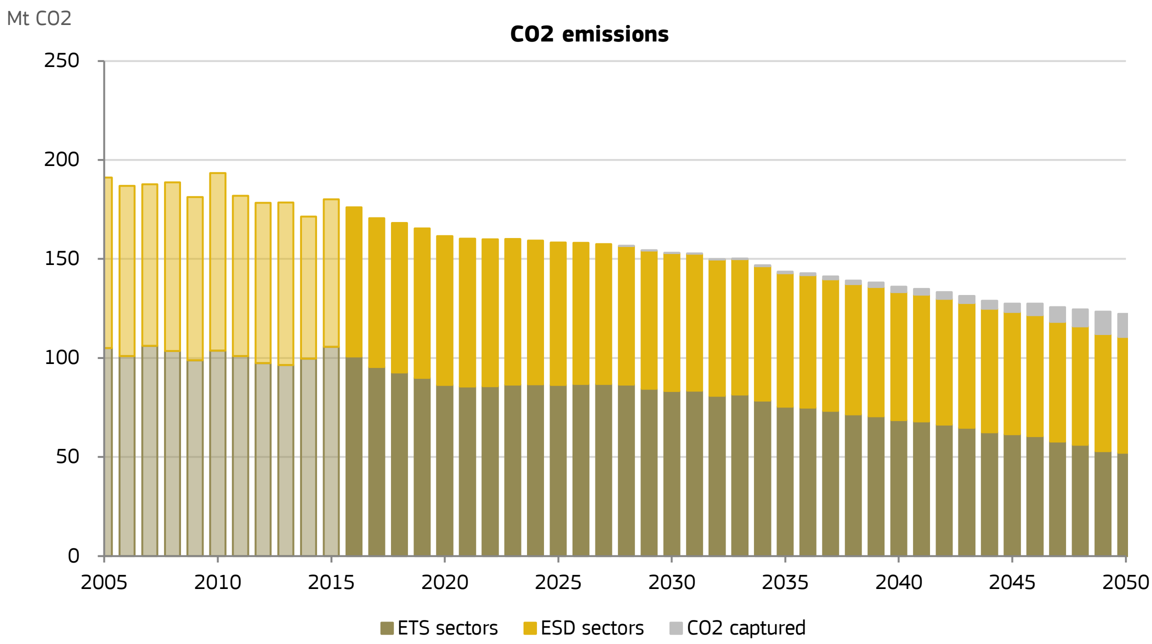


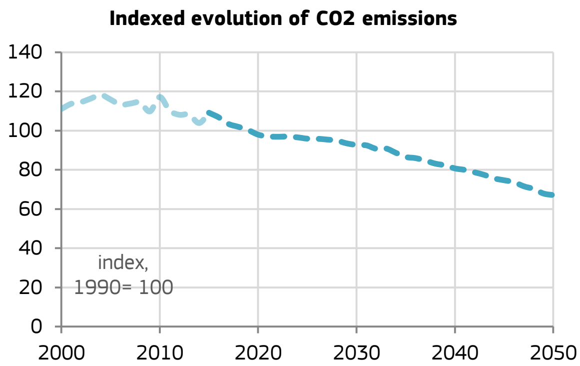


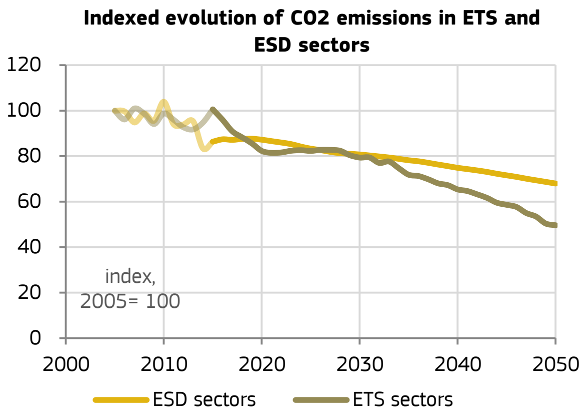


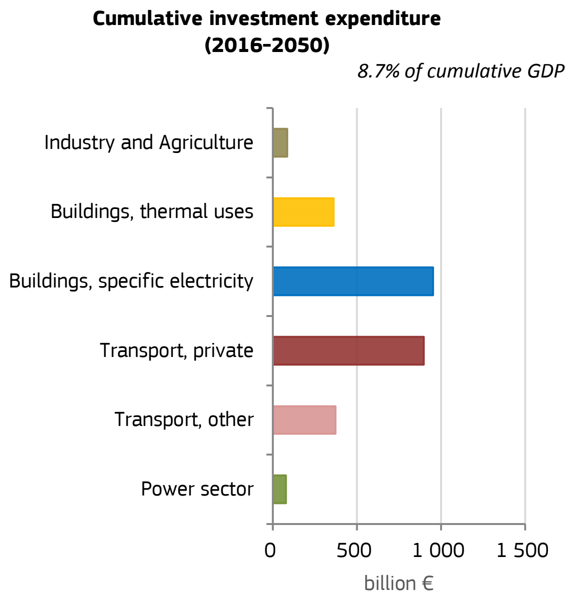
Share of renewable energies

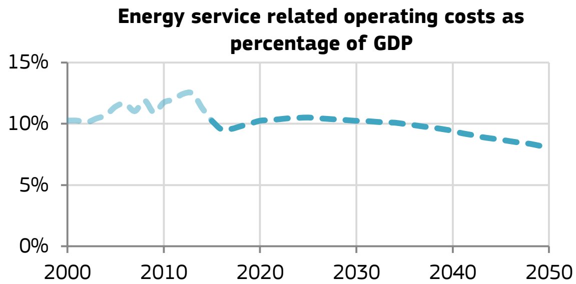


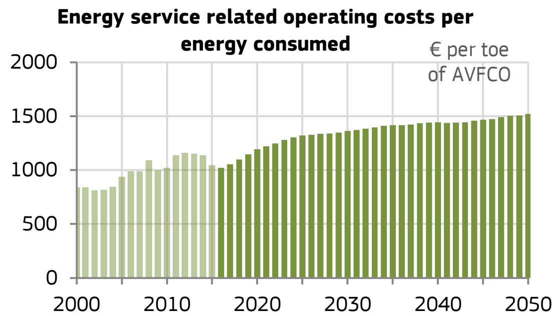

CO2 emissions
Mt CO2
250
200
150
100
50
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured

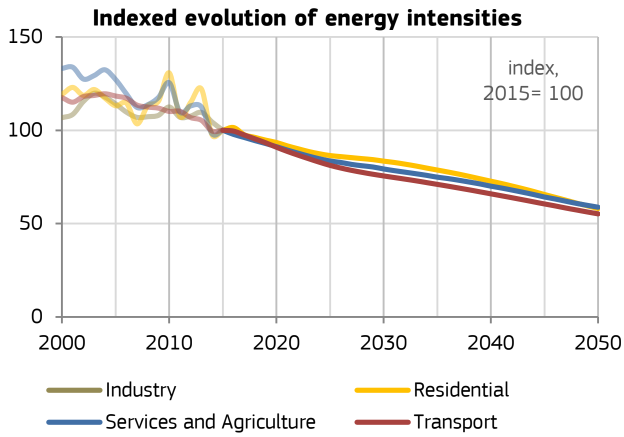

Indexed evolution of CO2 emissions
140
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

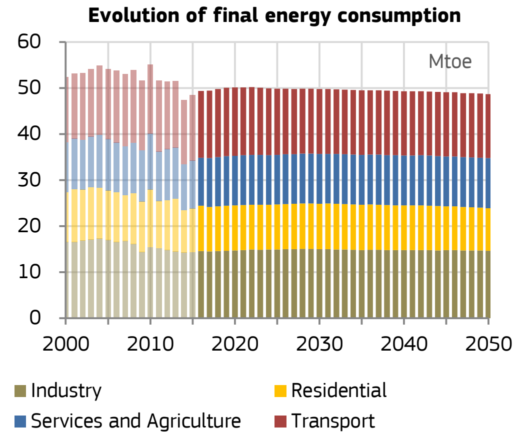

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors

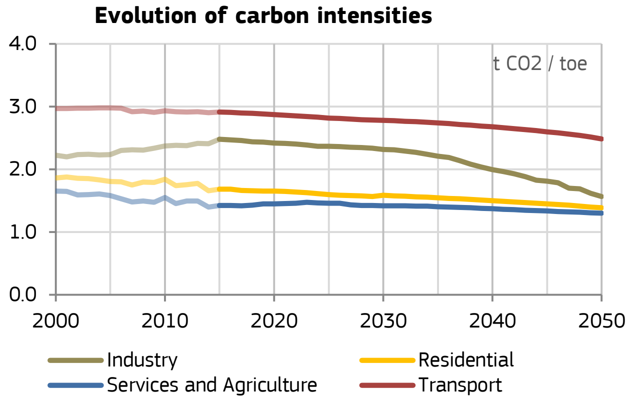

Cumulative investment expenditure (2016-2050)
8.7% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
500
1 000
1 500
billion €

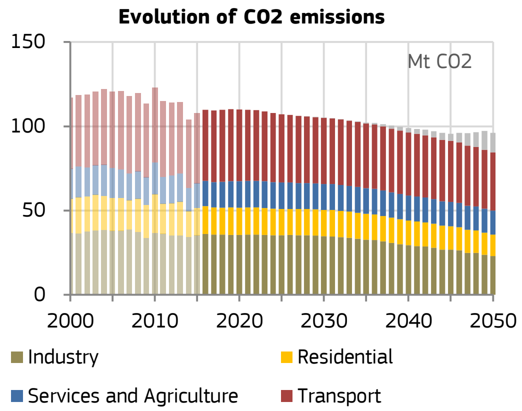

Energy service related operating costs as percentage of GDP
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050

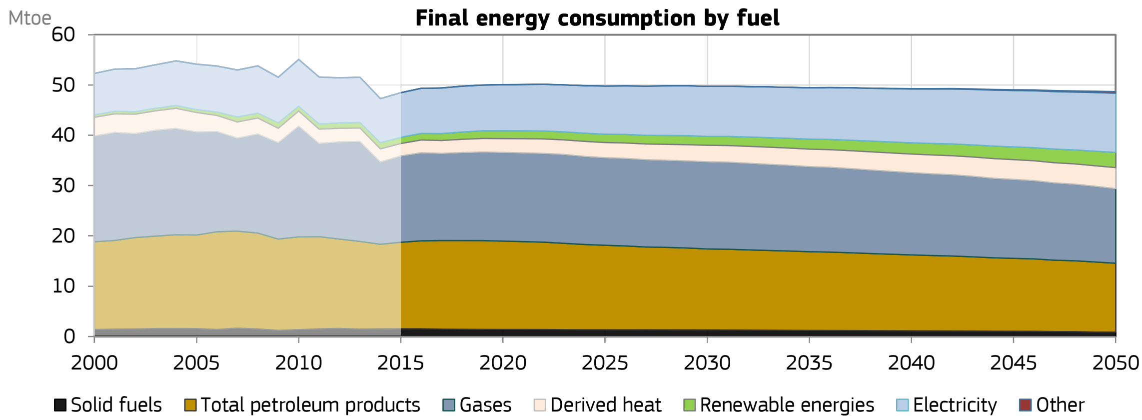

Energy service related operating costs per energy consumed
€ per toe
of AVFCO
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

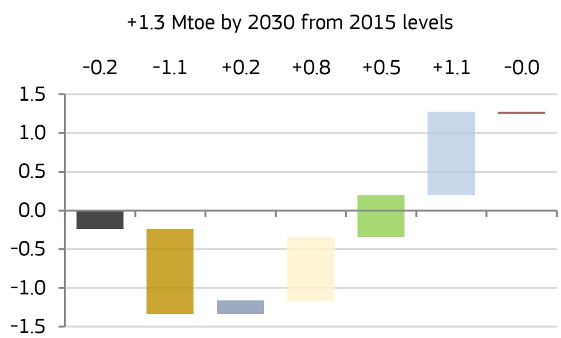

Indexed evolution of energy intensities
index, 2015= 100
150
100
50
0
2000 2010 2020 2030 2040 2050
Industry
Residential
Services and Agriculture
Transport

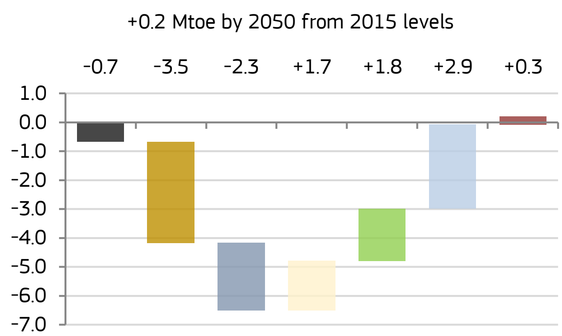

Evolution of final energy consumption
Mtoe
60
50
40
30
20
10
0
2000 2010 2020 2030 2040 2050
Industry
Residential
Services and Agriculture
Transport

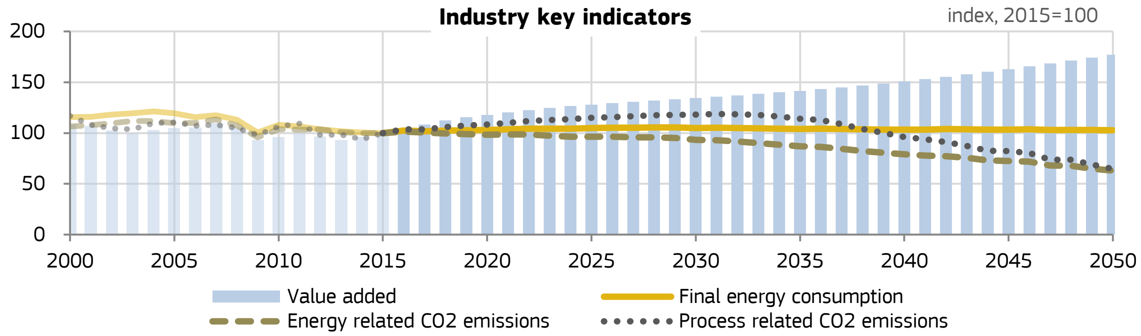

Evolution of carbon intensities
t CO2 / toe
4.0
3.0
2.0
1.0
0.0
2000 2010 2020 2030 2040 2050
Industry
Residential
Services and Agriculture
Transport

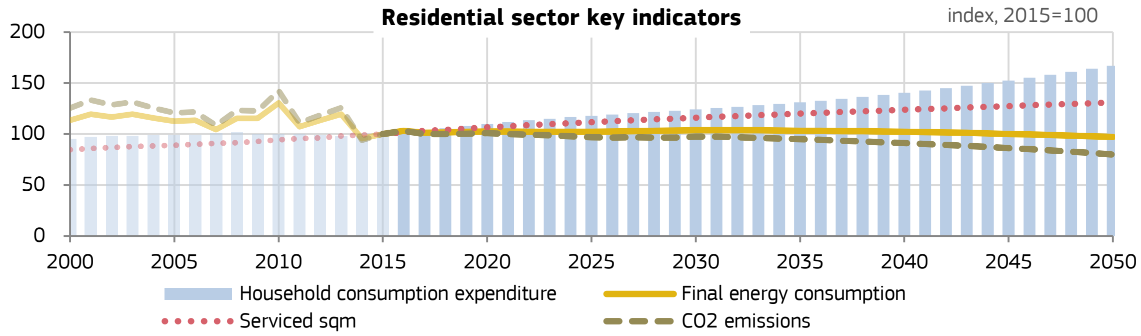

Evolution of CO2 emissions
Mt CO2
150
100
50
0
2000 2010 2020 2030 2040 2050
Industry
Residential
Services and Agriculture
Transport

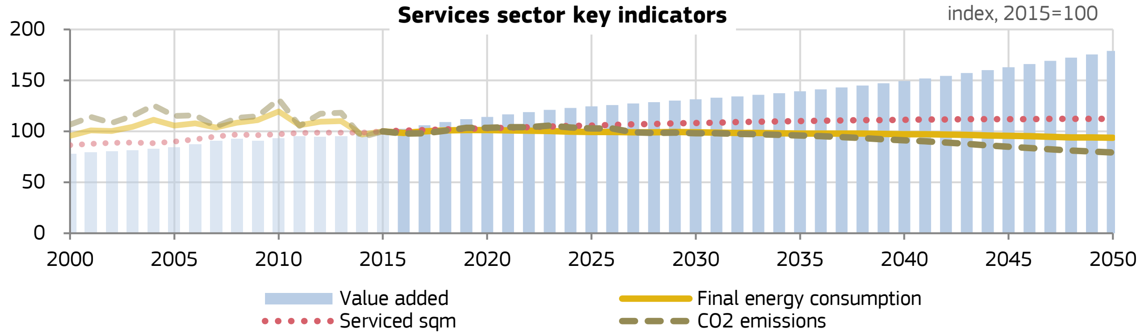

Final energy consumption by fuel
Mtoe
60
50
40
30
20
10
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

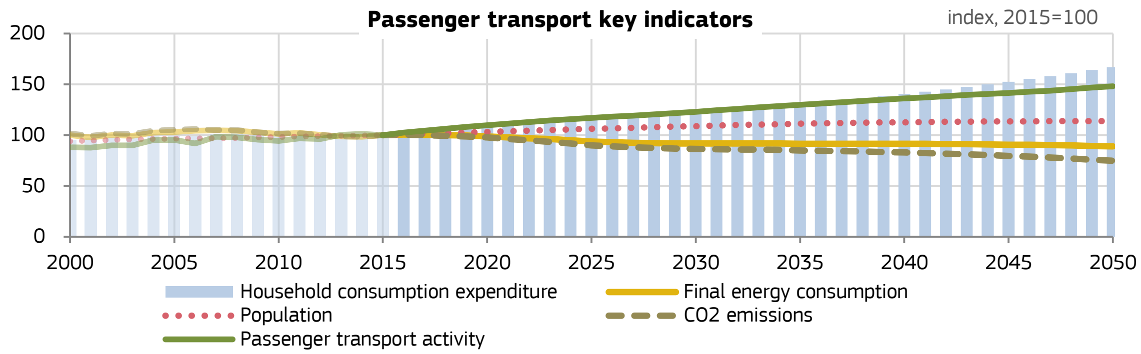

+1.3 Mtoe by 2030 from 2015 levels
-0.2 -1.1 +0.2 +0.8 +0.5 +1.1 -0.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5

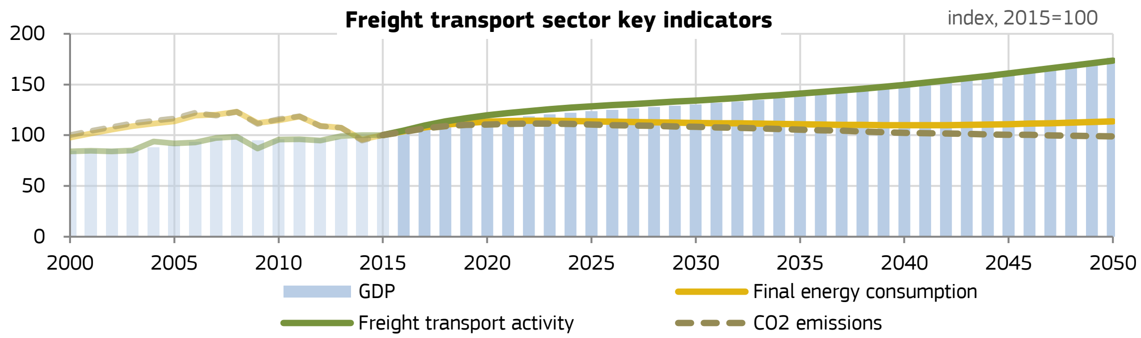

+0.2 Mtoe by 2050 from 2015 levels
-0.7 -3.5 -2.3 +1.7 +1.8 +2.9 +0.3
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0

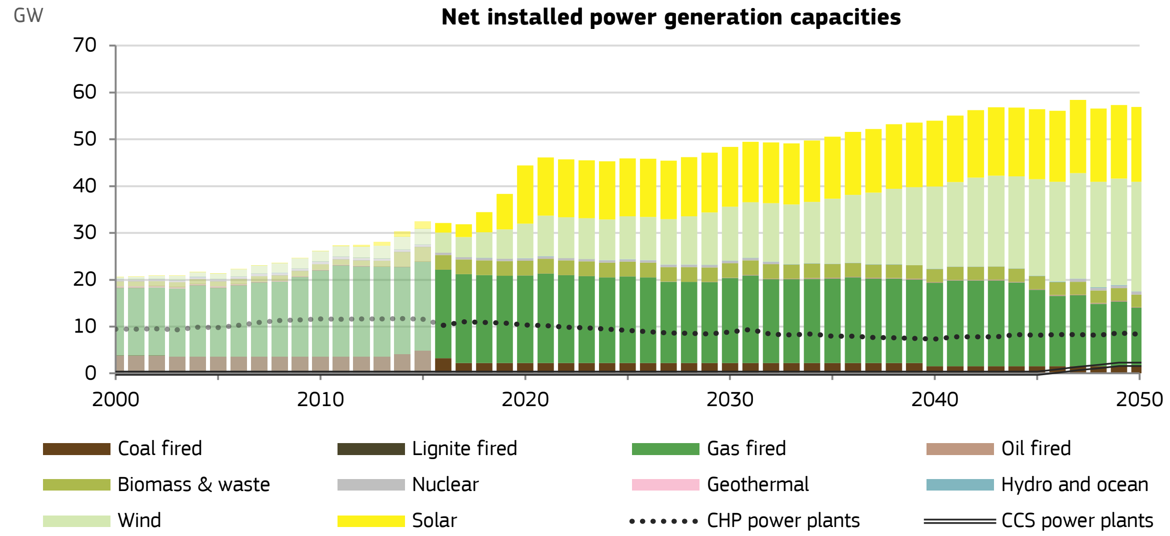

Industry key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

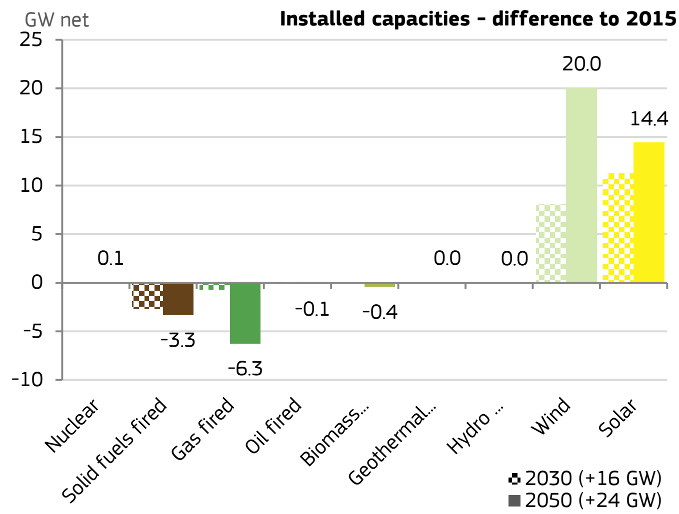

Residential sector key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

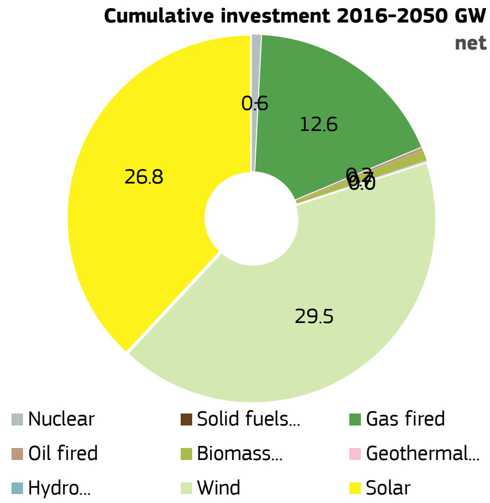

Services sector key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

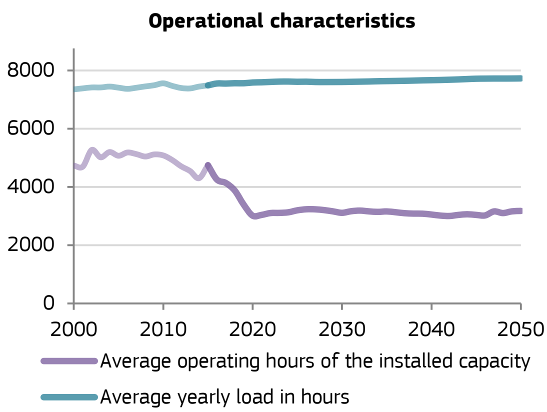

Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

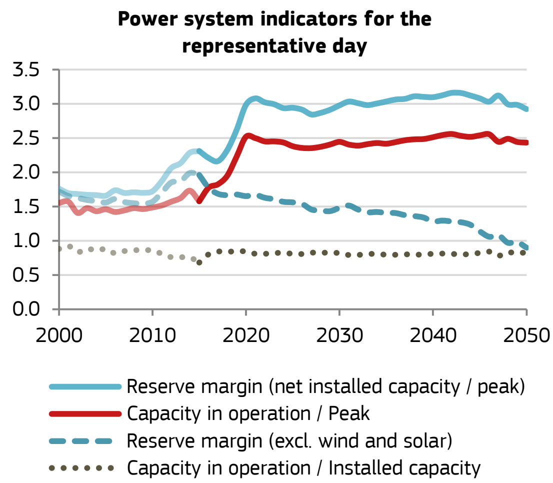

Freight transport sector key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

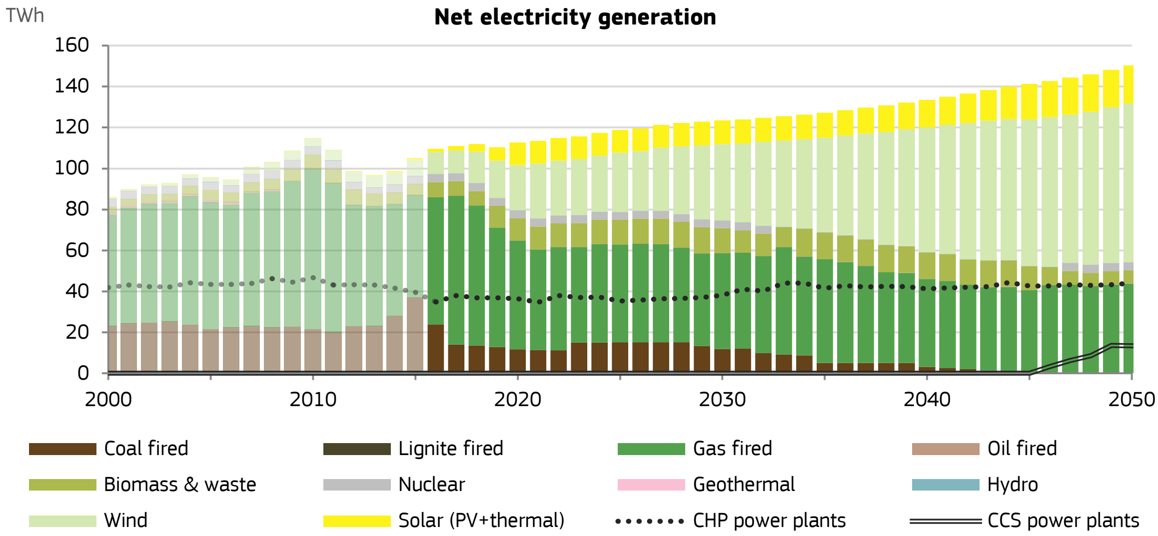

Net installed power generation capacities
GW
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

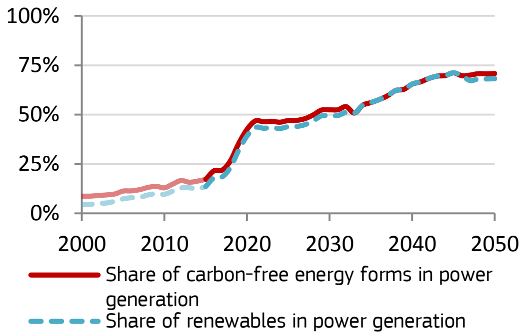

Installed capacities - difference to 2015
GW net
25
20
15
10
5
0
-5
-10
0.1
-3.3
-6.3
-0.1
-0.4
0.0
0.0
20.0
14.4
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+16 GW)
2050 (+24 GW)

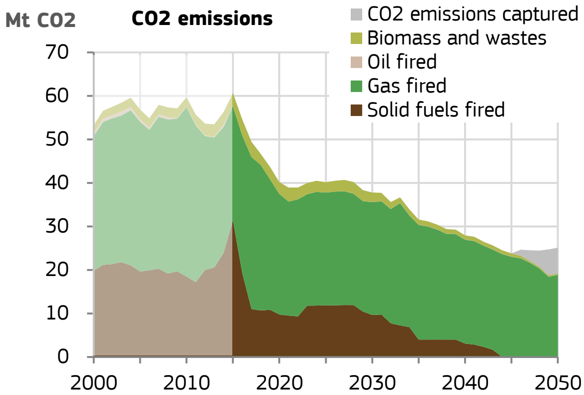

Cumulative investment 2016-2050 GW net
0.6
12.6
0.3
0.0
26.8
29.5
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

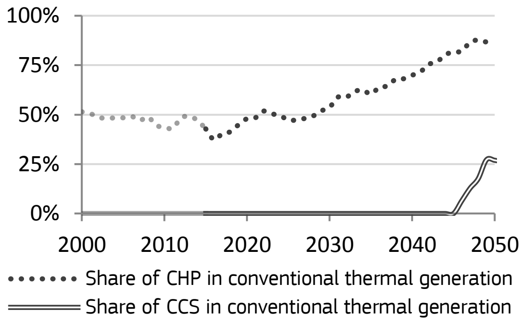

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

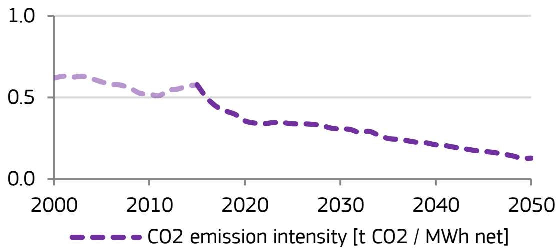

Power system indicators for the representative day
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

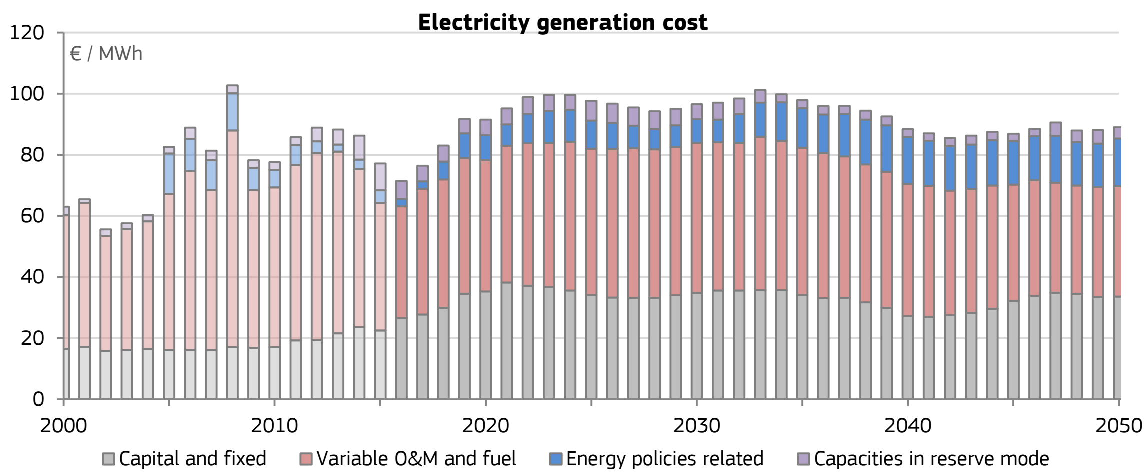

Net electricity generation
TWh
160
140
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants


100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation

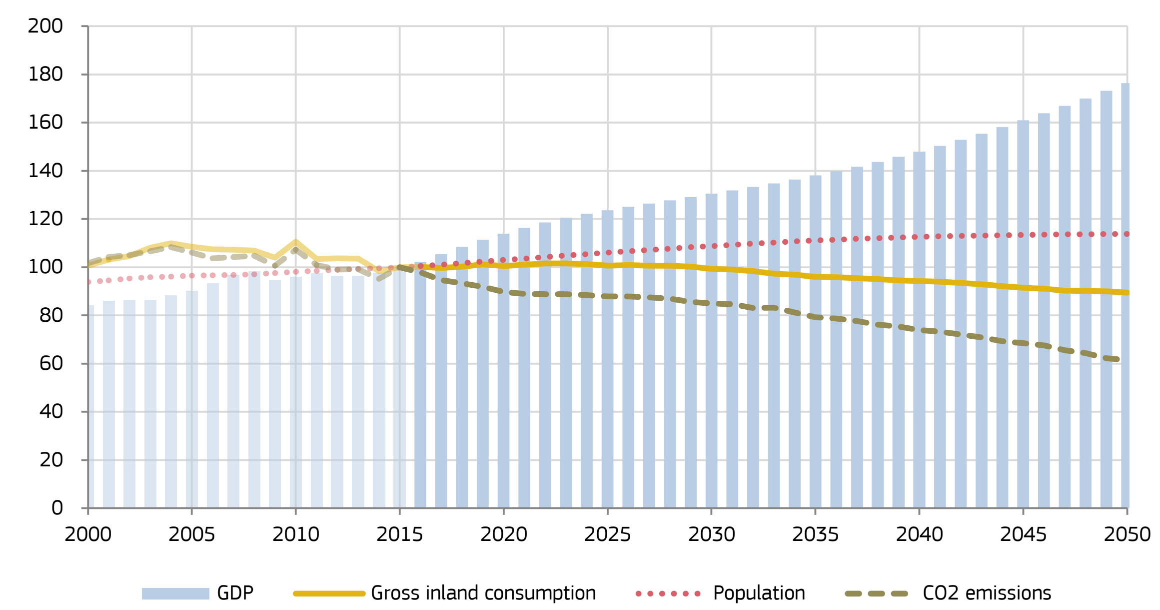

Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050


100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation


1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]

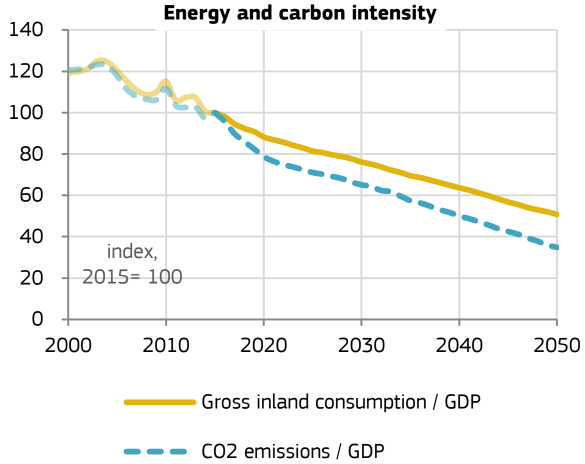

Electricity generation cost
€ / MWh
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode

Key indicators of the NL energy system

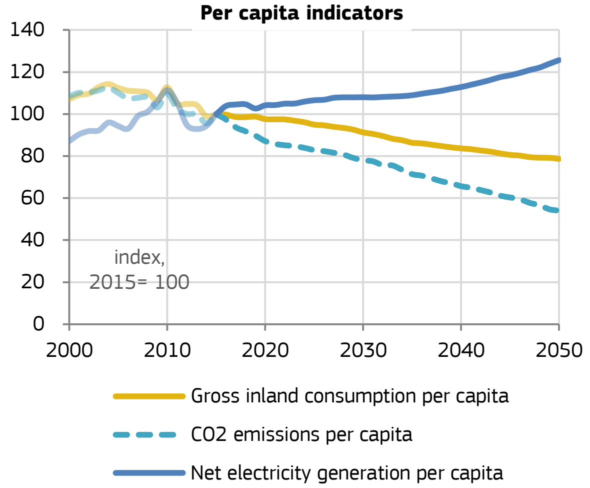


Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	45.5	54.2	48.5	50.1	49.8	48.7
Primary energy consumption [Mtoe]	57.7	68.9	64.6	63.8	62.4	56.5
RES [%] - Share of energy from renewable sources		2.5%	5.9%	11.3%	15.1%	28.0%
RES-E [%] - Share of electricity from renewable sources		5.6%	10.8%	34.9%	46.2%	64.8%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	165.0	191.2	180.1	161.6	153.0	110.7
reduction to 1990		*16%*	*9%*	*-2%*	*-7%*	*-33%*
Emissions in current ETS sectors |(NL) [Mt CO2]		105.0	105.6	86.5	83.4	52.1
reduction to 2005			*1%*	*-18%*	*-21%*	*-50%*
Emissions in current ESD sectors [Mt CO2]		86.1	74.4	75.2	69.6	58.6
reduction to 2005			*-14%*	*-13%*	*-19%*	*-32%*

Energy and carbon intensity

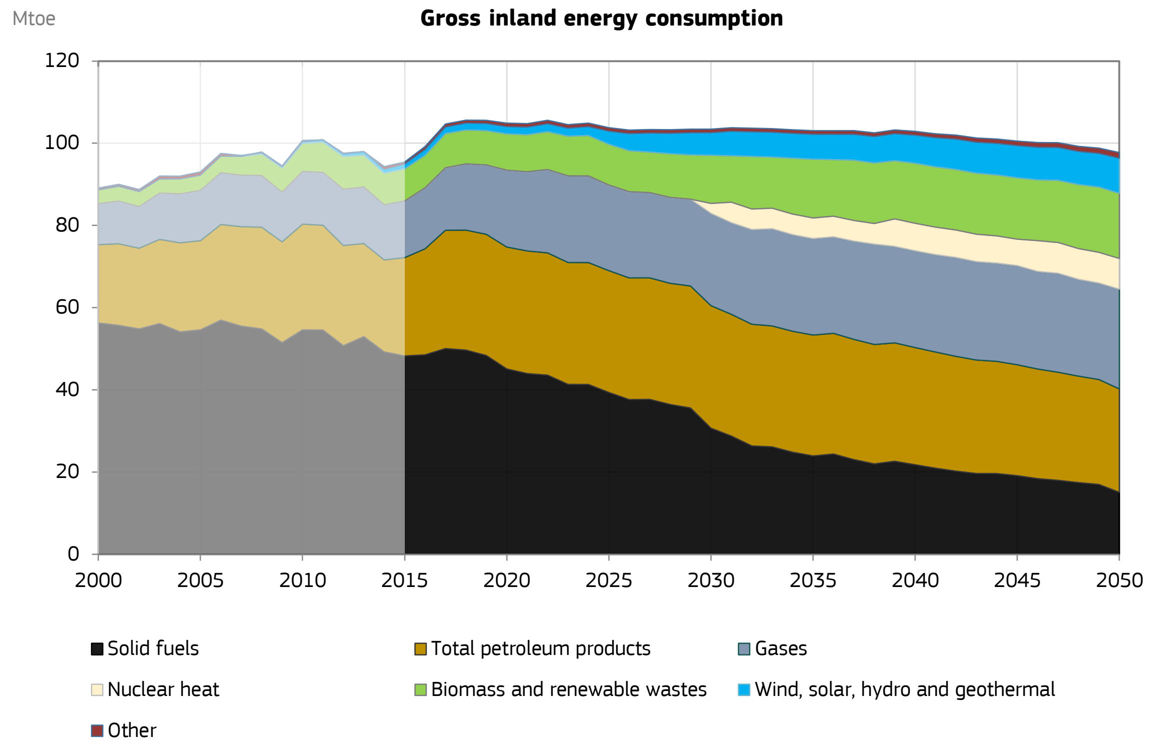


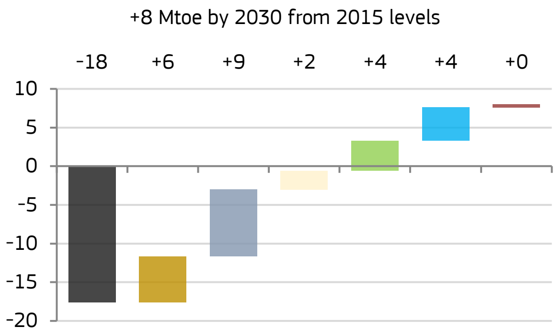
Per capita indicators

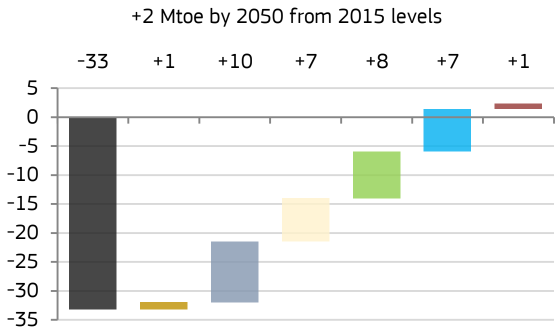


Poland

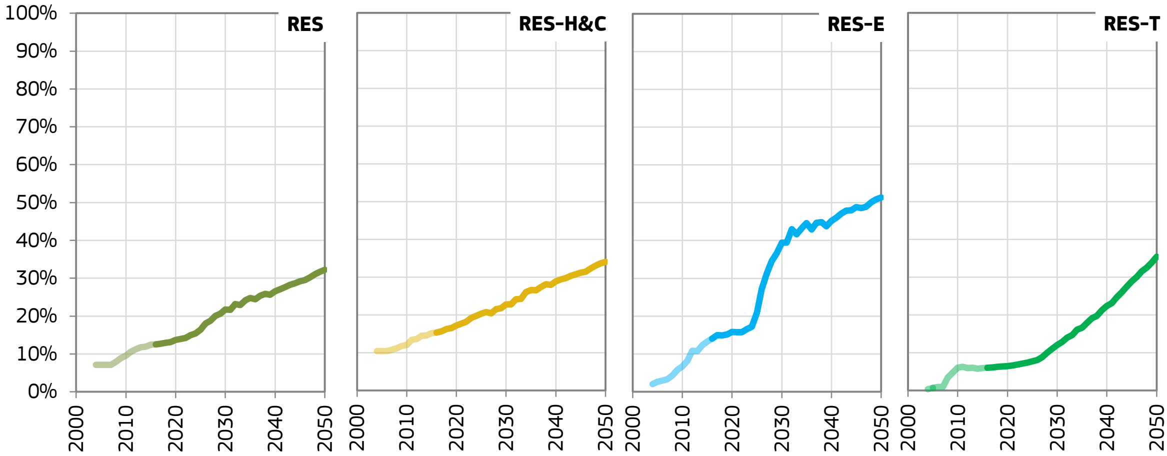
Central_2018 scenario

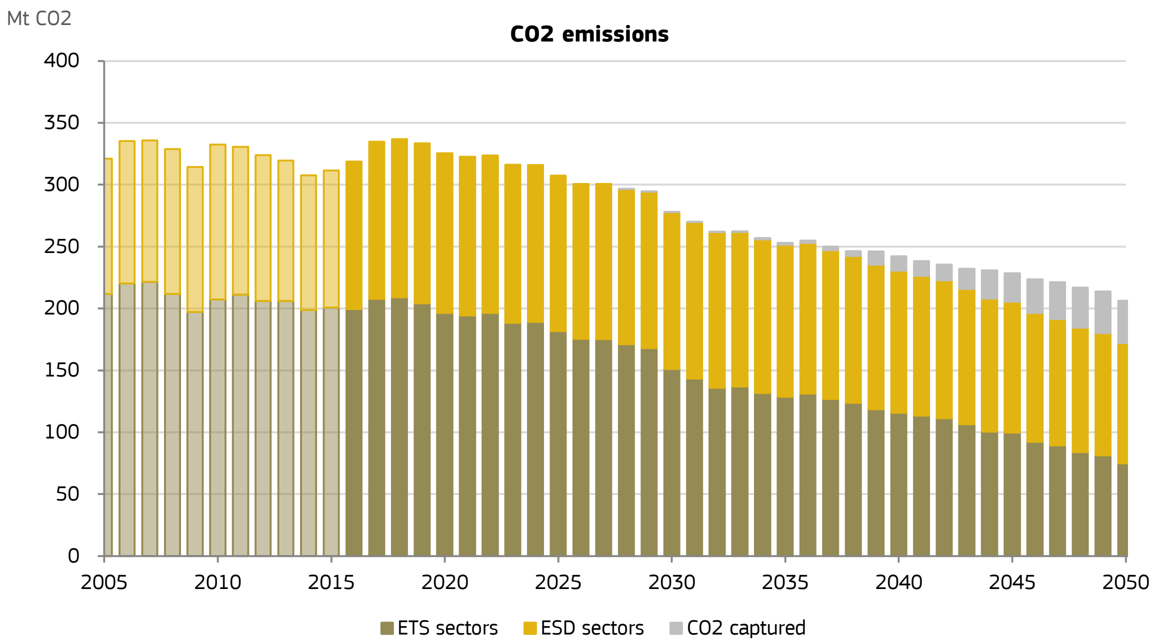


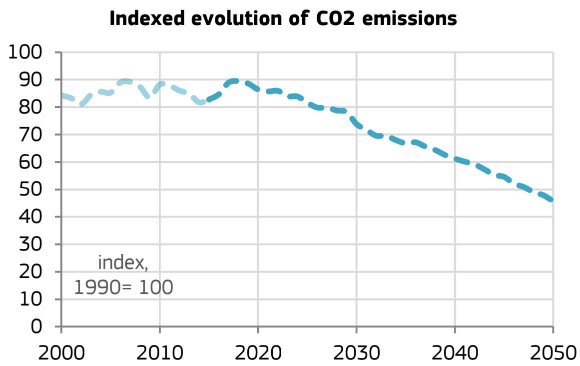


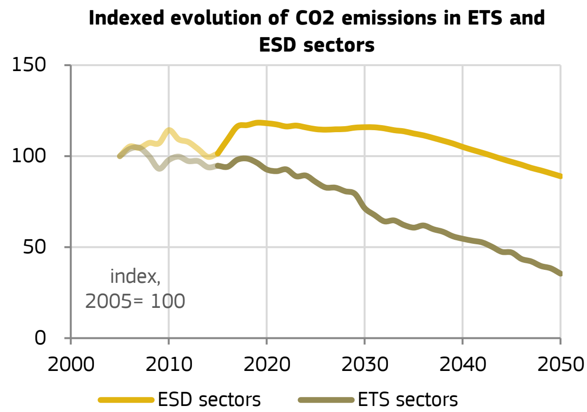


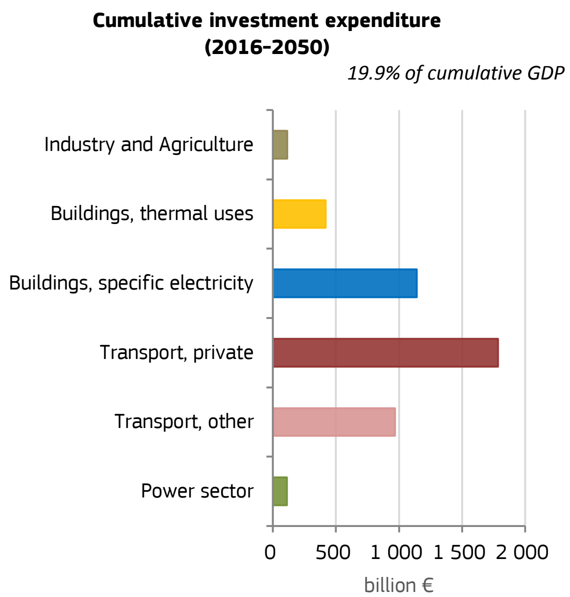
Share of renewable energies

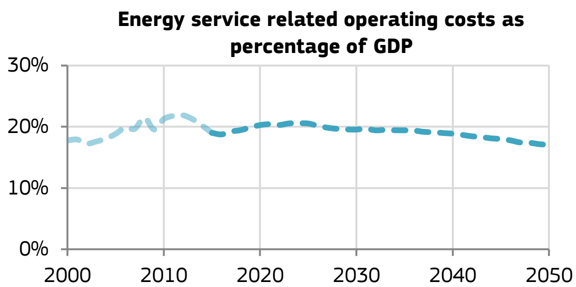


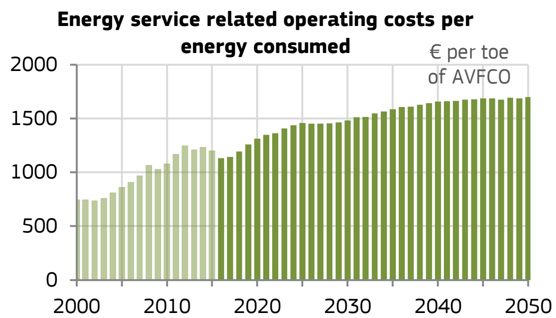

Mt CO2
CO2 emissions
400
350
300
250
200
150
100
50
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured

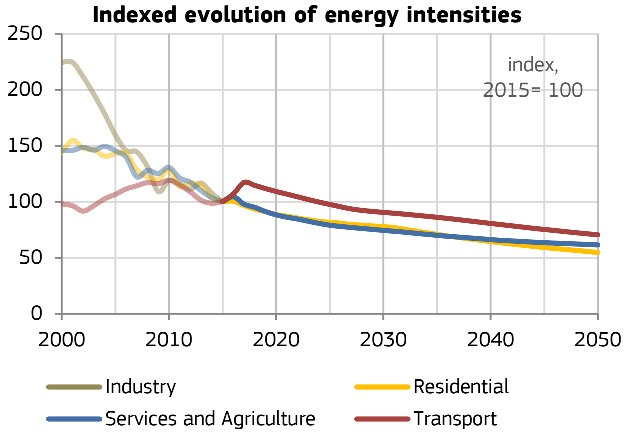

Indexed evolution of CO2 emissions
100
90
80
70
60
50
40
30
20
10
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

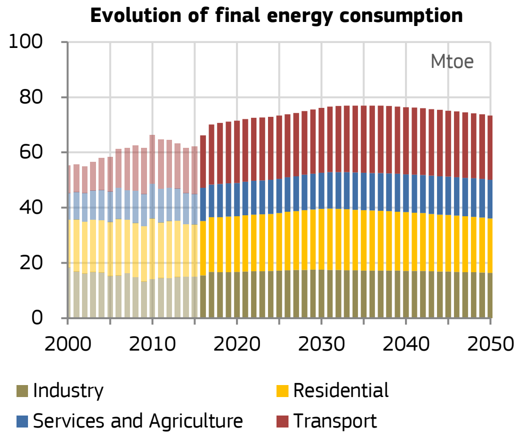

Indexed evolution of CO2 emissions in ETS and ESD sectors
150
100
50
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors

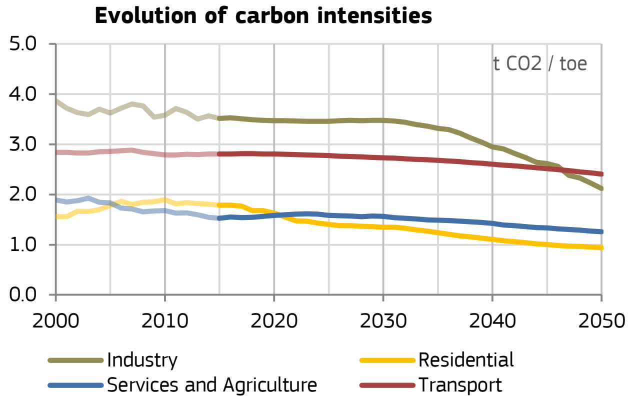

Cumulative investment expenditure (2016-2050)
19.9% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
500
1 000
1 500
2 000
billion €

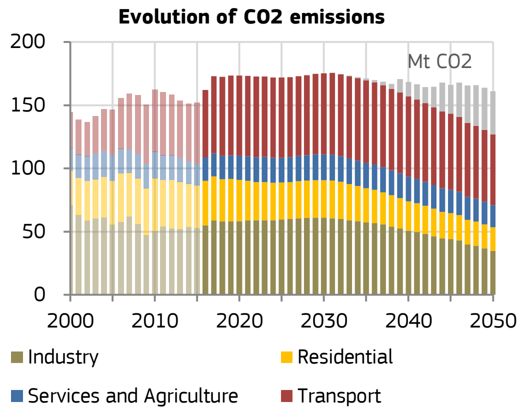

Energy service related operating costs as percentage of GDP
30%
20%
10%
0%
2000
2010
2020
2030
2040
2050

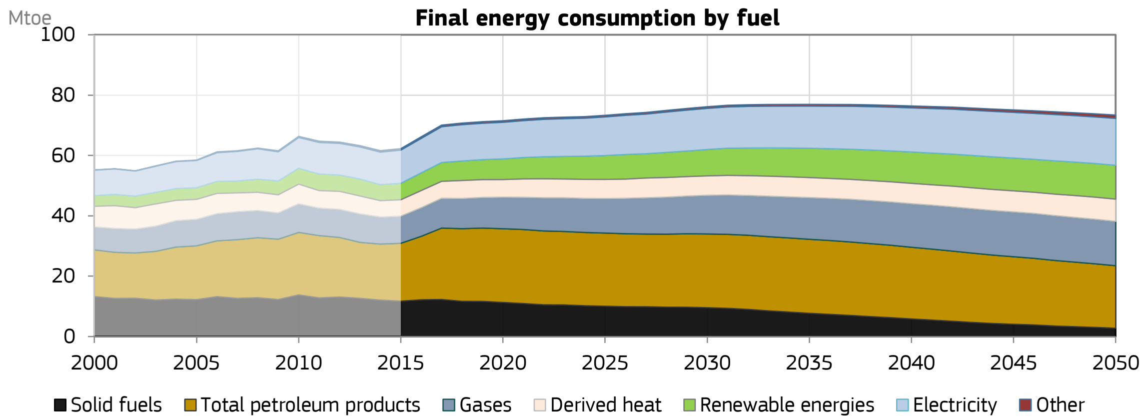

Energy service related operating costs per energy consumed
€ per toe
of AVFCO
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

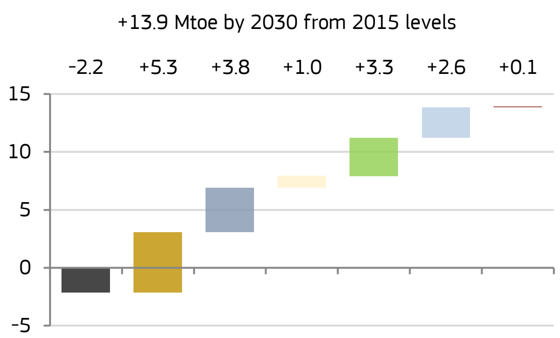

Indexed evolution of energy intensities
index, 2015= 100
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

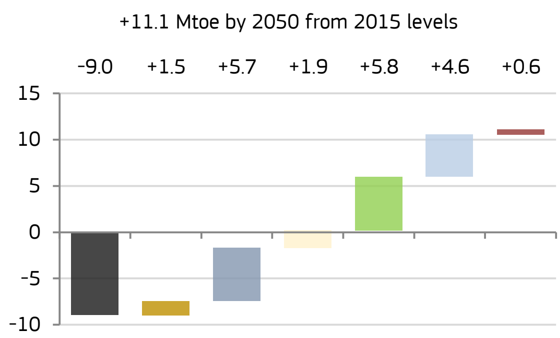

Evolution of final energy consumption
Mtoe
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

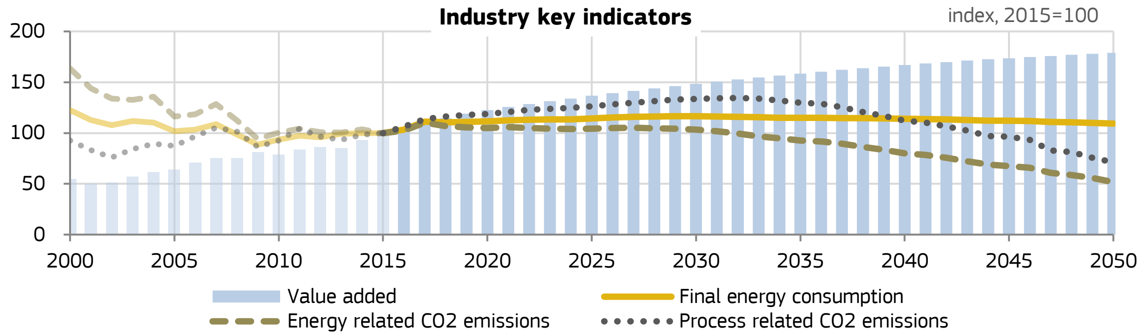

Evolution of carbon intensities
t CO2 / toe
5.0
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

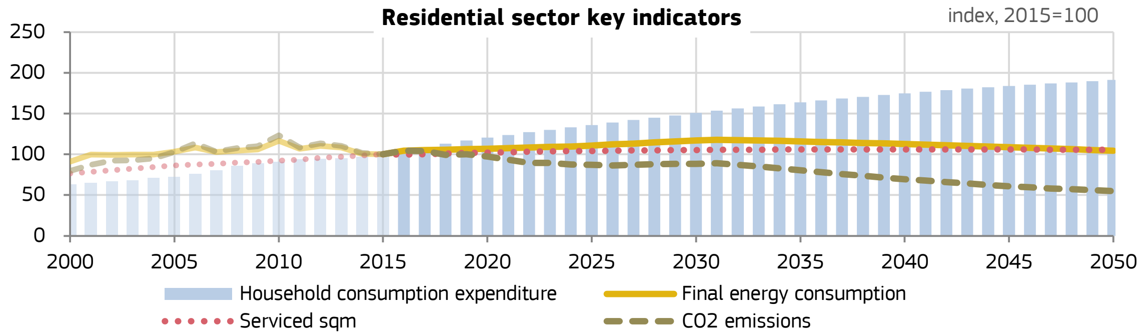

Evolution of CO2 emissions
Mt CO2
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

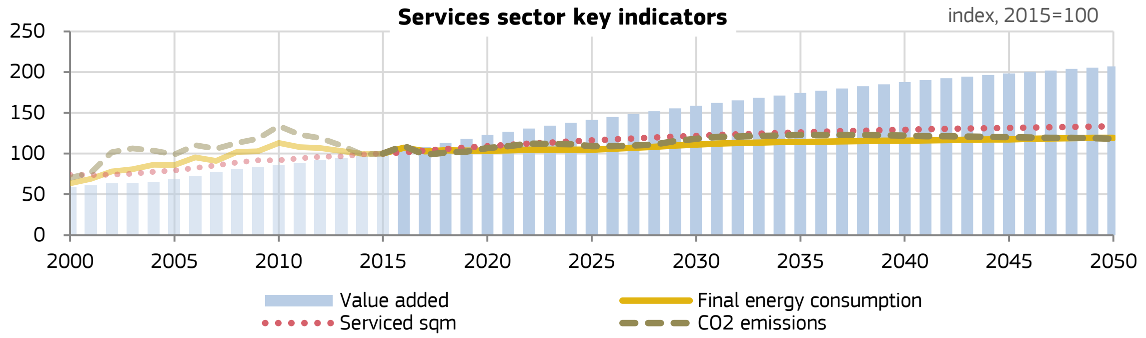

Final energy consumption by fuel
Mtoe
100
80
60
40
20
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

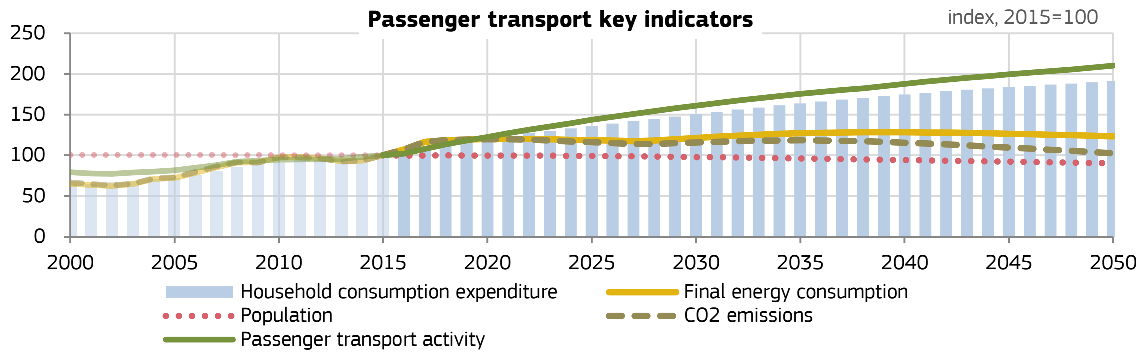

+13.9 Mtoe by 2030 from 2015 levels
-2.2
+5.3
+3.8
+1.0
+3.3
+2.6
+0.1
15
10
5
0
-5

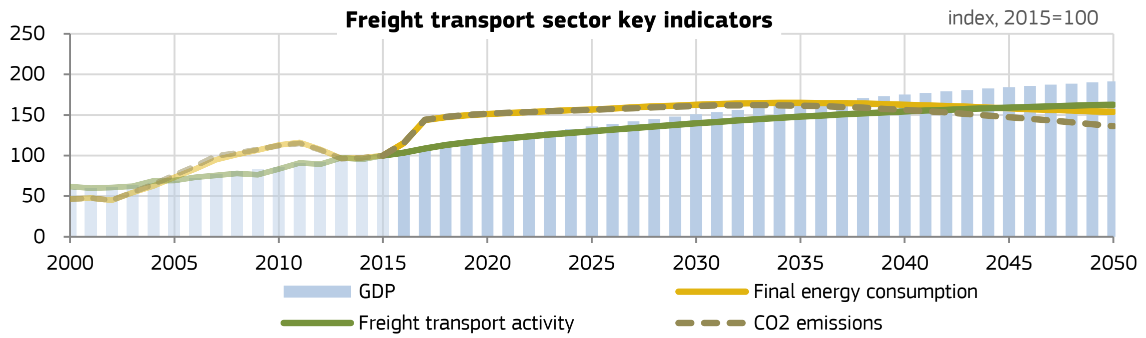

+11.1 Mtoe by 2050 from 2015 levels
-9.0
+1.5
+5.7
+1.9
+5.8
+4.6
+0.6
15
10
5
0
-5
-10

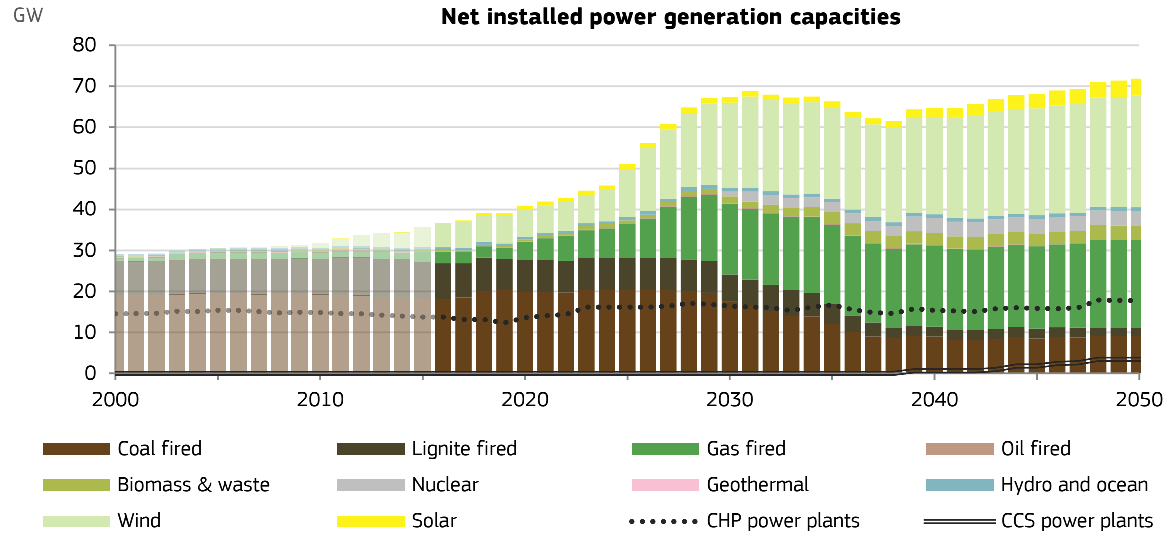

Industry key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

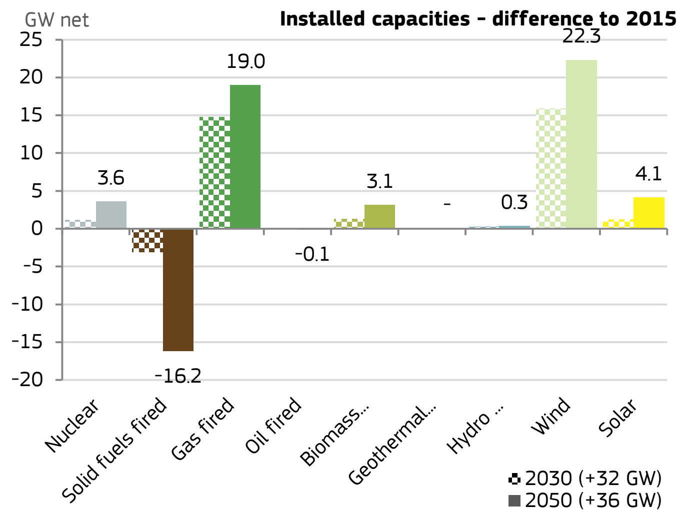

Residential sector key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

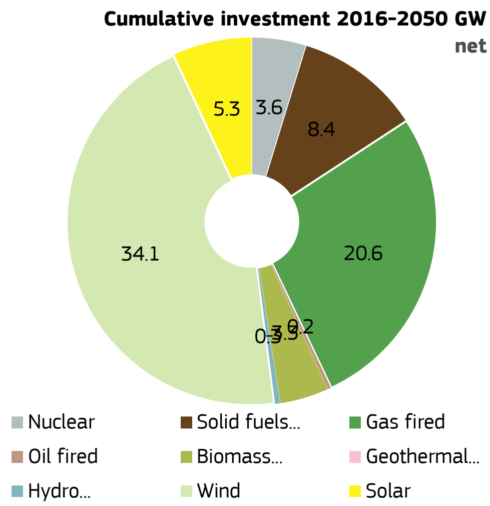

Services sector key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

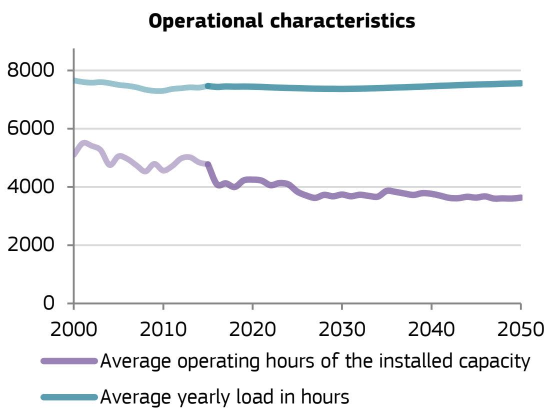

Passenger transport key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

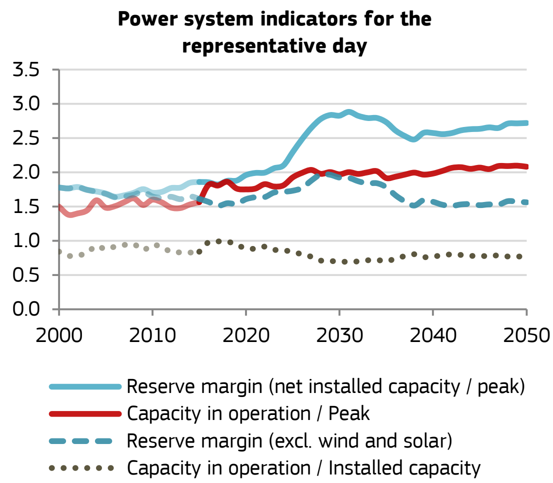

Freight transport sector key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

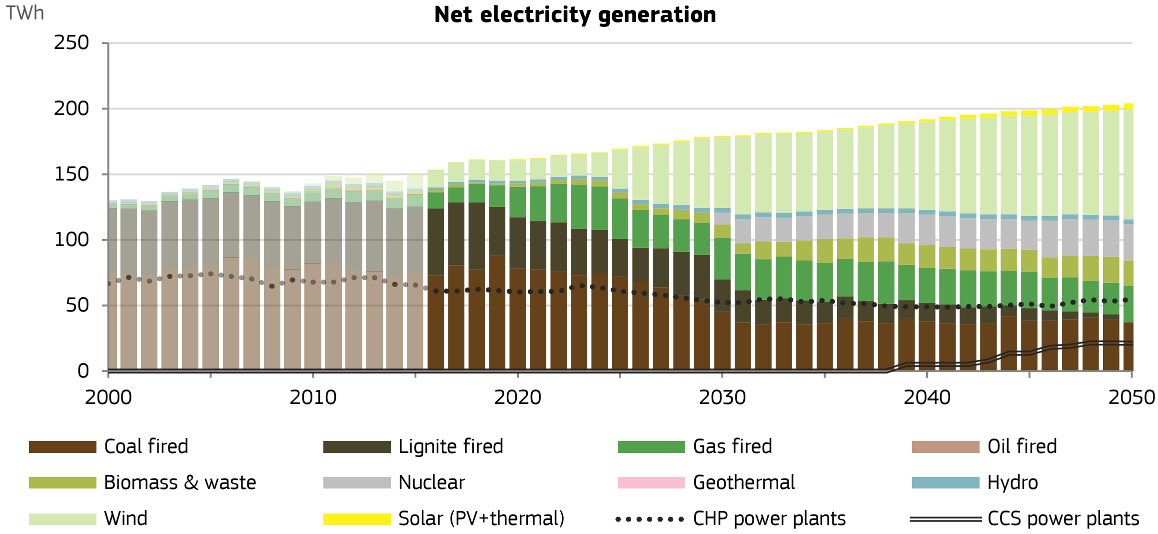

Net installed power generation capacities
GW
80
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

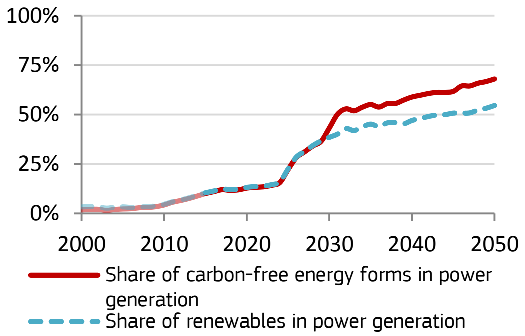

Installed capacities - difference to 2015
GW net
25
20
15
10
5
0
-5
-10
-15
-20
3.6
-16.2
19.0
-0.1
3.1
-
0.3
22.3
4.1
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+32 GW)
2050 (+36 GW)

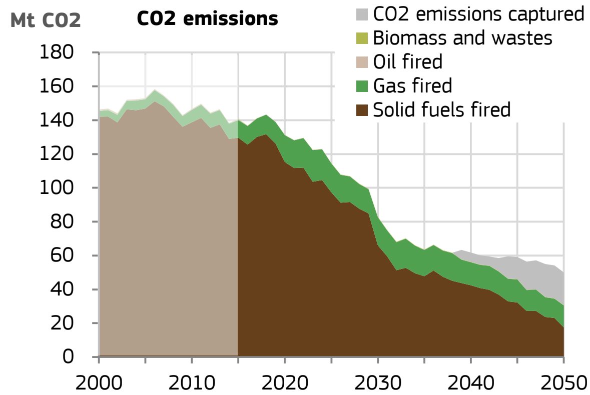

Cumulative investment 2016-2050 GW net
5.3
3.6
8.4
20.6
34.1
0.3
3.3
0.2
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

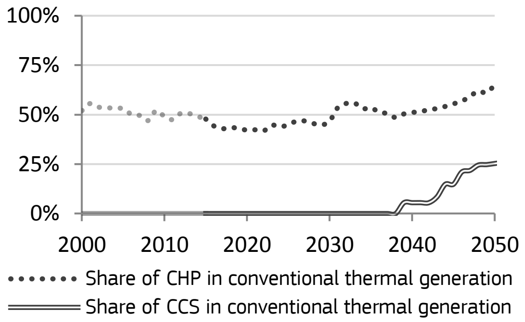

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

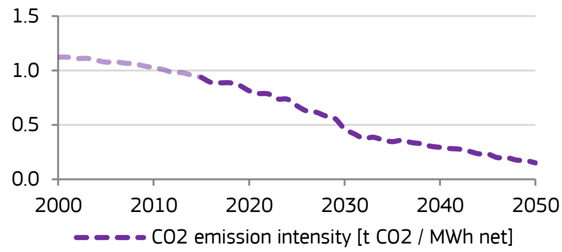

Power system indicators for the representative day
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

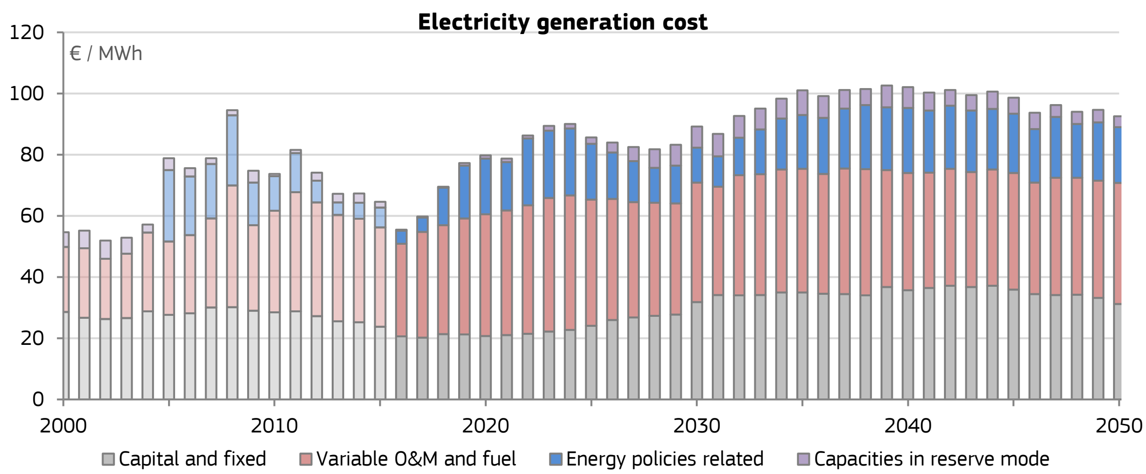

TWh
Net electricity generation
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

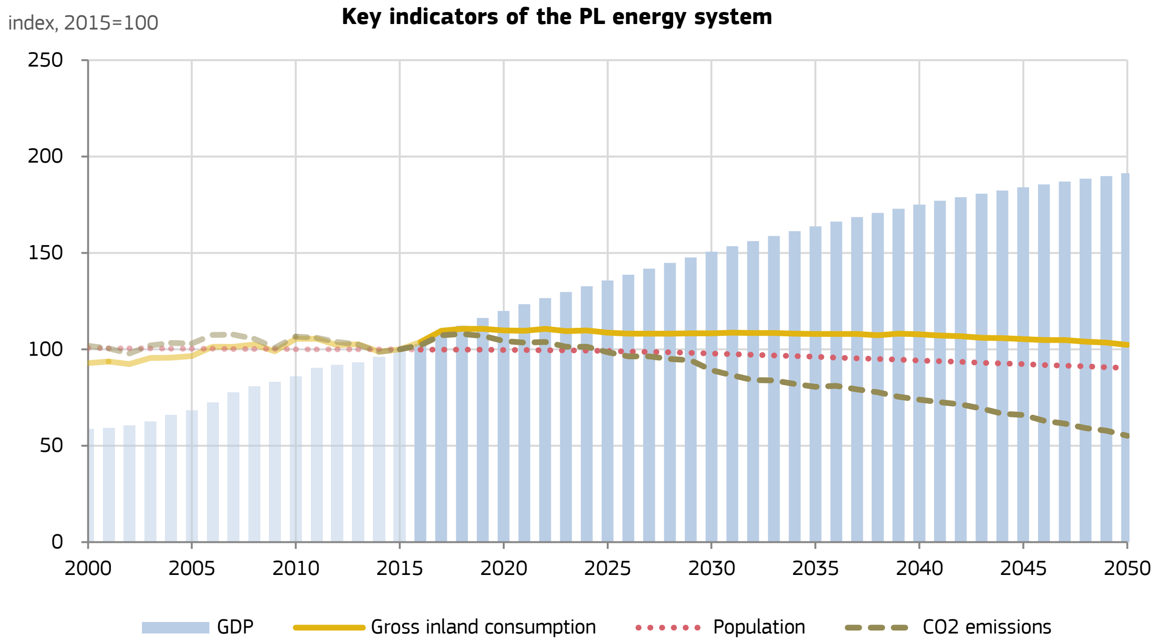

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
180
160
140
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050

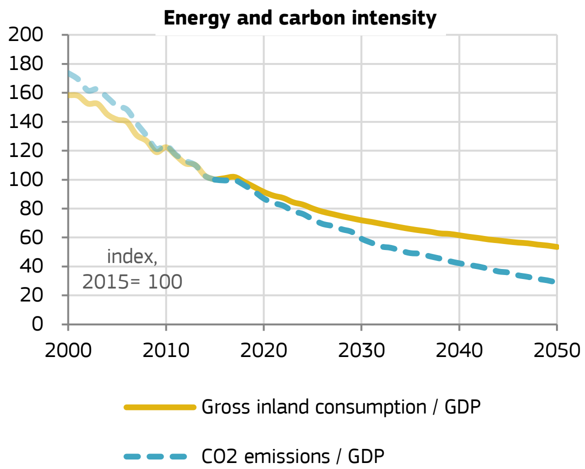

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

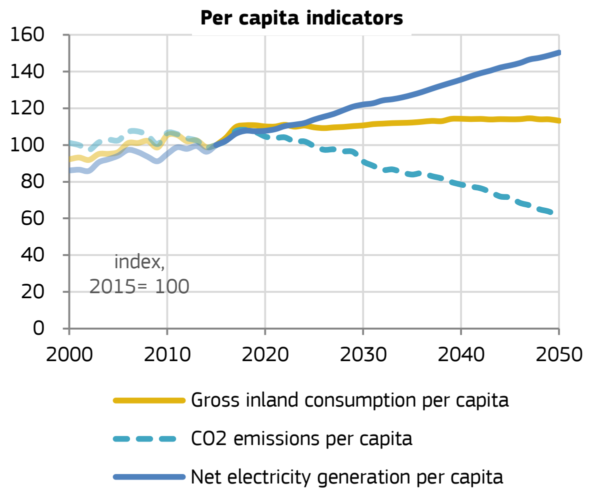

1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	59.9	58.5	62.3	71.5	76.2	73.4
Primary energy consumption [Mtoe]	99.1	87.7	90.0	98.6	96.1	90.5
RES [%] - Share of energy from renewable sources		7.1%	12.4%	13.7%	21.7%	32.3%
RES-E [%] - Share of electricity from renewable sources		2.6%	13.3%	15.9%	39.5%	51.4%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	376.5	321.0	311.6	325.3	277.9	172.2
reduction to 1990		*-15%*	*-17%*	*-14%*	*-26%*	*-54%*
Emissions in current ETS sectors |(PL) [Mt CO2]		211.8	200.7	196.3	151.3	75.0
reduction to 2005			*-5%*	*-7%*	*-29%*	*-65%*
Emissions in current ESD sectors [Mt CO2]		109.2	110.9	129.0	126.7	97.2
reduction to 2005			*1%*	*18%*	*16%*	*-11%*



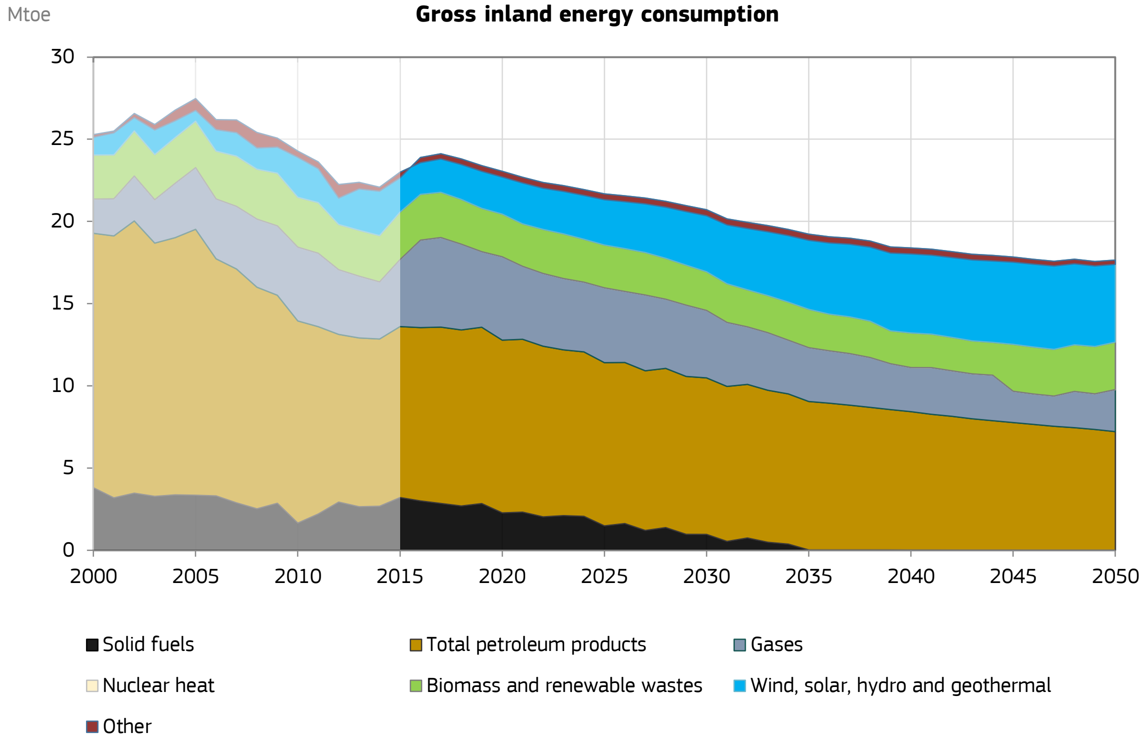


POTEnCIA - Model results overview

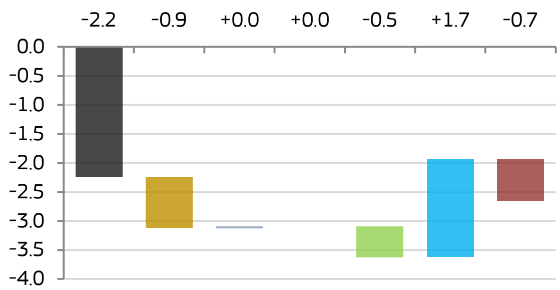
Portugal

Central_2018 scenario

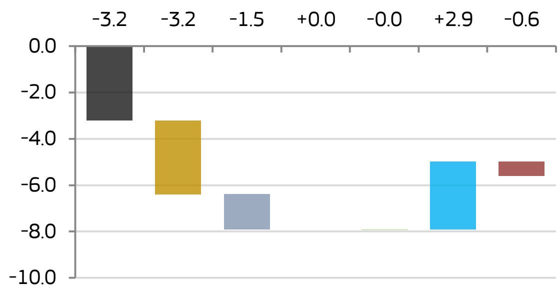
Gross inland energy consumption



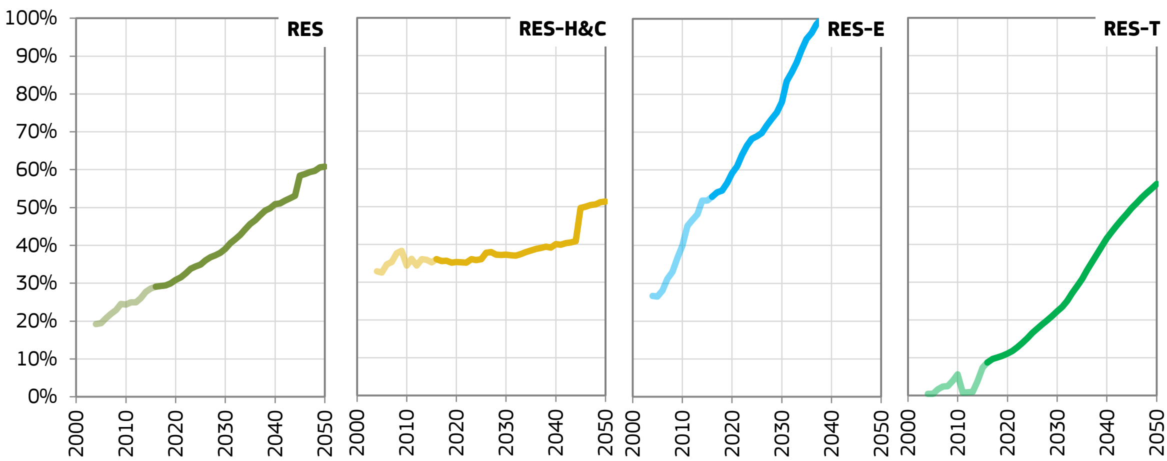
-2.7 Mtoe by 2030 from 2015 levels

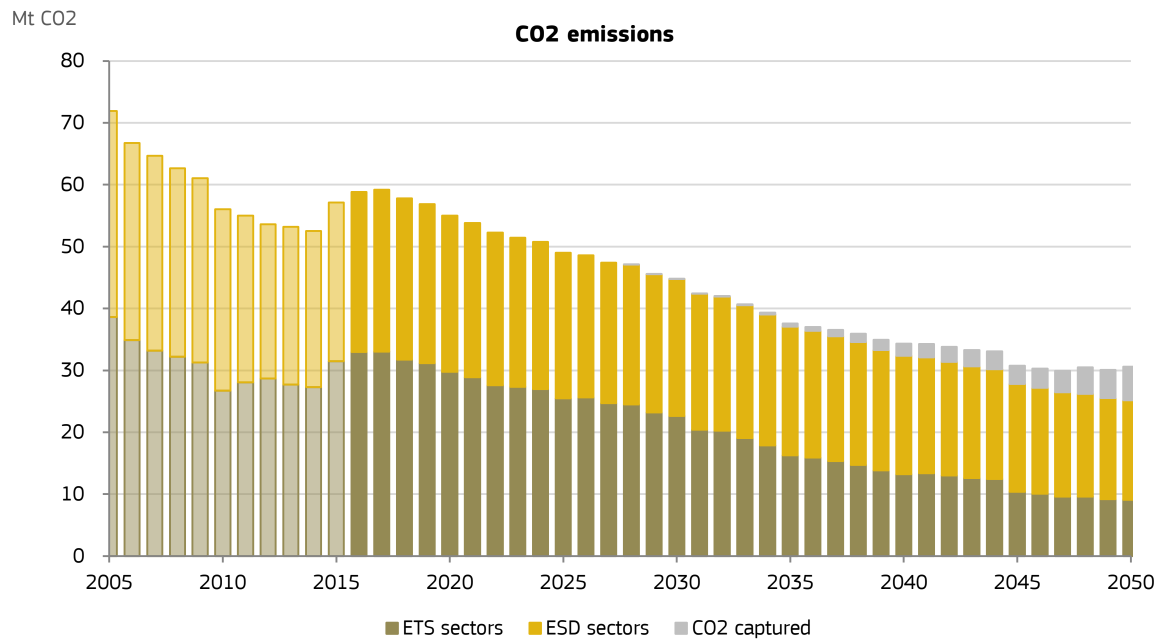


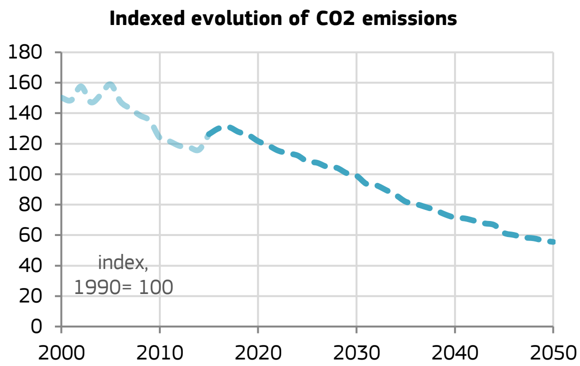
-5.6 Mtoe by 2050 from 2015 levels

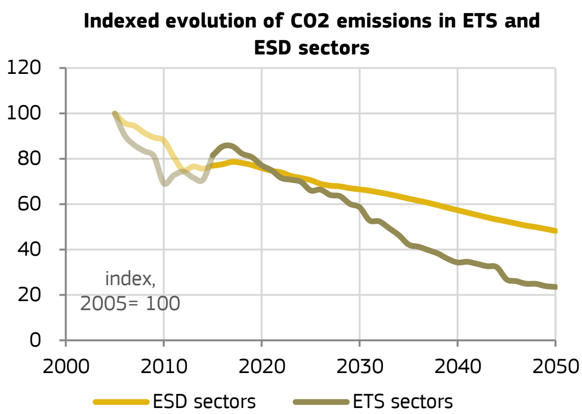


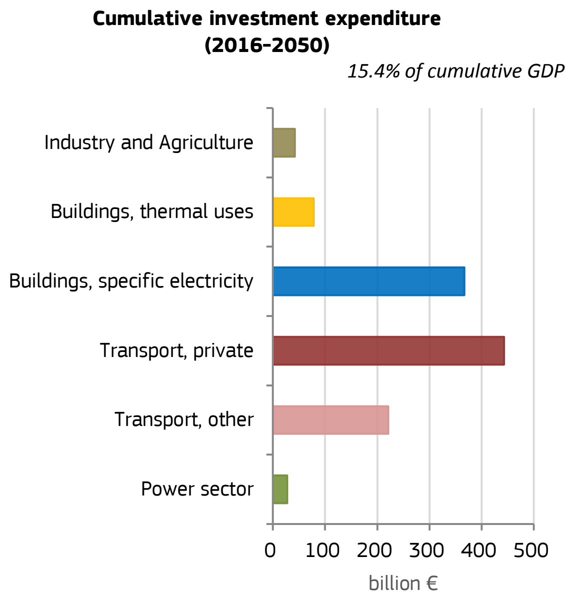
Share of renewable energies

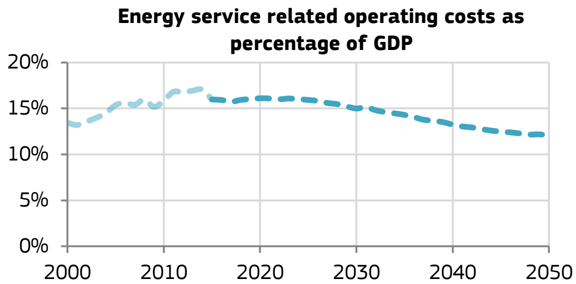


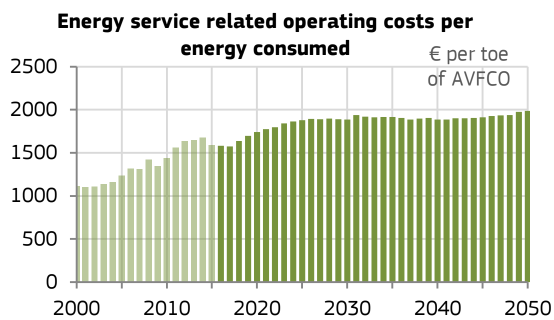

Mt CO2
CO2 emissions
80
70
60
50
40
30
20
10
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured


Indexed evolution of CO2 emissions
180
160
140
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

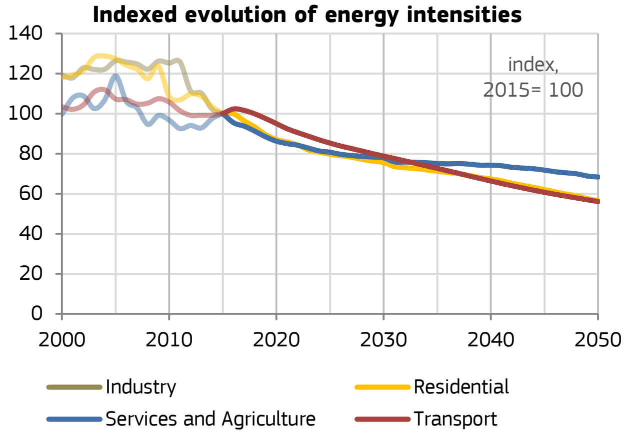

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors


Cumulative investment expenditure (2016-2050)
15.4% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
100
200
300
400
500
billion €

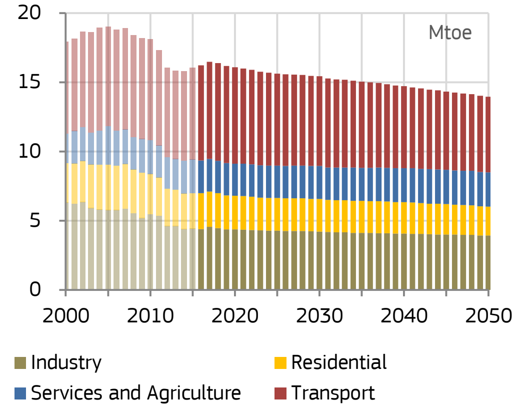

Energy service related operating costs as percentage of GDP
20%
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050


Energy service related operating costs per energy consumed
€ per toe
of AVFCO
2500
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

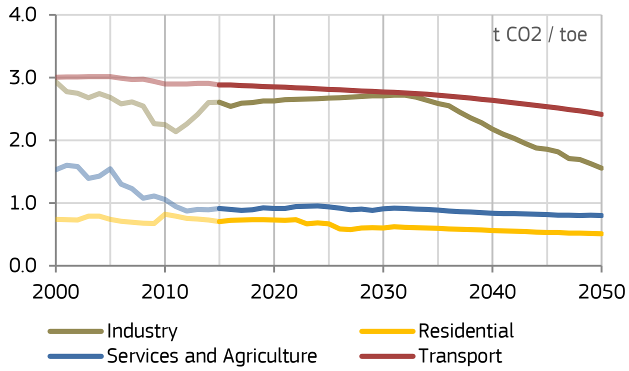
Indexed evolution of energy intensities



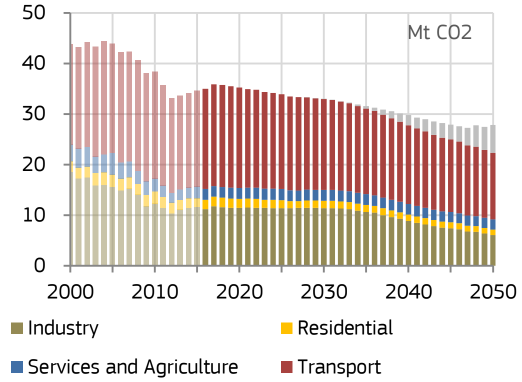
Evolution of final energy consumption



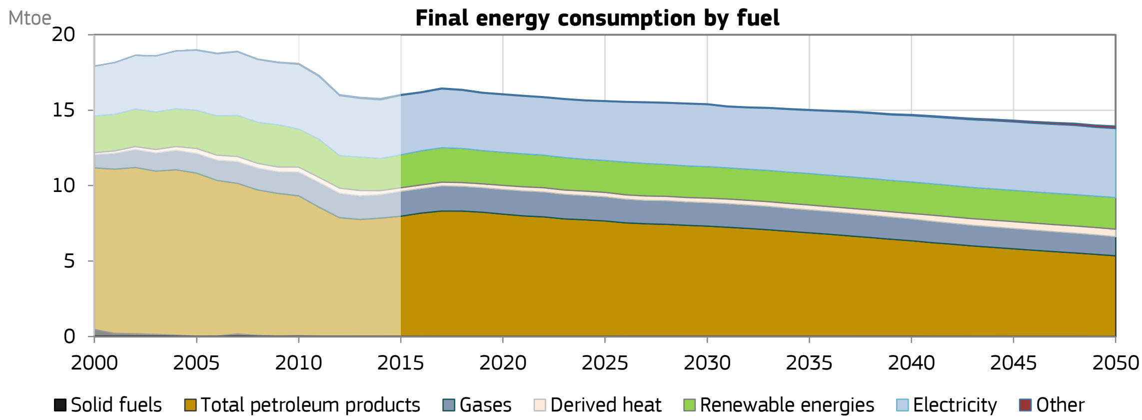
Evolution of carbon intensities



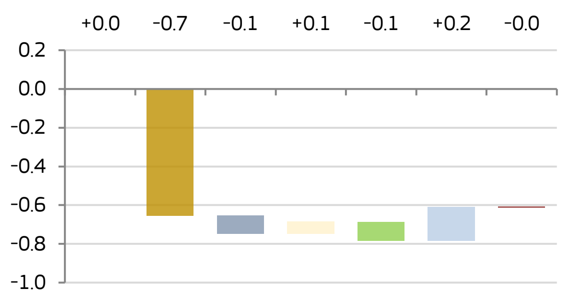
Evolution of CO2 emissions



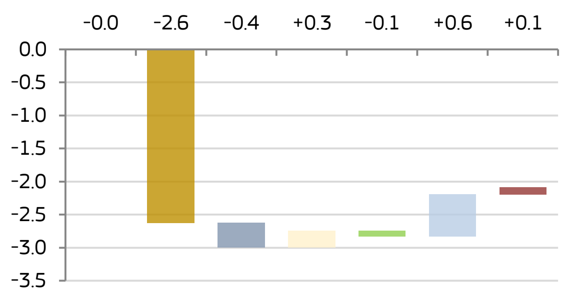
Final energy consumption by fuel

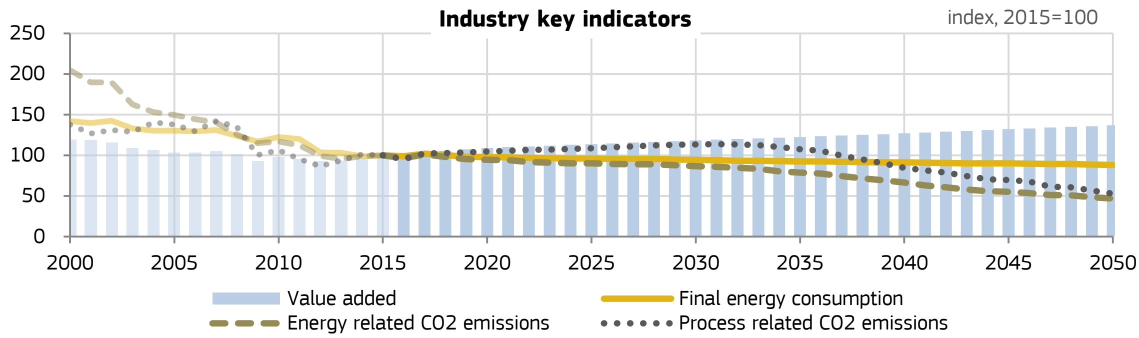


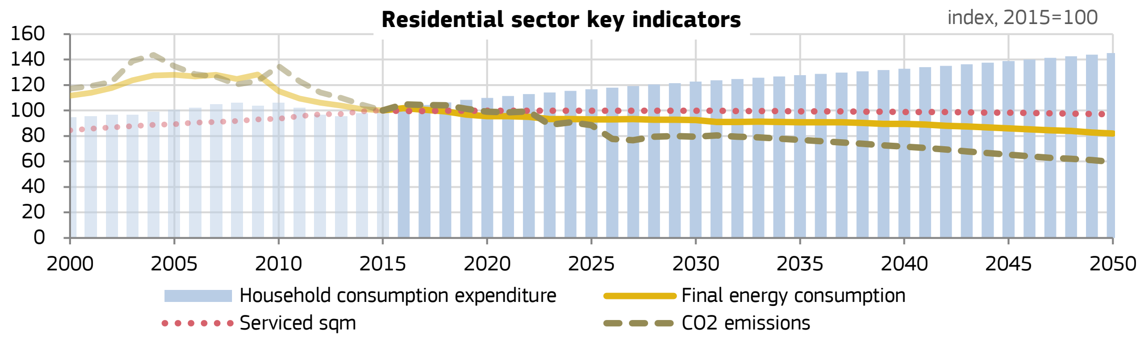
-0.6 Mtoe by 2030 from 2015 levels

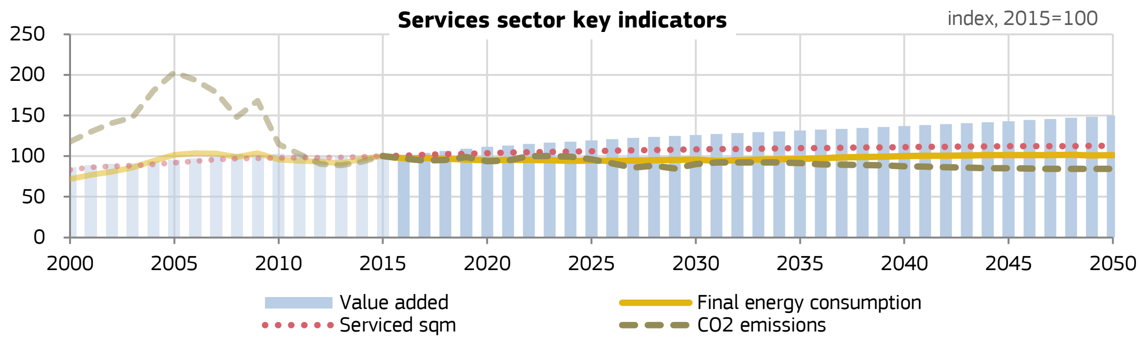


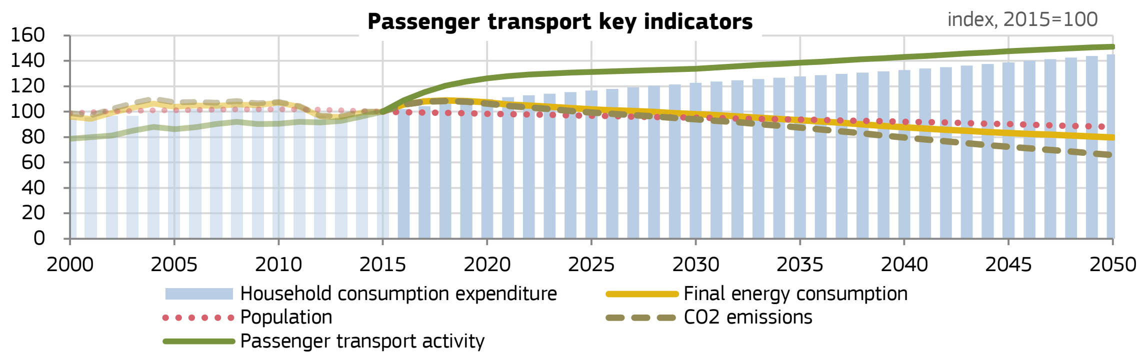
-2.1 Mtoe by 2050 from 2015 levels

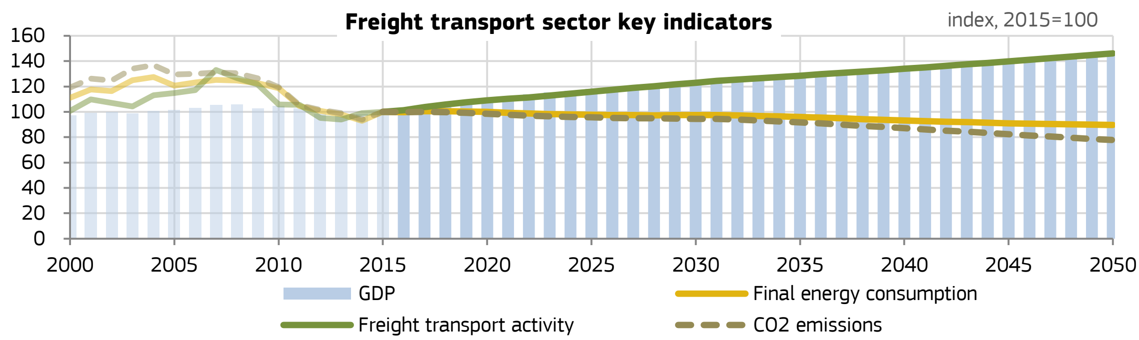



Industry key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

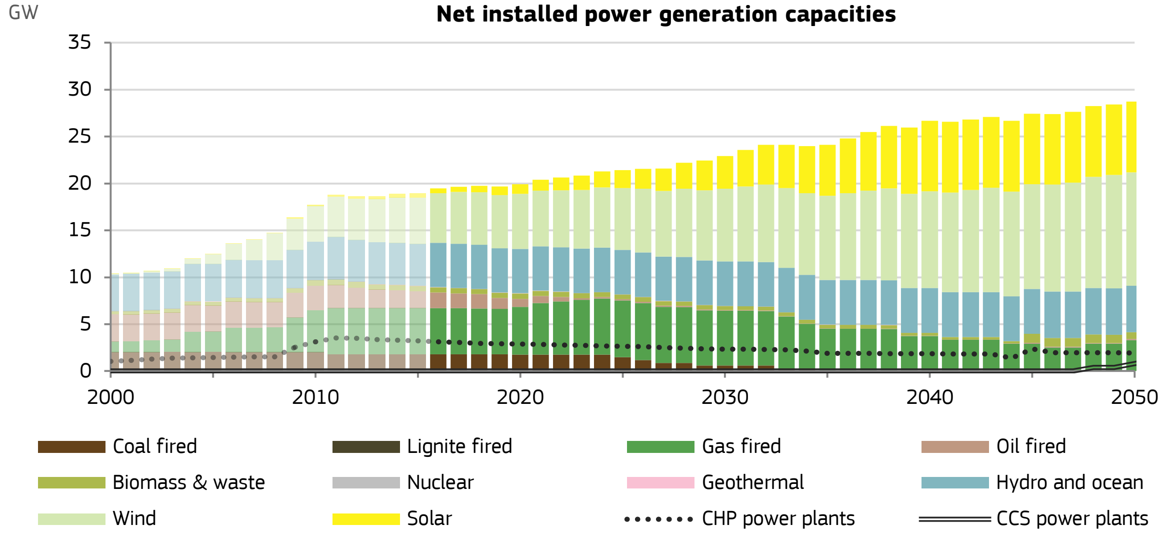

Residential sector key indicators
index, 2015=100
160
140
120
100
80
60
40
20
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions


Services sector key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

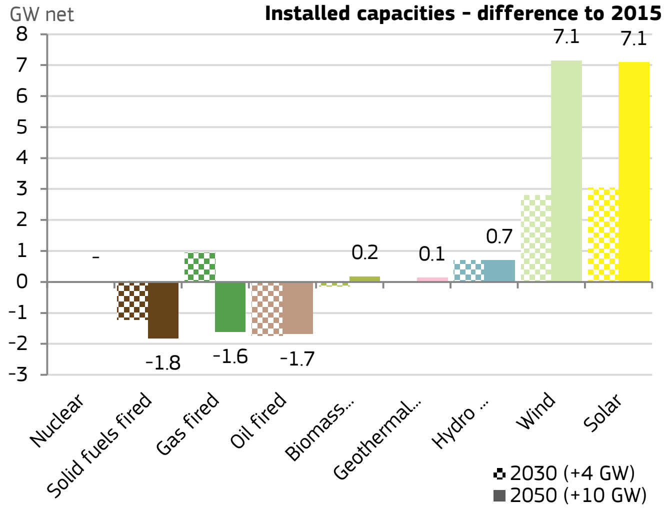

Passenger transport key indicators
index, 2015=100
160
140
120
100
80
60
40
20
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity


Freight transport sector key indicators
index, 2015=100
160
140
120
100
80
60
40
20
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

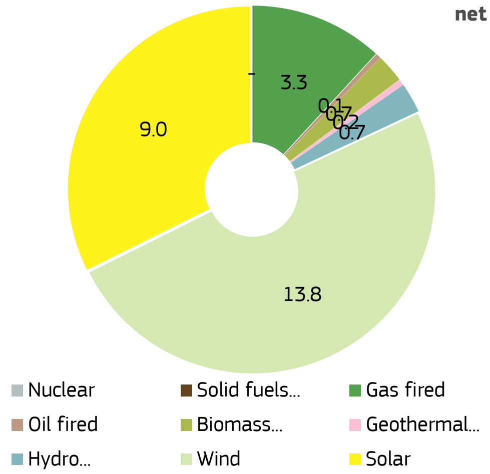
Net installed power generation capacities



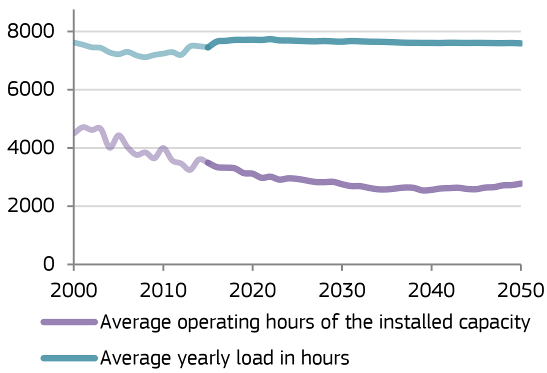
Installed capacities - difference to 2015



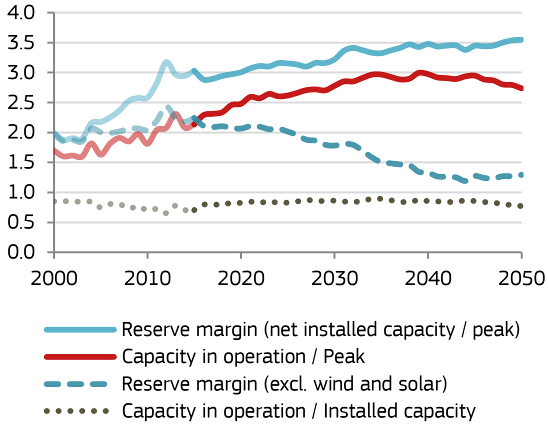
Cumulative investment 2016-2050 GW net

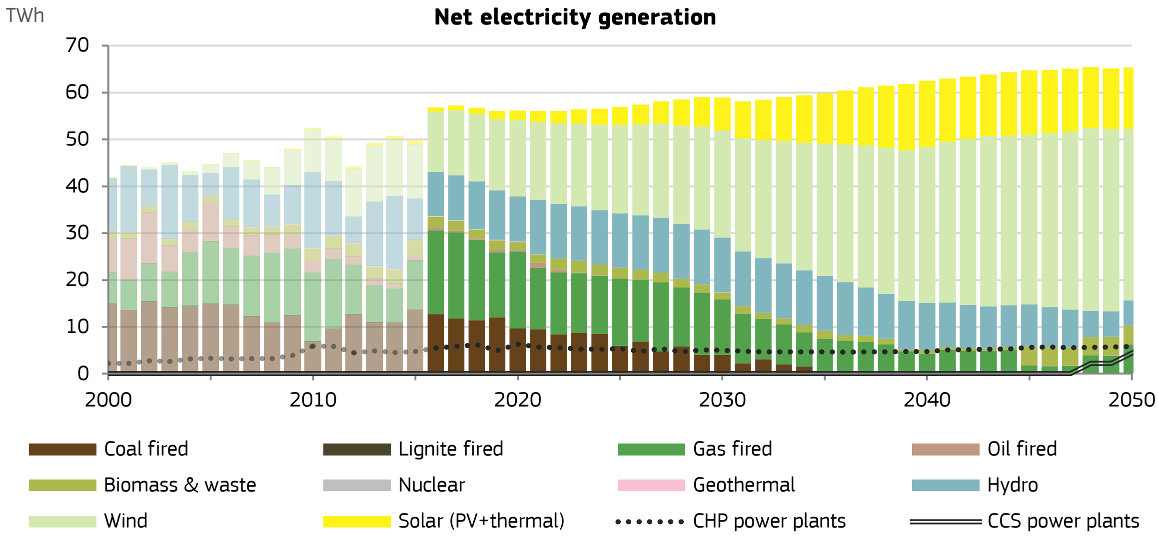


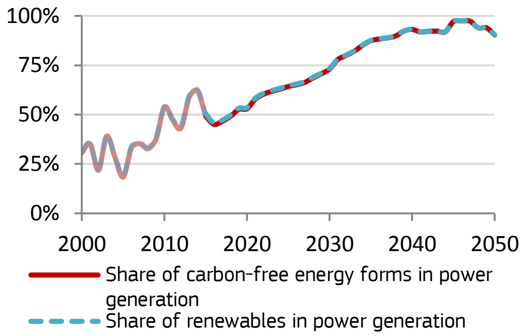
Operational characteristics

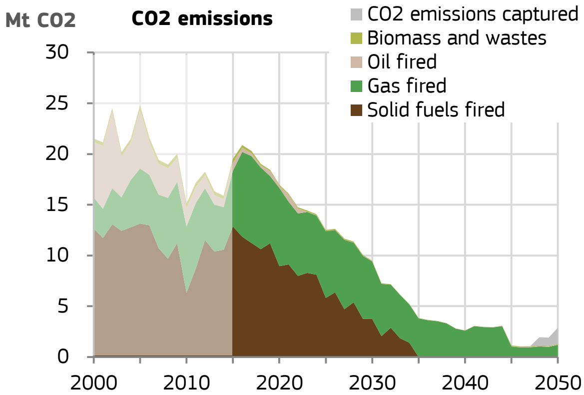


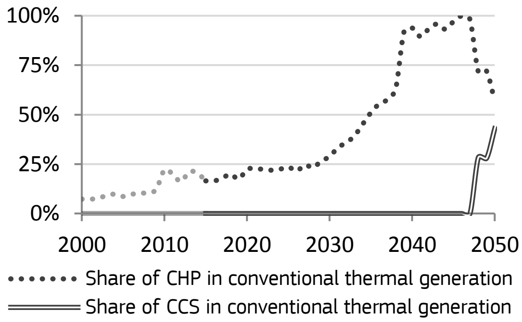
Power system indicators for the representative day

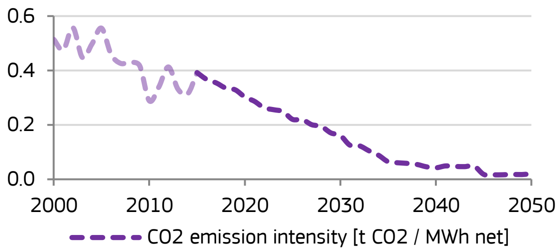


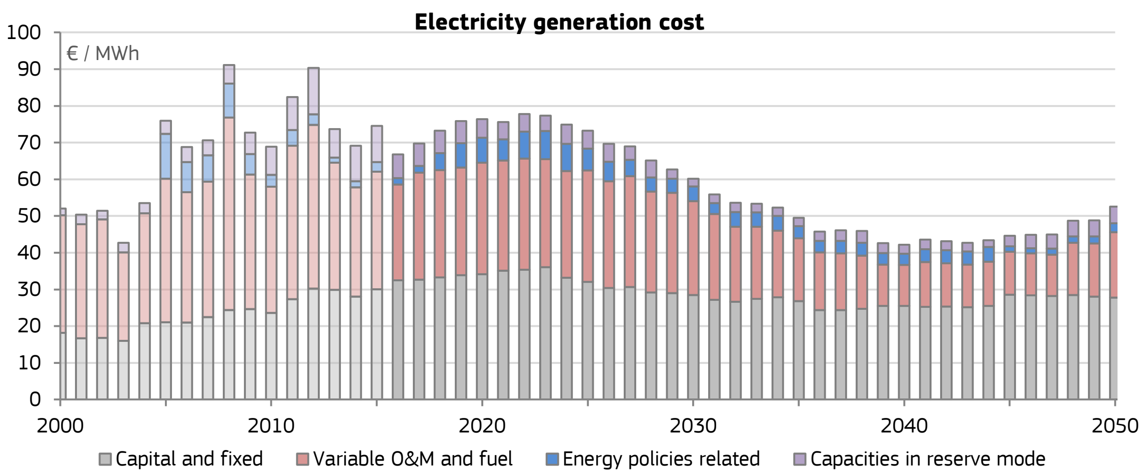

TWh
Net electricity generation
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

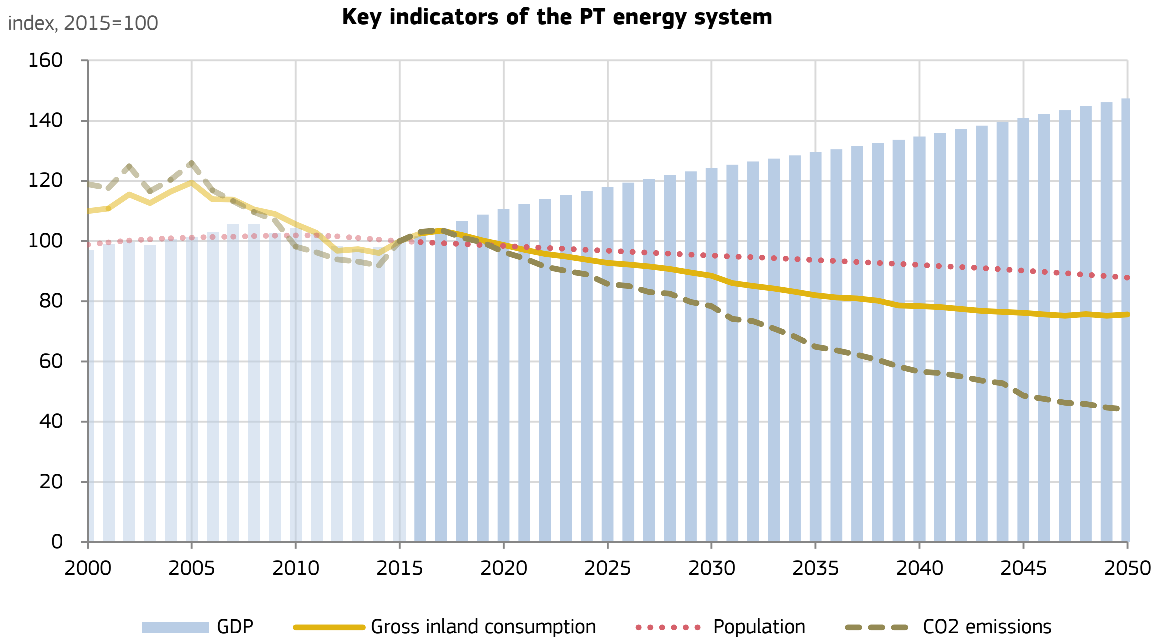

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation


Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050

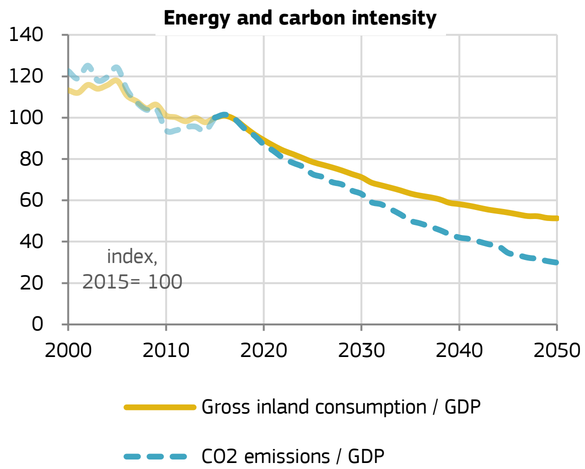

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

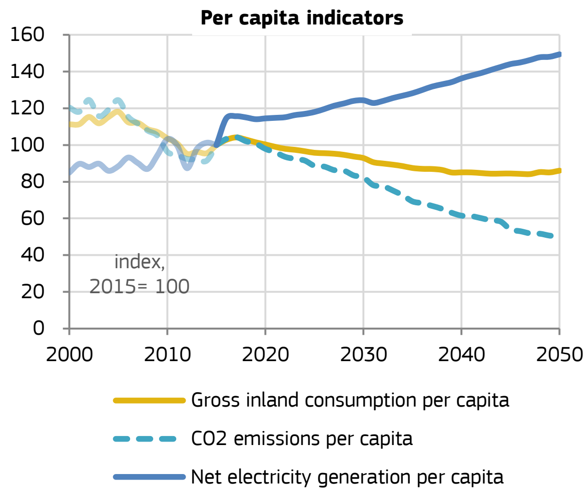

0.6
0.4
0.2
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
100
90
80
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	11.9	19.0	16.0	16.1	15.4	14.0
Primary energy consumption [Mtoe]	16.1	24.9	21.7	21.2	18.8	15.9
RES [%] - Share of energy from renewable sources		19.5%	28.6%	30.9%	39.1%	60.8%
RES-E [%] - Share of electricity from renewable sources		26.5%	51.9%	59.1%	78.0%	100.0%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	45.2	71.9	57.1	55.0	44.8	25.1
reduction to 1990		*59%*	*26%*	*22%*	*-1%*	*-44%*
Emissions in current ETS sectors |(PT) [Mt CO2]		38.6	31.5	29.8	22.6	9.1
reduction to 2005			*-18%*	*-23%*	*-41%*	*-76%*
Emissions in current ESD sectors [Mt CO2]		33.3	25.6	25.3	22.2	16.1
reduction to 2005			*-23%*	*-24%*	*-33%*	*-52%*

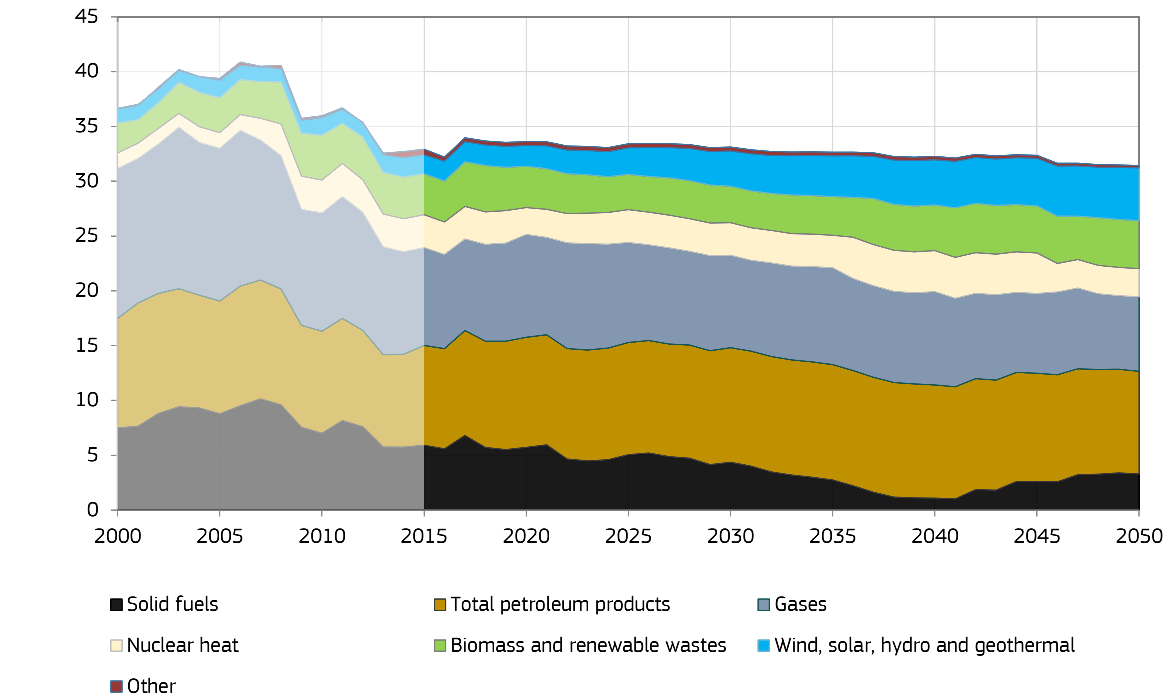




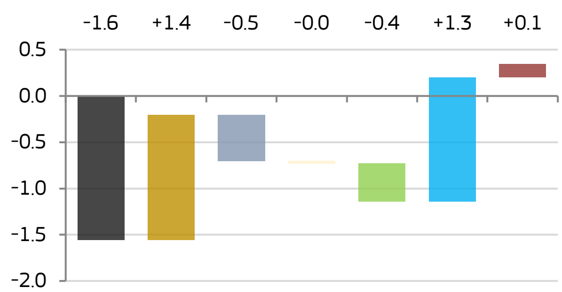
Romania

Central_2018 scenario

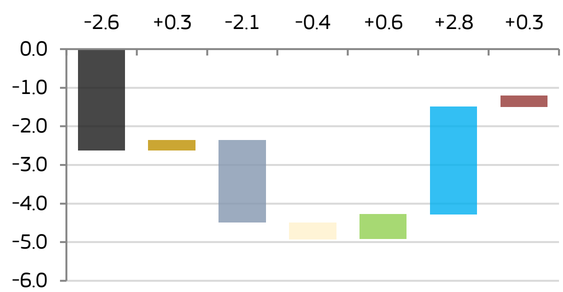
Gross inland energy consumption



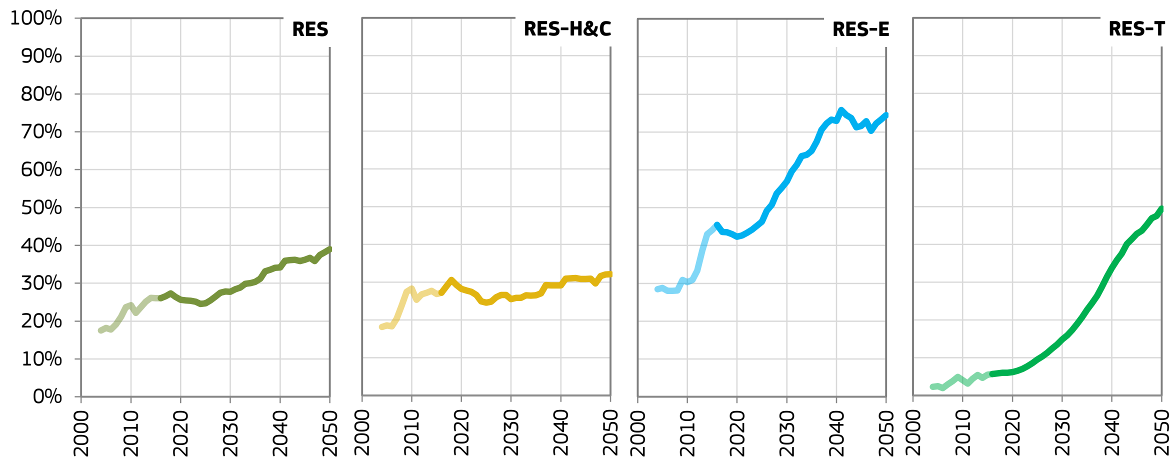
+0.3 Mtoe by 2030 from 2015 levels



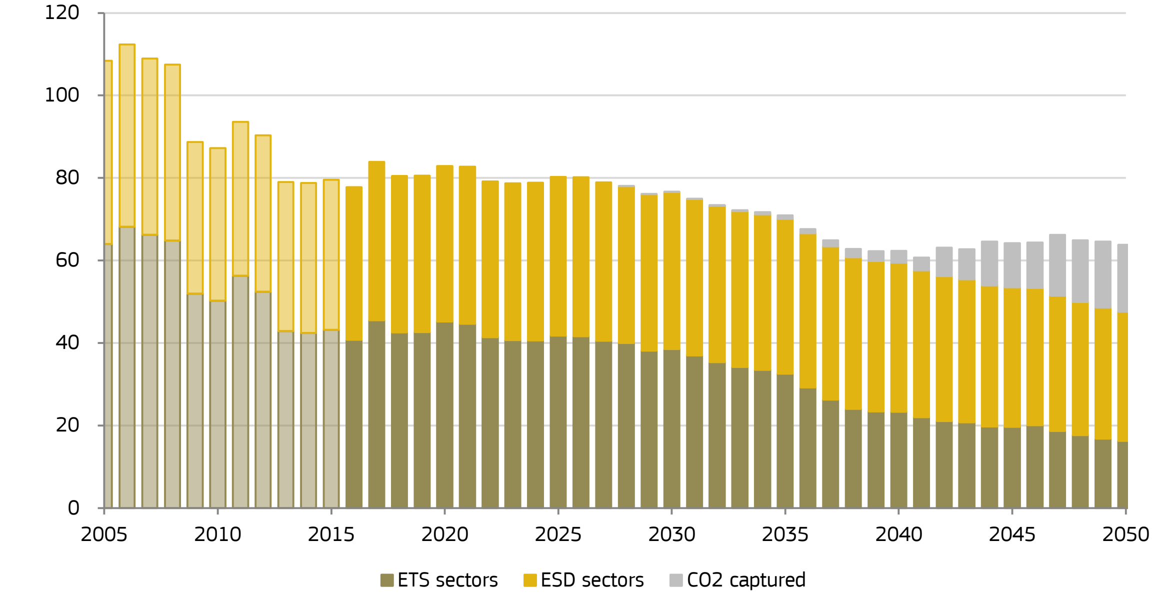
-1.2 Mtoe by 2050 from 2015 levels



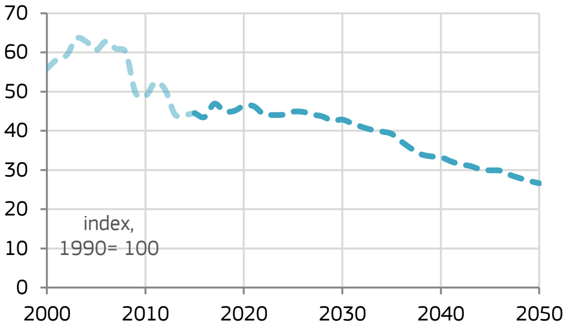
Share of renewable energies



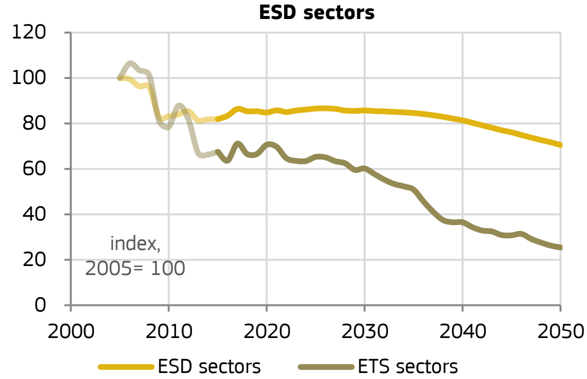
CO2 emissions



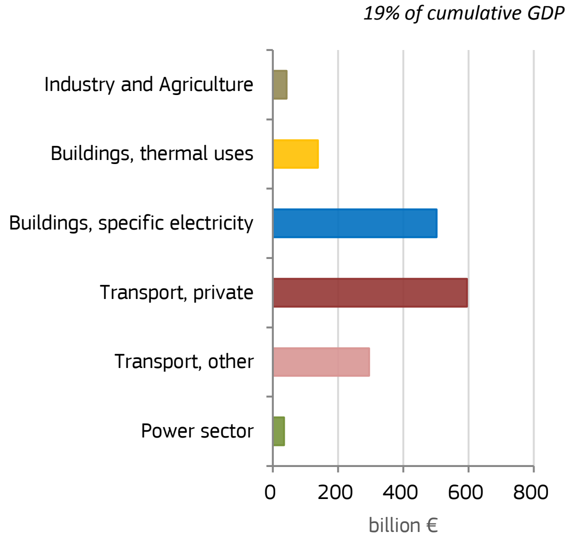
Indexed evolution of CO2 emissions



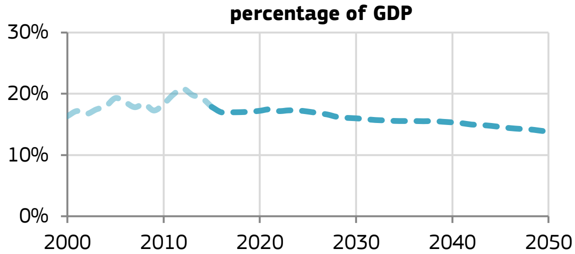
Indexed evolution of CO2 emissions in ETS and ESD sectors



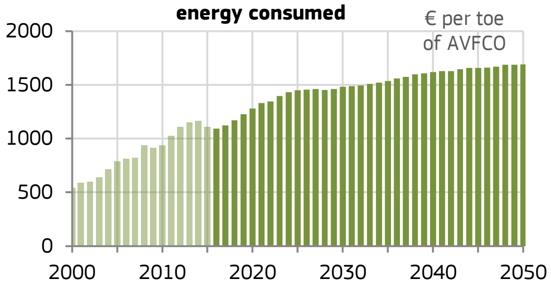
Cumulative investment expenditure (2016-2050)

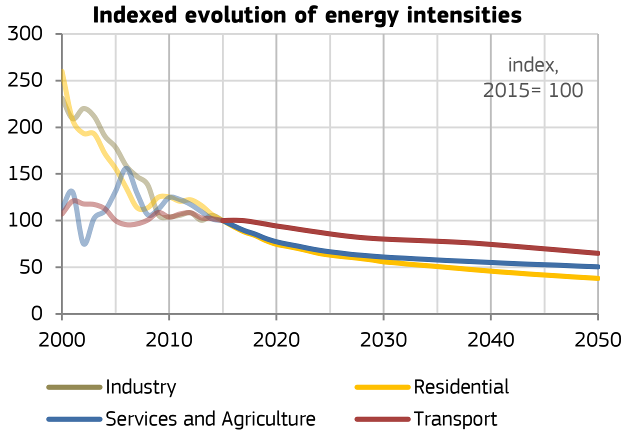


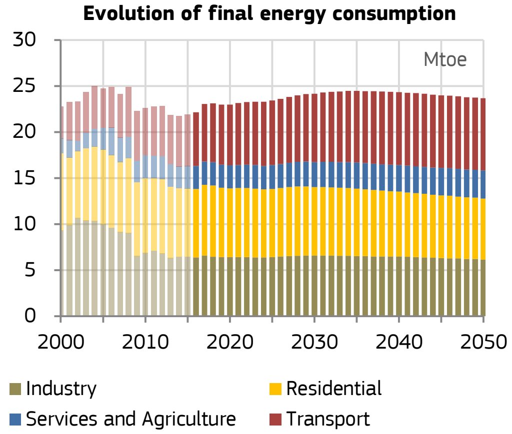
Energy service related operating costs as percentage of GDP

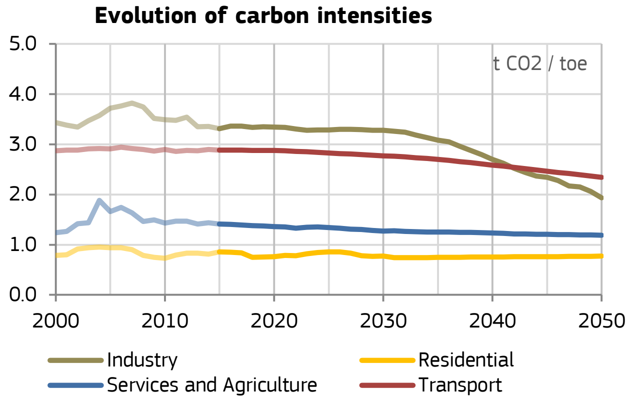


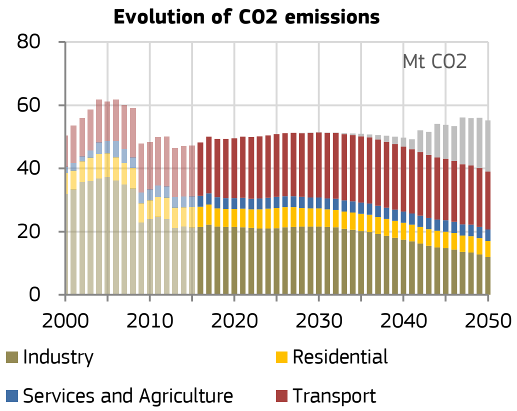
Energy service related operating costs per energy consumed

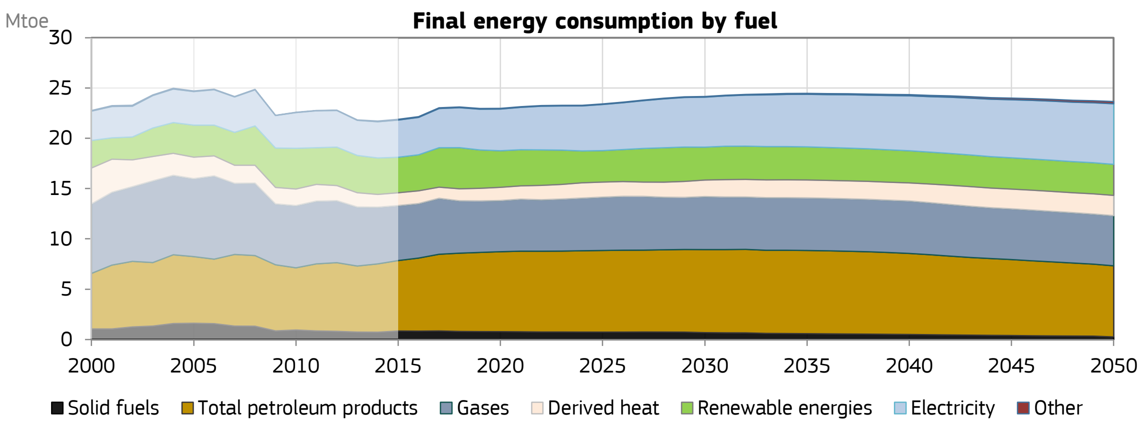


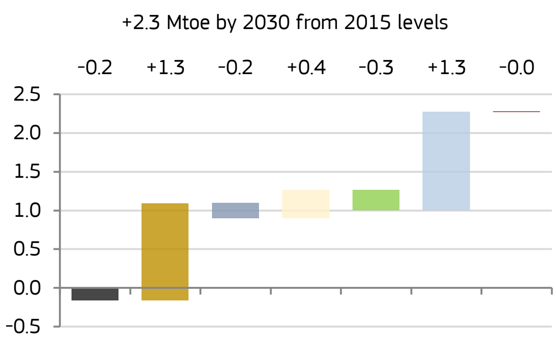

Indexed evolution of energy intensities
index, 2015= 100
300
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

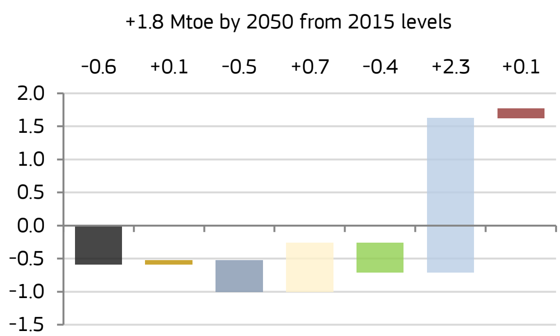

Evolution of final energy consumption
Mtoe
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

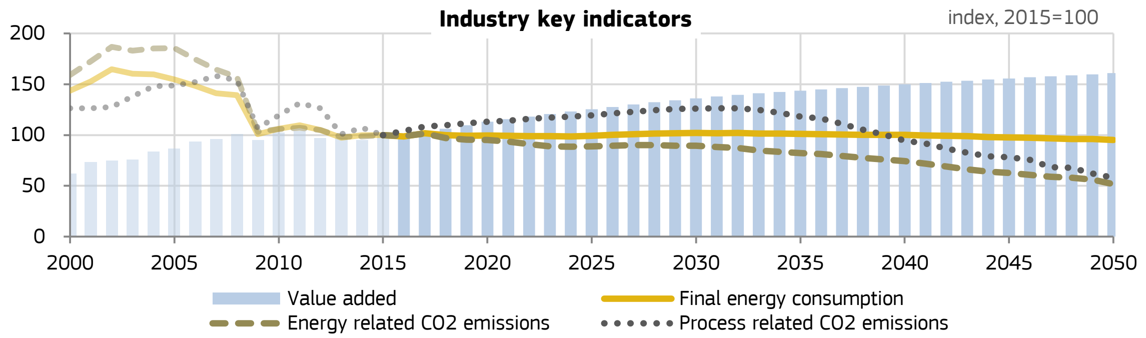

Evolution of carbon intensities
t CO2 / toe
5.0
4.0
3.0
2.0
1.0
0.0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

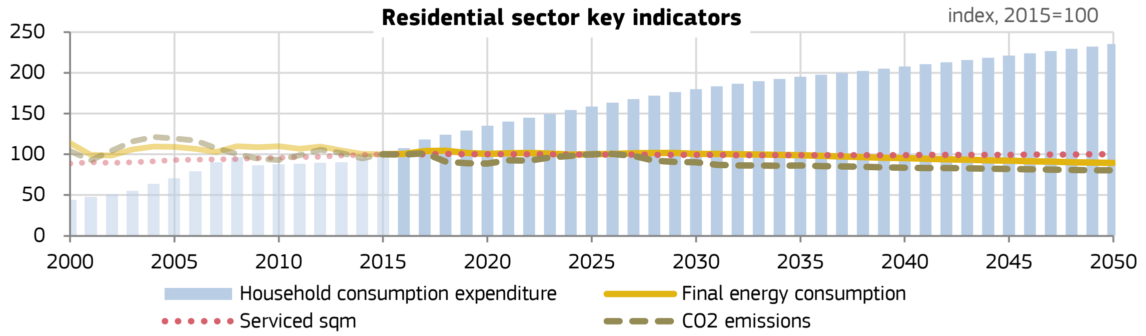

Evolution of CO2 emissions
Mt CO2
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Industry
Residential
Services and Agriculture
Transport

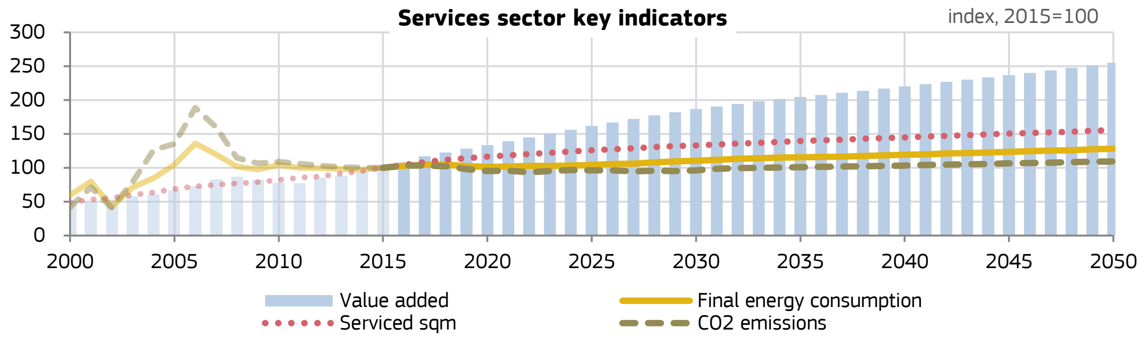

Final energy consumption by fuel
Mtoe
30
25
20
15
10
5
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

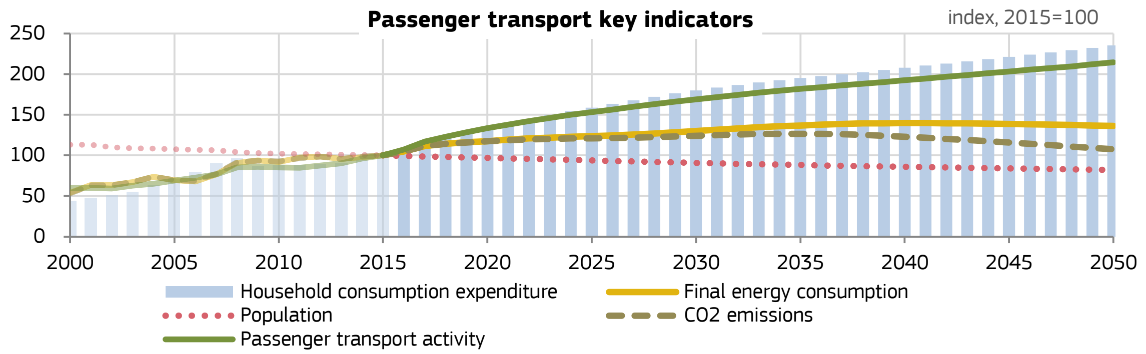

+2.3 Mtoe by 2030 from 2015 levels
-0.2
+1.3
-0.2
+0.4
-0.3
+1.3
-0.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5

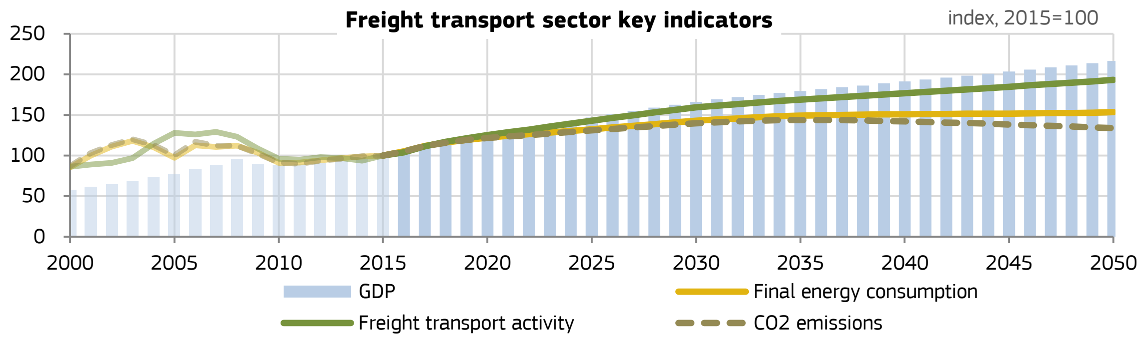

+1.8 Mtoe by 2050 from 2015 levels
-0.6
+0.1
-0.5
+0.7
-0.4
+2.3
+0.1
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5

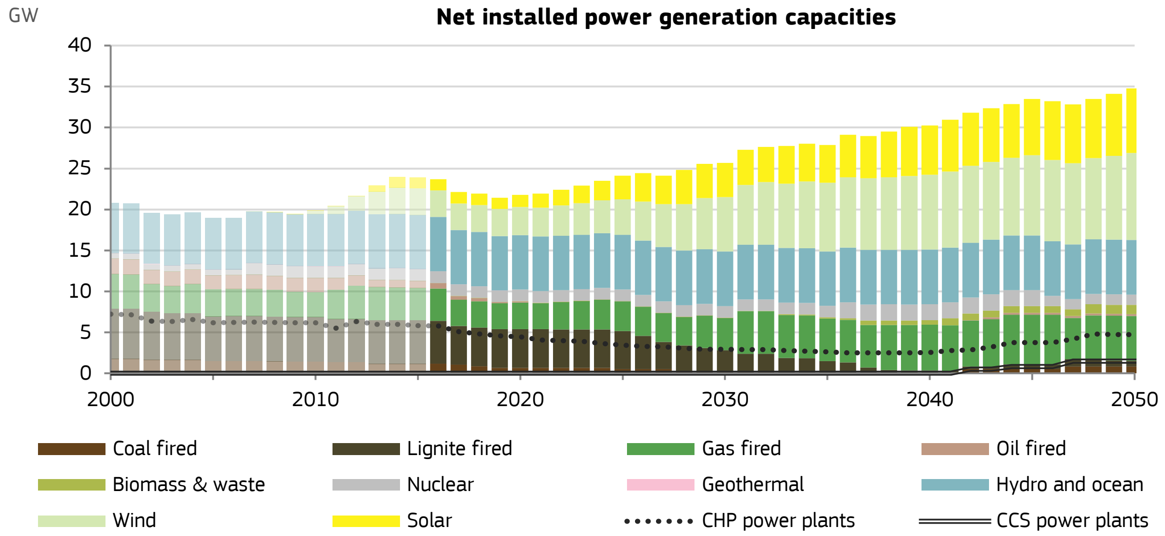

Industry key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

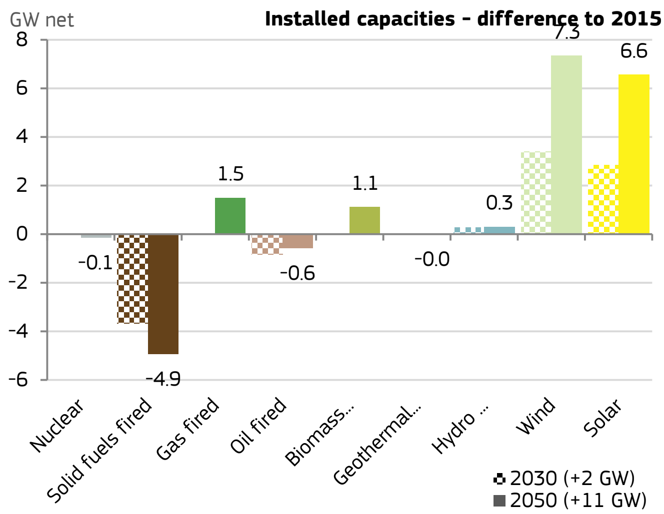

Residential sector key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

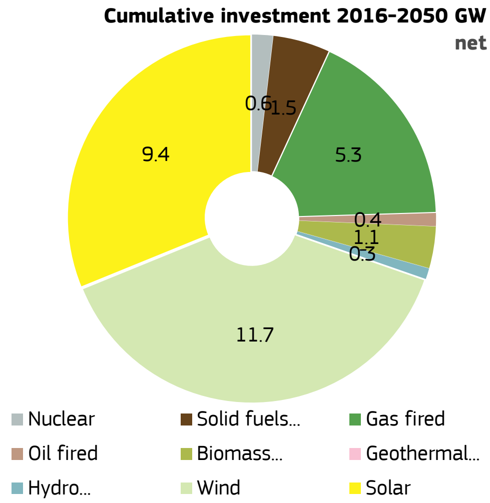

Services sector key indicators
index, 2015=100
300
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

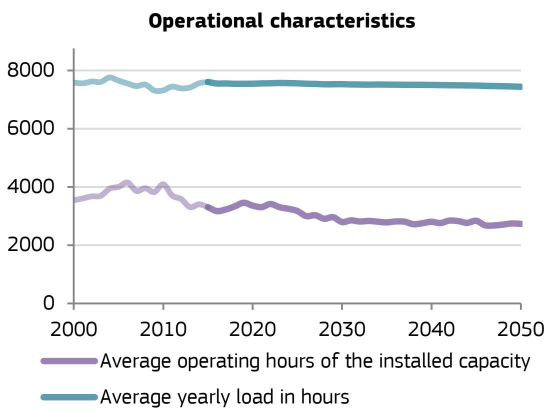

Passenger transport key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

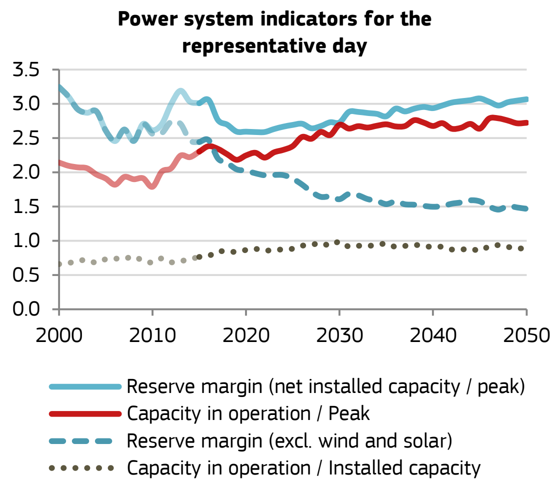

Freight transport sector key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions


GW
Net installed power generation capacities
40
35
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

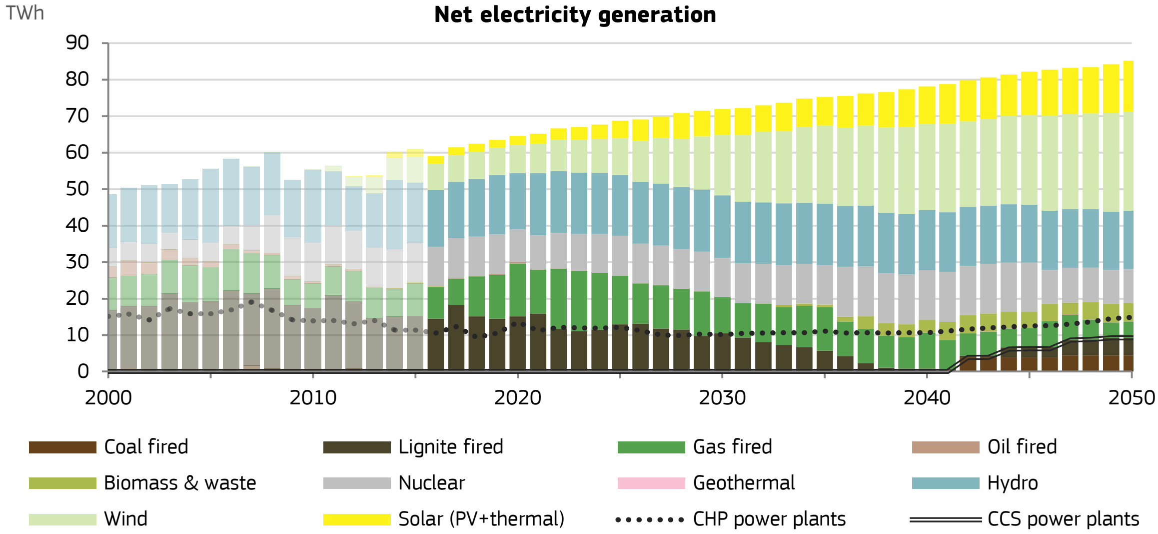

GW net
Installed capacities - difference to 2015
8
6
4
2
0
-2
-4
-6
-0.1
-4.9
1.5
-0.6
1.1
-0.0
0.3
7.3
6.6
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+2 GW)
2050 (+11 GW)

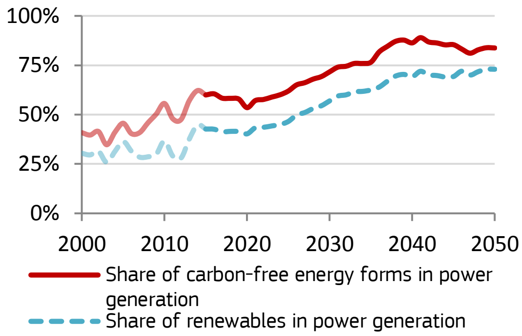

Cumulative investment 2016-2050 GW net
0.6
1.5
5.3
0.4
1.1
0.3
11.7
9.4
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

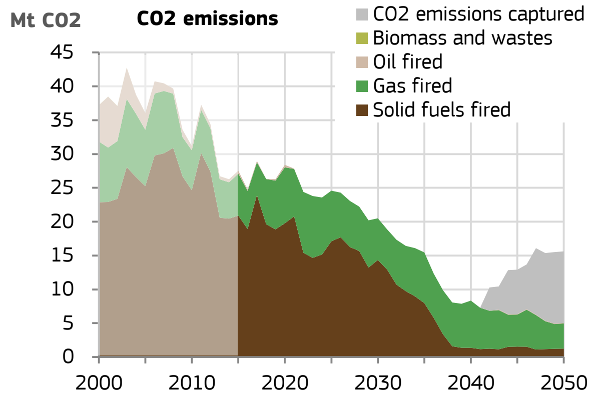

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

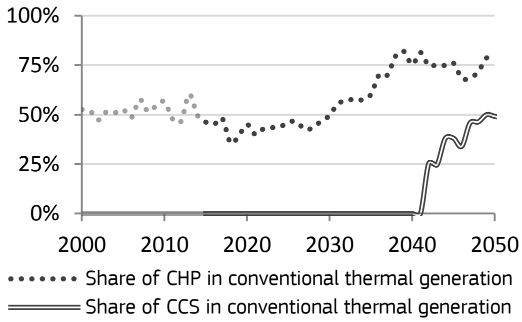

Power system indicators for the representative day
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

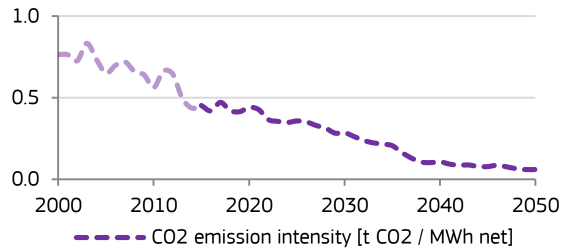
Net electricity generation



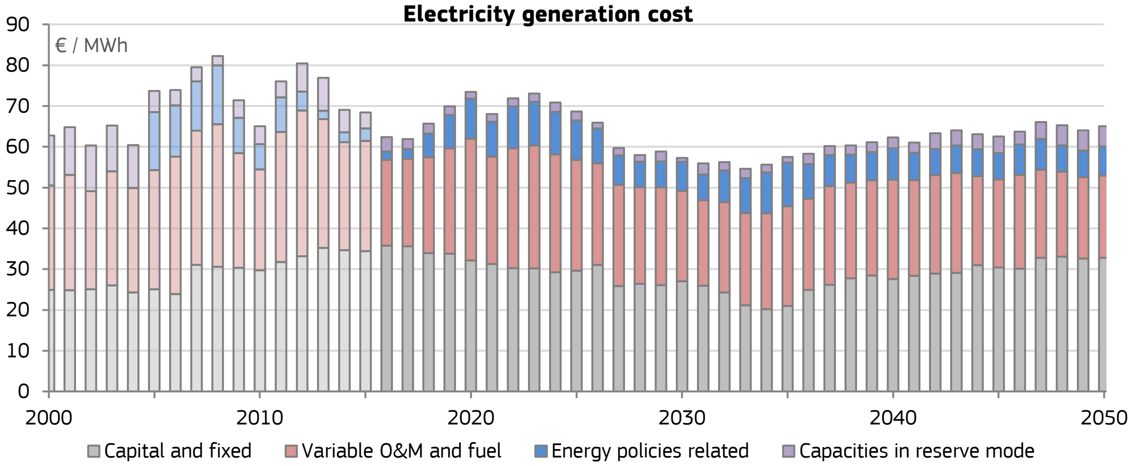


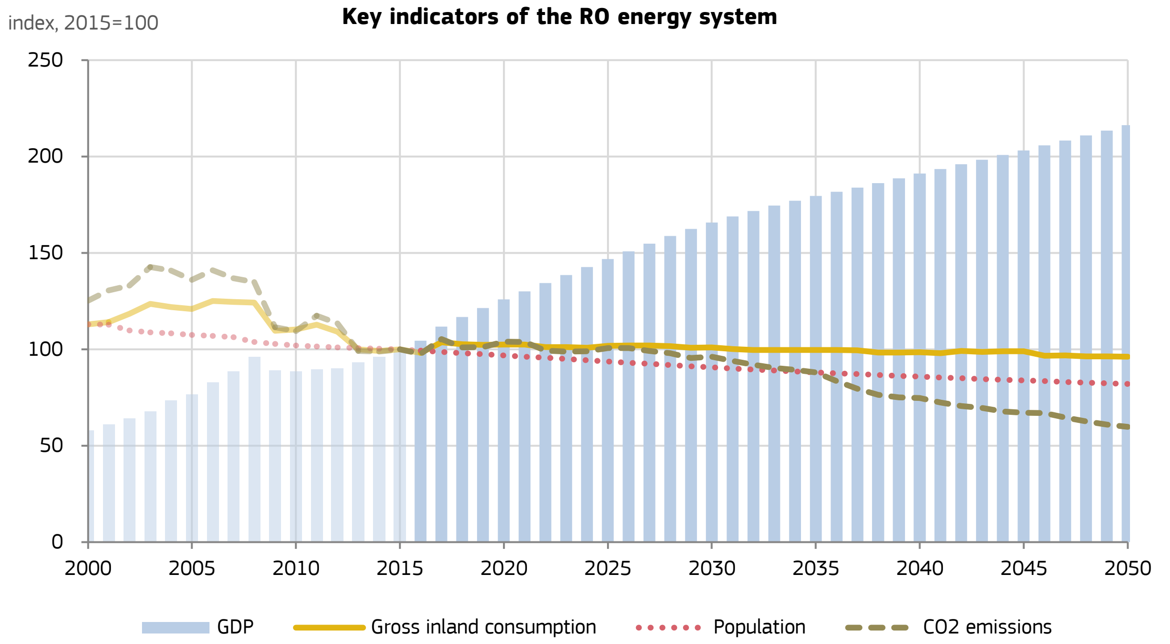




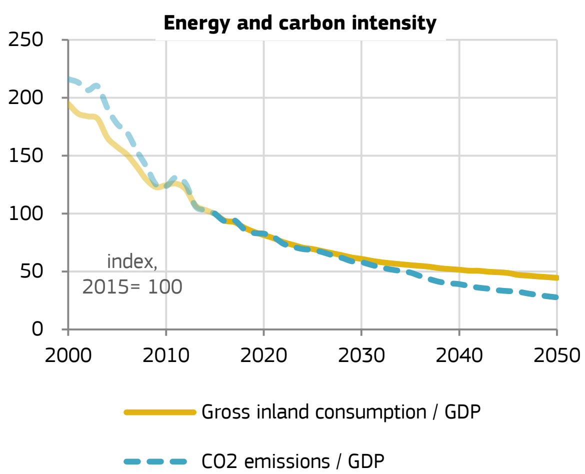


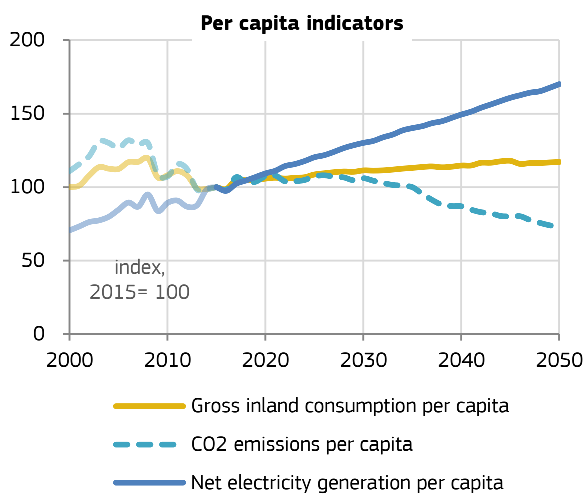
Electricity generation cost





Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	40.8	24.7	21.9	23.0	24.2	23.7
Primary energy consumption [Mtoe]	57.3	36.7	31.3	32.0	31.3	29.6
RES [%] - Share of energy from renewable sources		18.2%	26.0%	25.6%	27.7%	39.0%
RES-E [%] - Share of electricity from renewable sources		28.8%	44.1%	42.3%	56.9%	74.5%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	178.8	108.4	79.6	82.9	76.6	47.6
reduction to 1990		*-39%*	*-55%*	*-54%*	*-57%*	*-73%*
Emissions in current ETS sectors |(RO) [Mt CO2]		64.0	43.2	45.2	38.5	16.3
reduction to 2005			*-32%*	*-29%*	*-40%*	*-75%*
Emissions in current ESD sectors [Mt CO2]		44.4	36.4	37.7	38.1	31.3
reduction to 2005			*-18%*	*-15%*	*-14%*	*-29%*



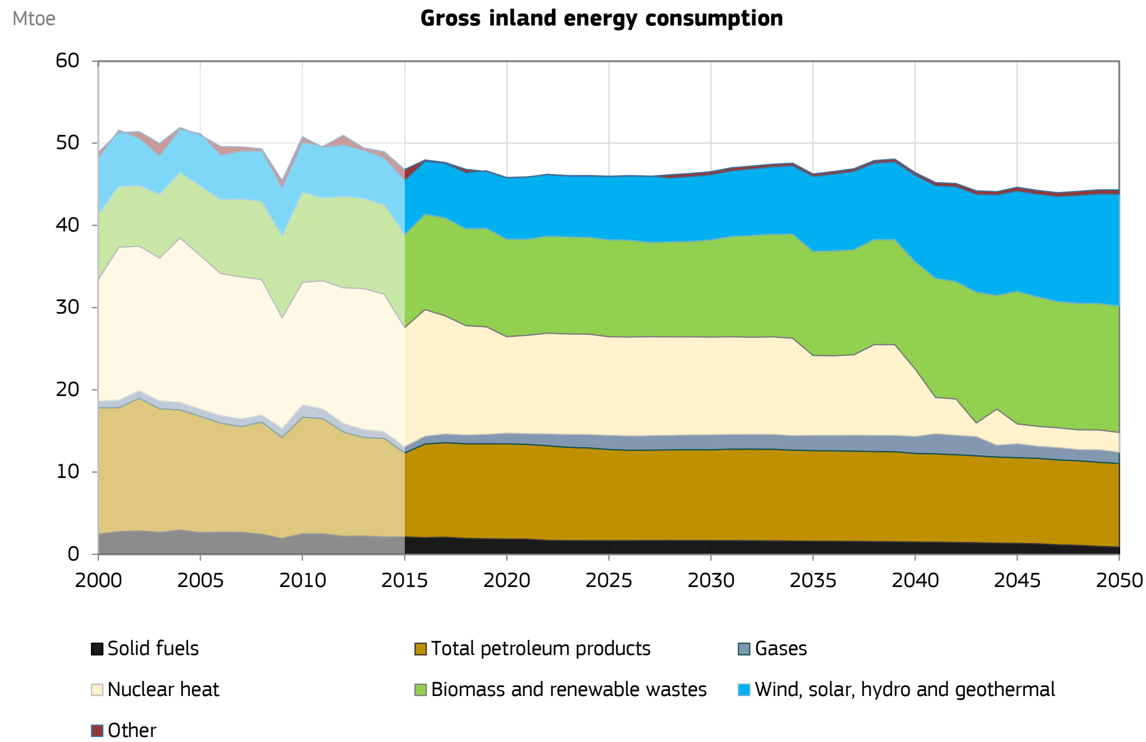


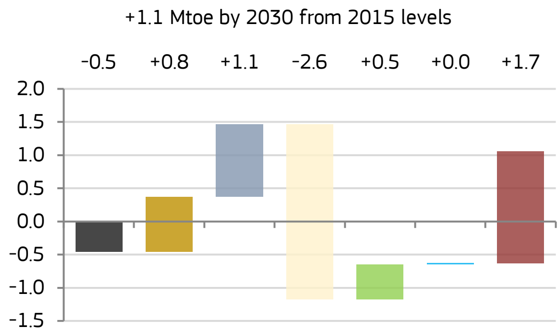
POTEnCIA - Model results overview

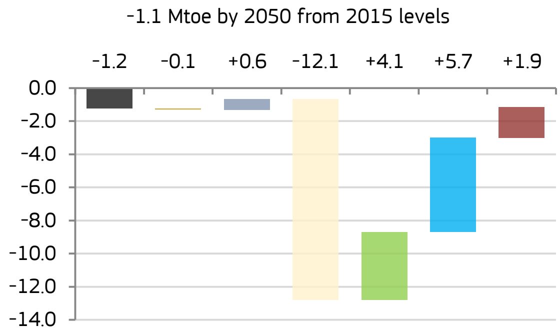
Sweden

Central_2018 scenario

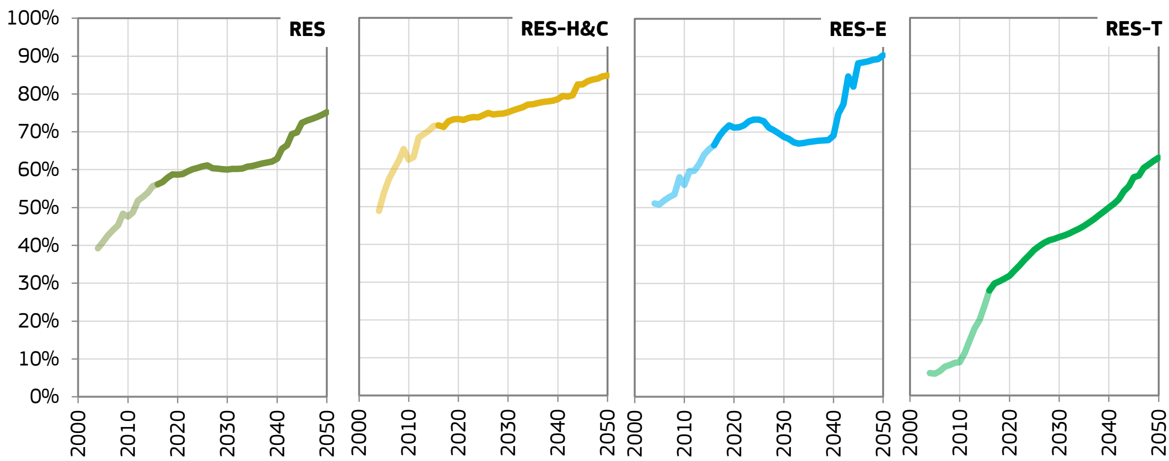
Gross inland energy consumption

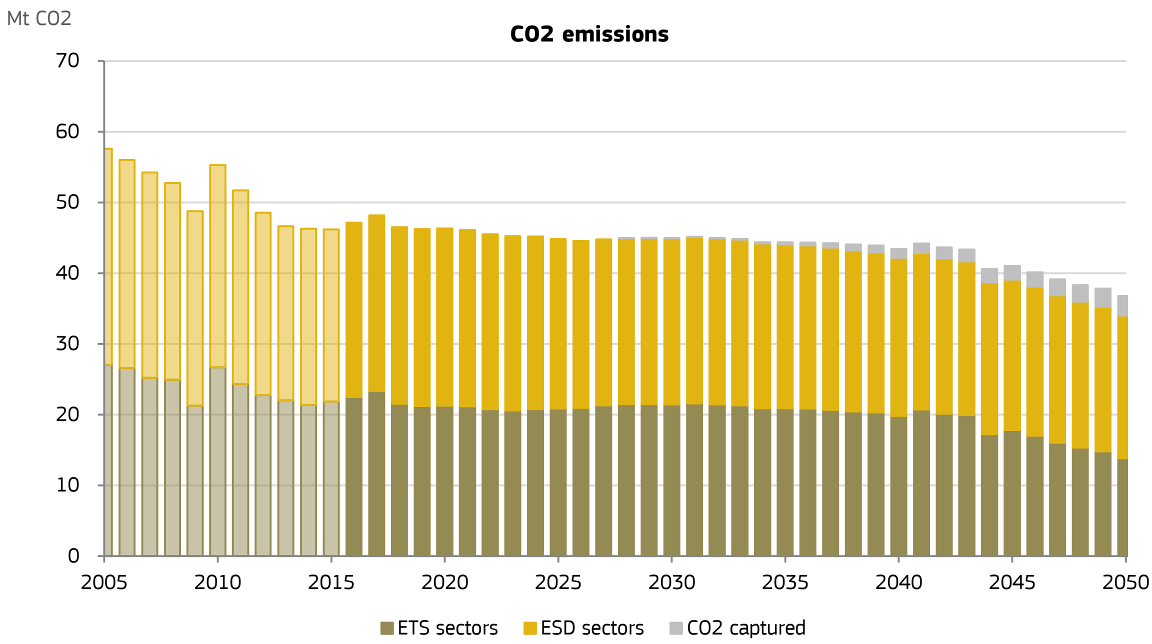


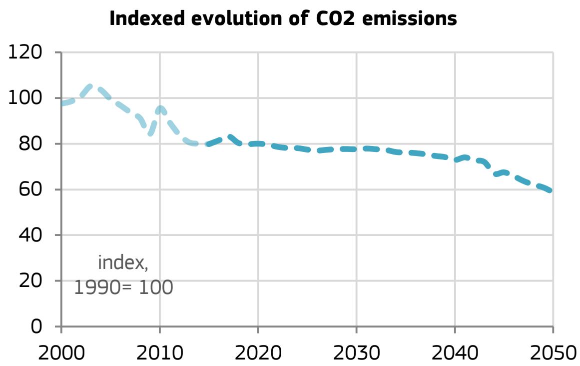


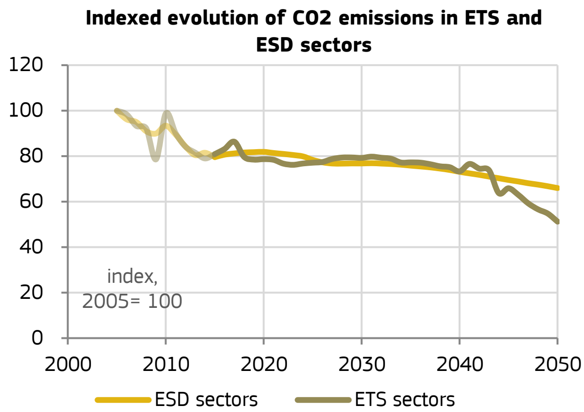


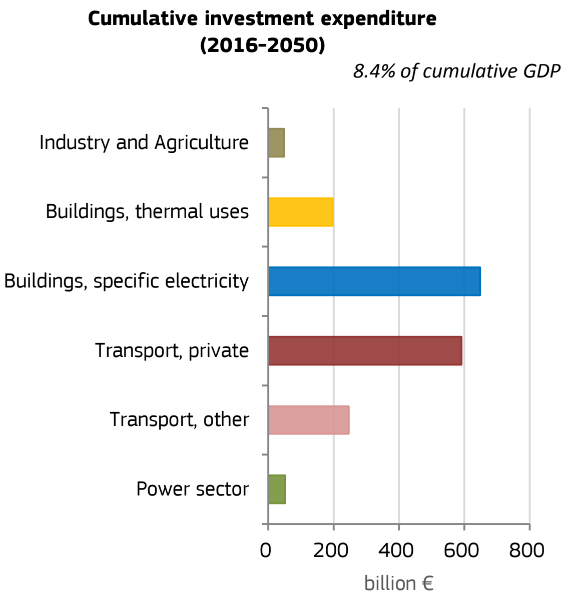
Share of renewable energies

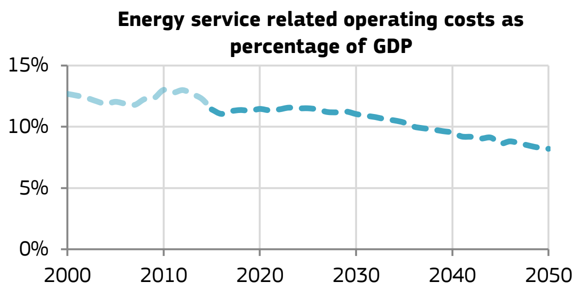


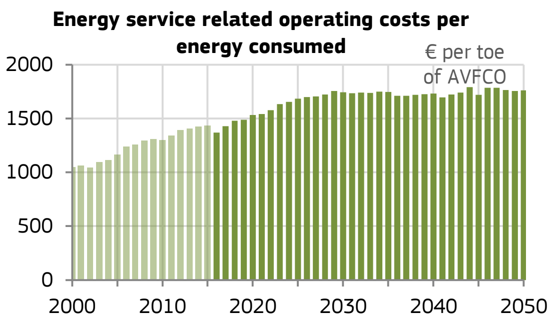

Mt CO2
CO2 emissions
70
60
50
40
30
20
10
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured


Indexed evolution of CO2 emissions
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

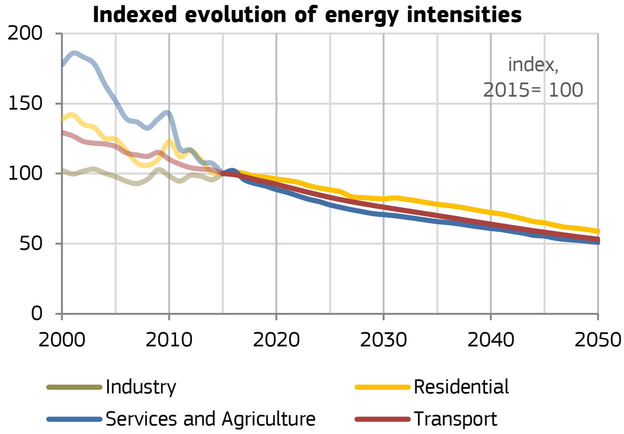

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors


Cumulative investment expenditure (2016-2050)
8.4% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
200
400
600
800
billion €

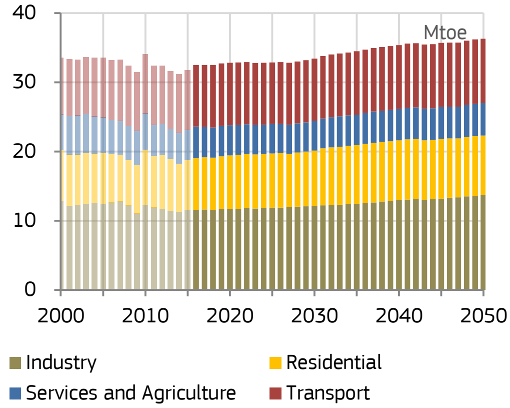

Energy service related operating costs as percentage of GDP
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050


Energy service related operating costs per energy consumed
€ per toe
of AVFCO
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

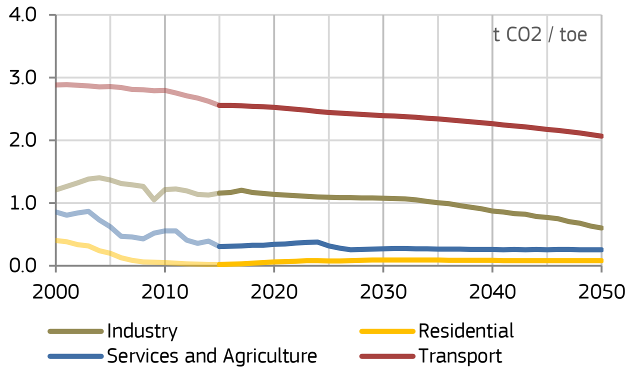
Indexed evolution of energy intensities



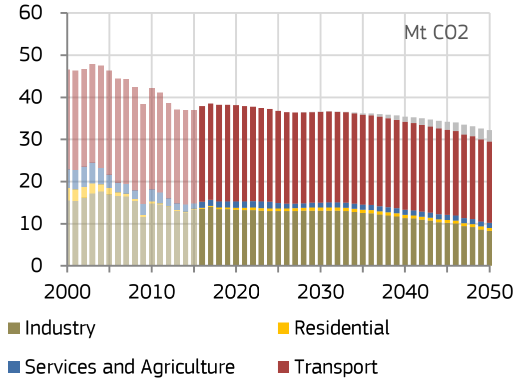
Evolution of final energy consumption



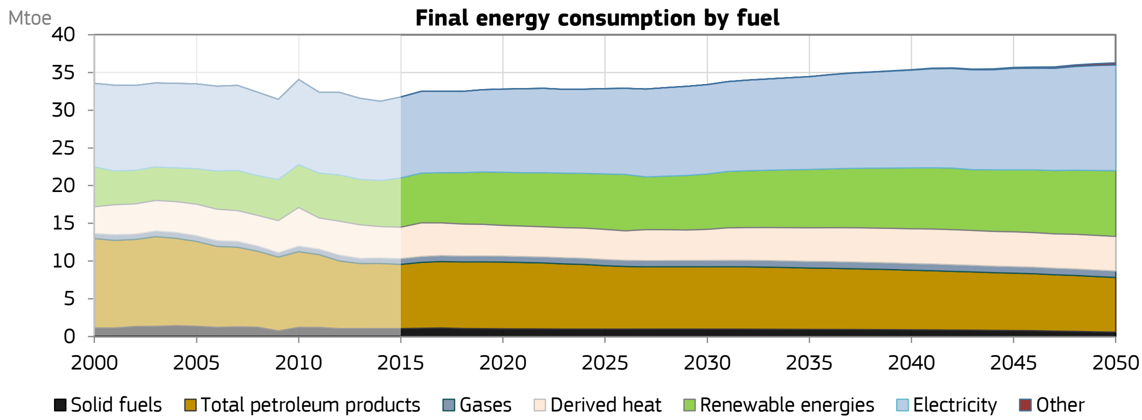
Evolution of carbon intensities



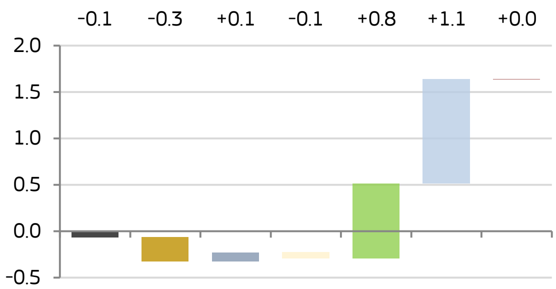
Evolution of CO2 emissions



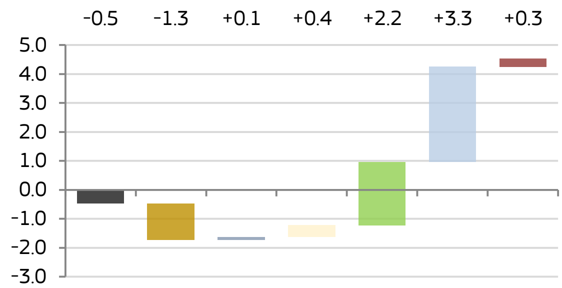
Final energy consumption by fuel

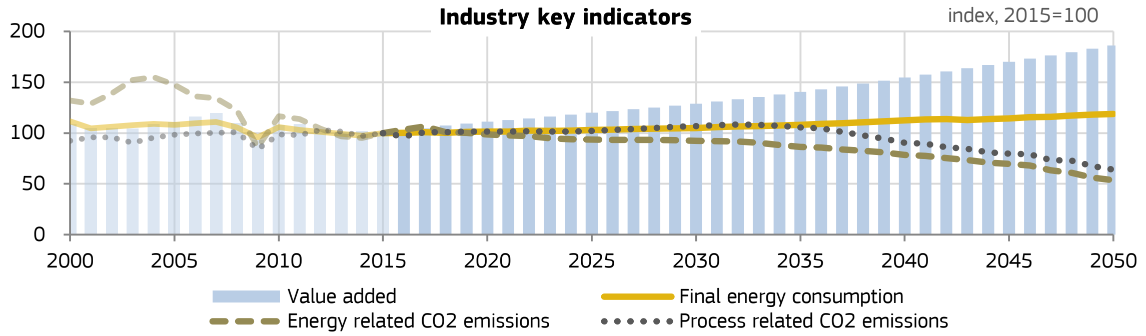


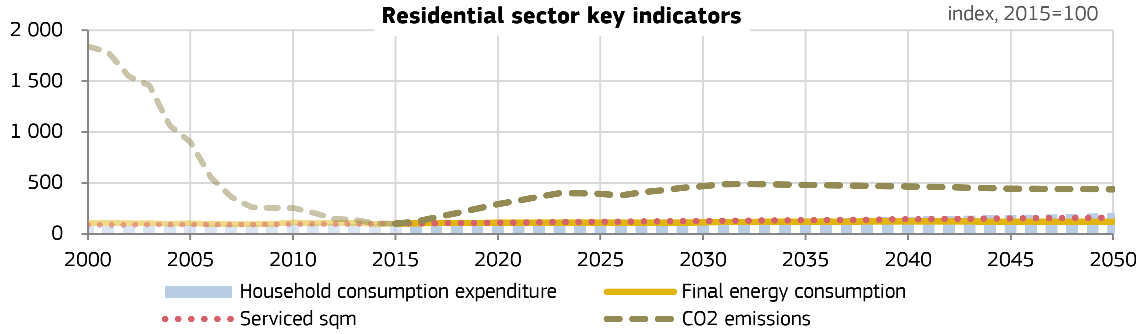
+1.6 Mtoe by 2030 from 2015 levels

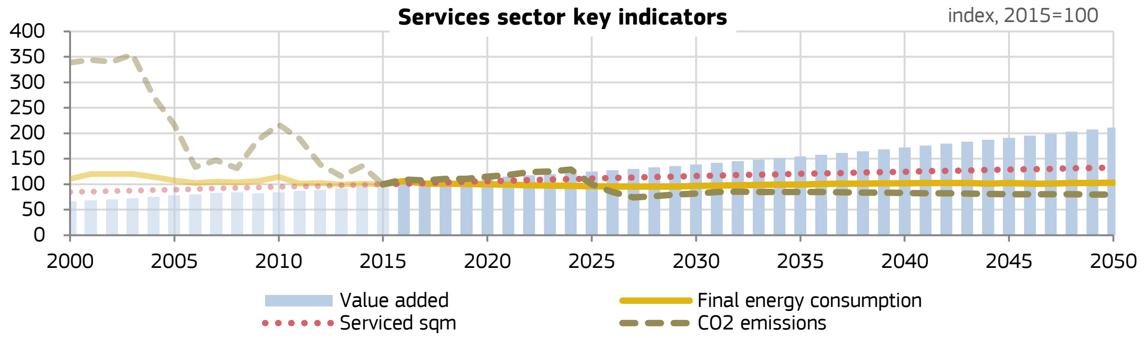


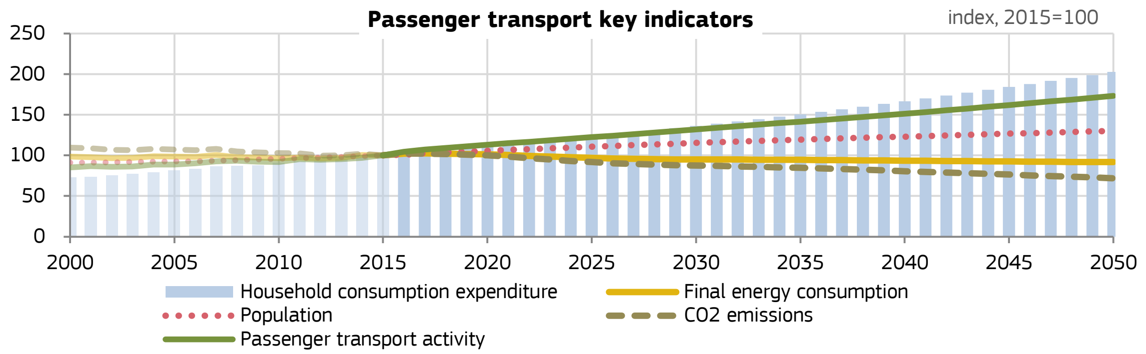
+4.5 Mtoe by 2050 from 2015 levels

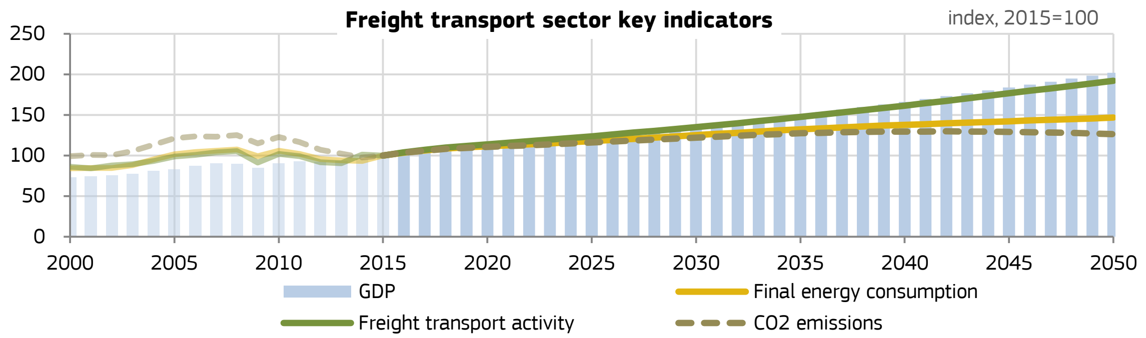


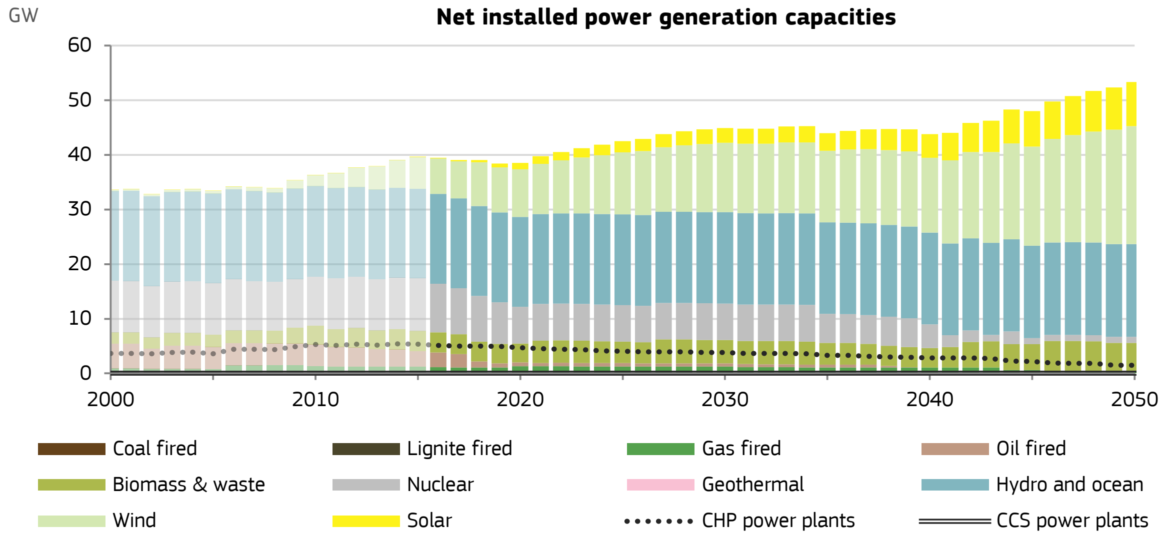

Industry key indicators
index, 2015=100
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

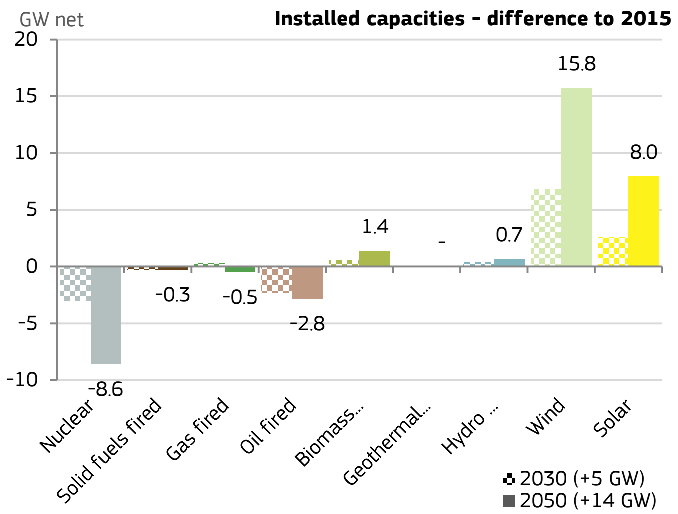

Residential sector key indicators
index, 2015=100
2 000
1 500
1 000
500
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

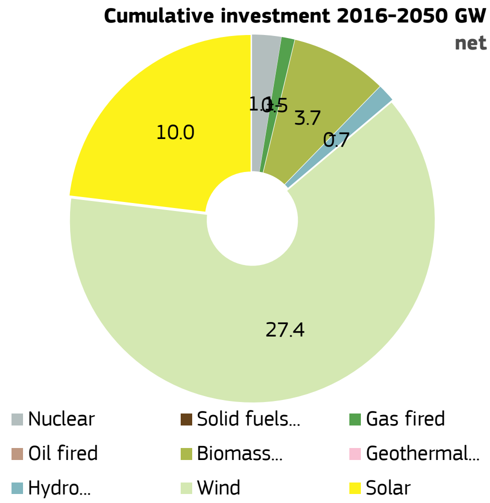

Services sector key indicators
index, 2015=100
400
350
300
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

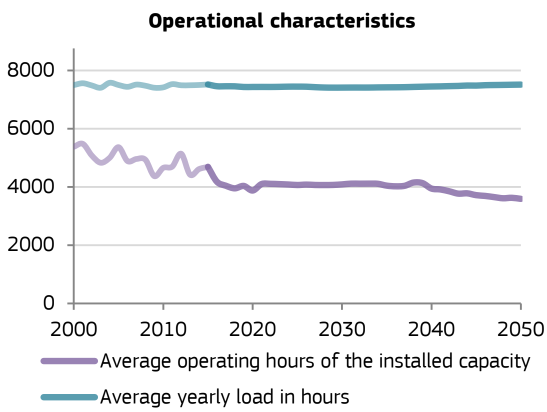

Passenger transport key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

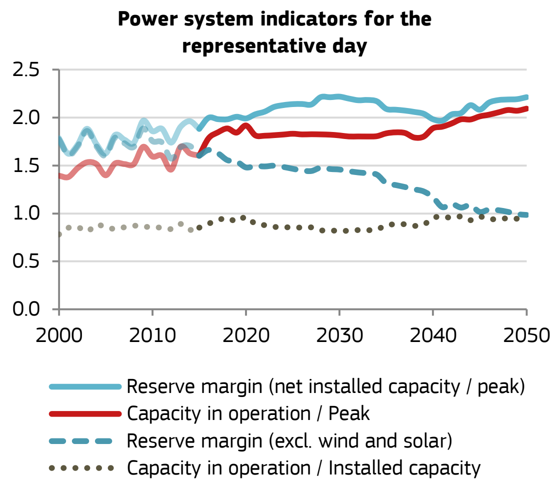

Freight transport sector key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

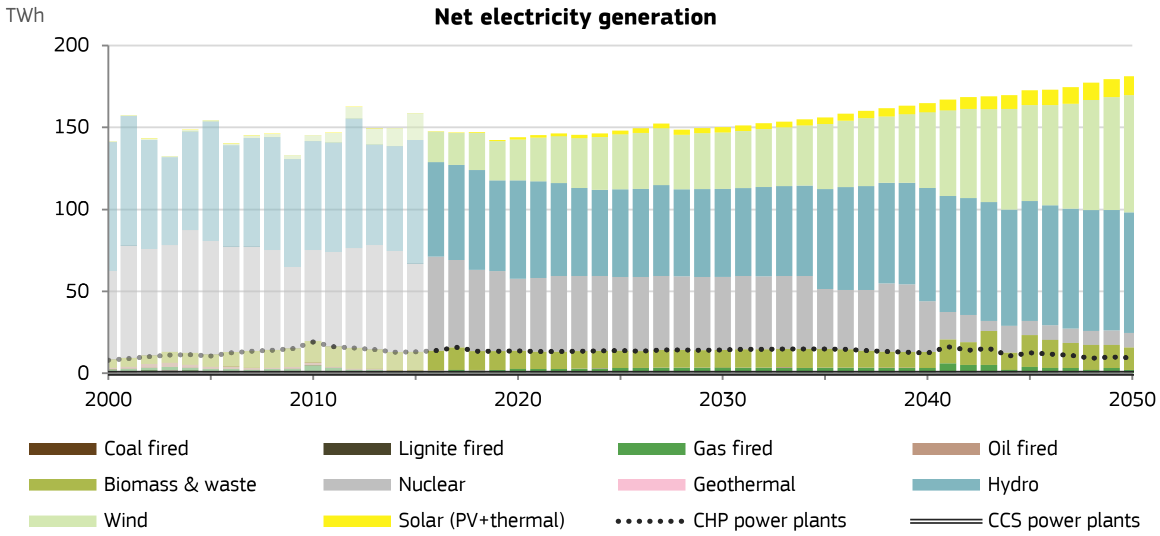

GW
Net installed power generation capacities
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

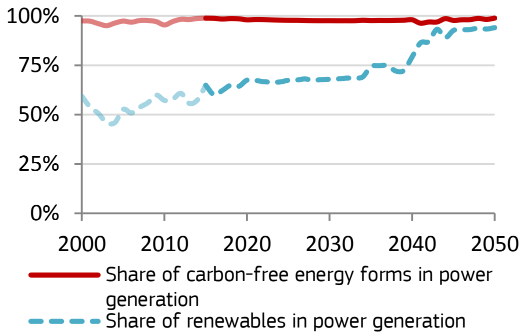

GW net
Installed capacities - difference to 2015
20
15
10
5
0
-5
-10
15.8
8.0
1.4
0.7
-0.3
-0.5
-2.8
-8.6
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+5 GW)
2050 (+14 GW)

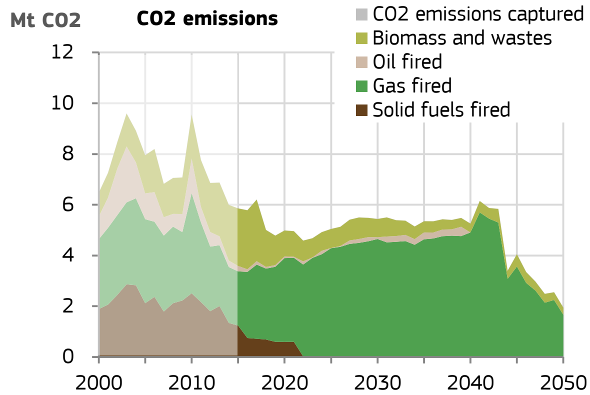

Cumulative investment 2016-2050 GW net
10.0
3.7
0.7
27.4
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

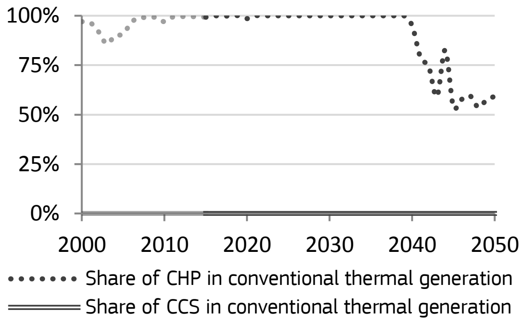

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

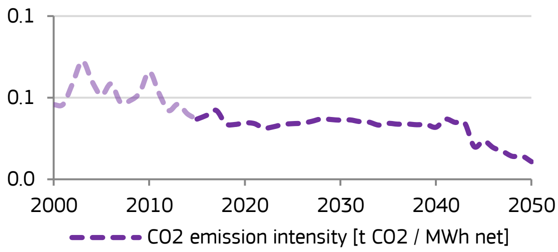

Power system indicators for the representative day
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

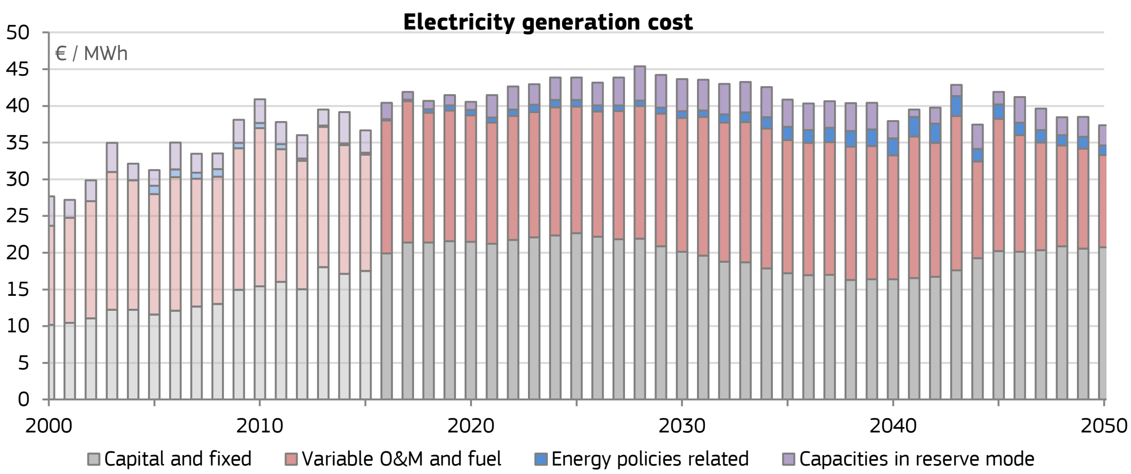

TWh
Net electricity generation
200
150
100
50
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants


100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation

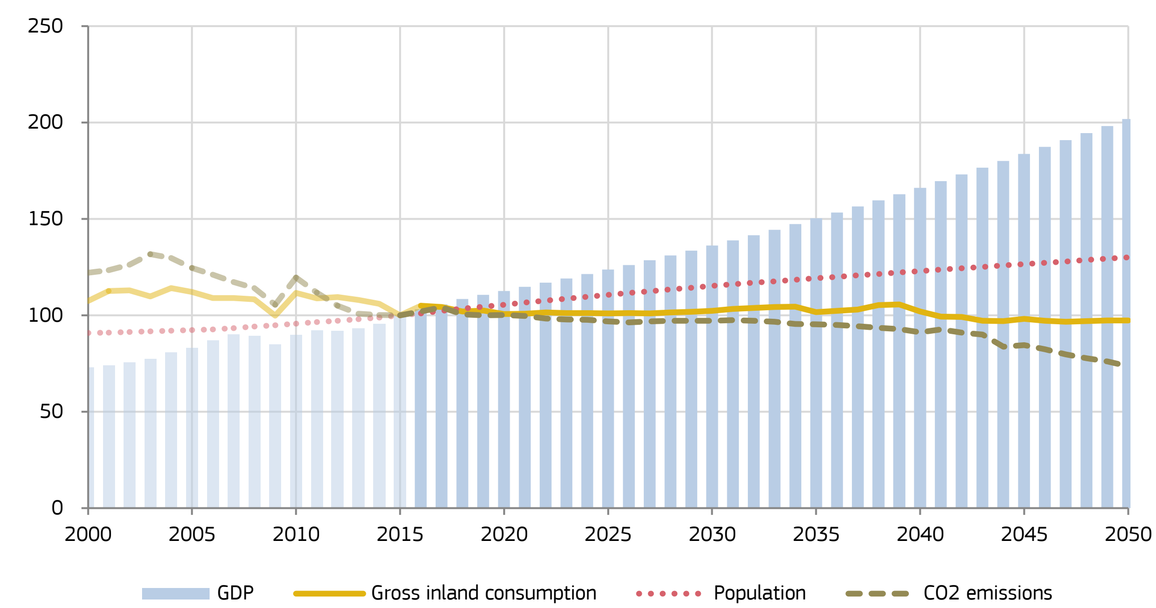

Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
12
10
8
6
4
2
0
2000
2010
2020
2030
2040
2050


100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation


0.1
0.1
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]

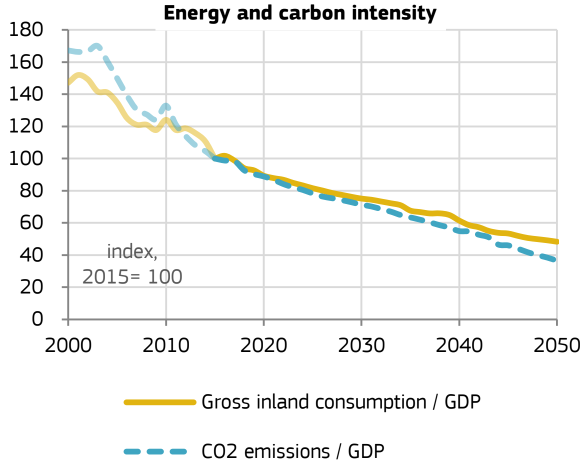

Electricity generation cost
€ / MWh
50
45
40
35
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode

Key indicators of the SE energy system

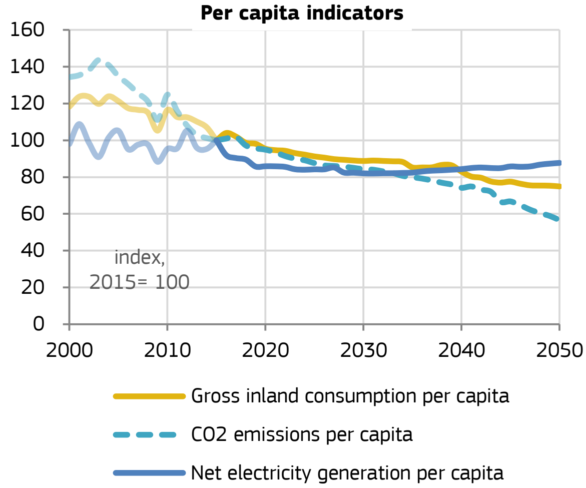


Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	30.7	33.5	31.8	32.8	33.4	36.3
Primary energy consumption [Mtoe]	45.1	48.5	43.7	44.0	44.6	42.1
RES [%] - Share of energy from renewable sources		40.9%	55.7%	58.7%	60.0%	75.2%
RES-E [%] - Share of electricity from renewable sources		50.9%	65.5%	71.2%	68.7%	90.4%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	57.9	57.6	46.2	46.3	44.9	34.0
reduction to 1990		*-1%*	*-20%*	*-20%*	*-22%*	*-41%*
Emissions in current ETS sectors |(SE) [Mt CO2]		27.0	21.9	21.3	21.4	13.8
reduction to 2005			*-19%*	*-21%*	*-21%*	*-49%*
Emissions in current ESD sectors [Mt CO2]		30.6	24.3	25.0	23.5	20.2
reduction to 2005			*-20%*	*-18%*	*-23%*	*-34%*

Energy and carbon intensity

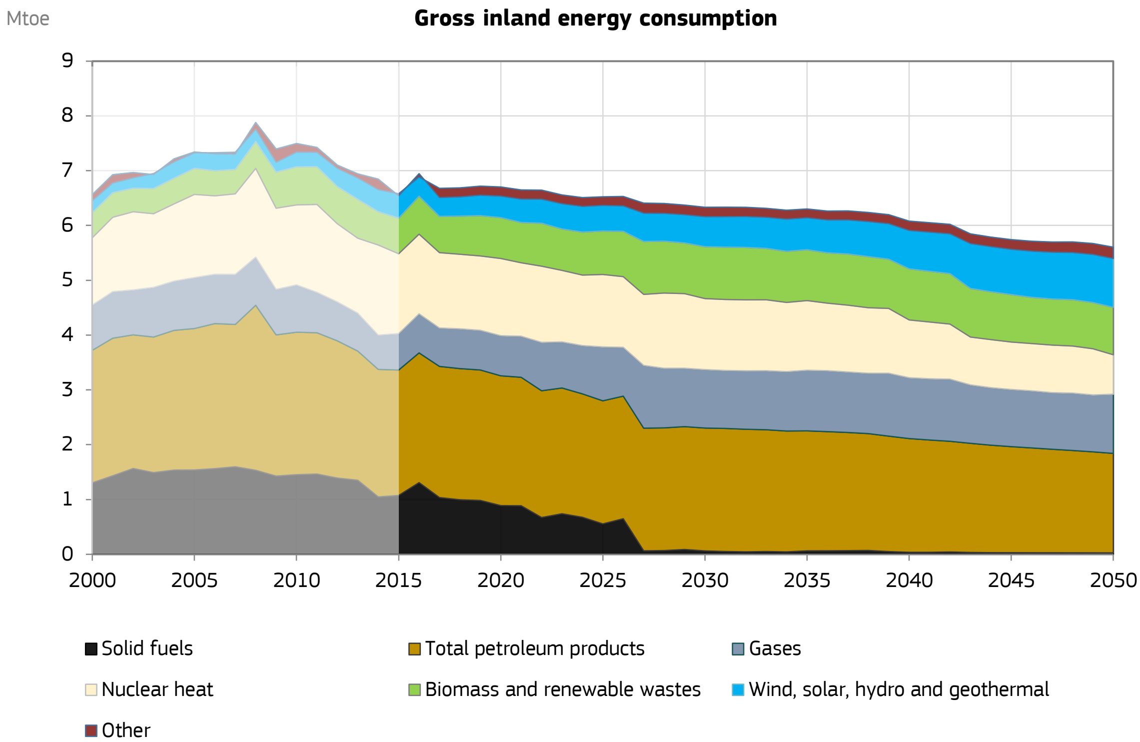


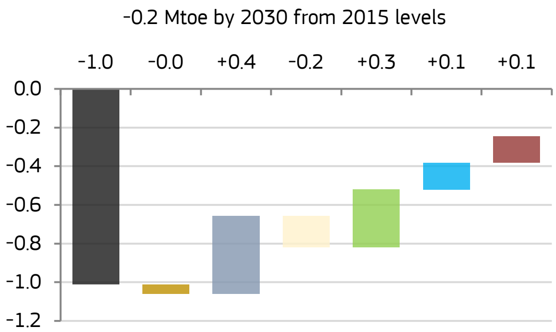
Per capita indicators

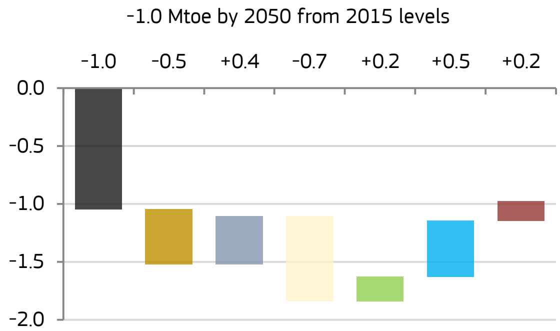


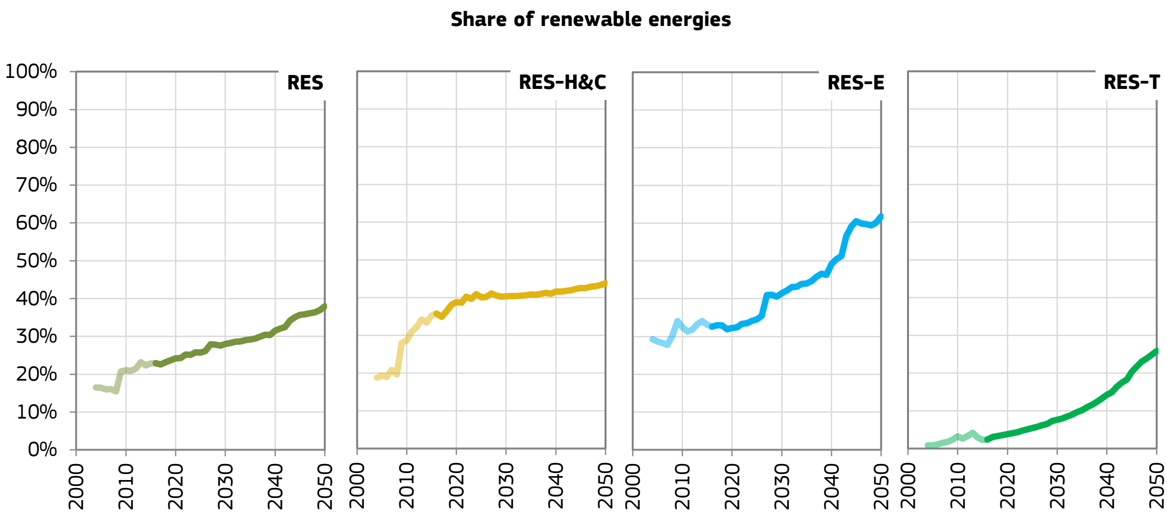
Slovenia

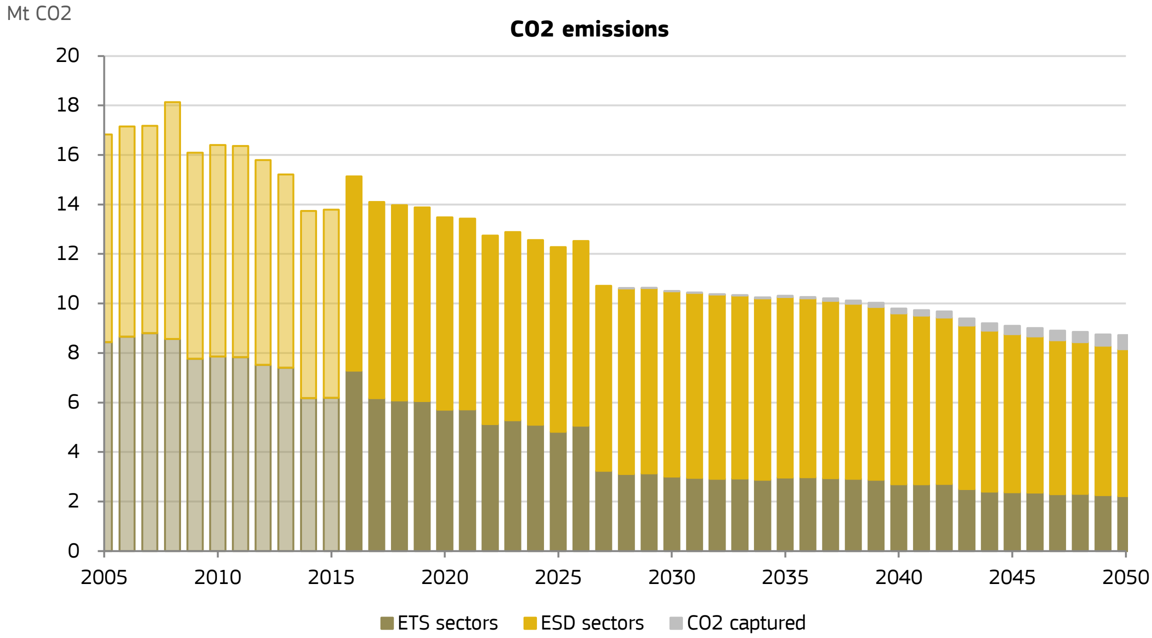
Central_2018 scenario

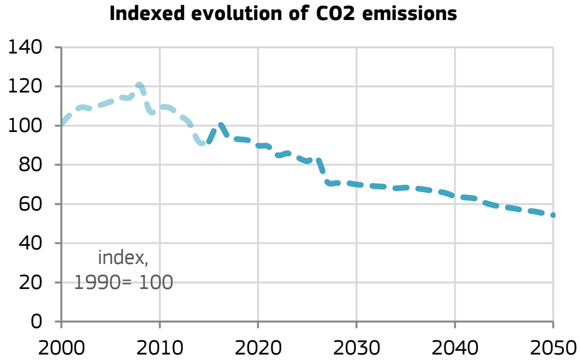

Mtoe
Gross inland energy consumption
9
8
7
6
5
4
3
2
1
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Solid fuels
Total petroleum products
Gases
Nuclear heat
Biomass and renewable wastes
Wind, solar, hydro and geothermal
Other

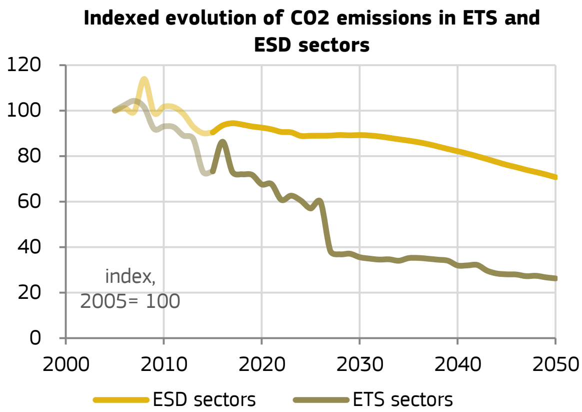

-0.2 Mtoe by 2030 from 2015 levels
-1.0
-0.0
+0.4
-0.2
+0.3
+0.1
+0.1
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2

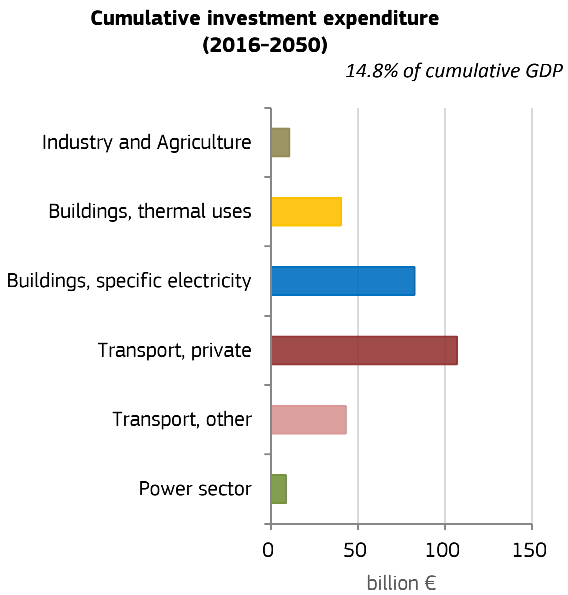

-1.0 Mtoe by 2050 from 2015 levels
-1.0
-0.5
+0.4
-0.7
+0.2
+0.5
+0.2
0.0
-0.5
-1.0
-1.5
-2.0

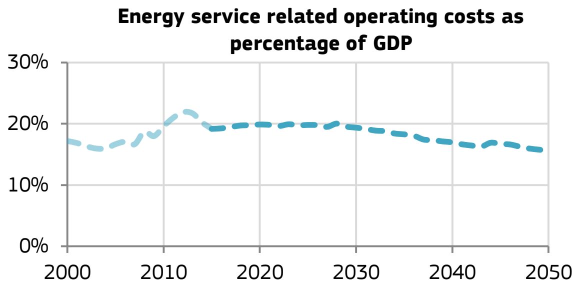

Share of renewable energies
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
RES
RES-H&C
RES-E
RES-T
2000
2010
2020
2030
2040
2050

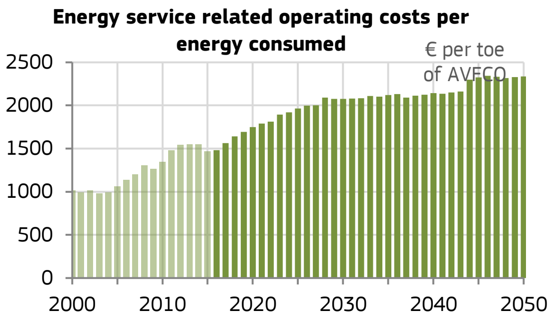

CO2 emissions
Mt CO2
20
18
16
14
12
10
8
6
4
2
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured

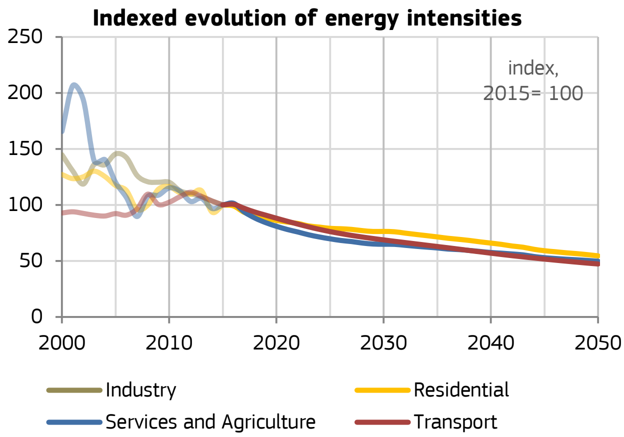

Indexed evolution of CO2 emissions
140
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

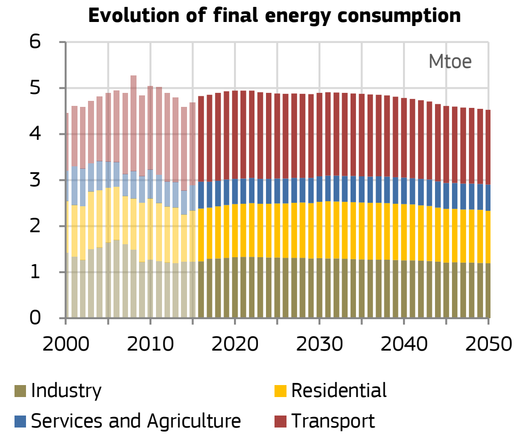

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors

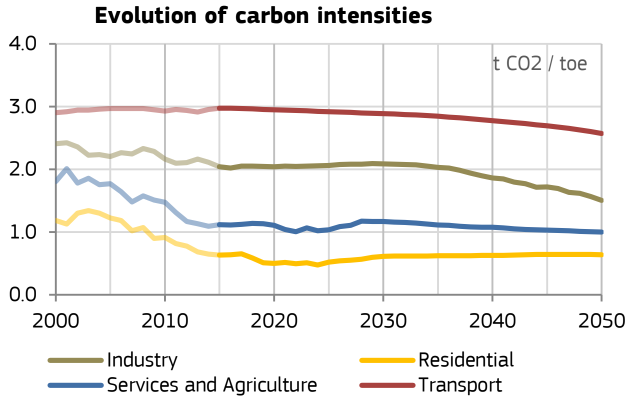

Cumulative investment expenditure (2016-2050)
14.8% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
50
100
150
billion €

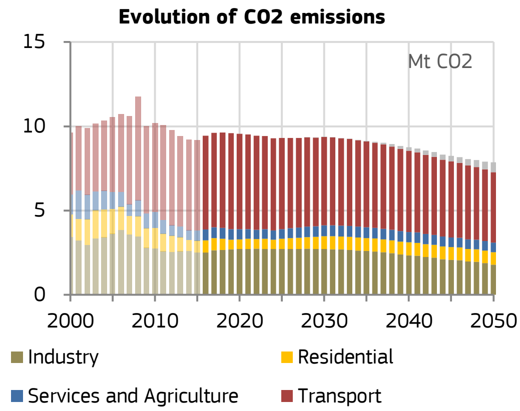

Energy service related operating costs as percentage of GDP
30%
20%
10%
0%
2000
2010
2020
2030
2040
2050

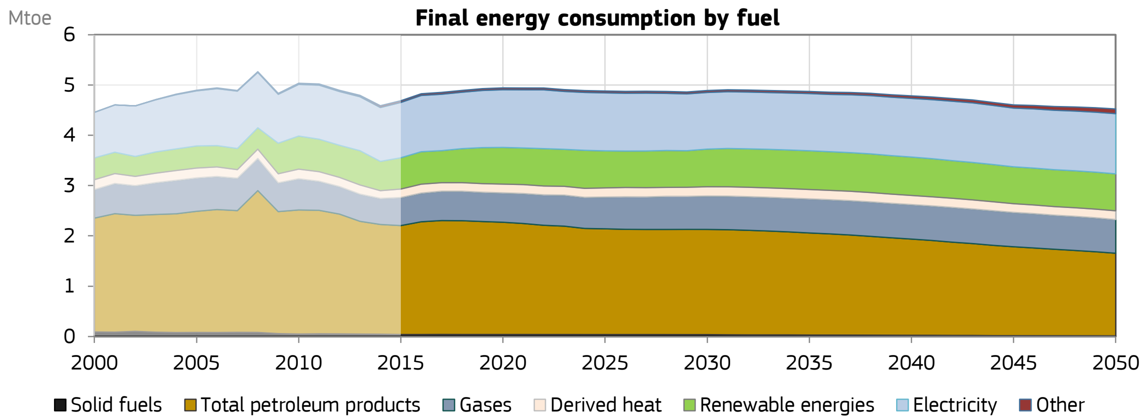

Energy service related operating costs per energy consumed
€ per toe of AVECO
2500
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

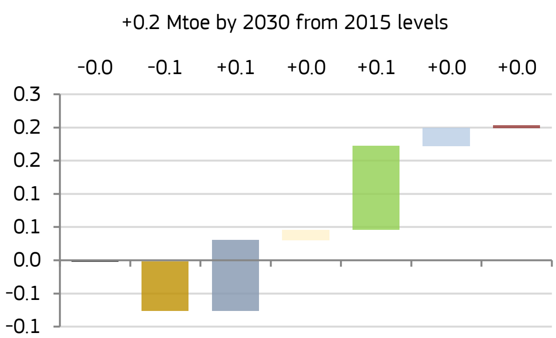

Indexed evolution of energy intensities
index, 2015= 100
250
200
150
100
50
0
2000 2010 2020 2030 2040 2050
Industry
Residential
Services and Agriculture
Transport

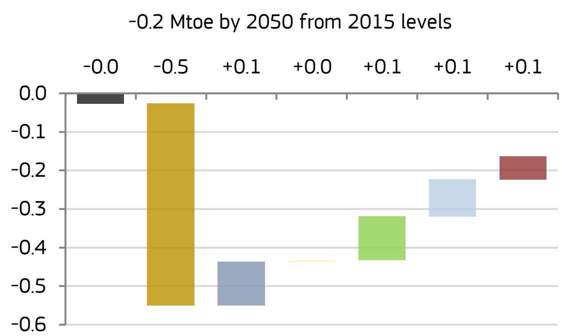

Evolution of final energy consumption
Mtoe
6
5
4
3
2
1
0
2000 2010 2020 2030 2040 2050
Industry
Residential
Services and Agriculture
Transport

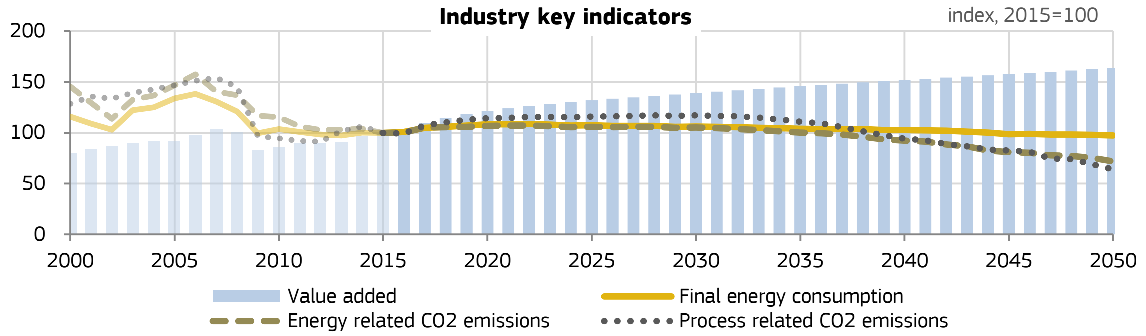

Evolution of carbon intensities
t CO2 / toe
4.0
3.0
2.0
1.0
0.0
2000 2010 2020 2030 2040 2050
Industry
Residential
Services and Agriculture
Transport

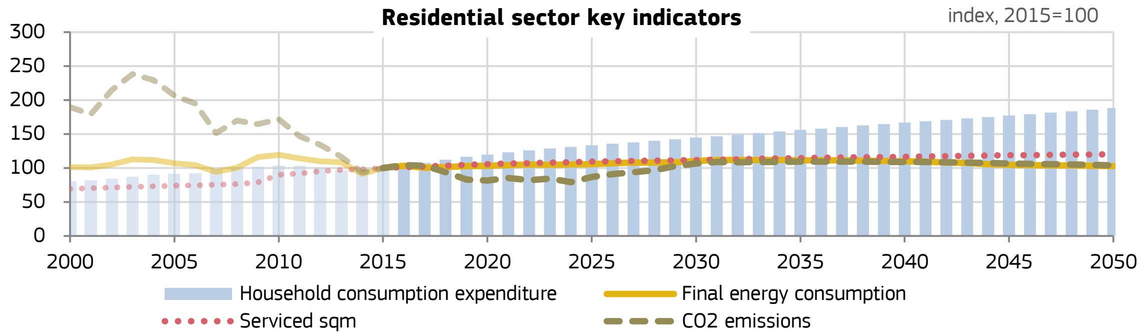

Evolution of CO2 emissions
Mt CO2
15
10
5
0
2000 2010 2020 2030 2040 2050
Industry
Residential
Services and Agriculture
Transport

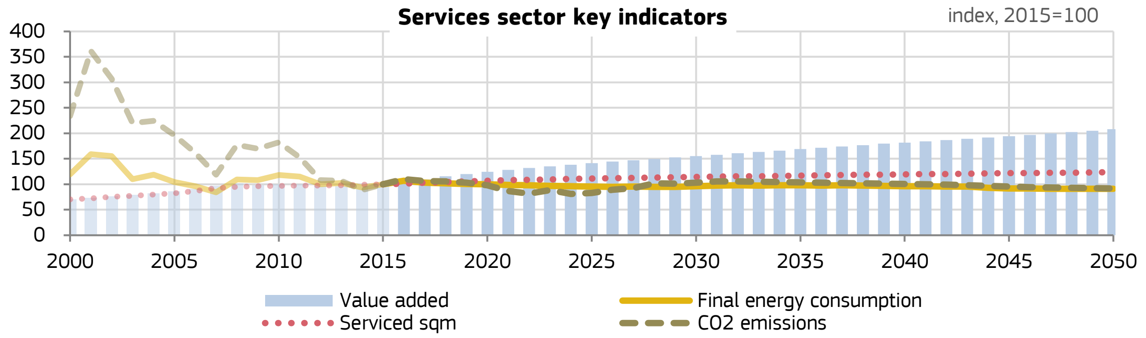

Mtoe
Final energy consumption by fuel
6
5
4
3
2
1
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Solid fuels
Total petroleum products
Gases
Derived heat
Renewable energies
Electricity
Other

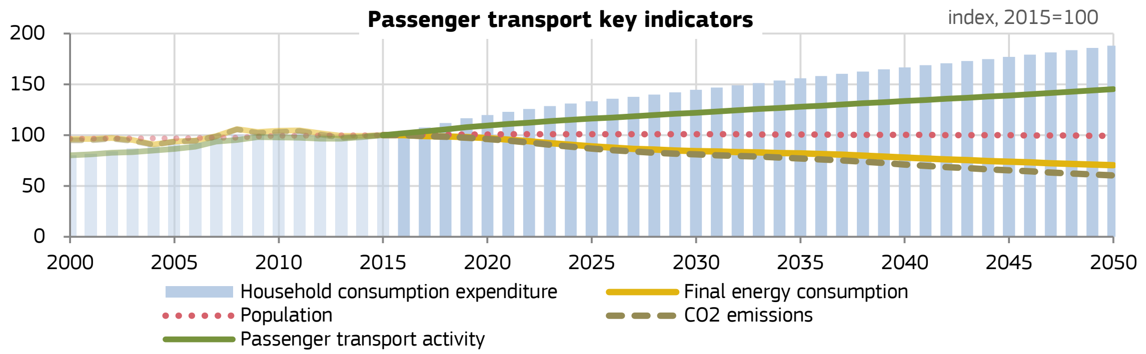

+0.2 Mtoe by 2030 from 2015 levels
-0.0 -0.1 +0.1 +0.0 +0.1 +0.0 +0.0
0.3
0.2
0.2
0.1
0.1
0.0
-0.1
-0.1

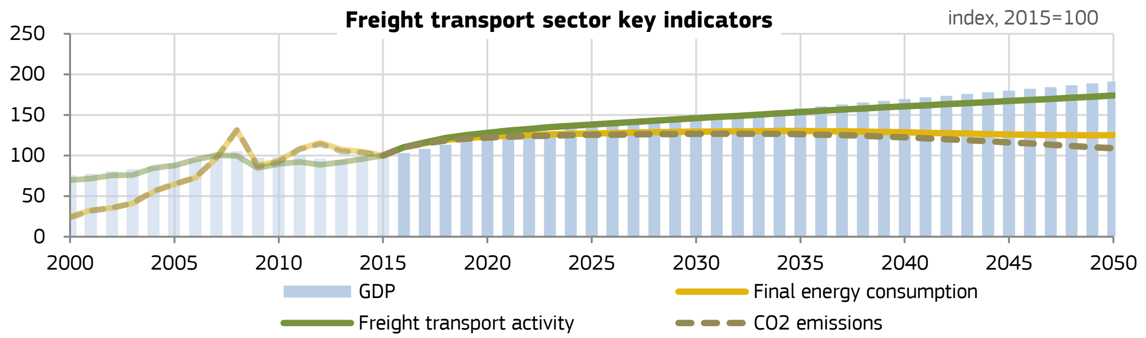

-0.2 Mtoe by 2050 from 2015 levels
-0.0 -0.5 +0.1 +0.0 +0.1 +0.1 +0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6

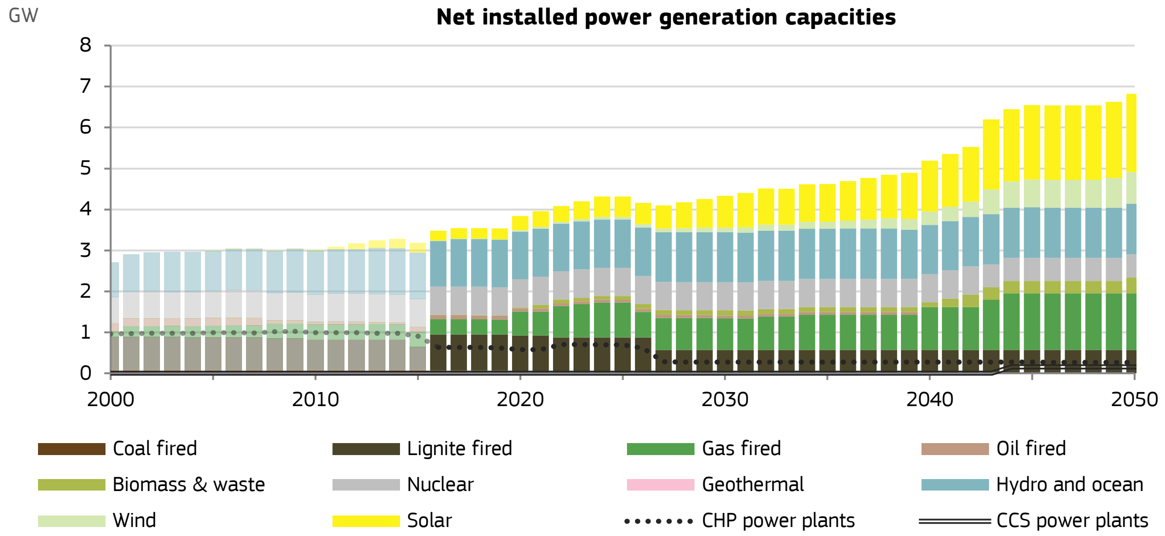

Industry key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

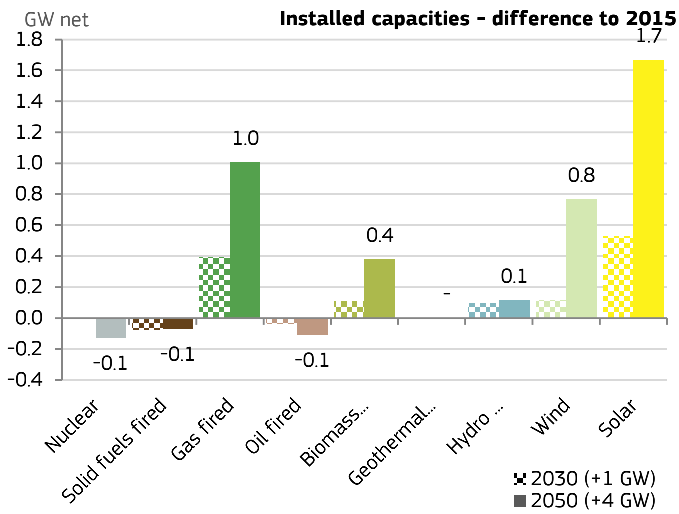

Residential sector key indicators
index, 2015=100
300
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

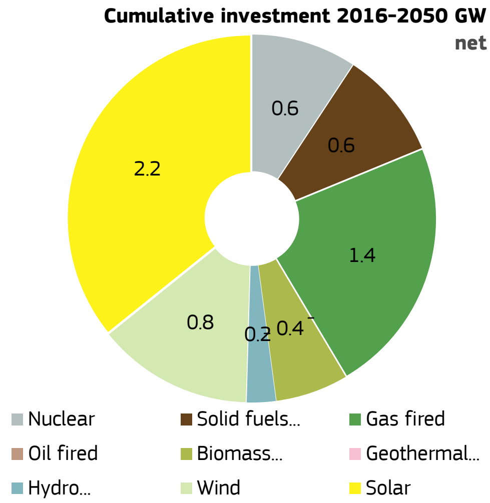

Services sector key indicators
index, 2015=100
400
350
300
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

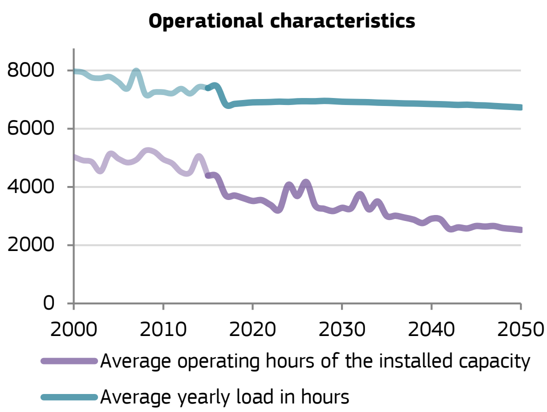

Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

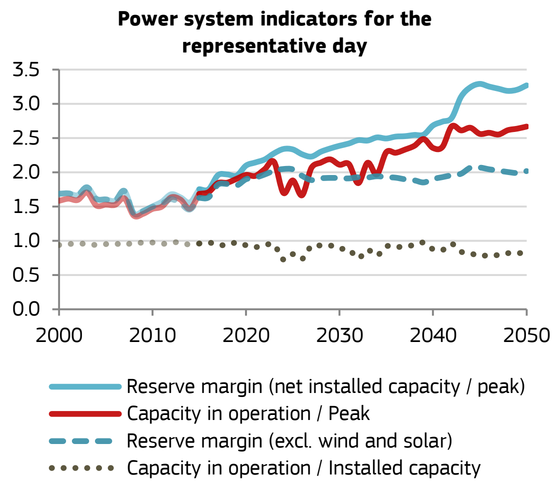

Freight transport sector key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

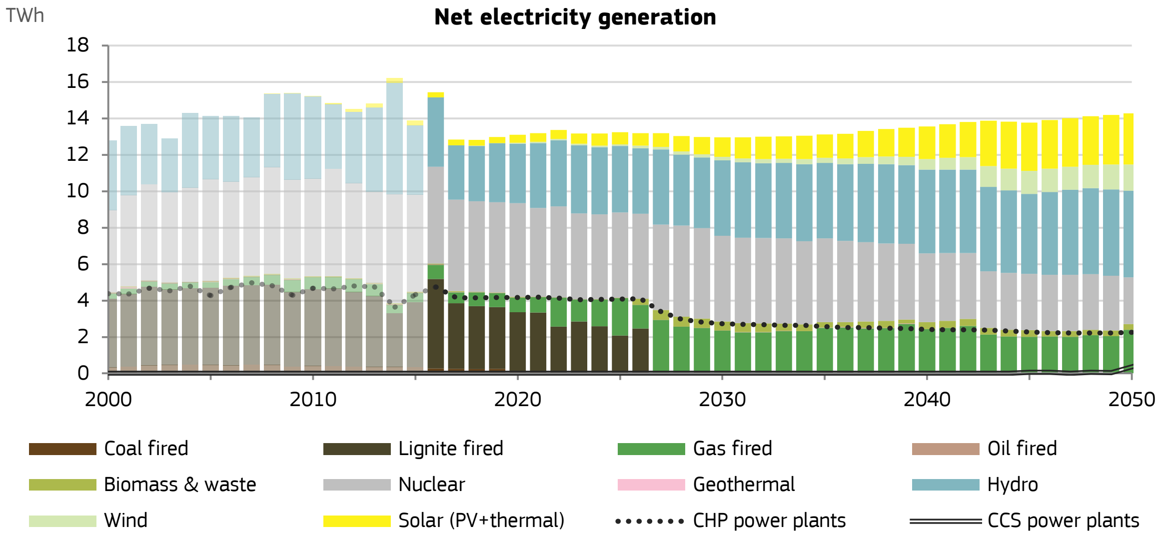

Net installed power generation capacities
GW
8
7
6
5
4
3
2
1
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

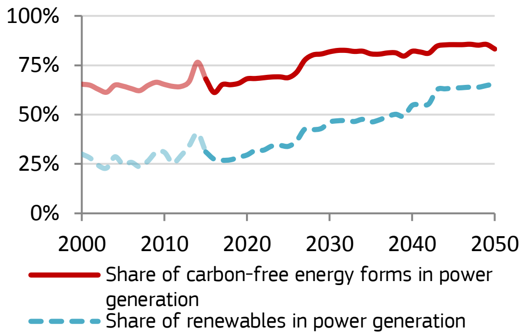

Installed capacities - difference to 2015
GW net
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.1
-0.1
1.0
-0.1
0.4
0.1
0.8
1.7
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+1 GW)
2050 (+4 GW)

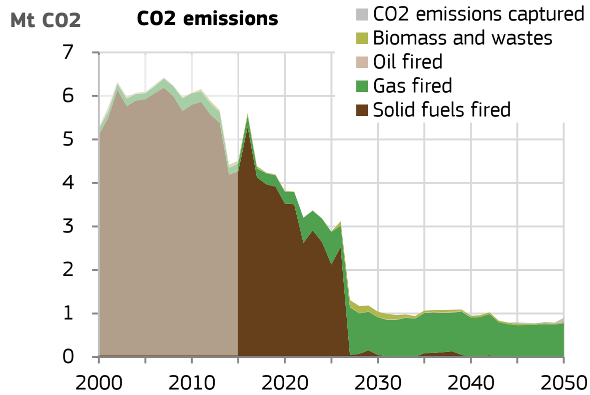

Cumulative investment 2016-2050 GW net
0.6
0.6
1.4
0.4
0.2
0.8
2.2
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

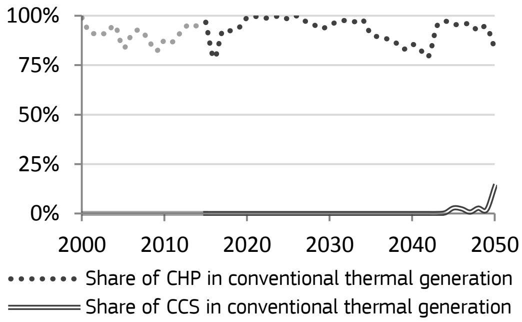

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

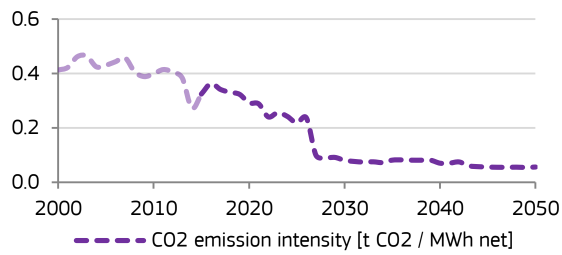

Power system indicators for the representative day
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

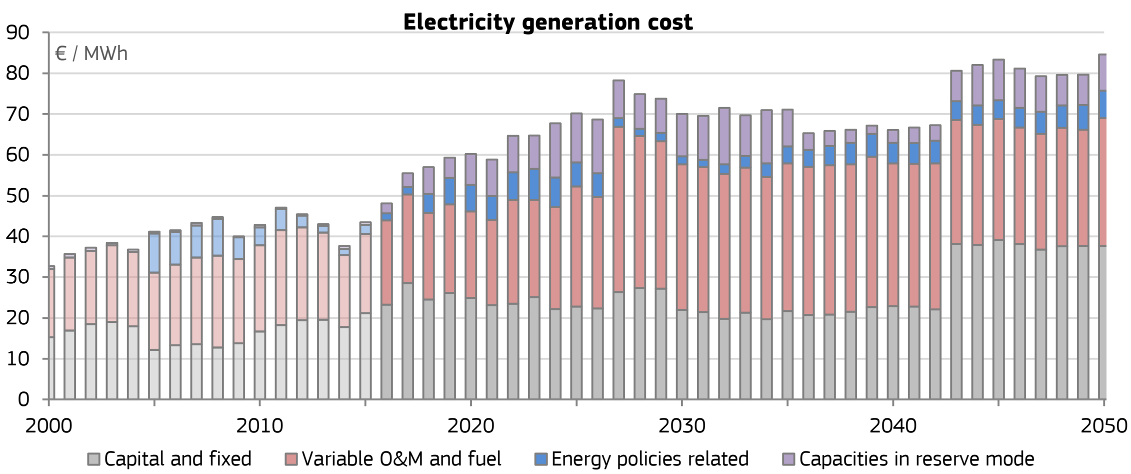

TWh
Net electricity generation
18
16
14
12
10
8
6
4
2
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants


100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation

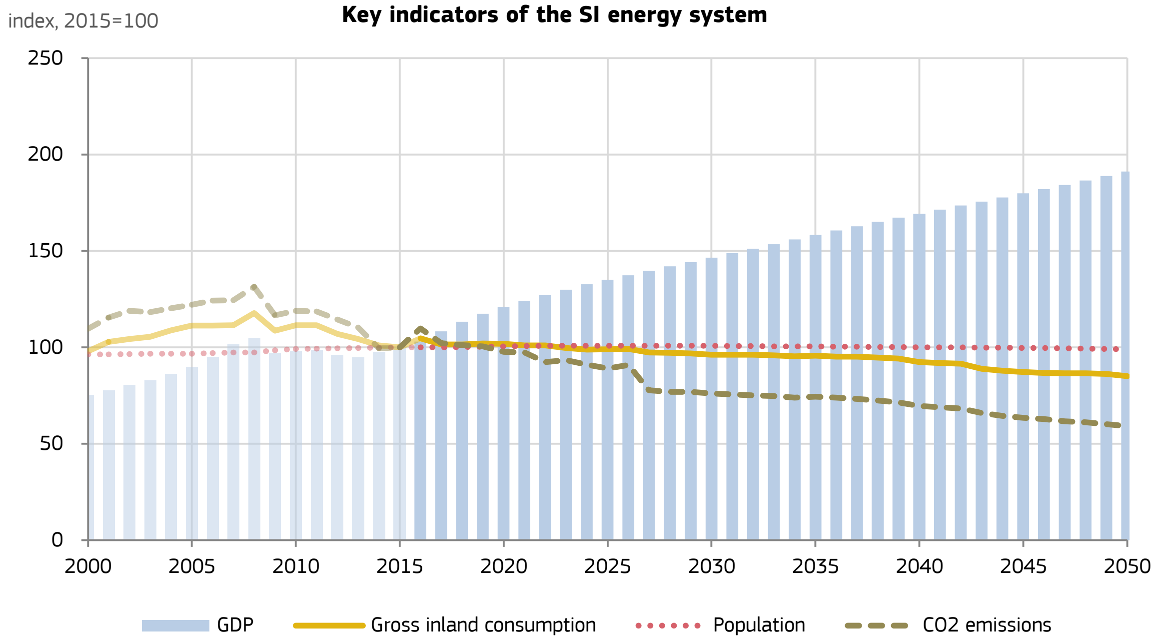

Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
7
6
5
4
3
2
1
0
2000
2010
2020
2030
2040
2050


100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation


0.6
0.4
0.2
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]

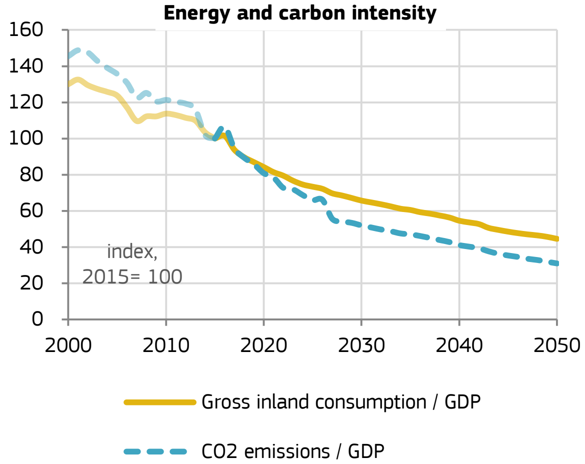

Electricity generation cost
€ / MWh
90
80
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode

Key indicators of the SI energy system

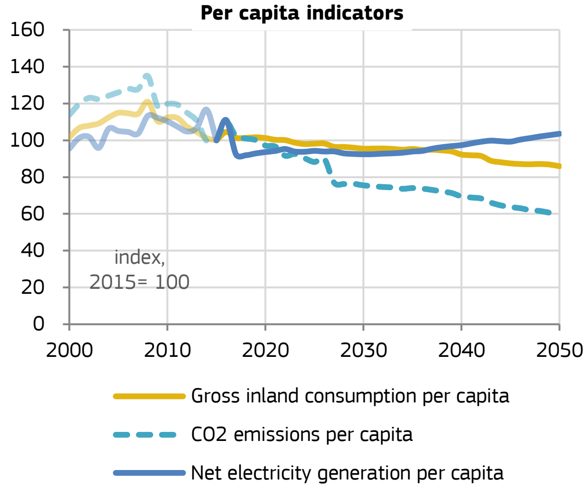


Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	3.7	4.9	4.7	4.9	4.9	4.5
Primary energy consumption [Mtoe]	5.7	7.0	6.5	6.6	6.2	5.4
RES [%] - Share of energy from renewable sources		16.4%	22.9%	24.2%	28.0%	38.0%
RES-E [%] - Share of electricity from renewable sources		28.7%	33.1%	32.3%	41.5%	61.8%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	15.0	16.8	13.8	13.5	10.5	8.2
reduction to 1990		*12%*	*-8%*	*-10%*	*-30%*	*-46%*
Emissions in current ETS sectors |(SI) [Mt CO2]		8.4	6.2	5.7	3.0	2.2
reduction to 2005			*-27%*	*-32%*	*-64%*	*-74%*
Emissions in current ESD sectors [Mt CO2]		8.4	7.6	7.8	7.5	5.9
reduction to 2005			*-10%*	*-7%*	*-11%*	*-29%*

Energy and carbon intensity



Per capita indicators

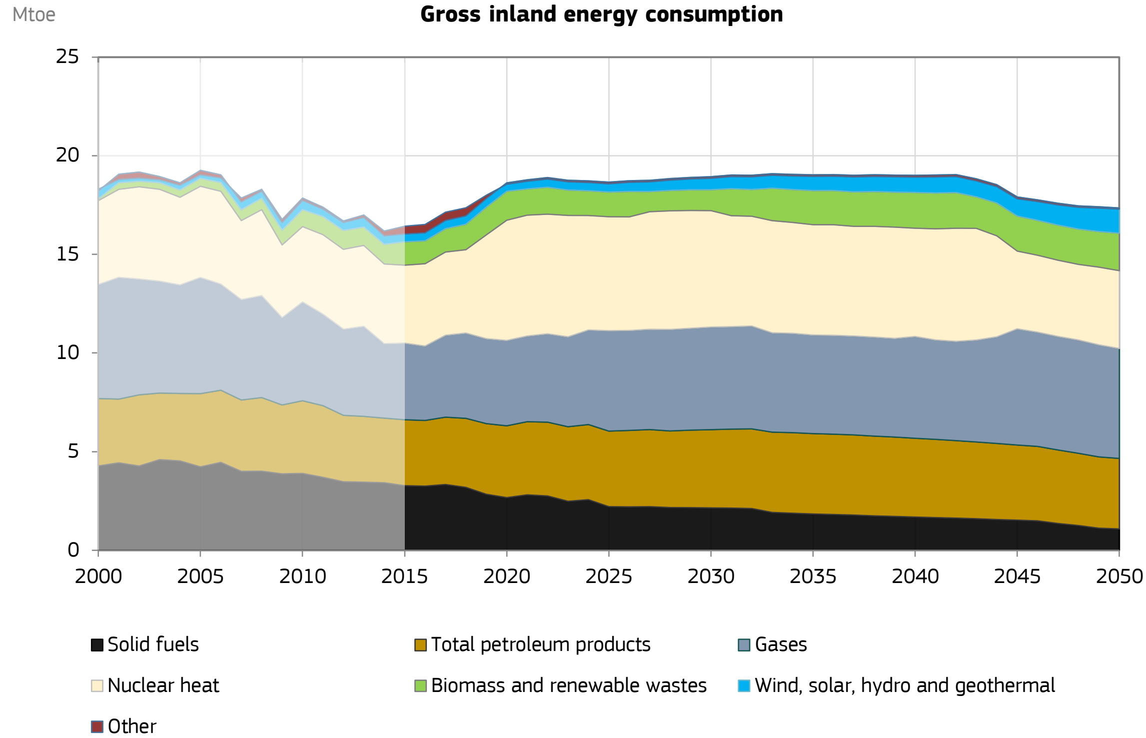


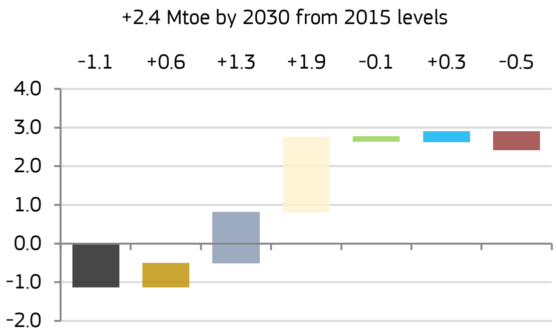
POTEnCIA - Model results overview

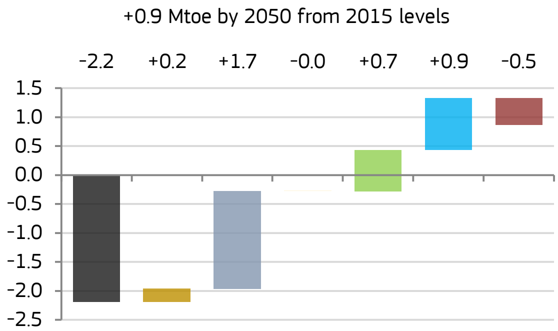
Slovak Republic

Central_2018 scenario

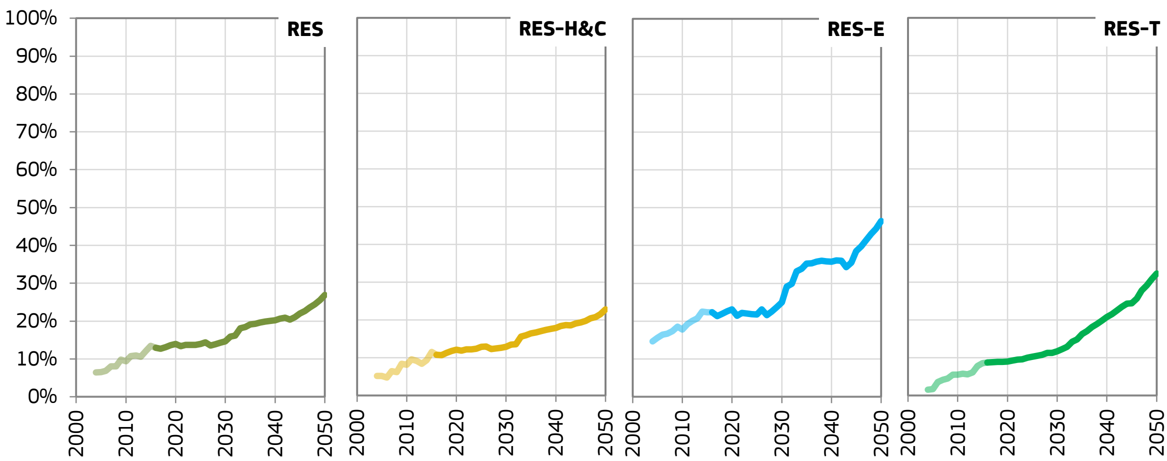
Gross inland energy consumption

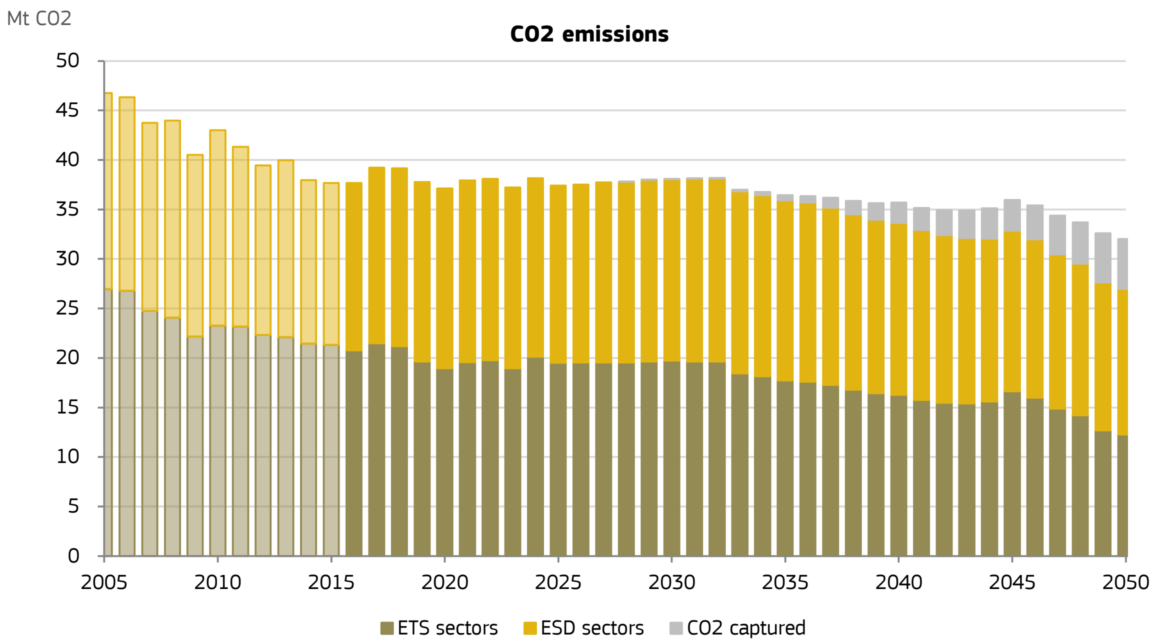


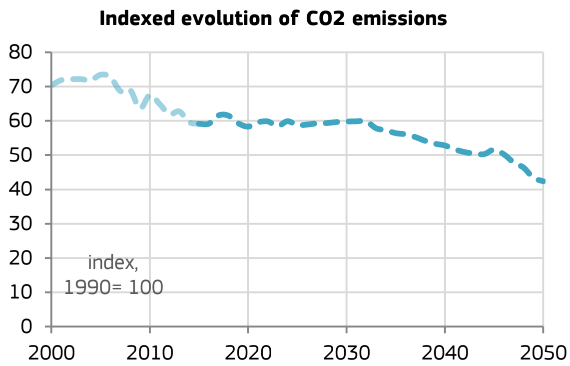


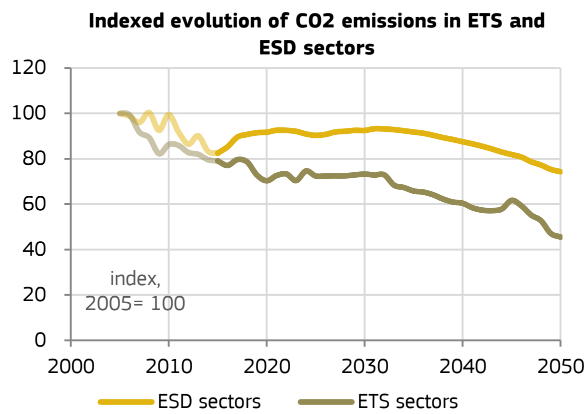


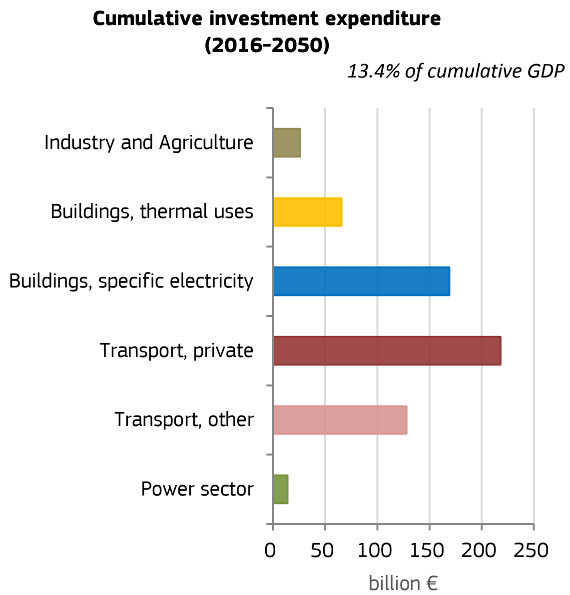
Share of renewable energies

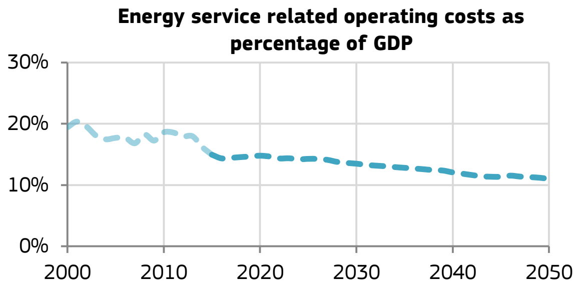


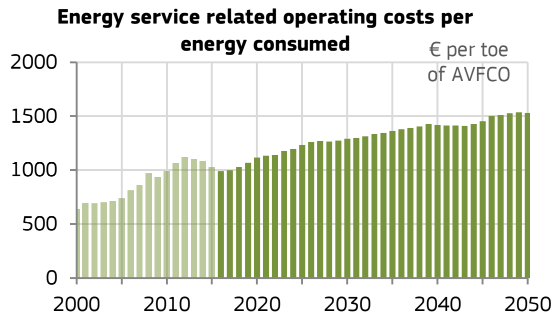

Mt CO2
CO2 emissions
50
45
40
35
30
25
20
15
10
5
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured


Indexed evolution of CO2 emissions
80
70
60
50
40
30
20
10
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

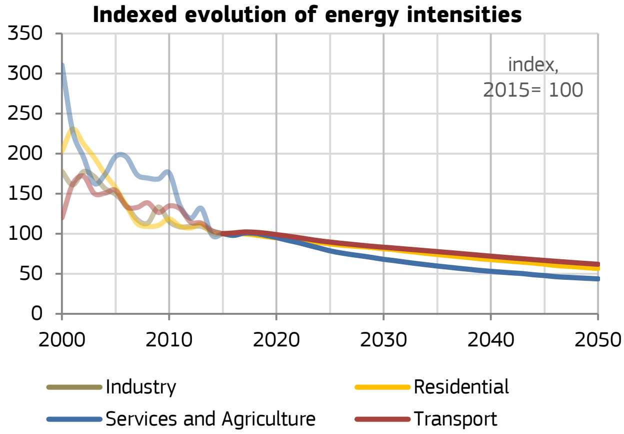

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors


Cumulative investment expenditure (2016-2050)
13.4% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
50
100
150
200
250
billion €

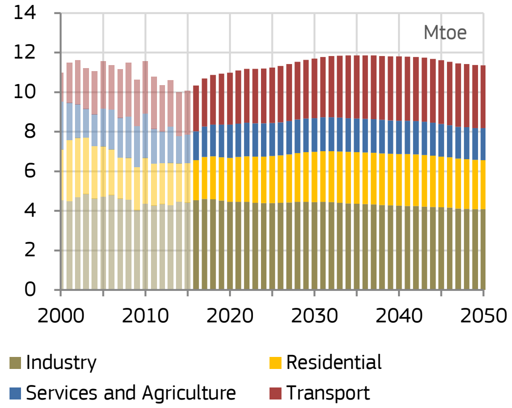

Energy service related operating costs as percentage of GDP
30%
20%
10%
0%
2000
2010
2020
2030
2040
2050


Energy service related operating costs per energy consumed
€ per toe
of AVFCO
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

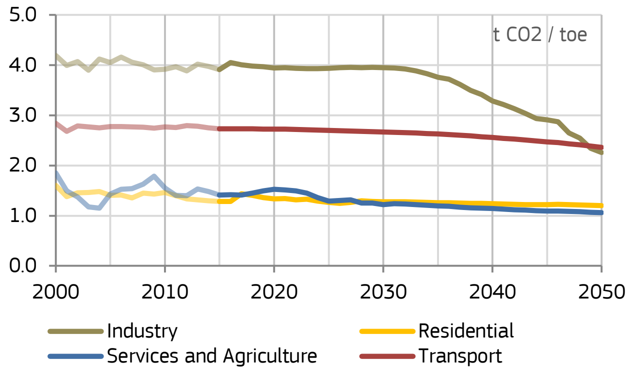
Indexed evolution of energy intensities



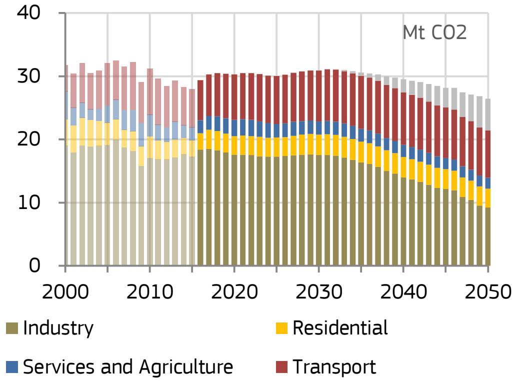
Evolution of final energy consumption



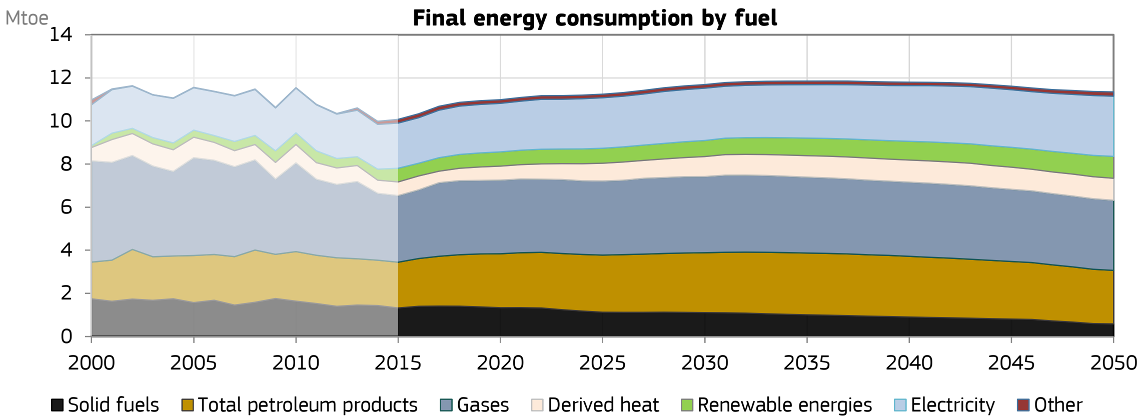
Evolution of carbon intensities



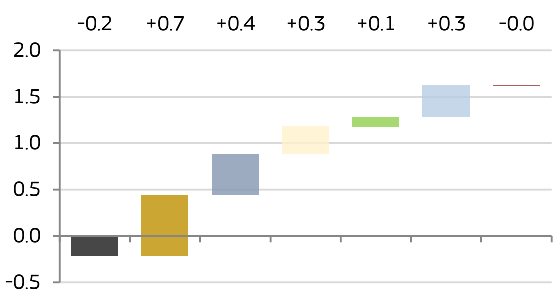
Evolution of CO2 emissions



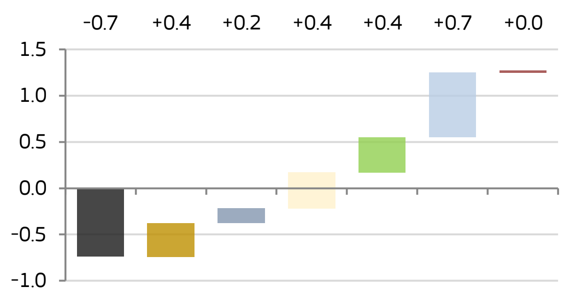
Final energy consumption by fuel

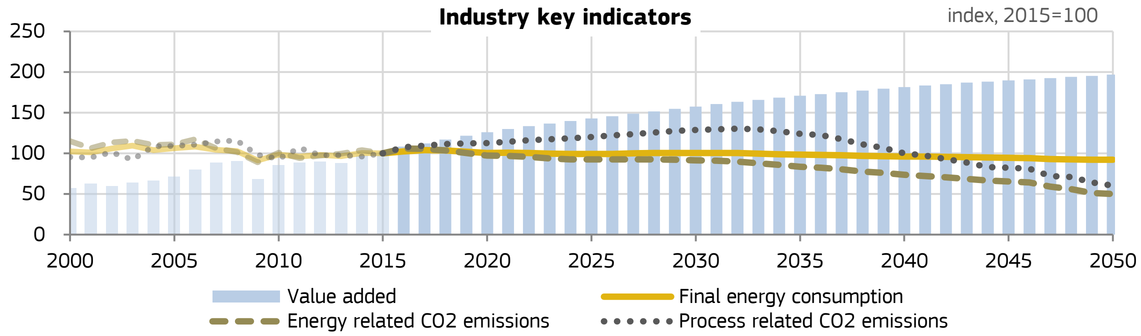


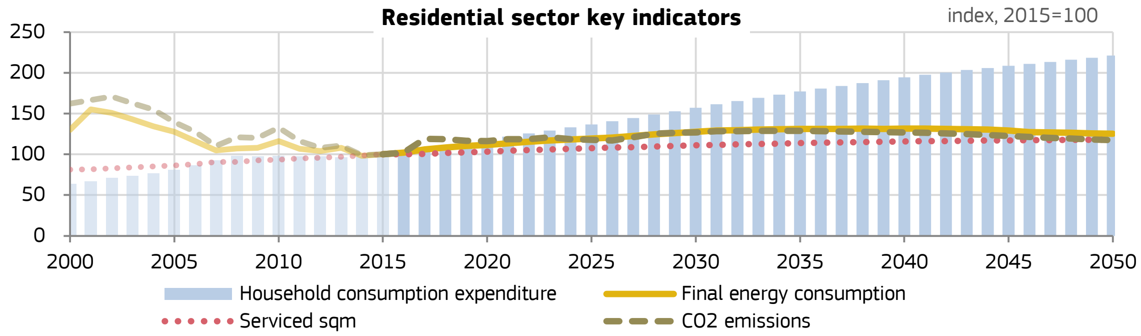
+1.6 Mtoe by 2030 from 2015 levels

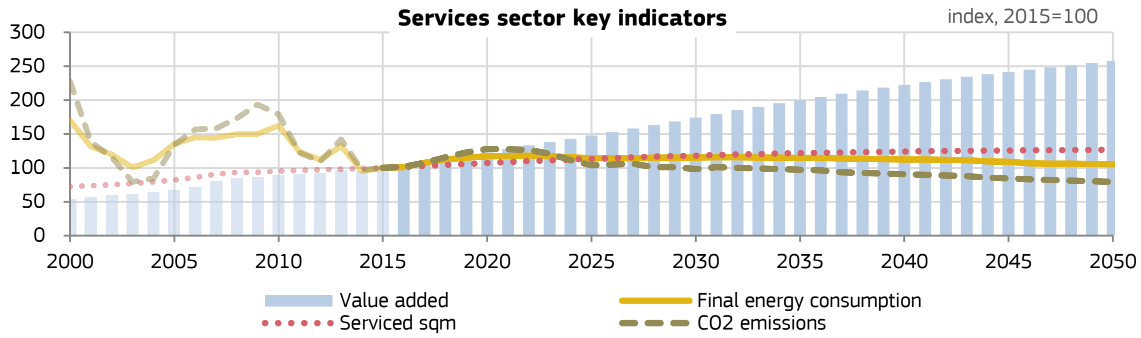


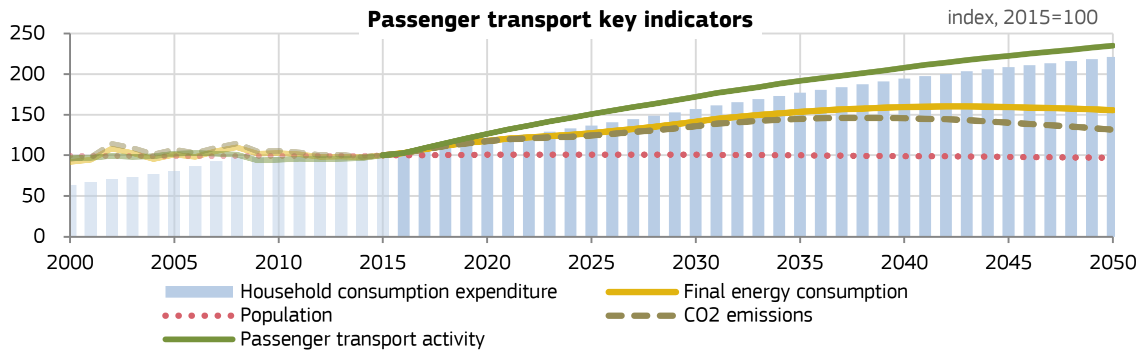
+1.3 Mtoe by 2050 from 2015 levels

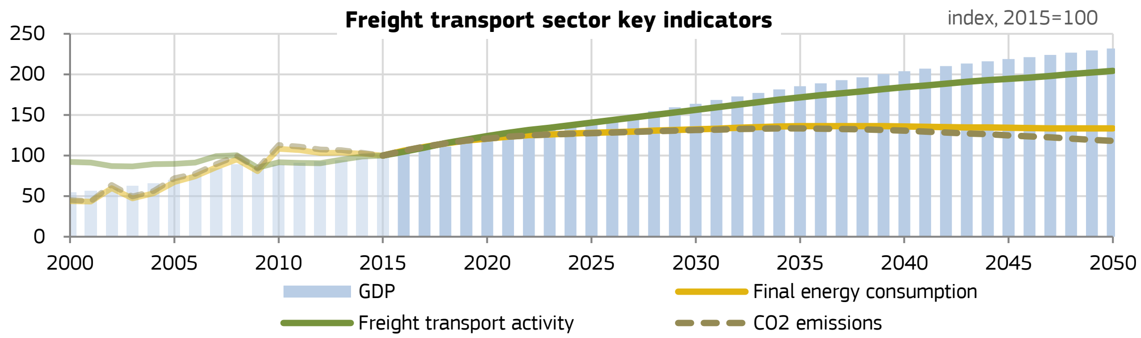


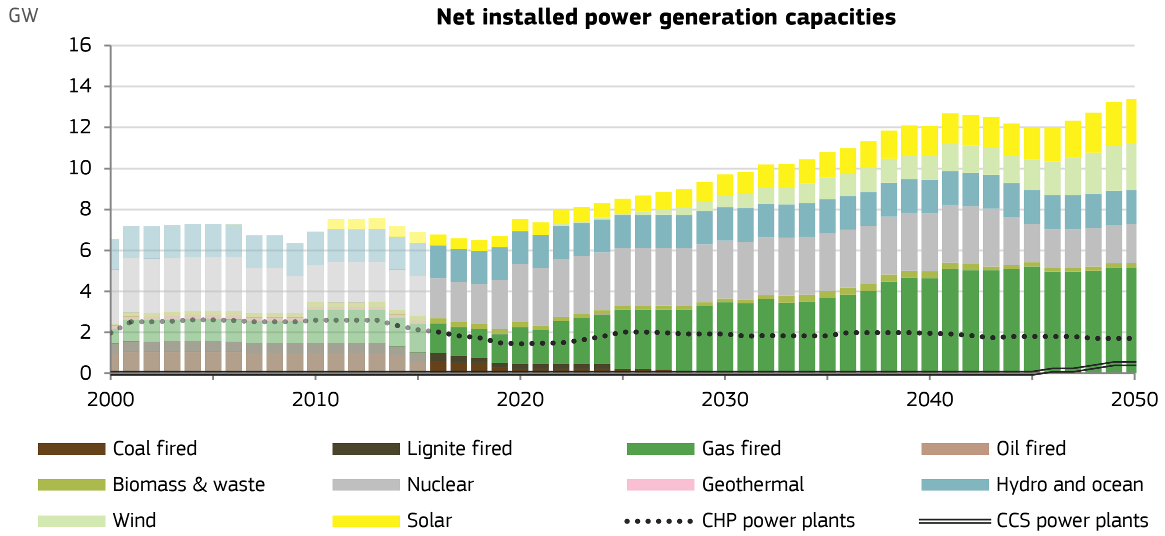

Industry key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

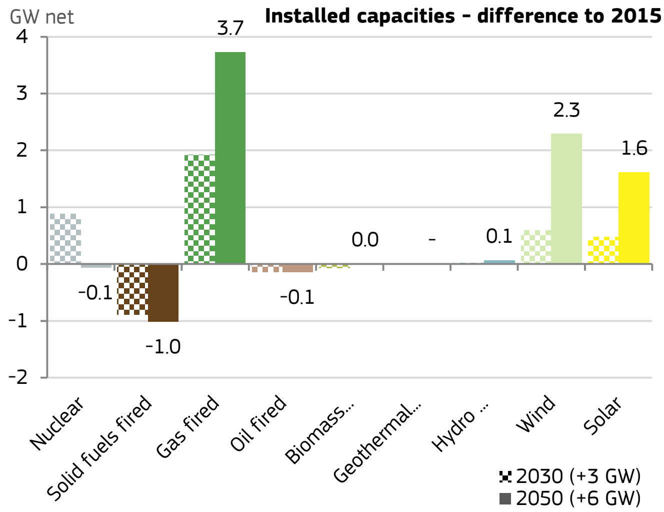

Residential sector key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

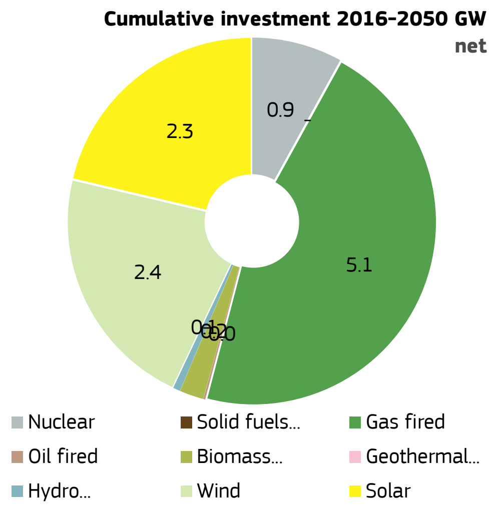

Services sector key indicators
index, 2015=100
300
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

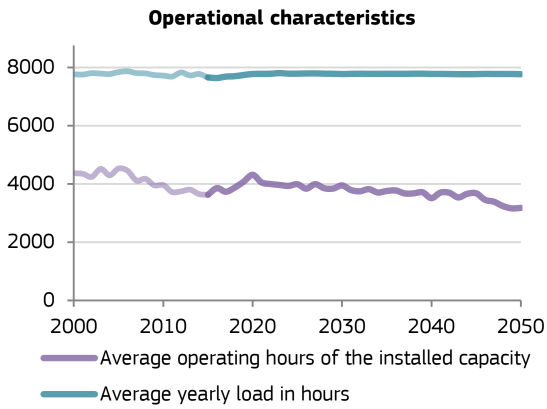

Passenger transport key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

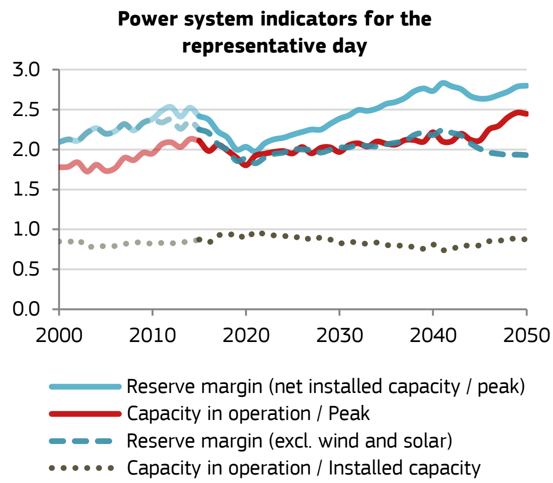

Freight transport sector key indicators
index, 2015=100
250
200
150
100
50
0
2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

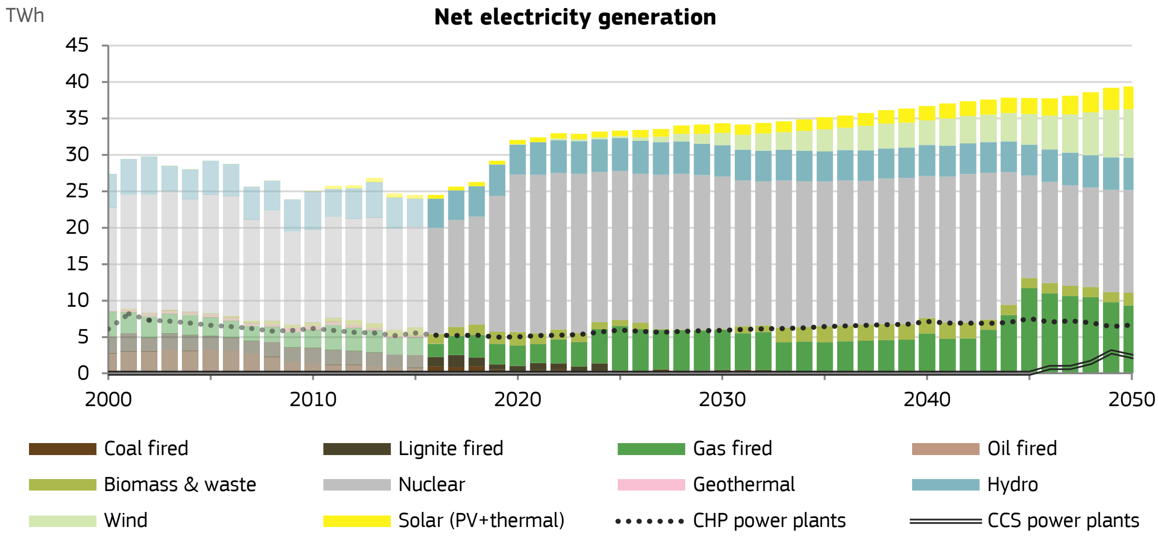

Net installed power generation capacities
GW
16
14
12
10
8
6
4
2
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

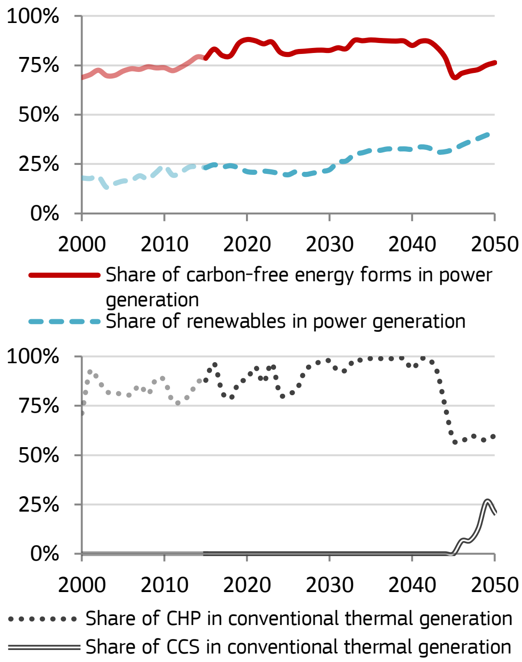

Installed capacities - difference to 2015
GW net
4
3
2
1
0
-1
-2
3.7
2.3
1.6
0.0
-
0.1
-0.1
-0.1
-1.0
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+3 GW)
2050 (+6 GW)

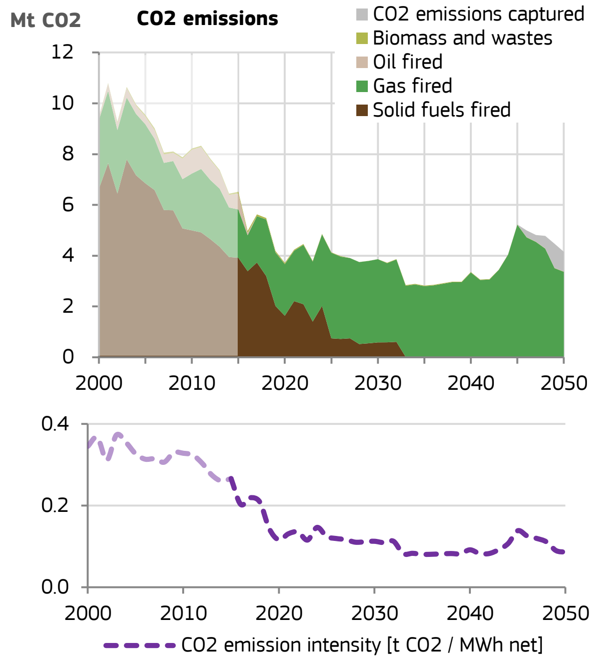

Cumulative investment 2016-2050 GW net
0.9
2.3
5.1
2.4
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

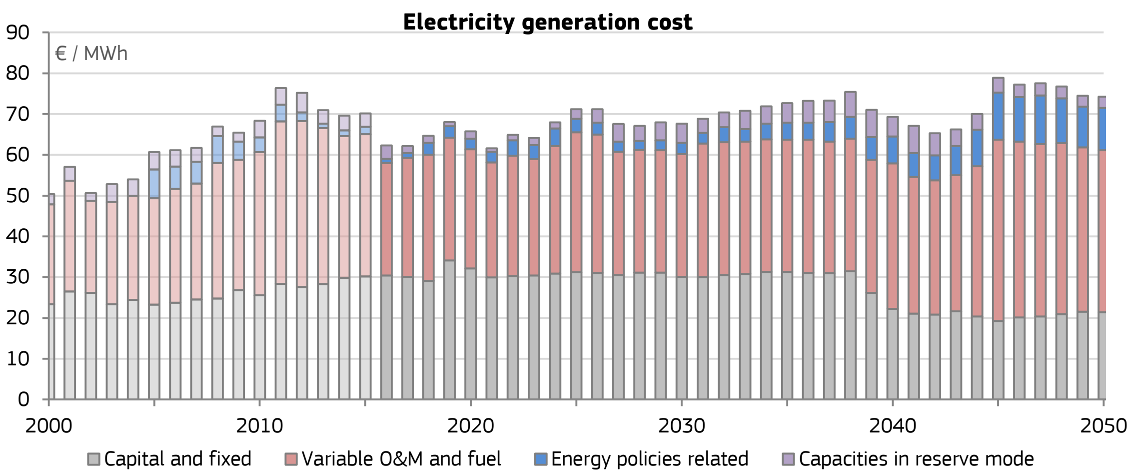

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

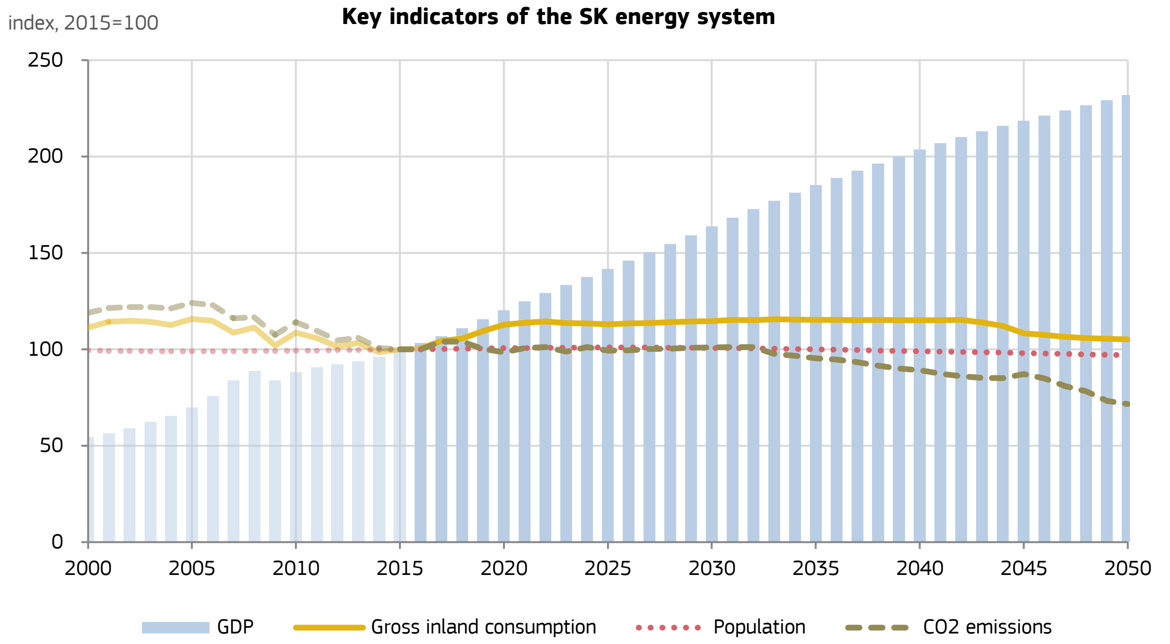

Power system indicators for the representative day
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity


Net electricity generation
TWh
45
40
35
30
25
20
15
10
5
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants

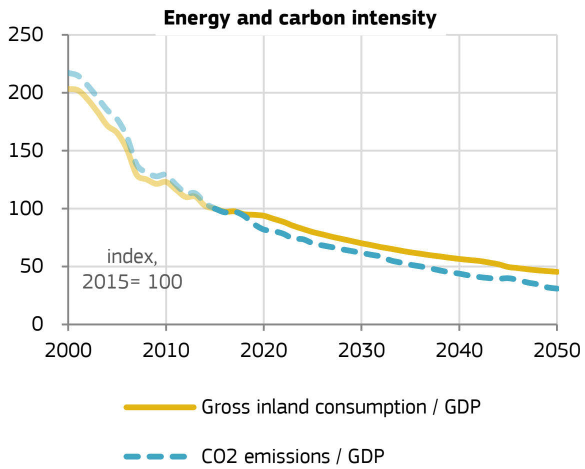

100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation
100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

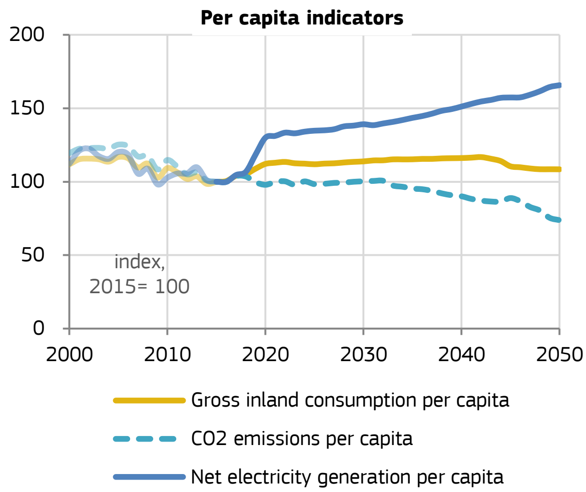

Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
12
10
8
6
4
2
0
2000
2010
2020
2030
2040
2050
0.4
0.2
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]


Electricity generation cost
€ / MWh
90
80
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	15.2	11.6	10.1	11.0	11.7	11.4
Primary energy consumption [Mtoe]	20.2	17.8	15.4	17.3	17.5	15.9
RES [%] - Share of energy from renewable sources		6.5%	13.5%	13.9%	14.7%	26.9%
RES-E [%] - Share of electricity from renewable sources		15.5%	22.3%	23.1%	25.0%	46.5%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	63.7	46.8	37.7	37.1	38.1	27.0
reduction to 1990		*-27%*	*-41%*	*-42%*	*-40%*	*-58%*
Emissions in current ETS sectors |(SK) [Mt CO2]		27.0	21.3	19.0	19.7	12.3
reduction to 2005			*-21%*	*-30%*	*-27%*	*-54%*
Emissions in current ESD sectors [Mt CO2]		19.8	16.4	18.2	18.3	14.7
reduction to 2005			*-17%*	*-8%*	*-8%*	*-26%*

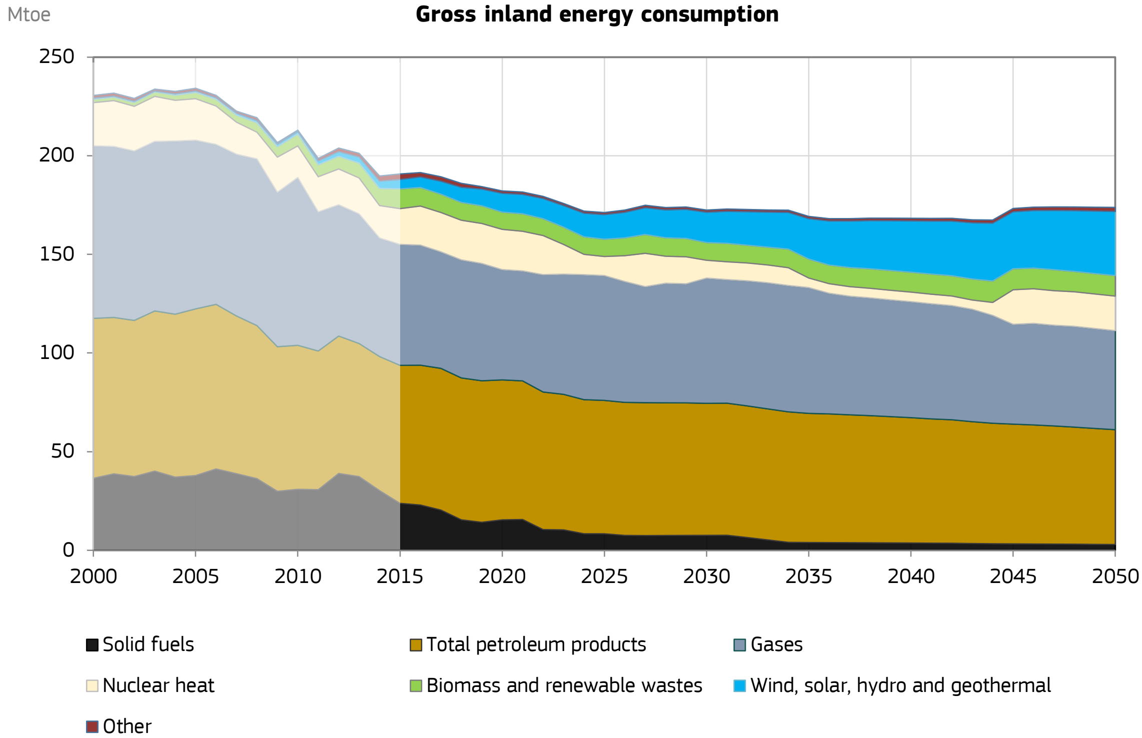




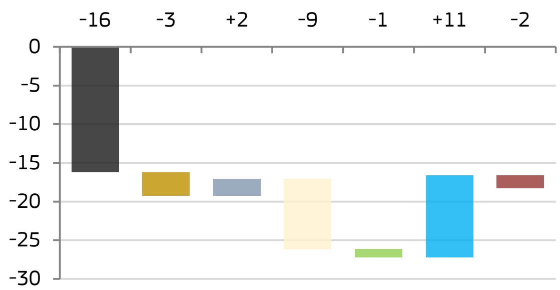
United Kingdom

Central_2018 scenario

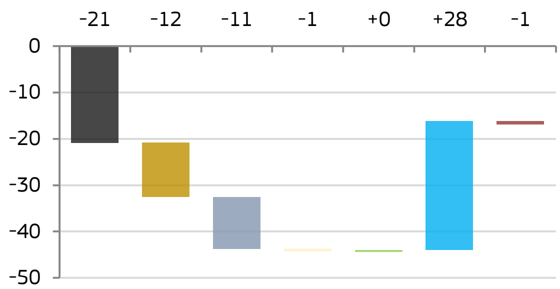
Gross inland energy consumption



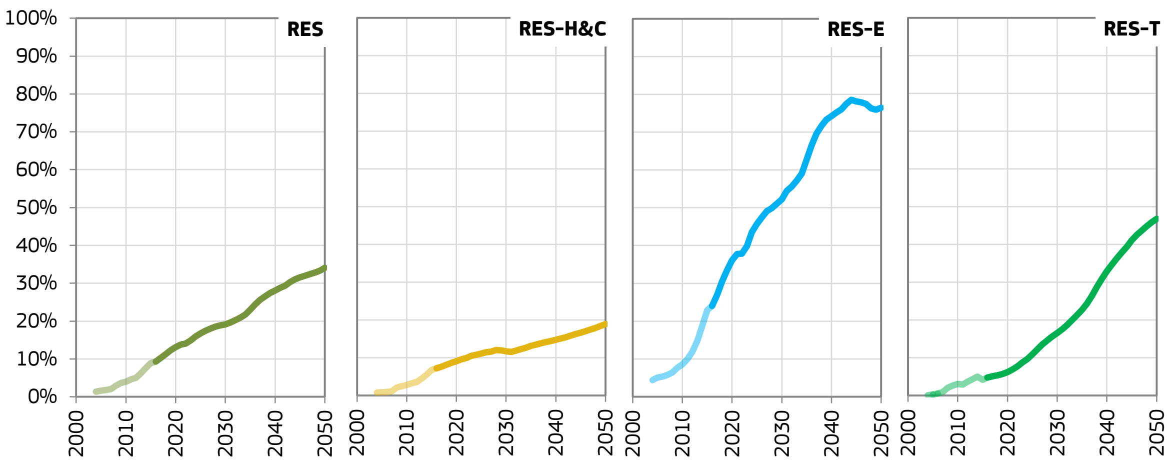
-18 Mtoe by 2030 from 2015 levels

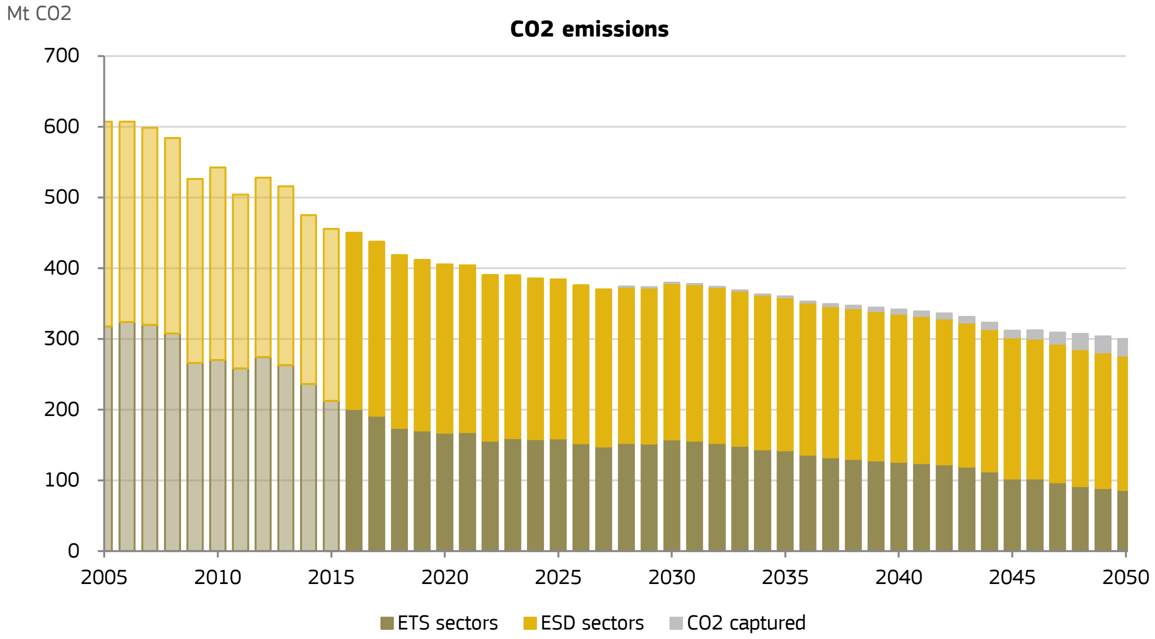


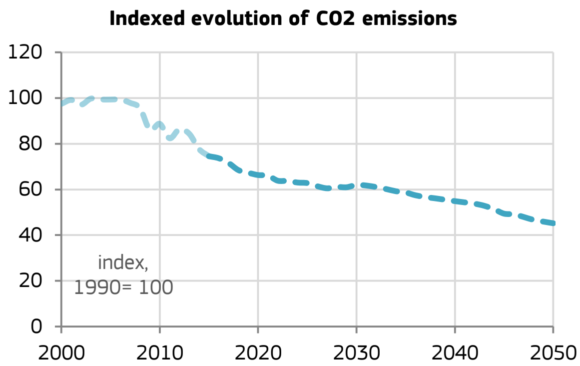
-17 Mtoe by 2050 from 2015 levels

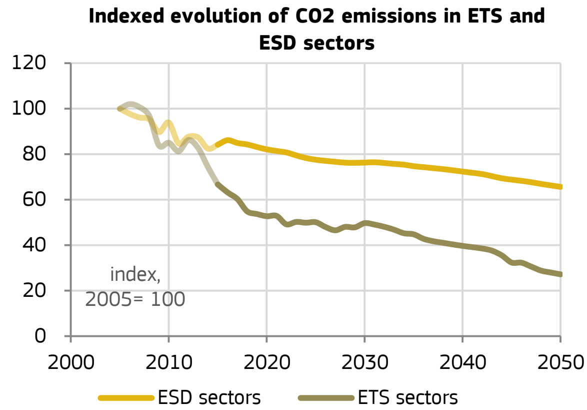


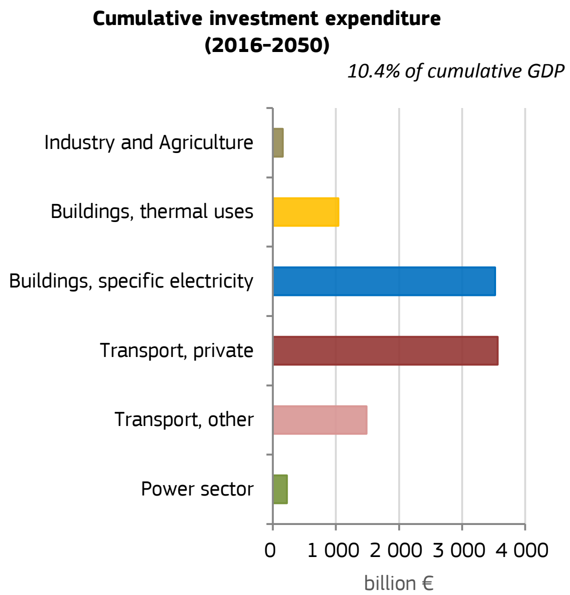
Share of renewable energies

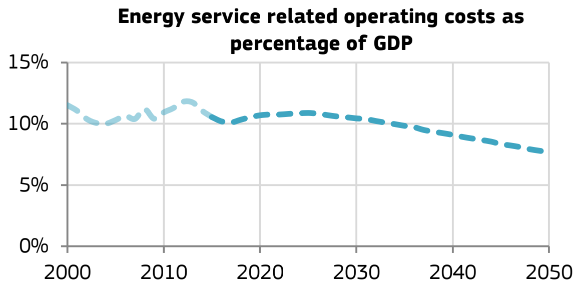


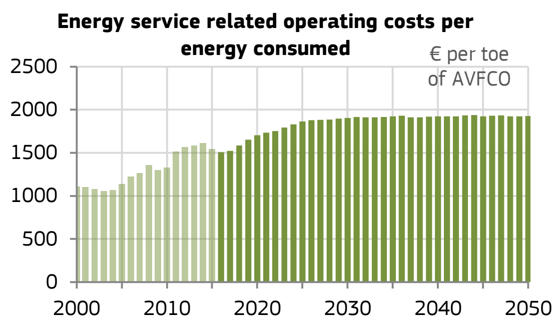

Mt CO2
CO2 emissions
700
600
500
400
300
200
100
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
ETS sectors
ESD sectors
CO2 captured


Indexed evolution of CO2 emissions
120
100
80
60
40
20
0
index,
1990= 100
2000
2010
2020
2030
2040
2050

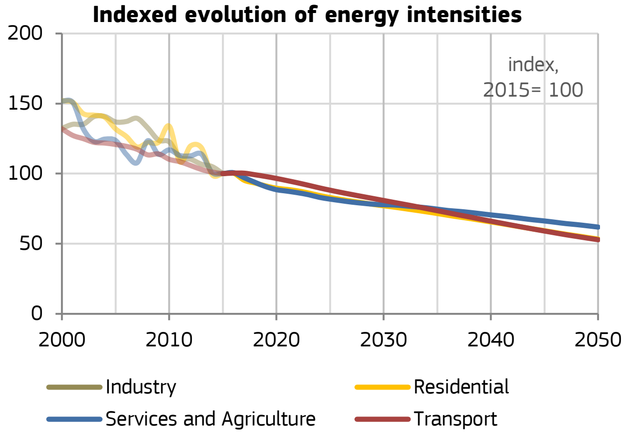

Indexed evolution of CO2 emissions in ETS and ESD sectors
120
100
80
60
40
20
0
index,
2005= 100
2000
2010
2020
2030
2040
2050
ESD sectors
ETS sectors


Cumulative investment expenditure (2016-2050)
10.4% of cumulative GDP
Industry and Agriculture
Buildings, thermal uses
Buildings, specific electricity
Transport, private
Transport, other
Power sector
0
1 000
2 000
3 000
4 000
billion €

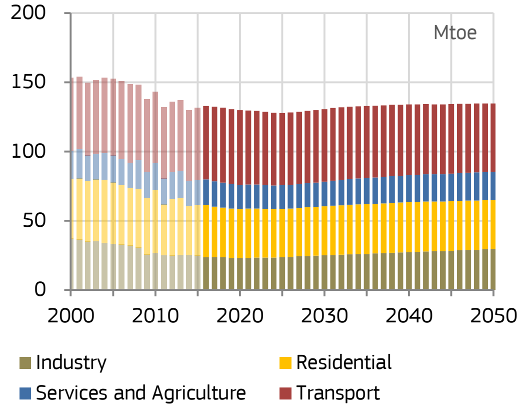

Energy service related operating costs as percentage of GDP
15%
10%
5%
0%
2000
2010
2020
2030
2040
2050


Energy service related operating costs per energy consumed
€ per toe of AVFCO
2500
2000
1500
1000
500
0
2000
2010
2020
2030
2040
2050

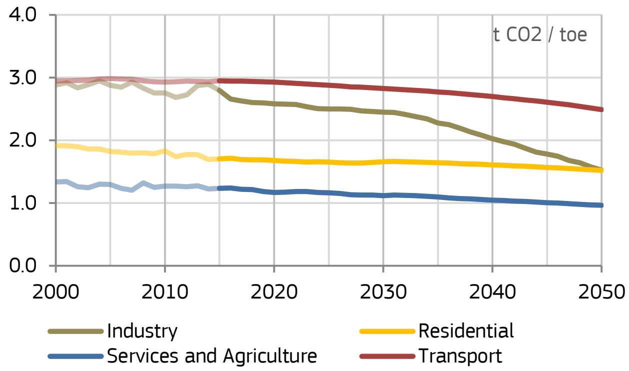
Indexed evolution of energy intensities



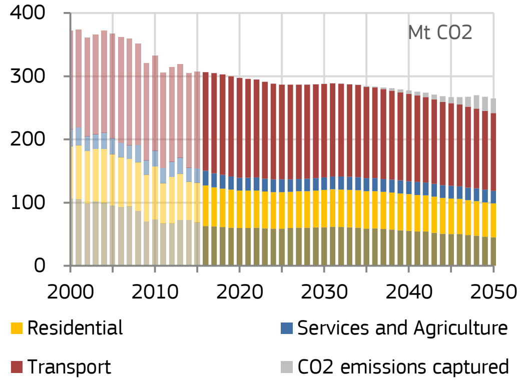
Evolution of final energy consumption



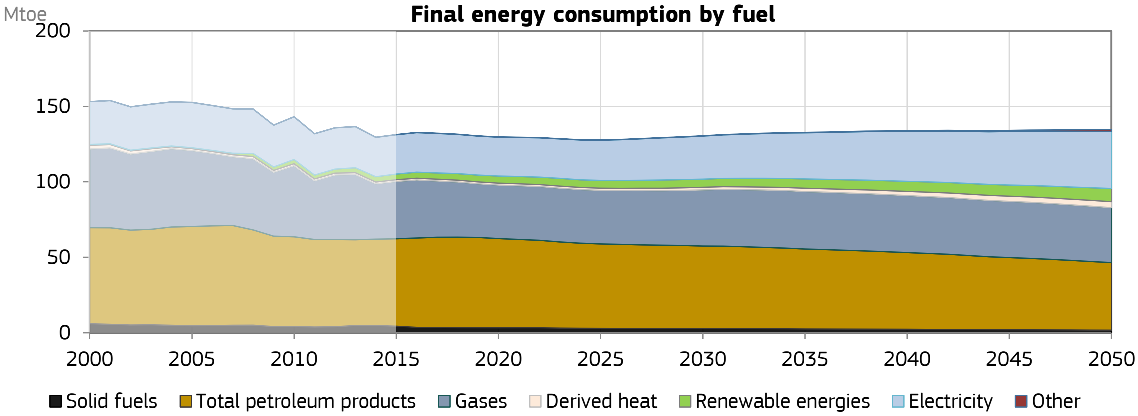
Evolution of carbon intensities



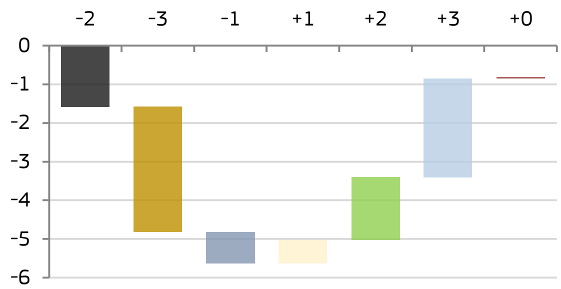
Evolution of CO2 emissions



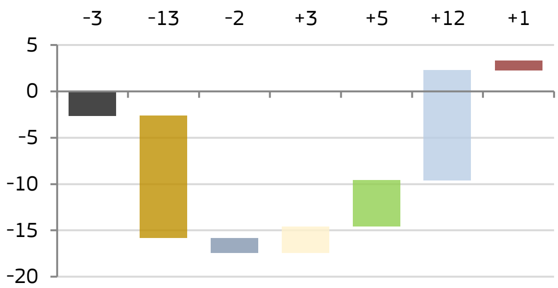
Final energy consumption by fuel

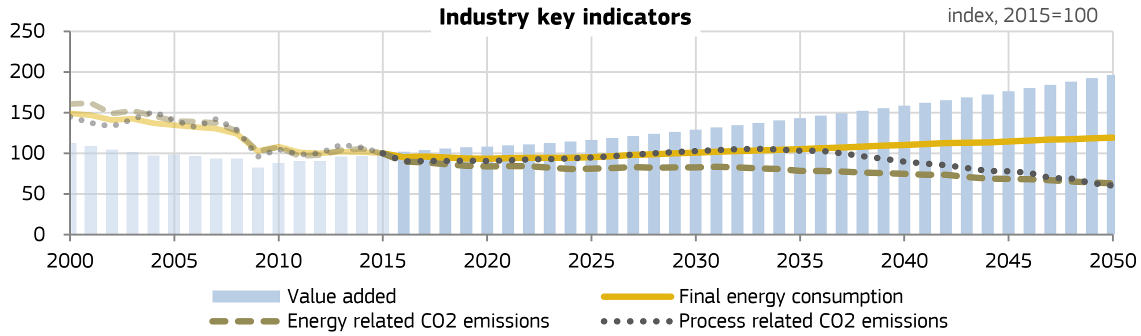


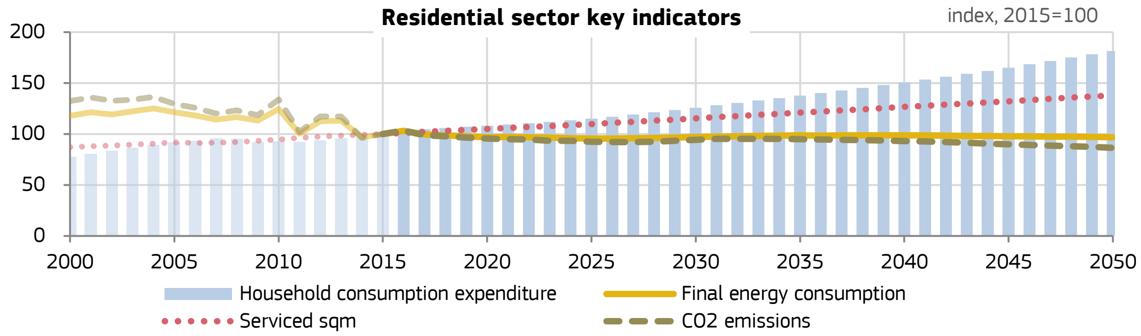
-1 Mtoe by 2030 from 2015 levels

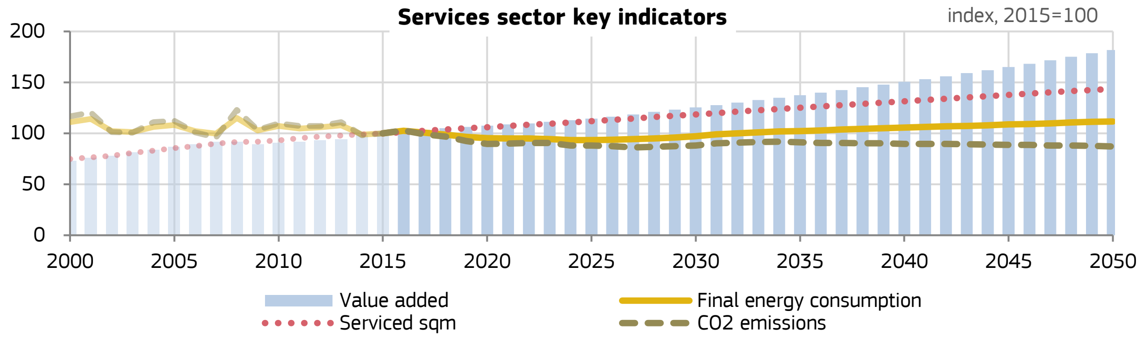


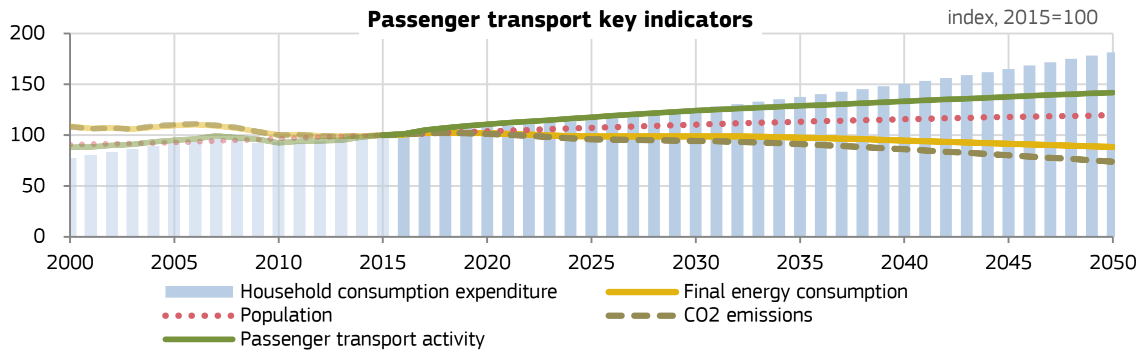
+3 Mtoe by 2050 from 2015 levels

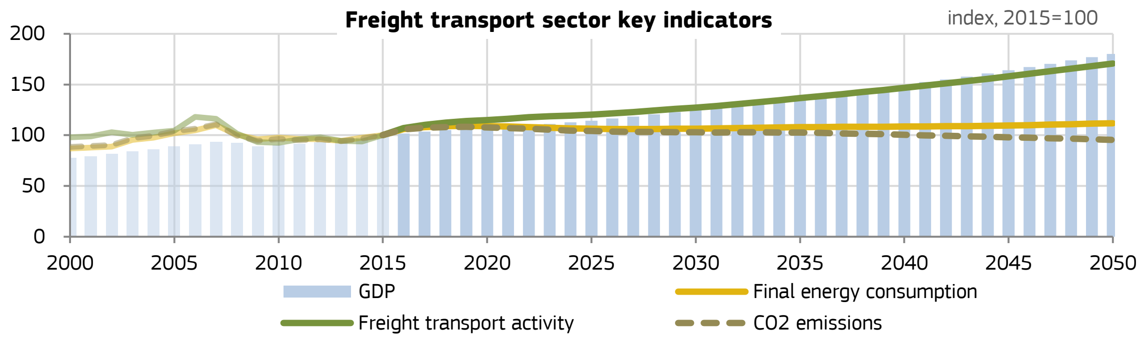


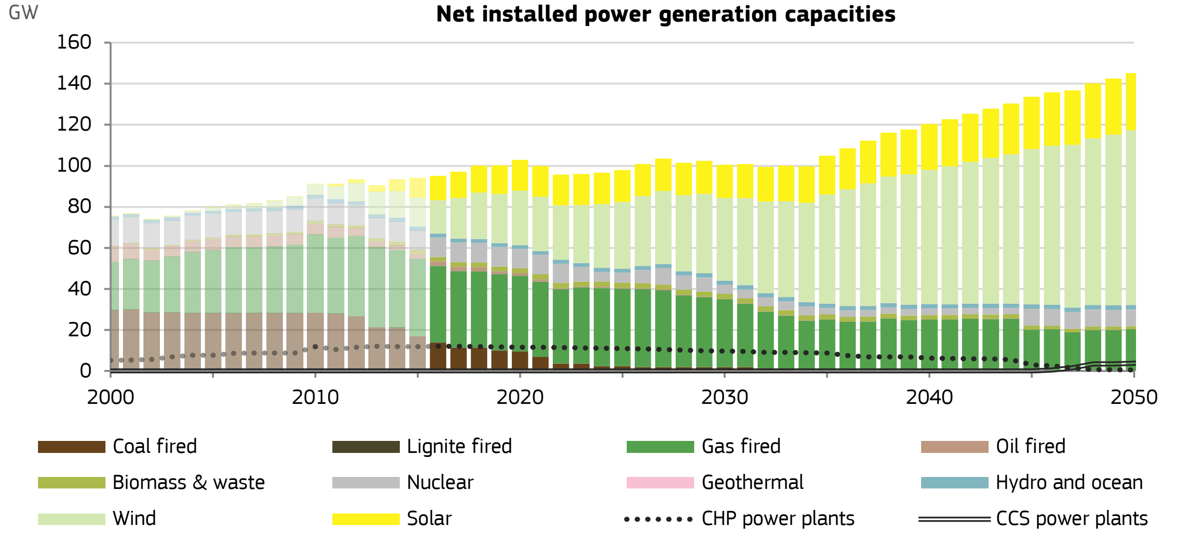

Industry key indicators
index, 2015=100
250
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Energy related CO2 emissions
Process related CO2 emissions

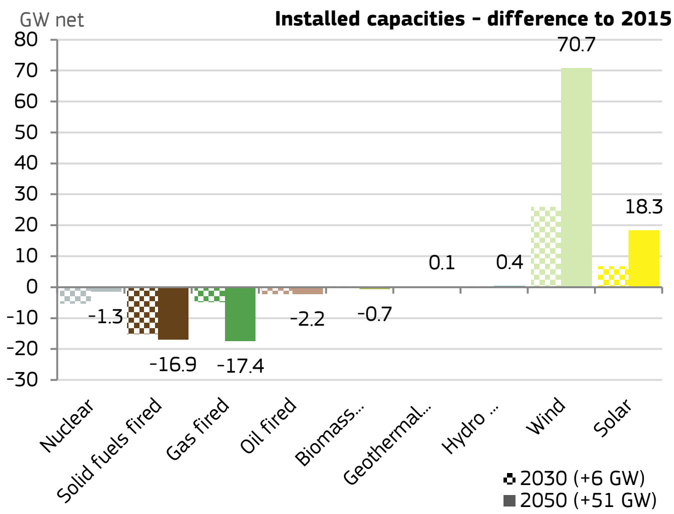

Residential sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Serviced sqm
CO2 emissions

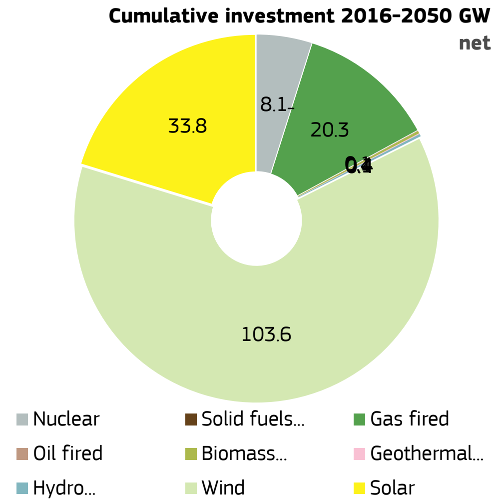

Services sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Value added
Final energy consumption
Serviced sqm
CO2 emissions

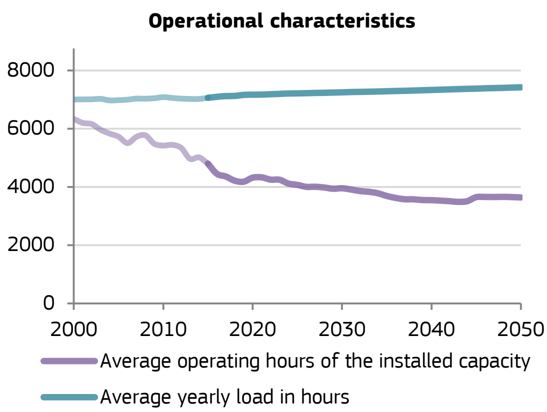

Passenger transport key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Household consumption expenditure
Final energy consumption
Population
CO2 emissions
Passenger transport activity

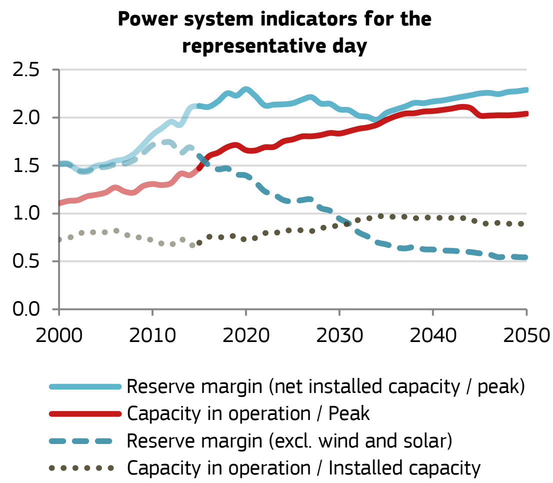

Freight transport sector key indicators
index, 2015=100
200
150
100
50
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
GDP
Final energy consumption
Freight transport activity
CO2 emissions

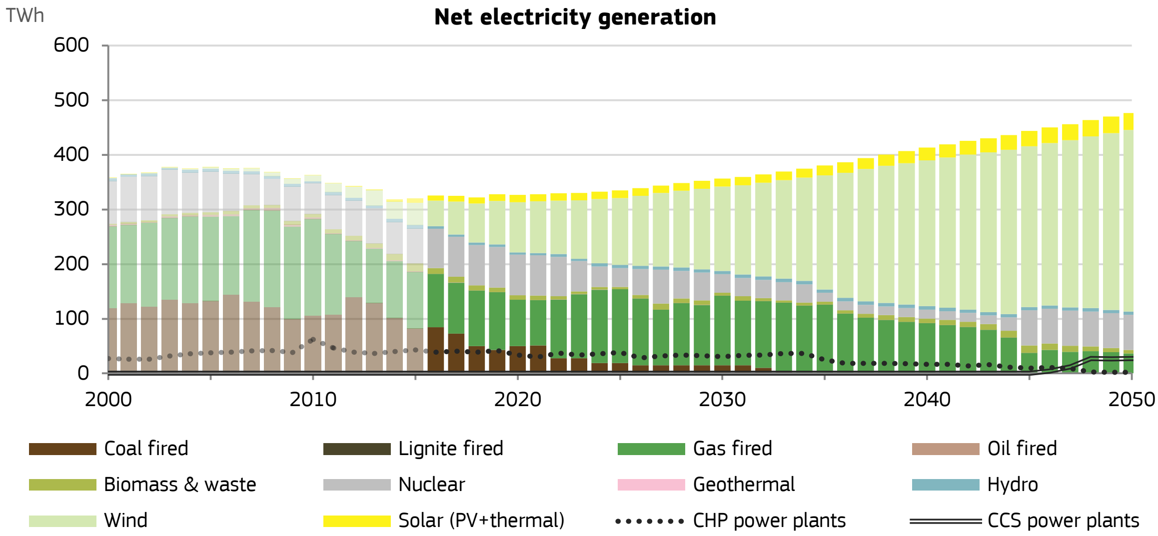

Net installed power generation capacities
GW
160
140
120
100
80
60
40
20
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro and ocean
Wind
Solar
CHP power plants
CCS power plants

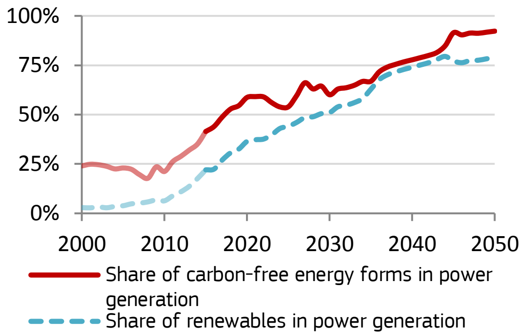

Installed capacities - difference to 2015
GW net
70.7
18.3
0.1
0.4
-1.3
-16.9
-17.4
-2.2
-0.7
Nuclear
Solid fuels fired
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro ...
Wind
Solar
2030 (+6 GW)
2050 (+51 GW)

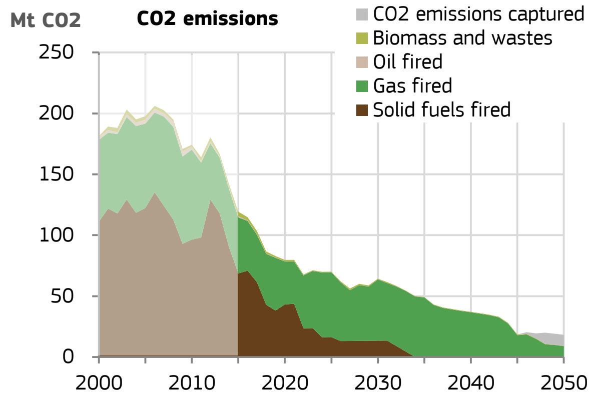

Cumulative investment 2016-2050 GW net
8.1
20.3
0.4
33.8
103.6
Nuclear
Solid fuels...
Gas fired
Oil fired
Biomass...
Geothermal...
Hydro...
Wind
Solar

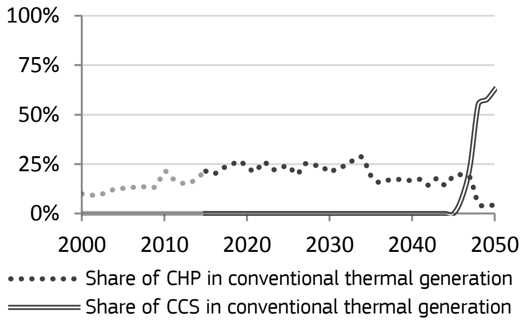

Operational characteristics
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
Average operating hours of the installed capacity
Average yearly load in hours

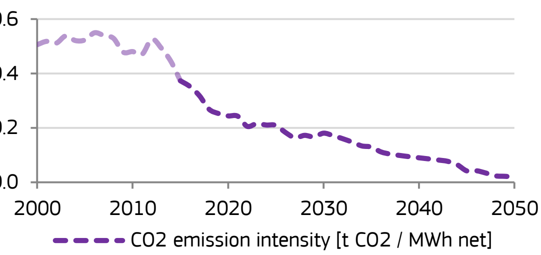

Power system indicators for the representative day
2.5
2.0
1.5
1.0
0.5
0.0
2000
2010
2020
2030
2040
2050
Reserve margin (net installed capacity / peak)
Capacity in operation / Peak
Reserve margin (excl. wind and solar)
Capacity in operation / Installed capacity

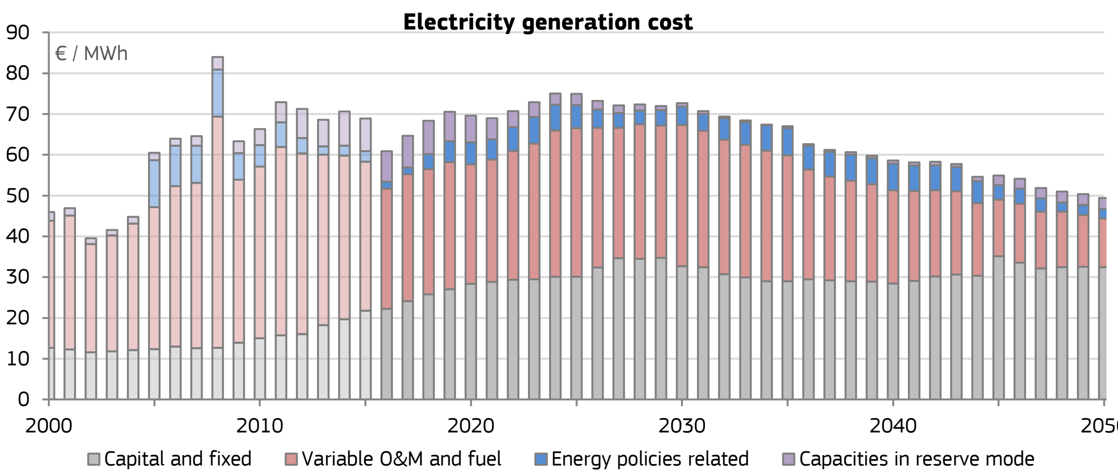

TWh
Net electricity generation
600
500
400
300
200
100
0
2000
2010
2020
2030
2040
2050
Coal fired
Lignite fired
Gas fired
Oil fired
Biomass & waste
Nuclear
Geothermal
Hydro
Wind
Solar (PV+thermal)
CHP power plants
CCS power plants


100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of carbon-free energy forms in power generation
Share of renewables in power generation

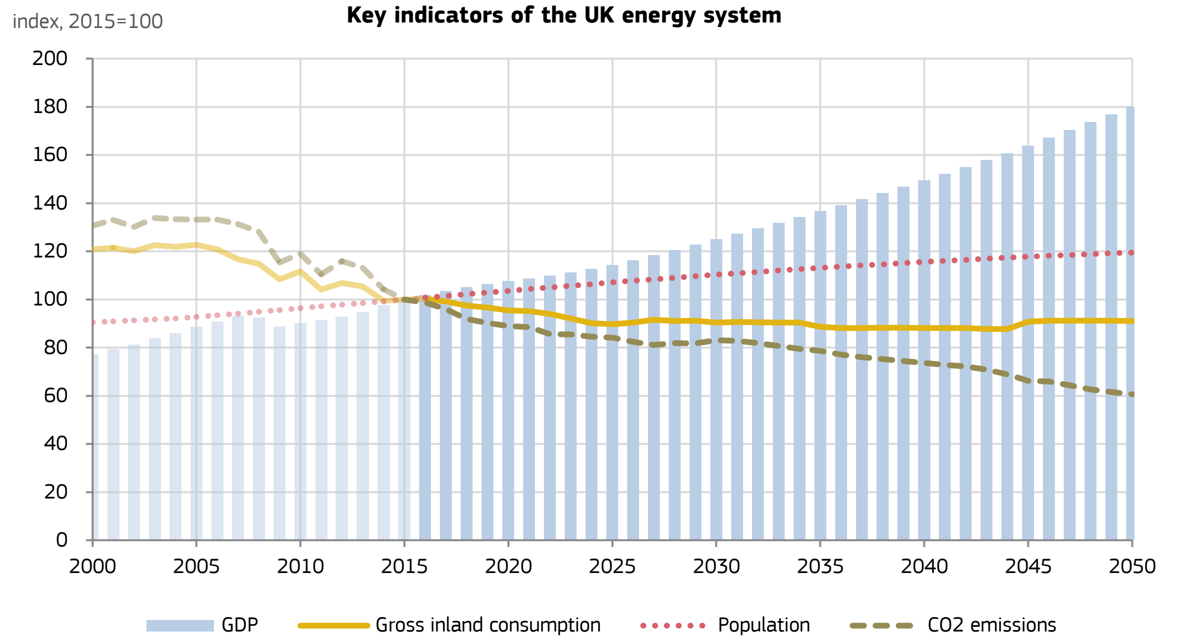

Mt CO2
CO2 emissions
CO2 emissions captured
Biomass and wastes
Oil fired
Gas fired
Solid fuels fired
250
200
150
100
50
0
2000
2010
2020
2030
2040
2050


100%
75%
50%
25%
0%
2000
2010
2020
2030
2040
2050
Share of CHP in conventional thermal generation
Share of CCS in conventional thermal generation

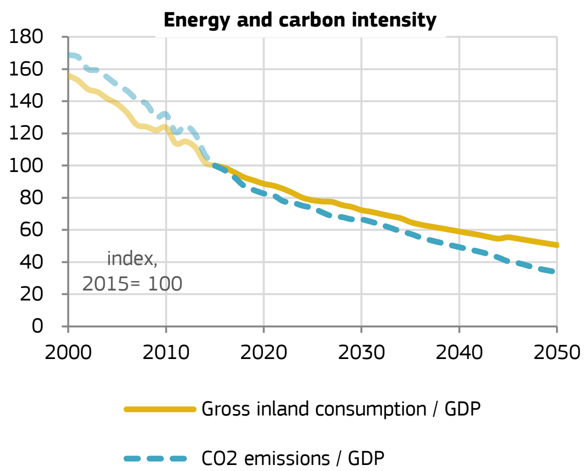

0.6
0.4
0.2
0.0
2000
2010
2020
2030
2040
2050
CO2 emission intensity [t CO2 / MWh net]

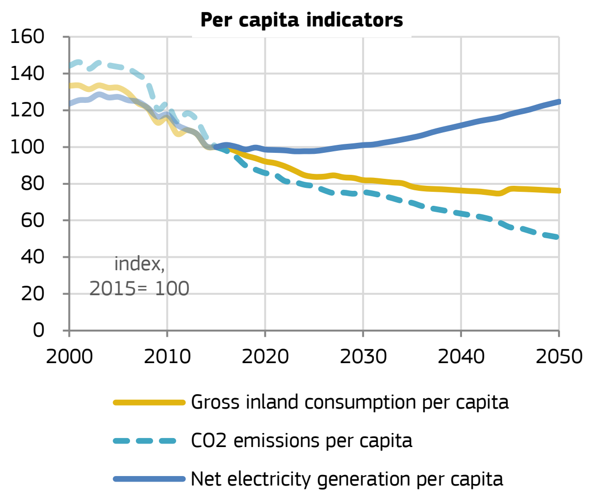

Electricity generation cost
€ / MWh
90
80
70
60
50
40
30
20
10
0
2000
2010
2020
2030
2040
2050
Capital and fixed
Variable O&M and fuel
Energy policies related
Capacities in reserve mode

United Kingdom **Central_2018 - Indicators**



Key figures concerning the evolution of the Central_2018 - Indicators energy system						
	1990	2005	2015	2020	2030	2050
Final energy consumption [Mtoe]	137	153	131	130	131	135
Primary energy consumption [Mtoe]	200	223	183	174	163	162
RES [%] - Share of energy from renewable sources		1.6%	8.9%	13.2%	19.1%	34.1%
RES-E [%] - Share of electricity from renewable sources		5.1%	23.0%	36.1%	52.2%	76.4%
Total CO2 emissions [Mt CO2] (with intern. aviation, without LULUCF)	611	607	456	405	379	276
reduction to 1990		*-1%*	*-25%*	*-34%*	*-38%*	*-55%*
Emissions in current ETS sectors |(UK) [Mt CO2]		318	212	167	158	86
reduction to 2005			*-33%*	*-47%*	*-50%*	*-73%*
Emissions in current ESD sectors [Mt CO2]		290	244	238	221	190
reduction to 2005			*-16%*	*-18%*	*-24%*	*-34%*





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