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Renewable technologies in the EU electricity sector: trends and projections

Analysis in the framework of the EU 2030 climate and energy strategy

Banja M. and Jégard M.

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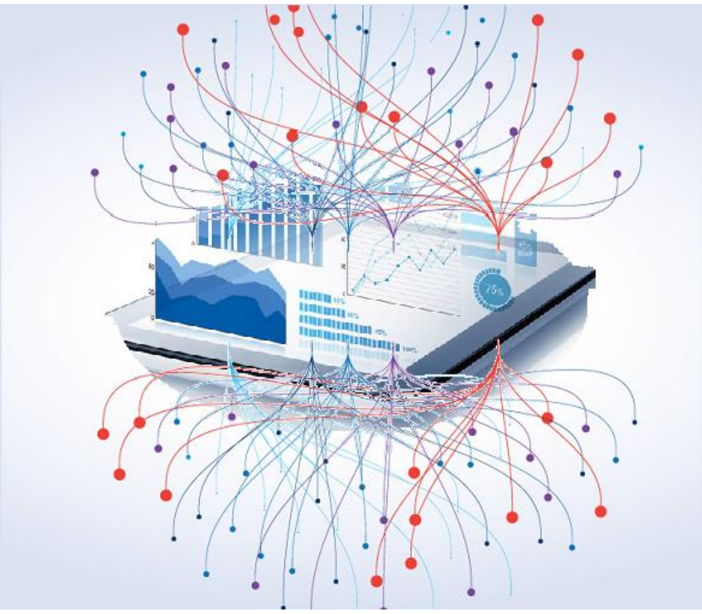

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Joint Research Centre

Contact information
Name: Manjola Banja
Address: European Commission, Joint Research Centre, Via Enrico Fermi 2749, I-21027, Ispra, Italy
Email: Manjola.Banja@ec.europa.eu
Tel.: +390332783992

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Renewable technologies in the EU electricity sector: trends and projections - Analysis in the framework of the EU 2030 climate and energy strategy

The slowdown of renewable energy deployment is a concern and needs to be avoided in the time the EU is aiming higher shares of renewables in 2030. Through a cost-optimal approach the EU ought to double in 2030 the current share of renewables in electricity sector. The important changes in electricity sector and in the related markets have already occurred, bringing to the question on how much these changes are reflected in the European Commission scenarios assumptions and results.

Contents

Acknowledgements

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The report uses established data, available for download and sourced from EU Member States' databases under the Renewable Energy Directive, as well as data from Eurostat's SHARES tool. It includes the data sourced by the PRIMES and PRIMES climate mitigation scenarios and JRC POLES model.

Manjola Banja (C.2) and Fabio Monforti-Ferrario (Air and Climate Unit, C.5) led the work on maintaining and updating the renewable energy database used in this report.

Manjola Banja led the analysis of (i) progress made on using renewable energy technologies in the EU electricity sector compared to the planned use and (ii) trend projections based on the seven scenarios included in this analysis.

Martin Jégard was responsible for — (i) data extraction for the EUCO30 and EUCO3030 energy scenarios, organising them in the appropriate format for subsequent analysis and visualisation; (ii) data input for the section on renewable energy support schemes and renewable energy patents in the EU.

The authors would like to thank Katalin Bódis for preparing the EUCO27 scenario data in the proper format for data analysis and visualisation.

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Executive summary

Policy context: The 2030 Climate and Energy Policy Framework that preceded the EU contribution to the Paris Agreement was adopted in October 2014. It set three key targets: (i) a binding target of at least 40 % reduction in greenhouse gas emissions by 2030 compared to 1990, for the EU; (ii) a binding EU-level target of at least a 27 % share of renewable energy in 2030; (iii) an indicative EU-level target to improve energy efficiency by at least 27 % in 2030 compared to projections of future energy consumption. In November 2016, the European Commission proposed an update to the Energy Efficiency Directive, including a binding EU energy efficiency target of 30 %.

Key conclusions

The fast deployment of variable renewable energy technologies (wind and solar photovoltaics) is causing significant transformation of the EU electricity sector and related markets. The 2020-2030 decade is crucial for this transformation, largely defined by the 2020 targets that are set as a benchmark in the energy modelling projections for 2030. A number of scenarios have explored the possibility of reaching the 2030 target for renewable energy primarily as a greenhouse gas (GHG) mitigation option. In the meantime, there have been significant changes in the electricity sector and in related markets, raising the question: **to what extent are these changes reflected in the scenario assumptions and results**? To reach its 2020 renewable energy target of 20 %, the EU needs to increase its final renewable electricity consumption by 31 % compared to the 2016 figure. All projections coming from Reference and EUCO scenarios are in line with the aggregated 2020 EU figure calculated based on national renewable energy action plans (NREAPs). To reach its overall 30 % renewable energy target, in 2030 the EU needs to meet 54 % of its gross electricity generation using renewable technologies. Reaching a higher share of renewable electricity use would require a sustained increase in renewable capacity; to reach the 2030 target the EU will need to increase its current renewable electricity installed capacity by 90 %.

Renewable electricity is expected to replace coal and gas between 2020 and 2030. Projections show that reaching the 30 % target for renewable energy and energy efficiency will cause gas displacement that is at least five times higher compared with the displacement that would be expected from a renewable energy share of 27 % and an energy efficiency target of 30 %.

The projections stemming from the scenarios used to underpin EU energy policy assume higher costs of electricity generation in 2030 compared with the current trend. The reference and EUCO scenarios overestimated the projected 2015 average electricity generation costs in the EU by at least a factor of 2. Moreover, the average electricity generation cost in a scenario that projects a renewables share of 27 % is almost equal to the cost in a scenario that projects a share of 30 %. In the medium term, these projections do not apply significant pressure on electricity prices, but in the long term electricity prices are likely to considerably increase.

The analysis presented here explores a series of scenarios and tries to understand the following within the limitation of assumptions used: (i) how much can renewable energy technologies, in aggregate, contribute to projected gross electricity generation in the EU in 2030? (ii) what is the highest penetration of renewables such as wind and solar photovoltaic, within the established targets? (iii) to what extent do the assessments reflect the cost-optimal contribution of renewables to achieving the 2030 target?

Main findings

- The EU energy policy should ensure that the overall 2020 renewable energy share target is achieved;
- The required deployment of renewables in 2020 is projected to happen via an average annual increase of 11.8 Mtoe meanwhile the overall renewable energy share is projected to increase by 0.8 percentage points each year.
- All projections relating to the EU 2020 overall renewable energy share target are in line with the aggregated national renewable energy action plans (NREAPs);
- All PRIMES scenarios are in line with the 2020 final renewable energy consumption planned in the aggregated NREAPs, 249 Mtoe;
- Compared with the NREAPs, a higher share of renewables in the power sector is projected for 2020 in all scenarios;
- Achieving the 2030 target of an overall 30 % renewable energy share will require that the share of renewables in projected EU gross electricity generation doubles compared with the current figure;
- To reach a target of 30 % in 2030 the EU needs to increase its 2015 final consumption of renewable energy by 68 %. The EU renewable electricity installed capacity needs to be increased by 75% from its figure in 2016. The EU renewable electricity consumption needs to increase by 92% from the 2016 level;
- A higher renewable energy and energy efficiency target in the EUCO3030 scenario will bring a displacement of gas that is at least five times higher compared with the displacement projected in the Reference, EUCO27 and EUCO30 scenarios;
- The increased role of energy savings in the EUCO30 scenario compared with EUCO27 scenario will bring to a 3.4% drop in the final consumption of renewables, meanwhile the final consumption of energy decreases by 4.3%;
- The PRIMES climate mitigation scenarios (EUCO scenarios) project wind to be the second biggest source of gross electricity generation in the EU in 2030. To achieve the target of a 30 % share of renewables, wind power needs to account for 24 % of gross electricity generation and 45 % of final renewable electricity;
- In the PRIMES climate mitigation scenarios (EUCO scenarios) a power system with a share of 27 % of renewables has the same average cost of electricity generation as a power system with a share of 30 %;
- The PRIMES projections overestimated by a factor larger than 3 the 2015 averaged price of electricity in the EU;
- The increase of only energy efficiency target keeping almost unchanged the renewable energy target results to an increase of the energy costs (EUCO+40 scenario);
- The Intended Nationally Determined Contributions (INDC) and below 2 degree scenarios shift away from the Reference and EUCO scenarios, especially after 2020;
- The INDC and below 2 degree scenarios project that other RES technologies, such as biomass, geothermal and marine, will contribute considerably to achieving the target;
- In the PRIMES scenarios, the projected contribution of other RES technologies is marginal.

Other findings

- To date, gross domestic consumption of fossil fuels has remained high in the EU. After 2015, gross domestic gas consumption increased twice as fast as that of renewables.
- Despite the decrease in investment in renewables in the EU after 2012, increases in renewable electricity capacity in 2016, driven mainly by cost reductions, reached their largest figure in the last 4 years. While almost 70 % of renewable energy capacity was added between 2010 and 2016, investment fell by more than 50 %. New investments in renewables in 2016 grew by more than 22 % from 2015, to $ 59.9 billion;
- Over 2005-2015, the overall renewable energy share increased by an annual average of 0.8 percentage points. In the same period, final renewable energy consumption increased by an average of 7.8 Mtoe per year.
- Adding 2.8 GW annually, the EU increased its renewable electricity capacity almost threefold since 2005, increasing from 157 GW. This growth is equivalent to a 9 % per year compound annual growth rate (CAGR). In 2016, renewable electricity capacity in the EU accounted for 86 % of all new power installations
- In 2016, electricity in the EU from renewable sources grew to almost 40 % of total installed capacity and 29.4 % of gross electricity generation. Installed renewable electricity capacity exceeded 400 gigawatts (GW) in 2016, generating almost 1000 terawatt-hours (TWh).
- With a total installed capacity of 154 GW in 2016 (a 17 % share of total EU installed capacity) wind energy has now overtaken coal as the second largest form of power generation capacity in the EU after gas. Wind electricity installed capacity increased by almost 280 % (113 GW) between 2005 and 2016, and accounted for 38 % of all newly renewable electricity capacity installed in the EU in 2016. In this year the EU wind electricity capacity increased by 9 % (12 GW) compared to 2015.
- Germany was the largest market for new wind power capacity installations with 44 % of all EU installations, followed by Spain, the UK and France. Sixteen EU Member States have more than 1 GW of wind power installed and nine of these have more than 5 GW installed. Five EU Member States had a record year for new wind energy installations in 2016: France (1.6 GW), the Netherlands (887 MW), Finland (570 MW), Ireland (384 MW) and Lithuania (178 MW).
- The capacity of new connected solar photovoltaic systems in the EU decreased by 22 % in 2016 (6.1 GW) comparing with additional capacity in 2015 (7.8 GW). There are now solar photovoltaic systems with a capacity of 101 GW in the EU accounting for about 11 % of total EU installed capacity. Solar accounted for nearly 19 % of new renewable electricity capacity installations in the EU in 2016.
- With 36 % of total EU connections, the UK was the country which connected most of the new solar power capacity, followed by Germany, France, the Netherlands and Italy. Twelve EU Member States have more than 1 GW solar photovoltaic power installed, and five of them have more than 5 GW installed.
- The combined share of wind power and solar photovoltaic as a percentage of total renewable electricity (capacity and generation) continues to grow in the EU. In

2016, these two technologies accounted for two-thirds of renewable electricity capacity and nearly 45 % of renewable electricity generation in the EU.

- There was an annual increase of 10 TWh from biomass used for electricity production between 2005 and 2015, with a CAGR of 9.8 %.

Related and future JRC work

The EU countries biennial progress reports, which provided data for 2009-2010, 2011-2012 and 2013-2014 complemented with Eurostat SHARES Tool data for 2015 was analysed by the JRC in a previous set of publications [1], [2], [3], [4], [5], [6], [7], [8], [9] and [10].

Quick guide: This report provides an assessment of progress made on the use of renewable energy technologies/sources in the EU from baseline year 2005 up to 2016. The assessment is based on data reported in Table 10 of the NREAPs and Table 1b of the renewable energy progress reports. The ***first part*** of the report presents: (i) a snapshot of the recent renewable energy trends in the EU; and (ii) an analysis of deviations from the aggregated NREAP plans[1] for each technology. The ***second part*** presents how each renewable technology in electricity sector is expected to evolve in order to achieve the 2020 planned values according to the aggregated NREAPs. In the ***third part*** it is shown the expected trends in the use of renewable technologies in the EU electricity sector moving towards 2030 targets, through the assessment of 7 scenarios: the Reference 2016 scenario, EUCO27 scenario, EUCO30 scenario, EUCO3030 scenario, EUCO+40 scenario, INDC and below 2 degree scenario.

([1]) Data reported for 2016 are sourced from different databases. Due to the lack of Eurostat official data on the 2016 deployment of renewable energy technologies in the EU, the analysis of the deviation from NREAPs only includes the 2005-2015 period.

1 Introduction

Energy systems around the world are undergoing substantial changes. Many of these changes are being driven by deliberate government policies, whether these are to put a country on a low-carbon transition path, reduce air pollution, secure energy independence and security, or reduce costs and improve efficiencies. Other changes are being driven by external forces, including broader movements in energy markets or by deep societal transformations, such as the increased use of information and communications technologies in every walk of life [11].

Technologies are critical in accelerating energy access. Supportive government policies are essential to enable these technologies to succeed [12]. The EU is a leader in renewable energy technologies. It holds 40 % of the world's renewable energy patents and in 2016 almost half of the world's renewable electricity capacity (excluding hydropower) was located within its borders.

Renewable energy technologies/sources (hydropower, wind power, solar power, marine-energy, geothermal energy, heat pumps, biomass and biofuels) are alternatives to fossil fuels that contribute to reducing greenhouse gas emissions, diversifying energy supply and reducing dependence on fossil fuel markets, in particular oil and gas. Tracking driver metrics for specific sectors or technologies can pinpoint where progress is needed and inform policy decisions. Tracking energy sector investment also makes it possible to assess short-term actions' consistency with long-term goals [11].

The Paris Agreement on climate change influences the future of renewable energy technologies by establishing the international community's clear intention to pursue a sustainable low-carbon pathway.

The EU 2020 targets are the indispensable stepping stones to the future 2030 climate and energy targets. If the EU wants to remain a global leader in the fight against climate change and ensure its global leadership in renewables, all EU countries will have to continue their efforts to increase the share of renewable energy sources in their energy mix, so as to put the EU on a sustainable path to meeting the 2030 targets.

To implement the 2030 strategy, on 30 November 2016 the European Commission submitted the clean energy package calling for, among others, the recast of Renewable Energy Directive, the recast of the Energy Efficiency Directive and strong Energy Union Governance. The recast will require the EU countries to produce Integrated National Energy and Climate Plans that cover the five dimensions of the Energy Union for the period 2021 to 2030 [13].

The eight legislative proposals of this package aim at implementing the 2015 strategy for an Energy Union with a forward-looking climate policy. The package as a whole was presented at the Energy Council meeting of December 2016. EU ministers had a first exchange of views on the entire package in February 2017 and assessed the progress made on governance, renewable energy and the electricity market design in June 2017.

The 2030 renewable energy targets are currently under discussion in the European Parliament with a view to making them more robust, as part of the Parliament's consideration of the Energy Governance Regulation. On 17th May 2017, the European Parliament's draft report on the Energy Governance Regulation proposed higher collective EU targets of 45 % for renewable energy and 40 % for energy efficiency as a way of achieving the goals of the Paris Climate Agreement [14].

On 18th December 2017 the European Council adopted its position on the directive promoting the use of renewable energy across the EU confirming the binding target of 27% in 2030 [15].

Current support for renewable energy technologies is largely based on EU countries' national targets as described in their national renewable energy action plans (NREAPs). The European Commission monitors the development of renewable energy technologies in the EU on the basis of progress reports submitted by Member States every two years.

To develop its climate and energy policy proposals, the Commission uses the extensive modelling that is an essential part of its impact assessments. The starting point of the energy modelling is the EU Reference Scenario 2016 [16] projections for indicators such as the share of renewable energy sources or levels of energy efficiency over a five-year period until 2050 for the EU as a whole and for each Member State. However, the EU Reference Scenario 2016 is not designed as a forecast of what is likely to happen in the future. It provides a benchmark against which new policy proposals can be assessed. Using the EU reference Scenario as a starting point, EUCO scenarios [17] are created to model the achievement of the 2030 climate and energy targets as agreed by the European Council in 2014.

The JRC has developed a global energy model (JRC POLES) [18] that examines the effects on greenhouse gas emissions and energy markets [19] of:

- a reference scenario where current trends continue beyond 2020;
- the Intended Nationally Determined Contributions (INDC) scenario; and
- a 2 °C scenario in line with keeping global warming below the limits agreed in international negotiations.

Box 1. JRC Poles model description

POLES is a global energy model that covers the entire energy balance, from final energy demand, transformation and power production to primary supply and trade of energy commodities across countries and regions. It makes it possible to assess how much the various energy types (fossil fuels, nuclear, renewables) and energy vectors are expected to contribute to future energy needs.

In addition, it calculates the evolution of GHG emissions endogenously for the energy-industry sectors, and through links with specialist models for GHG emissions from agriculture and land use.

The model includes a detailed geographical representation, with a total of 66 regions modelled, including all G-20 countries, OECD and the main non-OECD economies. It works on an annual basis, making it possible to include recent developments.

The POLES model is well suited to evaluate changes in energy demand in the main global economies and international markets and to assess climate and energy policies. It has been used by several Directorates-General of the European Commission and by national authorities. The POLES modelling groups are also involved in several research projects, and analyses based on POLES have been widely published.

Summarized from: POLES model description https://ec.europa.eu/jrc/en/poles

As the NREAPs are now outdated for some EU countries, this report provides an overview of the analysis and impact assessments provided by the mathematical models and tools that are used by the Commission to assess policy effectiveness and evaluate the potential consequences of policy proposals.

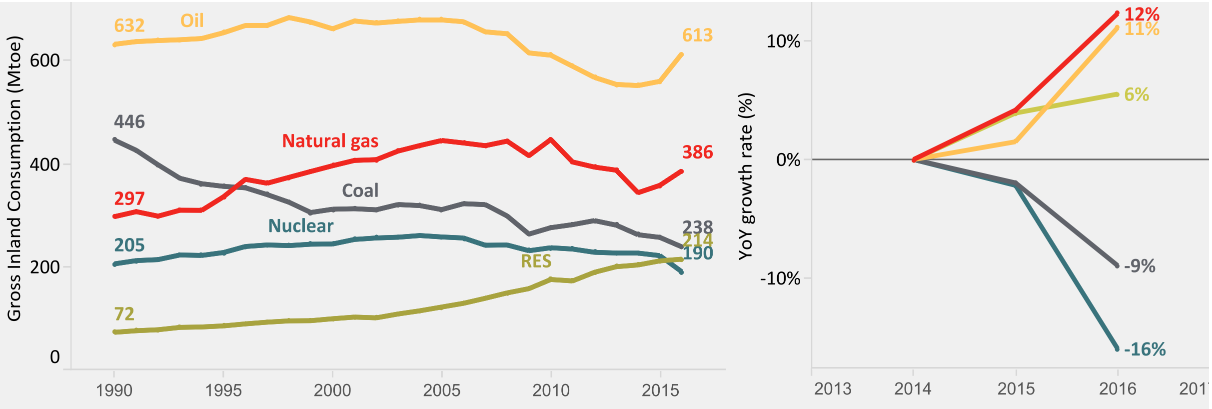
2 Outlook on some energy and climate indicators in the EU

The **EU's gross domestic energy consumption** saw a 0.9 % increase between 2015 and 2016, amounting to 1642 Mtoe [20]. This was only 1.7 % below 1990 levels and down by 10.7 % compared with its peak of almost 1840 Mtoe in 2006.

Fossil fuels continued to represent the lion's share of energy sources, accounting for over 75 % of the EU's domestic energy consumption in 2016,[2] though this was lower than its share in 1990 (83 %). About 15 % of consumption needs were met by solid fuels, 23.5 % by natural gas and 37 % by oil. The share of renewables remained stable in 2016, at 13 % (214 Mtoe).

Figure 1 shows the gross inland consumption trends in the main fossil fuels (coal, oil, natural gas), nuclear and renewables from 1990 to 2016, and their relative growth versus 2014.

Figure 1. Gross inland consumption of fossil fuels and RES, 1990-2016 (left) – relative change vs. 2014 (right)



Between 1990 and 2016, the gross inland consumption of coal (hard coal and lignite) fell by 47 %, while the gross inland consumption of natural gas for energy purposes increased by 30 %. Between 1990 and 2005, the gross inland consumption of natural gas in the EU rose by 50 %; after 2005, it started to fall.

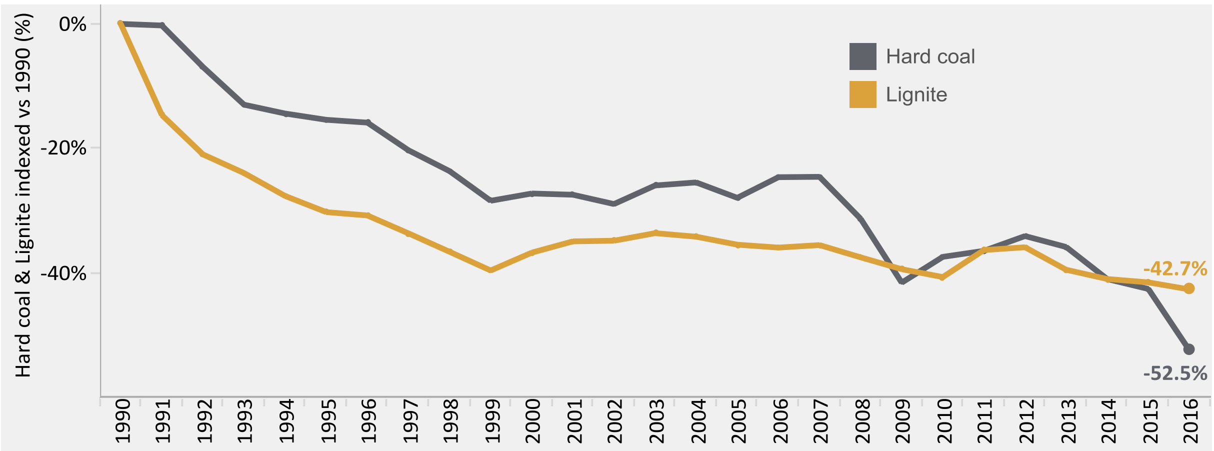
The consumption of renewables grew by 197 % between 1990 and 2016; it started to rise faster after 2002 and grew faster than the consumption of other energy sources between 1990 and 2016. Between 2014 and 2015, the growth rate of renewables was comparable with that of gas and faster than the growth rate of oil.

After 2015, these two fossil fuels saw a faster increase compared with renewables: gas rose by 8 %, oil rose by 9 % and renewables rose by only 2 %. Between 2014 and 2016, the growth rate of gas was double the growth rate of renewables (Figure 5).

Figure 2 shows how the gross inland consumption of hard coal and lignite changed over these 26 years comparing with 1990. As seen from the figure, the gross inland consumption of lignite experienced a smooth decrease over 2014-2016. The gross inland consumption of hard coal experienced a more pronounced decrease over the same period.

(2) In 2015, fossil fuels accounted for 72 % of gross inland consumption in the EU: about 16 % of consumption was met by solid fuels, 22 % by gas and 34 % by petroleum products [xx].

Figure 2. Trend of gross inland consumption of hard coal and lignite in EU, 1990-2016

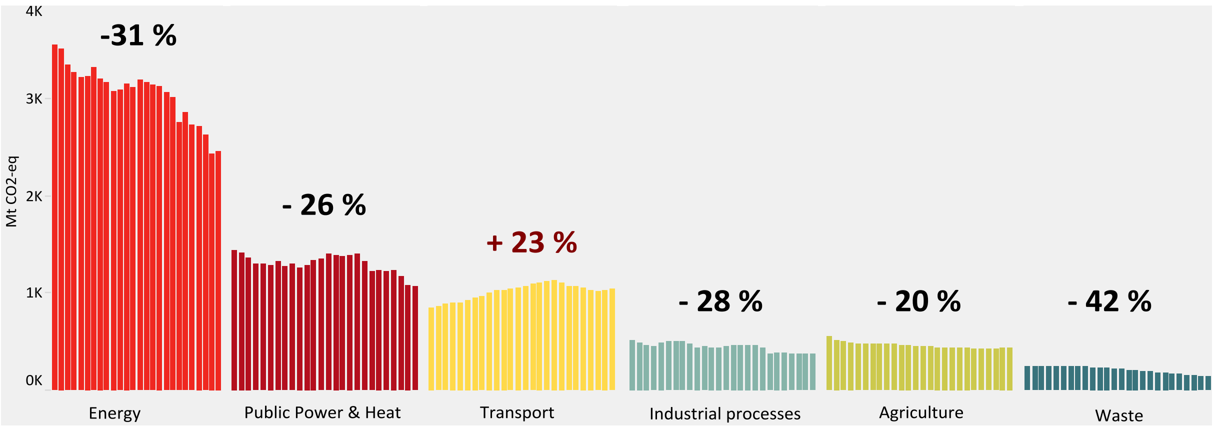


In 2015, GHG emissions[3] in the EU reached 4452 Mt CO_2-eq, a fall of 22 % compared with 1990. Comparing against 2014, they rose by 0.6 % (28 Mt CO2-eq) in 2015.

The **energy sector**[4] accounted for 55 % of 2015 greenhouse gas emissions in the EU. The transport sector remained the second largest source of emissions in the EU, accounting for 23.2 % of total emissions in that year. Agriculture was the third largest source of greenhouse emissions in the EU, its share of total emissions reached 9.8 % in 2015, slightly higher than in 1990 (9.6 %). The proportion of emissions from waste management remained marginal, having fallen from 4.2 % in 1990 to 3.3 % in 2015. The share of emissions from industrial processing fell slightly to 8.5 % in 2015 from 9 % in 1990. Emissions from public power and heat production represented 25.2 % of total greenhouse emissions in 2015 and 33 % of energy related emissions.

Figure 3 illustrates the change of emissions in the main sectors over 1990-2015. Since 1999, emissions from waste management have fallen, with the biggest drop since 1990 (by 42 %) occurring in 2015.

Figure 3. Evolution of greenhouse gas emissions in the EU by sectors, 1990-2015



Energy-related emissions fell by 31 % over the same period. In 2015, emissions from the transport sector were 23 % higher than in 1990. In the agriculture sector, the steepest drop from 1990 levels occurred in 2012 (22.7 %), while there was a fall of 20 % in 2015. The emissions from industrial processes and product use fell by 28 % in 2015 compared

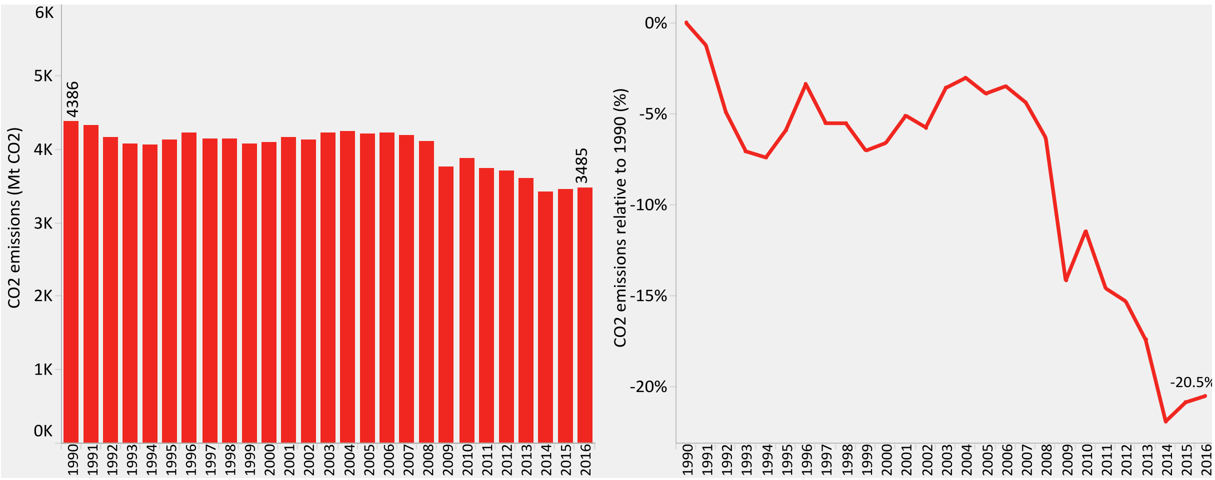
(3) Greenhouse emissions without LULUCFC, with indirect CO_2 and international aviation.
(4) Energy-related greenhouse emissions include emissions from fuel combustion and fugitive emissions from fuels without emissions from the transport sector.

with 1990. The drop in emissions from public power and heat production since 1990 reached 26 % in 2015.

Global CO_2 emissions have risen by 55 % over the 26 years since 1990. However, CO_2 emissions in the EU have fallen by 20.5 % (901 Mt CO_2) over the same period. In 2016, the EU was responsible for 10.4 % of global CO_2 emissions from fossil fuels [20].

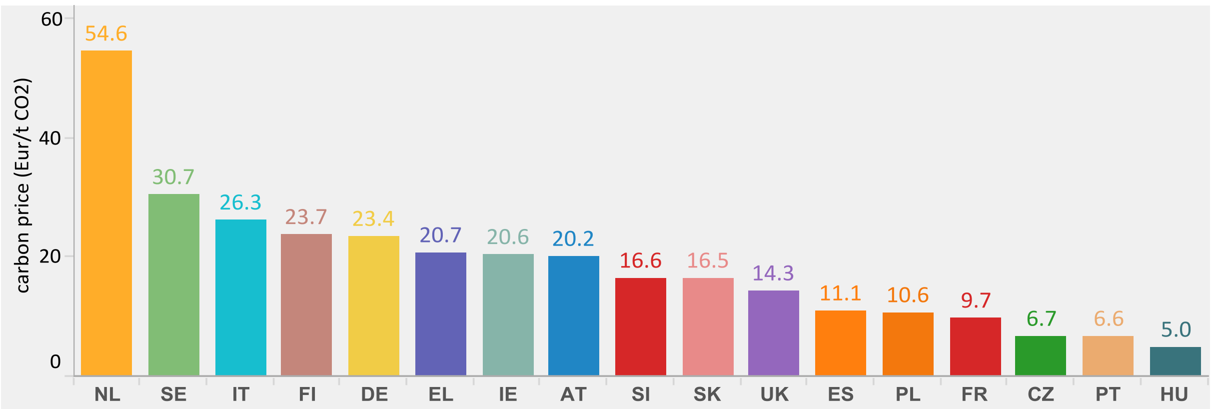
Figure 4 shows the overall trend of EU CO_2 emissions from 1990 to 2016, and relative changes in comparison with 1990. As shown in the figure, CO_2 emissions in the EU took a downward trajectory after 2011. However, they rose by 1.8 % (61 Mt CO_2) between 2014 and 2016,[5] reaching 3485 Mt CO_2. Over the same period, global CO_2 emissions remained almost unchanged, with only a 0.3 % rise above 2014 levels. CO_2 emissions in the EU almost stalled between 2015 and 2016.

Figure 4. CO_2 emissions in the EU, 1990 – 2016 (left) - Relative change vs. 1990 (right)



Since the financial crisis of 2007-2008, the **carbon price** in the EU has tumbled from highs of more than 30 €/t CO_2 to 5 €/t CO_2 because of excess supply of permits. This carbon price was designed to set a minimum price, related to emissions from fossil fuels, which would rise annually and encourage manufacturers to switch to greener fuels [21].

Figure 5. The average effective carbon price for industry, power and buildings in EU countries, 2015



Due to the low price of carbon allowances in the Emission Trade System (ETS), rather than replacing coal, a big share of the new renewable energy capacity has replaced more

([5]) CO_2 emissions in the EU rose by 1.3 % between 2014 and 2015. The increase between 2015 and 2016 had a lower growth rate of 0.4 %.

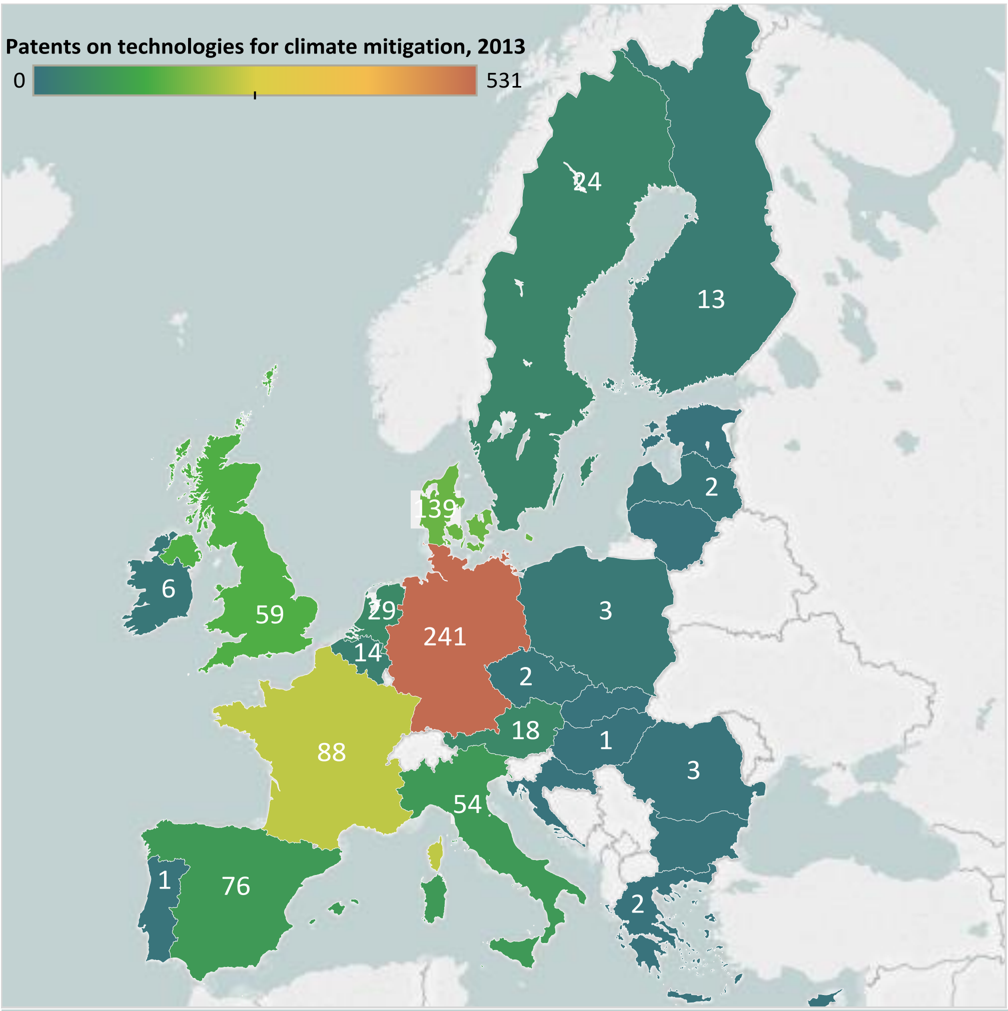
expensive energy sources such as gas, leading to a slower decrease in the power sector's CO_2 emissions [22].

The Netherlands has the highest carbon price for industry, power and buildings from among the EU countries (Figure 5). The UK has set a carbon price floor at 24 $/$CO_2$-eq. Sweden has the highest carbon tax, at 131 $/t$CO_2$-eq, followed by Finland (65 $/$CO_2$-eq).

Renewable energy patents and standards show the growth and innovation taking place in the energy sector. Patents show who is developing what and where, and which countries are leading the charge in which technology. International standards ensure that renewable energy technology works safely, and bring more money into the industry by boosting investor confidence. Patents can also help policy makers judge the effectiveness of policies to promote renewable energy innovation.

Figure 6 shows the distribution of patents related to technologies for climate change mitigation and the number of patents related to renewable energy technologies. As shown in the figure, Germany holds the highest number of patents in both areas [23].

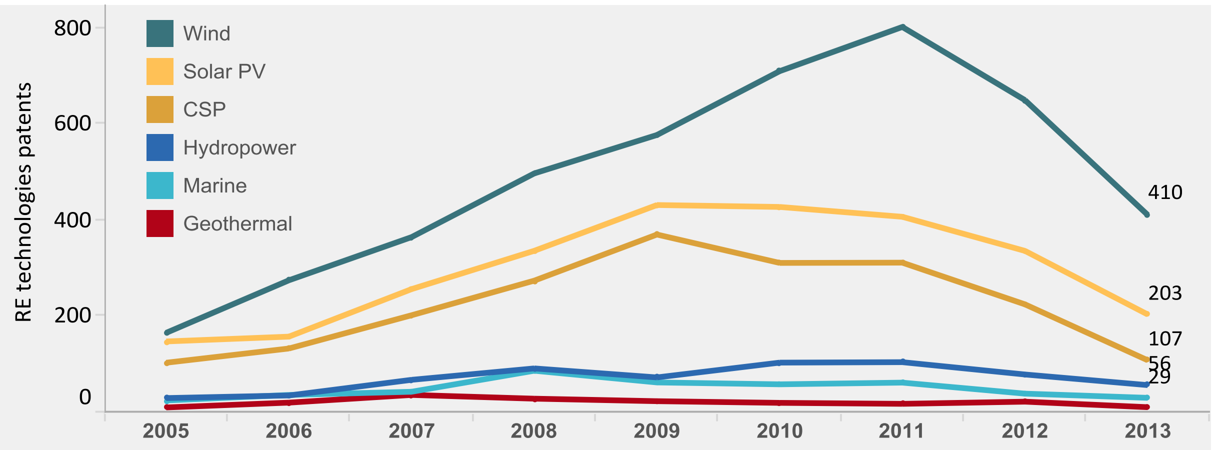
Figure 6. Distribution of patents on technologies for climate change mitigation, 2013[6]



In 2013, the EU owned more than 43 % of global patent applications related to technologies for mitigation of or adaptation to climate change. Patents related to the

([6]) Numbers in the map present the patents related to renewable energy technologies [23] energy from renewable sources accounted for more than 50 % of the total number of patents related to technologies for climate change mitigation. In the same year, EU patents related to energy from renewables accounted for more than 53 % of the global number of patents in this area [23].

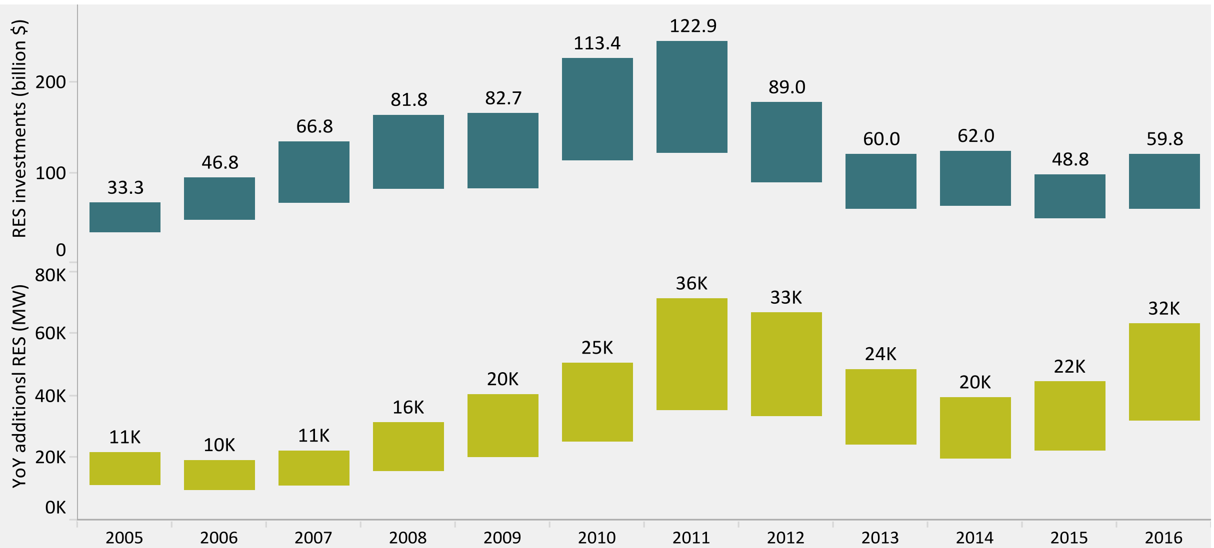
Figure 7. Evolution of patents for main renewable energy technologies in EU, 2005-2013



In 2013, applications for patents related to wind technology covered almost 53 % of the EU patents related to energy from renewables. Patents related to solar photovoltaics accounted for 26 %. The number of patents related to renewable energy technologies peaked in 2011. Wind power technology patents rose by 16.6 % year-on-year over 2005-2013, a fivefold increase on the 2005 figure. Solar photovoltaic patents rose by 4.3 % per year, a threefold increase on the 2005 figure during the same period [23].

Investment in renewables fell in 2015, reaching its lowest total since 2006. The pace of the EU investment in renewable energy has been slowing down since 2011, falling by about $ 74 billion between 2011 and 2015, after a steady increase from $ 33.3 billion to $ 122.9 billion between 2005 and 2011 [24].

Figure 8. Evolution of RES investments and the annual additions in RES capacity, 2005-2016



Despite this drop, the EU was able to continue adding new renewable electricity capacity due to the falling costs of renewables. The largest year-on-year additions happened in

2011, the year in which investment in renewables peaked. In 2016, the additional installed capacity almost reached 2012 levels.

In 2016, all forms of renewables were estimated to account for 17.0 % to 17.2 %[7] of the EU's gross final energy consumption. In 2015, renewables accounted for 16.7 % of gross final energy consumption in the EU, with the heating/cooling sector accounting for 8.4 %, electricity for 7 % and transport for 1.3 %. Over 2005-2015, the overall renewable energy share increased by an *annual average of 0.8 percentage points*. In the same period, final renewable energy consumption increased by *an average of 7.8 Mtoe per year*.

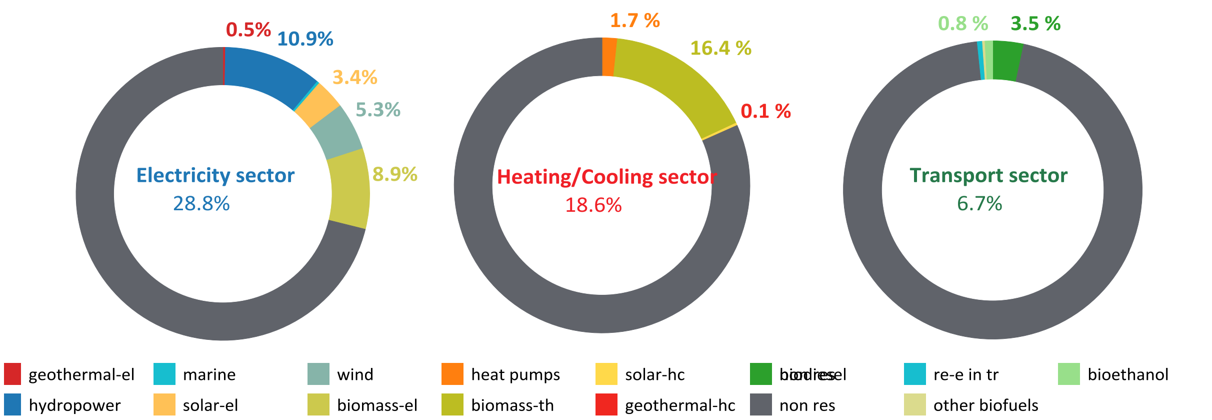
Member States are moving at different speeds in terms of the use of renewables and most are on track to achieve their targets. Based on the aggregated **national renewable energy action plans (NREAPs)**, renewables are expected to represent 20.6 % of energy in the EU by 2020, slightly above the 20 % target. They are expected to reach at least 27 % by 2030.

Renewables have become one of the mainstays of the **electricity sector** in the EU. In 2005, the share of renewables in total EU electricity consumption was just above 14 %. Within a decade, the share of the EU's gross electricity consumption derived from renewables doubled to almost 29 %.

The progress in use of renewables in the **heating/cooling sector**, which comprises almost half of final renewable energy consumption in the EU, has been slower than that in the electricity sector. Nonetheless, there have been positive developments in this sector and most Member States met and/or exceeded their 2020 planned shares, mainly due to the higher than expected use of biomass, the early widespread introduction of heat pumps, and a decrease in gross final heat/cold consumption.

Even though its development lags behind expectations, the part of the **transport sector** covered by renewables increases further the use of electrical power (above 11 %) in its fuel composition.

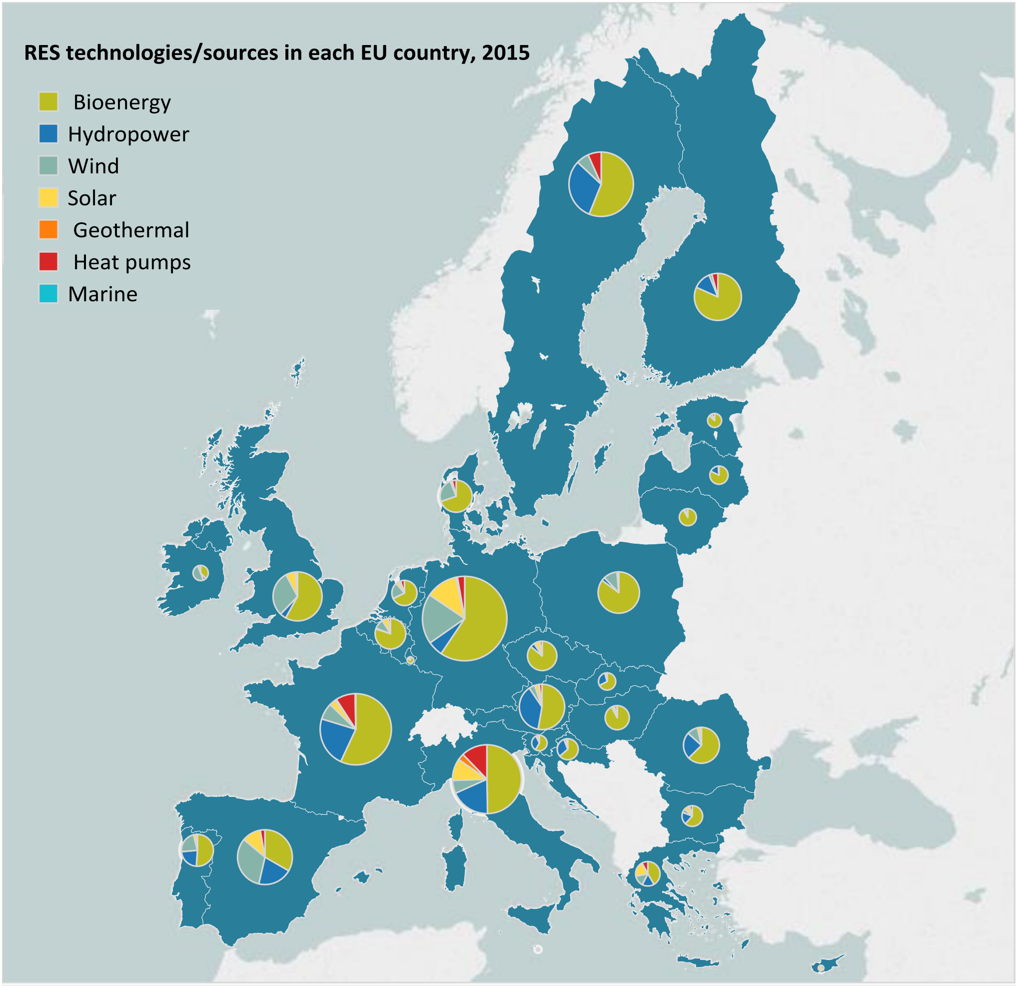
Figure 9. Share of renewables in the EU: contribution to the gross final energy consumption by sector, 2015



Biomass was the main renewable energy source in the EU, with a contribution of 52.4 % in final renewable energy in 2015, followed by hydropower with 16.7 %, wind with 12.5 %, biofuels with 7.7 %, solar with 6.0 %, heat pumps with 4.7 % and geothermal with 0.7 %.

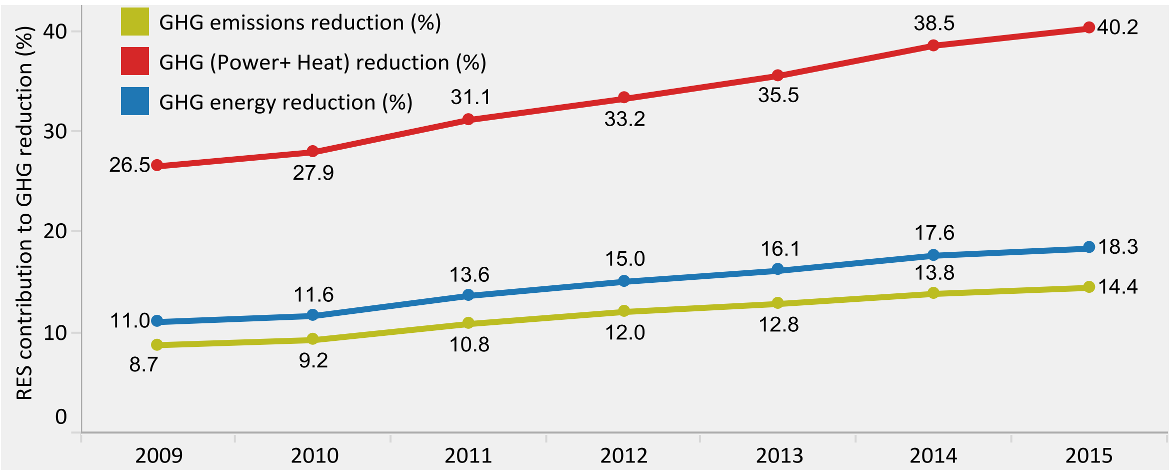
(7) Banja M, Monforti-Ferrario F, Bódis K, Jäger Waldau A, Taylor N, Scarlat N, Dallemand JF, (2017), 'Renewable energy in the European Union — Renewable energy in the EU further to Renewable Energy Directive reporting — Volume 3', JRC Science for Policy Report, EUR 28512 EN [9].

Figure 10. Contribution of renewable technologies in each EU country final renewable energy, 2015



In 2015 renewables competed effectively against fossil fuel generation in power markets. The aggregated **greenhouse emissions savings created through the use of renewables** in the EU were estimated at 751 Mt CO_2-eq, 64 % higher than savings in 2009 [10].

Figure 11. Progress of the renewables contribution in GHG emission savings in EU, 2009-2015



Electricity from renewable sources was the main contributor to final GHG emissions savings in the EU, with a 65.8 % share in 2015, higher than the 53 % share seen in 2009. The role of the heating/cooling sector in final GHG emission savings in the EU declined between 2009 and 2015, from 41.6 % to 30 %. The role of the transport sector remained marginal, with figures falling from 5.3 % in 2009 to 4 % in 2015 [10].

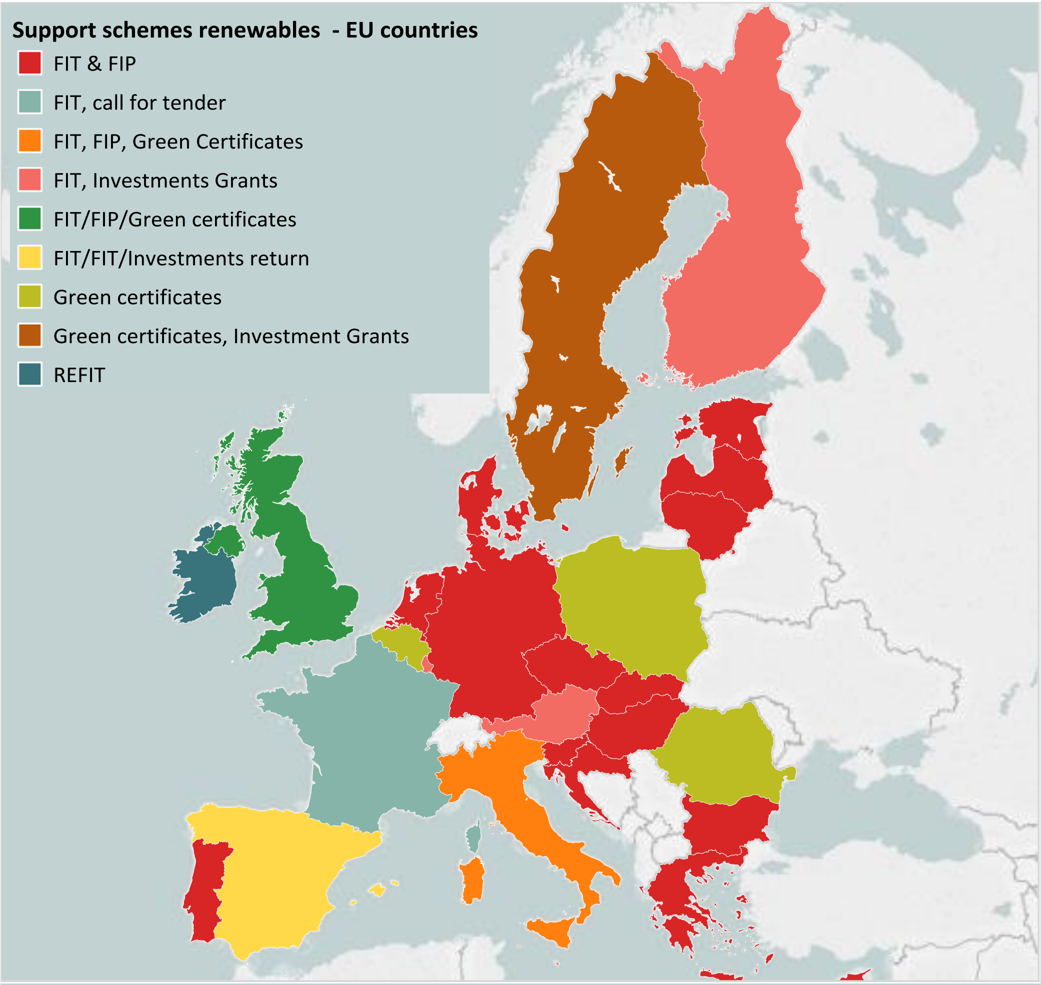
Without the current deployment of renewables, EU emissions would have been 8.7 % higher in 2009, 13.8 % higher in 2014 and 14.4 % higher in 2015. Reductions in emissions in the energy sector (including transport) due to the use of renewables ranged from 11 % in 2009 to 17.6 % in 2014 and 18.3 % in 2015. Over the same period, the largest reduction due to the use of renewables in electricity and heating/cooling was seen in emissions from power and heat, from 26.5 % in 2009 to 38.5 % in 2014 and 40.2 % in 2015 [10].

3 EU electricity sector - renewables

Increasing the share of renewables in the electricity sector raises the question of how these technologies have been supported to date. **Support schemes** are currently the major drivers for investment in the electricity sector, while investments in grid assets are driven mainly by regulation that guarantees investors a reasonable return on equity.

In 2015, feed-in tariffs (FIT) and feed-in-premiums (FIP) in the form of grants, bonuses, premiums, etc. were the main support schemes for the deployment of renewable technologies in the EU electricity sector; they were applied in 24 EU countries. The FIT scheme has been used to promote the deployment of renewable technologies on a larger scale by ensuring a largely risk-free environment for RES plant operators. Under this framework, renewable electricity was fed into the grid regardless of market signals [25].

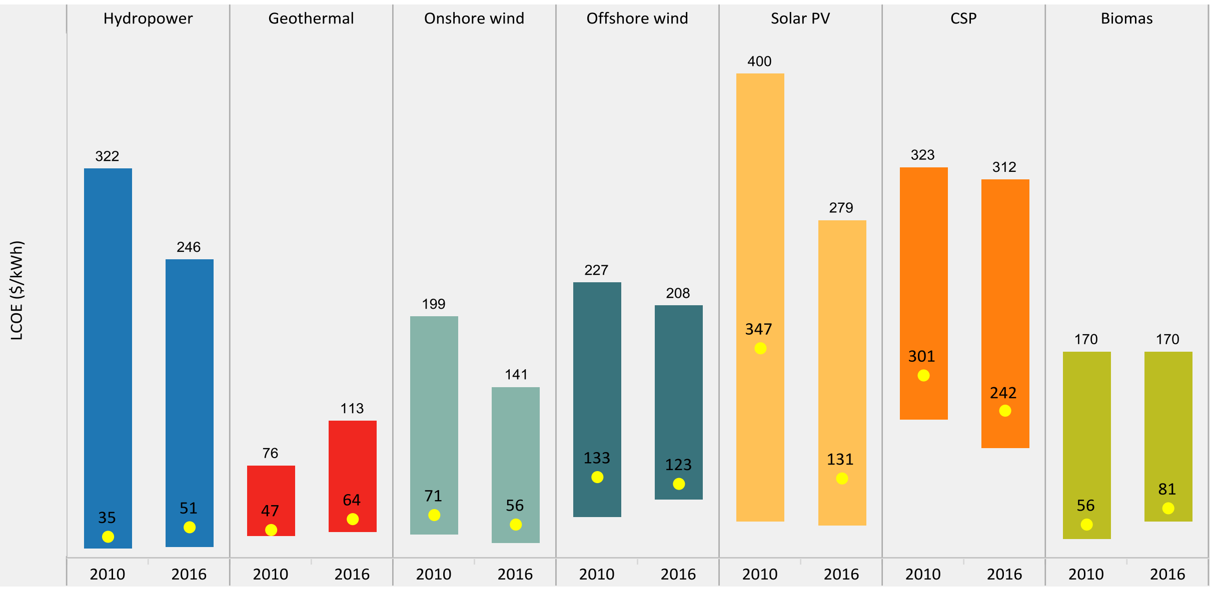
Figure 12. Renewables support schemes applied in the EU countries electricity sector



The FIP scheme obliges RES plant operators to sell, directly or through a third party, their electricity produced in a market place, as a prerequisite for claiming an entitlement to support (i.e. the market premium) in addition to their market revenue (linked to the quantity sold and the market price achieved). There are different design options possible for a FIP system, including a fixed premium, a floating premium and a premium with a cap and floor. Currently, 10 EU countries have introduced FIP to support the deployment of renewables in the electricity sector [25].

Renewable electricity technologies can now provide electricity competitively, compared to fossil fuel-fired power generation. The largest decrease in **average levelised costs of electricity (LCOE)** over 2010-2016 was seen in solar PV technology, by more than 62 %: from the average LCOE of 347 $/MWh in 2010 to 131 $/MWh in 2016. Over the same period: onshore wind maximum LCOE dropped by 29 %; for hydropower the drop reached almost 24 %; geothermal maximum LCOE rose by 48 %; biomass as a matured source saw a slight increase in their low and average LCOE values.

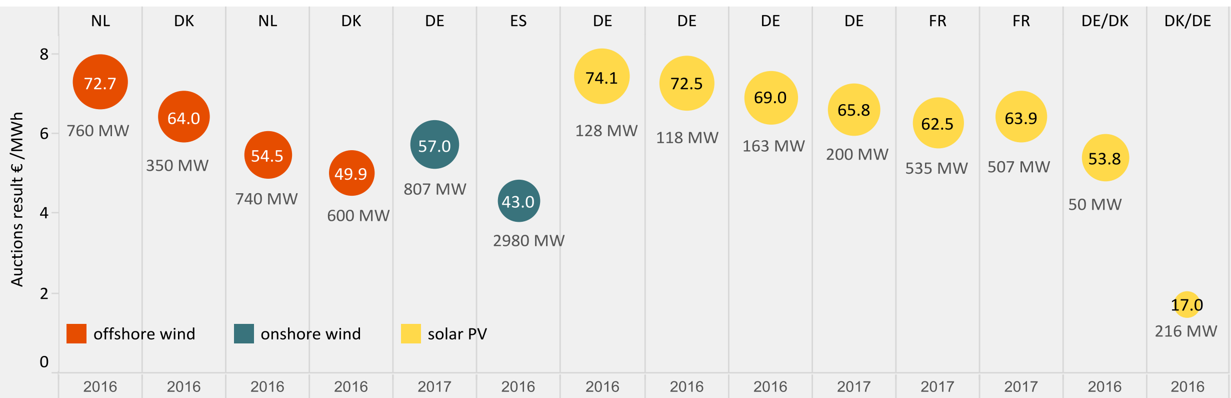
Figure 13. Global levelised cost of renewable technologies in electricity sector (max & average), 2010 & 2016[8]



EU countries as Denmark, Germany, Ireland, France, Cyprus, Croatia, Netherlands, Poland, Portugal, Slovenia and UK have already introduced a **tender procedure** to determine the levels of renewable technologies support. Tendering schemes for renewable technologies are competitive mechanisms for allocating financial support usually on the basis of the cost of electricity production. The first EU countries to experiment with RES tendering schemes have been Portugal, Ireland and the UK. The support that is granted to the winning bids can be in the form of FIT, FIP, capacity payments, certificate prices or investment grants.

Figure 14 illustrates the most recent auction results for offshore wind, onshore wind and solar PV in some EU countries during 2016-2017.

Figure 14. Auction results for offshore, onshore and solar PV in some EU countries, 2016-2017[9]

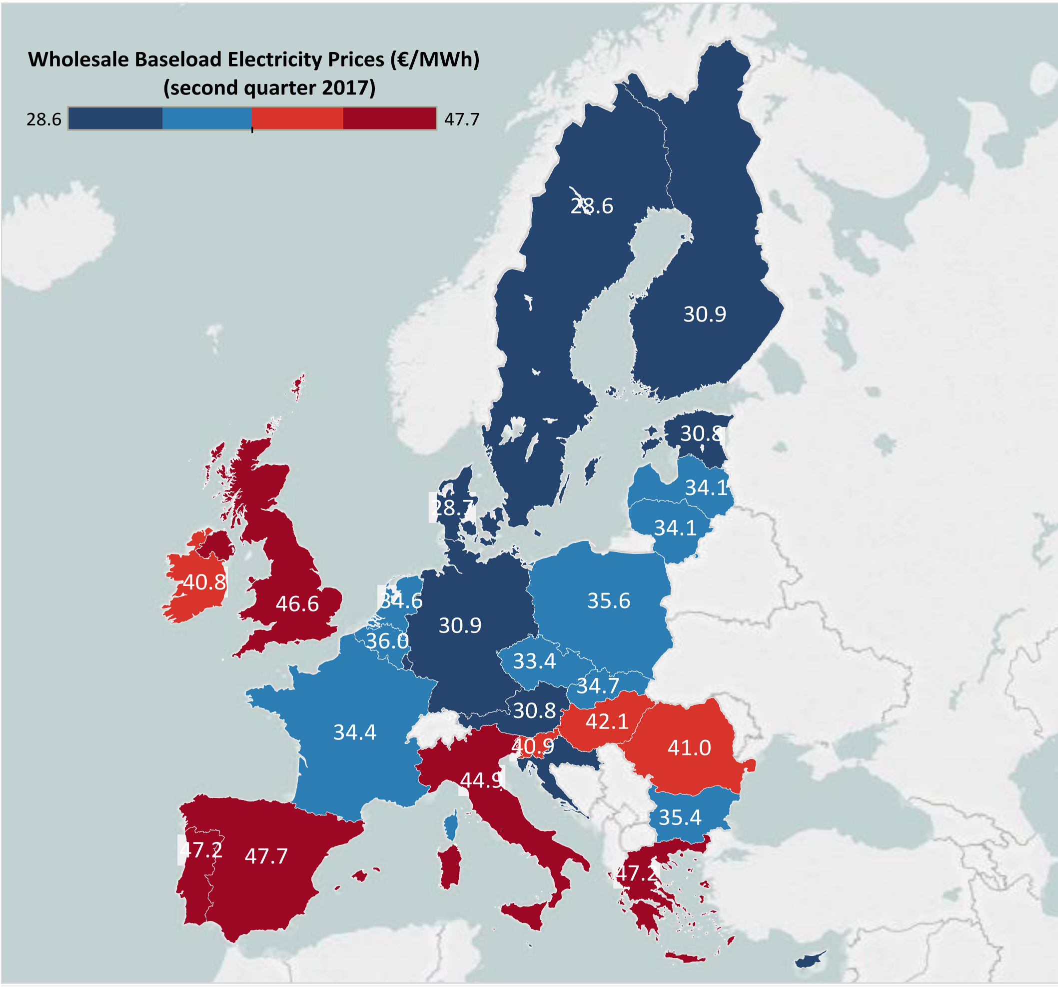


([8]) Source: IRENA Data Statistics [26]
([9]) Adopted from Agora Discussion Paper June 2017 [27].

The renewable energy auction in Spain has set a record low onshore wind prices in 2016. The Spain's auction has been settled with the award of 3000 MW of renewable facilities, the maximum expected, and at no cost to the electric consumer in the scenario of average reference prices. The Spanish auction awarded 2980 MW of onshore wind energy, 1 MW for solar PV installations, and 19 MW for other technologies, all of which is expected to be operational before 2020 [28]. This auction resulted with a *wind energy for 43 €/MWh* [27], reportedly the lowest level ever awarded in an onshore wind tender in the EU. In November 2016 the first cross border (Germany – Denmark) auction for ground-mounted photovoltaic (PV) installations was opened: five bids totalling 50 MW have been accepted at a price of *53.8 €/MWh* [29]. On May 2017 the results of the first auction for onshore wind energy in Germany were announced. The average bid amount was *57.1 €/MWh* and the highest bid accepted for outside the network expansion area was 57.8 €/MWh. The highest bid price that could be accepted within the network expansion area was 55.8 €/MWh [30]. In 2017 France's second tender (507 MW) for large-scale solar PV concludes with average price of 55.5 €/MWh (5-17 MW in size). For all projects combined, the average price was €63.9/MWh.

EU **wholesale electricity prices** peaked in the third quarter of 2008 and, apart from a slight recovery in 2011, have been falling ever since. According to the Platts' European Power Index (PEP), they fell to 30 €/MWh in February 2016, the lowest since March 2007.

Figure 15. Wholesale electricity prices in EU countries, 2017



In the second quarter of 2017, the European benchmark day-ahead baseload wholesale electricity price fluctuated in a narrow range of 35-40 €/MWh and reached 37 €/MWh on average [31]. There were significant differences in wholesale electricity prices across the EU. The highest 2017 quarterly average prices were seen in Spain, Portugal, Greece and the UK (all of them around 47 €/MWh).At the same time, the lowest quarterly wholesale averages could be found in Denmark and Sweden (both 29 €/MWh). Comparing with the same period in 2016, 2017 prices increased significantly in Portugal (63 %) and Spain (60 %). The biggest price decrease was seen in Poland (11 %) [31].

In 2016, **wind power installed capacity surpassed the capacity of both coal and lignite,** becoming the second-largest source of electricity in the EU. Solar installed capacity rose by 22 % year-on-year since 2010, reaching 101 GW in 2016 (Figure 16).

Figure 16. Electrical installed capacity in the EU break down by source, 2016

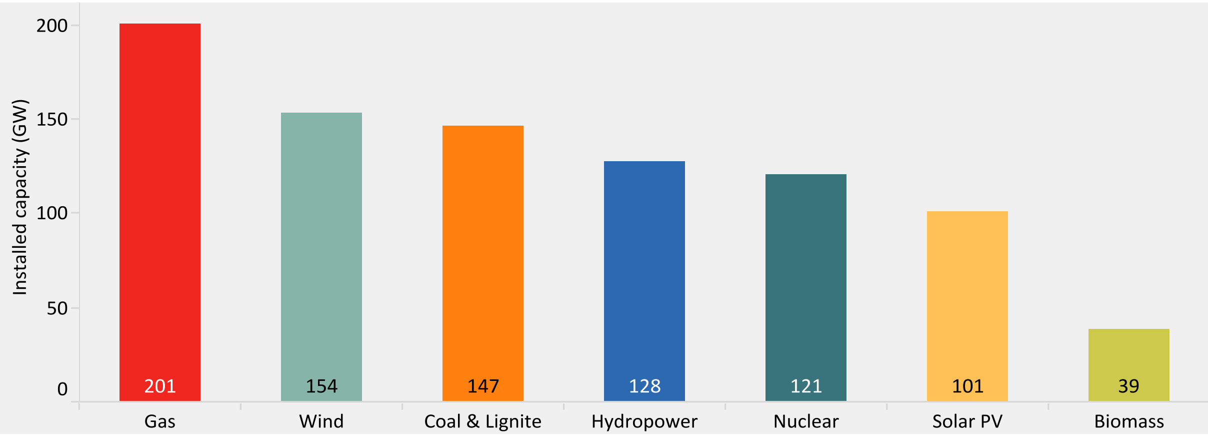
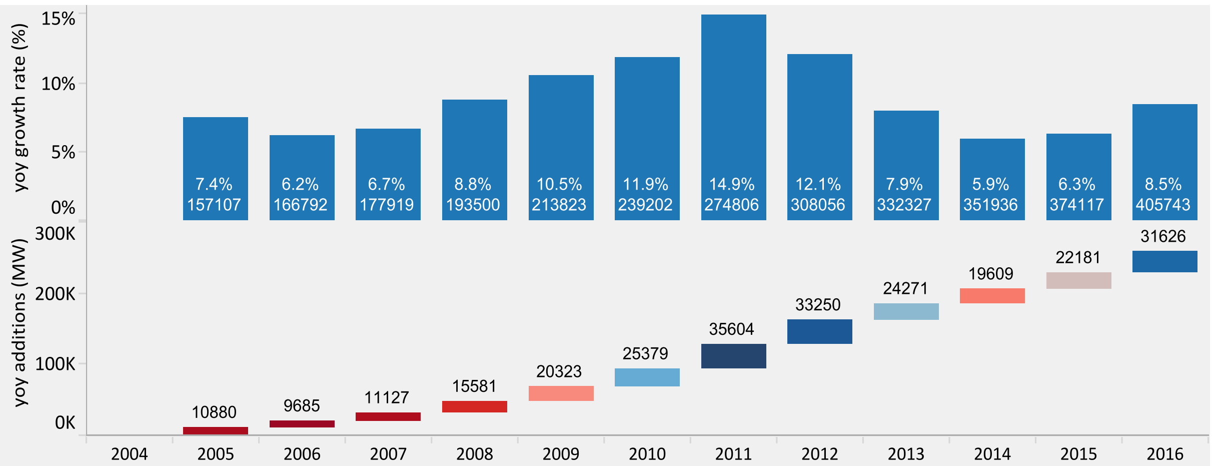


Figure 17 illustrates the year-on-year additions and year-on-year growth rates of renewable electricity capacity in 2004–2016. Since 2005, the EU cumulative installed renewable electricity capacity increased almost threefold, from 157 GW to more than 405 GW in 2016. This growth is equivalent to an average of 2.8 GW installed capacity per year and a 9 % per year compound annual growth rate (CAGR).

Figure 17. Progress of renewable electricity capacity in the EU, 2004-2016



All EU countries increased their renewable electricity capacity over 2010-2015. Since 2010, Malta saw the fastest increase in its renewable electricity capacity, with an increase to 46 times the capacity in 2010. Poland had the second fastest increase, with a

CAGR of 29.4 %, followed by the UK (CAGR of 26.8 %), Cyprus (CAGR of 20.3 %) and Belgium (CAGR of 17.3 %).

The highest and fastest year-on-year increase in installed renewable electricity capacity in the EU was seen in 2011. The slowest increase occurred in 2014, with a 5.9 % increase in that year. In 2015, the year-on-year growth rate of renewable electricity capacity in the EU was comparable with the year-on-year growth rate in 2006.

Renewable electricity capacity in the EU exceeded the estimates in aggregated plans since 2011. In 2015, the difference was at almost 20 GW. In 2005 and 2010, the deployment of renewable electricity capacity was slower than planned, under by 13 GW and 9.2 GW respectively.

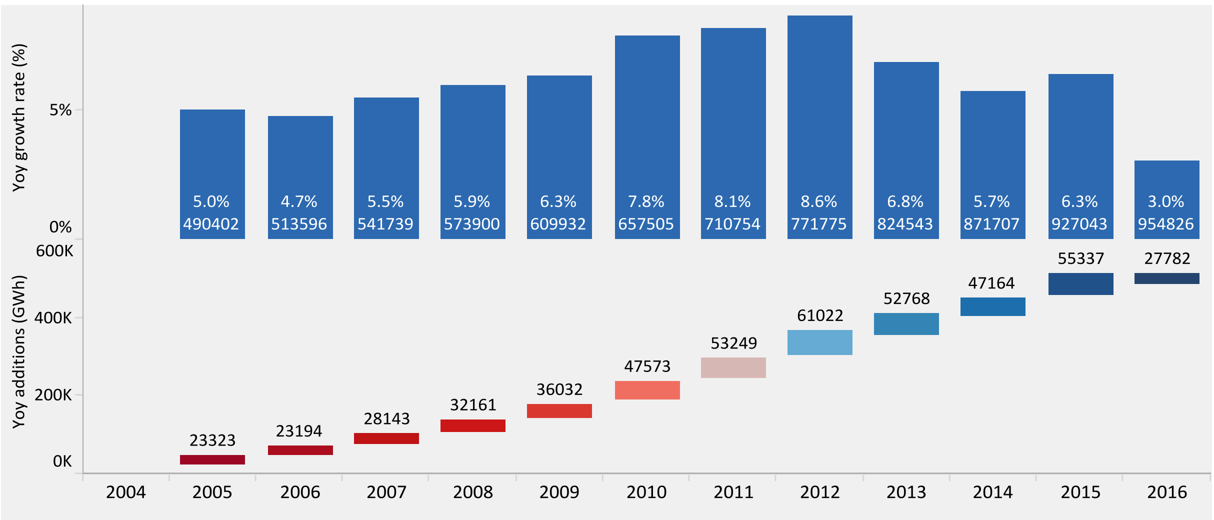
In 2015, 11 EU countries (Greece, Spain, France, Croatia, Hungary, Ireland, Luxembourg, Netherlands, Portugal, Romania and Slovakia) did not meet their renewable electricity capacity goals. Spain saw the largest negative deviation from the 2015 plan, at 5.9 GW below its target. France and Portugal installed less renewable electricity than they planned through the entire 2005-2015 period. After negative deviations in 2005 and 2010, Italy's renewable electricity capacity began increasing faster than expected, with a CAGR of 12.8 %. Germany had the highest positive deviations from its plans from 2013. In 2015, it installed 13.2 GW more renewable electricity than it had planned. Italy followed with a 10.8 GW positive deviation. Until 2012, the UK had experienced negative deviations from its plans for installed renewable electricity capacity. After 2012, however, its deployment of renewable electricity capacity started increasing faster, exceeding plans by nearly 7 GW in 2015.

Table 1. Deviations from NREAPs – renewable electricity installed capacity (MW), 2005-2015

	2005	2010	2011	2012	2013	2014	2015
AT	263	436	553	651	497	543	952
BE	541	1565	1340	1287	1015	530	20
BG	-209	98	2	802	559	355	87
CY	1	3	25	41	2	-35	-33
CZ	102	272	301	514	499	465	415
DE	-981	208	3587	8272	10241	11593	13281
DK	-128	152	249	1010	397	563	909
EE	12	102	148	122	54	111	74
EL	-700	-751	-763	-684	-600	-1157	-1919
ES	-370	157	-706	-1058	-1882	-3888	-5910
FI	-419	35	-116	-249	-156	-110	123
FR	-3739	-2934	-2322	-2345	-3027	-3623	-4326
HR	-279	-286	-283	-265	-192	-169	-248
HU	409	86	48	-177	-284	-115	-27
IE	23	-751	-727	-637	-923	-768	-785
IT	-1915	-2122	6989	11413	12547	11498	10851
LT	-11	-63	-19	11	-7	-77	6
LU	-4	3	10	26	22	-8	-37
LV	0	45	44	76	103	67	19
MT	0	-3	3	8	3	-3	13
NL	-217	-521	-548	-1365	-1864	-3033	-2925
PL	-604	-631	-321	23	365	187	654
PT	-1088	-1548	-1499	-2942	-2961	-3070	-4544
RO	0	-196	-475	-391	194	467	-127
SE	-43	986	1499	2548	2560	3272	4124
SI	-2	-4	36	113	124	147	49
SK	-4	-5	401	243	212	192	-43
UK	-2872	-2923	-1881	-413	1723	4164	6944
EU	-12697	-9157	5407	17605	20810	19817	19637

Between 2005 and 2016, the final consumption of renewable electricity in the EU almost doubled, reaching 955 TWh (82 Mtoe). This growth is equivalent to an average of 42 TWh of renewable electricity consumed per year and a 6.2 % per year compound annual growth rate. The highest and fastest year-on-year increases in final consumption of renewable electricity in the EU were seen in 2012. The slowest increase in consumption was seen in 2016, a 3 % annual increase (Figure 18).

Figure 18. Progress of renewable electricity in the EU, 2004-2016



Final consumption of renewable electricity in the EU exceeded the level estimated in the aggregated NREAPs throughout 2005-2015. Italy was the EU country with the highest absolute positive deviations since 2011. In 2015, this deviation reached almost 28 TWh. Germany and the UK followed with the second and the third highest absolute positive deviations in 2015. 15 EU countries did not meet their goals for final consumption of renewable electricity in 2015. France is the EU country with the highest absolute negative deviation over the 2005-2015 period. Greece is the second EU country with a negative deviation from their plans for the entire 2005-2015 period. The Netherlands experienced its second negative deviation in 2015.

Table 2. Deviations from NREAPs – renewable electricity consumption (GWh), 2005-2015

	2005	2010	2011	2012	2013	2014	2015
AT	320	785	549	1066	1807	2097	2279
BE	-299	2075	2178	2578	1879	466	920
BG	310	916	636	1195	1405	910	446
CY	1	5	-84	-27	-84	-223	-209
CZ	200	35	84	129	381	603	534
DE	2268	5723	9785	16869	16927	19515	24443
DK	-613	-62	-391	-35	-1693	-90	576
EE	-8	406	454	826	139	141	78
EL	-1189	-852	-1673	-1918	-1474	-3020	-4173
ES	1316	1188	-1336	-2369	-1360	-4559	-8927
FI	-145	2546	1949	1679	2145	1873	1950
FR	-5680	-8311	-9880	-11548	-15015	-18781	-21889
HR	-343	846	619	620	752	768	793
HU	1855	180	-140	-546	-700	-954	-664
IE	-463	-1676	-2238	-1953	-3186	-2939	-2677
IT	6	2094	11335	20319	27238	28580	27792
LT	-22	-64	-118	-56	-94	-323	-362
LU	-5	21	8	-26	-51	-86	-134
LV	4	117	69	200	282	136	-17
MT	0	-5	1	7	-11	-148	-130
NL	195	1073	595	-3267	-7595	-12713	-14280
PL	69	-266	206	2126	695	1700	2324
PT	5751	143	684	-1702	-1375	-839	-1258
RO	-910	627	-596	-1566	-2358	-1723	-1980
SE	-124	562	569	1630	626	-1943	1122
SI	25	40	-49	-51	-109	-64	-495
SK	-258	-416	-131	-306	-456	-174	-604
UK	-316	-3514	-4708	-2047	3895	10222	19531
EU	2031	4330	8502	21964	22749	18385	25150

4 Renewable electricity technologies - tracking progress

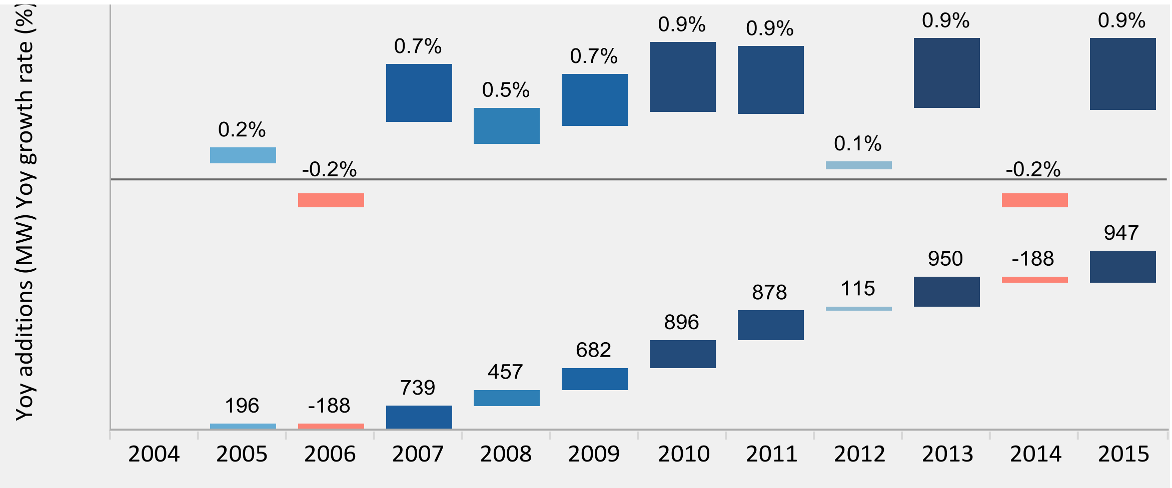
4.1 Hydropower

In 2016, the EU's cumulative **hydropower installed capacity** rose by 8.8 % (or 8.8 GW) in comparison with 2005, reaching a total of 108.3 GW. This growth is equivalent to an average of 2.8 GW installed capacity per year and a 9 % compound annual growth rate (CAGR). The contribution of this technology to total renewable electricity capacity in 2016 was 26 %, against the expected contribution of 32 %.

Figure 19 illustrates the year-on-year additions and year-on-year growth rates for hydropower capacity over the 2004–2015 period.

As shown in the figure, the year-on-year additions of hydropower capacity fluctuated over this period and reached the highest absolute yearly value of 950 MW in 2012-2013. The installed capacity for this technology deployed with a CAGR of 0.5 % in 2010-2015. Yearly additions saw negative values in 2004-2006, in 2012 and in 2014.

Figure 19. Progress of hydropower installed capacity in the EU, 2004-2015



Denmark is the only EU country with a clear downward trend in the deployment of hydropower installed capacity in 2005-2015. In 2015, capacity was 36 % below the capacity reported for the baseline year. In other EU countries, this technology was deployed with very low rates, the highest of them in Bulgaria (CAGR of 1.6 %).

Table 3 illustrates the deviations from NREAPs of installed hydropower capacity in the EU countries during period 2005-2015. As in the table the EU hydropower installed capacity was below expected levels for the entire 2005-2015 period. In 2015, it was 14.5 GW below the expected value, the largest negative deviation since 2005.

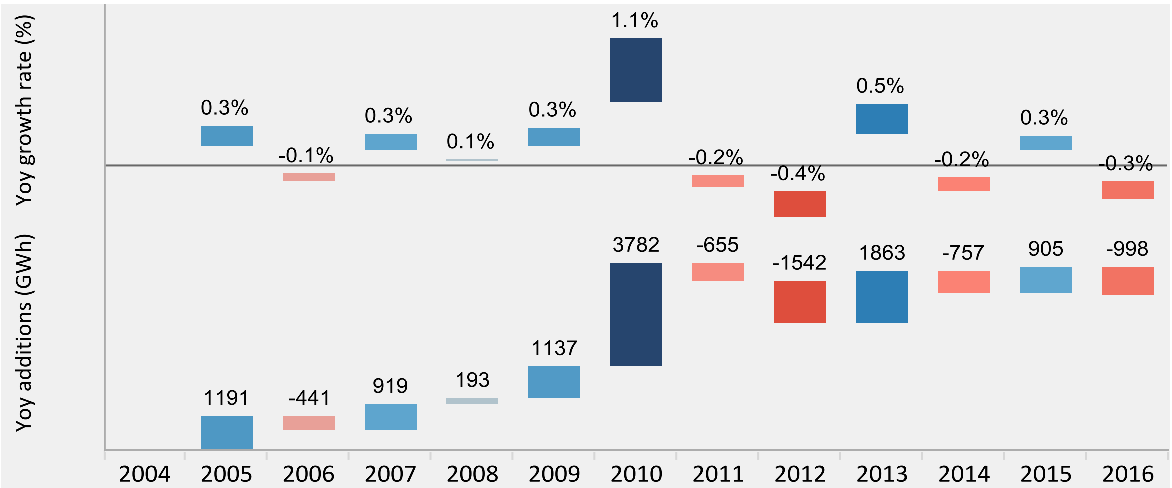
In the same year, 19 EU countries did not meet their goals for hydropower installed capacity. The highest negative deviation was reported by France, 4.3 GW below expectations. The UK reported the second negative deviation from the 2015 plan in this area. In 2016, France remained the EU country with the highest negative deviation from its plan. Since 2013, Spain has reported the largest positive deviation from its plans for hydropower installed capacity.

Table 3. Deviations from NREAPs – hydropower electricity installed capacity (MW), 2005-2015

	2005	2010	2011	2012	2013	2014	2015
AT	-240	-321	-310	-319	-284	-307	-303
BE	7	3	3	3	3	-5	-8
BG	-216	-280	-356	-366	-377	-387	-24
CY	0	0	0	0	0	0	0
CZ	0	1	0	4	15	1	5
DE	-195	200	401	363	323	287	412
DK	1	-1	-1	-1	-1	-2	-3
EE	0	-1	-3	0	0	-3	-2
EL	-700	-721	-719	-896	-1057	-918	-922
ES	-275	49	-85	-115	628	583	538
FI	-5	95	136	136	164	188	189
FR	-3238	-3265	-3526	-3714	-3928	-4122	-4295
HR	-279	-291	-291	-292	-252	-258	-252
HU	49	2	4	5	6	6	5
IE	0	3	3	3	3	3	3
IT	-1576	-2604	-2510	-2499	-2492	-2562	-2562
LT	-11	-11	-11	-12	-14	-14	-16
LU	0	-4	-4	-4	-4	-4	-4
LV	0	40	40	40	53	54	39
MT	0	0	0	0	0	0	0
NL	0	-10	-19	-30	-31	-31	-31
PL	-373	-392	-398	-403	-409	-410	-414
PT	-893	-922	-535	-1365	-1440	-1727	-2638
RO	0	-31	-146	-231	-608	-831	-928
SE	0	317	170	6	85	-414	-82
SI	-2	3	2	3	-17	-24	-78
SK	-1	-22	-25	-34	-53	-61	-126
UK	-2788	-2858	-2872	-2896	-2922	-2947	-2951
EU	-10745	-10819	-10788	-12276	-12250	-13528	-14448

Figure 20 illustrates the year-on-year additions and year-on-year growth rates for renewable electricity from hydropower in 2004–2016. As shown in the figure, renewable electricity from hydropower had its largest absolute annual increase in 2010, when it grew by 3.8 TWh. After 2010, renewable electricity from hydropower saw more decreases than increases. The year-on-year additions of renewable electricity from hydropower only increased in 2014 and 2015.

Figure 20. Progress of renewable electricity from hydropower in the EU, 2004-2016



Renewable electricity generation from hydropower rose by 1.6% (5.4 TWh) between 2005 and 2015 reaching 349.5 TWh. This growth is equivalent to an average of 0.5 TWh per year and a CAGR of 0.2%. The contribution to the final renewable electricity in 2015 was 39.5% slightly above the planned share of 39.3%. In 2015 electricity generation from hydropower was 5.5 TWh below expected levels in 2015. In the same year, 17 EU countries did not meet their goals for this technology (Table 4). France remained the EU country with the highest negative deviations from its plans for renewable electricity from hydropower across the entire 2005-2015 period. Romania reported the second highest negative deviation from the 2015 plan on renewable electricity from hydropower. In 2015, Italy had the largest positive deviation from its plan for renewable electricity generation from this technology, 3.9 TWh above the expected level. Germany follows, with almost 3 TWh more than its 2015 plan for this technology.

Table 4. Deviations from NREAPs – renewable electricity from hydropower (GWh), 2005-2015

	2005	2010	2011	2012	2013	2014	2015
AT	602	1047	1086	1433	1725	1618	985
BE	-12	20	11	8	-6	-14	-60
BG	310	879	791	878	903	923	866
CY	0	0	0	0	0	0	0
CZ	189	2	0	-34	-12	-105	-164
DE	1967	3575	3970	3880	2922	2640	2988
DK	6	-9	-9	-9	-9	-10	-15
EE	-6	-4	-10	3	3	-9	-4
EL	-1266	-478	-617	-891	-993	-849	-742
ES	1324	831	3	-928	629	880	507
FI	1	-303	-200	13	-130	-92	-72
FR	-5021	-5969	-7863	-8441	-8182	-9104	-10205
HR	-348	855	707	634	731	627	934
HU	184	15	22	24	30	35	34
IE	0	53	49	58	39	8	11
IT	17	1248	1886	2028	2885	3680	3863
LT	-22	-12	-7	-3	-5	-12	-19
LU	-6	-3	-3	-2	-2	0	-2
LV	5	127	112	149	155	78	-39
MT	0	0	0	0	0	0	0
NL	0	-26	-51	-81	-83	-82	-85
PL	-58	70	53	18	-14	-34	-86
PT	6054	1732	2348	731	478	623	973
RO	-913	748	352	-266	-1515	-2065	-2202
SE	1	3	257	282	-333	-2740	-1472
SI	26	124	-1	-38	-89	-53	-269
SK	-257	-451	-482	-497	-503	-530	-759
UK	-228	-204	-109	-154	-310	-406	-415
EU	2550	3871	2295	-1205	-1689	-4993	-5450

Figure 21. Hydropower installed capacity in EU countries, 2016

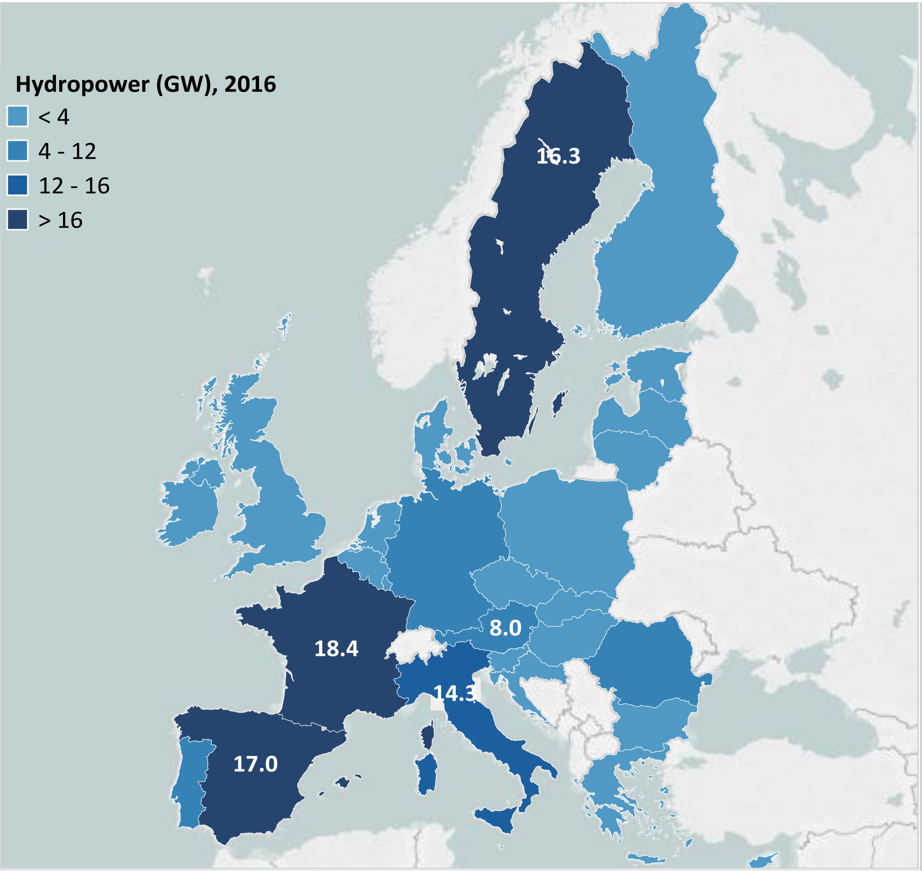
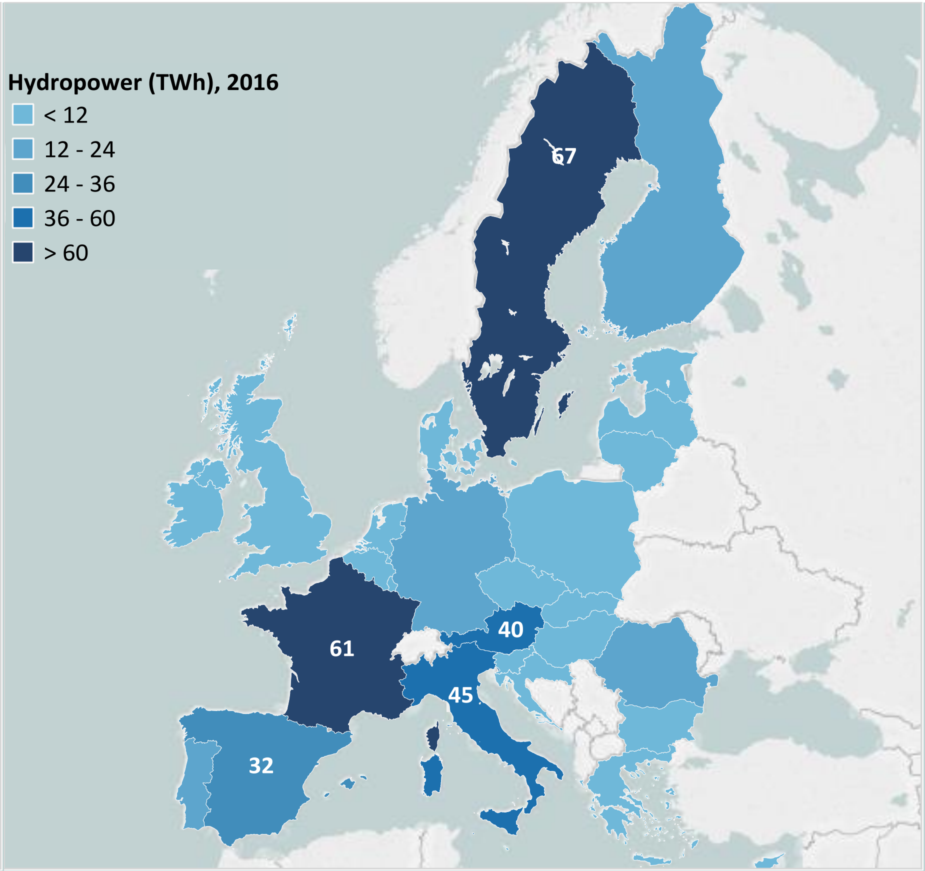


Figure 22. Electricity from hydropower in EU countries, 2016

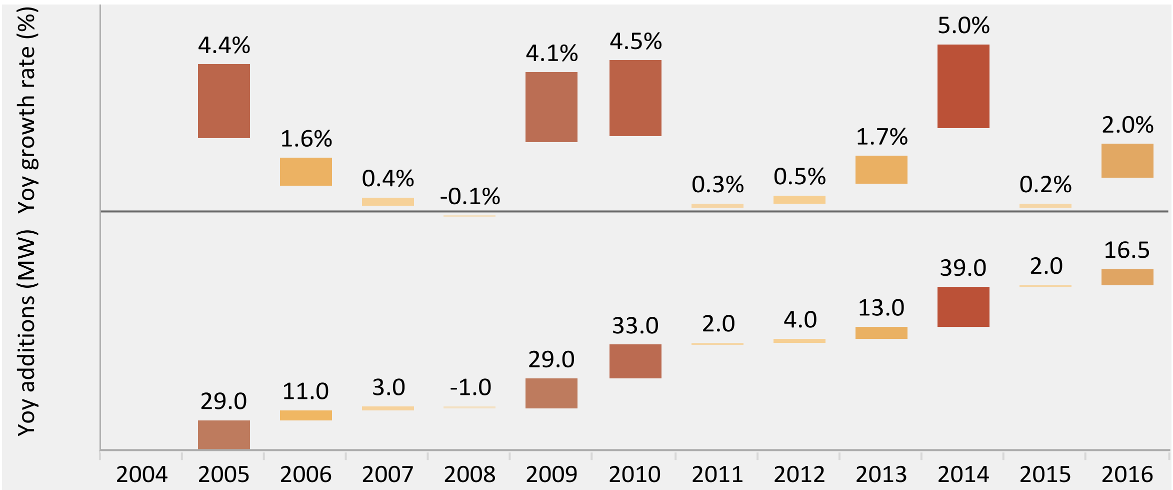


4.2 Geothermal electricity

In 2016, the EU geothermal **installed capacity** rose by 28 % (or 181 MW) in comparison with 2004, reaching a total of 838.5 MW. This growth is equivalent to an average of 2.3 MW installed capacity per year and a 2 % annual compound annual growth rate (CAGR). The contribution of this technology to total renewable electricity capacity in this year was very marginal, providing just 0.2 %.

Figure 23 illustrates the year-on-year additions and year-on-year growth rates for geothermal electricity capacity in 2004–2016. This technology saw its fastest growth in deployment in 2014, with a growth rate of 5 % (39 MW).

Figure 23. Progress of geothermal-el installed capacity in the EU, 2004-2016



Italy remained the leading Member State in terms of using geothermal technology in the electricity sector, reaching the capacity of 768 MW in 2016. This already represents 93 % of total geothermal installed capacity in the EU.

Table 5. Deviations from NREAPs – geothermal electricity installed capacity (MW), 2005-2015

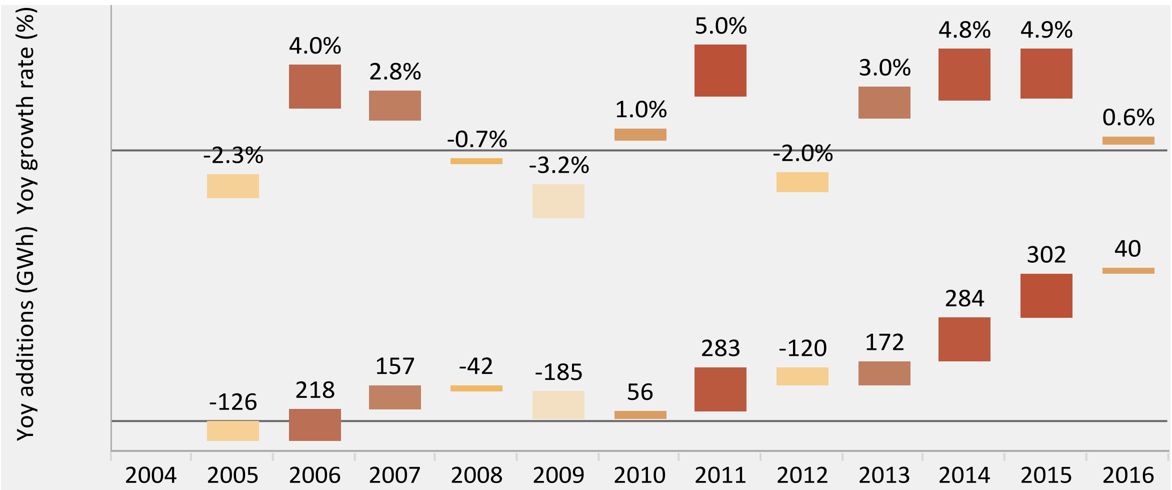
	2005	2010	2011	2012	2013	2014	2015
AT							
BE							
BG							
CY							
CZ							-4.0
DE	-0.2	-2.0	-9.0	-15.0	-16.0	-33.0	-53.0
DK							
EE							
EL						-20.0	-20.0
ES							
FI							
FR	-15.0	-26.0	-29.0	-35.0	-40.0	-45.0	-51.0
HR							-5.0
HU					-4.0	-4.0	-4.0
IE							
IT	-40.0	-26.0	-42.0	-59.0	-75.0	-52.0	-69.0
LT							
LU							
LV							
MT							
NL							
PL							
PT					-3.0	-5.0	-15.0
RO							
SE							
SI							
SK						-4.0	-4.0
UK							
EU	-54.2	-54.0	-80.0	-113.0	-146.0	-167.0	-225.0

10 EU countries (Czech Republic, Germany, Greece, France, Italy, Croatia, Hungary, Austria, Portugal and Slovakia) planned to include geothermal electricity in their total renewable electricity capacity in 2015. Only 5 countries reported on geothermal electricity for this year. Germany, France, Italy and Portugal reported lower installed geothermal capacity than expected in their NREAPs. With 1 MW of installed geothermal capacity, Austria met its target for 2015. In 2020, the number of Member States with geothermal electricity providing some of their total renewable electricity capacity is expected to increase to 12, with the addition of Belgium, Czech Republic, Greece, Spain, Croatia and Hungary. Italy remains the leading Member State for using this technology, with a capacity of 920 MW. It is followed by Germany with 298 MW and Greece with 120 MW.

Renewable electricity from geothermal sources reached 564 GWh in 2016, a 19 % increase (89 GWh) compared with 2004. This increase is equivalent to a 1.6 GWh annual addition of renewable electricity from geothermal sources and a CAGR of 1.4 %.

Figure 24 illustrates the year-on-year additions and year-on-year growth rates for renewable electricity generation from geothermal technology in 2004–2016. As shown in the figure, the year-on-year additions of renewable electricity from geothermal sources saw their fastest deployment in 2011, with an annual increase of 5 % (283 GWh). Deployment in 2013-2015 was comparable with that of 2010-2011. There were negative deviations from the aggregated NREAPs for this technology during the 2009-2010 period and in 2012.

Figure 24. Progress of renewable electricity from geothermal-el, 2004-2016



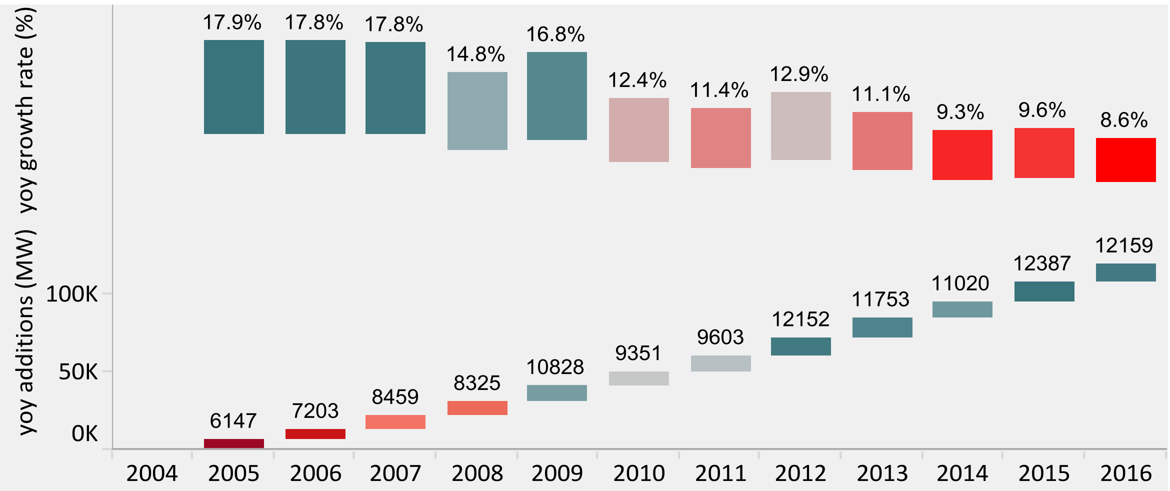
Italy accounted for almost 95 % of total renewable electricity made from geothermal sources in 2015. The technology was deployed with a CAGR of 1.5 % in Italy over the 2005-2015 period. It was deployed in Portugal with a CAGR of 11 % during the same period. Germany experienced the fastest growth in deployment of this technology with a CAGR of 94 %. 12 EU countries (Belgium, Czech Republic, Germany, Greece, Spain. France, Italy, Croatia, Hungary, Poland, Portugal and Slovakia) are expected to contribute to achieving the 2020 targets for renewable electricity from geothermal technology. The five EU countries that reported on this technology in 2015 did not meet their goals for renewable electricity generation from geothermal technology. Germany reported 243 GWh less renewable electricity from geothermal sources, followed by Greece with 123 GWh less. Portugal only reported negative deviations from its NREAP in 2012 and 2015.

4.3 Wind

Wind **installed capacity** in the EU amounted to 154 GW in 2016, increasing since 2005 with a CAGR of 13 %, equal to the planned growth rate. In 2016, the contribution of wind technology to total renewable electricity capacity was 37 %, compared with an expected 41 %. The EU is expected to increase wind installed capacity by 40 % by 2020, in order to reach its 2020 target of 211 GW.

Figure 25 illustrates the year-on-year additions and year-on-year growth rates for wind power capacity in 2004–2016. As shown in this figure, wind power technology saw the highest annual additional capacity of 12.4 GW in 2015. Annual wind power installations in the EU have increased more or less steadily over the past 11 years, from almost 6.2 GW in 2005 to nearly 12.2 GW in 2016, at an average annual rate of 11 GW per year. The fastest deployment of wind capacity took place between 2005 and 2010 with an average CAGR of 17 %.

Figure 25. Progress of wind power installed capacity in the EU, 2004-2016



All EU countries increased their wind power capacity over the 2010-2015 period. The fastest increase took place in Finland with a CAGR of 38 % (430 MW). Germany had the highest increase in absolute terms over this period with 12 GW, followed by the UK with 7.6 GW. In 2015, Germany remained the EU Member State with the highest installed capacity, followed by Spain, the UK, France and Italy. Four other EU countries (Sweden, Denmark, Poland and Portugal) have more than 5 GW installed. Seven other EU countries have over 1 GW of installed capacity: Austria, Belgium, Finland, Greece, Ireland, the Netherlands and Romania.

Compared with what was planned in the NREAPs, the EU's wind power capacity stood 1.7 GW below the aggregated plans for 2015. The deviation remained negative for the entire 2005-2015 period. 17 EU countries did not meet their goals for wind capacity in 2015. Spain reported the largest negative deviation from its plan for this technology (5 GW below the planned level) followed by France (3.2 GW below the planned level). Since 2013, deployment of wind power in Germany showed the largest positive deviation from the plan. Sweden had the second largest positive deviation from the plan for this technology.

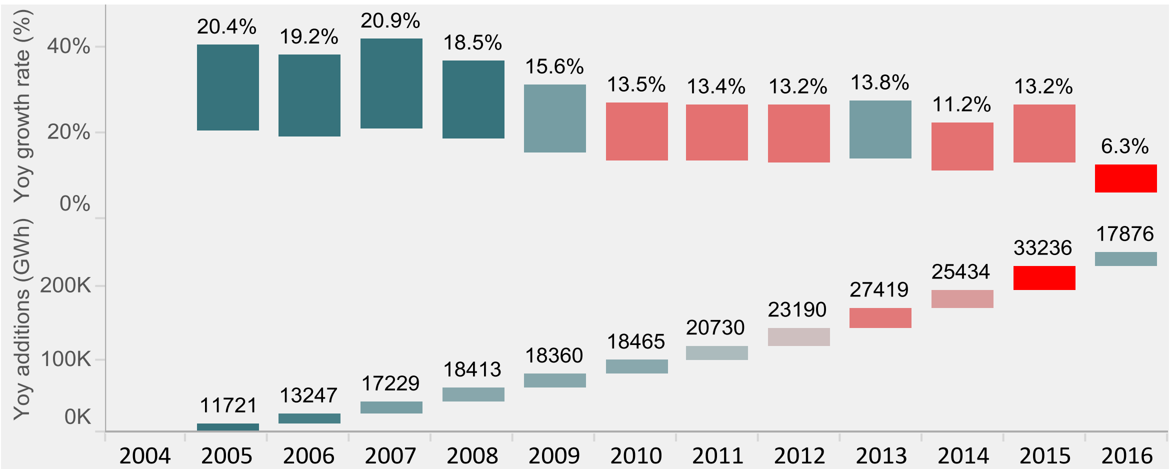
Table 6. Deviations from NREAPs – wind power installed capacity (MW), 2005-2015

	2005	2010	2011	2012	2013	2014	2015
AT	84	-30	-152	-119	24	293	538
BE	-23	179	53	147	350	205	127
BG	0	152	-19	-95	-297	-415	-574
CY	0	0	20	33	-18	-18	-22
CZ	0	0	0	5	-31	-55	-92
DE	-40	-496	-547	-54	1686	4390	8023
DK	-1	218	173	323	598	674	895
EE	0	-39	2	-45	-102	-59	-100
EL	0	-29	-284	-768	-1310	-1738	-2212
ES	0	-51	-326	-766	-2030	-3463	-4926
FI	2	27	-81	-123	-33	47	335
FR	-62	370	-151	-748	-1643	-2504	-3228
HR	0	2	5	22	38	59	18
HU	17	-37	-62	-120	-223	-239	-248
IE	23	-714	-694	-606	-853	-697	-711
IT	-4	-6	498	1062	782	274	69
LT	0	-46	2	25	-21	-62	47
LU	0	9	5	4	-13	-31	-41
LV	0	2	-1	10	4	-11	-35
MT	0	0	0	0	-2	-4	-7
NL	0	16	93	-522	-894	-2018	-2187
PL	0	8	250	564	979	936	1536
PT	1	-460	-672	-1188	-990	-744	-1188
RO	0	-171	-262	-28	323	364	-70
SE	-43	146	628	1199	1518	2155	2630
SI	0	-2	-2	-2	-4	-4	-55
SK	0	-2	-2	-147	-145	-147	-297
UK	0	-29	-782	279	1025	997	81
EU	-47	-984	-2308	-1656	-1281	-1815	-1693

EU electricity generation from wind technology reached 302 TWh in 2016, a fourfold increase over the 2005 figure.

Figure 26 illustrates the year-on-year additions and year-on-year growth rates for wind power capacity in 2004–2016. As shown in this figure, wind power technology saw the highest annual additional capacity of 12.4 GW in 2015. Annual wind power installations in the EU have increased more or less steadily over the past 11 years, from almost 6.2 GW in 2005 to nearly 12.2 GW in 2016, at an average annual rate of 11 GW per year. The fastest deployment of wind capacity took place between 2005 and 2010 with an average CAGR of 17 %.

Figure 26. Progress of renewable electricity from wind power in the EU, 2004-2016



All EU countries increased their electricity generation from wind power between 2010 and 2015. The fastest increase was seen in Romania, with a CAGR of 86 %. Cyprus experienced the second fastest increase with a CAGR of 46 %. Wind power deployment in Slovakia was slower than in any other EU country, with a CAGR of only 2.6 % over the same period.

No plans were met for this technology over the 2005-2015 period. The largest negative deviation was in 2014, 26.5 TWh below the planned level. In 2015, the deviation reached 23.4 TWh. 22 EU countries produced less renewable electricity from this technology than they expected. France reported the highest negative deviation, 10.7 TWh below the planned level.

Table 7. Deviations from NREAPs –renewable electricity from wind (GWh), 2005-2015

	2005	2010	2011	2012	2013	2014	2015
AT	-31	1	-373	-435	-178	344	955
BE	-86	476	310	-259	-709	-1028	-1028
BG	0	-1	-206	-351	-544	-706	-926
CY	0	0	-84	-29	-86	-88	-95
CZ	0	-1	0	1	-26	-85	-128
DE	-17	-1594	-2674	-3720	-4602	-4819	940
DK	-546	-878	-636	-360	-737	744	1821
EE	-5	-90	-10	158	-192	-272	-331
EL	50	-225	-1146	-1969	-3063	-4275	-5177
ES	0	369	-239	-13	-29	-1886	-4549
FI	4	-37	-188	-346	-314	-152	465
FR	-56	-1158	-1958	-3865	-6189	-8850	-10755
HR	3	-8	-96	-48	-43	26	-34
HU	13	-174	-47	-228	-446	-599	-676
IE	-477	-1694	-2229	-1975	-2871	-2624	-2277
IT	0	389	908	2084	2591	2312	1646
LT	0	-51	-64	-1	-54	-163	-88
LU	1	7	-4	-24	-48	-82	-101
LV	-1	-3	-8	-2	-8	-35	-82
MT	0	0	0	0	-4	-11	-17
NL	-33	35	255	-1636	-2954	-5975	-6739
PL	67	-610	-333	210	865	1194	2317
PT	-22	-1813	-1842	-2239	-1465	-809	-1478
RO	0	-162	-697	-671	-210	6	-48
SE	-33	-993	28	1014	2079	3201	5471
SI	0	-2	-4	-4	-10	-9	-103
SK	0	-3	-3	-115	-233	-233	-475
UK	-80	-2898	-4981	-4390	-1995	-1569	-1816
EU	-1249	-11116	-16323	-19209	-21477	-26439	-23309

Figure 27. Wind installed capacity in EU countries, 2016

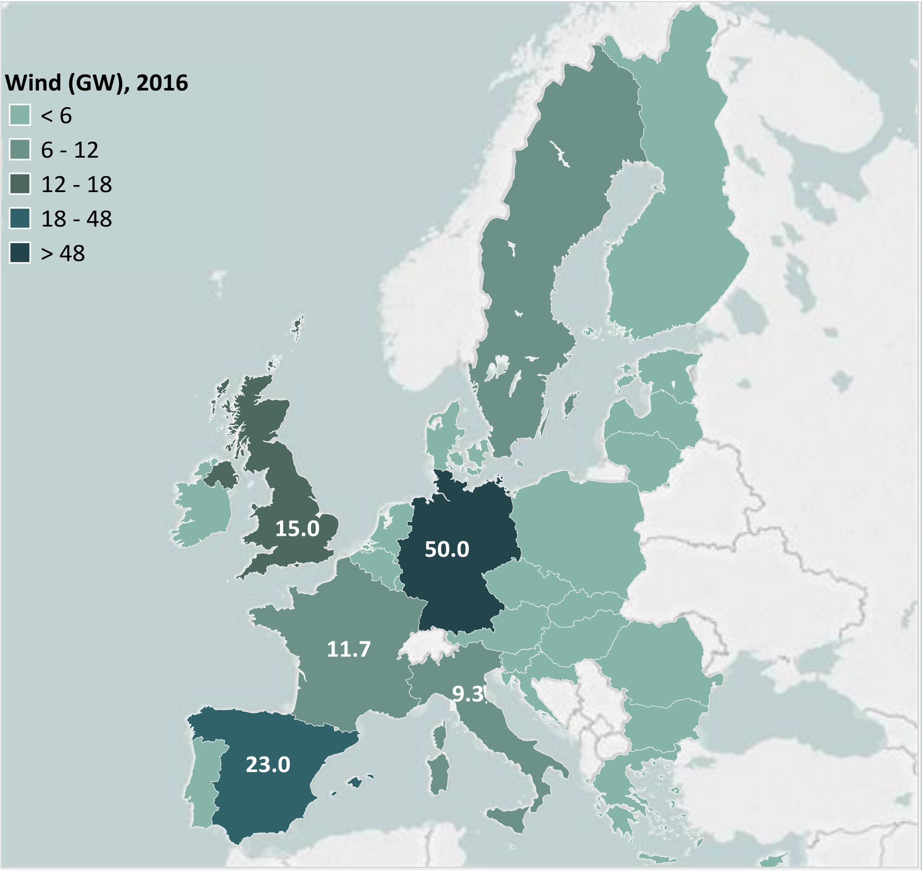
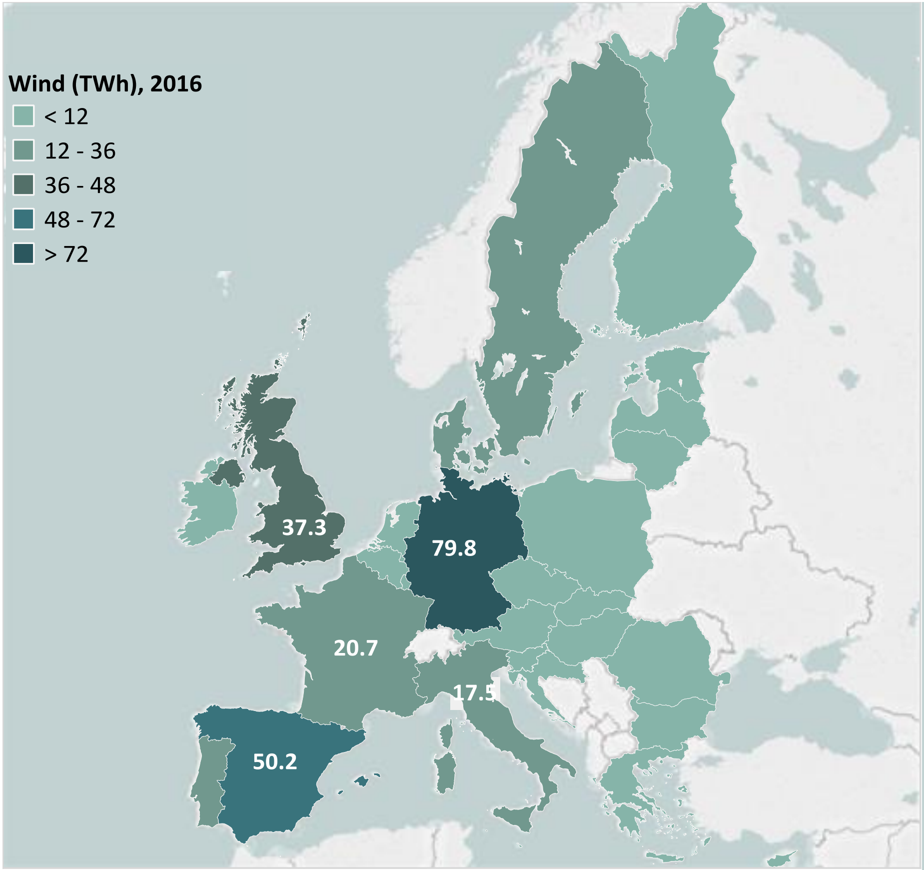


Figure 28. Electricity from wind in EU countries, 2016

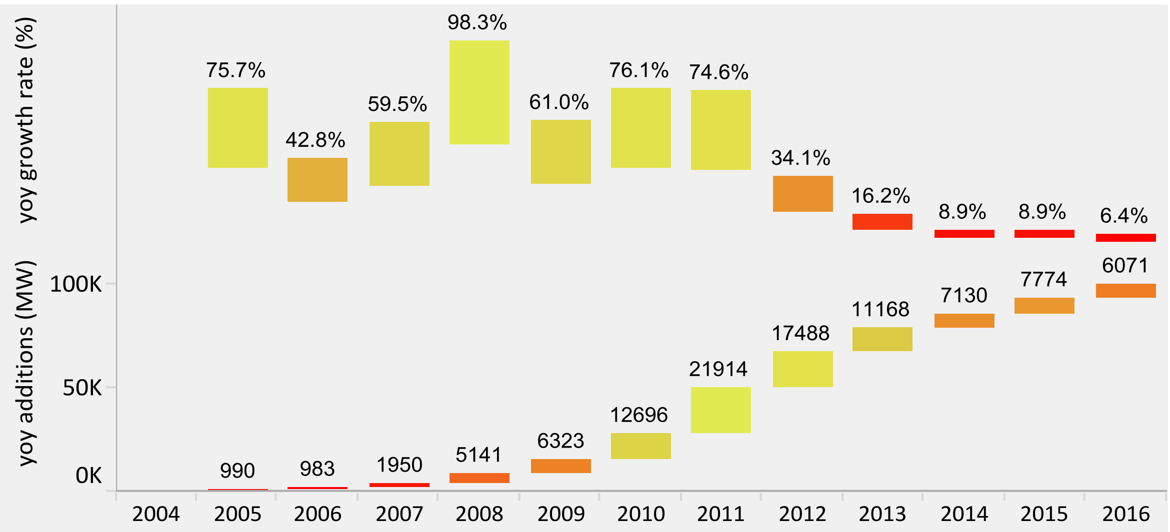


4.4 Solar photovoltaic

In 2016, **solar photovoltaic capacity** in the EU was 44 times higher than the 2005 figure, reaching 101 GW. The largest growth in solar photovoltaic capacity happened in 2011. Between 2015 and 2016, the deployment of solar photovoltaic saw its lowest year-on-year growth, a rate of only 6.4 % (6.1 GW in absolute terms). In absolute terms this increase is almost equal to the increase that took place between 2008 and 2009. The share of solar photovoltaic capacity in the EU's renewable electricity capacity reached 23 % in 2016.

Figure 29 illustrates the year-on-year additions and year-on-year growth rates for solar photovoltaic capacity in 2004–2016. As shown in the figure, the year-on-year additions of solar photovoltaic capacity reached their highest value of 22 GW in 2011. The installed capacity of this technology saw a CAGR of 23 % in 2010-2016.

Figure 29. Progress of solar photovoltaic installed capacity in the EU, 2004-2016



Over the 2010-2016 period, the deployment of solar photovoltaic capacity was fastest in Hungary (CAGR of 129 %), Germany (CAGR of 122 %) and the UK (CAGR of 122 %). The slowest deployment in this period took place in the Czech Republic (CAGR of 3 %). In 2016, the UK provided almost 40 % of new installed solar photovoltaic capacity. The UK (11.6 GW), Germany (41.3 GW) and Italy (19.3 GW) provided more than 71 % of the EU's solar photovoltaic capacity in 2016.

EU solar photovoltaic capacity exceeded planned levels throughout the 2005-2015 period. The positive deviation from aggregated plans reached almost 40 GW in 2015. The deployment of solar photovoltaic capacity was fastest in the 23 EU countries that have already surpassed their 2020 targets for this technology. Only five EU countries (Czech Republic, Germany, Spain, Cyprus and Portugal) are still below their 2020 plans. In 2016, there were only four EU countries (Cyprus, Spain, Croatia and Portugal) that did not meet their goals for solar photovoltaic capacity. Italy registered the highest absolute deviation from its 2016 plan, 13.3 GW.

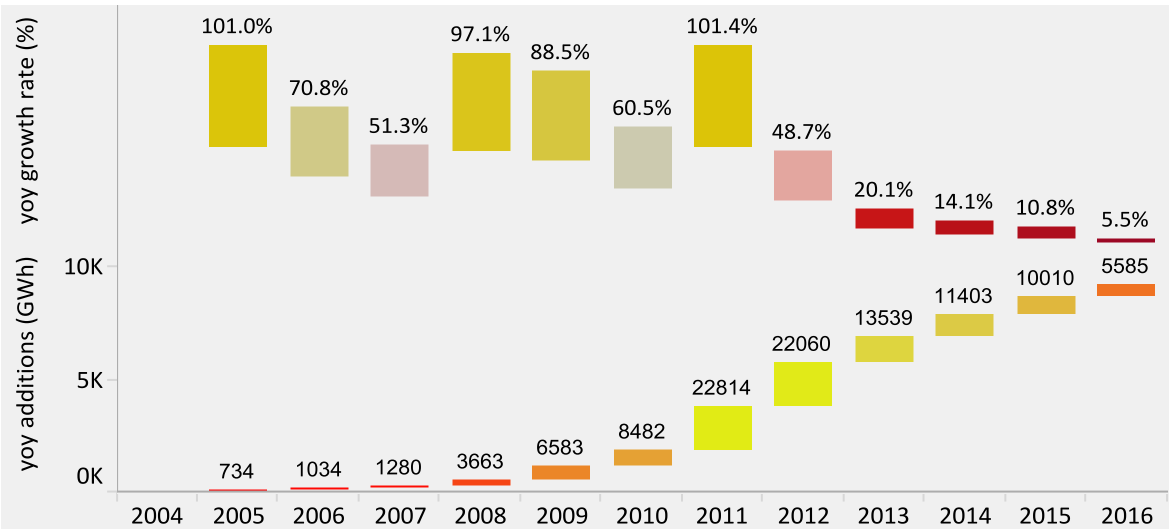
Table 8. Deviations from NREAPs – solar photovoltaic installed capacity (MW), 2005-2015

	2005	2010	2011	2012	2013	2014	2015
AT	8	64	213	243	488	628	758
BE	0	554	963	2096	2380	2399	2409
BG	0	16	116	938	890	840	778
CY	1	1	2	5	18	31	39
CZ	0	0	0	87	106	85	62
DE	76	1768	4753	8858	9053	7453	5507
DK	0	4	14	399	568	603	778
EE	0	0	0	0	0	0	0
EL	0	18	255	1005	1801	1572	1334
ES	0	134	87	-23	-109	-356	-561
FI	4	7	7	8	9	11	15
FR	-12	515	2009	2864	3527	4202	4604
HR	0	0	-6	-2	9	17	-4
HU	0	2	2	6	26	63	149
IE	0	1	1	1	1	2	2
IT	0	970	9273	12420	13920	13609	13392
LT	0	-1	-2	4	63	61	59
LU	0	2	14	36	50	44	28
LV	0	0	0	-1	-1	-1	-1
MT	0	-3	0	5	2	28	47
NL	0	-2	0	184	517	775	1198
PL	0	-1	0	-1	0	25	106
PT	-1	-22	-56	-62	-89	-45	-93
RO	0	0	-7	-2	683	1180	1178
SE	0	6	6	18	37	54	97
SI	0	0	40	120	160	191	201
SK	0	-41	376	383	393	383	373
UK	0	46	855	1476	2361	4647	8117
EU	76	4038	18916	31065	36863	38502	40572

Renewable electricity generated from solar photovoltaic reached almost 108 TWh in 2016, 23-fold the 2005 figure.

Figure 30 illustrates the year-on-year additions and year-on-year growth rates for renewable electricity from solar photovoltaic in 2004-2016. The fastest increase of renewable electricity from this technology took place in 2011. Between 2015 and 2016, the deployment of renewable electricity from solar photovoltaic saw its lowest annual increase, only 5.5 % (5.6 TWh). The share provided by renewable electricity from solar photovoltaic of total EU renewable electricity reached 11 % in 2016.

Figure 30. Progress of renewable electricity from solar photovoltaic in the EU, 2004-2016



EU renewable electricity from solar photovoltaic exceeded planned levels in 2010-2015. The positive deviation from aggregated plans reached almost 51 TW in 2015. The increase of renewable electricity from solar photovoltaic was fastest in the 23 EU countries that have already exceeded their 2020 targets for this technology. Only three EU countries (Czech Republic, Spain and Croatia) are still below their 2020 targets. Italy registered the largest absolute deviation from its 2016 plan, 16.8 TWh. Germany follows with a deviation of 12.6 TWh. Over 2010-2016, deployment of renewable electricity from solar photovoltaic was fastest in Romania (CAGR of 555 %), Croatia (CAGR of 192 %) and Bulgaria (CAGR of 174 %). The slowest deployment over this period took place in Spain (CAGR of 5.6 %).

Table 9. Deviations from NREAPs – renewable electricity from solar photovoltaic (GWh), 2005-2015

	2005	2010	2011	2012	2013	2014	2015
AT	0	4	75	223	451	636	767
BE	0	256	800	1731	2178	2345	2455
BG	0	3	51	723	1187	1006	1040
CY	0	0	-1	3	20	31	68
CZ	0	0	0	-42	-184	-121	-12
DE	0	2230	5632	8983	10717	12838	12565
DK	0	4	13	102	516	593	601
EE	0	0	0	0	0	0	0
EL	0	-84	140	996	2626	2447	2232
ES	0	146	525	526	125	-587	-793
FI	3	5	5	6	6	8	10
FR	-11	7	1131	2702	3028	3781	4643
HR	0	0	-12	-5	-8	4	-3
HU	0	-1	-4	-1	11	36	97
IE	0	0	1	1	1	1	2
IT	0	-61	7496	14856	16878	16889	16820
LT	0	0	-2	-1	39	64	60
LU	0	1	6	9	40	46	39
LV	0	0	0	-1	-1	-1	-1
MT	0	-6	-2	0	-11	28	52
NL	-5	-17	0	94	320	584	872
PL	0	-1	-2	-1	-1	5	55
PT	0	-19	-56	-50	-89	-52	-1
RO	0	0	-9	-42	320	1476	1802
SE	2	7	9	17	33	45	94
SI	0	1	49	141	188	225	237
SK	0	-13	307	294	448	447	346
UK	0	1	124	1112	1598	3430	6671
EU	-9	2462	16275	32375	40436	46203	50717

Figure 31. Solar PV installed capacity in EU countries, 2016

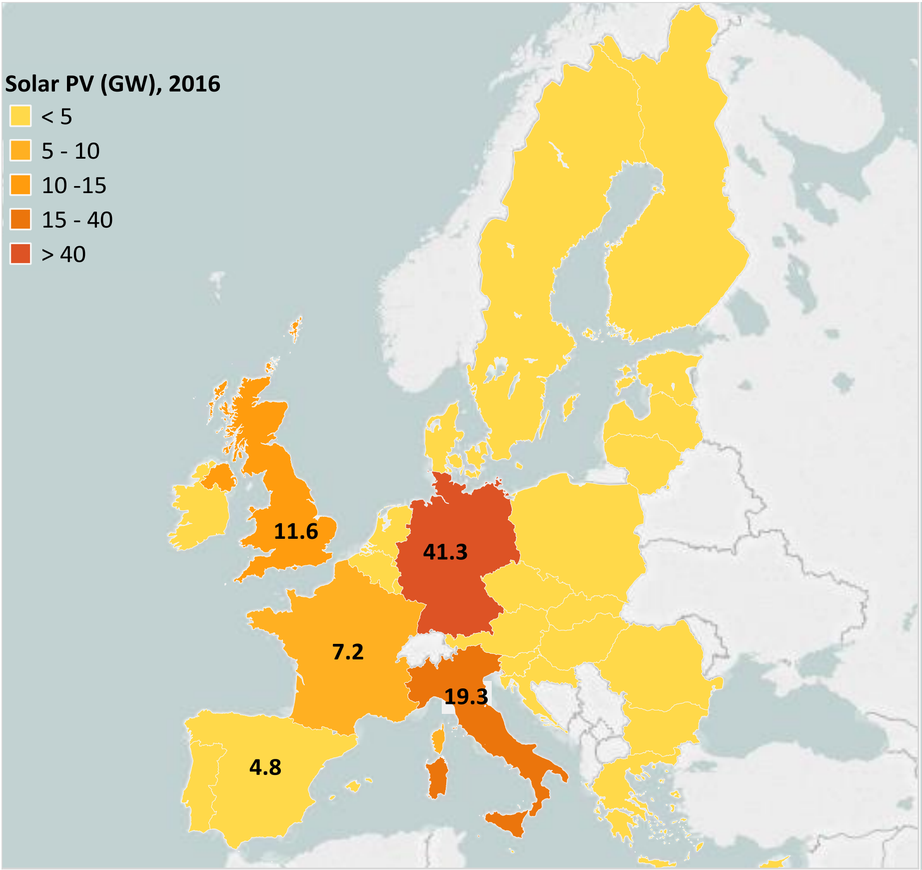
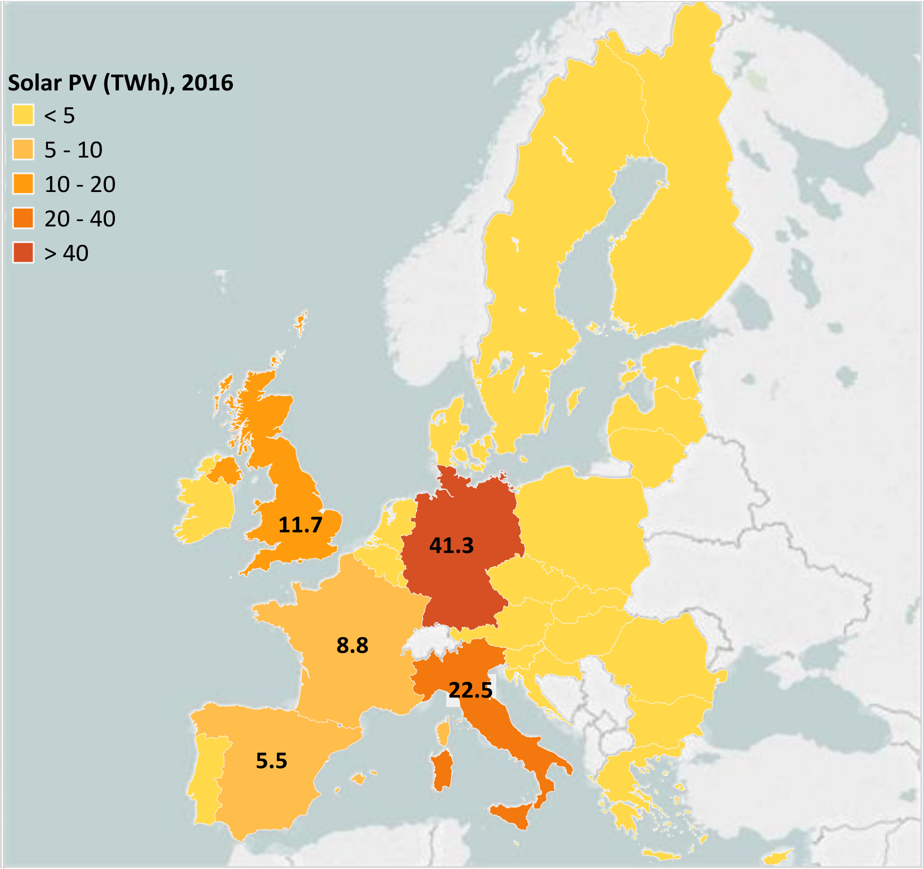


Figure 32. Electricity from solar PV in EU countries, 2016

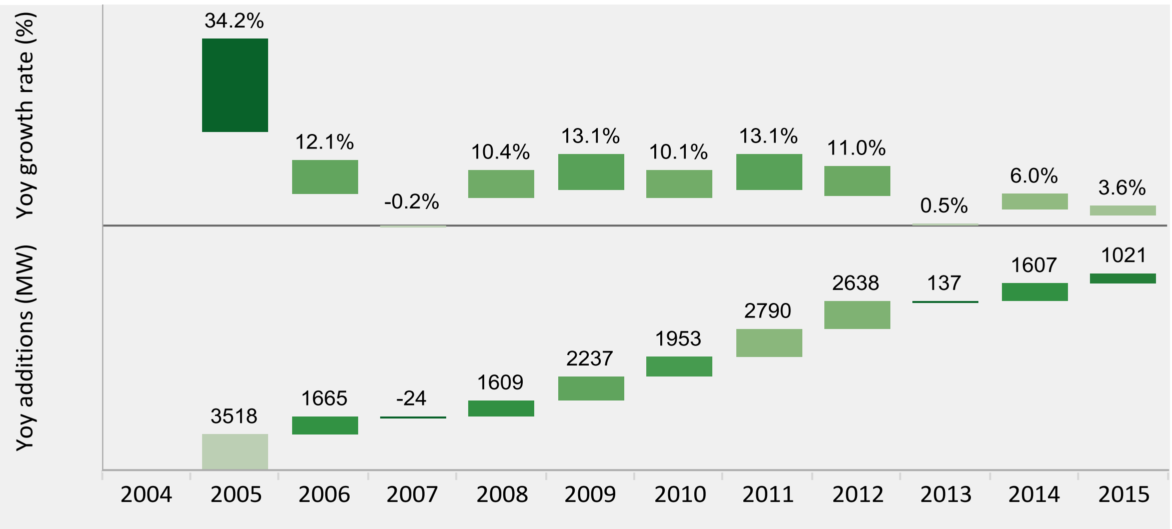


4.5 Biomass electricity

By 2015 biomass **installed capacity** in the EU almost two-folded in comparison with the 2005 figure reaching 29.5 GW. Its share in the total renewable electricity installed capacity reached 8 % in 2015, lower than 9.3% in the baseline year.

Figure 33 illustrates the year-on-year additions and year-on-year growth rates for biomass electricity capacity in 2004–2015. Biomass capacity had the fastest annual increase in 2005 (34.2 % or 3.5 GW), and there was a 0.2 % (24 MW) decrease in 2007. After 2009, the deployment of biomass capacity in the electricity sector saw a CAGR of 6.7 %. In 2013, the year-on-year growth rate reached the lowest level since 2009, only 0.5 % (137 MW in absolute terms). Between 2014 and 2015, the increase in biomass capacity was 3.6 %, with only 1 GW installed.

Figure 33. Progress of biomass-el installed capacity in the EU, 2004-2015



In 2010-2015, the deployment of biomass capacity was fastest in Latvia (CAGR of 51 %), Poland (CAGR of 48 %), Romania (CAGR of 42.6 %), Croatia (CAGR of 42.6 %) and Bulgaria (CAGR of 40 %). The Netherlands and Austria experienced a decrease in the use of biomass for electricity over this period, with a CAGR of 9 % each. With 7 GW, Germany was the leading EU country in terms of biomass installed capacity. Sweden and the United Kingdom followed with 4.2 GW each. The contribution from these three EU countries accounted for more than 53 % of biomass installed capacity in the EU in 2015.

Biomass capacity in the EU (3.2 GW less) did not reach the aggregated NREAP target in 2005-2015. Nineteen EU countries did not reach their 2015 targets in this area. The Netherlands had the largest negative deviation in this year, with 1.9 GW less capacity than expected. France had the second largest negative deviation, 1.1 GW less. The deployment of biomass capacity in the United Kingdom saw a CAGR of 18 % in 2010-2015, showing the largest positive deviation from its NREAP (1.7 GW more). Sweden had the second largest positive deviation (1.5 GW more), followed by the Czech Republic (0.4 GW more). Only four EU countries (Cyprus, Czech Republic, Estonia and Latvia) exceeded their biomass capacity targets over the 2005-2015 period.

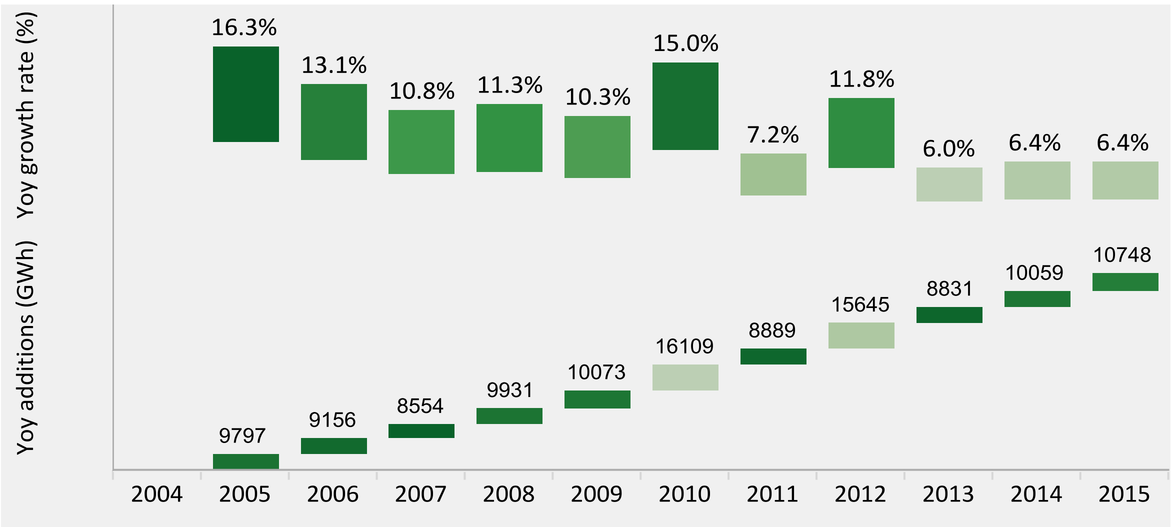
Table 10. Deviations from NREAPs – biomass-el installed capacity (MW), 2005-2015

	2005	2010	2011	2012	2013	2014	2015
AT	410	723	802	846	269	-71	-41
BE	105	259	149	6	-133	-357	-469
BG	7	10	1	-8	-12	-54	-93
CY	0	2	3	3	2	2	0
CZ	102	271	301	418	413	438	444
DE	-822	-1,264	-1,013	-882	-807	-506	-610
DK	-128	-69	63	289	-768	-712	-761
EE	12	142	149	167	156	173	176
EL	0	-19	-15	-25	-34	-53	-69
ES	-95	-75	-152	-126	-150	-182	-261
FI	-420	-94	-178	-270	-296	-356	-406
FR	-412	-528	-625	-676	-844	-972	-1,091
HR	0	4	9	7	12	13	-5
HU	343	119	104	-68	-89	59	71
IE	0	-41	-37	-35	-74	-76	-79
IT	-295	-451	-219	503	438	267	83
LT	0	-5	-8	-6	-35	-62	-84
LU	-4	-4	-5	-10	-11	-17	-20
LV	0	3	5	27	47	25	16
MT	0	0	3	3	3	-27	-27
NL	-217	-525	-622	-997	-1,456	-1,759	-1,905
PL	-231	-246	-173	-137	-205	-364	-574
PT	-195	-139	-201	-282	-349	-385	-370
RO	0	6	-60	-130	-204	-246	-307
SE	0	517	695	1,325	920	1,477	1,479
SI	0	-5	-4	-8	-15	-16	-19
SK	-3	60	52	45	21	21	11
UK	-84	-83	917	725	1,256	1,464	1,693
EU	-1,927	-1,432	-59	703	-1,945	-2,276	-3,219

Renewable electricity from biomass reached 178 TWh in 2015, a rise with a CAGR of 9.8 % compared with the 2005 figure.

Figure 34 illustrates the year-on-year additions and year-on-year growth rates for renewable electricity from biomass in 2004-2015. Renewable electricity from this source saw the fastest deployment in 2005 (a 16.3 % annual increase). Since 2009, renewable electricity from biomass had the fastest deployment in 2010 (a 15 % annual increase). The largest yearly additions of renewable electricity from biomass were seen in 2010 and 2012. After 2013, the deployment rate of biomass in electricity production remained at around 6.4 %.

Figure 34. Progress of renewable electricity from biomass-el in the EU, 2004-2015



In 2010-2015, the deployment of renewable electricity from biomass was fastest in Ireland (CAGR of 77.5 %), Latvia (CAGR of 63 %), Romania (CAGR of 49.7 %), Bulgaria (CAGR of 49.6 %) and Lithuania (CAGR of 25 %).

EU renewable electricity from biomass exceeded the aggregated NREAP figures in the 2005-2015 period. Nineteen EU countries did not meet their targets for renewable electricity from biomass in 2015. The Netherlands had the largest negative deviation in this year, with 8.3 TWh less than expected. France had the second largest negative deviation from its plan, with 4.6 TWh less. The deployment of biomass in the production of electricity in the UK took place with a CAGR of 19.8 % in 2010-2015, registering the highest positive deviation from a NREAP (15 TWh more). Germany had the second highest positive deviation (8.2 TWh more), followed by Italy (5.6 TWh more). Only four EU countries (Czech Republic, Germany, Estonia and Finland) exceeded their targets for renewable electricity from biomass in the 2005-2015 period.

Table 11. Deviations from NREAPs – renewable electricity from biomass (GWh), 2005-2015

	2005	2010	2011	2012	2013	2014	2015
AT	-244	-259	-231	-147	-182	-492	-418
BE	-201	1323	1059	1098	417	-835	-445
BG	0	35	1	-54	-140	-312	-533
CY	0	5	2	0	-18	-17	-33
CZ	11	35	85	205	612	933	857
DE	327	1524	2906	7812	7990	9031	8211
DK	-71	821	242	234	-1460	-1414	-1829
EE	2	499	474	665	329	422	414
EL	27	-64	-48	-52	-41	-217	-273
ES	0	-214	-920	-1001	-462	-1202	-1380
FI	-149	2882	2333	2009	2585	2113	1550
FR	-429	-1001	-967	-1559	-3052	-3828	-4571
HR	3	0	21	41	73	112	-68
HU	1657	341	-112	-340	-265	-398	-89
IE	14	-34	-57	-36	-353	-323	-412
IT	-1	793	1172	1669	5271	5978	5651
LT	0	-1	-44	-51	-73	-212	-315
LU	0	15	9	-10	-42	-50	-70
LV	1	-7	-35	54	136	95	105
MT	0	0	3	7	4	-165	-165
NL	232	1082	392	-1643	-4876	-7237	-8323
PL	60	275	488	1900	-154	537	38
PT	-296	213	253	-41	-140	-312	-256
RO	6	43	-238	-583	-949	-1136	-1527
SE	-82	1558	288	331	-1139	-2435	-2957
SI	0	-81	-92	-148	-197	-226	-359
SK	0	52	49	41	-139	171	313
UK	-7	-411	261	1387	4601	8771	15094
EU	860	9428	7293	11786	8334	7350	8212

Figure 35. Biomass installed capacity in EU countries, 2015

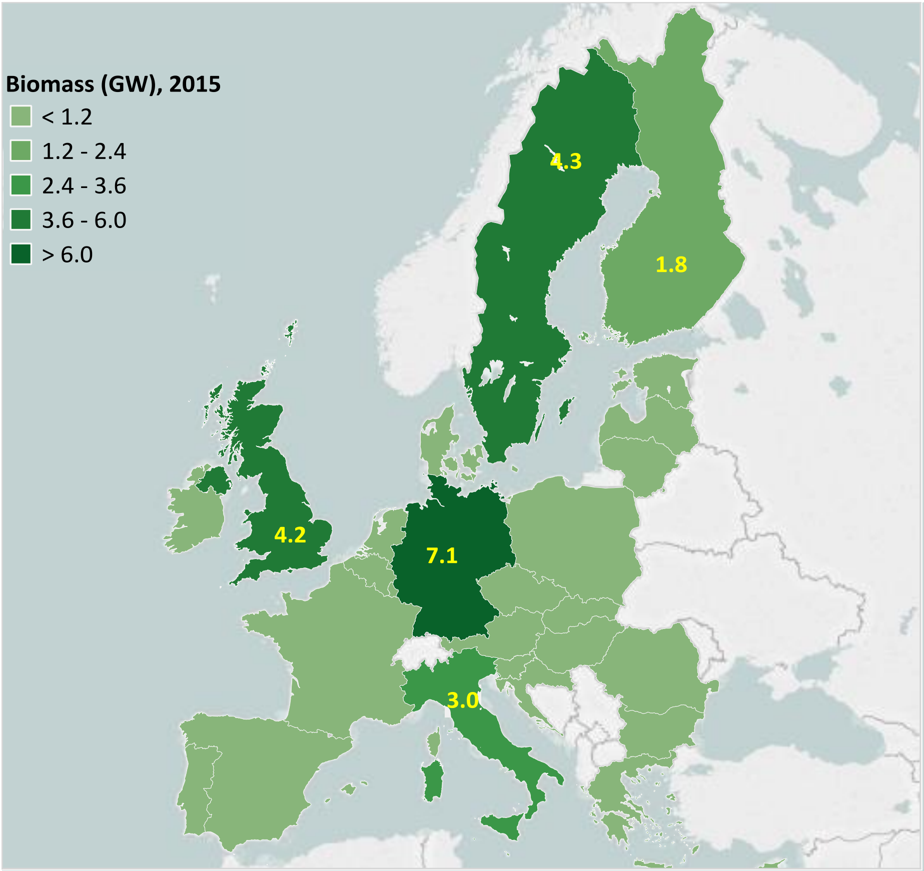
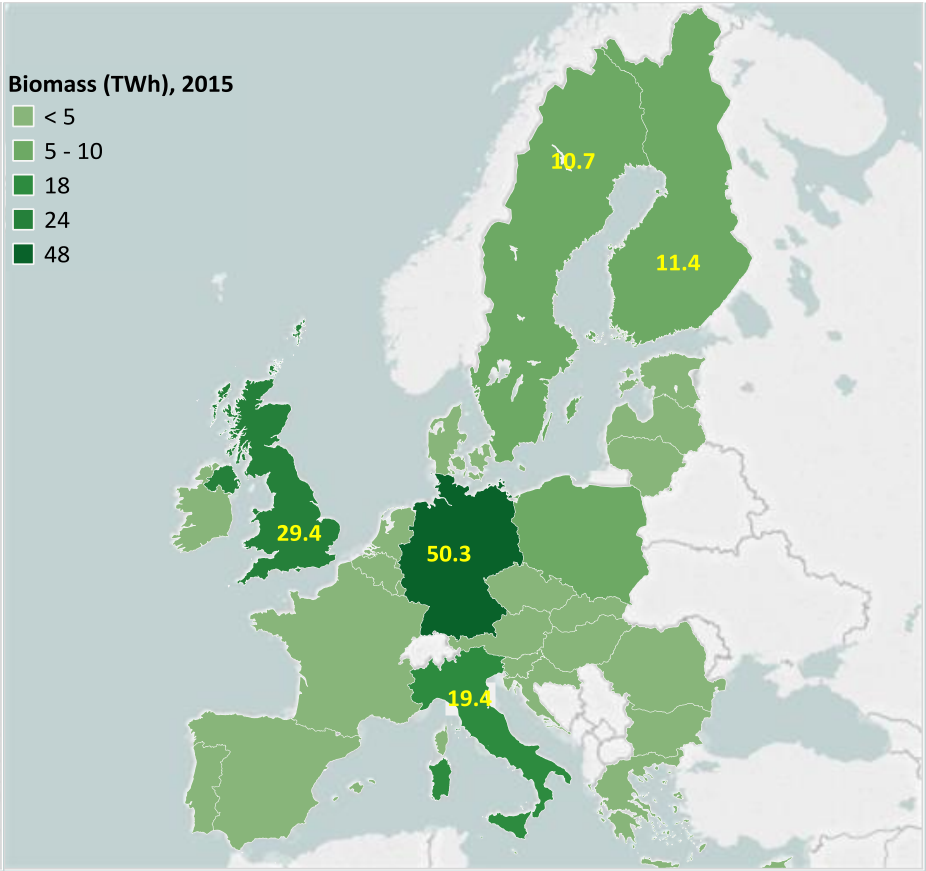


Figure 36. Electricity from biomass in EU countries, 2015



5 Renewable electricity technologies – futures as in NREAPs

We are setting below a short assessment based on data reported in Table 10 of NREAPs and Table 1b of Renewable Energy Progress Reports complemented with Eurostat SHARES Tool data. The assessment shows how each renewable technology in electricity sector has evolved so far and how it is expected to evolve in order to achieve the 2020 planned values. The assessment is based on the comparison of indexed planned and achieved growth of different technologies for periods 2010-2015 and 2015-2020. As the aggregated NREAPs are outdated for solar photovoltaic technology the target growth rate for 2020 are based on the projected figure of PRIMES scenarios (both capacity and electricity generation).

2010-201Y planned growth rate of X = $((XNREAPs_{201Y} - XNREAPs_{2010})/XNREAPs_{2010})*100$

2010-201Y reported growth rate of X = $((XPR_{201Y} - XNREAP_{2010})/XNREAPs_{2010})*100$

2015-202Y planned growth rate of X = $((XNREAPs_{202Y} - XNREAPs_{2015})/XNREAPs_{2015})*100$

2015-202Y target growth rate of X = $((XNREAPs_{202Y} - XPRs_{2015})/XPRs_{2015})*100$

where:

201Y – each year of period 2010 - 2015

202Y – each year of period 2015 - 2020

XNREAPs are the data reported in the aggregated NREAPs for the relevant years and XPRs are the data reported in the aggregated progress reports for the relevant years.

For each variable a 2015 value larger than planned implies a 2010-2015 reported growth larger than the 2010-2015 planned growth and, as a consequence, a 2015-2020 target growth smaller than its planned value. Vice-versa, a 2015 value smaller than planned implies a 2010-2015 achieved smaller than planned and conversely a target 2015-2020 growth larger than planned.

5.1 Hydropower

The contribution of this technology to total renewable electricity capacity in 2016 was 26 %, against the expected contribution of 32 %. %. According to the aggregated NREAPs, development with a CAGR of 4 % (19 GW) is expected until 2020, in order to achieve the planned capacity of 127.2 GW. According to the aggregated NREAPs, the share of hydropower capacity in the final renewable electricity capacity in the EU in 2020 is expected to reach 26.7 %. Over period 2010-2015 hydropower capacity deployed slower than planned in the aggregated NREAPs. By 2015 these relative deployments reached 2.6% lower than the planned 5.6%. Until 2020 the growth target rate of this technology needed to meet the plan should be almost 3 times higher than the growth rate planned (Table 12).

Table 12. Hydropower installed capacity: 2010-2015 vs 2010 (left) & 2015-2020 vs 2015 (right)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Current	0.9%	1.0%	1.9%	1.7%	2.6%	15.5%	17.3%	18.4%	20.1%	21.2%
NREAPs	0.7%	2.2%	3.0%	3.9%	5.6%	1.6%	3.1%	4.1%	5.6%	6.5%

In 2020 the renewable electricity from hydropower is expected to reach 363 TWh while its contribution in renewable electricity for this year is expected to 30.5%. Renewable electricity from hydropower was below the plans all over period 2010-2015. To reach the 2020 aggregated plans the target growth rate of the electricity generation from this technology needs to be higher than the planned growth rate (Table 13).

Table 13. Renewable electricity from hydropower: 2010-2015 vs 2010 (left) & 2015-2020 vs 2015 (right)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Current	-0.2%	-0.6%	-0.1%	-0.3%	-0.1%	2.0%	3.1%	3.7%	4.8%	5.8%
NREAPs	0.3%	0.8%	1.5%	2.2%	2.6%	0.5%	1.6%	2.1%	3.2%	4.1%

5.2 Geothermal electricity

In 2020 the EU is expected to almost double its geothermal capacity from the level of year 2016 reaching 1613 MW with a share equal to 0.3% in total expected renewable electricity capacity. The deployment of this technology was much slower than what was expected from the aggregated NREAPs all over period 2010-2015. The expected growth until 2020 should be much higher than the planned one (Table 14).

Table 14. Geothermal installed capacity: 2010-2015 vs 2010 (left) & 2015-2020 vs 2015 (right)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Current	0.3%	0.8%	2.5%	7.6%	7.9%	34.5%	42.3%	59.2%	71.2%	97.4%
NREAPs	3.4%	8.0%	13.6%	21.0%	28.3%	5.6%	11.7%	25.0%	34.4%	55.0%

Up to 2020 geothermal technology is expected to contribute with 0.9% in the EU renewable electricity reaching 11 TWh. Renewable electricity from this technology needs to speed up its growth rate towards 2020 by a factor of 5 compared with the planned aggregated growth rate. By 2015 the increase of renewable electricity from this technology took place with a growth rate of 16.4%, lower than the growth rate planned (23.4%).

Table 15. Renewable electricity from geothermal: 2010-2015 vs 2010 (left) & 2015-2020 vs 2015 (right)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Current	5.0%	2.9%	6.0%	11.0%	16.4%	18.8%	24.6%	38.3%	47.8%	68.1%
NREAPs	2.8%	6.5%	10.9%	17.3%	23.4%	5.0%	4.9%	11.0%	6.8%	13.8%

5.3 Wind

According to the aggregated NREAPs, the share of wind power capacity in total renewable electricity capacity in 2020 is expected to reach 44 % and wind is to be the dominant renewable electricity source in that year. Wind is expected to cover almost 17 % of the EU's electricity needs by 2020. Wind installed capacity rose in 2015 by 67.3% comparing with 2010. This deployment was in line with the planned growth rate according to the aggregated NREAPs (Table 16). Until 2020 the EU will need to accelerate slightly the deployment of wind technology in electricity sector.

Table 16. Wind installed capacity: 2010-2015 vs 2010 (left) & 2015-2020 vs 2015 (right)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Current	11.4%	25.7%	39.6%	52.7%	67.3%	10.2%	19.4%	29.2%	38.7%	49.1%
NREAPs	12.8%	26.2%	39.5%	53.0%	67.4%	8.9%	18.0%	27.7%	37.0%	47.4%

For 2020 the electricity generation from wind power is projected to reach 489 TWh expecting a CAGR of 12.8%. Wind electricity is expected to become the dominant renewable electricity source, further increasing its contribution to 40.4%. Renewable electricity from wind grew over period 2010-2015 slightly slower than planned. Until 2020 renewable electricity coming from this technology is expected to increase with a higher growth rate compared with the planned one (Table 17).

Table 17. Renewable electricity from wind: 2010-2015 vs 2010 (left) & 2015-2020 vs 2015 (right)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Current	13.4%	28.4%	46.1%	62.5%	84.0%	19.8%	32.1%	45.2%	57.5%	71.7%
NREAPs	15.6%	31.3%	49.2%	67.6%	85.7%	10.7%	22.1%	34.2%	45.6%	58.7%

5.4 Solar photovoltaic

The aggregated NREAPs are now outdated in relation to the deployment of this technology. The 2020 projected an installed capacity of 129 GW[10]. This requires an annual solar photovoltaic capacity increase of 8.8 GW. Comparing with 2015 the growth rate of this technology capacity is expected to reach around 36%. In 2016 the annual growth rate of solar photovoltaic capacity was 7.5% compared with 2015 level (Table 18).

Table 18. Solar PV installed capacity: 2010 - 2015 vs 2010 (left) & 2015-2020 vs 2015 (right)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Current	74.6%	134.1%	172.1%	196.3%	222.8%	7.5%				36.2%
NREAPs	27.8%	48.8%	70.0%	91.7%	114.1%					

The projected renewable electricity from solar photovoltaic in 2020 is expected at around 136 TWh[11]. Over 2010-2015 renewable electricity from solar photovoltaic grew more than 2 times faster comparing with the aggregated plans. By 2020 renewable electricity from solar photovoltaic is expected to rise by nearly 33% comparing with 2015 figure. In 2016 the renewable electricity from this technology rose by 5.5% (Table 19).

Table 19. Renewable electricity from solar PV: 2010-2015 vs 2010 (left) & 2015-2020 vs 2015 (right)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Current	101.4%	199.4%	259.6%	310.2%	354.7%	5.5%				32.6%
NREAPs	44.9%	74.7%	102.0%	130.1%	157.5%					

([10]) The 2020 projected capacity for solar technology in the PRIMES EUCO scenarios is 136 GW. Expecting in 2020 an installed capacity for the Concentrated Solar Power (CSP) at 6.8 GW (according to the aggregated NREAPs) the solar photovoltaic capacity has to reach 129 GW.

([11]) The 2020 projected renewable electricity from solar technology in the PRIMES EUCO scenarios is 154 TWh. Expecting in 2020 a contribution of 19 TWh from the CSP (according to the aggregated NREAPs) the renewable electricity from solar photovoltaic has to reach 136 TWh.

5.5 Biomass electricity

Biomass installed capacity in the EU deployed slower than planned in the aggregated NREAPs over period 2010-2015. The reported growth rate of biomass capacity in 2015 indexed vs 2010 figure was at nearly 39% compared with the planned 44%.

Until 2020 biomass capacity installation in the EU needs to be accelerated. The EU plans to reach a bioelectricity installed capacity of 43.7 GW by 2020, which is 9.1 % of the total renewable electricity expected to be installed. This trend will require an average annual increase of 2.8 GW in biomass installed capacity in the EU.

2016 data reported from IEA [32] on the capacity of biomass in electricity sector shows an increase by 29% between 2015 and 2016, a growth rate much higher than what is expected.

Table 20. Biomass installed capacity: 2010-2015 vs 2010 (left) & 2015-2020 vs 2015 (right)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Current	13.1%	25.5%	26.2%	33.7%	38.5%	17.9%	24.7%	31.8%	40.4%	48.5%
NREAPs	6.2%	14.5%	26.8%	35.3%	44.0%	6.2%	12.4%	18.8%	26.5%	33.8%

In 2020 bioelectricity use is expected to reach 233.2 TWh accounting for 19.3% of the expected final renewable electricity and 8.1% of expected final renewable energy in the EU. The picture on the expected growth rates of biomass until 2020 look different from the capacity one. Until 2015 the deployment of renewable electricity from biomass was slower than what was expected from the aggregated NREAPs. Using as a baseline the achieved level of 2015, that is larger than the planned one, the target growth rate is lower than the planned growth rate. By 2020 the growth rate expected indexed vs 2015 will be 31% whereas according to the aggregated NREAPs the planned growth rate is expected around 37%.

Table 21. Renewable electricity from biomass: 2010-2015 vs 2010 (left) & 2015-2020 vs 2015 (right)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Current	7.2%	19.8%	27.0%	35.1%	43.8%	1.4%	8.4%	15.4%	23.2%	31.1%
NREAPs	9.6%	19.4%	30.1%	39.8%	48.5%	6.3%	13.7%	21.0%	29.1%	37.4%

6 Overview of trends by scenario – the way towards 2030

The approach used in this section is to compare the estimated progress path of renewable energy technologies in the electricity sector as described in the PRIMES and PRIMES climate mitigation scenarios: (i) the Reference 2016 scenario, (ii) the EUCO27 scenario; (iii) the EUCO30 scenario, (iv) the EUCO3030 scenario and (v) the EUCO+40 scenario, used as official European Commission projections of energy and greenhouse gas emissions in the EU. The assessment also includes two scenarios produced using the global energy and GHG model JRC-POLES: (vi) the INDC scenario and (vii) the below 2 °C scenario.

All these scenarios assume that the EU reduced greenhouse gas emissions as stated in the 2030 energy and climate strategy and as committed in the COP21. The analysis included scenarios with different renewable electricity levels to make it possible to explore the extent to which aggregated renewable energy technologies can be used in the electricity sector. The scenario analysis does not prescribe a set of policy recommendations for renewable electricity generation in the EU; it presents an outlook for what renewable electricity is projected to look like in the future.

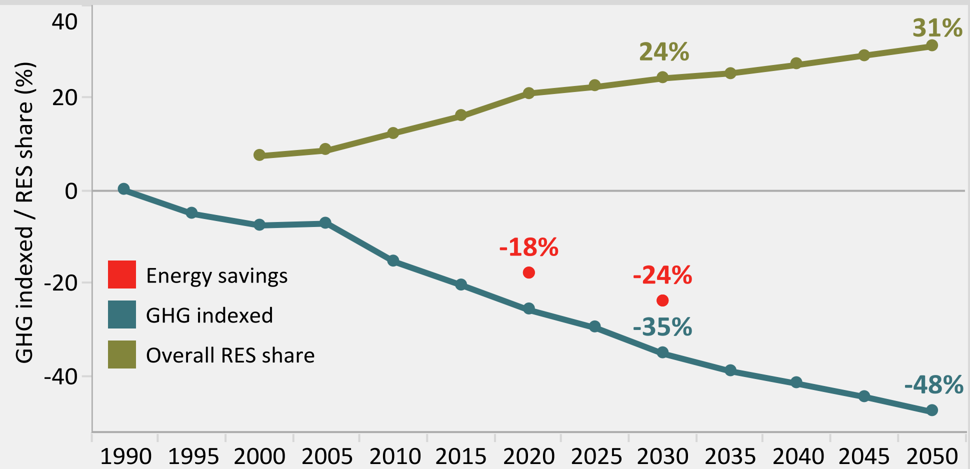
Box.2 The Reference scenario

The EU Reference Scenario 2016 (REF2016) is set up to meet the binding energy and climate targets for 2020. The Reference Scenario includes policies and measures adopted at EU level and in the Member States by December 2014. In addition, amendments to three Directives only agreed in the beginning of 2015 are also considered. This concerns the Indirect Land Use Change (ILUC) amendment to the Renewable Energy Directive (RED) and Fuel Quality Directive (FQD) and the Market Stability Reserve Decision amending the Emission Trading System Directive (ETS). This scenario shows that:

Current policies and market conditions will deliver neither our 2030 targets nor our long-term 2050 objective of a 80 to 95 % reduction in GHG emissions;

Based on current market trends and adopted policies, the energy efficiency 2020 non-binding target is not met in REF2016, with the scenario projecting a reduction in primary energy savings (relative to the 2007 baseline) of 18 % in 2020 and 24 % in 2030 respectively;

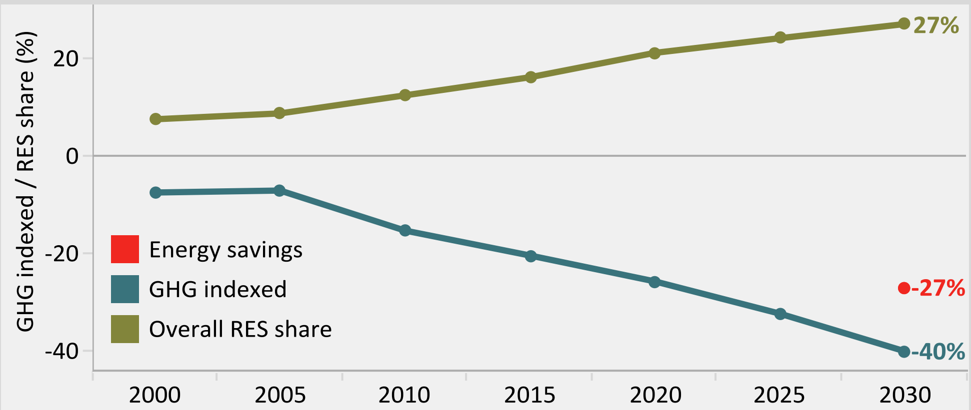
GHG emissions from sectors covered by the Effort Sharing Decision are projected to decrease by 16 % in 2020 and by 24 % in 2030 below 2005 levels, less than emissions in sectors covered by the EU emissions trading system.



Box. 3 The EUCO27 scenario

The EUCO27 scenario is one of the core policy scenarios reflecting the 2030 targets agreed by the European Council. This scenario is designed to meet all 2030 targets set by the European Council:

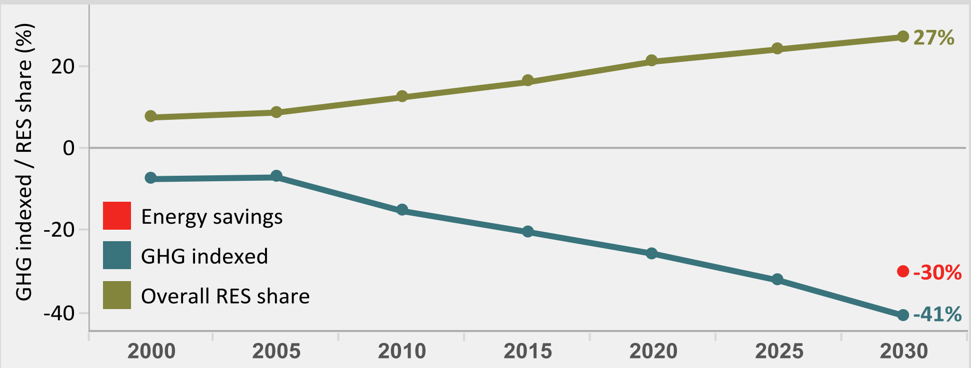
— at least a 40 % reduction in GHG emissions (relative to 1990 levels);
— a 43 % reduction in GHG emissions in ETS sectors (relative to 2005 levels);
— a 30 % reduction in GHG emissions in effort sharing sectors (relative to 2005 levels);
— at least a 27 % share from RES of final energy consumption;
— a 27 % reduction in primary energy consumption (i.e. achieving 1369 Mtoe in 2030) compared to the PRIMES 2007 baseline (1887 Mtoe in 2030). This equals a 20 % reduction of primary energy consumption compared to 2005 primary energy consumption (1713 Mtoe in 2005).



Box. 4 The EUCO30 scenario

A scenario that achieves:

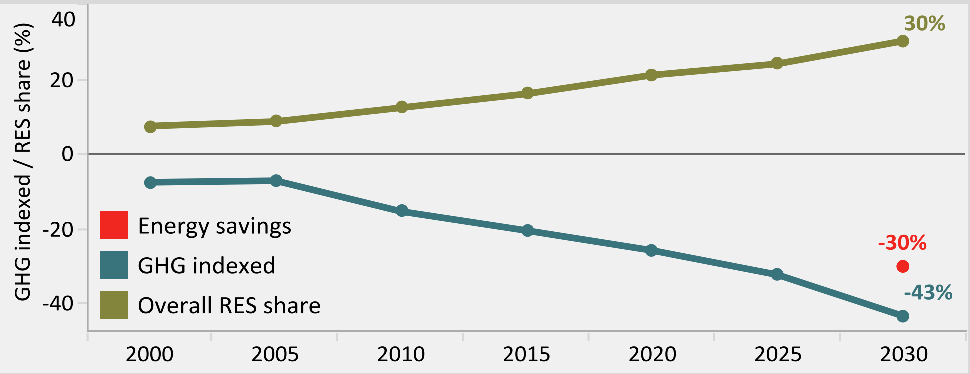
— at least a 40 % reduction in GHG emissions (relative to 1990 levels);
— a 43 % reduction in GHG emissions in ETS sectors (relative to 2005 levels);
— a 30 % reduction in GHG emissions in effort sharing sectors (relative to 2005 levels);
— at least a 27 % share from RES of final energy consumption;
— a 30 % reduction in primary energy consumption (i.e. 1321 Mtoe in 2030) compared to the PRIMES 2007 baseline (1887 Mtoe in 2030). This equals a 23 % reduction of primary energy consumption compared to 2005 primary energy consumption (1713 Mtoe in 2005).



Box. 5 The EUCO3030 scenario

The EUCO3030 sensitivity builds on the EUCO30 scenario with a 30 % energy efficiency target but also achieves a 30 % RES share:

— a 43 % reduction in GHG emissions (relative to 1990 levels);
— a 48 % reduction in GHG emissions in ETS sectors (relative to 2005 levels);
— a 31 % reduction in GHG emissions in effort sharing sectors (relative to 2005 levels).



Box. 6 The EUCO+40 scenario

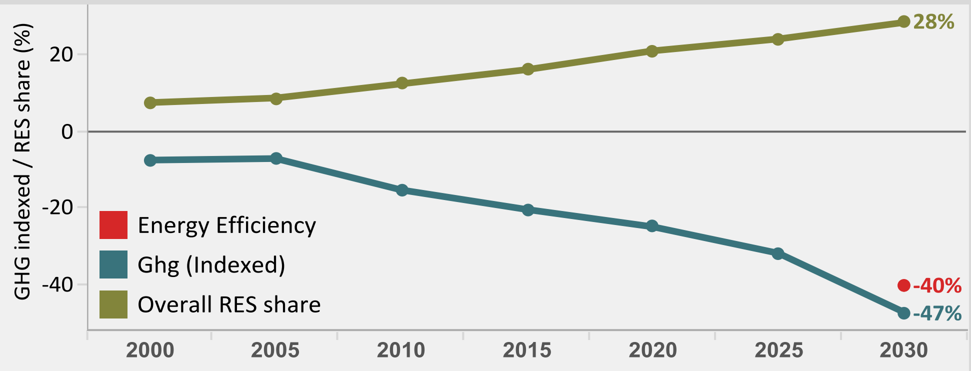
A 40 % primary energy consumption reduction target is set (i.e. achieving 1129 Mtoe in 2030) compared to the PRIMES 2007 baseline (1887 Mtoe in 2030). This equals a 34 % reduction of primary energy consumption compared to 2005 primary energy consumption (1713 Mtoe in 2005). As a result, all 2030 GHG targets set by the European Council are significantly overshot:

- a 47 % reduction in GHG emissions is achieved (relative to 1990 levels);

- a 48 % reduction in GHG emissions is achieved in ETS sectors (relative to 2005 levels);

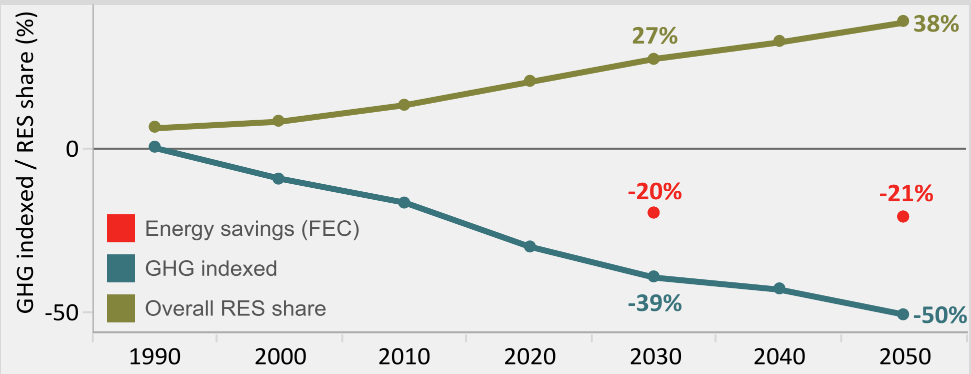
- a 39 % reduction in GHG emissions is achieved in effort sharing sectors (relative to 2005 levels);

Also, as a result of energy efficiency policies reducing demand, a 28 % RES share in final energy consumption is achieved.



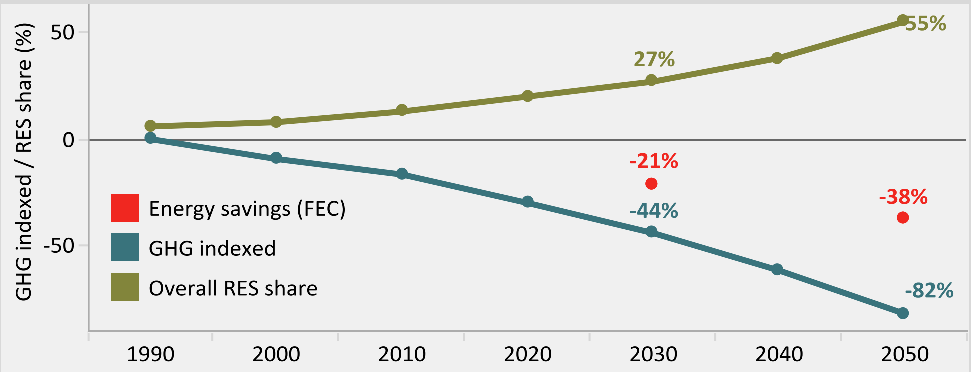
Box. 7 The INDC scenario

All Intended Nationally Determined Contributions (INDCs) are implemented, including all conditional contributions. Beyond 2030, regional carbon values increase, including for countries that previously had no climate policies, and progressively converge at a speed that depends on their per capita income. On average, world GHG intensity over 2030-2050 decreases at the same rate as for 2020-2030.



Box. 8 The below 2 degree scenario

This scenario assumes that the global GHG trajectory over 2010-2100 will be compatible with a likely chance of the temperature rise staying below 2 degree above pre-industrial levels. It assumes further intensification of energy and climate policies as of 2018, shown in the modelling through the increasing carbon value, and a progressive convergence of countries' carbon values after 2030 depending on their per capita income.



All scenarios are in line with the overall renewable energy share that the aggregated NREAPs expect to have achieved by 2020. For 2030, the Reference scenario projected a share of 24 %. In the EUCO3030 scenario the overall renewable energy share reaches 30 %. The EUCO+40 scenario projected a 28 % share of renewables by 2030. All other scenarios have projected an overall renewable energy share of 27 % by 2030.

Figure 37 illustrates the overall EU renewable energy shares planned/projected for 2020 and 2030 in the scenarios included in this analysis.

Figure 37. Projected overall renewable energy shares in the EU, 2020 & 2030

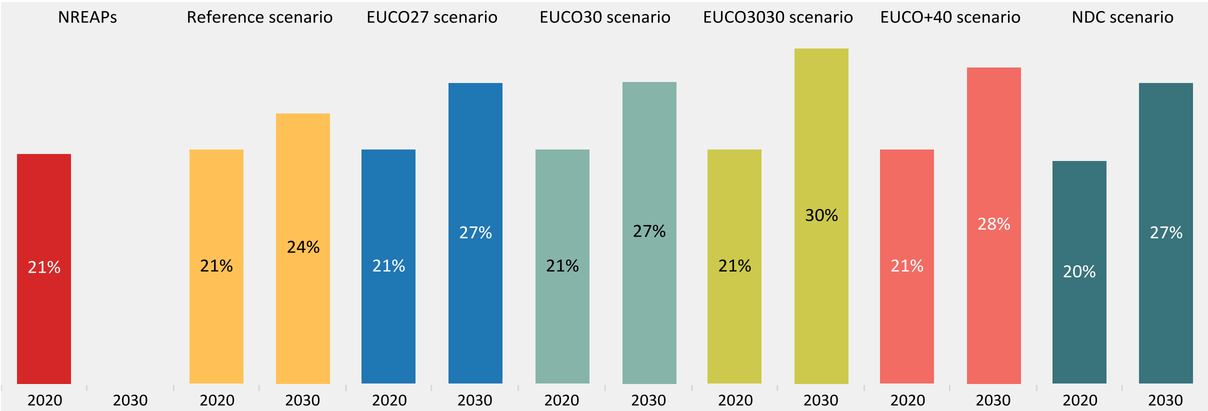
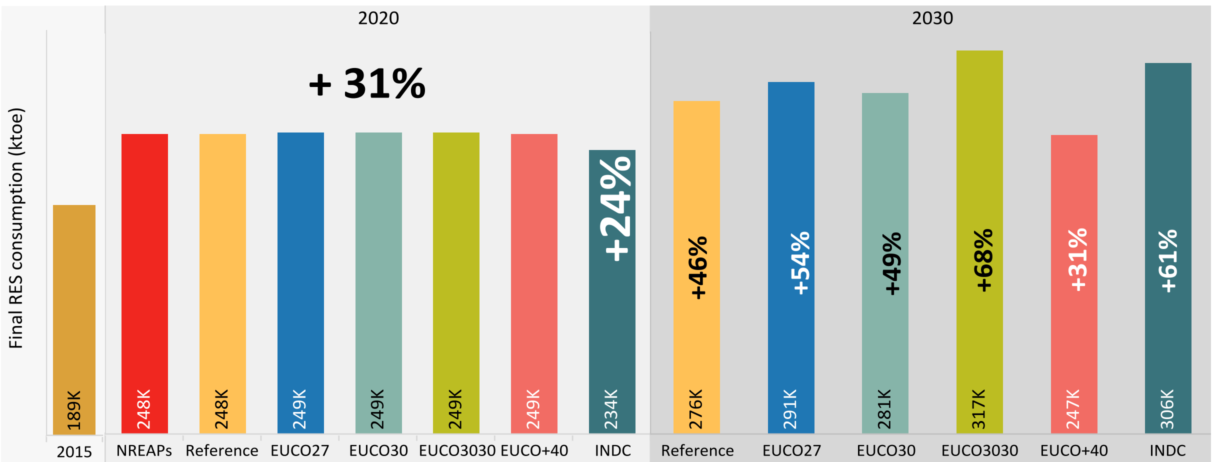


Figure 38 illustrates the projections of the final consumption of renewables made in the aggregated NREAPs and the seven scenarios. It also shows the required growth (in relative terms) in 2015-2020 and 2015-2030.

As shown in the figure, all PRIMES scenarios are in line with the 2020 final renewable energy consumption planned in the aggregated NREAPs, **249 Mtoe**. Achieving this target will require a *31 %* increase in final renewable energy consumption from the current level. This implies a *4-percentage-point* increase in the overall renewable energy share. The required deployment of renewables is projected to happen via an average *annual increase of 11.8 Mtoe* meanwhile the overall renewable energy share is projected to *increase by 0.8 percentage points each year*.

Figure 38. Projected final consumption of renewables in EU and the relative increase vs 2015, 2020 & 2030



The INDC and below 2 degree scenarios project a lower final consumption of renewables in 2020, **at 234 Mtoe**. This projection will require *a 24 %* increase in the EU's final energy consumption over 2015-2020.

For 2030, the scenarios project different levels of final renewable energy consumption in the EU. From among the scenarios that project a renewables share of 27 %, *the EUCO27, and the INDC scenarios* project the largest increases comparing with 2015, respectively *54%* and *61%* (Figure 36).

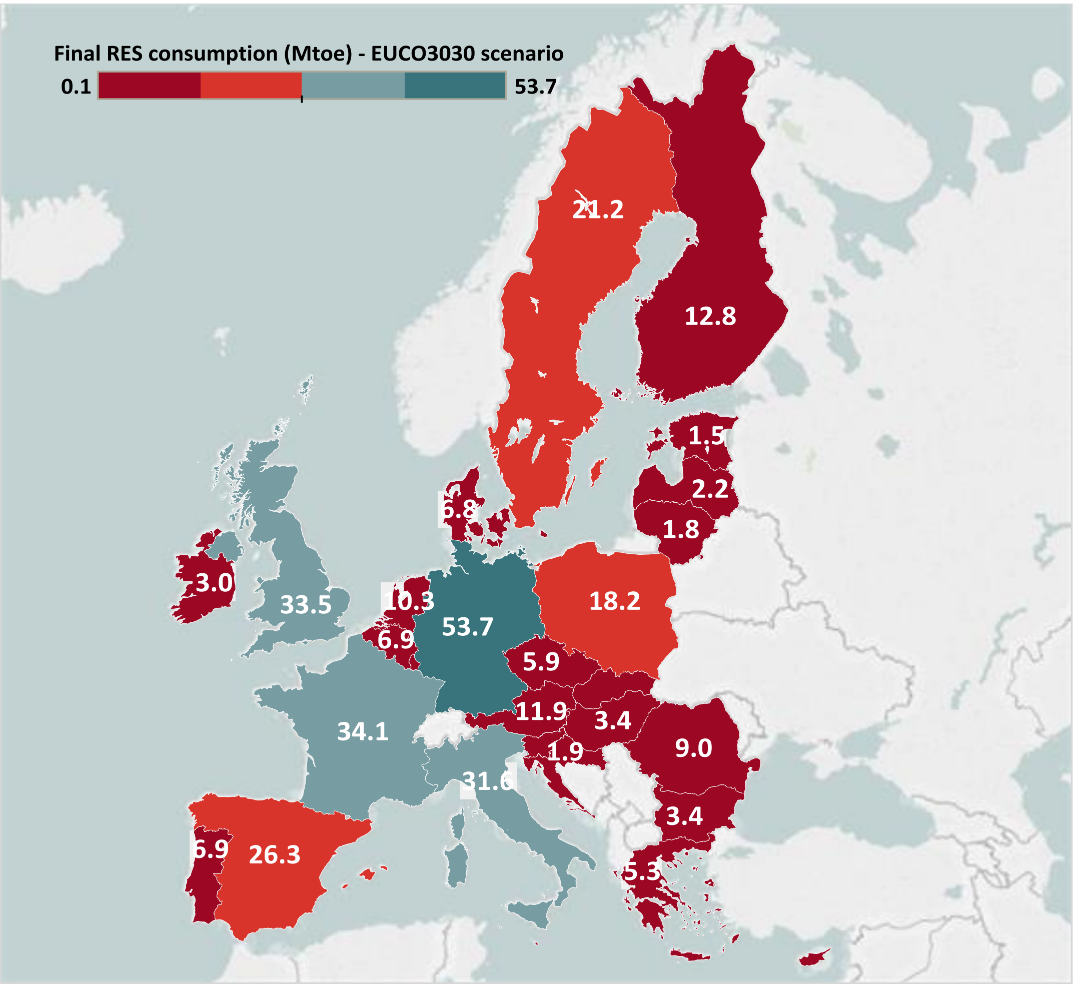
The increased role of energy savings in the EUCO30 scenario is reflected in the lowest increase projected for the final consumption of renewables in 2030, 49 %. This equals to a *3.4% drop* comparing with the final consumption of renewables projected in the EUCO27 scenario, meanwhile the final consumption of energy decreases by *4.3%.*

Comparing with current final consumption of renewables the EUCO3030 scenario projects a deployment that will implies an *increase by 68%* in 2030. Increasing the share of renewables from 27% to 30% when keeping unchanged the energy savings target, as in EUCO3030 scenario, requires an increase by *12.6%* of the final renewable energy consumption.

The EUCO+40 scenario projects almost the same figure as in 2020, at *247 Mtoe*. This reflects the impact that a higher energy efficiency target has in the deployment of renewables.

Figure 39 shows how the EUCO3030 scenario projects final consumption of renewable energy in 2030 across the EU. Germany is still expected to lead in terms of renewables consumption in the EU in 2030.

Figure 39. Projected final renewable energy consumption in EU countries, 2030 – EUCO3030 scenario

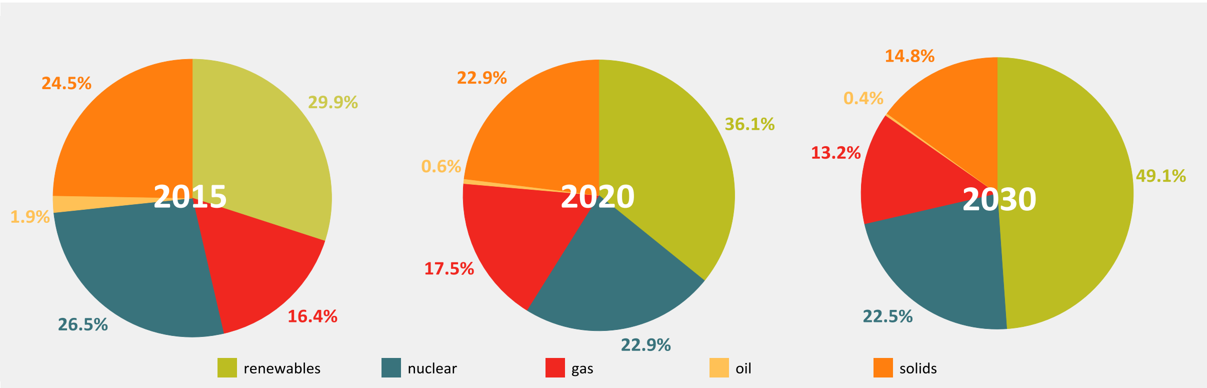


6.1 Decarbonisation of the EU electricity sector

Reducing greenhouse gas emissions in the EU requires the wide-scale deployment of renewables in the electricity sector. From a long-term perspective, this will require deep changes in the electricity system. Renewables accounted for nearly 40 % of the EU's electricity capacity in 2015. The share of renewables in gross electricity generation surpassed the contributions of each fossil fuel, reaching 29.9 %. Wind power is now the second largest source of electricity capacity in the EU, leaving behind both coal and lignite.

Figure 40 illustrates how the portfolio of gross electricity generation is projected to change under the EUCO30 scenario. As shown in the figure, reaching the 2030 targets (27% renewables and 30% energy efficiency) will require an increase by almost 20 percentage points the share of renewables in the projected EU gross electricity generation.

Figure 40. Current and projected gross electricity generation in EU, 2015 & 2020-2030 (EUCO30)



The projection shows that this increase will come mainly through the displacement of solid fuels — the proportion of electricity they provide is projected to have the largest drop in 2030 compared with 2015. All EUCO scenarios project a similar composition of the EU's gross electricity generation in 2020.

Table 22 shows the 2020 and 2030 absolute projections of gross electricity generation sources. To reach the 27% share of renewables with an energy efficiency target of 30%, wind power is projected to play the main role in the EUCO30 scenario. Its share is projected to *reach 20% of gross electricity generation* in this year. Towards the 30 % share of renewables with an energy savings of 30%, the share of wind is projected to reach *24 % of gross electricity generation*.

Table 22. Projected EU gross electricity generation broken down by sources (TWh), 2020 & 2030

	Reference scenario		EUCO27 scenario		EUCO30 scenario		EUCO3030 scenario		EUCO+40 scenario		INDC scenario	
	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
nuclear	773	778	773	775	773	769	773	724	773	691	847	863
wind	463	608	463	692	463	691	463	811	457	626	409	558
gas	581	655	590	565	589	449	589	358	571	310	475	597
solids	767	563	773	487	773	507	773	439	820	459	664	480
hydropower	376	379	376	380	376	380	376	382	376	378	387	386
solar	155	232	155	304	155	306	155	322	155	293	173	267
biomass & waste	213	283	214	298	215	289	215	308	215	258	235	327
oil	22	19	22	16	22	12	22	10	21	11	49	35
other res	8	10	8	10	8	10	8	10	8	10	59	107
Gross Electricity	3358	3528	3375	3526	3374	3413	3374	3365	3397	3035	3298	3620

The EUCO scenarios project the same figure for gross electricity consumption in 2020. The effect of the energy efficiency target in the EUCO30 scenario results in a difference of 3.2 % in the gross electricity generation compared with the EUCO27 scenario. The effect of the increase in both renewable energy and energy efficiency targets in the EUCO3030 scenario results in a difference of 4.6 % against the EUCO27 scenario and 1.4 % against the EUCO30 scenario. The INDC scenario projects for this year the lowest figure, at 3298 TWh.

Larger projected energy savings as in EUCO+40 scenario has no decreasing effect in the gross electricity generation for 2020 comparing with EUCO 30: it resulted 0.6% higher.

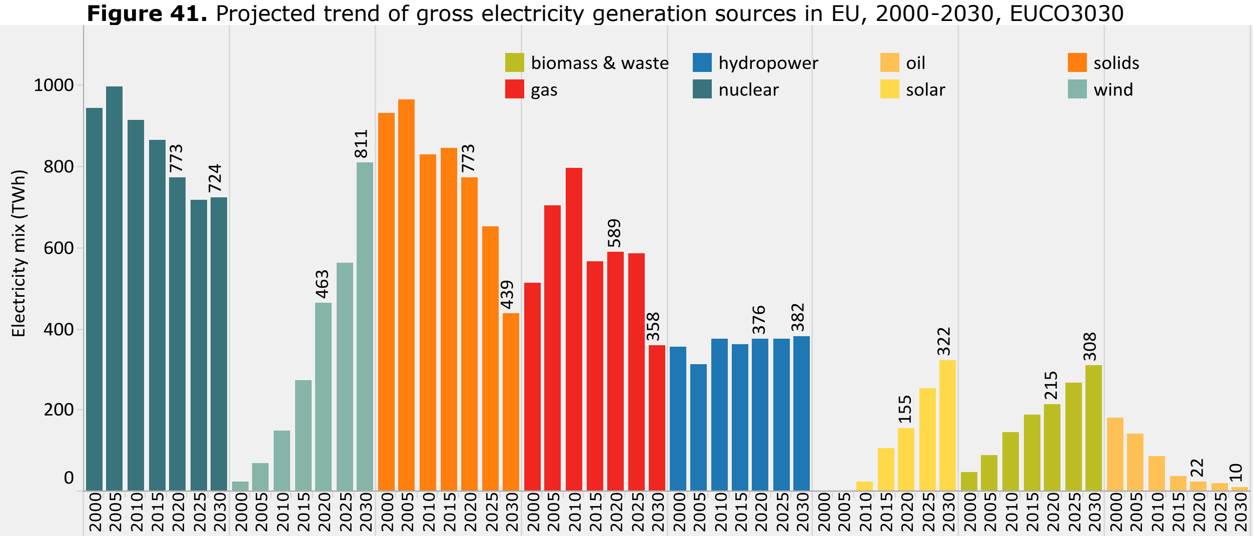
The EUCO27 and EUCO30 scenarios project that wind power will become the second largest source, with an almost 20 % share of gross electricity generation. The EUCO3030 scenario projects a higher share of gross electricity generation from wind power in 2030, at 24 %. In the INDC scenario, wind power is projected to be in third place in 2030.

The projections of the Reference and EUCO scenarios show that, together with solar photovoltaic, wind power will dominate electricity generation in the EU in 2030. The contribution of these two technologies taken together is projected to be lower than the contribution of nuclear power in the INDC scenario.

A higher renewable energy and energy efficiency target in the EUCO3030 scenario will bring a displacement of gas that is at least five times higher compared with the displacement projected in the Reference, EUCO27 and EUCO30 scenarios.

Figure 41 shows how the sources of gross electricity generation are projected to progress over the 2000-2030 period in the EUCO3030 scenario.

Figure 41. Projected trend of gross electricity generation sources in EU, 2000-2030, EUCO3030



The post-2020 deployment of renewable electricity from wind power technology in EUCO3030 scenario is projected to take place with an annual growth of almost 35 TWh (a rise of 75 %). A contribution of 155 TWh is expected from solar in 2020, an increase of 44 % (47 TWh) compared with the 2016 figure. By 2030, the deployment of this technology is projected to take place with an average annual growth of nearly 17 TWh.

Figure 42 illustrates the breakdown by source of the electricity capacity and generation in the EU in 2030 according to INDC scenario. As shown in this figure in the INDC scenario wind and gas are projected to be increasing the most their contributions in the EU gross electricity generation after 2020. By 2030 renewables are projected to account for more than 54% of the electricity capacity and more than 42% of gross electricity generation.

Figure 42. Electricity capacity and gross electricity generation broken down by source, 2030 – INDC scenario

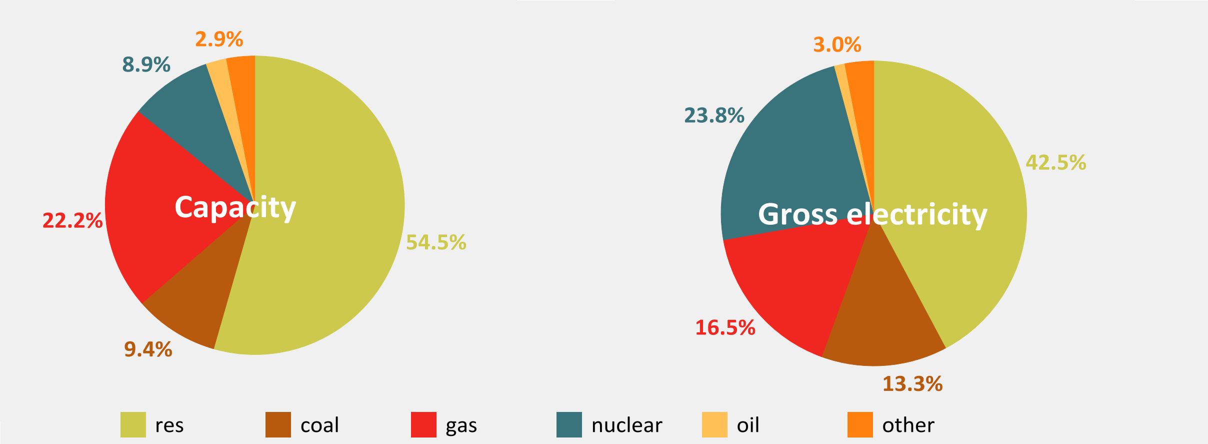
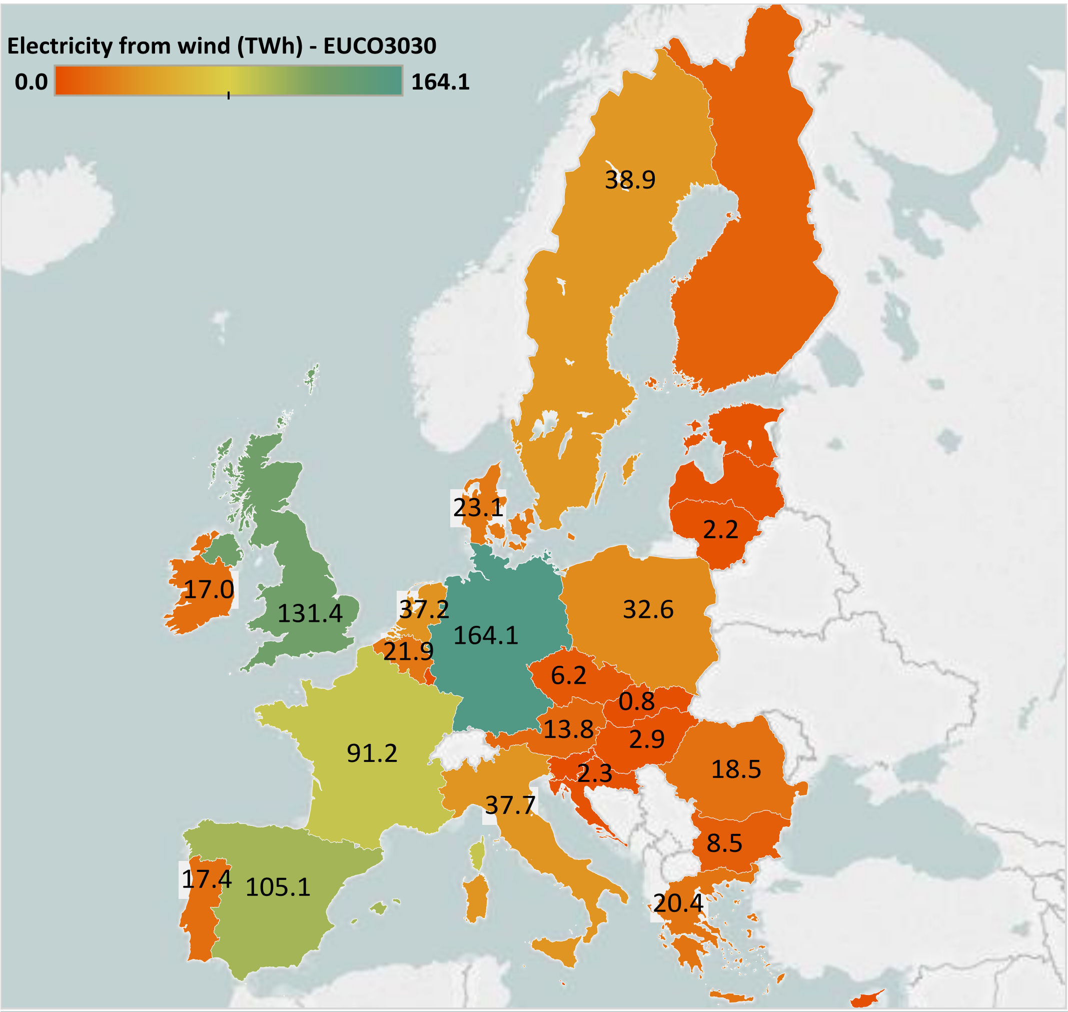


Figure 43 illustrates the projected electricity generation from wind power in EU countries in 2030 according to EUCO3030 scenario. Germany is projected to cover one-fifth of the renewable electricity from wind technology in 2030 increasing with a CAGR of 5.4% since 2016. The fastest increase needs to happen in Czech Republic (CAGR of 16.6%), Latvia (CAGR of 12.8%), Finland (CAGR of 11.5%) and Sweden (CAGR of 10.7%).

Figure 43. Projected electricity from wind power in EU countries, 2030 (TWh) – EUCO3030

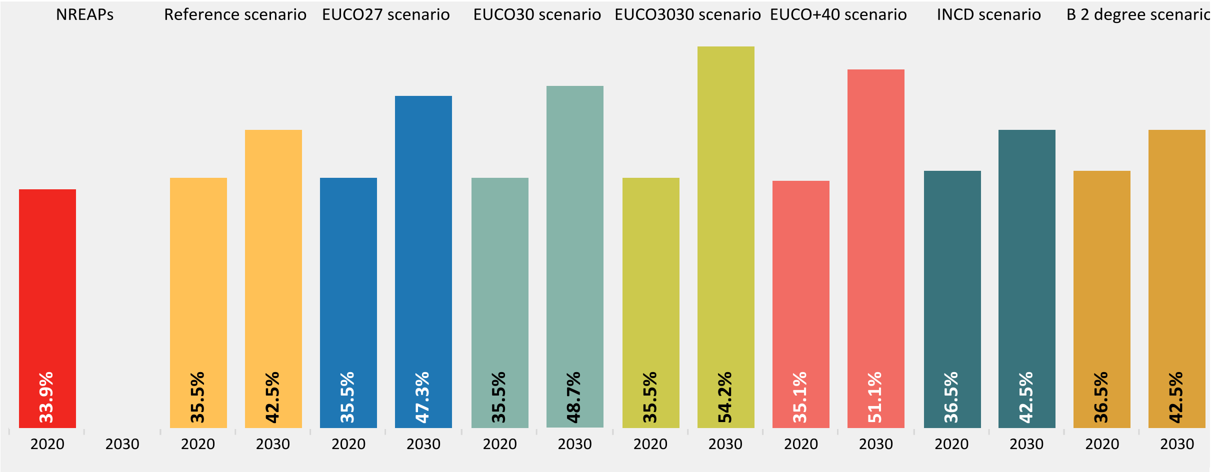


6.2 Projected renewable electricity

The 27 % target for the overall renewable energy share in the Reference scenario is projected to correspond to 42.5 % of gross final electricity consumption being supplied by renewables in 2030.

Figure 44 illustrates the projected share of renewable energy in electricity sectors in seven scenarios under analysis. As shown in this figure, compared with the 34 % share expected in the NREAPs, all scenarios project a higher share of renewables in the electricity sector, at 35.5 % in the Reference and EUCO scenarios and 36.5 % in the INDC and below 2 degree scenarios. The EUCO scenarios projected higher shares of renewable energy in the electricity sector by 2030 compared with the reference scenario: (i) 47.3 % in the EUCO27 scenario; (ii) 48.7 % in the EUCO30 scenario. The share of renewable energy in the electricity sector projected by the other two scenarios is slightly lower than in the Reference scenario, at 42.5%.

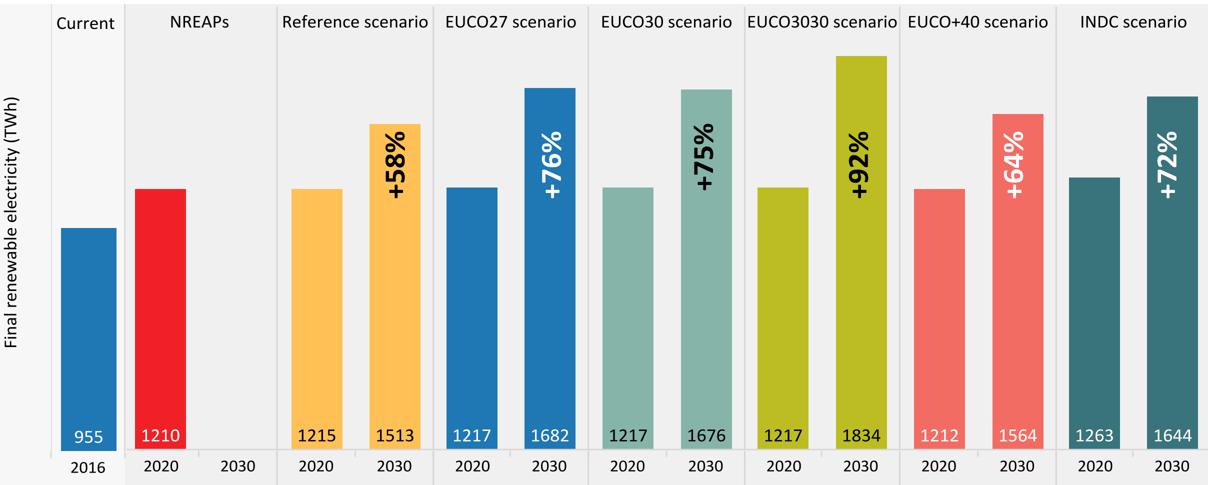
Figure 44. Projected renewable electricity share in the EU in 7 scenarios, 2020 & 2030



To reach its target of a 30 % share of renewable energy, the EU needs to reach **a share of 54.2 % in gross final electricity consumption** as projected in the EUCO3030 scenario, almost double of current share.

Figure 45 shows the planned/projected final renewable electricity consumption in the EU in 2020 and 2030, according to the scenarios under analysis.

Figure 45. Projected final renewable electricity consumption in the EU, 2020 & 2030 – the increase vs 2016



As shown in the figure, based on the aggregated NREAPs, final EU renewable electricity consumption in 2020 is expected to reach 1210 TWh. All scenarios in this analysis are in line with the aggregated NREAPs figure for 2020, projecting final renewable electricity consumption in the EU at 1217 TWh (EUCO scenarios) and 1208 TWh (INDC and 2 degree scenarios).

The EUCO27 and EUCO30 scenarios project a 38 % increase by 2030, compared with the planned/projected 2020 figures. The INDC and the 2 degree scenarios project a 36 % increase. The EUCO3030 scenario projects that a 51 % increase in final EU renewable electricity is needed to reach the 30 % overall renewable energy target in 2030.

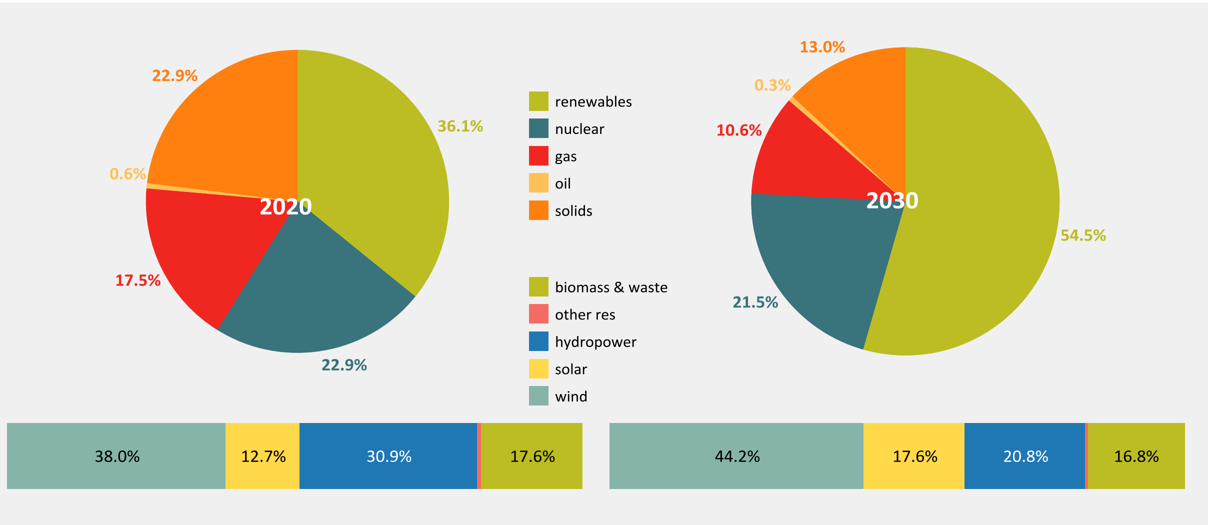
Table 23 illustrates the projected renewable electricity consumption broken down by source in 2020 and 2030 according the aggregated NREAPs[12] and the scenarios under this analysis. The projected 2020 renewable electricity technologies shares are found almost the same in all PRIMES EUCO scenarios. The INDC scenario projects a slightly different composition of final renewable electricity in 2020 with higher shares of solar and biomass & waste. The INDC scenario projects lower shares of wind power in 2030 compared with PRIMES EUCO scenarios. The highest share of solar in renewable electricity is projected in EUCO+40 scenario even that in absolute terms the projected contribution of solar technology is lower than in EUCO scenarios.

Table 23. Projected renewable electricity consumption broken down by source, 2020 & 2030

	NREAPs	Reference scenario		EUCO27 scenario		EUCO30 scenario		EUCO3030 scenario		EUCO+40 scenario		INDC scenario	
	2020	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
wind	40.4%	38.1%	40.2%	38.1%	41.1%	38.0%	41.0%	38.0%	44.2%	38.0%	40.0%	34.0%	36.3%
hydropower	30.5%	30.9%	25.1%	30.9%	22.6%	31.0%	23.0%	30.9%	20.8%	31.0%	24.0%	32.1%	25.1%
solar	8.4%	12.7%	15.3%	12.7%	18.0%	13.0%	18.0%	12.7%	17.6%	13.0%	19.0%	14.4%	17.4%
biomass	19.3%	17.5%	18.7%	17.6%	17.7%	18.0%	17.0%	17.6%	16.8%	18.0%	16.0%	19.5%	21.3%
other res	1.0%	0.7%	0.6%	0.7%	0.6%	1.0%	1.0%	0.7%	0.5%	1.0%	1.0%		

Figure 46 illustrates the projected contributions of different gross electricity generation and renewable electricity sources in 2020 and 2030, based on the EUCO3030 scenario. The EUCO3030 scenario projects a significant increase in the share of renewables in gross final electricity consumption, from 36 % in 2020 to almost 55 %[13] in 2030.

Figure 46. Electricity generation and renewable electricity broken down by source, 2020 & 2030 – EUCO3030



(12) The 2020 shares according to aggregated NREAPs are presented in this table for comparative purposes.
(13) The shares of renewables calculated towards gross electricity generation differs slightly from the shares presented in Figure 44 that shows the shares of renewables in gross final electricity consumption.

This scenario projects that wind power will contribute around 38 % of final renewable electricity in 2020. This figure is projected to increase to 44 % by 2030. The contribution of solar technology is projected to be around 18 %. Hydropower share is projected to drop by 10 percentage points. The scenario also projects a drop in biomass share in the 2020-2030 period, from 17.6 % to 16.8 %.

Figure 47 illustrates the projections of electricity generation from solar technology in each EU countries in 2030 according to EUCO3030 scenario.

Figure 47. Projected electricity from solar technology in EU countries, 2030 (TWh) – EUCO3030

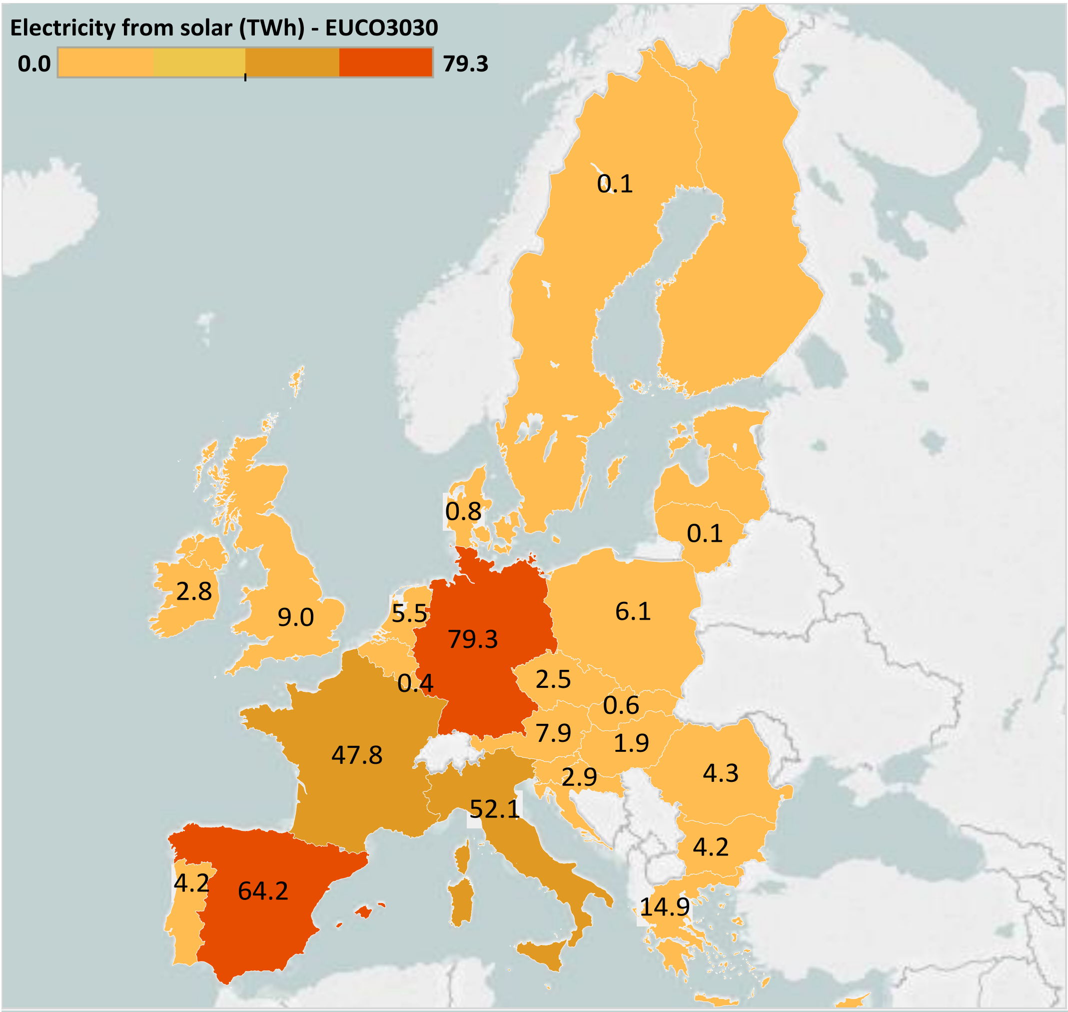
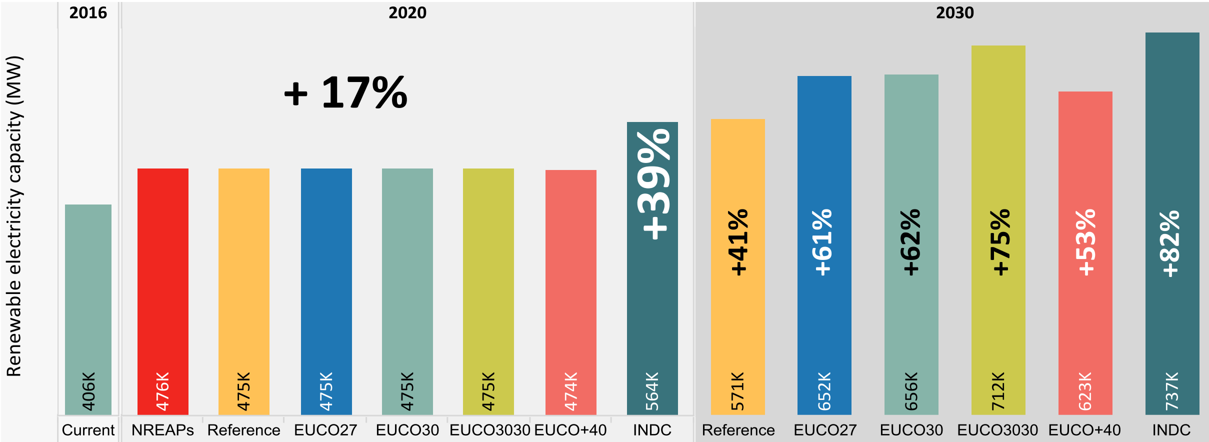


Figure 48 shows the planned/projected renewable electricity capacity in 2020 and 2030 compared with current capacity installed in the EU. As shown in the figure, the Reference and EUCO scenarios are in line with NREAP plans for 2020. They project an installed capacity[14] of 475 GW from renewables in 2020. In relative terms, the EU needs to increase its current renewable electricity installed capacity by 17 %. The INDC scenario projects that the EU needs to install more renewables by 2020 in order to reach its target for this year. A projected 39 % increase is required from the current capacity. Reaching the 27 % target by 2030 will require significant growth in the EU's renewable electricity capacity: a 41 % increase is projected in the Reference scenario; a 61 % increase in the EUCO27 scenario; a 62 % increase in the EUCO30 scenario; a 53% increase in the

(14) The 2020 average load factors of net power capacity is projected at 35.5 % in the Reference and EUCO scenarios. In 2030, this factor is projected at: 36.5 % in the Reference scenario; 34.3 % in the EUCO27 scenario; 33.3 % in the EUCO30 scenario; and 32 % in the EUCO3030 scenario.

EUCO+40 scenario and an 82 % more in the INDC scenario. To reach its 30 % target in 2030, the EU will need an increase in its current installed capacity of *75 %.*

Figure 48. Projected renewable electricity capacity in EU, 2020 & 2030



The fast increase in solar photovoltaic capacity is changing the relative contributions of renewable technologies/sources to the final renewable electricity installed capacity planned for 2020. Of the capacity planned in the aggregated NREAPs in 2020, wind power is expected to account for 44.3%, hydropower 26.7%, solar 19%, biomass 9.2%, marine 0.5% and geothermal 0.3%.

Table 24. Projected shares of renewable energy technologies in renewable electricity capacity, 2020 & 2030

	NREAPs	Reference scenario		EUCO27 scenario		EUCO30 scenario		EUCO3030 scenario		EUCO+40 scenario		INDC scenario	
	2020	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
wind	44.3%	43.6%	44.8%	43.6%	43.5%	43.6%	43.4%	43.6%	45.6%	43.40	42.17	34.2%	35.5%
solar	19.0%	28.6%	31.7%	28.6%	35.9%	28.6%	36.1%	28.6%	35.5%	28.71	36.31	26.2%	31.3%
hydropower	26.7%	27.7%	23.3%	27.7%	20.4%	27.7%	20.3%	27.7%	18.8%	27.78	21.35	27.5%	21.2%
other res	10.0%	0.1%	0.2%	0.1%	0.2%	0.1%	0.2%	0.1%	0.1%	0.10	0.17	12.1%	11.9%

The Reference and EUCO scenarios are broadly in line with the aggregated NREAPs. They project the wind power as the main source of renewable electricity capacity in 2020, at 43.6%. The INDC scenario also project wind power as the main source. But this scenario projects a lower share of wind power, at 34.2%, lower even than in the aggregated NREAPs.

The contribution projected in PRIMES EUCO scenarios for solar technology in 2020 are higher than what is planned in the aggregated NREAPs, at around 28%. The INDC scenario projects a share slightly lower, at 26%. The share of hydropower projected in all scenarios is in line with the aggregated NREAPs, at around 27% in 2020. The contribution of other renewable technologies (biomass, geothermal and marine) is very marginal in the PRIMES EUCO scenarios, whereas the INDC scenario projects a contribution at around 12% broadly in line with the aggregated NREAPs.

Towards the 2030 target the PRIMES EUCO projections rely mostly in the deployment of solar technology. Its share in final renewable electricity capacity is projected to reach at least 36%. In meanwhile the share of wind remains almost unchanged.

Table 25 shows the growth rate needed to reach the EU 2020 plans for solar and wind technologies installed capacities compared with their current levels. As shown in the table PRIMES scenarios project growth rates by 30% and 34% respectively for solar and wind technologies. The INDC scenario projects a higher growth rate for solar photovoltaic (41%) and a lower growth rate for wind (25%) for period 2016-2020. Between 2020 and

2030 a growth rate of 86% is projected for solar photovoltaic capacity under EUCO3030 scenario.

Table 25. Projected growth rate for solar and wind installed capacities in the EU, 2016-2030

	2016-2020						2020-2030					
	Reference	EUCO27	EUCO30	EUCO3030	EUCO+40	INDC	Reference	EUCO27	EUCO30	EUCO3030	EUCO+40	INDC
solar PV	+30%	+30%	+30%	+30%	+30%	+41%	+33%	+72%	+74%	+86%	+66%	+56%
wind	+34%	+34%	+34%	+34%	+34%	+25%	+23%	+37%	+38%	+57%	+28%	+36%

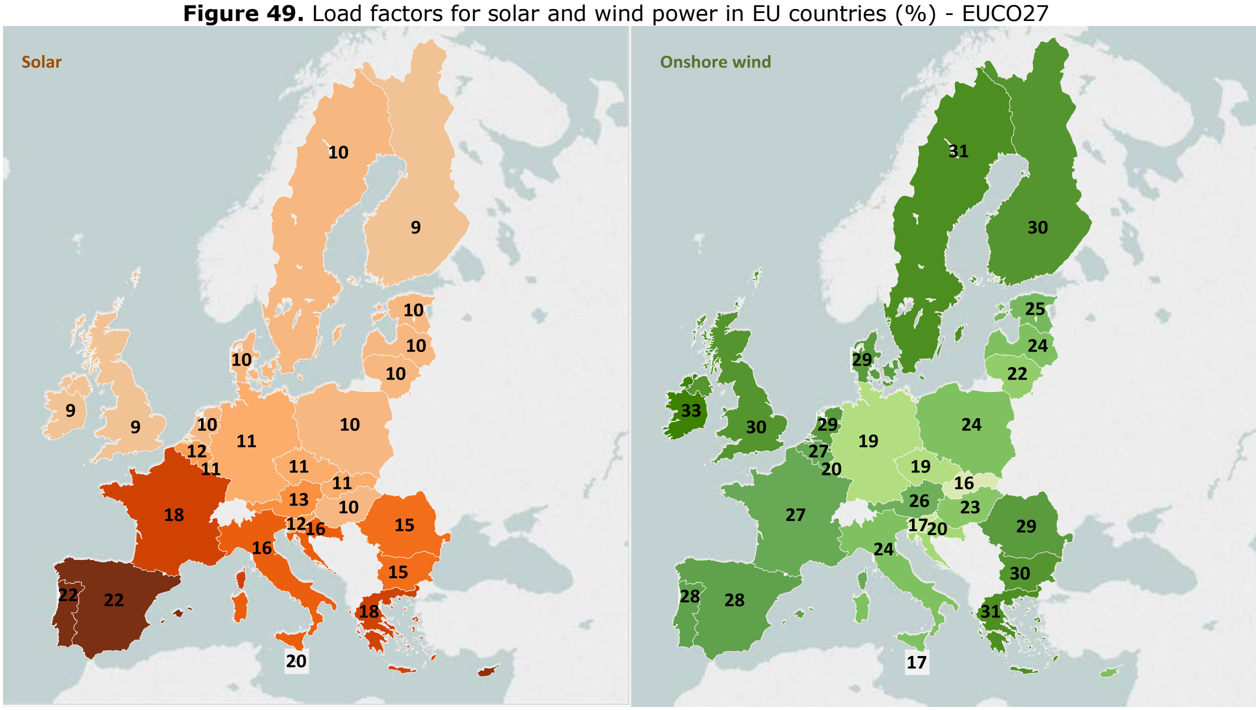
Table 26 illustrates the average load factors of net generation capacity used in PRIMES EUCO scenarios. Up to 2020 the Reference and EUCO+40 scenarios apply different load factors on the net generation capacities. Post 2020 the applied load factors of net generation capacity are different in all PRIMES EUCO scenarios.

Table 26. Average load factors of net generation capacity (%)

	2000	2005	2010	2015	2020	2025	2030
Reference scenario	47.50	48.14	42.12	36.53	35.53	36.62	36.54
EUCO27 scenario	47.50	48.10	42.10	36.50	35.60	35.20	34.30
EUCO30 scenario	47.50	48.10	42.10	36.50	35.60	35.10	33.30
EUCO3030 scenario	47.50	48.10	42.10	36.50	35.60	35.20	31.50
EUCO+40 scenario	47.50	48.10	42.10	36.50	35.90	36.20	30.90

Figure 49 shows how the EUCO27 scenario projects the load factors for solar and onshore wind net generation capacities.

Figure 49. Load factors for solar and wind power in EU countries (%) - EUCO27



6.3 Prices and costs

The EU modelling results play an important role in the analysis of costs and effects of specific proposals. The EU electricity market is constantly changing. The electricity price trend in the run up to 2020 will align with future market price trends. The expected trend for prices and costs between now and 2030 is based on two sets of modelling: (i) Reference and EUCO scenarios and (ii) INDC and below 2 degree scenarios.

A lot has changed since the EU's publication of the Reference and EUCO scenarios. The rapid deployment of renewable technologies has been accompanied by a significant drop in their costs. These changes are not reflected in the models, which project higher costs of electricity generation.

Figure 50 illustrates how the Reference scenario projected the trend of LCOE for onshore & offshore wind and solar PV over period 2010-2050. Comparing with the current levels of LCOE achieved by these technologies the projections results much higher[15].

Figure 50. LCOE for onshore wind, offshore wind and solar PV, Reference scenario, 2010-2050

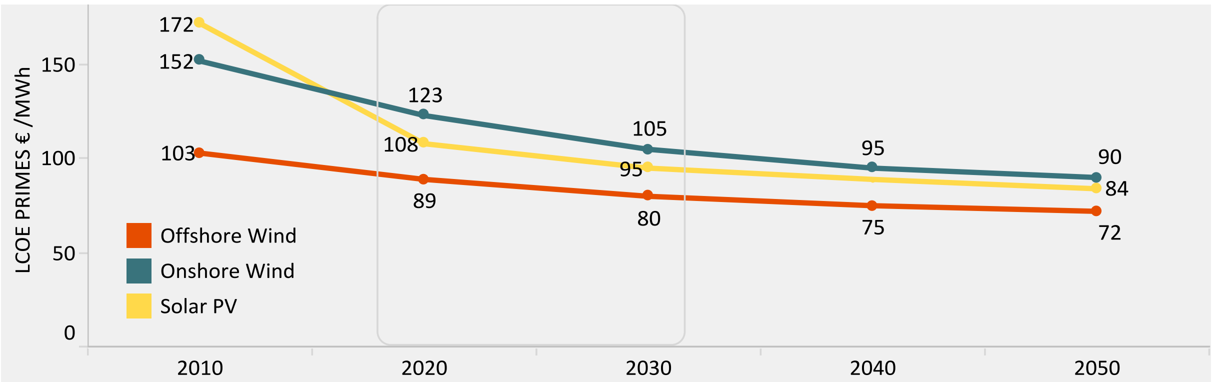
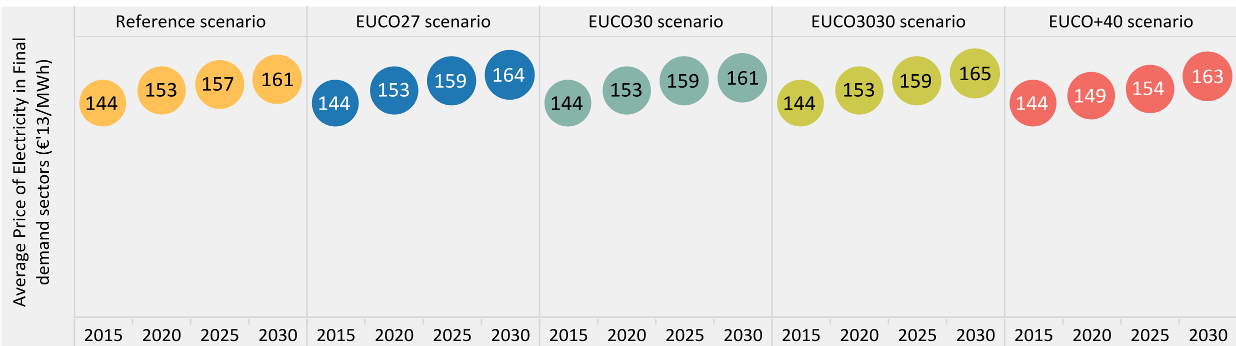


Figure 51 illustrates the projected trend for the average price of electricity according to Reference and EUCO scenarios. As shown in the figure on average, the prices of electricity in the EUCO scenarios do not increase in 2030 compared to the Reference projection. The projections shown here do not envisage significant pressure on electricity prices in the medium term, but prices are likely to significantly increase in the long term. The projection of rising electricity prices in the long term is mainly due to the increasing costs of grids, smart systems and system services. The projections overestimated by a factor larger than 3 the 2015 averaged price of electricity in the EU.

Figure 51. Projected average price of electricity in final demand sectors, 2015-2030



([15]) See section 3 to compare these LCOE with current auction results for onshore & offshore wind and solar PV.

Figure 52 illustrates the average price of electricity in final demand sectors in each EU country in 2030 as projected in EUCO3030 scenario.

Figure 52. Average price of electricity in final demand sectors in EU countries, 2030 – EUCO3030

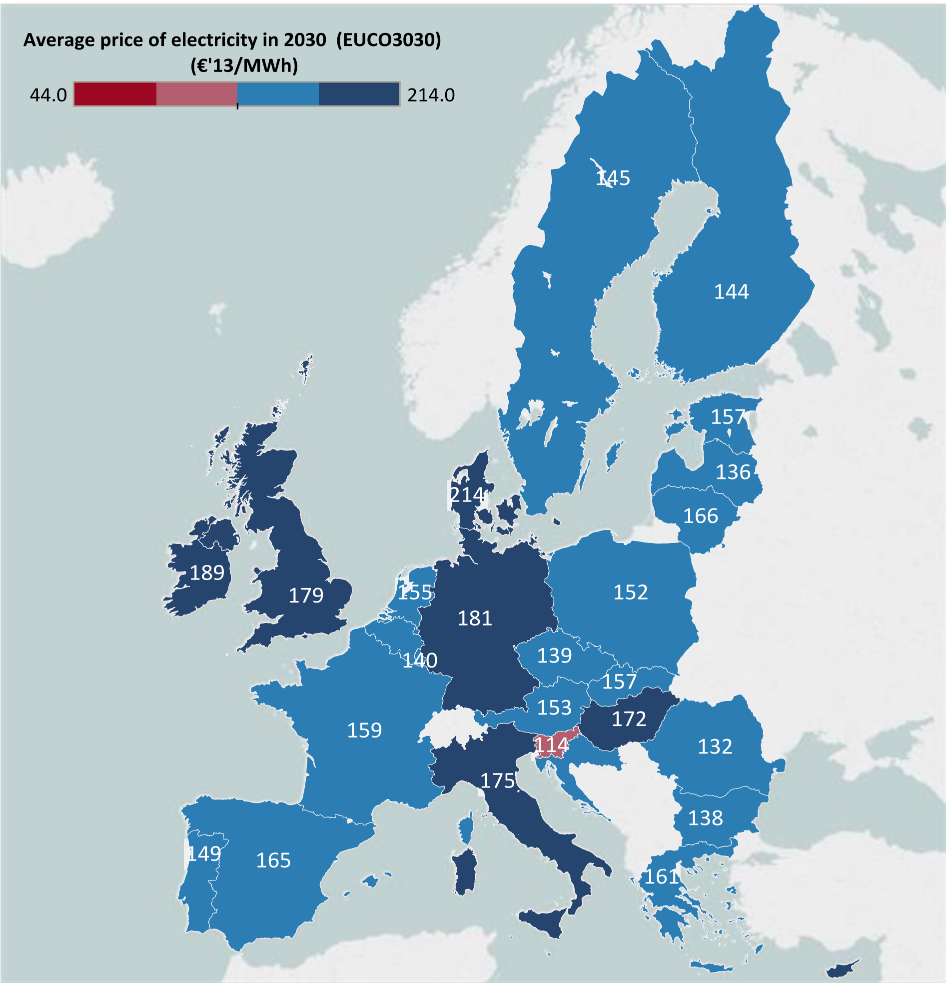


Figure 53 illustrates the average cost of electricity generation in the EU in the Reference and EUCO scenarios. As shown in the figure, the average cost of electricity generation for a scenario that projects a share of renewables of 27 % is almost the same as for a scenario that projects a share of 30 %.

Figure 53. Projected average costs of electricity generation in EU, 2015 -2030

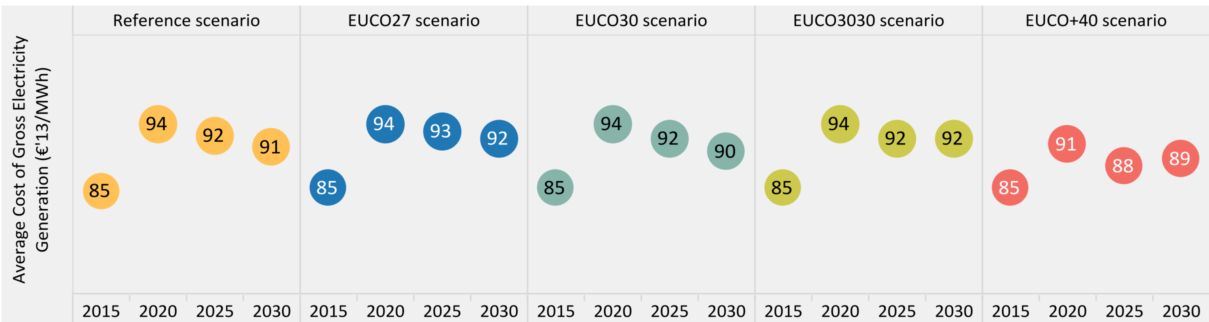


Figure 54 shows the projected annual costs incurred for energy services of end-users including annualised capital costs, variable and fuel costs in the EU for period 2015-2030. Investment expenditure is likely to considerably increase in 2020-2030 and beyond. Moderate increases in 2030 total costs relative to the Reference scenario are expected in

EUCO30 and EUCO3030. There is a considerable increase in investment expected in the demand sectors when energy efficiency ambition increases. Rapid technology progress can offset the increase in energy costs in the long term. The increase of only energy efficiency target keeping almost unchanged the renewable energy target results to an increase of the energy costs (EUCO+40 scenario).

Figure 54. Projected energy related and other mitigation costs in EU, 2015 - 2030[16]

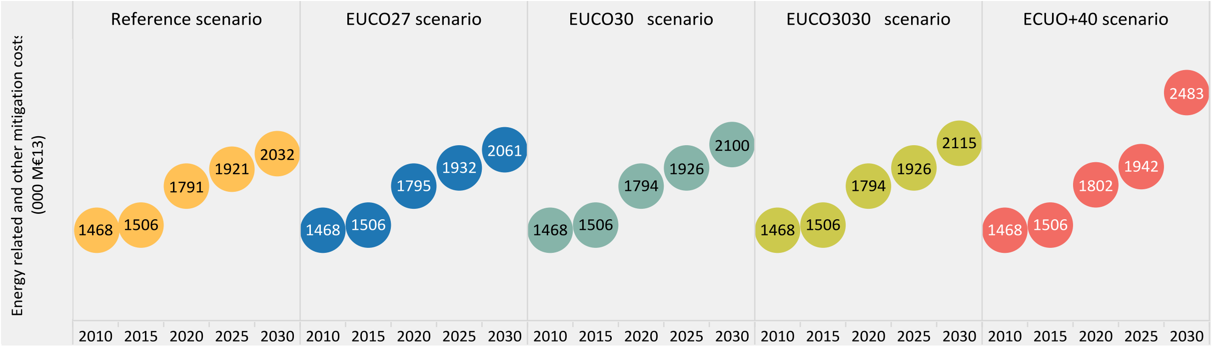
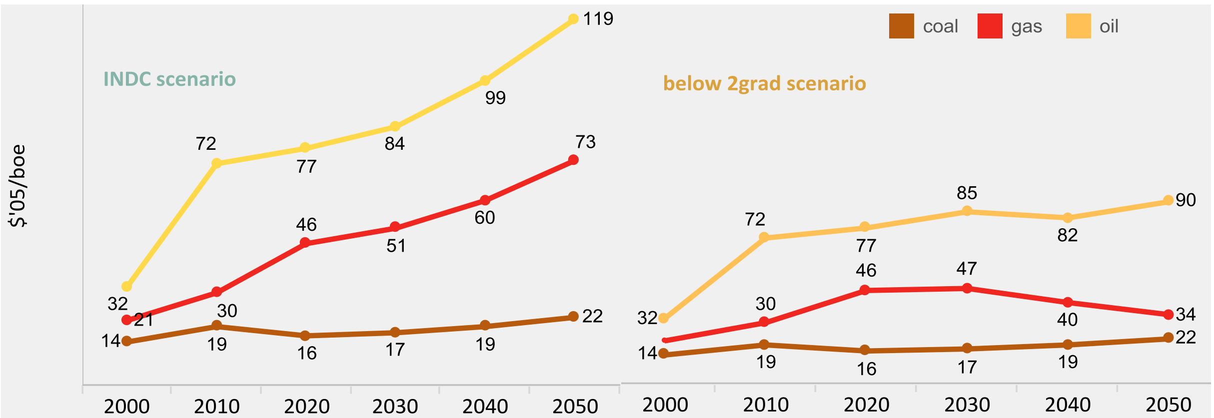


Figure 55 shows how the prices of coal, oil and gas are projected under the INDC scenario. Until 2020 there are no differences between these 2 scenarios. After 2020 the coal prices follows the same trend in both scenarios. The oil prices increase by 42% in the INDC scenario comparing with the below 2 degree scenario. Gas prices projections follow a different trend after 2020: they are increasing in the INDC scenario whereas decreasing in the below 2 degree scenario. Gas prices are projected to rise strongly in the short term, but decouple from oil prices after 2030.

Figure 55. Projected coal, oil and gas prices, INDC & below 2 degree scenarios



(16) The EUCO scenarios apply a flat-rate value for the capital costs at 7.5% for all EU countries.

Data sources

This report makes use of the following data sources to complete the statistics on renewable energy technologies for 2016.

Data Sources	Description
Directorate for Energy, Transport and Climate, Joint Research Centre, European Commission **http://iet.jrc.ec.europa.eu/remea/national-renewable-energy-action-plans-nreaps**	Database of NREAPs and progress reports of the EU Member States' established by the Energy Efficiency and Renewables Unit
Eurostat **http://ec.europa.eu/eurostat/web/energy/data/shares**	SHARES TOOL, Patents on climate mitigation and renewable technologies
IEA https://www.iea.org/publications/renewables2017/	Market Report Series - Renewables 2017
BP https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html	Statistical Review of World Energy June 2017
ENTSO-e **https://www.entsoe.eu/data/statistics/Pages/default.aspx**	2016 Electricity data
IRENA http://resourceirena.irena.org/gateway/#	LCOE for renewable technologies (2010-2016)

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List of abbreviations and units

EU – European Union

ETS – Emission Trading System

GW – Gigawatt

GWh – Gigawatt-hour

H/C – Heating /cooling sector

ktoe – kilo-tonnes oil equivalent

Mtoe – Mega-tonnes oil equivalent

MS – Member States

NREAPs – National renewable energy action plans

PR – Renewable Energy Progress Reports

PV – Solar photovoltaic

PJ – Petajoule

RES – Renewable Energy Sources

RES-H/C- Renewable Energy Sources in Heating/Cooling sector

RES-E – Renewable Energy Sources in Electricity sector

RES-T – Renewable Energy Sources in Transport sector

SHARES - SHort Assessment of Renewable Energy Sources

TWh- Terrawatt-hour

Units

1 Mtoe = 41.868 PJ = 11.63 TWh

1 ktoe = 41.868 TJ = 11.63 GWh

1 PJ = 0.278 TWh = 0.024 Mtoe

1 TWh = 3.6 PJ = 0.086 Mtoe

1 TJ = 277.8 MWh

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