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# Renewable energy in Europe — 2018

## Recent growth and knock-on effects

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# Executive summary

This report outlines the progress made in 2016 in the deployment of renewable energy sources (RES) in the European Union (EU) as a whole, and at country, market sector and technology level. It also provides early European Environment Agency (EEA) estimates for these developments in 2017.

The report confirms that the EU's RES share remained in line with the indicative trajectory designed to lead to achieving the mandatory EU RES targets for 2020: a 20 % RES share of energy consumption and the 10 % RES sub-target for transport. However, to meet these targets with certainty will require further efforts to deploy renewable sources of energy across the EU, especially in the context of recent increases in final energy consumption in some EU Member States.

The report also shows that the additional consumption of RES across Europe since 2005 has had a number of co-benefits: it allowed the EU to cut its demand for fossil fuels and their associated greenhouse gas (GHG) emissions by about one tenth, compared with a situation in which renewables would have remained at 2005 levels.

Taking a global perspective, the speed at which the EU has transformed its energy resource base between 2005 and 2016 has outpaced that of other world regions. However, while the EU is still the worldwide leader in terms of renewable power capacity per capita, it is now being surpassed by other world regions in terms of RES deployment.

## Renewable energy sources are playing a significant role in the EU's energy mix

RES are a major contributor to the transition of Europe's energy sector. The rapid development of some renewable energy technologies  has already allowed these technologies to achieve high market shares. Today, for solar photovoltaic (PV) electricity, biogas electricity and solid biomass use for heating and cooling, these shares are at, or close to, the 2020 levels anticipated by countries in their national renewable energy action plans (NREAPs), drafted in 2010.

In 2017, renewable energy again accounted for the overwhelming majority (85 %) of new EU electricity-generating capacity. Moreover, the EU continues to decommission more capacity from conventional sources than it installs. This has led to GHG emission reductions in the EU electricity sector, in the consumption of energy for heating and cooling, and, to a lesser extent, in transport.

## Recent increases in final energy consumption in some Member States are slowing down the pace of growth of the RES share across the EU

The EU-wide share of renewable energy in final EU energy use increased from 16.7 % in 2015 to 17.0 % in 2016 and to an expected 17.4 % in 2017, according to the EEA's early estimates. Accordingly, the EU has met its indicative trajectory for 2016-2017 as set out in the Renewable Energy Directive (RED), as well as the expected trajectory path for both years resulting from the NREAPs adopted by countries. However, the average yearly growth in the RES share slowed down in 2016 and2017, compared with the average annual pace of growth recorded between 2005 and 2015. As shown elsewhere (EEA, 2018b), the slower RES progress in recent years can largely be attributed to increasing energy consumption across Europe. Although installed renewable capacity has continued to grow, the proportion of energy from renewable sources has fallen as more energy from non-renewable sources is consumed. Currently, increases in final energy consumption from all sources observed since 2015 have led to a reversal in progress towards national and EU energy efficiency objectives for 2020, and this has subsequent effects on the progress at EU-level towards achieving a 20 % share of energy consumption from renewable sources by 2020.

Today, the RES shares continue to vary widely between countries, ranging from over 30 % of gross final energy consumption in countries such as Austria, Denmark, Finland, Latvia and Sweden to below 9 % in Belgium, Luxembourg, Malta and the Netherlands.

## In absolute terms, renewable energy sources are used the most for heating and cooling; in transport they are lagging behind

In absolute terms, **renewable energy for heating and cooling** remains the dominant RES market sector in Europe. At the EU level, RES made up close to one fifth of all final energy consumed for heating and cooling (19.1 % in 2016 and 19.3 % in 2017, according to reported data and early EEA estimates, respectively). Since 2005, despite biogas and heat pumps having the fastest compound annual growth rates, solid biomass-based technologies prevailed in this market sector.

In absolute terms, **renewable electricity** is the second largest RES market sector in the EU. Growth in this sector was driven especially by growth in onshore and offshore wind power and solar PV electricity generation, but also by other RES, such as an increase in solid biomass combustion for electricity purposes. In 2017, 85 % of all newly installed power capacity in the EU was of renewable origin, with wind power and solar PV accounting for three quarters of the annual increase in renewable power capacity and offshore wind power representing around 20 % of the total European wind power market. One third of all electricity consumed in the EU in 2016 and in 2017 originated from renewable sources.

The average renewable electricity capacity per capita for the EU more than doubled in 2016 compared with 2005 (0.8 kWe per person in 2016), with large differences between Member States. A similar development was observed for the average RES-E capacity per unit of gross domestic product (GDP). It more than doubled in 2016, compared with 2005, but large differences remain visible between the Member States.

In the EU **transport sector**, renewable energy made up around 7 % of all energy use in both 2016 and 2017, according to reported data and the EEA's early estimates. With renewable electricity currently playing only a small role in transport, the bulk of renewable energy use in this sector comes from biofuels. To prevent potential negative impacts on climate, the environment and interactions with food production from land-use (such as when natural forests and food crops are displaced by biofuels), only certified biofuels that comply with the sustainability criteria under the RED can be counted towards the RED targets. Certification is carried out through voluntary schemes recognised by the European Commission and through national systems set up by the Member States.

Transport biofuels grew fastest over the period 2005-2016 (at 14 % per year, on average), as they increased from a very low level in 2005. Nevertheless, comparable efforts are needed in this market sector in the run-up to 2020 to reach the 10 % RES target in transport by 2020 at the national and at the EU level. A higher share of renewable electricity use in the transport sector would reduce the pressure on transport biofuels to reach the EU's target of a 10 % RES share consumed in transport by 2020.

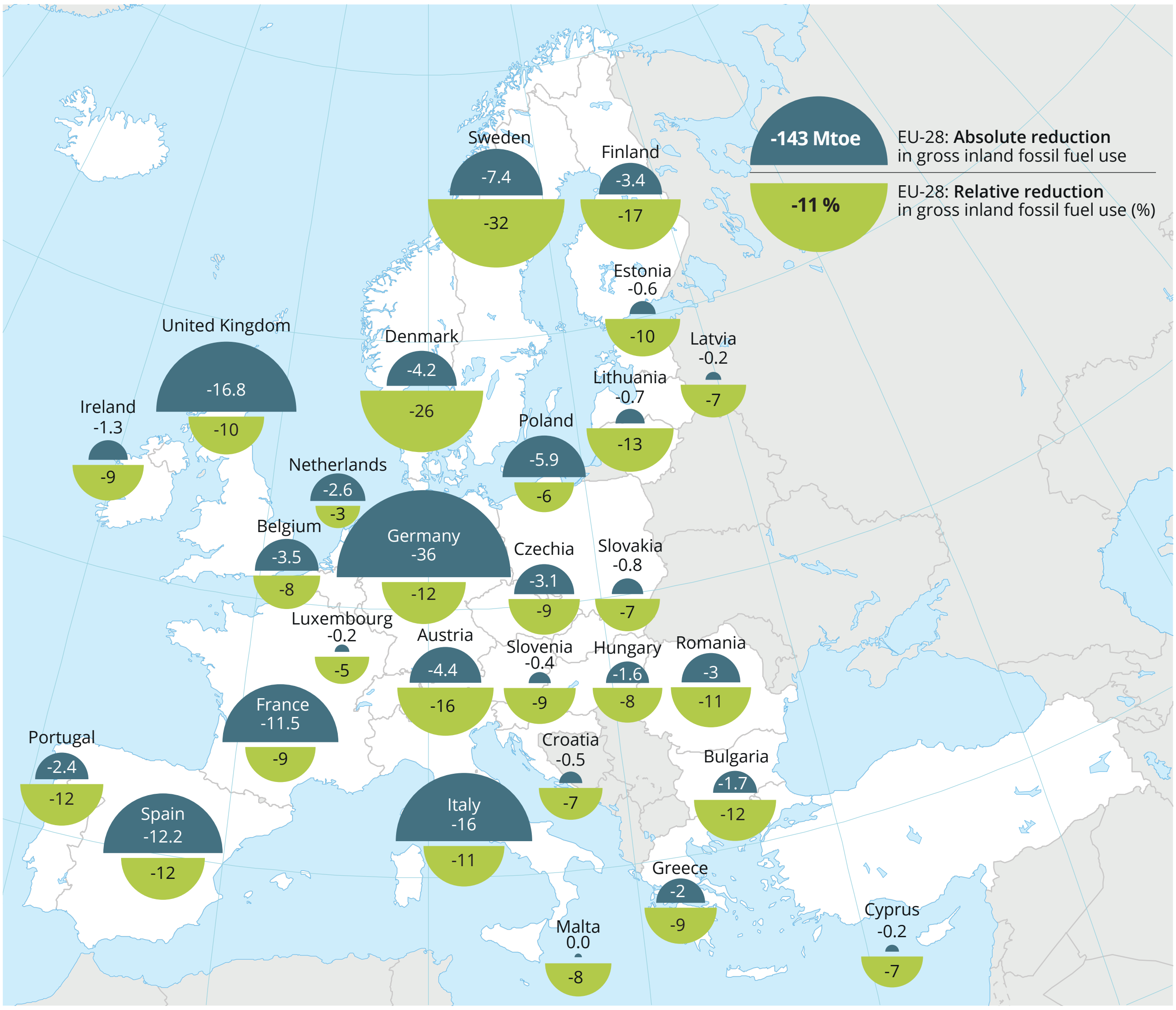
## The increased use of renewable energy sources since 2005 allowed the EU to cut its fossil fuel use and the associated greenhouse gas emissions by more than one tenth in 2017

In 2017, most climate mitigation policies and measures reported by the Member States under EU reporting requirements (the Monitoring Mechanism Regulation (MMR)) aimed to reduce GHG emissions from fossil fuel-based energy consumption (29 %), transport (21 %) and energy supply (15 %). The objective of such policies and measures was often to increase the RES share (EEA, 2018a). The additional consumption of renewable energy in 2016, compared with 2005 levels, allowed the EU to cut its demand for fossil fuels by 143 million tonnes of oil equivalent (Mtoe) in 2016. This is equivalent to 11 % of the EU's gross inland consumption of fossil fuels and comparable to the fossil fuel consumption of the United Kingdom (see Figure ES.1).

Coal was the fuel most substituted by renewables across Europe (representing 38 % of all avoided fossil fuels), followed by natural gas (representing 36 % of all avoided fossil fuels). The reduction in petroleum products and related fuels was less pronounced because of the lower share of RES used in the transport sector. In 2017, the amount of substituted fossil fuels is estimated to have increased by 12 Mtoe (to 155 Mtoe).

These fossil fuel savings due to the additional use of renewable energy after 2005 helped the EU achieve an estimated gross reduction in $CO_2$ emissions of 460 Mt $CO_2$ (9.4 %) in 2016, compared with a counterfactual scenario in which RES consumption would have stayed at the 2005 level (see Figure ES.2). This almost represents the annual GHG emissions of France. In 2017, the effect on $CO_2$ emissions increased further, resulting in a gross emission reduction of 499 Mt $CO_2$ (a 10 % gross reduction in the EU). Most of these changes took place in energy-intensive industrial sectors under the EU Emissions Trading System (ETS), as the increase in renewable electricity decreased the

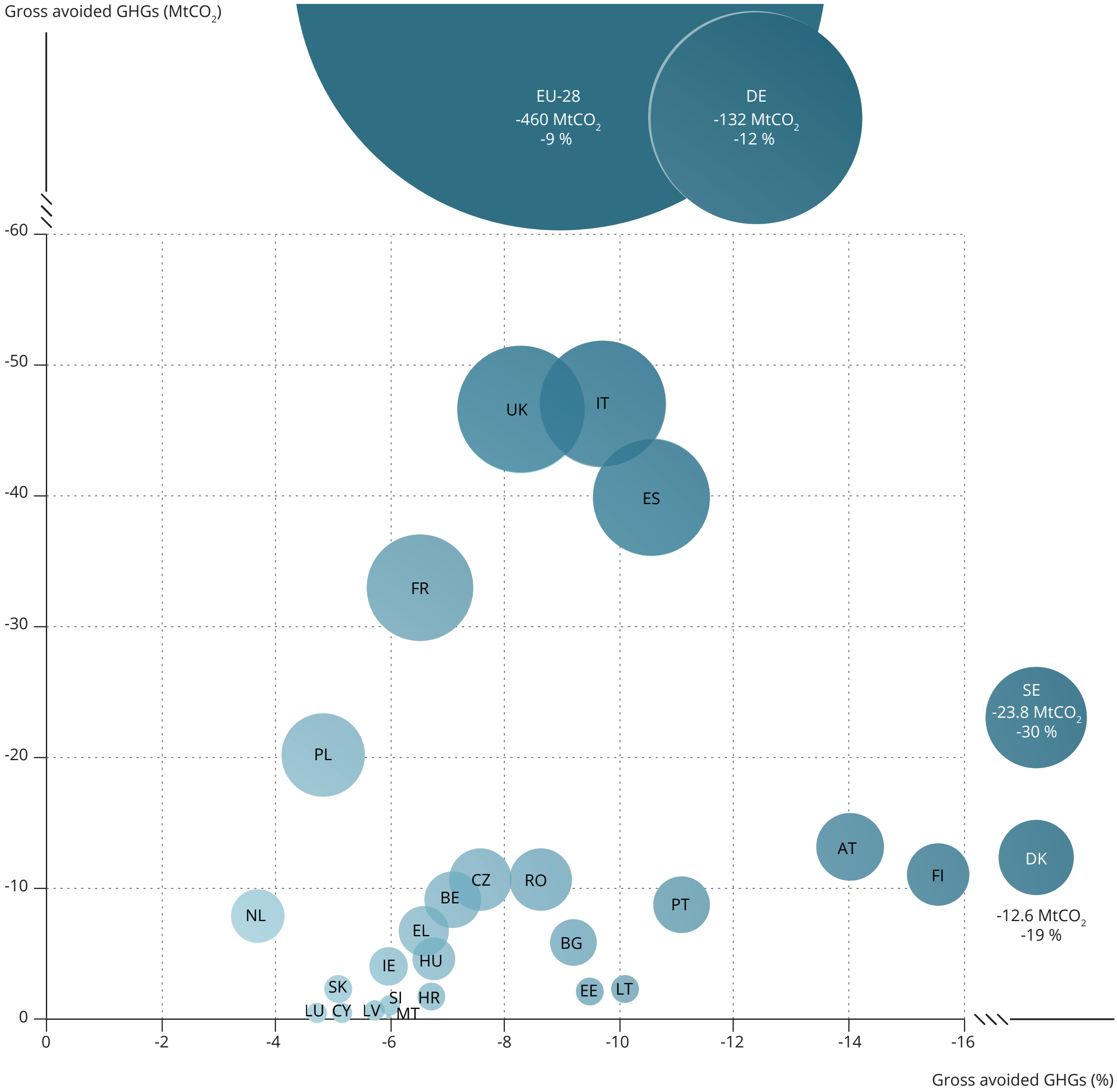
**Figure ES.1 Total and relative reduction in gross inland fossil fuel use (per year, in 2016)**




**Notes:** The absolute reduction in gross inland fossil fuel use in 2016, expressed in million tonnes of oil equivalent (Mtoe), is proportional with the increase of renewable energy consumption achieved between 2005 and 2016. It represents the annual estimate for 2016; the cumulative value over the period 2005-2016 is much larger. The relative reduction in gross inland fossil fuel use is expressed as the absolute reduction over a country's total gross inland consumption of fossil fuels.

**Source:** EEA.

**Figure ES.2 Total and relative gross avoided GHG emissions (per year in 2016)**




**Notes:** The vertical axis illustrates the absolute RES effects on GHG emissions in 2016, expressed as million tonnes (Mt) of gross avoided $CO_2$ emissions per country. The effect is proportional to the increase of national RES consumption between 2005 and 2016. The further up a country is situated, the higher its gross avoided GHG emissions ($MtCO_2$). The horizontal axis illustrates the (relative) impact of national RES growth since 2005 on national GHG emissions. The further to the right a country is, the more effective national RES consumption was to help reduce total national GHG emission (including international aviation and excluding LULUCF).

**Source:** EEA.

reliance on fossil fuels and made up roughly three quarters of the estimated total EU reductions.

National RES deployment since 2005 led to the largest absolute reduction in domestic fossil fuel use and avoided GHG emissions in Germany, Italy and the United Kingdom in both 2015 and 2016. However, in terms of their overall effectiveness in substituting fossil fuels and reducing GHG emissions by increasing their RES deployment three of the Nordic countries (Denmark, Finland and Sweden) remained the most effective Member States in the EU in 2016 (see Figure ES.1).

## Renewables accounted for approximately 70 % of net additions to global power capacity in 2017

Global investments in renewables have shown steady growth for more than a decade. This has led to a more than doubling of global renewable electricity capacity between 2005 and 2017. By 2017, for the third year in a row, more than half of all newly installed power capacity worldwide was of renewable origin, as RES accounted for an estimated 70 % of added net power generation capacity in that year (Frankfurt School-UNEP, 2018; IRENA, 2018b). In 2017, the EU still ranked second after China as regards total installed and grid-connected domestic renewable electricity capacity.

Viewed from the perspectives of technology and the market sector, global RES development in 2017 was dominated by high investment in solar and wind energy for electricity generation. Together, these technologies accounted for over 80 % of total global RES investments (Frankfurt School-UNEP, 2018). At the other end, investments in biofuels (used mainly in transport) were lower in 2015 than in 2005, possibly because interest in first-generation biofuel capacity is plateauing and second-generation biofuel technologies still struggle to overcome technical and financial obstacles.

## The EU is a global leader in renewable electricity capacity per capita, but fast activity becomes visible outside the EU

With an average renewable electricity capacity of 0.87 kW installed per person in 2017, the EU is the clear world leader on a per capita basis, ahead of the United States, Brazil and China. In absolute terms, in 2017, Europe still had the largest wind capacity in place globally. However, since 2017, China has displaced the EU as market leader in solar PV capacity and is poised to overtake the EU, in absolute terms, as the world leader in total installed wind energy capacity.

Over the period 2005-2017, the renewable electricity capacity installed per unit GDP in the EU grew faster than the rate of growth in other world regions. In general, growth in renewable electricity capacity in the EU has been particularly notable since 2009, which coincides with the adoption in 2009 of the EU climate and energy package. However, countries such as China and India had higher growth rates in 2016-2017 than the EU. The recent agreement on the revised RED (RED II), which sets the overall EU target for RES to 32 % in 2030, and requires Member States to ensure via obligations on fuel suppliers that renewables will reach a level of at least 14 % in transport by the same year, is expected to boost renewable energy investments again in the EU.

Between 2005 and 2012, Europe recorded the highest annual shares of global new investments in renewable power capacity. Despite declining from 46 % in 2005 to 15 % in 2017, these high annual shares highlight Europe's pioneering role in developing renewable energy globally. Since 2013, however, China has claimed the highest annual shares of global new investments in renewable power capacity. Moreover, China registered a steep jump in its share in global investment, from 35 % in 2016 to 45 % in 2017: global investment activity is spreading to new attractive markets outside the EU.

## Other countries are seeing faster progress in terms of the share of RES-related jobs per capita in the labour force

The EU is also a key global player in terms of employment in the renewable energy sector, with an estimated 1.3 million jobs related to renewables in 2017, or roughly 0.5 % of the total labour force (IRENA, 2017a). In 2017, it came third, after Brazil and China, with the United States coming in just behind in fourth place. Within the EU, Germany was the number one employer in terms of RES-related jobs per capita in the labour force, second only to Brazil.

The largest employers in the EU renewables sector are the wind, solar PV and solid biomass industries. Following job losses since 2012, the number of renewable energy jobs in the EU increased slightly in 2017 over the previous year. Job losses in solar PV installation and module manufacturing have been compensated for by increased employment in geothermal, wind and solid biomass power generation.

### For 2030, Member States and the EU need to intensify their climate and energy efforts

To reach the EU climate and energy targets for 2030 and to become a sustainable, low-carbon economy by 2050, Member States need to overcome a number of important challenges. In the short term, these concern formulating adequate national decarbonisation targets and policy responses for 2030 that will collectively deliver the EU's climate and energy targets and the commitments under the international Paris Agreement. In the medium term, Member States need to improve their national innovation capabilities to increase benefits from the ongoing energy transition in Europe.

To maintain this momentum, the EU and its Member States should reinforce and build existing, home-grown expertise and innovation capacity in renewable energy and energy efficiency solutions. This will also help retain Europe's global competitiveness in these growing knowledge-intensive sectors. To that end, in 2018, the EU institutions agreed on a more systematic cooperation and coordination of national policies and measures between Member States by adopting the RED II. The European Commission also recently put forward a climate vision for 2050 (EC, 2018c), which confirms the EU's willingness to lead global climate mitigation efforts and support the objective of full carbon neutrality by 2050.

# 1 Introduction

## 1.1 Background: international and European context

Limiting global warming in line with the Paris Agreement ([1]) (UNFCCC, 2015) to significantly reduce the risks and the impacts of climate change requires fundamentally transforming our energy system and adjusting our production and consumption patterns in just a few years.

Increased deployment of renewable energy sources (RES) plays an important role in mitigating climate change and unfolding this transformation. With long-term energy demand overall stable or decreasing in Europe, increasing the share of renewable sources of energy triggers the displacement of non-renewable sources (especially fossil fuels) in power supply, heat production and transport, thereby reducing greenhouse gas (GHG) emissions across all sectors. Renewables are thus a key pillar in delivering the European Energy Union's decarbonisation priority (see Box 1.1), achieving the EU's climate commitments under the Paris Agreement, and supporting the transition towards a greener, resource-efficient and more competitive low-carbon EU economy and society by 2050.

To date, a broad set of complementary climate and energy policies support low-carbon energy developments and aim to spur innovation in this field. Progress achieved in EU-wide renewable energy deployment since 2005 is largely attributed to the presence of binding national targets for 2020 under the Renewable Energy Directive, or RED (EU, 2009), and to national support instruments put in place in response to these targets, such as feed-in tariffs, feed-in premiums, auction/tender systems, quotas, tax credits and grants.

Technological advances, the scaling up of global production volumes and a reduction in capital costs have also each played an important role in lowering the costs of renewable energy, especially of wind power and solar photovoltaic (PV) technologies (EC, 2015; IRENA, 2016a).

Nevertheless, the rapid initial developments also triggered frequent adaptation of Member States' policies to establish cost-effective support and, in some cases, even to abrogate that support. As many of these changes fuelled uncertainty on the markets, auction-based programmes have come to replace the initial subsidy-based support measures in Europe, and increasingly globally, pushing renewable energy projects to become more cost-competitive and contributing to further reductions in the costs of renewable energy projects (Frankfurt School-UNEP, 2018).

In recent years, however, the annual pace of growth in the EU has stagnated or decreased for most renewable electricity (RES-E) technologies and for renewable heating (RES-H) from solar thermal and heat pumps. It has continued to increase for only a few other renewable energy technologies (i.e. geothermal and solid biomass-based technologies). This loss of speed initially took shape in the aftermath of the financial crisis, when many support mechanisms were scaled back. Subsequently, economic growth resumed across countries and, since 2015, energy consumption from non-renewable sources increased by more than that from renewable ones, as a result of increased energy use in the transport sector and low carbon prices in the EU's electricity market. The increasing number of countries getting closer to, or having reached their renewable energy targets for 2020 ahead of time, may offer a further explanation, in the context in which the recast of the RED sets a binding EU-level target for renewable energy consumption by 2030 (of 32 %) and invites Member States to define their own national contributions to achieving that target as part of their integrated national energy and climate plans under the Energy Union Governance Regulation (EU, 2018c).

However, to reach with certainty the mandatory 20 % share of EU renewable energy consumption by 2020 and the 10 % RES sub-target for the transport sector, in the context of the recent upwards trend in energy consumption, sustained efforts and corresponding

([1]) The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping the global temperature rise this century well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 °C. The Paris Agreement requires all Parties to put forward their best efforts through 'nationally determined contributions' (NDCs) and to strengthen these efforts in the years ahead (UNFCCC, 2015).

**Box 1.1 EU renewable energy policies up to 2020 and 2030**

The EU was an early adopter of renewable energy starting with the implementation of EU-wide policies from the mid-nineties. After the first directive on electricity production from renewable energy sources (2001) with indicative targets, the review (in 2005) of Member States' supporting schemes led to a period of debate and negotiations between Member States and the EU institutions. This resulted, in 2009, in the RED (2009/28/EC), which set legally binding national targets contributing to an EU-wide target of 20 % renewable energy in the total energy needs by 2020.

The binding national targets are set at different levels to reflect national circumstances. The EU's renewable energy target for transport (i.e. a 10 % share by 2020) is divided equally for all countries into 10 % national targets, with biofuels produced from energy crops grown on agricultural land limited to a maximum of 7 %. The RED also sets out options for cooperation to help countries achieve their targets cost-effectively.

In the run-up to 2020, two interim trajectories are of particular interest in assessing the EU and Member States' progress towards their binding targets:

- The minimum **indicative RED trajectories** for each country. These trajectories concern only the total RES share. They run until 2018, ending in 2020 with the binding national RES share targets. They are provided in the RED to ensure that the national RES targets will be met.

- The **expected trajectories**, adopted by Member States in their national renewable energy action plans (NREAPs) under the RED. These NREAP trajectories concern not only the overall RES share but also the shares of renewables in the electricity, heating and cooling, and transport sectors up to 2020.

For 2030, the recast of the RED sets a binding EU-wide target of 32 % (EU, 2018a) RES in gross final energy consumption. Member States will have to propose an indicative level of effort contributing to the EU binding target for renewables. The binding national RES targets for 2020 remain in the recast directive as baseline levels. The recast also includes:

- guiding principles concerning financial support schemes for RES-E;

- the requirement for Member States to set up 'one-stop shops' to coordinate the entire permit-granting process for new RES generation, transmission and distribution capacity;

- principles of renewable self-consumption and (local) renewable energy communities;

- enhancement of existing provisions on cross-border cooperation;

- provisions to improve the sustainability and GHG emissions-saving criteria for biofuels, bioliquids and biomass;

- mainstreaming of renewable heating and cooling (RES-H&C) applications, in particular by asking Member States to increase the share of renewable energy supplied for heating and cooling by a fixed rate (by an indicative 1.3 percentage points for 2021-2025 and higher thereafter) per year, starting from the level achieved in 2020.

adaptation of national policies to promote renewable energy projects will be indispensable in the very short run (EEA, 2018b).

### Outlook beyond 2020

In June 2018, European countries gave their endorsement to a binding EU-wide renewable energy target of a minimum of 32 % of gross final consumption by 2030 (RED II) (EU, 2018a). Building on the Energy Union strategy of 2015 (EC, 2015), as well as on the recently agreed Regulation on the Governance of the Energy Union ([2]), Member States will have to propose an indicative level of effort contributing to the EU binding target for renewable energy as part of their draft integrated national energy and climate plans, due by the end of 2018. In the run-up to 2030, the indicative RES trajectory of the EU (based on the collective efforts of the Member States) should reach at least the following reference points for the total increase in the RES share between the binding 20 % RES share target for 2020 and the binding 30 % RES share target for 2030: 18 % by 2020; 43 % by 2025; 65 % by 2027. Should the Commission identify a gap in ambition during the assessment of the integrated national energy and climate plans, the Commission may take measures at EU level to ensure that the target is achieved, thereby closing the gap. Should Member States fall behind similar reference points in relation to their RES trajectories in the integrated national energy and climate plans, they will need to implement additional measures to cover the gap within 1 year (EU, 2018c).

### Beyond Europe

In the past, the EU has been a frontrunner in renewable energy. Nevertheless, with developing countries investing more in green energy than developed economies, the situation may be changing in the short run (see Chapter 4).

## 1.2 About this report

This EEA report depicts changes in RES in Europe since 2005, at the level of individual technologies and countries (Chapter 2) and outlines key global developments to put European progress in perspective (Chapter 4). It also illustrates the co-benefits of growing RES consumption in Europe, notably the replacement of fossil fuels by a growing share of renewables and the resulting effects on energy dependence and on the reduction in GHG emissions (Chapter 3). This chapter sets the overall context.

The assessment uses Eurostat data for the period 2005-2016, complemented by early EEA estimates regarding GHG emissions and energy developments in 2017.

#### *1.2.1 Geographical scope*

Owing to the limited availability of primary data, this assessment focuses on the 28 EU Member States (EU-28). In Chapter 4, capacities and investments in RES-E are aggregated into relevant world regions to facilitate a comparison of the EU's progress with international developments. Details of the geographic aggregation are presented in the glossary.

#### *1.2.2 Data sources and methodologies*

*Approximated estimates for the share of gross final consumption of renewable energy resources* (*RES share proxies*)

The EEA 2017 RES shares are, ultimately, estimated values. The cut-off date for most data sources incorporated in the calculation of approximated RES shares was 26 July 2018. Although the 2017 RES shares proxies formed the basis of a specific EEA country consultation, carried out in September 2018 ([3]), these values are not a substitute for data that countries officially report to Eurostat.

The methodology applied for approximating RES values in the year *t*-1 was described in a previous EEA report (EEA, 2015) — see also Annex 2. Confidence in the estimated RES share proxy values is greatest in the electricity sector. The dynamics in the renewable heating and cooling market sector may be underestimated due to the more limited data available for this sector. Finally, the specific accounting rules in the RED concerning renewables consumed in transport remain difficult to replicate. Despite these challenges, the estimation of RES share proxies yields plausible

([2]) The Regulation on the Governance of the Energy Union, which is expected to be adopted by the end of 2018, is a horizontal piece of legislation that aims to streamline monitoring and reporting of progress, and increase synergies and cooperation across all dimensions of the Energy Union, so as to obtain a high level of policy coherence through integrated national energy and climate plans.

([3]) The approximated GHG emissions, energy consumption and RES proxy data were sent for consultation to the European Environment Information and Observation Network (Eionet) of environmental bodies and institutions active in the EEA member countries. These proxies were finalised in September 2018, after the Eionet consultation.

results in most cases and should be further improved, especially as more timely information and data that are relevant for the estimations become available.

*Gross avoided greenhouse gas emissions due to avoided fossil fuel use*

Chapter 3 estimates the gross effects of renewable energy consumption on GHG emissions based on primary data available from Eurostat and early EEA estimates for primary energy consumption in 2017. The term 'gross avoided GHG emissions' illustrates the theoretical character of the GHG effects estimated in this way, as these contributions do not necessarily represent 'net GHG savings per se' or are based on life-cycle assessment or full carbon accounting ([4]). Taking life-cycle emissions into account could lead to substantially different results. It is important to note that, because the base year of this analysis is 2005, the development of renewable energy from only that point in time is considered. Section 3.1.2 illustrates the avoided fossil fuel use at the Member State level. The relative effects are shown with respect to gross inland fossil fuel use per country (see Figure 3.2). Section 3.3 also estimates the effects on energy consumption. A detailed description of the methodology applied for approximating these effects was described in a previous EEA report (EEA, 2015).

*Renewable energy investments*

To date, a central, publicly available source of information on global RES technology investments is missing. The comprehensive information used in this assessment is sourced from the *Global trends in renewable energy investment annual report* (Frankfurt School-UNEP, 2018). The period covered is 2005-2017 and the focus is on new renewable energy investments per region. Data on investment are primarily sourced from that report. While analysing investment, that report includes projects on renewable power and fuels — wind, solar, biomass and waste, biofuels, geothermal and marine projects, and small hydro-electric dams of less than 50 MW — it does not cover larger hydro-electric dams of more than 50 MW. Investment figures were originally supplied in nominal billions of US dollars. Full comparability across regions and time remains limited, as nominal values include inflation ([5]).

For the purpose of this report, figures in US dollars have been converted to euros using the Eurostat data set on exchange rates (Eurostat, 2018b).

*Renewable energy employment*

The renewable energy sector requires specific skills and value chains, which lead to the creation of new jobs. Job numbers can be estimated using various methods with different levels of detail. As data availability varies across regions, and data differ in how they are generated and in their quality, a consistent time series is not yet available. For these reasons, only a snapshot of the recent past (2017), by available region and technology, can be shown. Direct and indirect jobs related to renewable energy per region for 2017 are presented below and stem from the International Renewable Energy Agency (IRENA, 2018b)

*Other observations*

For offshore wind, 2005-2017 data are calculated based on capacities reported by EurObserv'ER and based on an assumption of 4 000 full load hours of operation. The offshore wind production is then subtracted from the total wind production reported by Eurostat (Eurostat, 2018a, 2018d) and the result is attributed to onshore wind production. The total of onshore and offshore wind power generation is equal to the total for wind power reported by Eurostat. Data for 2020 originate from Table 10 in each country's NREAP, where there is separate reporting for onshore and offshore wind power.

In the context of renewable energy use in transport the terms, 'other biofuels' and 'all biofuels' are understood to also include biogas and other liquid biofuels used in transport. Similarly, in the context of RES-E generation, the term 'solid biomass' is understood to also include renewable municipal waste.

([4]) In the absence of specific information on current bioenergy systems, $CO_2$ emissions from the combustion of biomass (including biofuels/bioliquids) were not included in national GHG emission totals in this report, and **a zero emission factor** had to be applied to all energy uses of biomass. This should not be interpreted, however, as an endorsement of default biomass sustainability or carbon neutrality. It should be noted that, according to the United Nations Framework Convention on Climate Change (UNFCCC) reporting guidelines, these emissions have to be reported separately in GHG inventories as a memorandum item (mainly to avoid double counting of emissions from a reporting perspective), with the assumption being that unsustainable biomass production would show as a loss of biomass stock in the land use, land use change and forestry (LULUCF) sector and not in the energy sector.

([5]) To adjust for inflation one would need to consider individual inflation rates — or deflators — for each of the regions. As the regions are composed of heterogeneous countries, probably experiencing different levels of inflation, it is not possible to make this conversion. This needs to be taken into account when interpreting the data.

The methods applied in this report to estimate the impact of the uptake of renewable energy on energy consumption and GHG emissions cannot be used to assign these effects to particular drivers, circumstances or policies, other than the increased consumption of renewable energy itself. These methodologies provide valuable insights, but, as the assumptions are static (i.e. the same set of assumptions is applied to all years in the period), assumptions need to be re-adjusted at times to reflect real-life conditions. A detailed description of the methods was given in a previous report (EEA, 2015).

# 2 Developments in renewable energy sources in Europe

- The EU share of renewable energy in 2016 (17.0 %) was almost twice as high as in 2005 (9.0 %). However, it has increased by only 0.3 percentage points since 2015.
- According to preliminary estimates calculated by the EEA, the EU's RES share also continued to grow in 2017, reaching an estimated 17.4 % share in gross final consumption ([6]).
- For 12 Member States, the national RES share actually decreased in 2016 compared with 2015, in many cases due to an increase in final energy consumption.
- The EU RES share in both 2016 and 2017 exceeded the EU's indicative trajectory under the RED (13.8 % in 2016 and 16.0 % in 2017). However, reaching with certainty the mandatory 20 % EU RES share in energy consumption and the 10 % RES sub-target for transport by 2020 calls for continued efforts to deploy renewables and to address the recent increases in final energy consumption across some countries. Furthermore, ambitious national objectives and the recalibration and adaptation of national RES support policies are indispensable in the short run, if we are to meet the collective EU decarbonisation and energy targets for 2030 and in the longer term.
- On a per capita basis, the average RES-E capacity for the EU had more than doubled by 2016 (0.8 kWe per person) compared with 2005. While differences between Member States remain large, in 23 EU countries installed RES-E capacities per capita were larger than the world average (0.3 kWe per person) in 2016.
- Expressed per unit of gross domestic product (GDP) ([7]), the EU's average RES-E capacity has developed in a similar way since 2005, having more than doubled by 2016 (29 kWe per unit of GDP). Per unit of GDP, installed capacities in 2016 were larger than the world average (23.8 kWe per unit of GDP) in half of the EU Member States.
- Across the EU, the largest market sector for renewable energy use remains heating and cooling. Renewables made up close to one fifth of all final energy consumed for heating and cooling in the EU and more than half in 16 Member States (Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Greece, Hungary, Latvia, Lithuania, Poland, Romania, Slovenia and Sweden).
- Electricity is the second largest market sector for renewable energy use in the EU (29.6 % in 2016 and 30.6 % in 2017 according to the early EEA estimates). It represented over half of all final RES consumption in only four countries (in descending order: Ireland, the United Kingdom, Spain and Portugal).
- Transport is the third and smallest market sector for renewables (7.1 % in 2016 and only 0.1 percentage points higher in 2017, according to the early EEA estimates). Renewable energy use in transport (including only biofuels compliant with sustainability criteria) varied significantly among Member States, from a maximum of 43 % of all RES consumption (Luxembourg) to less than 1 % (Estonia and Croatia).
- Certain renewable energy technologies have already surpassed the levels of deployment expected for 2020 in NREAPs, notably RES-H&C from solid biomass and RES-E from solar PV and biogas.

([6]) The approximations are made using a harmonised method that can be applied to all Member States using centrally available and harmonised data sets. It is not intended to be a tailor-made approach and the results need to be considered with that in mind. Countries were invited to provide national data and estimates in the context of an Eionet consultation in 2017. For details, see Section 1.2.4 and Annexes 1 and 2.

([7]) GDP expressed in constant 2011 euro value ($EUR_{2011}$), at purchasing power parity (PPP).

## 2.1 Recent progress in deployment of renewable energy sources

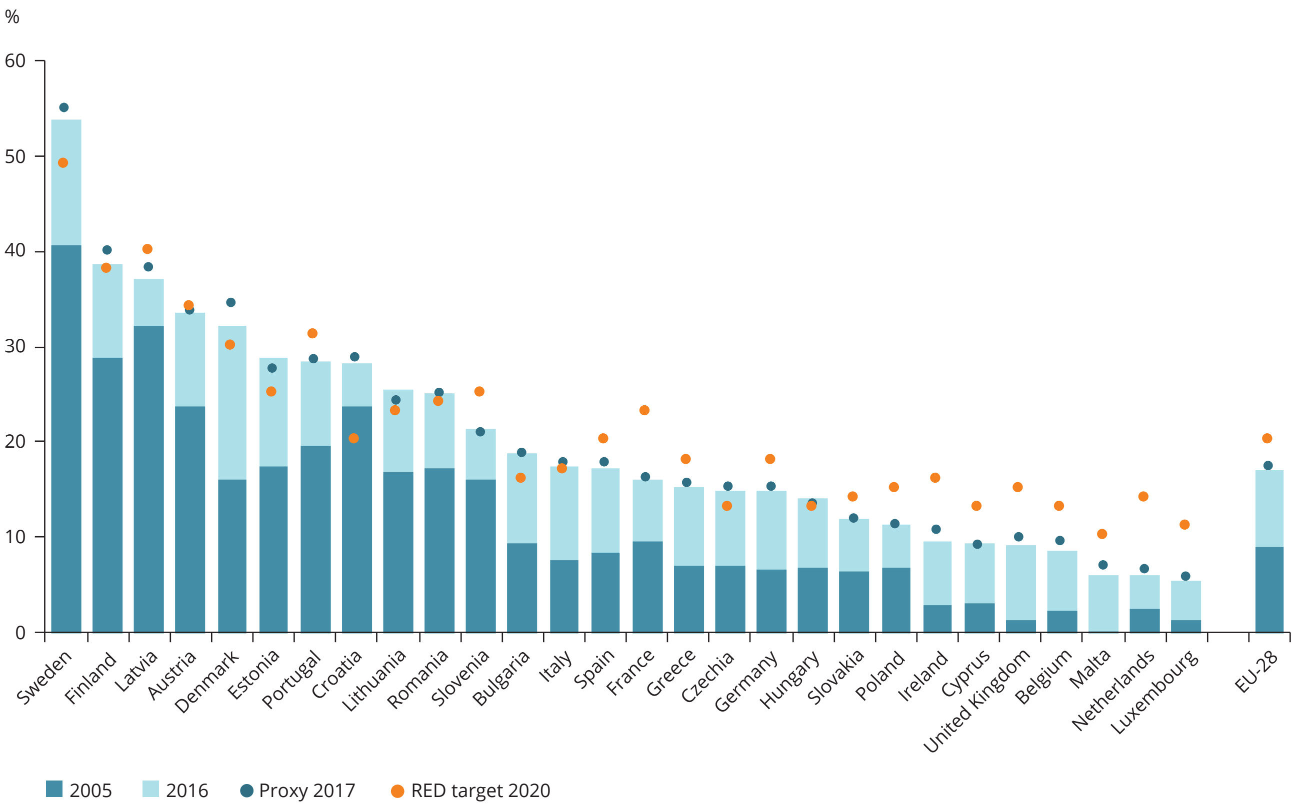
### *2.1.1 Renewable energy shares at the EU level and in individual Member States*

The RED sets minimum indicative trajectories for each country, which end in the binding national RES share targets for 2020. Progress towards these 2020 targets is assessed by comparing the most recent developments with these interim trajectories. The indicative RED target for the EU is 13.8 % for the years 2015 and 2016 and 16 % for the years 2017 and 2018. Having achieved a RES share of 17 % in 2016 and an estimated share of 17.4 % in 2017, the EU has surpassed the indicative target level set in the RED. In both years, the EU also surpassed the cumulative expected levels according to the Member States' NREAPs, of 16.2 % and 17.2 %, respectively.

The RES share increased annually by 5.5 %, on average, between 2005 and 2015, with the pace of growth decreasing slowly in 2016 (by 0.2 percentage points) and 2017 (by 0.3 percentage points) compared with the average pace of growth recorded between 2005 and 2015. It is worth noting that gross final energy consumption decreased, on average, by 0.5 % per year between 2005 and 2016, but it increased by 2.3 % and 1.9 % in 2015 and 2016, respectively. According to early EEA estimates, gross final energy consumption continued to increase by 1.3 % in 2017. As shown elsewhere, the slowdown in the annual increase in the RES share in recent years was due to the increase in final energy consumption in recent years. If this latter trend is not reversed, it could jeopardise the achievement of the 20 % renewable energy target at EU level for 2020 (EEA, 2018b). In addition, the current average pace of renewable energy deployment across Europe would not enable the EU to achieve the new RES target, of 32 % by 2030. Meeting the more ambitious EU-level RES (and climate mitigation targets) for 2030 and 2050 calls for steeper deployment rates of RES across all sectors and especially in heating and cooling, and in transport (EEA, 2018b).

Figure 2.1 shows the actual RES shares in the EU Member States and for the EU for 2005 and 2016, and the approximated RES shares for 2017. The RES shares vary widely among countries. In 2016, the highest shares of renewable energy were attained

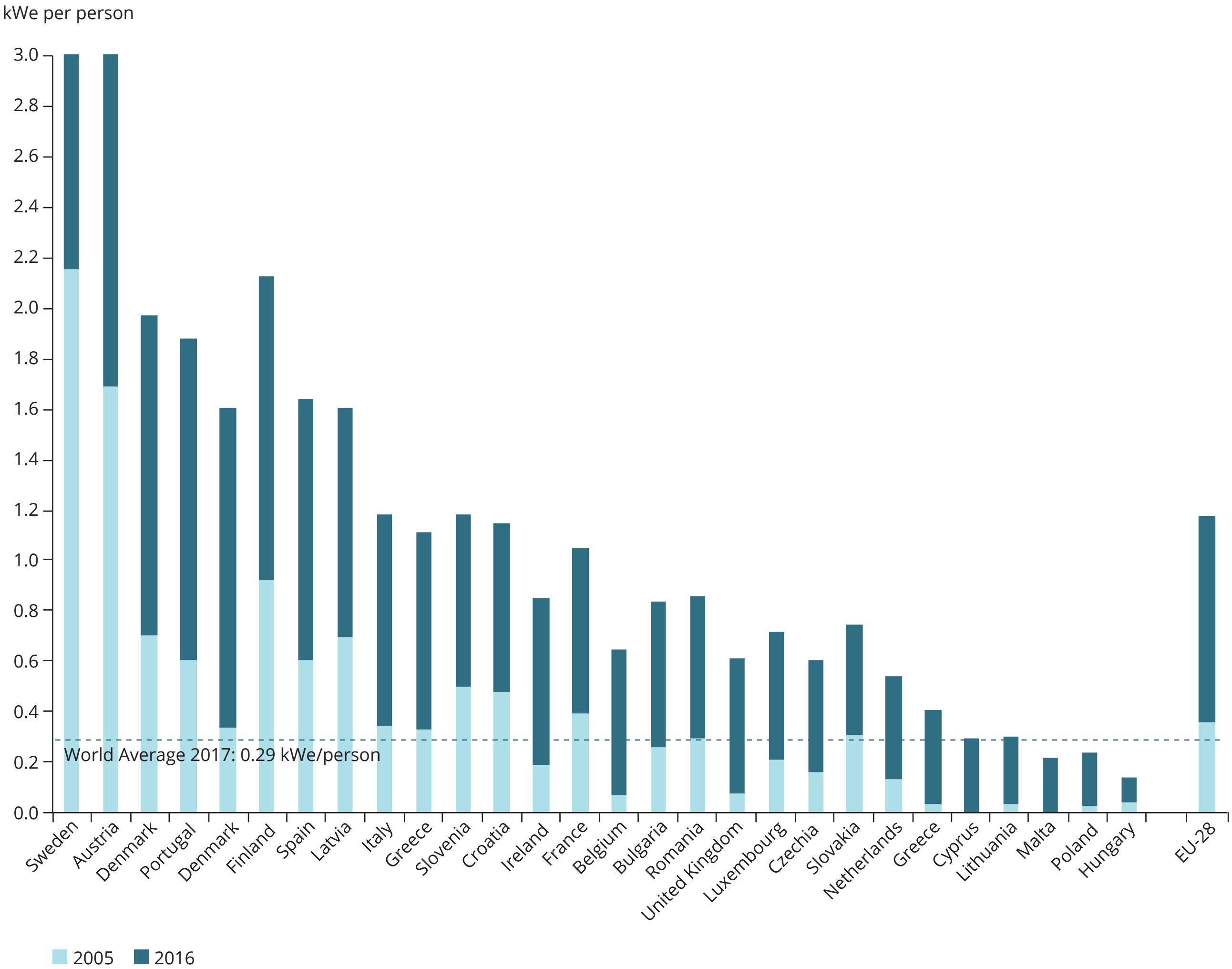
**Figure 2.1 Actual and approximated RES shares in the EU and its Member States**




**Notes:** The dark blue bars show the RES shares in 2005. The tops of the light blue bars show the levels that the RES shares reached in 2016.

**Sources:** EEA, 2017; Eurostat, 2018d; RED (2009/28/EC).

**Figure 2.2** **RES-E capacities, excluding pumped storage, per capita in the EU and its Member States, 2005 and 2016**




**Sources:** EEA; Eurostat, 2018c, 2018d; IRENA 2018a.

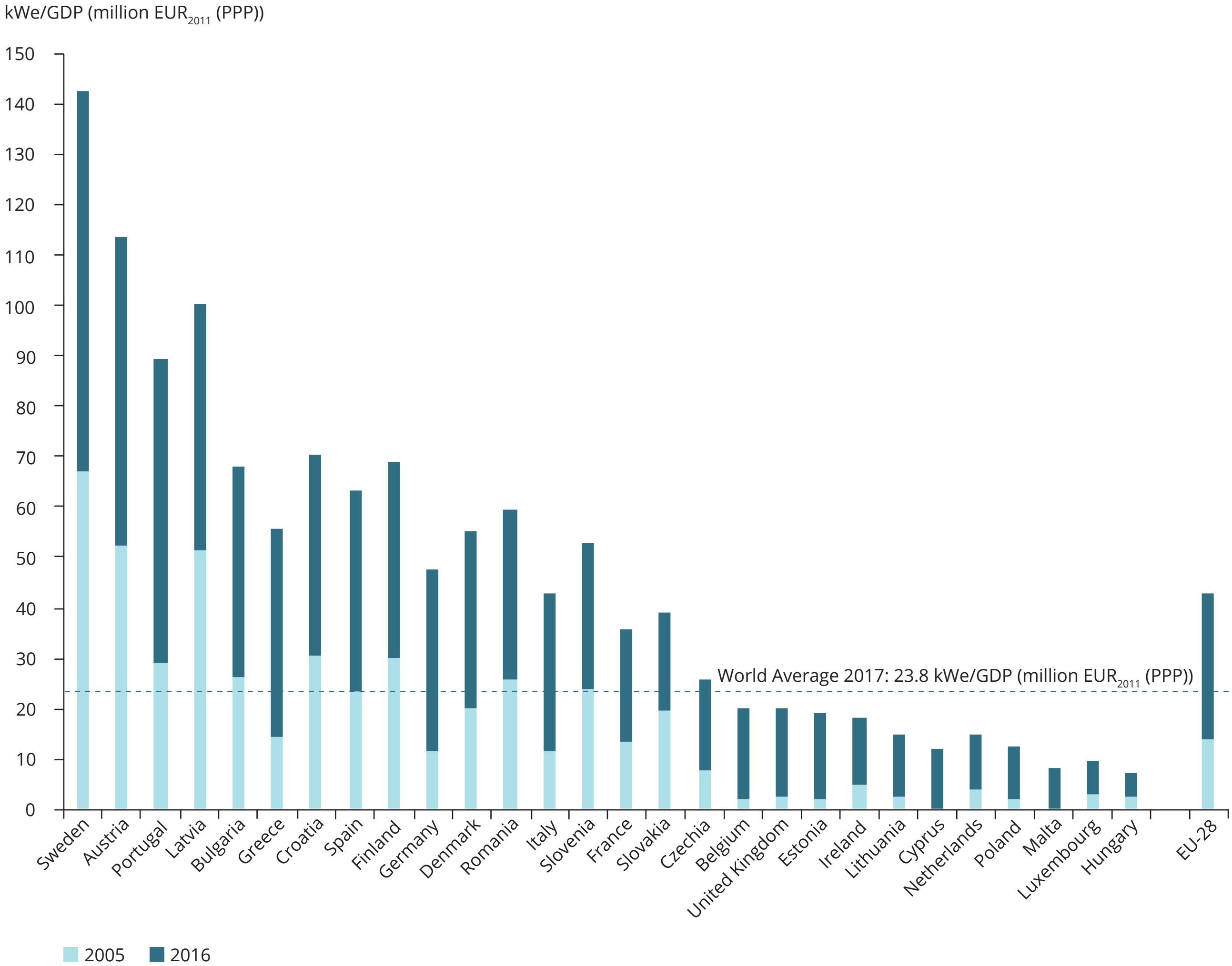
by Sweden (53.8 %), followed by Finland (38.7 %) and Latvia (37.2 %). Luxembourg (5.4 %), Malta (6.0 %) and the Netherlands (6.0 %) realised the lowest shares. Figure 2.1 also shows the RED target share for 2020. This overall target was calculated for individual Member States to reflect their national circumstances, RES potentials and starting points.

### *2.1.2 Renewable electricity capacities per capita and per unit of gross domestic product*

This subsection summarises RES-E developments in the EU, while a comparison with the global context is provided in Chapter 4.

The average RES-E capacity per capita for the EU-28 had more than doubled by 2016, compared with 2005, from around 0.4 kWe installed per person in 2005 to over 0.8 kWe installed per person in 2016. Sweden and Austria had the largest installed capacities per person in 2016, followed at a distance by Denmark, Portugal, Germany and Finland (around 1.2 kWe per person). However, since 2005, the largest growth in RES-E capacity per capita has been observed in Malta, Cyprus, Estonia, Belgium, Poland, Lithuania, the United Kingdom, Germany and Ireland (all more than 200 % growth), followed by the Netherlands, Czechia, Hungary, Italy, Luxembourg, Greece, Bulgaria and Portugal (growth between 100 % and 200 %). The remaining countries (Romania, Denmark, Spain, France, Slovakia, Croatia, Slovenia, Finland, Latvia, Sweden and Austria) showed lower growth rates (< 100 %). The majority of EU Member States (23) had installed capacities in 2016 that were greater than the world average (see Figures 2.2 and 4.2).

**Figure 2.3** **RES-E capacities, excluding pumped storage, per GDP in the EU and its Member States, 2005 and 2016**




**Sources:** EEA; Eurostat, 2018d; IMF, 2018; IRENA, 2018a; OECD, 2018; World Bank, 2018.

Similar to the average RES-E capacity per capita, the average RES-E capacity per unit of GDP for the EU-28 has more than doubled since 2005, reaching 29 kWe/GDP ([8]) in 2016. In 2016, Sweden, Austria and Portugal had the largest installed capacities per unit GDP (60 kWe/million $EUR_{2011}$ (PPP) or more), followed by Latvia, Bulgaria, Greece, Croatia, Spain, Finland, Germany, Denmark, Romania, Italy and Slovenia (30 to 50 kWe/million $EUR_{2011}$ (PPP)). The largest growth in RES-E capacity per GDP since 2005 can be observed in Malta, Cyprus, Estonia, Belgium, the United Kingdom, Poland and Lithuania (all more than 450 % growth), followed by Germany, Greece, the Netherlands, Italy, Ireland, Czechia, Luxembourg, Hungary, Portugal, Denmark, Spain, France and Bulgaria (between 150 % and around 300 % growth). The remaining countries (Croatia, Romania, Finland, Slovenia, Austria, Sweden, Slovakia and Latvia) showed lower growth rates (< 150 %) per unit of GDP. Per unit of GDP, installed capacities in 2016 were larger than the world average (23.8 kWe per unit GDP) in half of the EU Member States (see Figures 2.3 and 4.3).

## 2.2 Contributions of renewable energy sources by energy market sector and technology

In 2010, Member States submitted NREAPs in which they outlined their expected national paths to meet their binding 2020 RES targets and included separate trajectories for RES-E, RES-H&C and renewable energy consumption in the transport sector (RES-T). The expected paths in the NREAPs are, overall, more

([8]) GDP expressed in constant 2011 euro value ($EUR_{2011}$) at PPP.

ambitious than the indicative RED trajectories. This section shows the progress achieved by RES within the three energy market sectors and compares it with the expected (NREAP) development in these market sectors.

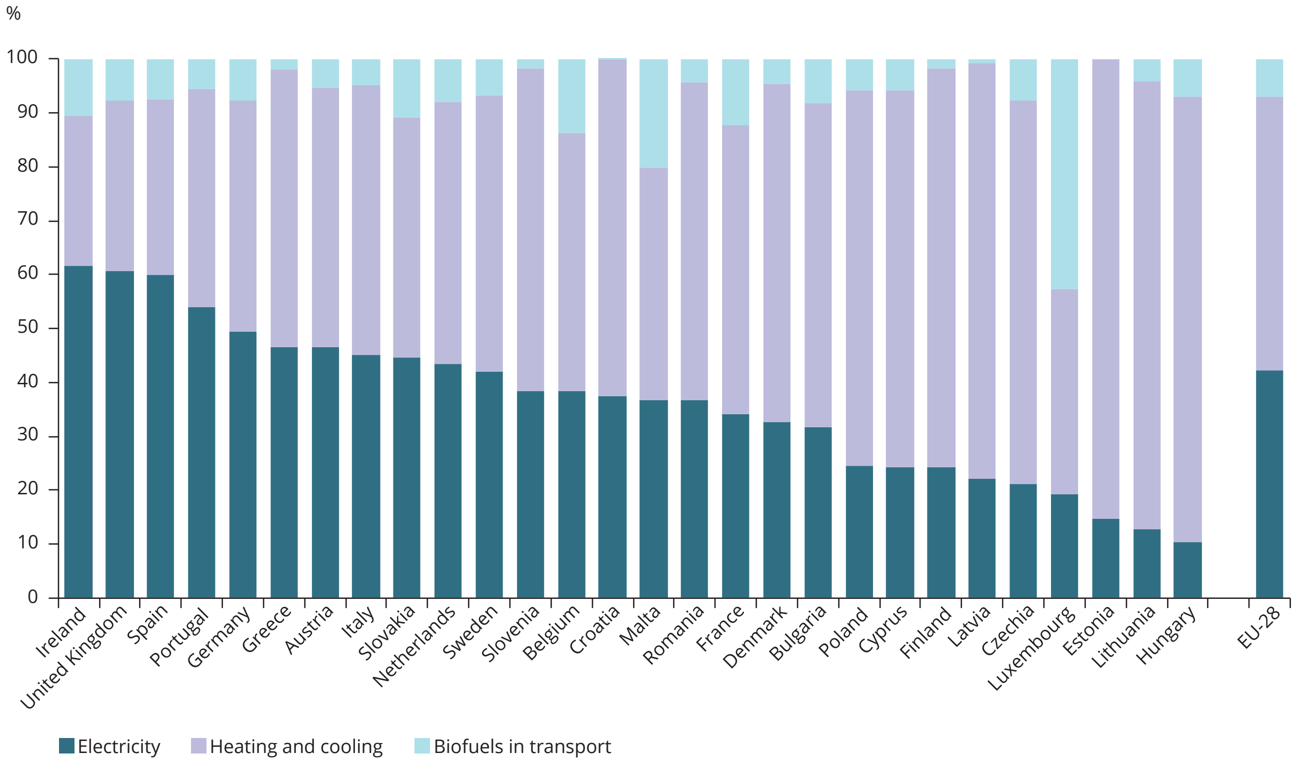
The expected (NREAP) trajectories of individual technologies enable progress to be monitored, but they become increasingly outdated as conditions and policies change ([9]). In fact, because of steep learning curves, the rapid development and consequent cost reductions achieved by some renewable energy technologies have already led to higher shares of these technologies than were anticipated to have been reached by 2020 in the NREAPs.

At EU level, in absolute terms RES-H&C remains the dominant RES market sector (see Section 2.2.3), followed by RES-E (see Section 2.2.1) and RES-T (see Section 2.2.4).

### *2.2.1 Breakdown of RES shares by energy market sectors in Member States*

At the country level, the significance of each energy market sector, and the role renewable energy plays therein, differs considerably. Figure 2.4 illustrates these differences by showing the split of gross final renewable energy consumption by market sector in each country. In 2016:

**Figure 2.4 Shares in 2016 RES consumption of renewable electricity, renewable heating and cooling, and biofuels in transport**




**Notes:** This figure shows how actual final renewable energy consumption in 2016 is distributed over RES-E, RES-H&C and biofuels in transport. Wind power and hydropower are normalised ([10]). The consumption of RES accounts for only biofuels complying with the RED sustainability criteria.

**Source:** Compiled from data in Eurostat, 2018d.

([9]) Some countries have updated their NREAPs since 2010. The most recent versions were used for this report. Austria, Bulgaria, Czechia, Denmark, Estonia, Ireland, Poland, Spain and Sweden updated their overall RES shares, or their RES shares per technology, for one or several years, as additional information to the Commission's questions or in a resubmission of their NREAP. Malta has submitted an update in 2018, but not all details were available at the time of final editing, so the 2017 version was used for this report.

([10]) Under the accounting rules in the RED, electricity generated by hydro- and wind power needs to be normalised to take into account annual variations (hydro for 15 years and wind for 5 years).

- **Renewable heating and cooling** represented more than half of all gross final consumption of renewables in 16 Member States (Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Greece, Hungary, Latvia, Lithuania, Poland, Romania, Slovenia and Sweden).

- **Renewable electricity** represented over half of all RES consumption in only four countries (in descending order: Ireland, the United Kingdom, Spain and Portugal).

- The contribution of **renewable transport fuels** (compliant biofuels) was on average 7.1 %, but varied significantly among Member States from a maximum of 43 % of all RES consumption (Luxembourg) to less than 1 % (Estonia and Croatia).

The variations observed across countries in the relative importance of each market sector are due to specific national circumstances, including different starting points in terms of the deployment of RES, different availability of low-cost renewables, country-specific demand for heating in the residential sector and different policies to stimulate the deployment of renewable energy.

### *2.2.2 Renewable electricity*

In 2016, the EU-wide share of RES-E amounted to 29.6 % — more than twice the level in 2005. Figure 2.5 and Table 2.1 show the consumption of RES-E up to 2016, approximated estimates for 2017 and the expected NREAP developments by 2020.

- The gross final energy consumption of RES-E continued to increase, reaching 82.5 Mtoe in 2016.

- In 2016, the largest contributions came from hydropower (36 % of all RES-E), onshore wind ([11]) (27 % of all RES-E), solid biomass (12 % of all RES-E) and solar PV systems (11 % of all RES-E). All the other technologies made smaller contributions, ranging from 0.1 % (tidal, wave and ocean energy) to 7 % (biogas).

- Over the period 2005-2016, the compound annual growth rate of RES-E consumption was 6 %. To achieve the expectations for 2020 in the NREAPs, a growth rate of 6 % per year will be required over the period 2016-2020. The compound annual growth rate was highest for solar PV systems (48 %), offshore wind (28 %), biogas (16 %) and onshore wind (13 %). Hydropower had the lowest growth rate (0 %).

According to EEA early estimates, RES-E generation increased in 2017 to 86.3 Mtoe, while total electricity generation from all sources increased to 282 Mtoe, resulting in a RES-E share of 30.6 % ([12]). Most of the increase in RES-E generation in 2016 was due to the greater contribution of wind energy (+2.2 Mtoe) and solar energy (+0.2 Mtoe). In 2016, electricity consumption in Europe increased for the second consecutive year following the decrease in 2014.

**Hydropower**

The normalised ([10]) production of renewable hydroelectric power remained quite stable over the period 2005-2016, as illustrated in Figure 2.6. According to the NREAPs, limited growth, from 30.1 to 31.8 Mtoe, is expected for the period 2016-2020. In 2016, the five countries with the most hydropower (Sweden, France, Italy, Austria and Spain) had a share of 70 % of all hydropower generation in the EU. In 2017, the normalised production of hydroelectricity is likely to have decreased slightly, to 30.0 Mtoe.

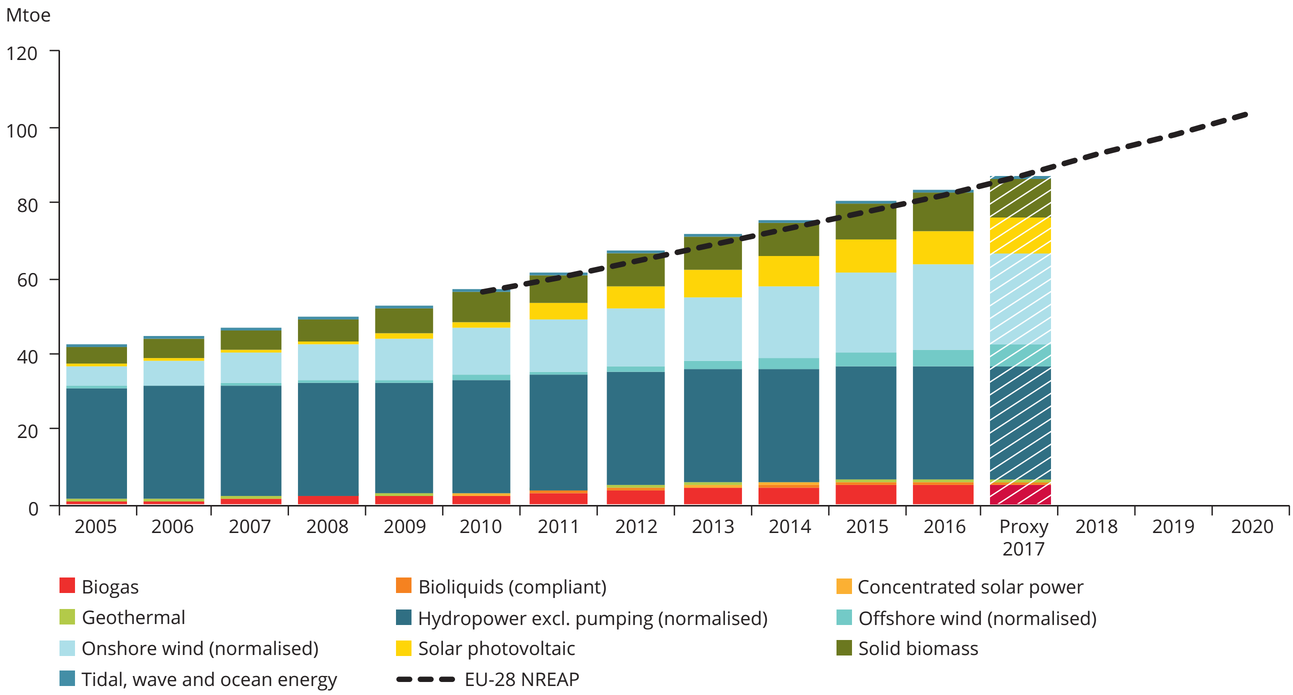
Hydropower is a flexible, mature technology for power generation, and hydropower reservoirs (dams) can provide energy storage. Investments in large-scale hydropower (> 10 MW) were mainly made before 2000. Most of the best sites have already been developed (amounting to about half of the technically feasible potential; Pedraza, 2014), which is why hydropower capacities evolve only a little across Europe and rainfall patterns determine annual changes in hydroelectricity production.

Small and medium run-of-river hydro plants (< 10 MW) have the potential to contribute to addressing future energy needs, providing that new projects do not

([11]) The SHARES tool contains only total offshore and onshore wind energy production. In this report, it is assumed that offshore wind turbines realise 4 000 full load hours per year.

([12]) Based on preliminary data submitted by countries as part of the EEA country (Eionet) consultation, aggregate RES-E values differ slightly from the detailed, technology-level assessment carried out in this report and shown above. When taking into account the preliminary 2017 data from Belgium, Germany, Ireland and Lithuania, the total RES-E generation was 86.2 Mtoe, the total electricity generation 281.7 Mtoe and the resulting RES-E share 30.61 % in 2017.

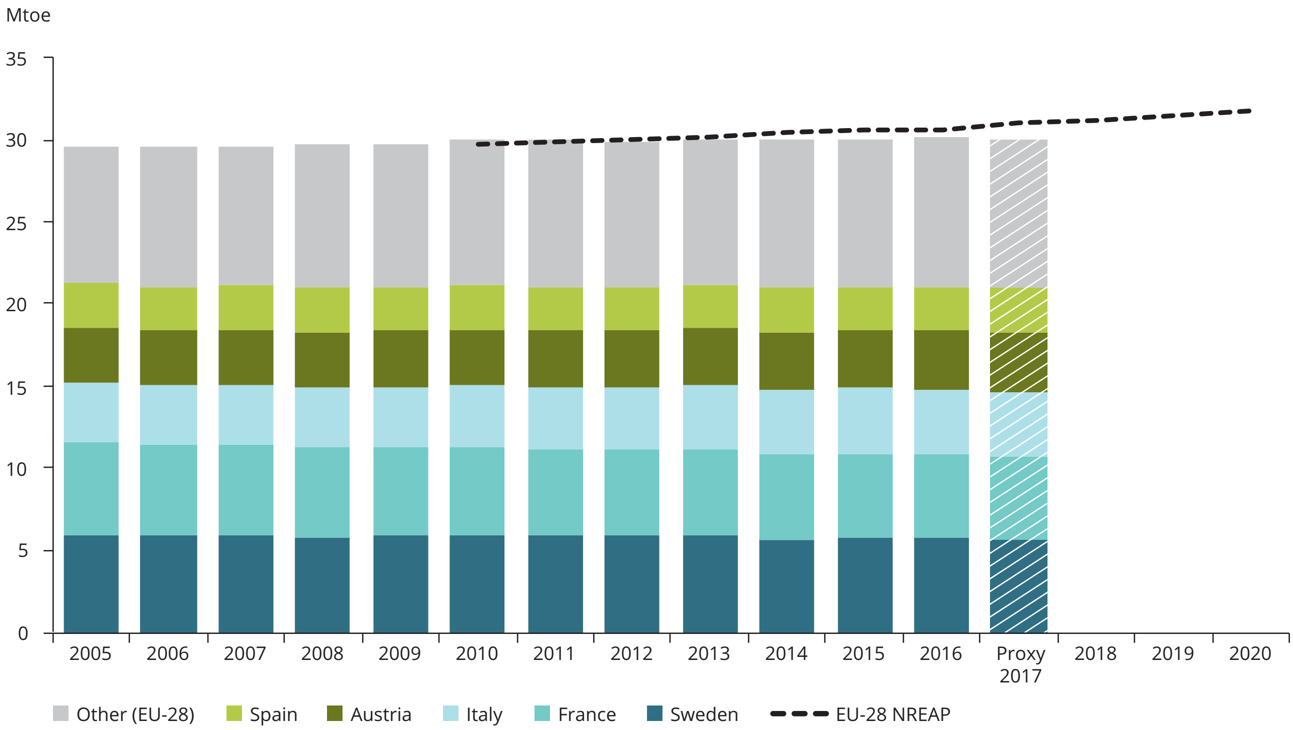
**Figure 2.5 RES-E in the EU**




**Notes:** This figure shows the actual final RES-E consumption for 2005-2016, approximated estimates for 2017 and the expected realisations in the energy efficiency scenario of the NREAPs for 2018-2020. Wind power and hydropower are normalised. The consumption of RES accounts for only biofuels complying with the RED sustainability criteria.

**Sources:** EEA; Eurostat, 2018d; NREAP reports.

**Figure 2.6 RES-E in EU hydropower excluding pumping (normalised)**




**Notes:** This figure shows the actual final RES-E consumption for 2005-2016, approximated estimates for 2017 and the expected realisations in the energy efficiency scenario of the NREAPs for 2018-2020.

**Sources:** EEA; Eurostat, 2018d; NREAP reports.

**Table 2.1 RES-E in the EU, by RES technology**

| Technology | Gross final renewable energy (ktoe) | | | | | Annual growth rate (%) | | |
|---|---|---|---|---|---|---|---|---|
| | 2005 | 2015 | 2016 | Proxy 2017 ([c]) | NREAP 2020 | 2005-2016 | 2015-2016 | 2016-2020 |
| Hydropower excl. pumping (normalised) | 29 589 | 30 056 | 30 100 | 30 033 | 31 786 | 0 | 0 | 1 |
| Onshore wind (normalised) | 5 666 | 20 744 | 22 495 | 24 374 | 30 303 | 13 | 8 | 8 |
| Solid biomass ([a]) | 4 743 | 9 566 | 9 672 | 10 081 | 13 460 | 7 | 1 | 9 |
| Solar PV systems | 126 | 8 797 | 9 047 | 9 504 | 7 062 | 48 | 3 | -6 |
| Biogas | 1 104 | 5 266 | 5 425 | 5 515 | 5 493 | 16 | 3 | 0 |
| Offshore wind (normalised) | 273 | 3 784 | 4 267 | 5 227 | 11 740 | 28 | 13 | 29 |
| Geothermal energy | 464 | 561 | 571 | 566 | 943 | 2 | 2 | 13 |
| Concentrated solar power | 0 | 481 | 480 | 480 | 1 633 | n.a. | 0 | 36 |
| Bioliquids (certified) | 0 | 467 | 440 | 440 | 1 096 | n.a. | -6 | 26 |
| Tidal, wave and ocean energy | 41 | 42 | 43 | 43 | 559 | 0 | 2 | 90 |
| **Total RES-E (normalised, certified biofuels)** | **42 007** | **79 763** | **82 541** | **86 264** | **104 075** | **6** | **3** | **6** |
| **Total RES-E (normalised, including all biofuels) ([b])** | **42 159** | **79 770** | **82 556** | **86 285** | **104 075** | **6** | **3** | **6** |

**Notes:** This table shows the actual final renewable energy consumption for 2005, 2015 and 2016, approximated estimates for 2017 and the expected realisations in the energy efficiency scenario of the NREAPs for 2020. The growth rates are the actual compound annual growth rates for the period 2005-2016, the growth from 2015 to 2016 and the compound annual growth rates required to reach the expected realisations in the NREAPs for 2020. Wind power and hydropower are normalised.

([a]) Renewable municipal waste has been included in solid biomass.

([b]) The series includes all biofuels and bioliquids consumed for electricity purposes, including uncertified ones after 2011.

([c]) Based on preliminary data submitted by Belgium, Germany, Ireland and Lithuania, aggregate RES-E values differ slightly from the detailed, technology-level assessment carried out in this report. Taking into account the preliminary 2017 data from Germany, Ireland and Lithuania, the EEA 2017 estimates would change for hydropower (29 996 ktoe), wind power (onshore and offshore: 29 640 ktoe), solar PV systems (9 646 ktoe) and total RES-E (86 217 ktoe). Concerning other RES technologies, the preliminary data submitted by Germany, Ireland and Lithuania cannot be used for calculating specific consumption levels because of their higher level of aggregation.

**Sources:** EEA; Eurostat, 2018d; NREAP reports.

conflict with the objectives of nature- and water-related legislation (as reflected by (EC, 2011a)). The European Commission published guidance for use by competent authorities, developers and consultants on how hydropower can be reconciled with the requirements of the Habitats and the Birds Directives (EC, 2018b).

Despite the low total growth rate anticipated up to 2020 at the EU level, the importance of hydropower may increase, in response to the need to create an overall more sustainable and climate-compatible energy system. Hydropower reservoirs (together with pumped hydropower) can provide energy storage, which contributes to the flexibility necessary to integrate high levels of renewable energy from intermittent sources. The benefits of balancing the power sector at a large scale with the help of hydropower and grid enhancements were illustrated in a study of Norwegian hydropower (Moser, 2015).

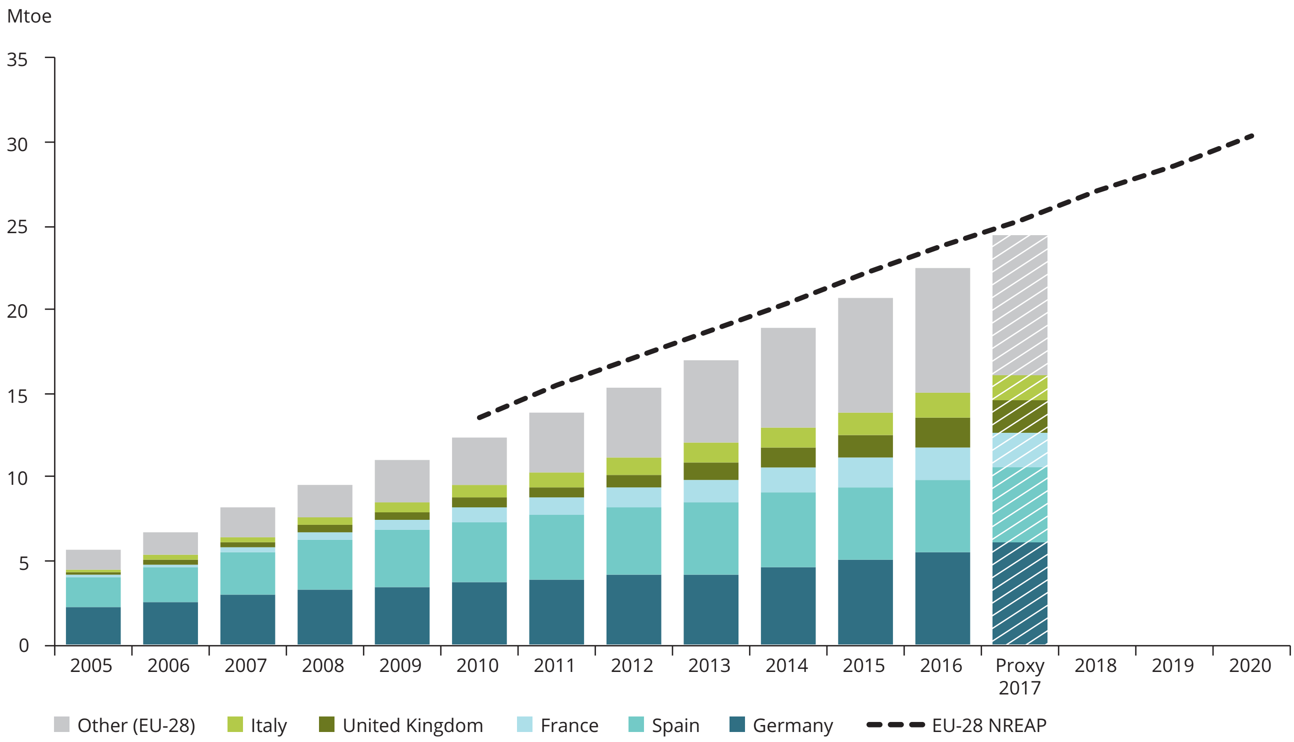
### Onshore wind

Onshore wind power generation increased from 5.7 Mtoe in 2005 to 22.5 Mtoe in 2016. The largest increases came from Germany (5.5 Mtoe) and Spain (4.4 Mtoe).

In 2017, the normalised onshore wind production of electricity was estimated to be 24.4 Mtoe (Figure 2.7). The greatest increase in normalised onshore wind production at the Member State level was recorded in Germany, followed by France and the United Kingdom. Germany installed additional onshore capacity of 5.1 GW, an increase of 4.7 GW net capacity, taking into account decommissioning of 0.4 GW (EurObserv'ER, 2018b).

Onshore wind is a rather mature and lower cost RES technology (IRENA, 2016; Roland Berger, 2016). The NREAPs indicate that onshore wind could increase to

**Figure 2.7 RES-E in the EU: onshore wind (normalised)**




**Notes:** This figure shows the actual final RES-E consumption for 2005-2016, approximated estimates for 2017 and the expected realisations in the energy efficiency scenario of the NREAPs for 2018-2020.

**Sources:** EEA; Eurostat, 2018d; NREAP reports.

30.3 Mtoe in 2020. The compound annual growth rate for onshore wind was 13 % over the period 2005-2016. Although a growth rate of 8 % in the period up to 2020 would be sufficient to meet expectations in the NREAPs, in reality wind power could continue to grow more rapidly until 2020, given the cost reductions that have taken place over the past 10 years.

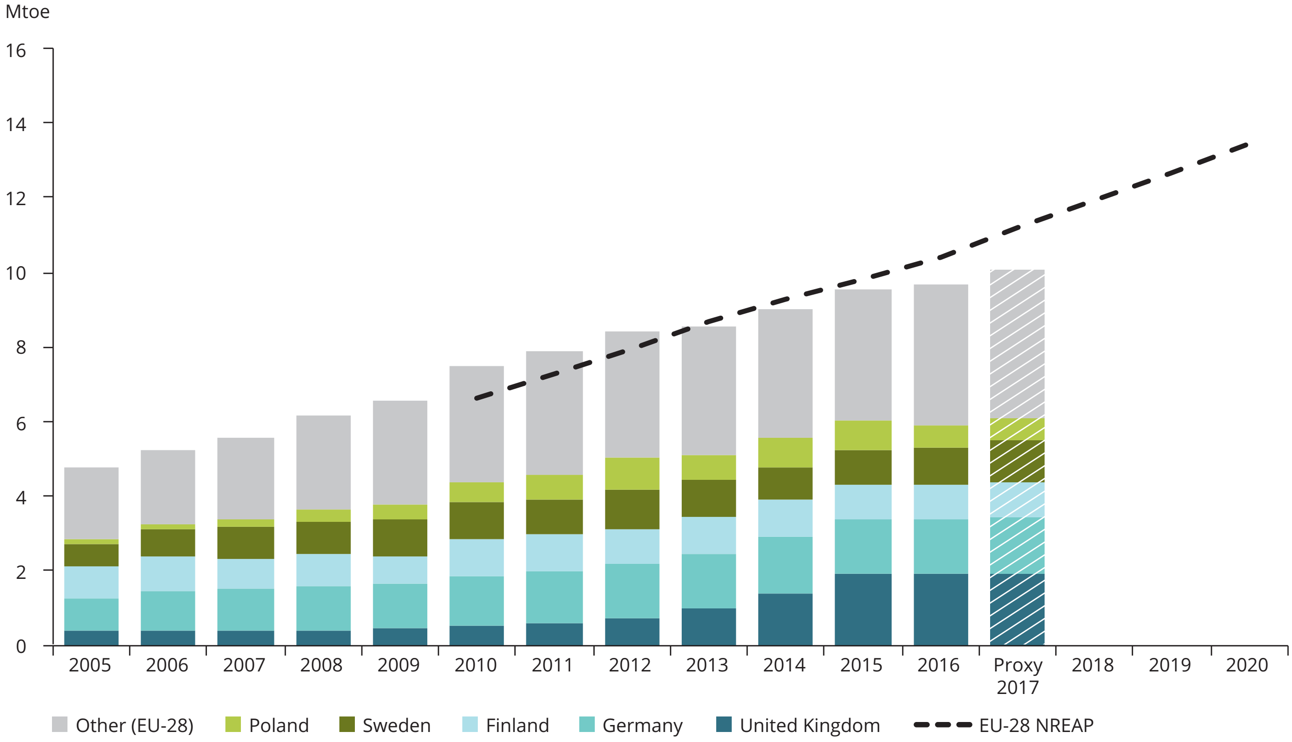
In the past, most Member States offered sufficient remuneration for onshore wind generation, but its deployment was often slowed down by barriers other than cost, such as spatial planning issues and long lead times for administrative and grid access procedures (Ecofys, 2014). To overcome the barrier of siting wind projects in such a way that they are compatible with protecting biodiversity and Europe's natural heritage, the European Commission developed guidance (EC, 2011b). It includes guidelines on how best to ensure that wind energy developments are compatible with the provisions of the Habitats and the Birds Directives (EC, 2014b). In 2016, despite a major reform of the support mechanism to a tendering system, an installation peak for Germany can be observed, as project developers rushed to install projects as fast as possible before payments decreased. Mechanisms are built in the system to ensure even distribution over the country, and citizen-led projects receive special bidding terms. France had a record year for the second year in row, with 1.8 GW installed in 2017, compared with 1.4 GW in 2016. Newly installed capacities also continued to increase sharply in Poland, the United Kingdom and, in 2017, also in Finland. However, the increases were not as steep in Sweden and in the Netherlands in 2017 as in 2016 (EurObserv'ER, 2018b).

### Solid biomass

Electricity generation from solid biomass grew from 4.8 Mtoe in 2005 to 9.7 Mtoe in 2016, driven by, inter alia, the expansion in biomass cogeneration and the conversion of coal-fired power plants to biomass installations ([13]). The growth rate over the

([13]) Municipal solid waste has been included in solid biomass.

**Figure 2.8 RES-E in the EU: solid biomass**




**Notes:** This figure shows the actual final RES-E consumption for 2005-2016, approximated estimates for 2017 and the expected realisations in the energy efficiency scenario of the NREAPs for 2018-2020.

**Sources:** EEA; Eurostat, 2018d; NREAP reports.

period 2005-2016 was 7 % (Figure 2.8). Since 2015, the United Kingdom has surpassed Germany in total electricity generated from solid biomass. In 2016, it accounted for 20 % of total electricity generated from solid biomass in the United Kingdom and in Germany it accounted for 15 %. Finland and Sweden each had shares of 10 %. Preliminary estimates for 2017 show a continued growth of 0.4 Mtoe (or 5 %), with the EU total electricity generated from solid biomass reaching 10.1 Mtoe.

Until 2020, the European Commission has left it up to Member States to decide whether or not to introduce sustainability criteria for solid (and gaseous) biomass fuels. For the post-2020 period, the recast of the RED proposed by the Commission strengthens the existing EU criteria regarding the sustainability of biofuels and bioliquids. It also extends them to the conversion of biomass and biogas to heat and power in plants with a capacity of at least 20 MW (EC, 2016). To safeguard the complete accounting of GHG emissions, the criteria require that GHG emissions and removals from land use, land use change and forestry (LULUCF) (EU, 2018b) are applied to forest biomass as of 2020. To impede further conversions of coal-fired plants into biomass plants, the criteria require that only high-efficiency cogeneration (with a yield of ≥ 80 %) counts towards national progress in RES generation, and that heat and power plants achieve at least an 80 % reduction in GHG emissions compared with fossil fuels from 2021 onwards, and 85 % from 2026 onwards (EU, 2018a).

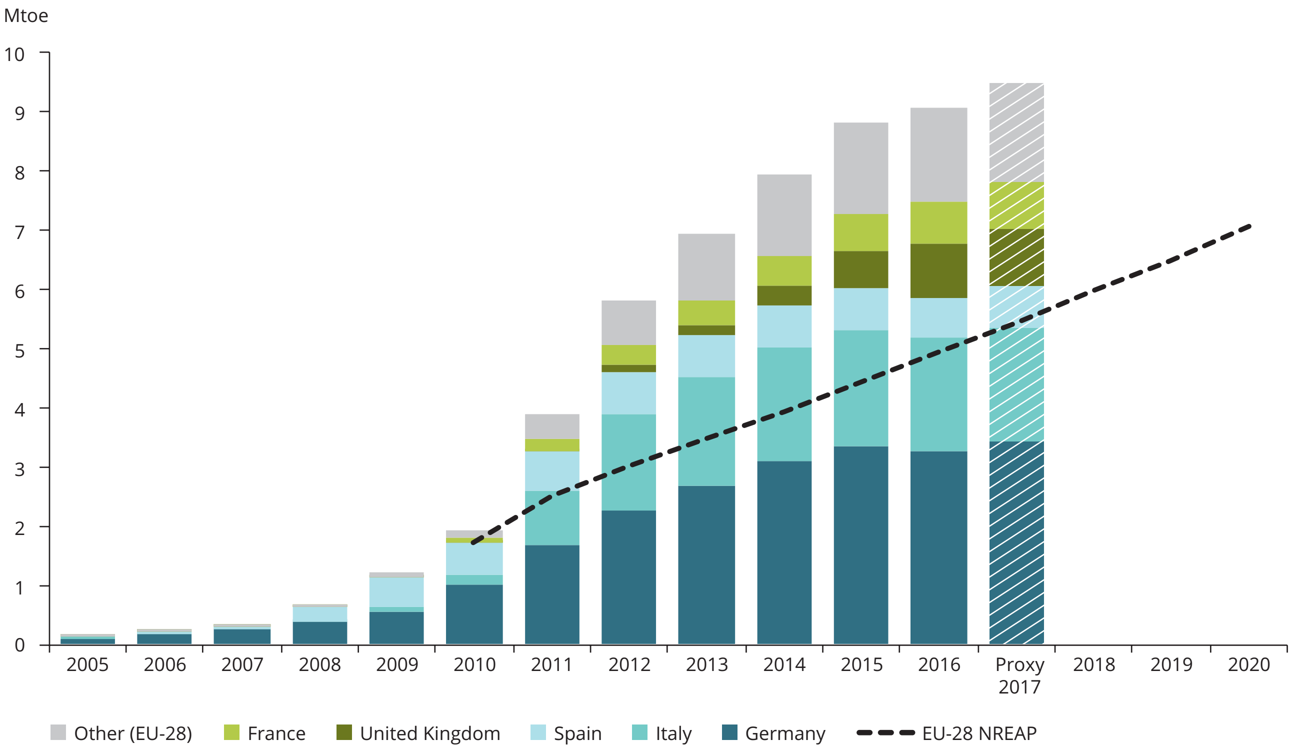
To meet NREAP expectations, a compound annual growth of 9 % in electricity generated from solid biomass over the period remaining up to 2020 would be necessary.

### Solar photovoltaic systems

Solar PV electricity production reached 9.0 Mtoe in 2016 (Figure 2.9), exceeding by more than one quarter (1.9 Mtoe) the level that was expected for 2020, according to the NREAPs (7.1 Mtoe). In 2016, 36 % of all solar PV electricity across the EU was generated in Germany. Italy too had a large share, 21 %, followed by the United Kingdom, Spain and France with shares of 10 %, 8 % and 8 %, respectively.

In 2017, early EEA estimates suggest that the production of solar PV electricity increased again, overtaking the NREAP levels for 2020 by 35 % and

**Figure 2.9 RES-E in the EU: solar PV energy**




**Notes:** This figure shows the actual final RES-E consumption for 2005-2016, approximated estimates for 2017 and the expected realisations in the energy efficiency scenario of the NREAPs for 2018-2020.

**Sources:** EEA; Eurostat, 2018d; NREAP reports.

reaching 9.5 Mtoe ([14]). Results show that within the EU an additional 6.3 GW of solar PV systems was installed in 2016 and 5.6 GW in 2017. The greatest increase in solar PV capacity at the Member State level was recorded in Germany (1.7 GW), followed by France (875 MW) and the United Kingdom (861 MW) ([15]). A further five Member States (Netherlands, Italy, Belgium, Austria and Spain) added more than 0.1 GW in 2017 (EurObserv'ER, 2018a).

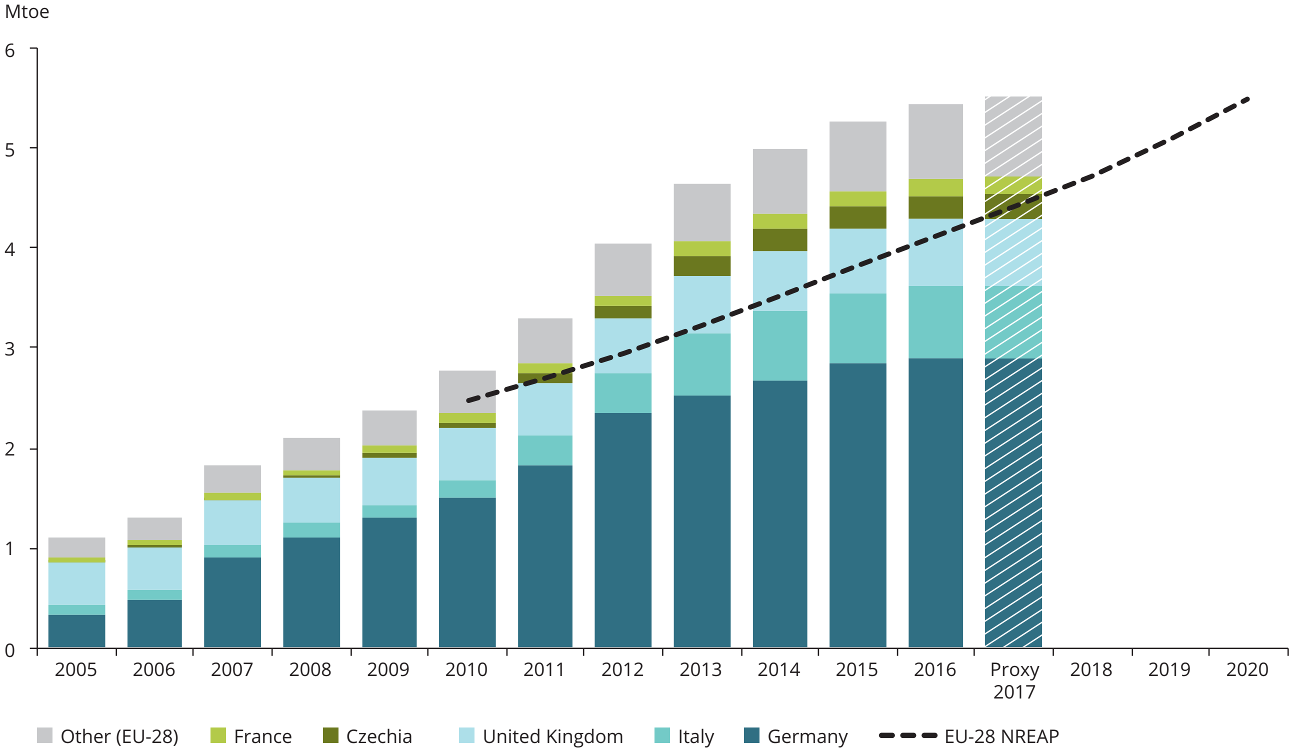
Rapid technological progress, cost reductions and the relatively short project development times are among the key drivers for the growth of solar PV energy over the past 10 years (Ecofys, 2014). After the peak years, 2011 and 2012, the market slowed down because of increased taxes on self-consumption and new policies reducing financial support. As a result, annually installed solar PV capacities have also slowed down since 2011.

The European electricity market has witnessed a number of changes. The revised guidelines for environmental protection and energy, of 2014, established public tendering in the electricity system as the new norm for medium- and high-capacity facilities (> 500 kW installations) as of 1 January 2016 (EC, 2014a). As of 1 January 2017, the guidelines require Member States to run transparent, technology-neutral tenders for all renewable energy projects, with certain exemptions being allowed for capacities of less than 1 MW (6 MW in the case of wind power). These measures aim to give Member States more control over their markets and over the prices charged to consumers. At the same time, guaranteed production-related support has become the preferred option to support small PV panel installations (as well as other small-scale variable renewables). This addresses consumer needs for at least the next few years, as the electricity

([14]) Based on preliminary data submitted by countries as part of the EEA country (Eionet) consultation, aggregate RES-E values differ slightly from the detailed, technology-level assessment carried out in this report. When taking into account the preliminary 2017 data submitted by Belgium, Germany and the United Kingdom, electricity generation from solar PV (excluding concentrated solar) increased to 9.96 Mtoe.

([15]) For 2017, capacity data for all Member States are taken from EurObserv'ER and, in some cases, they might vary slightly from national data.

**Figure 2.10 RES-E in the EU: biogas**




**Notes:** This figure shows the actual final RES-E consumption for 2005-2016, approximated estimates for 2017 and the expected realisations in the energy efficiency scenario of the NREAPs for 2018-2020.

**Sources:** EEA; Eurostat, 2018d; NREAP reports.

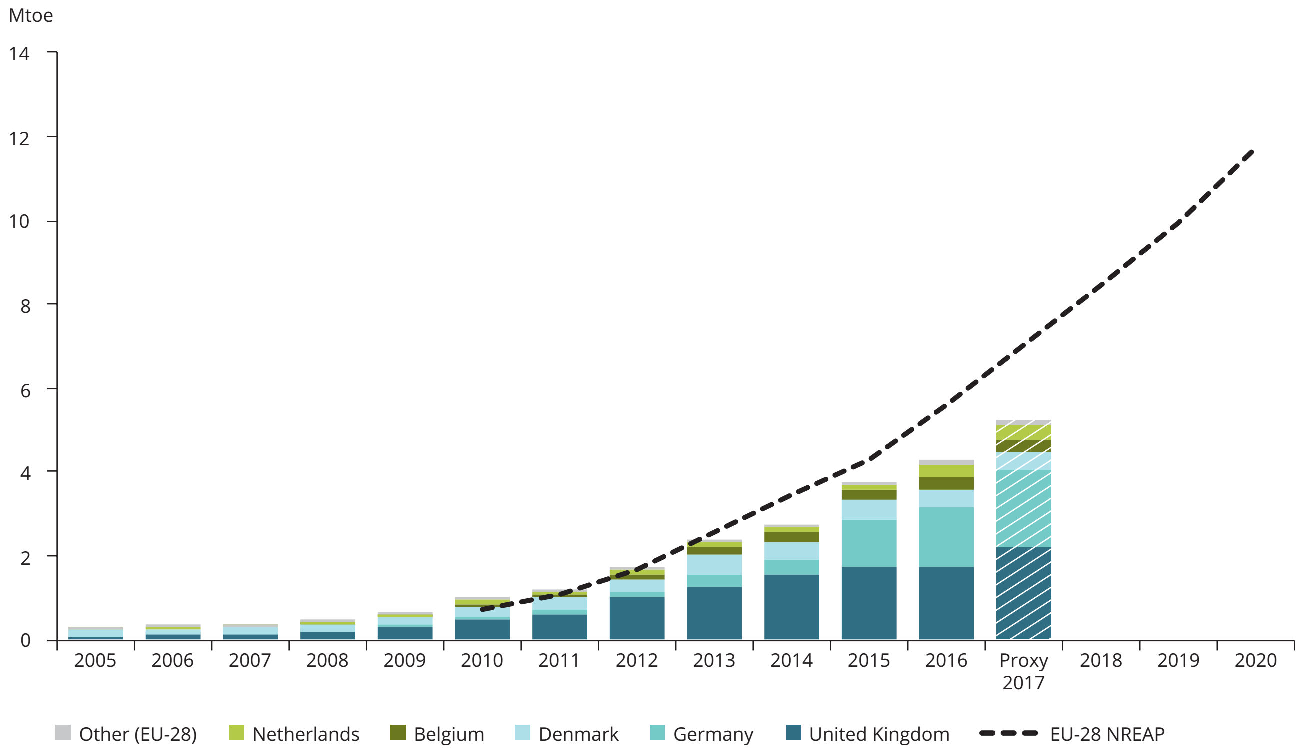
generation market in many Member States is shifting from a system of relatively stable and continuous, centralised supply towards a system with more and decentralised small-scale renewable sources used by prosumers for self-consumption and sale to the market (EurObserv'ER, 2017a). Since 2012, there has been a downwards trend in additional capacity (JRC, 2017). The European market is seeing less rapid development in large solar installations, compensated by more activity in commercial and domestic roof-mounted systems. The self-consumption market is supported by the power storage market (with 40 000 small battery systems sold in Germany in 2017, of which 80 % received financial support). In Spain, too, the self-consumption segment contributed to the rebound of the market, apart from the connection of a few large solar farms. In the United Kingdom, the growth in large installations stalled in the last three quarters of 2017, as no solar projects have qualified since the second auction under the Contract for Difference (CfD) system. In the last quarters, only small installations that continued to benefit from a feed-in tariff were installed (EurObserv'ER, 2018a). As the first solar panels come to the end of their lives, industry sees opportunities for recycling the demounted panels. In France, Europe's first recycling plant opened in June this year, the first of its kind in Europe (Reuters, 2018).

### Biogas

Electricity generation from biogas grew from 1.1 Mtoe in 2005 to 5.4 Mtoe in 2016 (Figure 2.10), within reach of the level expected for 2020 in the NREAPs (5.5 Mtoe). The compound annual growth rate for biogas was 16 % over the period 2005-2016. At the EU level, over half of the electricity sourced from biogas is recorded in Germany (53 %). Italy and the United Kingdom both accounted for 13 % of the EU total.

In 2017, electricity generation from biogas increased further, to 5.5 Mtoe, according to early EEA estimates, already slightly exceeding the levels of electricity generation from biogas expected for 2020 in the NREAPs. Therefore, the generation of electricity from biogas has grown faster than expected. After strong growth in 2011 and 2012, more moderate growth could be observed in the 2013-2016 period due to policy changes to discourage the use of energy crops in Germany, Italy and the United Kingdom. For a number of years, most of the EU's primary biogas

**Figure 2.11 RES-E in the EU: offshore wind (normalised)**




**Notes:** This figure shows the actual final RES-E consumption for 2005-2016, approximated estimates for 2017 and the expected realisations in the energy efficiency scenario of the NREAPs for 2018-2020.

**Sources:** EEA; Eurostat, 2018d; NREAP reports.

energy production has been taken up by the 'other biogas' category, whose share has constantly risen compared with the landfill and sewage plant biogas categories (EurObserv'ER, 2017c). At the European level, discussions on sustainability criteria are similar to those concerning solid biomass.

### Offshore wind energy

Offshore wind power grew from 0.3 Mtoe in 2005 to 4.3 Mtoe in 2016, adding approximately 0.5 Mtoe from 2015 to 2016 (Figure 2.11). The largest increase in normalised offshore wind power generation at the Member State level occurred in Germany and the Netherlands, which recorded increases of 0.3 Mtoe and 0.2 Mtoe, respectively, from 2015 to 2016. According to estimates from EurObserv'ER, 2.6 GW of additional offshore wind capacity was installed in 2017 in the EU, spread over 12 fully connected offshore wind farms and four partially connected wind farms. With these new additions in the United Kingdom, Germany, Denmark, Belgium and Finland, the total capacity grew in 2017 to 15.2 GW (EurObserv'ER, 2018b). At the EU level, more than 40 % of the total normalised electricity generation from offshore wind power in 2016 was recorded in the United Kingdom (41 %), and Germany has increased its share significantly, from 13 % in 2014 to 33 % in 2016.

According to early EEA estimates, European offshore wind generation in 2017 was 5.2 Mtoe, an increase of 23 % compared with 2016.

In 2017, Hywind Scotland, located 25 km off the Scottish coast (five wind turbines with a combined capacity of 30 MW and value of EUR 210 million) was the first commercial offshore wind farm in the world to be mounted on floating foundations. The masts of the turbines measure 253 m, of which 175 m are under water. Also in 2017, a demonstration project of a floating wind farm was inaugurated under the European Floatgen project, 22 km off the French coast (EurObserv'ER, 2018b)

Offshore wind power would need to grow to 11.7 Mtoe by 2020 to reach the expected realisations in the NREAPs. This corresponds to a compound annual growth rate of 29 % per year from 2016 to 2020. To be successful, the offshore wind sector needs to deliver the objectives of the EU integrated maritime policy's Blue Economy agenda and comply with nature and marine-related legislation and objectives.

### Other sources of renewable electricity

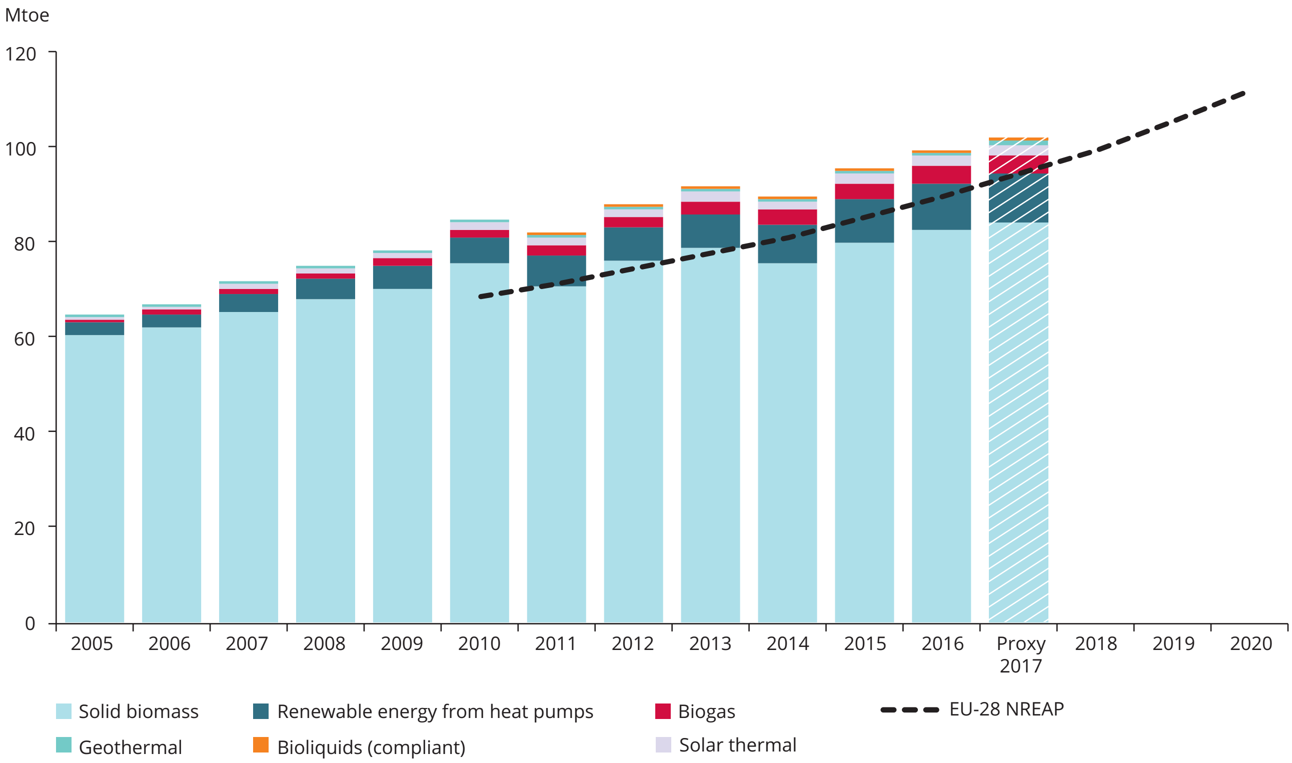
- Concentrated solar power (CSP) technology is currently only realistically applicable in southern Europe. CSP provided 0.5 Mtoe of renewable energy in 2016, and no change was expected in 2017. New CSP installations with approximately 500 MW capacity are under development in Europe, of which over 50 % are located in Italy (EurObserv'ER, 2017b).
- Geothermal electricity grew by only 2 % per year over the period 2005-2016, to reach 0.6 Mtoe in 2016. No significant change was expected in 2017.
- Electricity generation from tidal, wave and ocean energy remained at only 43 ktoe in 2016, and no significant change was expected in 2017.
- Electricity production from compliant bioliquids decreased by 6 % from 2015 to 2016 and remained at a moderate level, 0.4 Mtoe, in 2016. The EEA estimates the same level of generation in 2017.

### *2.2.3 Renewable heating and cooling*

At the EU level, the gross final consumption of renewable energy in the heating and cooling market sector (RES-H&C) reached a share of 19.1 % in 2016. Figure 2.12 and Table 2.2 show the development of RES-H&C from 2005 to 2016, approximated estimates for 2017 and the expected NREAP development by 2020.

- The gross final consumption of RES-H&C was 99.3 Mtoe in 2016, which corresponds to an increase of 4.0 Mtoe compared with 2015.
- In 2016, the largest contributions came from solid biomass (82.7 Mtoe, or 83 % of all RES-H&C), heat pumps (9.8 Mtoe, or 10 % of all RES-H&C) and biogas (3.6 Mtoe, or 4 % of all RES-H&C).
- Over the period 2005-2016, the compound annual growth rate of RES-H&C was 4 % per year. To realise the expectations in the NREAPs for 2020, a growth rate of 3 % per year would be required over the period 2016-2020.

**Figure 2.12 RES-H&C in the EU**




**Notes:** This figure shows the actual final RES-H&C for 2005-2016, approximated estimates for 2017 and the expected realisations in the energy efficiency scenario of the NREAPs for 2018-2020. The consumption of RES accounts for only biofuels complying with the RED sustainability criteria.

**Sources:** EEA; Eurostat, 2018d; NREAP reports.

- According to early proxy estimates, RES-H&C increased from 99.3 Mtoe in 2016 to 101.8 Mtoe in 2017, while the amount of fuel consumed for heating and cooling increased from 521 Mtoe to 524 Mtoe, resulting in a renewable share of heating and cooling consumption of 19.4 % in 2017 ([16]).

### Solid biomass

Solid biomass remains the largest source of renewable energy for heating (Figure 2.13) and in 2016 it exceeded the NREAP levels expected for 2020. The consumption of renewable heat originating from solid biomass increased from 79.9 Mtoe in 2015 to 82.7 Mtoe in 2016. The compound annual growth rate for heat from solid biomass was 3 % over the period 2005-2016. In 2017, the consumption of solid biomass for renewable heat increased to 84.2 Mtoe, according to the early EEA estimate, exceeding the expected NREAP level for 2020 by 3.3 Mtoe.

With the rising consumption of solid biomass as a renewable heating fuel, the sustainability of the current and future supply of the resource was the focus of two recent EU-financed studies (PWC et al., 2017; EC, 2018a). According to one of the studies, solid biomass for energy is largely supplied from North America, Russia and within the EU (EC, 2018a). Although about 88 % of biomass feedstock from within Member States was consumed close to the production source, net imports of bioenergy (solid biomass, biofuels) play a role and stood at 5.4 Mtoe in 2014, of which 5 % was ethanol, 9 % biodiesel, 48 % wood pellets and 37 % other wood fuels (PWC et al., 2017). The intra-EU trade in wood pellets amounted to 2.2 Mtoe in 2014, but it is projected to increase according to the study to 11.6 Mtoe by 2030, exceeding the projected 2030 extra-EU import of 10.3 Mtoe (PWC et al., 2017).

**Table 2.2 RES-H&C in the EU**

| Technology | Gross final renewable energy (ktoe) | | | | | Annual growth rate (%) | | |
|---|---|---|---|---|---|---|---|---|
| | 2005 | 2015 | 2016 | Proxy 2017 ([c]) | NREAP 2020 | 2005-2016 | 2015-2016 | 2016-2020 |
| Solid biomass ([a]) | 60 718 | 79 926 | 82 728 | 84 226 | 80 886 | 3 | 4 | -1 |
| Renewable energy from heat pumps | 2 315 | 9 108 | 9 813 | 10 552 | 12 289 | 14 | 8 | 6 |
| Biogas | 728 | 3 274 | 3 592 | 3 766 | 5 108 | 16 | 10 | 9 |
| Solar thermal | 701 | 2 057 | 2 120 | 2 171 | 6 455 | 11 | 3 | 32 |
| Geothermal | 557 | 682 | 766 | 772 | 2 646 | 3 | 12 | 36 |
| Bioliquids (certified) | 0 | 278 | 281 | 281 | 4 416 | n.a. | 1 | 99 |
| **Total RES-H&C (certified biofuels)** | **65 018** | **95 326** | **99 300** | **101 769** | **111 801** | **4** | **4** | **3** |
| **Total RES-H&C (including all biofuels) ([b])** | **65 184** | **95 451** | **99 433** | **101 902** | **111 801** | **4** | **4** | **2** |

**Notes:** This table shows the actual final RES-H&C for 2005, 2015 and 2016, approximated estimates for 2017 and the expected realisations in the energy efficiency scenario of the NREAPs for 2020. Also shown are the actual compound annual growth rates from 2005 to 2016, the growth from 2015 to 2016 and the compound annual growth rates required to reach the expected realisations in the NREAPs. The consumption of RES accounts for only biofuels complying with RED sustainability criteria.

([a]) Renewable municipal waste has been included in solid biomass.

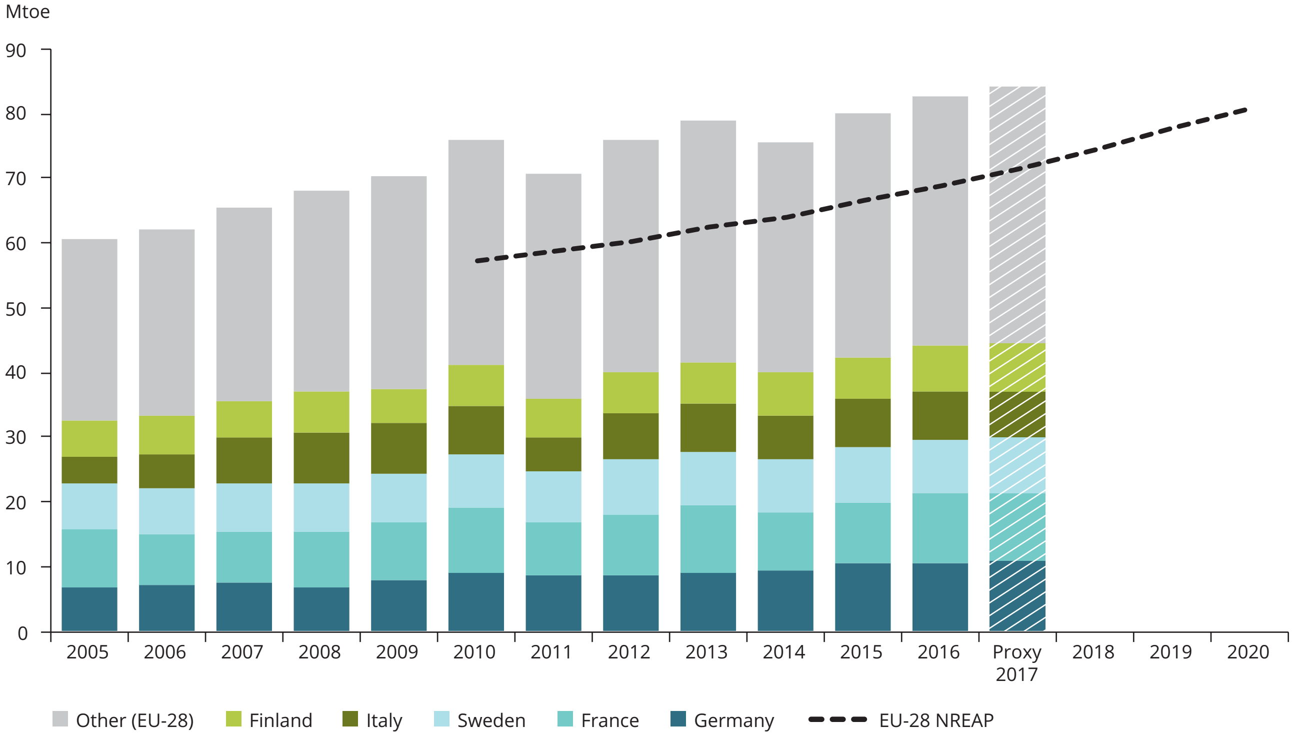
([b]) The series includes all biofuels and bioliquids consumed for heating and cooling, including uncertified ones after 2011.

([c]) See footnote ([17]) for 2017 proxy for 'Total renewable heat (certified biofuels)'. For the other values the preliminary data from Belgium, Germany, Ireland and Lithuania are not sufficiently detailed to allow a calculation of technology-specific consumption levels.

**Sources:** EEA; Eurostat, 2018d; NREAP reports.

([16]) Based on preliminary data submitted by countries as part of the EEA Eionet consultation, aggregate RES-H&C values differ slightly from the detailed, technology-level assessment carried out in this report. When taking into account the preliminary 2017 data submitted by Belgium, Germany, Ireland and Lithuania, the total RES-H&C consumption was 101.9 Mtoe, all fuels consumed for heating and cooling was 526.9 Mtoe and the resulting RES-H&C share was 19.3 % in 2017.

**Figure 2.13 RES-H&C in the EU: solid biomass**




**Notes:** This figure shows the actual final RES-H&C for 2005-2016, approximated estimates for 2017 and the expected realisations in the energy efficiency scenario of the NREAPs for 2018-2020.

**Sources:** EEA; Eurostat, 2018d; NREAP reports.

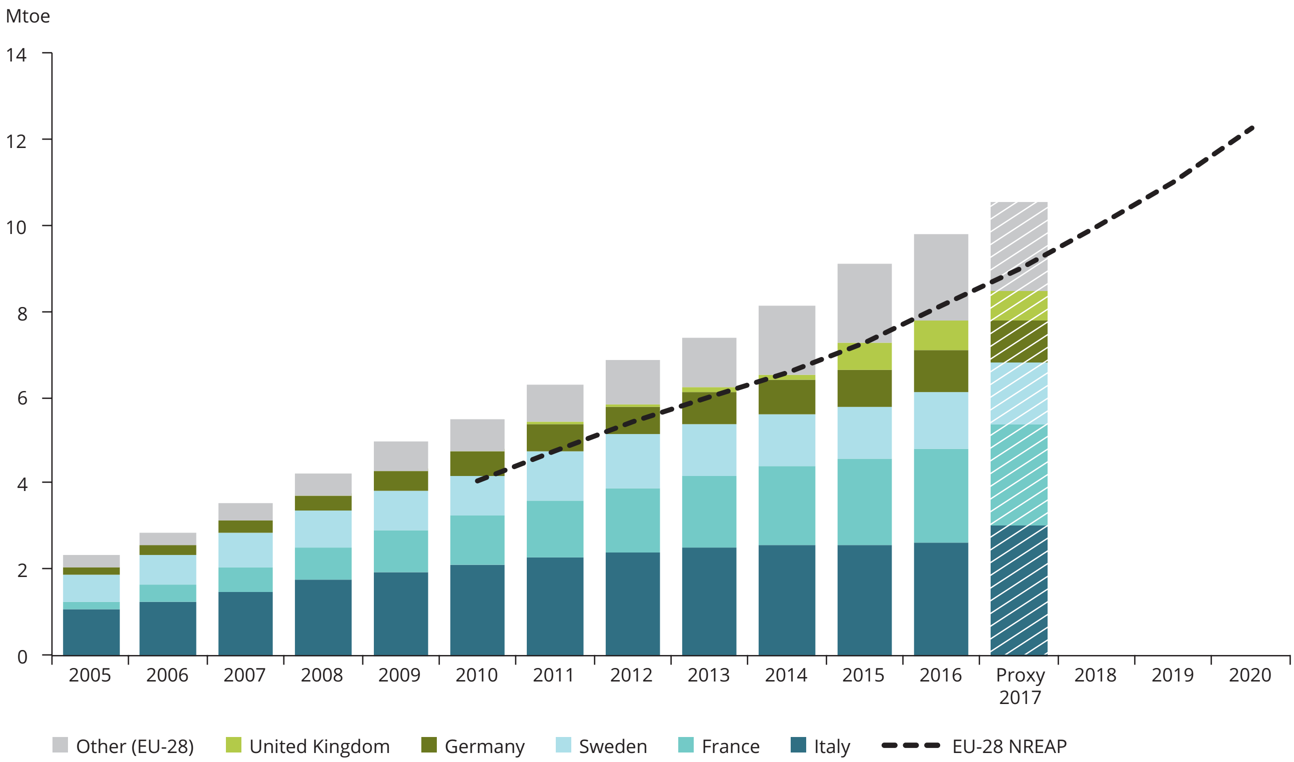
## Heat pumps

Renewable energy from heat pumps grew from 2.3 Mtoe in 2005 to 9.8 Mtoe in 2016 (Figure 2.14). In northern Europe, most heat pumps are used for heating, but elsewhere there is also a market for cooling. In 2016, Italy contributed 24 % to final EU-wide RES consumption from heat pumps. France (15 %), Sweden (15 %) and Germany (9 %) also made significant contributions.

The use of heat pumps increased considerably in 2016 for the second consecutive year and is forecast to do so again in the near future. After a growth in sales of 20 % in 2015, the market further expanded by 26.1 % in 2016, with over 3.3 million heat pumps units sold within the EU. Air-to-air heat pumps continue to lead sales (2.99 million units in 2016), being the preferred choice in home renovations. Among the EU Member States, Italy has recorded the highest sales of heat pumps (1.54 million units), followed by Spain (792 000) and France (447 000). The European Heat Pump Association and EurObserv'ER agree that in the next 3 years the market will probably expand further by 13-14 % annually. The main drivers behind this trend are the stable home construction market and a favourable price ratio of electricity and gas, which results in attractive recovery costs for home owners. Another technological aspect of heat pumps is that surplus electricity, e.g. from solar power, can be used for cooling with reversible heat pumps. This synergy may be particularly interesting in view of the growing PV self-consumption market in the coming years (EurObserv'ER, 2017c).

In 2017, renewable heat from heat pumps increased to 10.5 Mtoe, according to early EEA estimates. With a total growth rate over the period 2005-2016 of 14 % per year, the expectations in the NREAPs for 2016 continue to be exceeded, as in previous years. A 6 % compound annual growth rate would be sufficient to meet the expected contribution from heat pumps by 2020, according to the NREAPs.

**Figure 2.14 RES-H&C in the EU: renewable energy from heat pumps**




**Notes:** This figure shows the actual final RES-H&C for 2005-2016, approximated estimates for 2017 and the expected realisations in the energy efficiency scenario of the NREAPs for 2018-2020.

**Sources:** EEA; Eurostat, 2018d; NREAP reports.

### Solar thermal energy

The production of renewable heat from solar thermal technology increased by 11 % per year over the period 2005-2016, growing from 0.7 Mtoe to 2.1 Mtoe (Figure 2.15). However, despite a further estimated increase to 2.17 Mtoe in 2017, solar thermal energy has not been able to meet the expectations of the NREAPs.

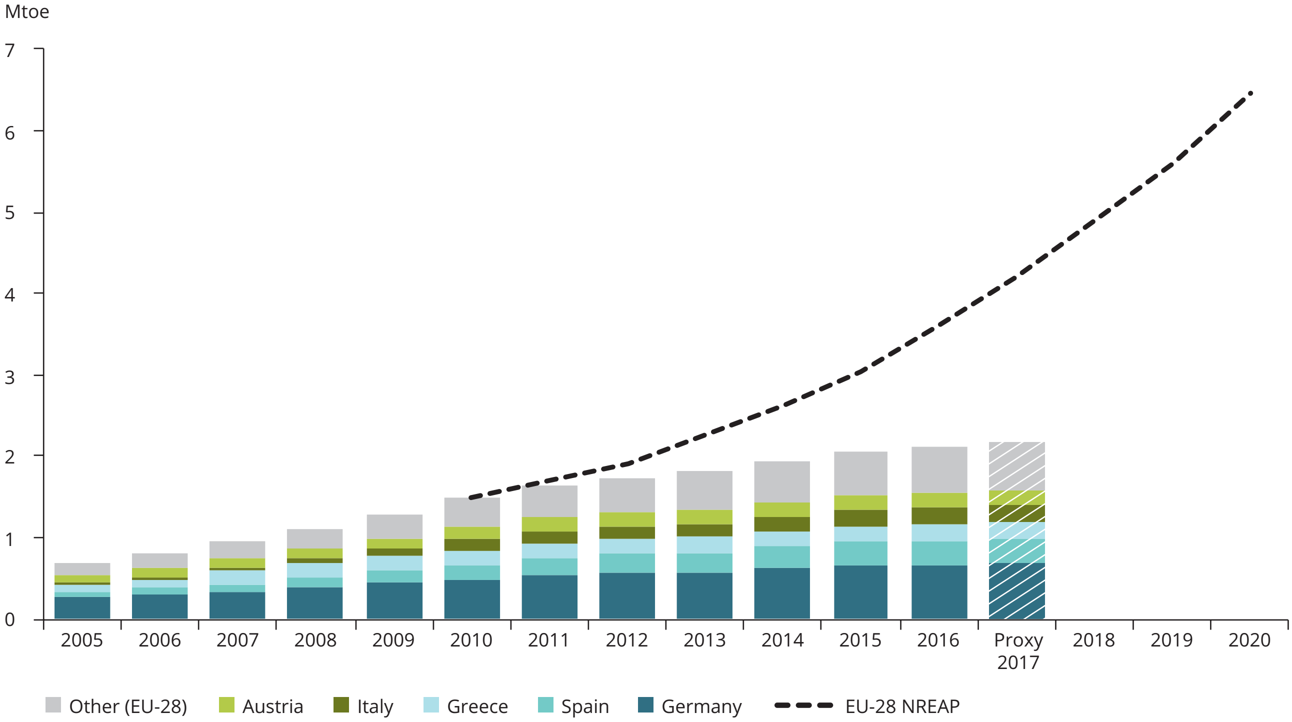
Solar thermal collectors 'harvest' heat from the sun for hot water or space heating. The European solar thermal market has been contracting since 2008 and installed surfaces decreased from 4.6 million $m^2$ in 2008 to 2.6 million $m^2$ in 2016 (EurObserv'ER, 2017b). EurObserv'ER attributes this to (1) the low price of natural gas, which affects solar heat's ability to compete by giving the advantage to the condensing gas boiler market, (2) stop-start and degressive subsidy policies operating in some countries and (3) competition from alternative technologies. However, Denmark installed 0.5 million $m^2$ in 2016, of which 99 % was intended to supply heating networks. Other countries are also interested in converting their heating networks to incorporate more solar thermal technologies (EurObserv'ER, 2017b).

A growth rate of 32 % per year would be needed to reach the NREAP expectations for 2020.

### Other sources of renewable heating and cooling

- Renewable heat from biogas grew from 0.7 Mtoe in 2005 to 3.6 Mtoe in 2016. According to EEA estimates, it reached 3.8 Mtoe in 2017.
- Geothermal heat will have to bridge a large gap if it is to achieve the target of 2.6 Mtoe anticipated for 2020. In 2016, the production of geothermal heat was 0.8 Mtoe, but substantial growth compared with 2015 was observed compared with previous years.
- The production of heat from liquid biofuels was 0.3 Mtoe in 2016, unchanged from 2015.

**Figure 2.15 RES-H&C in the EU: solar thermal energy**




**Notes:** This figure shows the actual final RES-H&C for 2005-2016, approximated estimates for 2017 and the expected realisations in the energy efficiency scenario of the NREAPs for 2018-2020.

**Sources:** EEA; Eurostat, 2018d; NREAP reports.

### *2.2.4 Renewable transport fuels*

The share of RES-T in the EU was 7.1 % in 2016. Figure 2.16 and Table 2.3 show the development of the use of biofuels in transport up to 2016, approximated estimates for 2017 and their expected NREAP development by 2020.

- The gross final consumption of compliant biofuels was 13.6 Mtoe in 2016, which is a 6 % increase compared with 2015.
- According to proxy estimates, the RES-T share grew from 7.1 % in 2016 to 7.3 % in 2017 ([17]).
- To realise the expectations in the NREAPs for 2020, a growth rate of 21 % per year would be required over the remainder of the period 2016-2020.

The use of RES-E in road transport in the EU was 38.8 ktoe in 2016, a modest increase from 33.5 ktoe in 2015, and is estimated to be 40.7 ktoe in 2017 ([18]). The amount of RES-E used in other transport modes was 1.8 Mtoe ([19]) in 2016 and is estimated to be 1.9 Mtoe in 2017.

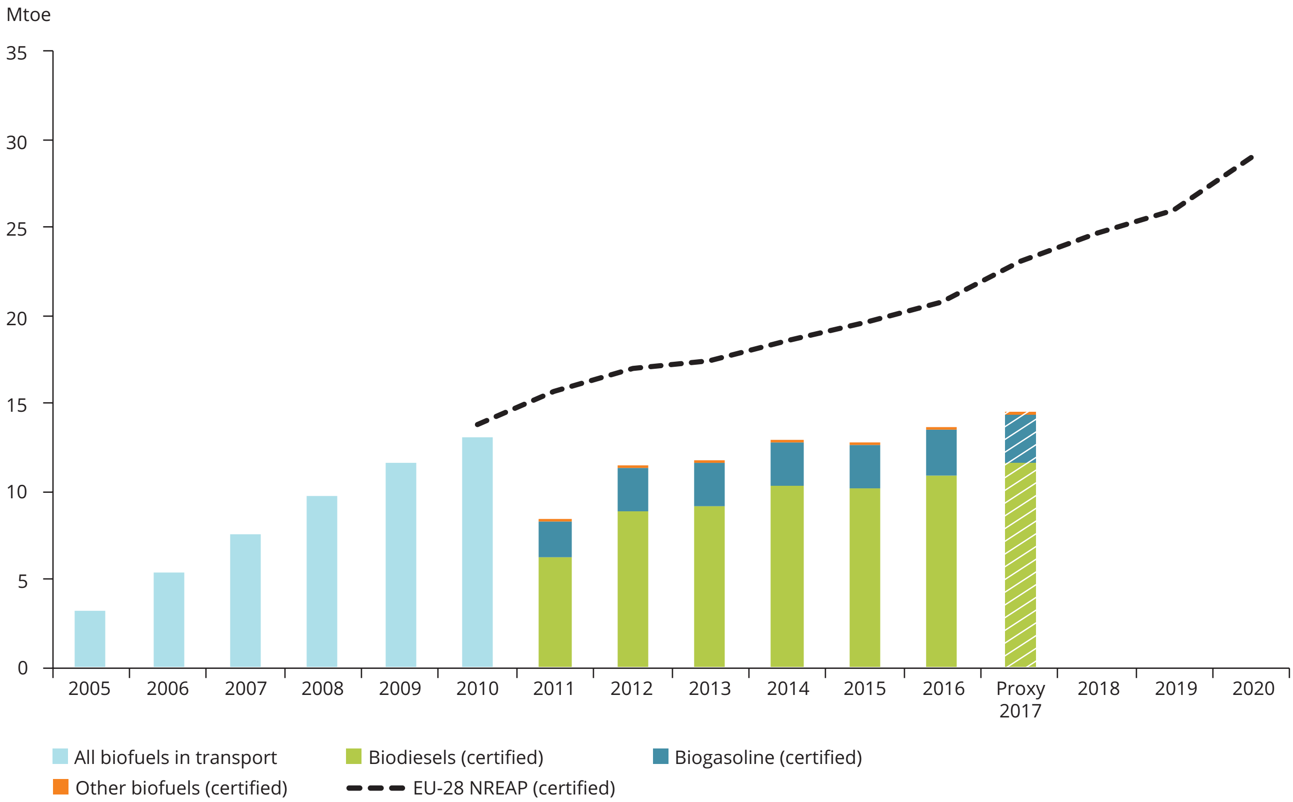
From 2005 to 2010, the gross final consumption of biofuels increased strongly, but that growth has slowed and more or less stalled since then (Figure 2.17). In 2016, there was a stable consumption of 13.8 Mtoe (all biofuels). The EEA estimates that the use of biofuels in transport was 14.7 Mtoe in 2017. Most countries' consumption of biofuels is below the expected realisations in their NREAPs, but there is no clear EU-wide trend.

([17]) Based on preliminary data submitted by countries as part of the EEA country (Eionet) consultation, aggregate RES-T values differ slightly from the detailed, technology-level assessment carried out in this report. When taking into account the preliminary 2017 data submitted by Belgium, Germany, Ireland and Lithuania, the RES-T share was 7.2 % in 2017.

([18]) When taking into account the preliminary 2017 data submitted by Belgium, Germany, Ireland and Lithuania, the consumption of renewable electricity in road transport increased to 42 ktoe in 2017.

([19]) This RES-E is produced by the energy technologies discussed in Section 2.2.2.

**Figure 2.16 RES-T in the EU: biofuels**




**Notes:** This figure shows the actual final RES-T for 2005-2016, approximated estimates for 2017 and the expected realisations in the energy efficiency scenario of the NREAPs for 2018-2020. The consumption of RES accounts for only biofuels complying with the RED sustainability criteria.

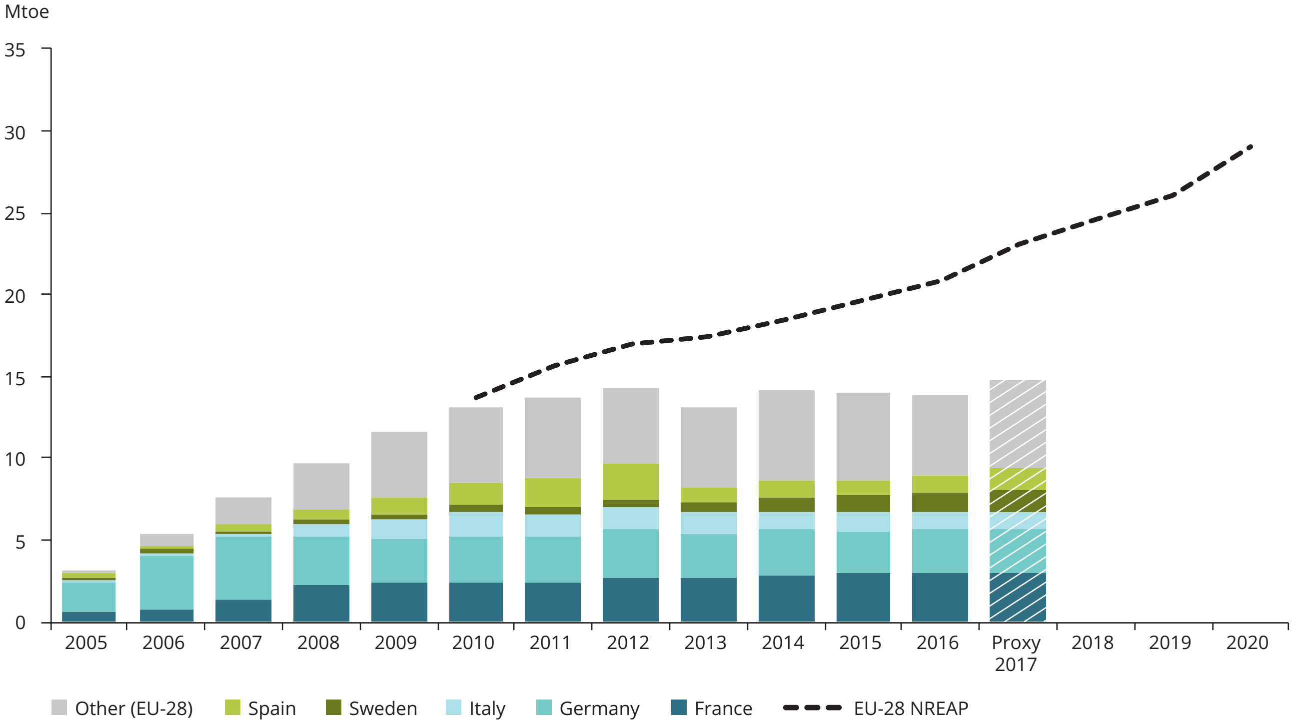
**Sources:** EEA; Eurostat, 2018d; NREAP reports.

The transport sector has a separate RES target for 2020, which is equal to a 10 % share of renewable energy consumption in each Member State. Concerns about the sustainability, and direct and indirect land use of first-generation biofuels led to a reconsideration of the role of food-based biofuels (Kampman et al., 2015). To reduce indirect land use impacts owing to biofuels and bioliquids, the Indirect Land Use Change (ILUC) Directive of 2015 (EU, 2015) attempts to tackle — among other things — these concerns. It limits the share of biofuels from crops grown on agricultural land to 7 % and obliges Member States to establish indicative national targets for advanced biofuels (second/third generation) for 2020, with a reference value of 0.5 %. Annex IX of the ILUC Directive also harmonises the list of feedstocks whose contribution would count double towards the 2020 national target of a 10 % share of RES-T. For electricity produced from RES and consumed by electric road vehicles and rail transport, the ILUC Directive increases the multiplier factors for calculating the market share of RES-T. It increases the minimum reduction threshold for GHG emissions applied to biofuels produced in new installations, and it obliges fuel suppliers to report annually the provisional mean values of the estimated ILUC emissions from biofuels traded (EU, 2015).

In recent years, a significant volume of biofuels could not be demonstrated to be compliant with the sustainability criteria for inclusion in the calculation for the RED ([20]).

([20]) Roughly 9 % of all biofuels consumed in transport in 2016 were not demonstrated to be compliant with the sustainability criteria in the RED.

**Figure 2.17 RES-T in the EU: biofuels including non-compliant biofuels**




**Notes:** This figure shows the actual final RES-T for 2005-2016, approximated estimates for 2017 and the expected realisations in the energy efficiency scenario of the NREAPs for 2018-2020.

**Sources:** EEA; Eurostat, 2018d; NREAP reports.

**Table 2.3 Renewable transport in the EU: biofuels**

| Technology | Gross final renewable energy (ktoe) | | | | | Annual growth rate | | |
|---|---|---|---|---|---|---|---|---|
| | 2005 | 2015 | 2016 | Proxy 2017 | NREAP 2020 | 2005-2016 | 2015-2016 | 2016-2020 |
| Biodiesels (all) | 2 470 | 11 159 | 11 083 | 11 736 | 20 920 | 15 | -1 | 17 |
| Biogasoline (all) | 584 | 2 671 | 2 604 | 2 841 | 7 324 | 15 | -3 | 29 |
| Other biofuels (all) | 155 | 132 | 136 | 146 | 746 | -1 | 3 | 53 |
| Certified biofuels | 0 | 12 843 | 13 646 | 14 538 | 28 989 | n.a. | 6 | 21 |
| All biofuels | 3 209 | 13 963 | 13 824 | 14 723 | 28 989 | 14 | -1 | 20 |

**Notes:** This table shows the actual final RES-T for 2005, 2015 and 2016, approximated estimates for 2017 and the expected realisations in the energy efficiency scenario of the NREAPs for 2020. Also shown are the actual compound annual growth rates for 2005-2016, the growth from 2015 to 2016 and the compound annual growth rates required to reach the expected realisations in the NREAPs. The consumption of RES accounts for only biofuels complying with RED sustainability criteria.

**Sources:** EEA; Eurostat, 2018d; NREAP reports.

# 3 Effects on fossil fuel consumption and greenhouse gas emissions

- The increased consumption of renewable energy in 2016 compared with 2005 levels allowed the EU in 2016 to:
  - reduce its total GHG emissions by 460 $MtCO_2$, equivalent to 9.4 % of total EU GHG emissions;
  - improve energy security by cutting demand for fossil fuels by 143 Mtoe, or roughly 12 % of total EU fossil fuel consumption;
  - improve energy efficiency by reducing the EU's primary energy consumption by 35 Mtoe, equivalent to a 2 % reduction in primary energy consumption across the EU.

Along with energy efficiency, renewable energy is a key decarbonisation pillar of Europe's transition to a low-carbon economy and society. Delivering the commitments under the Paris Agreement will require the EU to cut its GHG emissions by 80 % to 95 % by 2050 (compared with 1990 levels) and to decarbonise the energy generation sector almost completely.

The EU's renewable energy targets are already one important part of the combined efforts to decarbonise the energy system. Progressing towards them will effectively displace fossil fuels and complement the other climate mitigation efforts. As improvements in energy efficiency gradually reduce our consumption of energy, the growing share of renewables results in a progressively larger displacement of non-renewable energy alternatives.

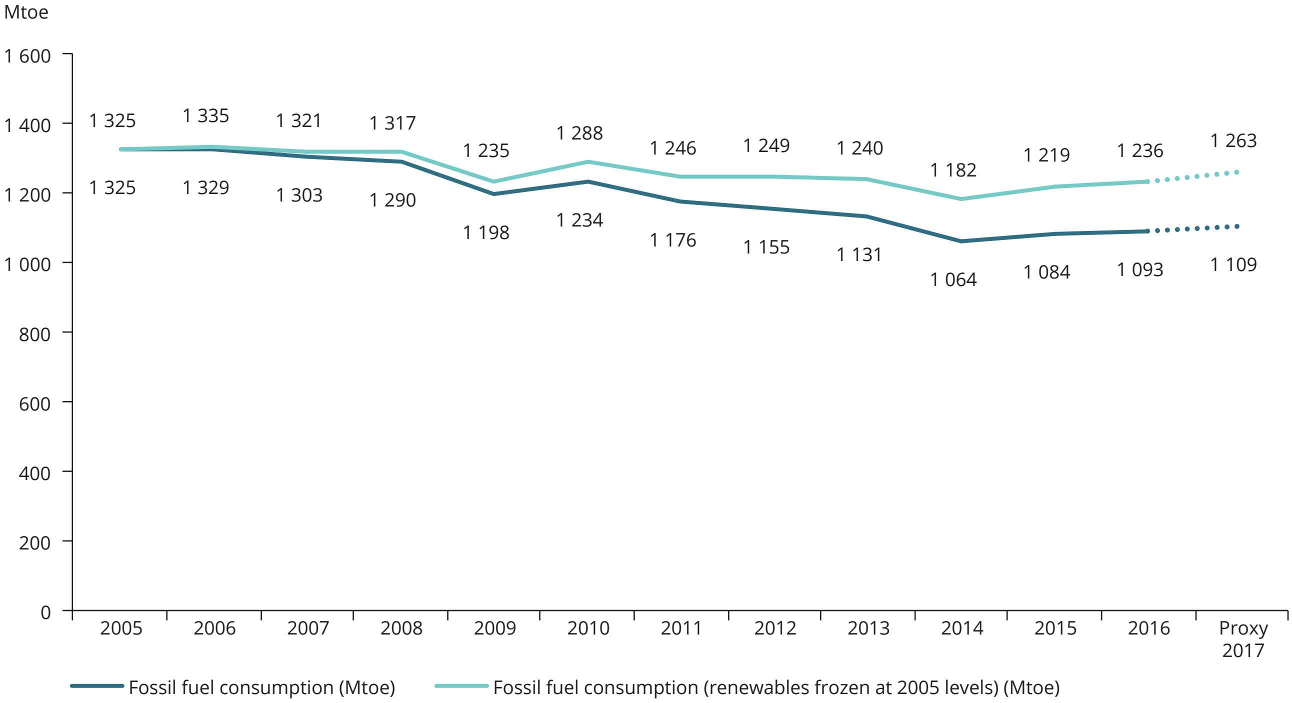
To date, the consumption of RES has steadily increased, both as a share of final energy consumption and in absolute numbers. The growth of renewable energy in the mix has already eroded market shares previously held by non-renewable sources, effectively reducing $CO_2$ emissions.

The following sections estimate the gross effect ([21]) of renewable energy on fossil fuel consumption and its associated GHG emissions and then — statistically — on primary energy consumption. The relative reductions in fossil fuel use and GHG emissions ([22]) are obtained by comparing actual growth in renewable energy since 2005 with a counter-factual scenario in which this growth would come from non-renewable energy sources. Effectively, this assumes that the growth in renewable energy since 2005 has substituted an equivalent amount of energy that would have been supplied by a country-specific mix of conventional sources. The approach takes into account neither life-cycle emissions nor carbon accounting. The method is described in detail in the EEA report *Renewable energy in Europe — Approximated recent growth and knock-on effects* (EEA, 2015).

([21]) The term 'gross' describes the theoretical character of the effects estimated in this way. The potential interactions between renewable energy deployment and the need to reduce GHG emissions under the EU-wide cap set by the Emissions Trading System (EU ETS), as well as wider interactions with the energy and economic system, were not modelled.

([22]) These concern the relative reduction in primary and gross inland consumption of fossil fuels, and the reduction in total GHG emissions including international aviation but excluding LULUCF. Definitions of primary and gross inland energy consumption are provided in the glossary.

**Figure 3.1 Estimated effect on fossil fuel consumption in the EU**




**Notes:** This figure shows the effect on primary energy consumption of fossil fuels due to the increase in renewable energy consumption since 2005 (excluding non-energy uses).

**Sources:** EEA; Eurostat, 2018a, 2018d.

## 3.1 Avoided fossil fuel use

### *3.1.1 Effects at the EU level*

The increase in the use of renewable energy compared with the level of RES consumption in 2005 allowed the EU to cut its demand for fossil fuels by 143 Mtoe in 2016 (approximately 12 % of total primary fossil fuel consumption) ([23]), as shown in Figure 3.1. This amount is comparable to the fossil fuel consumption of Italy. The largest reductions were made in the consumption of solid fuels (55 Mtoe, representing 38 % of all avoided fossil fuels) and gaseous fuels (51 Mtoe, representing 36 % of all avoided fossil fuels).

Estimates by the EEA show that avoided fossil fuel consumption will further increase from 135 Mtoe in 2016 to 155 Mtoe in 2017, which is approximately 12.2 % of total fossil fuel consumption (see Table 3.1).

### *3.1.2 Effects at the Member State level*

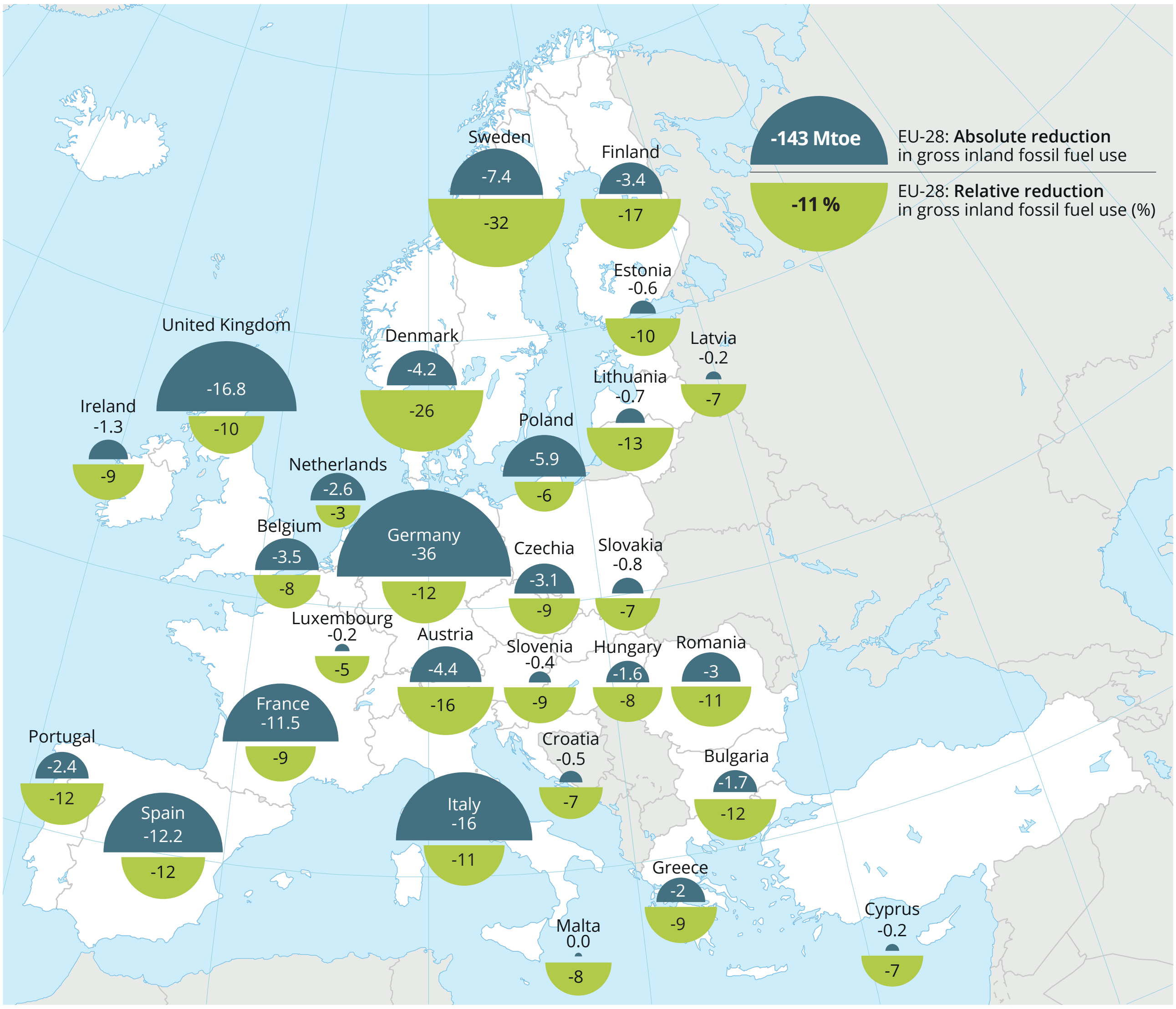
The increase in renewable energy consumption in the Member States since 2005 has also had an impact on fossil fuel use and GHG emissions in the countries themselves. According to EEA calculations, in 2016, the largest relative reductions in the consumption of fossil fuels were made by Sweden (32 %), Denmark (26 %) and Finland (17 %), in proportion to their gross domestic fossil fuel use. In absolute terms, the greatest quantities of fossil fuels were avoided in Germany, Italy and the United Kingdom, where most renewable energy was consumed (Figure 3.2).

([23]) This is equivalent to an 11 % reduction when the effects are calculated in proportion to the EU gross inland consumption of fossil fuels, as shown in Figure 3.5. Primary energy consumption is gross inland consumption, excluding all non-energy use of energy carriers. The RES effects were estimated with respect to primary energy consumption, given the availability of EEA early estimates for 2016 for primary energy consumption but not for gross inland consumption.

**Table 3.1 Estimated effect on fossil fuel consumption in the EU (Mtoe)**

| Fuel type | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Proxy 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Solid fuels | 0 | -4 | -8 | -11 | -14 | -19 | -28 | -40 | -49 | -56 | -60 | -55 | -60 |
| Gaseous fuels | 0 | -2 | -6 | -11 | -16 | -23 | -23 | -28 | -32 | -32 | -41 | -51 | -55 |
| Petroleum products | 0 | -1 | -4 | -5 | -7 | -11 | -11 | -14 | -15 | -15 | -19 | -21 | -23 |
| Petrol | 0 | 0 | 0 | 0 | 0 | 0 | -2 | -2 | -2 | -2 | -2 | -3 | -3 |
| Diesel | 0 | 0 | 0 | 0 | 0 | 0 | -6 | -9 | -9 | -10 | -10 | -11 | -12 |
| Non-renewable waste | 0 | -0 | -0 | -0 | -0 | -1 | -1 | -1 | -1 | -2 | -2 | -2 | -3 |
| **Total** | **0** | **-7** | **-18** | **-27** | **-37** | **-54** | **-70** | **-94** | **-109** | **-118** | **-135** | **-143** | **-155** |

**Figure 3.2 Total and relative reduction in gross inland fossil fuel use (per year, in 2016)**




**Notes:** The absolute reduction in gross inland fossil fuel use in 2016, expressed in million tonnes of oil equivalent (Mtoe), is proportional with the increase of renewable energy consumption achieved between 2005 and 2016. It represents the annual estimate for 2016; the cumulative value over the period 2005-2016 is much larger. The relative reduction in gross inland fossil fuel use is expressed as the absolute reduction over a country's total gross inland consumption of fossil fuels.

**Source:** EEA.

## 3.2 Gross avoided greenhouse gas emissions

### 3.2.1 *Effects at the EU level*

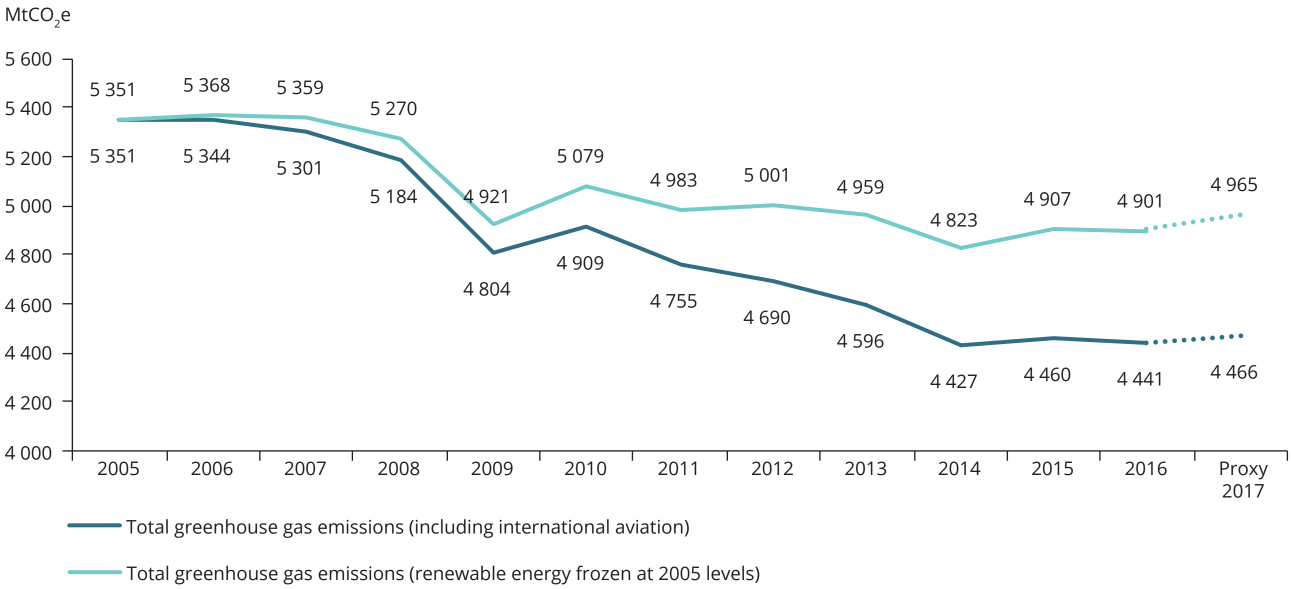
In 2016, total GHG emissions (including international aviation but excluding LULUCF) in the EU were 4 441 $MtCO_2$. According to the EEA, the growth in the consumption of renewable energy after 2005 resulted in an estimated 460 Mt of gross avoided $CO_2$ emissions at the EU level annually in 2016, delivering a gross reduction of 9.4 % of the EU's total GHG emissions in 2016. Compared with 2015, this effect increased by 3 % (see Figure 3.3).

The estimated reduction in GHG emissions due to renewables in 2016 was larger than the total GHG emissions of Italy in 2016. The contribution from RES-E (328 $MtCO_2$, or 71 % of all gross avoided emissions) was considerably larger than that of RES-H&C (90 $MtCO_2$, or 20 % of all gross avoided emissions) and biofuels in transport (42 $MtCO_2$, or around 9 % of total gross avoided emissions), as the increase in RES-E led to the strongest substitution of solid fuels — the most carbon-intensive fossil fuels — in the power sector. On the one hand, this testifies to the more rapid progress achieved since 2005 in decarbonising the EU power sector, compared with transport, heating and cooling, and industry. On the other hand, it hints at the increasing role that RES-E could play in decarbonising other end-use sectors. It also makes clear that a renewed focus on reducing GHG emissions in end-use sectors is necessary.

As shown in Figure 3.4 and Table 3.2, the gross avoided emissions within the Emissions Trading System (ETS) were estimated to be approximately 348 $MtCO_2$ in 2016. The gross avoided emissions in non-ETS sectors were estimated to be approximately 112 $MtCO_2$ ([24]).

Estimates by the EEA for 2017 show an increase in gross avoided GHG emissions of approximately 6 % from 2016 to 2017. The total avoided GHG emissions in Europe in 2017 are estimated to be 499 Mtoe, roughly 10 % of the total GHG emissions (including international aviation).

**Figure 3.3 Estimated gross effect on GHG emissions in the EU**

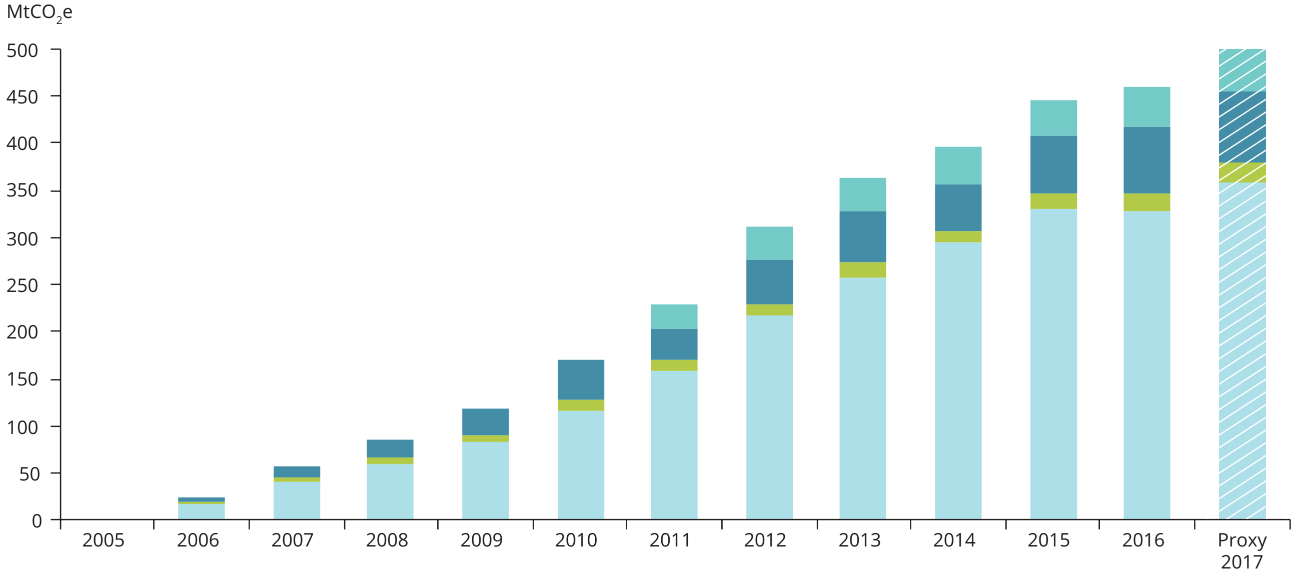



**Notes:** This figure shows the estimated gross reduction in total GHG emissions (including international aviation but excluding LULUCF) due to the increase in renewable energy consumption since 2005.

**Sources:** EEA; Eurostat, 2018a, 2018d.

([24]) These estimates are based on the assumption that RES-E generation always replaces a conventional mix of centralised electricity generation, which takes place within the EU ETS; transport emissions occur outside the ETS; renewable heat can replace heat that is produced in sectors falling either under the ETS or in non-ETS sectors. We assume that the share of ETS emissions in the industry sector is an indicator of the share of renewable heat production in the industry that takes place under the ETS.

**Figure 3.4 Estimated gross reduction in GHG emissions in the EU, by energy market sector**




**Notes:** This figure shows the estimated gross reduction in GHG emissions due to the increase in renewable energy consumption since 2005.

**Source:** EEA.

**Table 3.2 Estimated gross reduction in GHG emissions in the EU ($MtCO_2$)**

| | | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Proxy 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ETS** | Electricity | 0 | -18 | -40 | -60 | -83 | -116 | -160 | -216 | -258 | -294 | -330 | -328 | -358 |
| | Heating and Cooling | 0 | -1 | -4 | -6 | -8 | -13 | -9 | -14 | -16 | -14 | -17 | -20 | -21 |
| | Transport | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **All renewables** | **0** | **-19** | **-45** | **-66** | **-92** | **-129** | **-169** | **-230** | **-275** | **-308** | **-348** | **-348** | **-379** |
| **Non-ETS** | Electricity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Heating and Cooling | 0 | -5 | -13 | -21 | -26 | -41 | -34 | -45 | -52 | -48 | -59 | -70 | -75 |
| | Transport | 0 | 0 | 0 | 0 | 0 | 0 | -25 | -35 | -36 | -40 | -39 | -42 | -45 |
| | **All renewables** | **0** | **-5** | **-13** | **-21** | **-26** | **-41** | **-59** | **-80** | **-88** | **-88** | **-99** | **-112** | **-120** |
| **Total** | Electricity | 0 | -18 | -40 | -60 | -83 | -116 | -160 | -216 | -258 | -294 | -330 | -328 | -358 |
| | Heating and Cooling | 0 | -6 | -18 | -27 | -34 | -54 | -43 | -59 | -68 | -62 | -77 | -90 | -96 |
| | Transport | 0 | 0 | 0 | 0 | 0 | 0 | -25 | -35 | -36 | -40 | -39 | -42 | -45 |
| | **All renewables** | **0** | **-23** | **-58** | **-86** | **-118** | **-170** | **-228** | **-310** | **-363** | **-395** | **-447** | **-460** | **-499** |

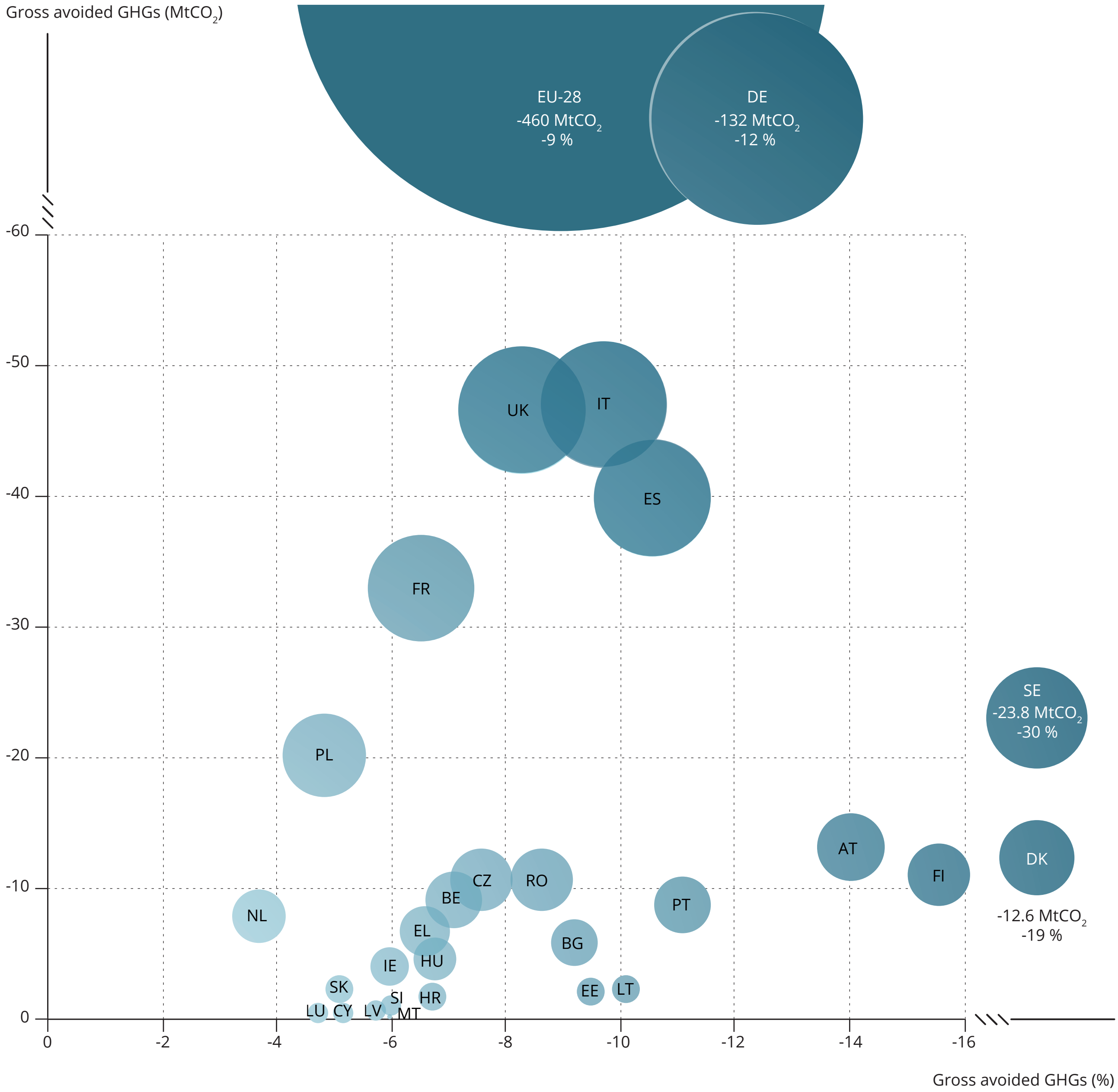
**Notes:** This table shows the estimated gross reduction in GHG emissions due to the increase in renewable energy consumption (normalised, certified biofuels) since 2005.

**Source:** EEA.

### 3.2.2 *Effects at Member State level*

In terms of gross avoided GHG emissions in 2016, the countries with the largest estimated gross reductions were Germany (132 $MtCO_2$), Italy and the United Kingdom (both 47 $MtCO_2$) (Figure 3.5). In relative terms, significant GHG emission reductions (of 10 % or more of the total national GHG emissions, including international aviation and excluding LULUCF) were recorded in eight countries in 2016 (Sweden, Denmark, Finland, Austria, Germany, Lithuania, Portugal and Spain), as illustrated in Figure 3.5. It should be noted again that these figures reflect the development of RES since 2005 — GHG emissions avoided through RES before this base year are excluded in this methodology.

**Figure 3.5 Total and relative gross avoided GHG emissions (per year in 2016)**




**Notes:** The vertical axis illustrates the absolute RES effects on GHG emissions in 2016, expressed as million tonnes (Mt) of gross avoided $CO_2$ emissions per country. The effect is proportional to the increase of national RES consumption between 2005 and 2016. The further up a country is situated, the higher its gross avoided GHG emissions ($MtCO_2$). The horizontal axis illustrates the (relative) impact of national RES growth since 2005 on national GHG emissions. The further to the right a country is, the more effective national RES consumption was to help reduce total national GHG emission (including international aviation and excluding LULUCF).

**Source:** EEA.

## 3.3 Statistical impacts of renewable energy sources on primary energy consumption

### 3.3.1 *Effects at EU level*

The main energy efficiency policies at the EU level — the recast Energy Performance of Buildings Directive (EPBD) (EU, 2010) and the recast Energy Efficiency Directive (EED) (EU, 2012) — set targets and objectives expressed in **primary** energy consumption (defined as gross inland energy consumption minus non-energy use; see glossary). As energy efficiency and renewable energy are key drivers for achieving Europe's climate and energy targets by 2020 and 2030, synergies between RES technologies and their statistical impacts on primary energy are presented below. The methodology underpinning these findings was described in a previous EEA report (EEA, 2015) ([25]).

At the EU level, primary energy consumption followed an intermittent, yet decreasing, trend until 2014 (EEA, 2017a), after which it increased again in both 2015 and 2016. Next to the key driving factors that affect primary energy consumption, such as energy efficiency improvements, unusual weather conditions and economic activity, several other factors are of statistical importance for the overall trend, given their opposing effects:

- Typically, a decreasing share of nuclear energy and thermal generation (excluding combined heat and power — CHP) in primary energy consumption is statistically diminishing the latter even if the final energy consumption is constant. Similarly, a growing share of certain renewable energy technologies, such as hydro- and wind power, statistically reduces the level of primary energy consumption, even where final energy use stays unchanged. This is because of the statistical methodologies in use: to estimate the primary energy of certain technologies or sources, energy statistics follow the common physical principle of the first measurable primary equivalent energy. For nuclear and geothermal energy, the first measurable primary equivalent energy is the heat that is being converted to electricity (at transformation efficiencies typically in the range of 40-60 %). In contrast, for solar PV and wind energy, the first measurable primary energy equivalent is the resulting electricity, which thus amounts to a 100 % transformation efficiency for these technologies, thereby improving the overall conversion efficiency of the energy system and statistically lowering the level of primary energy consumption.

- General factors driving the accounting of primary energy consumption upwards include an increasing share of specific renewable energy technologies, such as biomass-based electricity production. This is because the efficiency of electricity generation from biomass is, on average, lower than that from fossil fuels. Given these low efficiencies, converting the gross final electricity obtained from biomass into primary energy will, statistically, worsen the overall conversion efficiency of the energy system and thus increase total primary energy consumption.

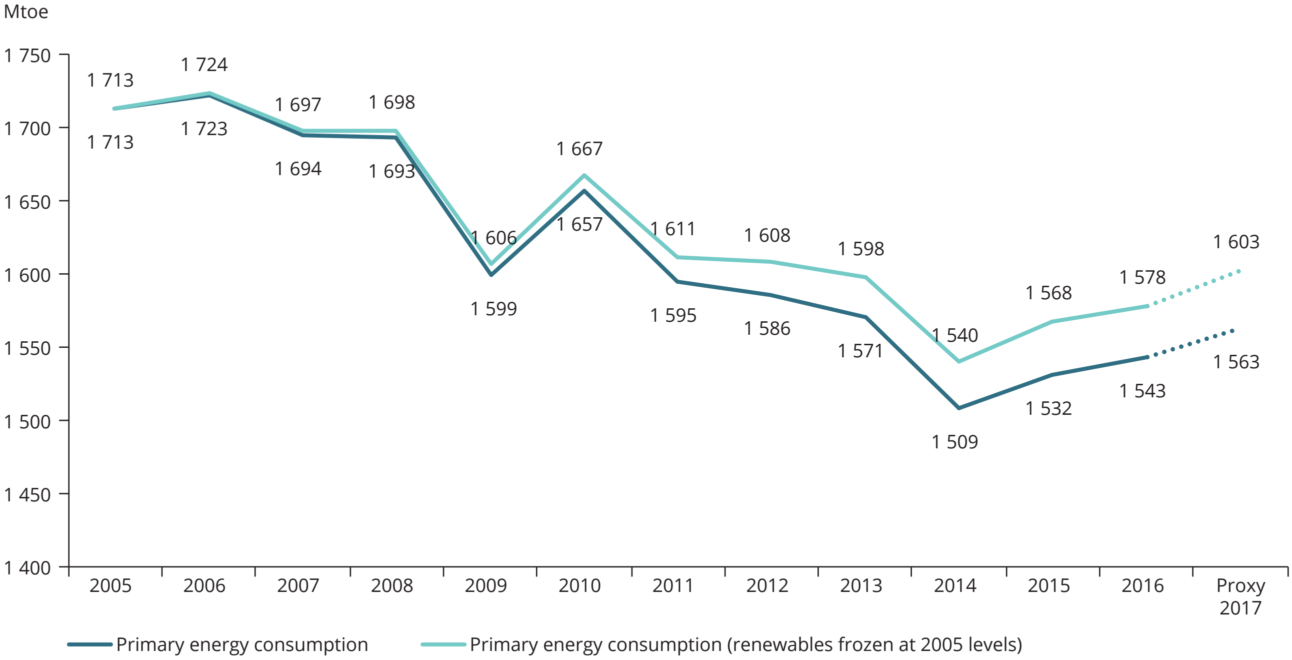
The EEA estimates that deploying renewable energy since 2005 reduced primary energy consumption by 35 Mtoe in 2016 — more than the primary energy consumption of Austria in 2016 (see Figure 3.6 and Table 3.3). The estimated reduction in primary energy consumption in 2017 was 40 Mtoe. Without the growth in renewable energy since 2005, primary energy consumption in the EU in 2016 could have been 2.2 % higher, while final energy use in end sectors could have remained unchanged.

### 3.3.2 *Effects at Member State level*

The most important statistical effects of renewable energy on primary energy consumption were recorded for Denmark, Portugal and Greece, where considerable reductions in primary energy consumption could be seen (-7 %, -7 % and -5 %, respectively). In Hungary, Latvia and Slovakia, the statistical conventions in place resulted in slight increases in primary energy consumption due to the prevalence of biomass-based renewable energy in these countries. The effects of renewable energy on GHG emissions and energy consumption in 2016 are summarised by country in Annex 1.

([25]) Some changes have been made to the methodology for calculating the effects of renewable energy on primary energy consumption. It is assumed that the use of renewable biofuels does not have an impact on primary energy consumption, because the use of fossil fuels (such as petrol and diesel) is replaced by the same amount of biofuels. Heat extracted from the environment by heat pumps counts as renewable energy. To estimate the effect of heat pumps on fossil energy consumption and primary energy consumption, we assume a seasonal performance factor (SPF) for heat pumps of 3.0.

**Figure 3.6 Estimated effect on primary energy consumption in the EU**




**Notes:** This figure shows the estimated effect on primary energy consumption due to the increase in renewable energy consumption since 2005.

**Sources:** EEA; Eurostat, 2018a, 2018d.

**Table 3.3 Estimated effect on primary energy consumption in the EU (Mtoe)**

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Proxy 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Renewable electricity (normalised, certified biofuels) | 0.0 | -1.4 | -3.8 | -5.3 | -8.5 | -11.5 | -16.1 | -22.9 | -28.3 | -31.9 | -36.6 | -36.2 | -40.3 |
| Renewable heating and cooling (certified biofuels) | 0.0 | 0.1 | 0.6 | 0.6 | 0.9 | 1.8 | 0.2 | 1.3 | 1.7 | 0.3 | 0.9 | 0.8 | 0.7 |
| Renewable transport fuels (certified biofuels) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| All renewables (normalised, certified biofuels) | 0.0 | -1.3 | -3.2 | -4.7 | -7.6 | -9.7 | -15.9 | -21.7 | -26.7 | -31.6 | -35.7 | -35.4 | -39.6 |

**Notes:** This table shows the estimated effect on primary energy consumption due to the increase in renewable energy consumption since 2005.

**Sources:** EEA; Eurostat, 2018a, 2018d.

## 3.4 Indirect effects by renewable energy technology

Table 3.4 shows the estimated impact of each renewable energy technology on GHG emissions, fossil fuel consumption and primary energy consumption.

In 2016, the largest amounts of gross avoided GHG emissions were attributable to onshore wind energy (137 $MtCO_2$), solar PV energy (73 $MtCO_2$) and heat from solid biomass (37 $MtCO_2$) ([26]). Onshore wind and solar PV energy are also the most significant contributors to avoided fossil fuel consumption and avoided primary energy consumption. In contrast, heat from solid biomass increased primary energy consumption by 3.5 Mtoe in 2016.

The use of solid biomass for electricity and heating leads to a reduction in GHG emissions and fossil fuel consumption, but it drives up primary energy consumption.

Owing to the statistical conventions in place, consumption of concentrated solar power and geothermal energy can also increase primary energy consumption. These statistical interactions suggest that primary energy consumption trends alone do not present the full picture of the deeper energy consumption trends in end-use sectors.

For 2017, preliminary estimates by the EEA show that the amount of avoided GHG emissions will further increase to 499 Mtoe. This is mainly driven by additional renewable energy consumption originating from onshore wind technologies, with estimated avoided GHG emissions of 152 $MtCO_2$ (an additional 15 Mtoe compared with 2016), followed by solid biomass, offshore wind and solar PV energy.

([26]) The impact of biomass consumption on actual GHG emissions is uncertain in the absence of accounting for LULUCF.

**Table 3.4 Effect of renewable energy on GHG emissions and energy consumption by technology in the EU**

| Source of renewable energy | Increase in renewable energy consumption since 2005 (ktoe) | | Gross avoided GHG emissions ($MtCO_2$) | | Avoided fossil fuel consumption (ktoe) | | Effect on primary energy consumption (ktoe) | |
|---|---|---|---|---|---|---|---|---|
| | 2016 | Proxy 2017 | 2016 | Proxy 2017 | 2016 | Proxy 2017 | 2016 | Proxy 2017 |
| **Renewable electricity** | | | | | | | | |
| Biogas | 4 321 | 4 411 | -38 | -39 | -10 278 | -10 495 | 10 | 7 |
| Bioliquids (certified) | 440 | 440 | -3 | -3 | -980 | -980 | 15 | 15 |
| Concentrated solar power | 480 | 480 | -4 | -4 | -1 185 | -1 186 | 254 | 255 |
| Geothermal | 107 | 102 | -1 | -1 | -240 | -230 | 827 | 790 |
| Hydropower excluding pumping (normalised) | 519 | 444 | -5 | -5 | -1 245 | -1 112 | -734 | -668 |
| Offshore wind (normalised) | 3 994 | 4 954 | -30 | -38 | -9 109 | -11 262 | -5 115 | -6 308 |
| Onshore wind (normalised) | 16 827 | 18 708 | -137 | -152 | -40 012 | -44 464 | -23 183 | -25 755 |
| Solar PV energy | 8 919 | 9 379 | -73 | -76 | -20 750 | -21 776 | -11 828 | -12 397 |
| Solid biomass | 4 929 | 5 338 | -37 | -41 | -11 427 | -12 460 | 3 510 | 3 715 |
| Tidal, wave and ocean energy | 2 | 2 | 0 | 0 | -3 | -3 | -2 | -2 |
| **Renewable heat** | | | | | | | | |
| Biogas | 2 864 | 3 038 | -9 | -9 | -3 204 | -3 399 | -22 | -23 |
| Bioliquids (certified) | 281 | 281 | -1 | -1 | -314 | -314 | 2 | 2 |
| Geothermal | 209 | 215 | -1 | -1 | -234 | -240 | 184 | 189 |
| Renewable energy from heat pumps | 7 498 | 8 237 | -6 | -7 | -3 885 | -4 298 | -3 885 | -4 298 |
| Solar thermal | 1 420 | 1 471 | -4 | -5 | -1 589 | -1 646 | -169 | -175 |
| Solid biomass | 22 010 | 23 509 | -69 | -74 | -24 652 | -26 330 | 4 694 | 5 015 |
| **Biofuels in transport** | | | | | | | | |
| Biodiesels (certified) | 10 927 | 11 575 | -34 | -36 | -10 927 | -11 575 | 0 | 0 |
| Biogasoline (certified) | 2 583 | 2 817 | -7 | -8 | -2 583 | -2817 | 0 | 0 |
| Other biofuels (certified) | 136 | 145 | 0 | 0 | -136 | -145 | 0 | 0 |
| **Total renewables (normalised, certified biofuels)** | **88 462** | **95 545** | **-460** | **-499** | **-142 753** | **-154 733** | **-35 440** | **-39 639** |

**Notes:** This table shows the estimated effect on GHG emissions, fossil fuel consumption and primary energy consumption due to the increase in renewable energy consumption since 2005.

**Source:** EEA.

# 4 EU developments in renewable energy sources in a global perspective

- Globally, RES-E capacity continued to increase, reaching 2 179 GW in 2017, up by 166 GW over the previous year.
- Every other newly installed megawatt of renewable power in 2017 came from solar PV. In fact, more solar PV capacity was added in 2017 than the net capacity additions of fossil fuel and nuclear power plants combined.
- Global investment in renewables in 2017 stood at EUR 248 billion, almost the same as in 2016.
- Renewables delivered more than one quarter (26.5 %) of the total global electricity generation in 2017.
- Historically, the EU dominated new investments in renewable energy, as a proportion of global investment, between 2005 and 2012. However, China surpassed the EU in 2013 and has maintained its leading position since then (45 % in 2017).
- In terms of installed RES-E capacity, the EU (444 GW) came second after China (619 GW) in 2017. Since 2017, China has displaced the EU as market leader in solar PV capacity. While the EU still had the largest wind power capacity in the world in 2017, China is poised to overtake the EU as world leader in wind energy, given its faster pace of deployment.
- Since 2015, the developing world invested more in green energy than developed economies. Developing economies (including China, Brazil and India) committed EUR 157 billion to renewables in 2017 compared with the EUR 91 billion committed by developed countries.
- On a per capita basis, the EU remains the clear world leader in renewable power, with 0.87 kW RES-E capacity installed per person in 2017. Per unit of GDP in 2017, the EU did reasonably well in deploying renewables compared with other world regions, e.g. the United States, ASOC (Asia and Oceania, excluding India and China) and India.
- Total global employment in the renewable energy industry in 2017 was 10.3 million, a 5.3 % increase over the previous year.
- Of world regions with sufficient available data, the EU came second after China in 2017 in terms of employment in the renewable energy industry. However, in terms of share of renewable energy jobs in the total labour force, the EU (0.51 % of the total labour force employed in the renewable energy industry), is almost on par with China (0.53 %). In the EU, Germany, with 0.77 % of its labour force working in jobs related to renewable energy, plays a leading role.

On a global scale, traditional biomass is still an important source of energy for a majority of the world's population, despite the associated health and environmental impacts ([27]). The available global data on gross renewable energy consumption do not make it possible for traditional biomass fuels to be excluded from the set of modern RES. The aggregate numbers therefore obscure underlying trends in modern RES, which offer the most relevant points of comparison for European developments. Therefore, this chapter focuses on global developments in RES-E only, such as installed RES-E capacities and investments, as a way of contrasting European developments in this market sector with the changes occurring in other parts of the world.

([27]) Traditional biomass energy refers to the burning of fuel wood, charcoal, agricultural and forest residues, or dung on open fires for cooking and heating. It is associated with considerable health and environmental impacts and it is still dominant in Africa (especially in sub-Saharan Africa) and in developing Asia (e.g. Bangladesh, Cambodia, Myanmar/Burma and Sri Lanka). It is estimated that roughly 68 % of all heat generated from biomass globally comes from traditional biomass (REN21, 2017).

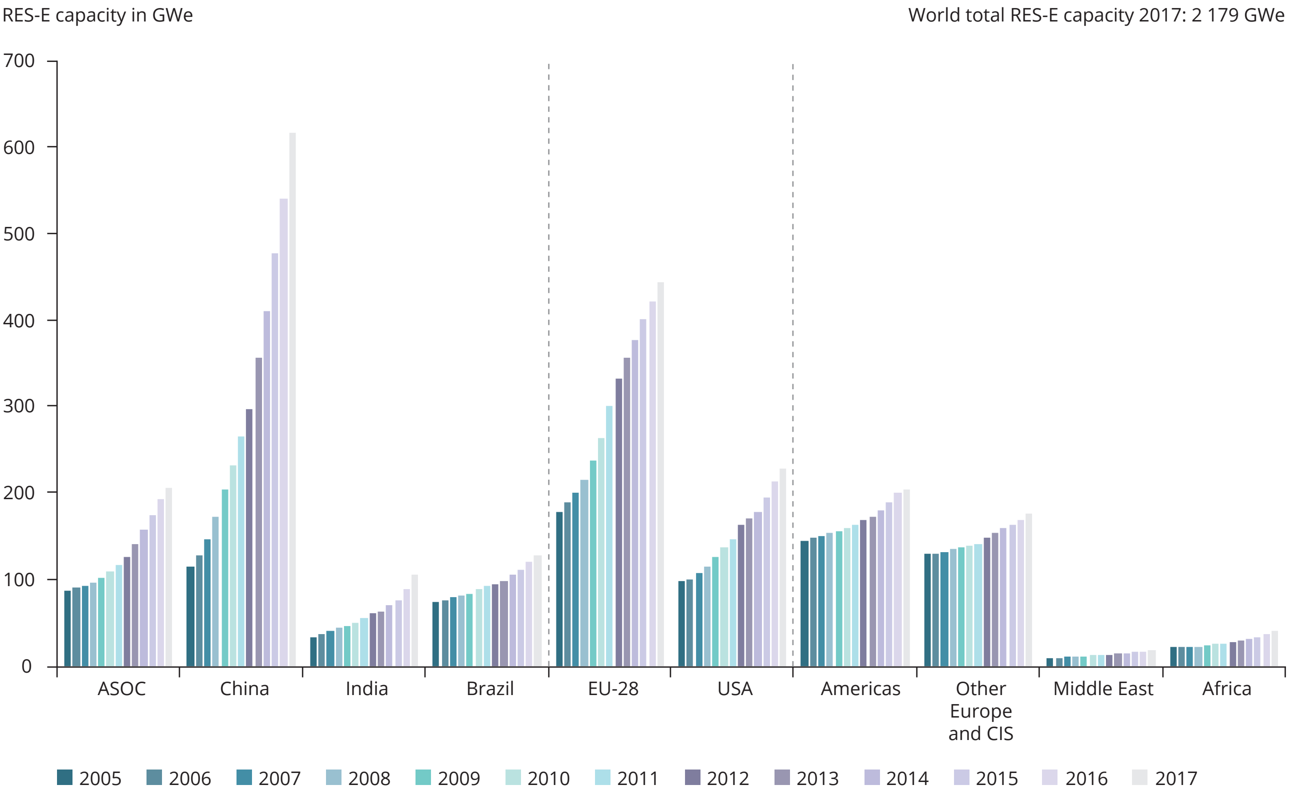
## 4.1 Renewable electricity capacities by region and main source

### *4.1.1 Renewable electricity development by region*

The year 2017 was another record-breaking one for renewable energy, characterised by the largest ever increase in renewable power capacity, falling costs, increases in investment and advances in enabling technologies (REN21, 2018). On a global scale, installed RES-E capacity saw its largest ever increase in 2017, with an estimated 166.7 GW capacity added (IRENA, 2018a; REN21, 2018). The share of RES-E in global electricity generation rose to an estimated 26.5 % by the end of 2017 (of which 16.4 % is provided by hydropower), a 2 % increase over the previous year. Globally, renewable capacity more than doubled over the decade from 2007 to 2017. Ongoing growth in capacity and geographical expansion in renewable power technologies are driven by a number of factors, including rising electricity demand in some countries, targeted renewable energy support mechanisms and continuing decreasing costs (particularly for solar PV and wind power).

For fossil fuel technologies, in 2017, a net 35 GW of coal-fired generation capacity was added to the global fleet ([28]) (Frankfurt School-UNEP, 2018). The net addition to gas-fired plants was 38 GW (made up of gross additions of 54 GW and retirements of 16 GW). The net addition to oil-fired capacity was -3 GW (more capacity was switched to gas or closed than opened), while 11 GW of nuclear power plant capacity was added on a global scale. Taken together, a net capacity of 81 GW of fossil fuel and nuclear power plant capacity was added in 2017. Overall, renewables thus accounted for approximately 70 % of net additions to global

**Figure 4.1 RES-E capacities in selected world regions, 2005-2017**




**Notes:** ASOC refers to Asia (excluding China and India) and Oceania; OE-CIS refers to Other Europe and the Commonwealth of Independent States; full information about the geographical coverage and regional aggregations is provided in the glossary.

In the 2018 edition of the RES-E capacity statistics (IRENA, 2018a), pumped storage is not included in the total RES-E capacity. IRENA has revised its data set for the past year's statistics (IRENA, 2018a). This causes slight differences from the total global RES-E capacities reported in the 2017 edition of the EEA report on renewable energy (EEA, 2017).

**Source:** IRENA, 2018a.

([28]) The gross addition was 67 GW (mainly in developing economies) and the capacity retired was 32 GW (mainly in the United States and Europe).

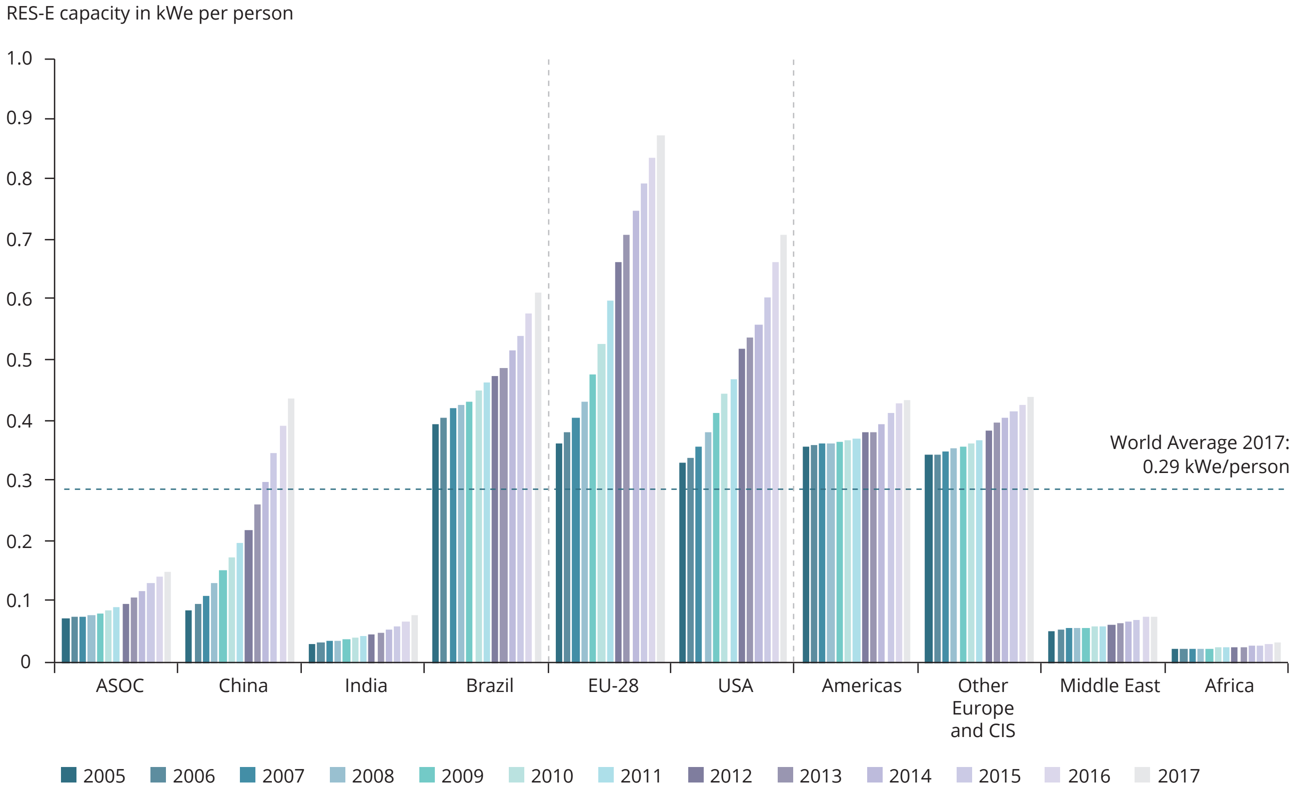
power capacity in 2017, due in large part to continued improvements in the cost-competitiveness of solar PV and wind power (REN21, 2018).

World regions can be clustered into **three groups of countries** on the basis of their RES-E capacity developments between 2005 and 2017 (expressed in total capacity, per capita capacity and capacity per unit GDP, as illustrated in Figure 4.1, Figure 4.2 and Figure 4.3):

- In the first group — China, India, Brazil, ASOC (Asia, excluding China and India, and Oceania) — electricity consumption is expanding rapidly, and both renewable energy and fossil fuel generation are being deployed to meet growing demand.
- The second group — EU-28 and the United States — is experiencing slow or negative growth in electricity consumption. In these countries/regions, renewable energy is increasingly displacing existing generation and disrupting traditional energy markets and business models.
- For the third group of countries — Africa, the Americas (excluding the United States and Brazil), the Middle East and OE-CIS (Other Europe and Commonwealth of Independent States) — RES-E development has been relatively slow, despite growing electricity consumption.

The prime example of the first group of countries is China. With 619 GW of RES-E capacity installed and grid connected, China managed to increase its RES-E capacity by a factor of 5.4 over the period 2005-2017, maintaining a strong compound annual growth rate of 15.0 %. China alone was home to nearly 30 % of the world's renewable power capacity in 2017. With 313 GW installed (not including pumped storage), hydropower is by far its largest RES-E source, with wind power (164 GW) coming in a distant second. At 131 GW, solar power is catching up rapidly. Of the other countries in this group, India almost tripled its RES-E capacity over the period 2005-2017 (from 35 to 106 GW) and has established itself as one of the top countries in terms of wind, solar PV and hydropower added capacity (IRENA, 2018a; REN21, 2018). Starting from a

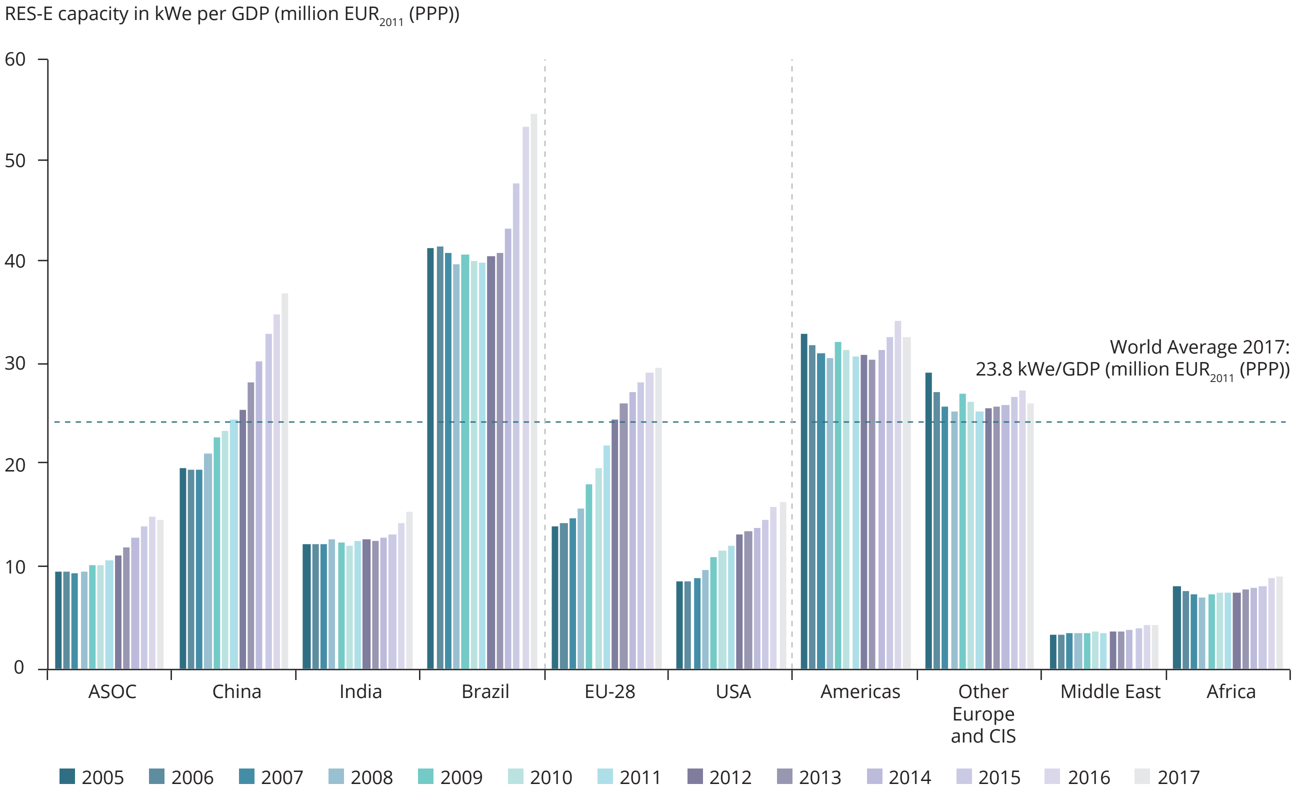
**Figure 4.2 RES-E capacities per capita in selected world regions, 2005-2017**




**Notes:** ASOC refers to Asia (excluding China and India) and Oceania; OE-CIS refers to Other Europe and the Commonwealth of Independent States; full information about the geographical coverage and regional aggregations is provided in the glossary. Population data are obtained from the UN/DESA/Population Division website (UN, 2017).

**Sources:** UN, 2017; IRENA 2018a.

**Figure 4.3 RES-E capacities per GDP in selected world regions, 2005-2017**




**Notes:** ASOC refers to Asia (excluding China and India) and Oceania; OE-CIS refers to Other Europe and the Commonwealth of Independent States; full information about the geographical coverage and regional aggregations is provided in the glossary. GDP is expressed as constant 2011 euro value ($EUR_{2011}$) at purchasing power parity (PPP) ([29]).

**Sources:** World Bank 2017; IMF, 2018; IRENA 2018a; OECD, 2018.

strong base in installed hydropower (71 GW or 95 % of the total RES-E capacity of 74 GW in 2005), Brazil has also experienced strong growth and diversification of its RES-E asset base. In 2017, hydropower (100 GW) accounted for 78 % of the total installed capacity of 128 GW.

In terms of RES-E development per capita or per GDP, the picture looks slightly different for the countries/regions in the first group:

- With 54.7 kW/million constant $EUR_{2011}$ (at PPP) installed in 2017, Brazil remains the best performing country, although growth in this indicator over the period 2005-2017 was relatively modest (32 % in total, or 2.3 % per year on average) compared with other countries/regions. In per capita terms, RES-E has grown steadily over time, from 0.39 kW/person in 2005 to 0.61 kW/person in 2017.
- Rapid growth in renewable capacity, coupled with population control policies, has led China to increase its RES-E capacity per capita by a factor of nearly five (from a mere 0.09 kW in 2005 to 0.44 kW in 2017). This helped the country score well above the world average but still far behind world leaders such as the EU (0.88 kW/person in 2017), the United States (0.71 kW/person in 2017)

([29]) Processing GDP data for the period 2005-2017: GDP data expressed as constant 2011 international dollars at PPP for all countries for the period 2005-2016 are obtained from the World Bank database (World Bank, 2018). For the year 2017, GDP data for all countries expressed as current prices in international dollars at PPP are obtained from the World Economy Outlook database of the International Monetary Fund (IMF, 2018). For each country, a conversion factor is calculated, dividing GDP data for 2016 expressed as constant 2011 international dollars at PPP by GDP data for 2016 expressed as current international dollars at PPP, and then it is multiplied by the 2017 GDP data of that country expressed as current prices in international dollars at PPP to transform it into GDP expressed as constant 2011 international dollars at PPP. The PPP conversion rate for the year 2011 between euros and dollars is obtained from the Organisation for Economic Co-operation and Development's database (OECD, 2018).

or even Brazil (0.61 kW/person in 2017). RES-E development in China has even outpaced its strong economic growth over the period 2005-2017. With 36.9 kW/million constant $EUR_{2011}$ (PPP), it is second only after Brazil at 54.7 kW per unit GDP in million constant $EUR_{2011}$ (PPP).

- Within this group, India performs least well in per capita terms (at 0.08 kW/person, well below the world average) and per unit GDP (15.5 kW per unit GDP in million constant $EUR_{2011}$ (PPP)). Between 2005 and 2017, it enhanced its RES-E capacity by a factor of three, starting from a low base. Despite that, growth over the period has been relatively modest in terms of capacity per unit GDP, at an average annual rate of 2 %, but higher for capacity per person, at an average annual rate of 8 %.

In the **second group of countries**, the EU more than doubled its RES-E capacity over the period 2005-2017, from 180 GW to 445 GW installed. With 169 GW installed, wind power was the EU's largest renewable power source in 2017, followed by hydropower (130 GW, not including pumped storage) and solar PV energy (106 GW). Continuing with the ongoing trend of renewables accounting for increasing shares of new power capacity each year, 85 % of newly installed power capacity in the EU was renewable (REN21, 2018). Wind power and solar PV accounted for three quarters of the annual increase in renewable power capacity, and offshore wind power represented around 20 % of the total European wind power market in 2017.

- By 2017, the EU had established itself as the clear world leader in per capita RES-E capacity (0.87 kW/person). With a compound annual growth rate of 6.4 % in RES-E capacity per unit GDP over the period 2005-2017, the EU is also clearly outpacing other regions in transforming the energy resource base of its economic activities.

In the United States, the installed RES-E capacity amounted to 230 GW in 2017. With 87 GW of capacity in 2017, wind has overtaken hydropower for the first time (84 GW, not including pumped storage) and started to dominate RES capacity. The United States also scores well in per capita terms (0.71 kW/person), but the country's performance per unit GDP (16.4 kW/million $EUR_{2011}$ (PPP)) was below the world average in 2017. Furthermore, most of the growth in this parameter has happened over the period 2005-2010, and it has slowed down over the period 2011-2017.

In the **third group of countries**, RES-E development has been less prominent to date in the Middle East, Africa and the Americas (excluding the United States and Brazil). The latter experienced a relatively limited growth in RES-E capacity over the period 2005-2017 (from 146 to 205 GW), despite some of the countries with the highest RES-E shares being located in this region ([30]). Concerning the OE-CIS, deployment of RES-E capacity is still mainly dominated by hydropower (with the Ukraine as a notable exception), although potential for sizable solar PV and onshore wind development exists throughout the region (Deng et al., 2015). In 2017, 74 % of the wind capacity and about 49 % of the solar PV capacity of the region existed in one country, namely Turkey (IRENA, 2018). Solar PV capacity in Turkey increased to 3 420 MW in 2017 from just 833 MW in 2016.

- Comparing the RES-E resource base with the size of the Middle East's economy reveals this region's weak performance on this parameter (4.2 kW per unit of GDP in million constant $EUR_{2011}$ (PPP), which is well below the world average). Furthermore, there are no signs yet that the speed of transforming the energy resource base of the Middle East's economy is picking up.

- Seen from a per capita perspective, the figure of 0.03 kW/person recorded in Africa is well below the world average. What is worrisome is that it has remained stagnant over the last 5 years.

- The Americas' (excluding the United States and Brazil) performance on a per capita or per unit GDP basis is well above the world average, although it should be noted that installed RES-E capacity per unit GDP has witnessed a drop from 34.2 kW per unit GDP in million constant $EUR_{2011}$ (PPP) in 2016 to 32.6 kW per unit GDP in million constant $EUR_{2011}$ (PPP) in 2017.

### *4.1.2 Wind and solar photovoltaic capacity deployment*

Wind and solar PV energy are among the most progressive renewable energy technologies that are experiencing strong growth worldwide due to significant cost reductions and further potential for innovation, technological learning and economies of scale.

Solar power rose to record prominence in 2017, as the world installed 93.6 GW of new solar PV power projects,

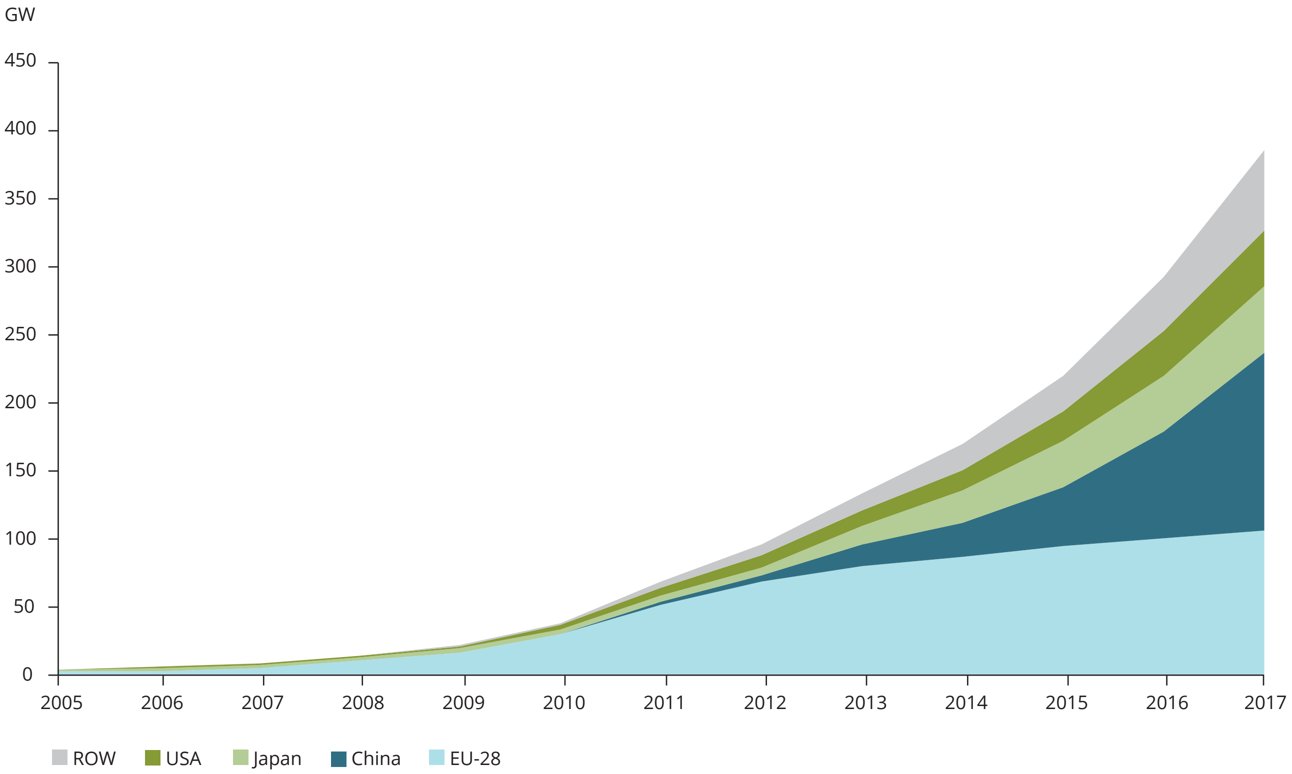
([30]) For example, Costa Rica and Uruguay generated almost 90 % of their electricity from RES in 2017, predominantly hydropower, although wind power also provided a significant contribution (REN21, 2018).

more than the net additions to fossil fuel and nuclear plants put together. The solar build-out ([31]) represented 38 % of all new net generating capacity added in 2017 (renewable, fossil fuel and nuclear energy included; Frankfurt School-UNEP, 2018). Solar PV accounted for nearly 55 % of newly installed renewable power capacity in 2017. Wind (29 %) accounted for most of the remaining net added capacity. Global solar PV and wind capacity (cumulative) in 2017 were 385 GW and 514 GW, respectively. Respective growth in added capacity over the previous year was 32 % and 10 %.

At least 10 countries generated 15 % or more of their electricity with solar PV and wind power in 2017 (REN21, 2018). With realistic global wind and solar electricity potentials ranging between 730 and 3 700 EJ per year, the long-term contribution of wind and solar power to the world's energy needs could far exceed our energy needs (Deng et al., 2015). Despite impressive growth, only a small fraction of this large potential has been realised to date. As a result, at the end of 2017, the estimated share of wind (5.6 %) and solar PV power (1.9 %) in global electricity production is small (REN21, 2018).

The EU has contributed significantly to the worldwide demonstration and commercialisation of solar PV and wind power (see Figure 4.4, Figure 4.5 and Table 4.1). Following the implementation of various market-pull policy support instruments, the EU has

**Figure 4.4 Growth in total solar PV capacity in the EU: the top three countries and the rest of the world, 2005-2017**




**Notes:** The figure shows the maximum net generation capacity installed and connected. ROW: rest of the world.

**Source:** IRENA, 2018a.

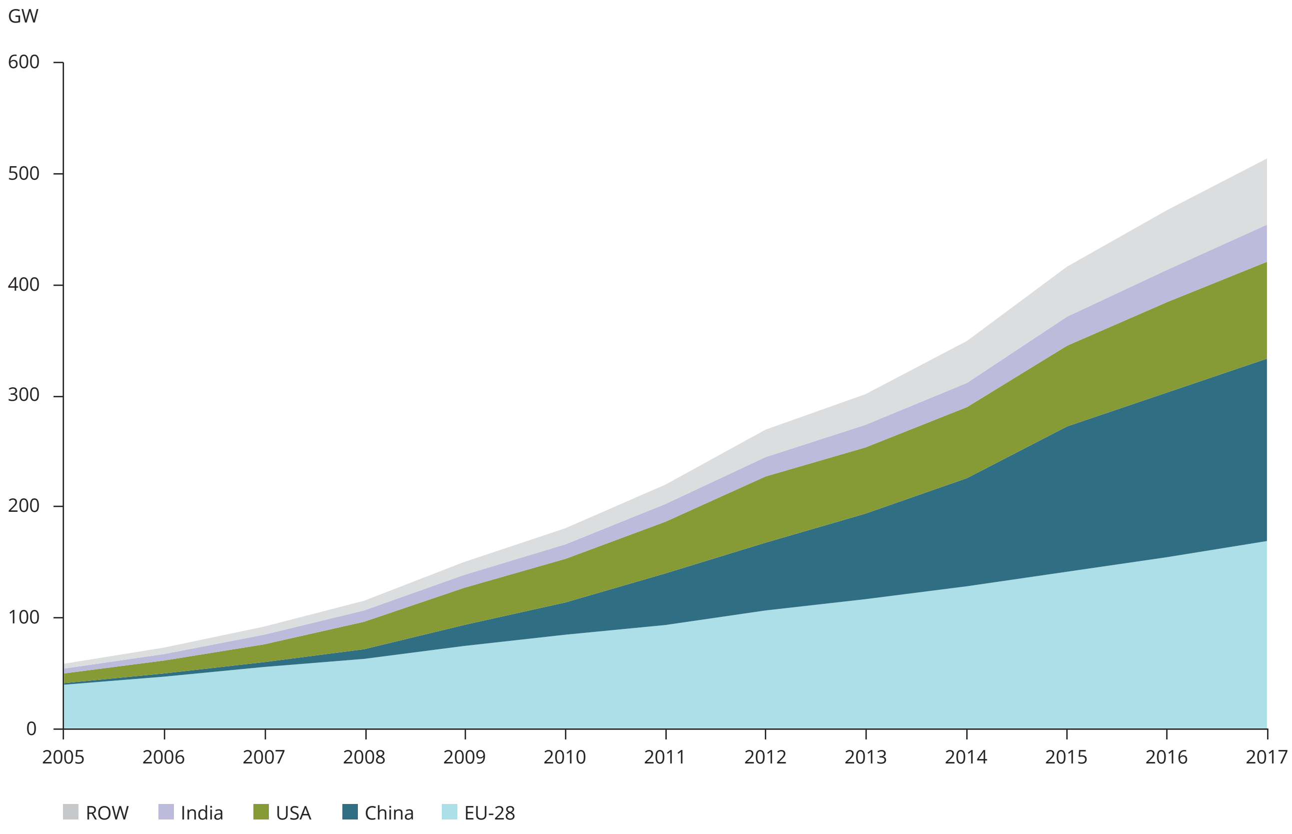
([31]) Almost all PV but with a few hundred megawatts of solar thermal.

been a clear leader since 2005 in the deployment of these technologies. However, more recently, the growth in solar PV installations has slowed down in the EU, with capacity increasing by only a modest 5.3 % in 2017 over the previous year. In 2017, China overtook the EU for the first time as regards installed solar PV capacity (131 GW), registering a 68 % growth in solar PV over the previous year. The EU (106 GW) is in second position, followed by Japan (49 GW) and the United States (41 GW). The rest of the world (ROW in the figures) accounted for the remaining 59 GW. China, the EU, the United States and Japan together account for 84 % of global solar PV capacity.

Growth rates for solar PV capacity installation between 2016 and 2017 in the United States (25 %) and Japan (17 %) by far surpassed the EU growth rate (5.3 %). It is also worth noting that, since 2010, the pace of solar PV deployment has been increasing in other parts of the world, with Australia, Canada, India, South Africa, South Korea and Thailand having contributed significantly to that growth.

Global wind capacity in 2017 was 514 GW, about 10 % (47 GW) higher than the previous year. In some of the largest wind power markets, strong growth was driven by looming regulatory changes; elsewhere, wind energy's cost-competitiveness and its potential environmental and developmental benefits drove deployment (REN21, 2018). The rapidly falling price of wind power has made it the least-cost option for new power capacity in a large and growing number of countries. The offshore wind sector had its best year yet, as total capacity increased by 30 %. China's offshore market started to take off in 2017, and the world's first commercial floating project was commissioned in Scotland. The sizes of turbines and projects continued to increase, and several

**Figure 4.5** **Growth in total wind power capacity in the EU: the top three countries and the rest of the world, 2005-2017**




**Notes:** The figure shows the maximum net generation capacity installed and connected. ROW: rest of the world.

In the 2018 edition of the RES-E capacity statistics (IRENA, 2018a), the data on the wind energy capacity installed in China, the United States and Brazil have been revised. Previous data were based on data reported by the Global Wind Energy Council, whereas 2017 data are based on data reported by official bodies. The main difference between the data sets is that the Global Wind Energy Council reports data on wind energy farms constructed in a certain year, while the official data keep track of only the farms that have been officially connected to the grid. This results in a downward revision of historical data.

**Source:** IRENA, 2018a.

manufacturers announced plans to produce machines with capacities of 10 MW and more.

For a long time, the EU has been the leader as far as wind capacity is concerned with an installed capacity far ahead of the other regions. However, over time (2007-2017), other regions, especially the United States and China have caught up rapidly to close the capacity gap between them and the EU. With 169 GW installed capacity in 2017, the EU was still the region with the largest total installed wind power capacity (both onshore and offshore), closely followed by China (164 GW), the United States (87 GW) and India (33 GW) (see Figure 4.5). The EU, China, the United States and India together accounted for 88 % of the total installed wind power capacity worldwide in 2017. With a 10 % growth rate in 2017, China is poised to overtake the EU as the world leader in wind energy. India registered the highest growth rate at 14.5 %. Significant additions to wind power capacity were also realised by Australia, Brazil, Canada, Chile, Japan and Mexico. At least 13 countries — including Costa Rica, Nicaragua, Uruguay and several countries in Europe — accounted for 10 % or more of their electricity consumption with wind power during 2017 (REN21, 2018).

## 4.2 Renewable energy investments

Global investment in renewable energy remained almost the same in 2017, at EUR 248 billion, as in the previous year. According to the latest REN21 report, if investments in hydropower projects larger than 50 MW are included, total new investment in renewable power and fuels was at least EUR 275 billion in 2017 (REN21, 2018). Investment in new renewable power capacity (including all hydropower) was three times the investment in fossil fuel-fired generating capacity and more than double the investment in fossil fuel and nuclear power generation combined (Frankfurt School-UNEP, 2018).

In 2015, the developing world for the first time invested more in green energy than developed economies. This trend has continued since then. Developing economies (including China, Brazil and India) committed EUR 157 billion to renewables in 2017, compared with EUR 91 billion for developed countries. This was the largest tilt in favour of developing countries yet seen.

The leading location by far in terms of renewable energy investment in 2017 was China, which accounted for EUR 112 billion, its highest figure ever and about 45 % of the global total. There was an extraordinary 'solar boom' in the country in 2017, with an investment in solar energy of EUR 76.7 billion, up 58 % (Frankfurt School-UNEP, 2018). Europe experienced a decline in investment of 37 % compared with the previous year, to EUR 36 billion in 2017. The biggest reason was a fall of 65 % in investment in the United Kingdom, reflecting an end to subsidies for onshore wind and utility-scale solar power, and a big gap between auctions for offshore wind projects. Germany also saw a drop in investment, of 35 %, which is partially attributed to the uncertainty over a shift to auctions for onshore wind. This, however, was partly compensated for by the lower costs per megawatt for offshore wind. The 13 % decrease in investment in 2017 in ASOC is the mixed result of a fall in Japanese outlays of 28 %, partially compensated for by sharp increases in renewable energy investment in Australia (147 %).

### *4.2.1 Share in global renewable energy investments*

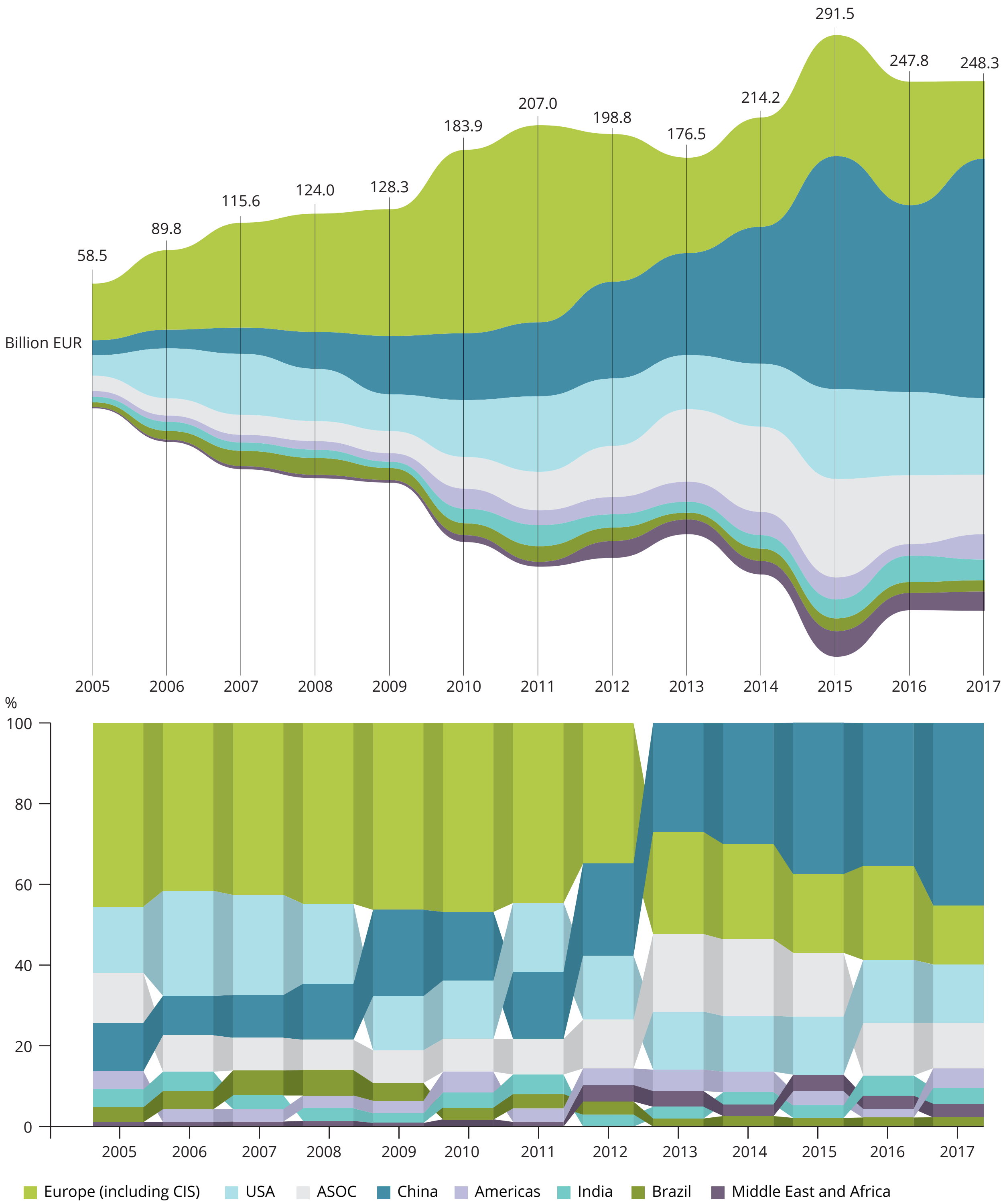
Throughout the period 2005-2012, Europe (including CIS) ([32]) has dominated global new investments in renewable energy (see Figure 4.6). However, investment activity spread rapidly to new markets, highlighting Europe's pioneering role in developing renewables. In 2013, for the first time, Europe came second as regards its share in global new investments in renewable energy, with the largest shares in new investments being taken over by China (27 %). Europe's share declined further to 14.6 % in 2017 from 23.4 % in the previous year. Since then, China has consolidated its position. In 2017, China registered a steep jump in its share in global investment in renewable energy to 45.2 % from 35.4 % in 2016. The share of investments in the United States has fluctuated around 15 % over the last 5 years. Together, China, Europe (including CIS) and the United States accounted for approximately 74 % of global new investments in renewable energy technologies in 2017, approximately the same as in the previous year.

### *4.2.2 Growth in renewable energy investments*

Between 2005 and 2008, renewable energy investments saw a steady increase in most global regions. In 2008 and 2009, the economic crisis affected liquidities and, as a consequence, renewable energy investments increased less than in previous years. Although investments recovered shortly after the crisis, in 2012, for the first time, there was a decline in global

([32]) CIS refers to the Commonwealth of Independent States. For full details, please see geographical notations in the glossary.

**Figure 4.6** New annual investments in renewable energy per region (billion EUR and %)




**Notes:** ASOC refers to Asia and Oceania; CIS refers to the Commonwealth of Independent States; full information about geographical coverage and regional aggregations is provided in the glossary.

Upper figure: New annual investments per region (billion EUR). Lower figure: Share of new annual investments in renewable power per region, in global annual investments in renewable power.

**Source:** Frankfurt School-UNEP, 2018.

investments in renewable energy. This took place against the backdrop of developments and significant cost reductions in certain technologies, policy uncertainties and retroactive policy changes (in Europe, where most investments were taking place, and in the United States, which had the second to third largest investments between 2005 and 2014), low natural gas prices in the United States and somewhat slower economic activity globally.

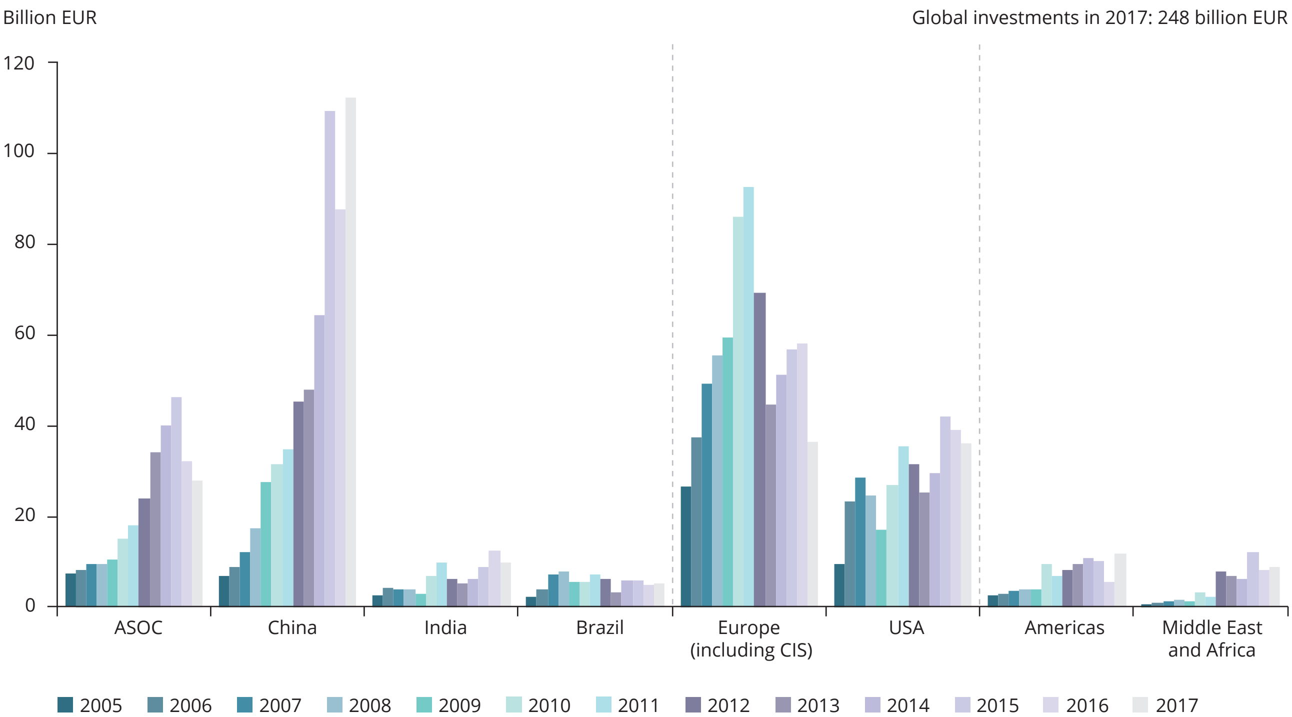
Taking into account the period from 2005 to 2011, in which there were no considerable policy uncertainties, the strongest average annual growth in renewable energy investments was distributed as follows: China (30 %), United States (25 %) and India (25 %). After difficult years in 2012-2013 (with declining or even negative growth in most regions), investments in renewables took a positive turn again in 2014-2015. In 2015, a new record in global investments was achieved. In 2016, however, global investments dropped significantly (by 15 %), despite the fact that a new record in added capacity (164 GW) was achieved. There are two main reasons for the decline in global investment in renewable energy during 2016 (Frankfurt School-UNEP, 2018). The first is the slowdown in investments in China (-20 %), ASOC (-30 %, mainly caused by a slowdown in investments in Japan) and some other emerging countries (Americas -47 %; Middle East and Africa -32 %). The second is the significant reductions in the costs of solar PV, and onshore and offshore wind power, which also improved the cost-competitiveness of those technologies. The result was that, in 2016, investors were able to acquire more renewable energy capacity for less money. Total investment in 2017 remained more or less the same as in 2016.

Overall, Figure 4.7 shows the following trend: in every single year between 2005 and 2012, Europe (including CIS) was the region with the highest new renewable energy investments. Since 2013, China has taken over and, despite the setback in 2016, is still the clear world leader in investments in renewable energy.

### *4.2.3 Total new investments by technology*

New investments in renewable energy in 2017 continued to be dominated by solar energy (mostly solar PV), accounting for 57 % of total investment in renewables, compared with 50 % in 2016. Wind power holds second position with a share of 38 %

**Figure 4.7 Total new investments in renewable energy by region, 2005-2017**




**Notes:** Figures converted to euros using annual exchange rates from the Eurostat database. ASOC refers to Asia (excluding India and China) and Oceania; CIS refers to the Commonwealth of Independent States; full information about the geographical coverage and regional aggregations is provided in the glossary.

**Sources:** Eurostat, 2018b; Frankfurt School-UNEP, 2018.

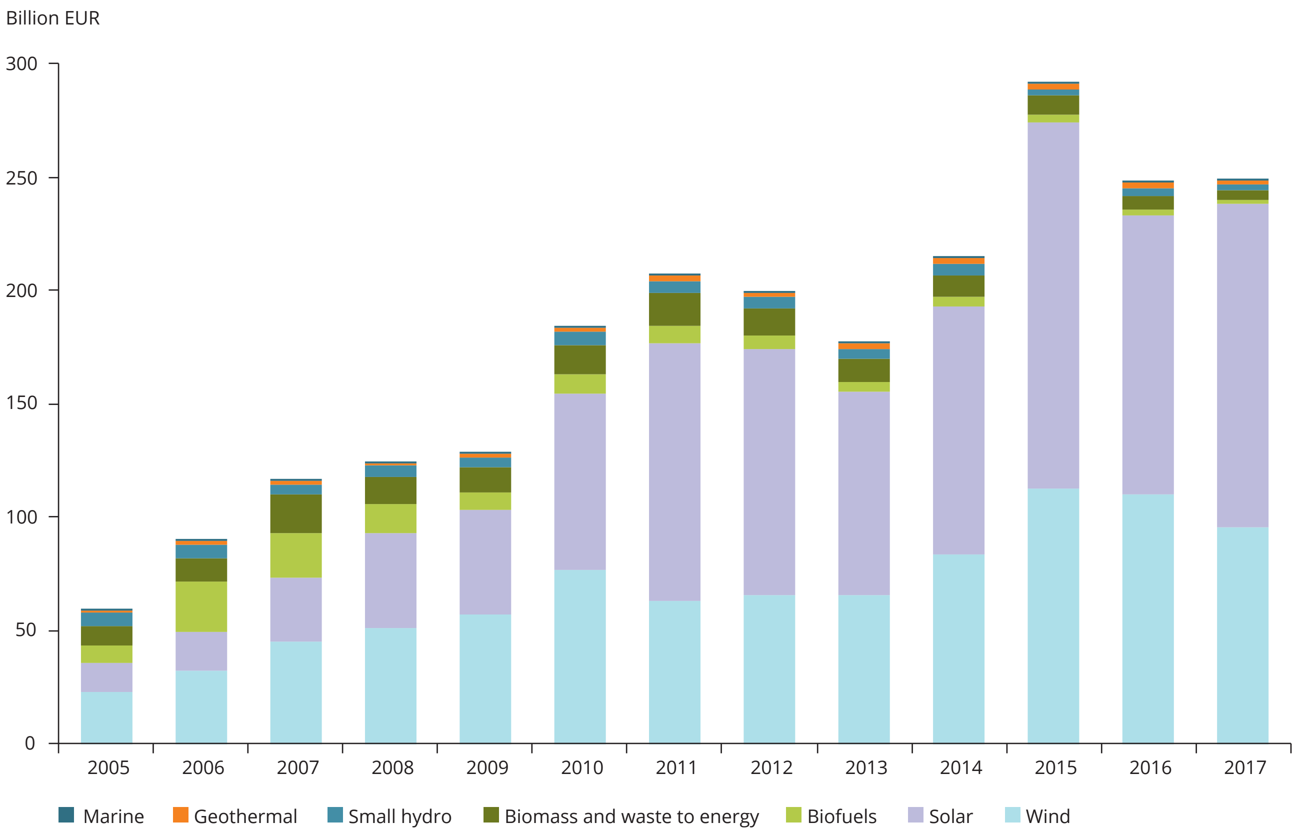
of the total investment, compared with 44 % in the previous year (Frankfurt School-UNEP, 2018). Both of these technologies received policy support — to varying extents — and experienced rapid technological learning that led to growing confidence on the part of investors. Over the period 2005-2015, total new investments in technology grew fastest for solar energy; however, there was a sharp decline (24 %) in 2016, although in 2017 investment picked up again to EUR 143 billion (about EUR 20 billion higher than 2016) but still less than the peak investment registered in 2015 (see Figure 4.8).

From 2005 to 2009, investments in wind power made up the largest share of total investments. In 2010, it moved to second place after solar energy. In 2011, investment in wind declined substantially and hovered around EUR 65 billion until 2013, remaining significantly less than investment in solar PV during those years. Thereafter, investment picked up and reached its peak at EUR 112 billion in 2015 before falling again in 2016 to EUR 110 billion and further to EUR 95 billion in 2017. Worries about curtailment and declining feed-in tariff rates contributed to the slowdown, but China remained the biggest onshore wind market in terms of new installations.

In 2015, emerging and developing economies accounted for more than half of global investment in both wind and solar power, but in 2016 they lost the lead in wind power and only narrowly maintained it in solar power. In 2017, while investment in wind power remained almost the same in developing and developed countries (around EUR 47 billion), investment in solar power was two and half times higher in developing countries (EUR 102 billion) than in developed countries (EUR 40 billion).

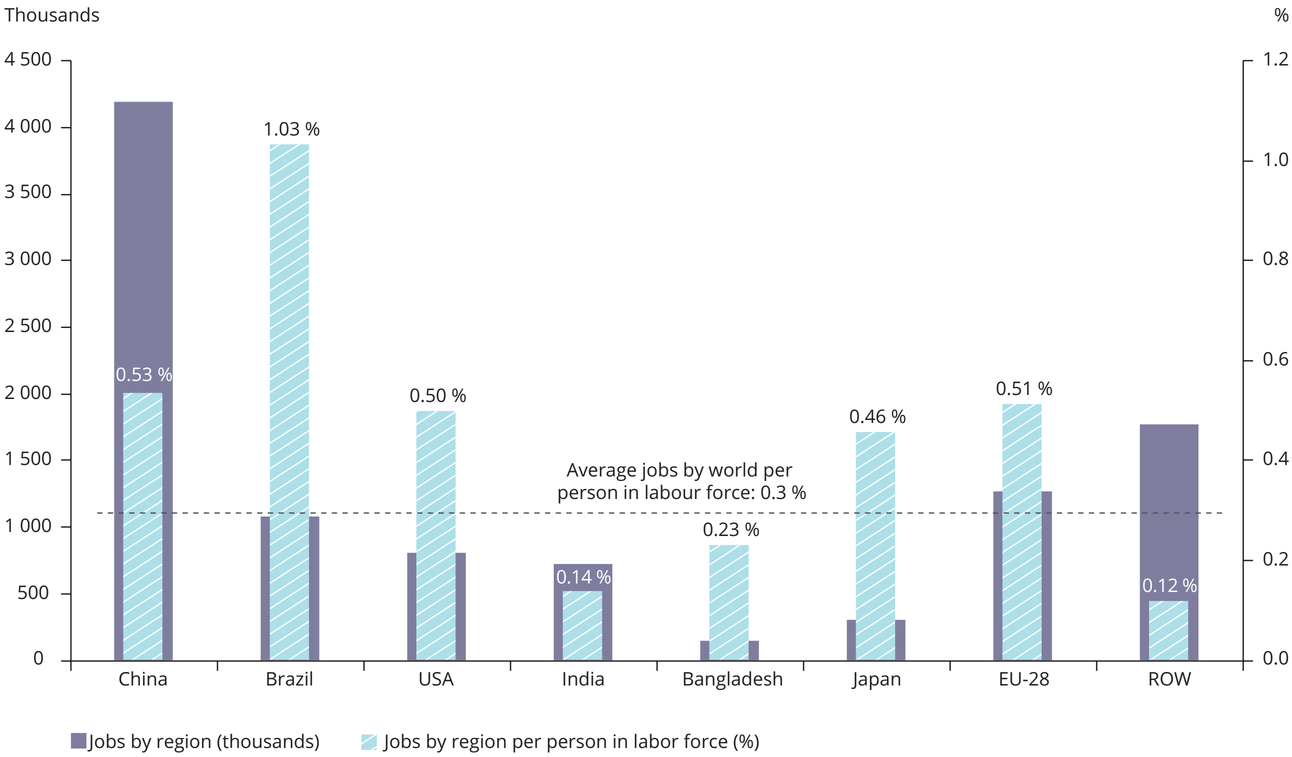
Investment in other renewable technologies, e.g. biomass/waste-to-energy, small-scale hydropower and geothermal power, remained relatively small over the period 2005-2017. Biofuels experienced a steady growth in new investment from 2005 to 2007, when growth in first-generation biofuels was increasing. After 2008, investments in biofuels started to decline and fluctuate at lower levels. In 2017, investment was lower than in 2005. Plateauing of first-generation capacity may explain this decline, including uncertainties over future legislation, the delayed development of second-generation biofuels and costs. Investment in geothermal power remained between EUR 1 and 2 billion during 2005-2017.

**Figure 4.8** **Total global new investment by technology, 2005-2017**




**Source:** Frankfurt School-UNEP, 2018.

**Figure 4.9 Direct and indirect jobs related to renewable energy in 2017 by region**




**Notes:** ROW: rest of the world.

The primary y-axis displays absolute numbers (thousands of jobs) in 2017. The secondary y-axis relates the absolute number of jobs to the total labour force of each region, thus displaying jobs in the renewable energy sector as percentages of the total labour force. The jobs displayed include both direct and indirect jobs along the value chain. For Bangladesh, job data in the solar industry is taken from IRENA (2018b), whereas, job data for other industries are sourced from IRENA in the previous year (2017a). The jobs data for the EU and its Member States are for 2016, the most recent year for which such information is available.

**Sources:** Absolute jobs (IRENA, 2017a, 2018b); data on labour force (World Bank, 2017).

## 4.3 Renewable energy employment

In 2017, a total of 10.3 million jobs (direct and indirect) were related to renewable energies globally (IRENA, 2018b). The regional distribution of these jobs is depicted in Figure 4.9. In absolute terms, China, the EU and Brazil were the largest employers. Figure 4.9 also presents renewable jobs in relative terms (i.e. as the share of the total labour force in the country occupied by renewable energy jobs — the blue-hatched bars in Figure 4.9) by region:

- Brazil, China and the EU are the top three countries/regions with respect to renewable energy-related jobs as percentages of the labour force in 2017, with the United States coming in just behind in fourth place.
- Within the EU, Germany was the number one per capita (labour force) employer (with 0.77 % of the total labour force working in the renewables sector).
- At the global level, on average 0.3 % of the labour force is engaged in the renewable energy sector.

In the EU, the largest employers are the wind, solar PV and solid biomass industries. The number of renewable energy jobs in the EU increased slightly in 2017 over the previous year. Job losses in solar PV installations and module manufacturing have been compensated for by increased employment in geothermal, wind and solid biomass power.

# Glossary and abbreviations

| | |
|---|---|
| CHP | Combined heat and power |
| CSP | Concentrated solar power |
| EEA | European Environment Agency |
| EED | Energy Efficiency Directive (Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC) (see also EU, 2012) |
| EJ | Exajoule (one quintillion joules) |
| ENTSO-E | European Network of Transmission System Operators for Electricity |
| EPBD | Energy Performance of Buildings Directive (Directive 2010/31/EU on the energy performance of buildings) (see also EU, 2010) |
| ETC/ACM | European Topic Centre for Air Pollution and Climate Change Mitigation. The ETC/ACM is a consortium of European institutes contracted by the EEA to carry out specific tasks in the field of air pollution and climate change |
| ETS | Emissions Trading System |
| EU | European Union |
| EU-28 | Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovenia, Slovakia, Spain, Sweden, United Kingdom |
| GDP | Gross domestic product |
| GFEC | Gross final energy consumption means the energy commodities delivered for energy purposes to industry, transport, households, services — including public services, agriculture, forestry and fisheries — as well as the consumption of electricity and heat by the energy branch for electricity and heat production, and including losses of electricity and heat in distribution and transmission (see Article 2(f) of Directive 2009/28/EC, the Renewable Energy Directive). It excludes transformation losses, which are included in gross inland energy consumption (GIEC). In calculating a Member State's GFEC for the purpose of measuring its compliance with the targets and interim Renewable Energy Directive (RED) and national renewable energy action plan (NREAP) trajectories, the amount of energy consumed in aviation shall, as a proportion of that Member State's GFEC, be considered to be no more than 6.18 % (4.12 % for Cyprus and Malta) |
| GHG | Greenhouse gas |

| | |
|---|---|
| GIEC | Gross inland energy consumption, sometimes shortened to gross inland consumption, is the total energy demand of a country or region. It represents the quantity of energy necessary to satisfy inland consumption of the geographical entity under consideration |
| GW | Gigawatt |
| GWe | Gigawatt electrical (referring to capacity) |
| IEA | International Energy Agency |
| ILUC | Indirect land use change, in the context of Directive (EU) 2015/1513 of the European Parliament and of the Council, of 9 September 2015, amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources (see also EU, 2015) |
| IRENA | International Renewable Energy Agency |
| ktoe | Kilotonnes of oil equivalent |
| kWe | Kilowatt electrical (capacity) |
| LULUCF | Land use, land use change and forestry — a term used in relation to the forestry and agricultural sector in the international climate negotiations under the United Framework Convention on Climate Change (UNFCCC) |
| Mt | Million tonnes (megatonnes) |
| $MtCO_2$ | Million tonnes of carbon dioxide |
| Mtoe | Million tonnes of oil equivalent |
| MW | Megawatt |
| NREAP | National renewable energy action plan |
| Primary energy consumption | In the context of the EED, this represents GIEC minus non-energy use |
| OECD | Organisation for Economic Co-operation and Development |
| PV | Solar photovoltaic energy |
| RED | Renewable Energy Directive (Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC) (see also EU, 2009) |
| RED II | As part of the Clean Energy for all Europeans initiative (November 2016), the Commission adopted a legislative proposal for a recast of the RED. The European Parliament and the EU Council proposed amendments and a final compromise was agreed among the EU institutions on 14 June 2018. The RED II is expected to be officially adopted by the end of 2018 |
| Renewable waste | The biodegradable fraction of industrial and municipal waste |
| RES | Renewable energy sources |

| | |
|---|---|
| RES-E | Renewable electricity |
| RES-H&C | Renewable heating and cooling |
| RES-T | Renewable energy consumed in transport |
| SHARES | Short Assessment of Renewable Energy Sources. A tool developed by Eurostat with the aim of facilitating the calculation of the RES share according to the RED |
| SPF | Seasonal performance factor |
| UNFCCC | United Nations Framework Convention on Climate Change |

## Geographical coverage in Chapter 4

The presentation of the global picture in Chapter 4 follows, as far as possible, the geographic coverage and regional aggregation used by the International Energy Agency (IEA). For investments, the aggregation used by Frankfurt School-UNEP (Frankfurt School-UNEP, 2018) was used, given that a finer corresponding aggregation was not available.

| | |
|---|---|
| Africa | Includes Algeria; Angola; Benin; Botswana (from 1981); Cameroon; Congo; Côte d'Ivoire; Democratic Republic of the Congo; Egypt; Eritrea; Ethiopia; Gabon; Ghana; Kenya; Libya; Mauritius; Morocco; Mozambique; Namibia (from 1991); Niger (from 2000); Nigeria; Senegal; South Africa; South Sudan; Sudan *; United Republic of Tanzania; Togo; Tunisia; Zambia; Zimbabwe and Other Africa. Other Africa includes Botswana (until 1980); Burkina Faso; Burundi; Cape Verde; Central African Republic; Chad; Comoros; Djibouti; Equatorial Guinea; The Gambia; Guinea; Guinea-Bissau; Lesotho; Liberia; Madagascar; Malawi; Mali; Mauritania; Namibia (until 1990); Niger (until 1999); Réunion; Rwanda; São Tomé and Príncipe; Seychelles; Sierra Leone; Somalia; Swaziland; and Uganda.<br><br>* South Sudan became an independent country on 9 July 2011. From 2012 onwards, data for South Sudan have been reported separately. |
| Americas | Consisting of OECD Americas (Canada; Chile; Mexico; and the United States) and non-OECD Americas (Argentina; Bolivia; Brazil; Colombia; Costa Rica; Cuba; Curaçao *; Dominican Republic; Ecuador; El Salvador; Guatemala; Haiti; Honduras; Jamaica; Nicaragua; Panama; Paraguay; Peru; Trinidad and Tobago; Uruguay; Venezuela; and Other non-OECD Americas). Other non-OECD Americas includes Antigua and Barbuda; Aruba; Bahamas; Barbados; Belize; Bermuda; British Virgin Islands; Cayman Islands; Dominica; Falkland Islands (Islas Malvinas); French Guiana; Grenada; Guadeloupe; Guyana; Martinique; Montserrat; Puerto Rico (for natural gas and electricity); Saint Kitts and Nevis; Saint Lucia; Saint Pierre and Miquelon; Saint Vincent and the Grenadines; Suriname; Turks and Caicos Islands; Bonaire (from 2012); Saba (from 2012); Saint Eustratius (from 2012); and Sint Maarten (from 2012).<br><br>* Netherlands Antilles was dissolved on 10 October 2010, resulting in two new constituent countries, Curaçao and Sint Maarten, with the remaining islands joining the Netherlands as special municipalities. In this edition, the methodology for accounting for the energy statistics of Netherlands Antilles has been revised to follow the above-mentioned geographical changes. From 2012 onwards, data account for the energy statistics of Curaçao only. Prior to 2012, data remain unchanged and still cover the entire territory of the former Netherlands Antilles. |
| ASOC | Asia and Oceania, including OECD Asia and Oceania (Australia; Israel; Japan; South Korea; and New Zealand) and Asia (Bangladesh; Brunei; Cambodia (from 1995); India; Indonesia; North Korea; Malaysia; Mongolia (from 1985); Myanmar/Burma; Nepal; Pakistan; Philippines; Singapore; Sri Lanka; Chinese Taipei; Thailand; Vietnam; and Other Asia. Other Asia includes Afghanistan; Bhutan; Cambodia (until 1994); China; Cook Islands; Fiji; French Polynesia; Kiribati; Laos; Macau, Maldives; Mongolia (until 1984); New Caledonia; Palau (from 1994); Papua New Guinea; Samoa; Solomon Islands; Timor-Leste; Tonga; and Vanuatu). |
| Other Europe and CIS (Commonwealth of Independent States) (OE-CIS) | Albania; Andorra; Armenia; Azerbaijan; Belarus; Bosnia and Herzegovina; Channel Islands; Georgia; Iceland; Isle of Man; Kazakhstan; Kosovo *; Kyrgyzstan; Liechtenstein; the Former Yugoslav Republic of Macedonia; Moldova; Monaco; Montenegro; Norway; Russia; San Marino; Serbia; Switzerland; Tajikistan; Turkey; Turkmenistan; Ukraine; and Uzbekistan.<br><br>* Under United Nations Security Council Resolution 1244/99. |
| Middle East | Bahrain; Iran; Iraq; Jordan; Israel; West Bank Gaza Strip; Kuwait; Lebanon; Oman; Qatar; Saudi Arabia; Syria; United Arab Emirates; and Yemen. |

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# Annex 1 Effects on fossil fuel consumption and greenhouse gas emissions

The table below summarises the effect of deploying renewable energy since 2005 on GHG emissions and energy consumption by country in 2016, as discussed in Section 2.3 of this report.

**Table A1.1 Effects on fossil fuel consumption and greenhouse gas emissions**

| Country | GHG emissions (including international aviation) | Effect of renewables | | Gross inland consumption of fossil fuels | Effect of renewables | | Primary energy consumption | Effect of renewables | |
|---|---|---|---|---|---|---|---|---|---|
| | $MtCO_2e$ | $MtCO_2$ | % | Mtoe | Mtoe | % | Mtoe | Mtoe | % |
| Austria | 82.0 | -13.3 | -14 | 23.2 | -4.4 | -16 | 31.8 | -0.6 | -2 |
| Belgium | 122.1 | -9.3 | -7 | 41.8 | -3.5 | -8 | 49.0 | -0.3 | -1 |
| Bulgaria | 59.7 | -6.0 | -9 | 12.6 | -1.7 | -12 | 17.6 | -0.6 | -3 |
| Croatia | 24.7 | -1.8 | -7 | 6.1 | -0.5 | -7 | 8.1 | -0.3 | -3 |
| Cyprus | 9.7 | -0.5 | -5 | 2.3 | -0.2 | -7 | 2.4 | -0.1 | -2 |
| Czechia | 131.3 | -10.8 | -8 | 32.2 | -3.1 | -9 | 39.9 | -0.4 | -1 |
| Denmark | 53.3 | -12.6 | -19 | 12.0 | -4.2 | -26 | 17.2 | -1.3 | -7 |
| Estonia | 19.7 | -2.1 | -9 | 5.4 | -0.6 | -10 | 6.1 | -0.1 | -1 |
| Germany | 935.8 | -132.0 | -12 | 260.9 | -36.0 | -12 | 295.8 | -10.5 | -3 |
| Greece | 94.7 | -6.7 | -7 | 20.7 | -2.0 | -9 | 23.5 | -1.2 | -5 |
| Finland | 60.8 | -11.2 | -16 | 16.4 | -3.4 | -17 | 33.1 | -0.2 | 0 |
| France | 475.4 | -33.0 | -6 | 123.7 | -11.5 | -9 | 235.4 | -2.8 | -1 |
| Hungary | 62.1 | -4.5 | -7 | 17.5 | -1.6 | -8 | 23.9 | 0.1 | 0 |
| Ireland | 64.2 | -4.1 | -6 | 13.8 | -1.3 | -9 | 14.6 | -0.5 | -3 |
| Italy | 438.2 | -47.0 | -10 | 125.5 | -16.0 | -11 | 148.4 | -3.3 | -2 |
| Latvia | 11.7 | -0.7 | -6 | 2.7 | -0.2 | -7 | 4.3 | 0.0 | 1 |
| Lithuania | 20.4 | -2.3 | -10 | 4.9 | -0.7 | -13 | 6.0 | 0.0 | -1 |
| Luxembourg | 11.5 | -0.6 | -5 | 3.4 | -0.2 | -5 | 4.2 | 0.0 | 0 |
| Malta | 2.3 | -0.1 | -6 | 0.6 | 0.0 | -8 | 0.7 | 0.0 | -3 |
| Netherlands | 207.0 | -7.9 | -4 | 73.4 | -2.6 | -3 | 64.8 | -0.6 | -1 |
| Poland | 397.8 | -20.2 | -5 | 91.0 | -5.9 | -6 | 94.3 | -0.8 | -1 |
| Portugal | 71.2 | -8.9 | -11 | 18.1 | -2.4 | -12 | 22.1 | -1.5 | -6 |
| Romania | 113.4 | -10.7 | -9 | 23.7 | -3.0 | -11 | 31.3 | -1.3 | -4 |
| Slovakia | 41.2 | -2.2 | -5 | 10.8 | -0.8 | -7 | 15.5 | 0.0 | 0 |
| Slovenia | 17.8 | -1.1 | -6 | 4.3 | -0.4 | -9 | 6.7 | 0.0 | -1 |
| Spain | 340.5 | -40.0 | -11 | 89.0 | -12.2 | -12 | 117.2 | -4.5 | -4 |

**Table A1.1 Effects on fossil fuel consumption and greenhouse gas emissions (cont.)**

| Country | GHG emissions (including international aviation) | Effect of renewables | | Gross inland consumption of fossil fuels | Effect of renewables | | Primary energy consumption | Effect of renewables | |
|---|---|---|---|---|---|---|---|---|---|
| | $MtCO_2e$ | $MtCO_2$ | % | Mtoe | Mtoe | % | Mtoe | Mtoe | % |
| Sweden | 55.5 | -23.8 | -30 | 15.7 | -7.4 | -32 | 47.1 | -2.0 | -4 |
| United Kingdom | 516.8 | -46.6 | -8 | 154.1 | -16.8 | -10 | 181.7 | -2.7 | -1 |
| **All 28 Member States** | **4 441** | **-460** | **-9** | **1 206** | **-143** | **-11** | **1 543** | **-35** | **-2** |

**Notes:** This table shows the estimated effect of the increase in renewable energy consumption since 2005 on GHG emissions (total emissions, including international aviation and excluding LULUCF), gross inland consumption of fossil fuels and primary energy consumption.

**Source:** EEA (based on data from Eurostat, 2017b, 2017c).

# Annex 2 Methodology and data sources for calculating approximated RES shares

The general methodology to calculate the approximated RES shares is laid out in the EEA report *Renewable energy in Europe — Approximated recent growth and knock-on effects* (EEA, 2015). The data have been updated to reflect the most up-to-date values available at the end of July 2018, when no officially reported RES data for 2016 were available.

Some improvements in the methodology were made for the estimation of 2016 RES shares:

- The calculation is made in Eurostat's Short Assessment of Renewable Energy Sources (SHARES) tool. This improves consistency with the methodology laid out in the RED and RES shares data published by Eurostat.

- An exponential trend extrapolation, instead of a linear extrapolation, is used as the standard fall-back option.

- Final energy consumption of oil and gas is linked to the EEA's energy efficiency proxy.

For 2016, one change was made:

- Exponential trends are no longer a standard forecasting assumption, because strong historical growth rates (common in the early stages) frequently lead to implausible results. They are still applied in very few select cases in which an exponential extrapolation seems useful.

For 2017, one change was made:

- Since EurObserv'ER's Biofuel barometer 2018 was not published in July, as in previous years, that source was replaced with the Eurostat data on biofuel consumption. However, the data in the latter source have a much coarser resolution than the data in EurObserv'ER's Biofuel barometer. Therefore, these data were used only for countries that exceeded a biofuel consumption of 60 kilotonnes in both 2016 and 2017, in order to avoid calculation artefacts due to quantification errors. For countries below that threshold, biofuel consumption in transport was estimated to stay constant. As a consequence, the share of certified biofuels was estimated to remain constant.

The following list documents the data sources used in the RES proxy calculation:

- EEA:
  - final energy consumption estimate for 2017 in the industry sector;
  - final energy consumption estimate for 2017 in households and services.

- ENTSO-E (European Network of Transmission System Operators for Electricity):
  - monthly generation of electricity.

- Eurostat:
  - supply and transformation of oil monthly data [nrg_102m]:
    - consumption of various liquid fossil fuels in transport;
    - consumption of biofuels in transport.
  - supply of electricity [nrg_105m]:
    - consumption of electricity;
    - total gross production;
    - electricity imports and exports;
    - gross production from hydro- and pumped storage.

- EurObserv'ER:
  - Photovoltaic barometer 2018:
    - electricity production from solar PV power.
  - Solar thermal barometer 2018:
    - total heat production from solar thermal installations.
  - Wind energy barometer 2018:
    - electricity production from wind energy.

- Member State data (not included by default, but received during Eionet consultation):
  - Belgium submitted detailed energy consumption data, which improved the EEA's proxy calculation.

- Denmark submitted basic energy consumption data, which improved the EEA's proxy calculation.
- Germany submitted detailed and complete RES shares data for 2017, which replaced the EEA's proxy calculation.
- Ireland submitted detailed and complete RES shares data for 2017, which replaced the EEA's proxy calculation.
- Lithuania submitted detailed and complete RES shares data for 2017, which replaced the EEA's proxy calculation.
- Malta submitted partially complete RES shares data, which improved the EEA's proxy calculation.

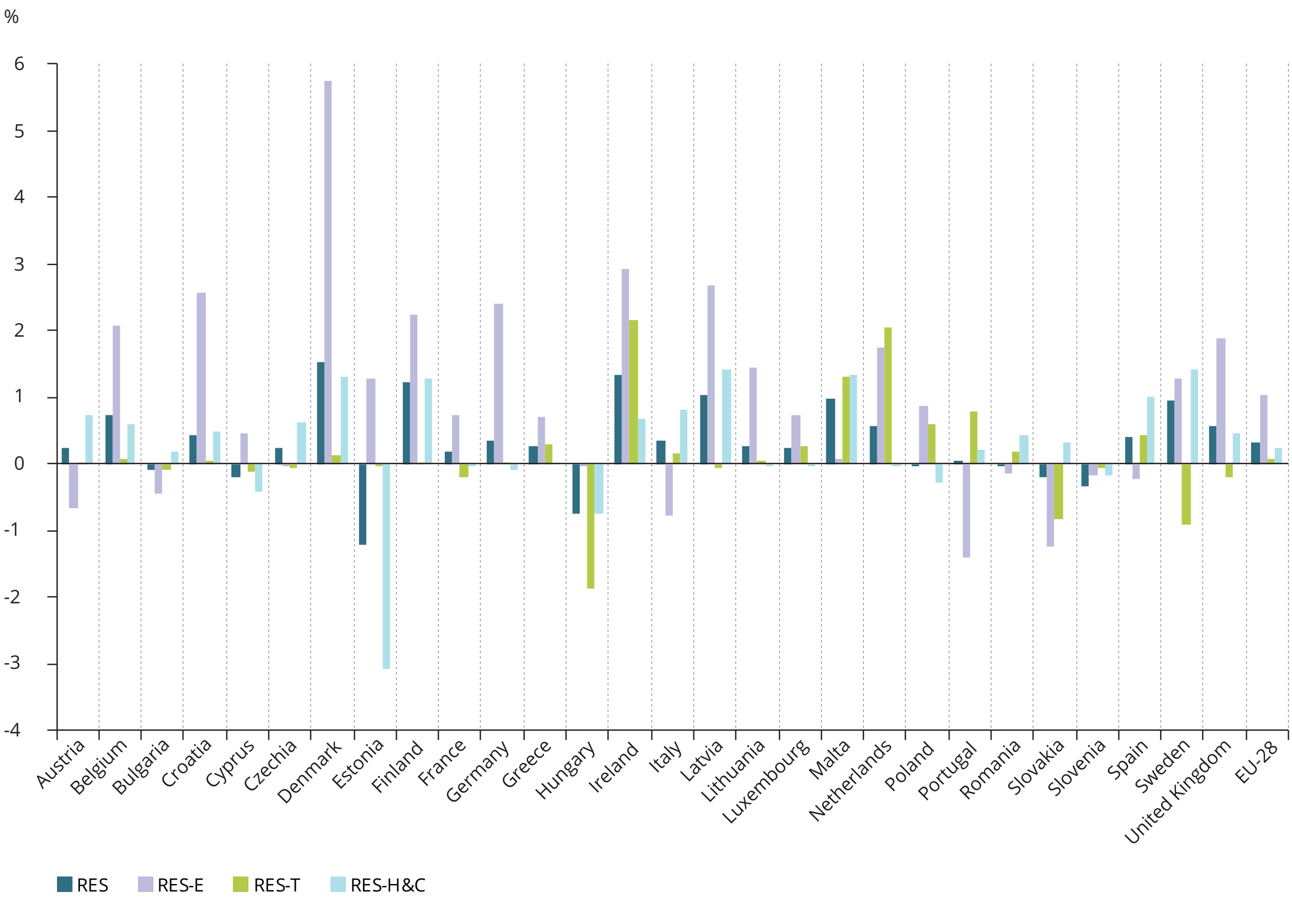
# Annex 3 Discussion of main 2016/2017 changes by sector and country

Changes in calculated RES shares proxies for the years 2016/2017 are compared with historically (2005-2016) observed changes in RES shares by way of descriptive statistics to determine statistically significant deviations from the historical changes.

If, in 2016/2017, changes in RES shares were significantly different but within the historically observed minima and maxima, the results were considered plausible without further analysis. If the 2016/2017 changes in RES shares were higher or lower than historically observed changes, further in-depth analysis was performed. The reasons for these strong decreases or increases were found and are described below.

Figure A3.1 shows the changes between approximated 2017 RES shares and 2016 RES shares, while Table A3.1 provides detailed insights.

**Figure A3.1 Changes in approximated RES shares in 2017 compared with 2016 in percentage points**




**Source:** EEA.

**Table A3.1 Shares of renewable energy (%) in 2016 and 2017**

| | RES | | | RES-E | | | RES-T | | | RES-H&C | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | Delta | 2016 | 2017 | Delta | 2016 | 2017 | Delta | 2016 | 2017 | Delta |
| Austria | 33.5 | 33.7 | 0.2 | 72.6 | 72.0 | -0.7 | 10.6 | 10.6 | 0.0 | 33.3 | 34.1 | 0.7 |
| Belgium | 8.7 | 9.4 | 0.7 | 15.8 | 17.8 | 2.1 | 5.9 | 6.0 | 0.1 | 8.1 | 8.7 | 0.6 |
| Bulgaria | 18.8 | 18.7 | -0.1 | 19.2 | 18.8 | -0.4 | 7.3 | 7.2 | -0.1 | 30.0 | 30.2 | 0.2 |
| Croatia | 28.3 | 28.7 | 0.4 | 46.7 | 49.3 | 2.6 | 1.3 | 1.3 | 0.1 | 37.6 | 38.1 | 0.5 |
| Cyprus | 9.3 | 9.1 | -0.2 | 8.6 | 9.0 | 0.5 | 2.7 | 2.5 | -0.1 | 23.0 | 22.6 | -0.4 |
| Czechia | 14.9 | 15.1 | 0.2 | 13.6 | 13.6 | 0.0 | 6.4 | 6.3 | -0.1 | 19.9 | 20.5 | 0.6 |
| Denmark | 32.2 | 33.7 | 1.5 | 53.7 | 59.5 | 5.7 | 6.8 | 6.9 | 0.1 | 41.7 | 43.0 | 1.3 |
| Estonia | 28.8 | 27.6 | -1.2 | 15.5 | 16.8 | 1.3 | 0.4 | 0.4 | 0.0 | 51.2 | 48.1 | -3.1 |
| Finland | 38.7 | 39.9 | 1.2 | 32.9 | 35.2 | 2.2 | 8.4 | 8.4 | 0.0 | 53.7 | 55.0 | 1.3 |
| France | 16.0 | 16.1 | 0.2 | 19.2 | 19.9 | 0.7 | 8.9 | 8.7 | -0.2 | 21.1 | 21.1 | 0.0 |
| Germany | 14.8 | 15.2 | 0.3 | 32.2 | 34.6 | 2.4 | 6.9 | 7.0 | 0.0 | 13.0 | 12.9 | -0.1 |
| Greece | 15.2 | 15.5 | 0.3 | 23.8 | 24.5 | 0.7 | 1.4 | 1.7 | 0.3 | 24.5 | 24.5 | 0.0 |
| Hungary | 14.2 | 13.4 | -0.8 | 7.2 | 7.2 | 0.0 | 7.4 | 5.5 | -1.9 | 20.8 | 20.0 | -0.7 |
| Ireland | 9.5 | 10.8 | 1.3 | 27.2 | 30.1 | 2.9 | 5.0 | 7.2 | 2.1 | 6.8 | 7.5 | 0.7 |
| Italy | 17.4 | 17.8 | 0.3 | 34.0 | 33.2 | -0.8 | 7.2 | 7.4 | 0.2 | 18.9 | 19.7 | 0.8 |
| Latvia | 37.2 | 38.2 | 1.0 | 51.3 | 53.9 | 2.7 | 2.8 | 2.7 | -0.1 | 51.9 | 53.3 | 1.4 |
| Lithuania | 25.6 | 25.8 | 0.3 | 16.8 | 18.3 | 1.4 | 3.6 | 3.7 | 0.1 | 46.5 | 46.5 | 0.0 |
| Luxembourg | 5.4 | 5.7 | 0.2 | 6.7 | 7.4 | 0.7 | 5.9 | 6.2 | 0.3 | 7.3 | 7.3 | 0.0 |
| Malta | 6.0 | 7.0 | 1.0 | 5.6 | 5.7 | 0.1 | 5.4 | 6.7 | 1.3 | 15.3 | 16.6 | 1.3 |
| Netherlands | 6.0 | 6.5 | 0.6 | 12.5 | 14.3 | 1.8 | 4.6 | 6.7 | 2.0 | 5.5 | 5.4 | 0.0 |
| Poland | 11.3 | 11.2 | 0.0 | 13.4 | 14.2 | 0.9 | 3.9 | 4.5 | 0.6 | 14.7 | 14.4 | -0.3 |
| Portugal | 28.5 | 28.5 | 0.0 | 54.1 | 52.7 | -1.4 | 7.5 | 8.3 | 0.8 | 35.1 | 35.3 | 0.2 |
| Romania | 25.0 | 25.0 | 0.0 | 42.7 | 42.6 | -0.1 | 6.2 | 6.4 | 0.2 | 26.9 | 27.3 | 0.4 |
| Slovakia | 12.0 | 11.8 | -0.2 | 22.5 | 21.3 | -1.3 | 7.5 | 6.7 | -0.8 | 9.9 | 10.2 | 0.3 |
| Slovenia | 21.3 | 21.0 | -0.3 | 32.1 | 31.9 | -0.2 | 1.6 | 1.5 | -0.1 | 34.0 | 33.8 | -0.2 |
| Spain | 17.3 | 17.7 | 0.4 | 36.6 | 36.4 | -0.2 | 5.3 | 5.7 | 0.4 | 16.8 | 17.8 | 1.0 |
| Sweden | 53.8 | 54.8 | 1.0 | 64.9 | 66.1 | 1.3 | 30.3 | 29.4 | -0.9 | 68.6 | 70.0 | 1.4 |
| United Kingdom | 9.3 | 9.9 | 0.6 | 24.6 | 26.5 | 1.9 | 4.9 | 4.7 | -0.2 | 7.0 | 7.5 | 0.4 |
| **European Union** | **17.0** | **17.4** | **0.3** | **29.6** | **30.6** | **1.0** | **7.1** | **7.2** | **0.1** | **19.1** | **19.3** | **0.2** |

**Sources:** EEA; Eurostat, 2018b.

*Renewable electricity*

The change in the RES-E shares proxy for 2017 compared with 2016 (+1.0 %) for the whole EU is smaller by 0.4 standard deviations than the average annual change in RES-E shares in the period from 2005 to 2016 (+1.3 %).

The calculated changes in the RES-E shares proxies for half of the Member States are within 1 standard deviation of the average changes for the period 2005-2016. In 18 Member States, the 2016/2017 change is significantly different from the 2005-2016 average at the 5 % level (Austria, Belgium, Bulgaria, Croatia, Czechia, Denmark, Germany, Finland, Ireland, Italy, Latvia, Luxembourg, Malta, Netherlands, Portugal, Romania, Spain and Slovakia), as shown in Figure A3.2. Of those, eight Member States showed changes in RES-E shares that were larger than the historically observed average ±1 standard deviation.

The following eight Member States show larger changes in RES-E shares than have been historically observed.

**Bulgaria:** The absolute contribution of RES-E generation increased (+1 %) but electricity consumption grew more strongly (+3 %) leading to a significantly decreasing RES-E share (from 19.2 % in 2016 to 18.8 % in 2017).

**Denmark:** Strong increases in wind (+6 %), solid biofuels (+9 %) and other renewables (+15 %, mainly biogas) led to a total increase in RES-E generation of 7 %, while electricity consumption fell by 2 %. The RES-E share increased from 53.7 % in 2016 to 58.4 % in 2017.

**Finland:** RES-E generation grew by 7 % with the largest absolute increases in wind energy followed by hydroelectricity. Combined with a constant electricity consumption this led to a significantly increasing RES-E share (from 32.9 % in 2016 to 35.2 % in 2017).

**Ireland:** RES-E generation grew much more strongly (+13 %) than electricity consumption (+2 %). By far the largest absolute increase was from wind energy, which increased by 15 %. As a result, the RES-E share increased from 27.2 % in 2016 to 30.1 % in 2017.

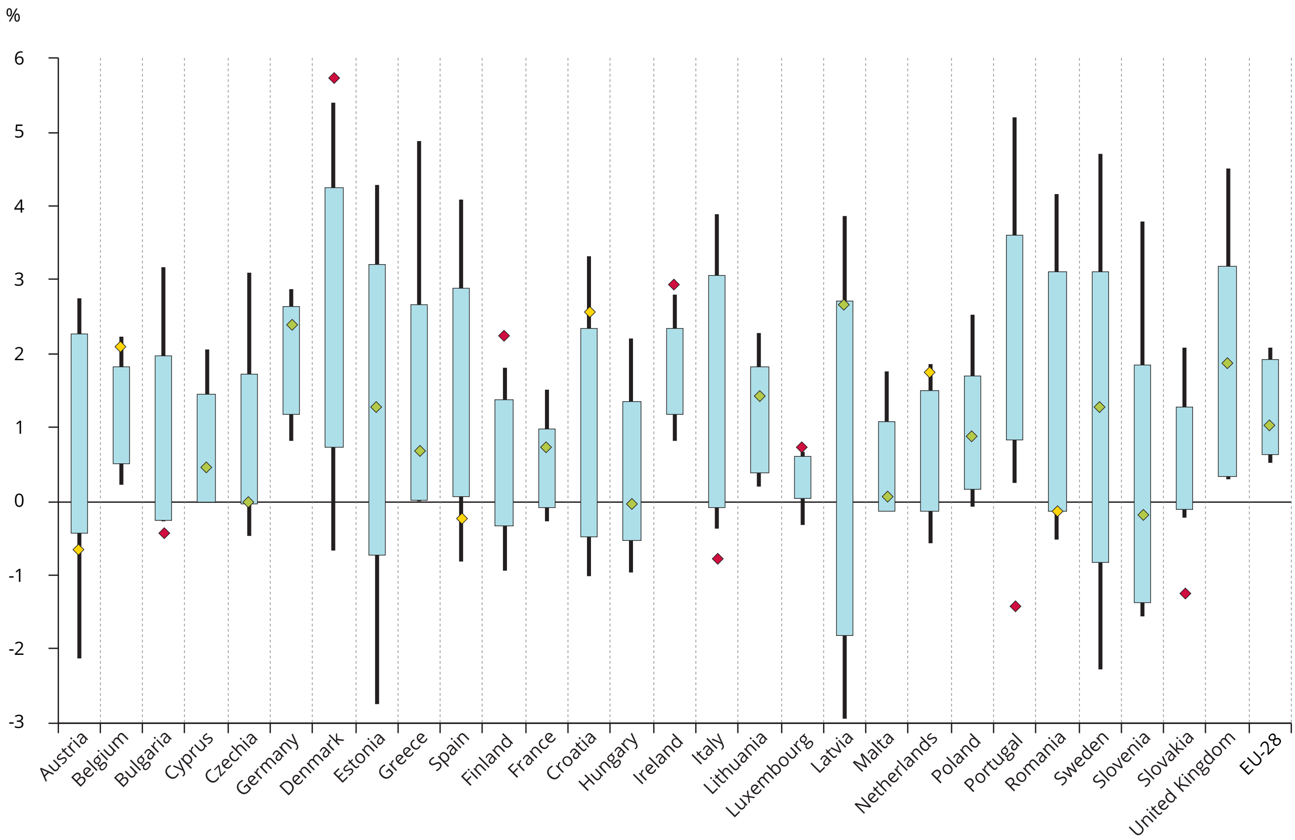
**Italy:** The absolute contribution of RES-E generation increased (+1 %), but electricity consumption grew more strongly (+3 %), leading to a significantly decreasing RES-E share (from 34.0 % in 2016 to 33.2 % in 2017).

**Luxembourg:** In 2017, RES-E generation from wind grew strongly (+40 %) as a result of a large increase in wind capacity installed in 2016. Total RES-E generation increased by 12 %, while electricity consumption increased by only 1 %, leading to a significantly increasing RES-E share (from 6.7 % in 2016 to 7.4 % in 2017).

**Portugal:** The absolute contribution of RES-E generation increased (+2 %), but electricity consumption grew more strongly (+4 %), leading to a significantly decreasing RES-E share (from 54.1 % in 2016 to 52.7 % in 2017).

**Slovakia:** Total RES-E generation decreased by 1 %, as the predominant source, hydroelectricity, decreased by

**Figure A3.2 Changes in RES-E shares between 2016 and 2017 compared with historically observed annual changes in RES-E shares (2005-2016) in percentage points**




**Notes:** Blue bars show the range of average annual changes in RES-E shares between 2005 and 2016, plus or minus one standard deviation. Thin lines represent minimum and maximum year-to-year changes in this period. Diamonds show the change in proxy RES share for 2017 compared with 2016. Green: change between 2016 and 2017 within 1 standard deviation of changes from 2005 to 2016. Yellow: change between 2016 and 2017 within minimum and maximum change from 2005 to 2016. Red: change between 2016 and 2017 larger than changes from 2005 to 2016.

**Source:** EEA.

2 % and increases in other kinds of RES-E generation (mainly solid biofuels) could only partly compensate. Combined with a 5 % increase in electricity consumption, this led to a significantly decreasing RES-E share (from 22.5 % in 2016 to 21.3 % in 2017).

*Renewable heating and cooling*

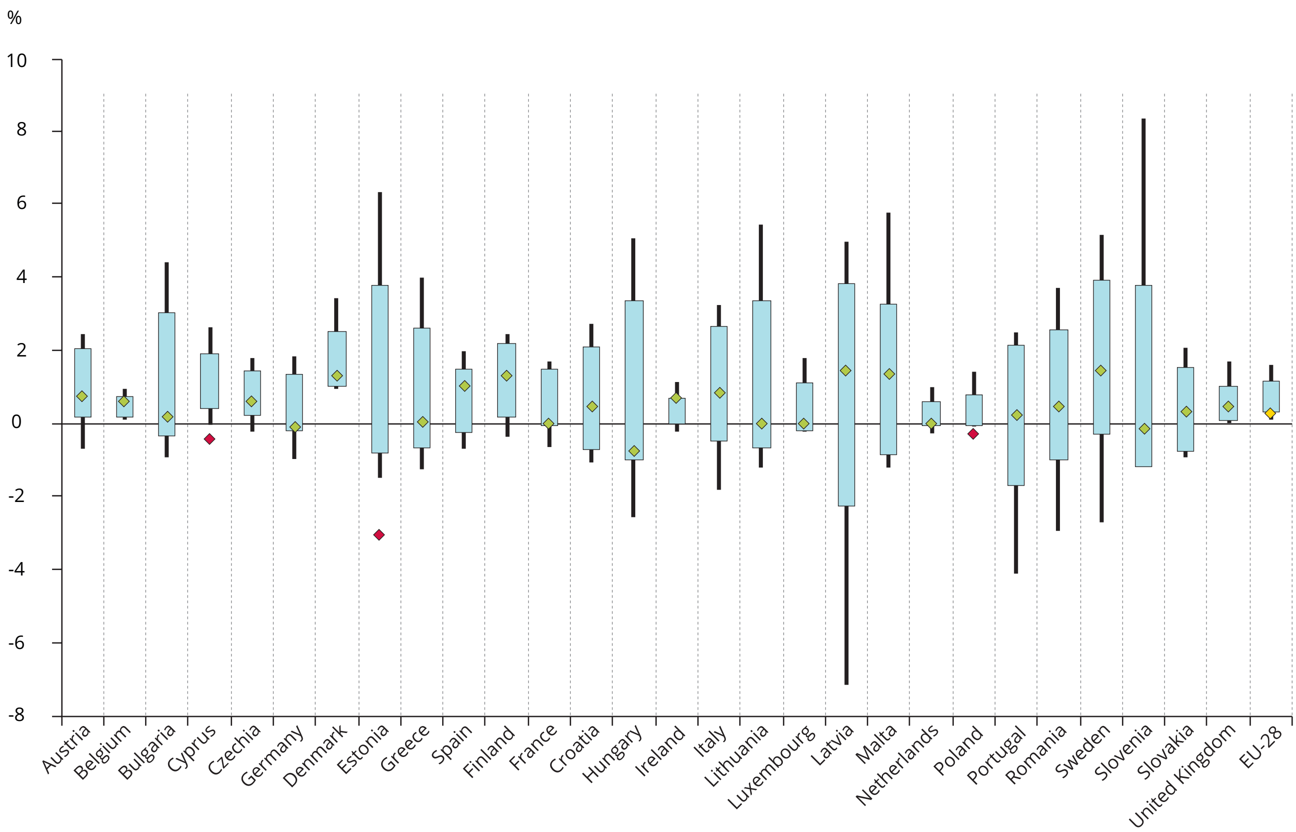
The change in the RES-H&C shares proxy for 2017 compared with 2016 (+0.2 %) for the whole EU is smaller by 1.1 standard deviations than the average annual change in RES-H&C shares in the period from 2005 to 2016 (+0.7 %). This deviation is significant at the 5 % level (p = 0.002).

The calculated changes in the RES-H&C shares proxies for 21 Member States are within 1 standard deviation of the average changes for the period 2005-2016. In 11 Member States, the 2016/2017 change is significantly different from the 2005-2016 average at the 5 % level (Bulgaria, Cyprus, Estonia, France, Germany, Hungary, Ireland, Lithuania, Luxembourg, Netherlands and Poland), as shown in Figure A3.3. Of those, three Member States showed changes in RES-H&C shares that are larger than the historically observed average ±1 standard deviation.

The following three Member States show larger changes in RES-H&C shares than have been historically observed. The changes detailed below may be calculation artefacts due to the lack of timely data available on bioenergy consumption in heating and cooling.

**Cyprus:** It is estimated that the energy consumption for heating and cooling increased by 1 % in 2017, while RES-H&C decreased by 1 %. This led to a decrease in the RES-H&C share from 23.0 % in 2016 to 22.6 % in 2017.

**Figure A3.3 Change in RES-H&C shares between 2016 and 2017 compared with historically observed annual changes in RES-H&C shares (2005-2016) in percentage points**




**Notes:** Blue bars show the range of average annual changes in RES-H&C shares between 2005 and 2016, plus or minus one standard deviation. Thin lines represent minimum and maximum year-to-year changes in this period. Diamonds show the change in proxy RES share for 2017 compared with 2016. Green: change between 2016 and 2017 within 1 standard deviation of changes from 2005 to 2016. Yellow: change between 2016 and 2017 within minimum and maximum change from 2005 to 2016. Red: change between 2016 and 2017 larger than changes from 2005 to 2016.

**Source:** EEA.

**Estonia:** It is estimated that the energy consumption for heating and cooling stayed constant in 2017, while RES-H&C decreased by 6 %, mainly due to a decrease in heat derived from renewable sources. This led to a decrease in the RES-H&C share from 51.1 % in 2016 to 48.1 % in 2017.

**Poland:** Renewable energy consumption in the heating and cooling sector is expected to decrease slightly, despite an increase in total energy consumption for heating and cooling. This would lead to a slight decrease in the RES-H&C share from 14.7 % in 2016 to 14.4 % in 2017.

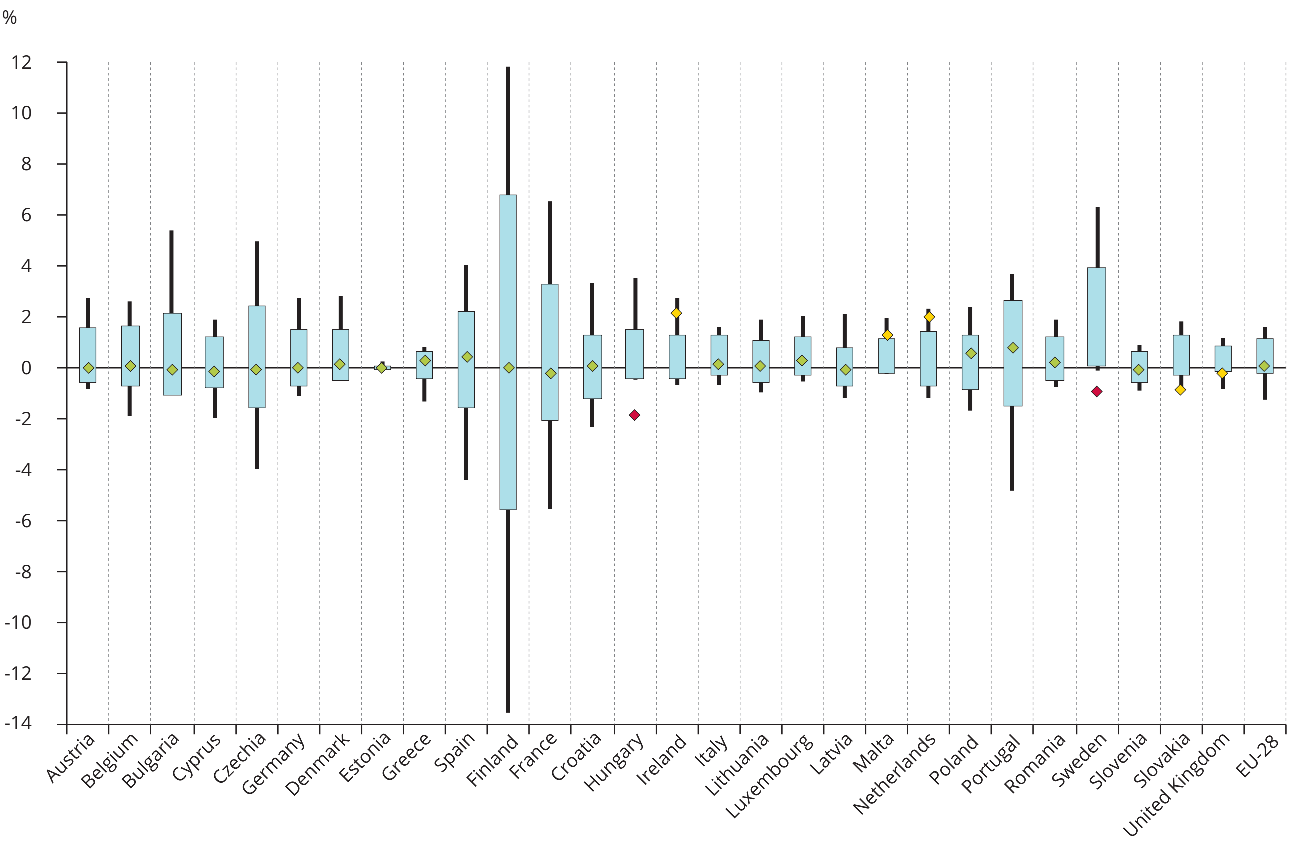
### *Renewable transport fuels*

At the EU level, the RES-T shares proxy for 2017 increased only slightly compared with 2016 (+0.1 %). This small increase is lower by 0.6 standard deviations than the average annual change in RES-T shares over the period from 2005 to 2016 (+0.6 %), and it is only at the threshold of being significantly different at the 5 % level (p = 0.05) because the change between 2010 and 2011 (-1.3 %) showed a decrease in the RES-T share.

The calculated changes in the RES-T shares proxies for 20 Member States are within 1 standard deviation of the average changes for the period 2005-2016. In seven Member States, the change between 2016 and 2017 was significantly different from the 2005-2016 average at the 5 % level (Hungary, Ireland, Malta, Netherlands, Sweden, Slovakia and United Kingdom), as illustrated in Figure A3.4. Of those, two Member States showed changes in RES-T shares that are larger than the historically observed average ±1 standard deviation.

The following two Member States show larger changes in RES-T shares than have been historically observed.

**Figure A3.4** **Changes in RES-T shares between 2016 and 2017, compared with historically observed annual changes in RES-T shares (2005 -2016) in percentage points**




**Notes:** Blue bars show the range of average annual changes in RES-T shares between 2005 and 2016 ±1 standard deviation. Thin lines represent minimum and maximum year-to-year changes in this period. Diamonds show the change in proxy RES share for 2017 compared with 2016. Green: change between 2016 and 2017 within 1 standard deviation of changes from 2005 to 2016. Yellow: change between 2016 and 2017 within minimum and maximum change from 2005 to 2016. Red: change between 2016 and 2017 larger than changes from 2005 to 2016.

**Source:** EEA.

**Hungary:** Consumption of (compliant) biofuels decreased by 32 % leading to a 23 % reduction in the RES-T numerator. Combined with an increasing RES-T denominator (+3 %), this led to a decrease in the RES-T share from 7.4 % in 2016 to 5.6 % in 2017.

**Sweden:** A 6 % decrease in consumption of (compliant) biofuels was only partly compensated for by a 5 % increase in RES-E in rail transport, leading to a 4 % reduction in the RES-T numerator. The RES-T denominator decreased by only 1 %. As a result the RES-T share decreased from 30.3 % in 2016 to 29.4 % in 2017.

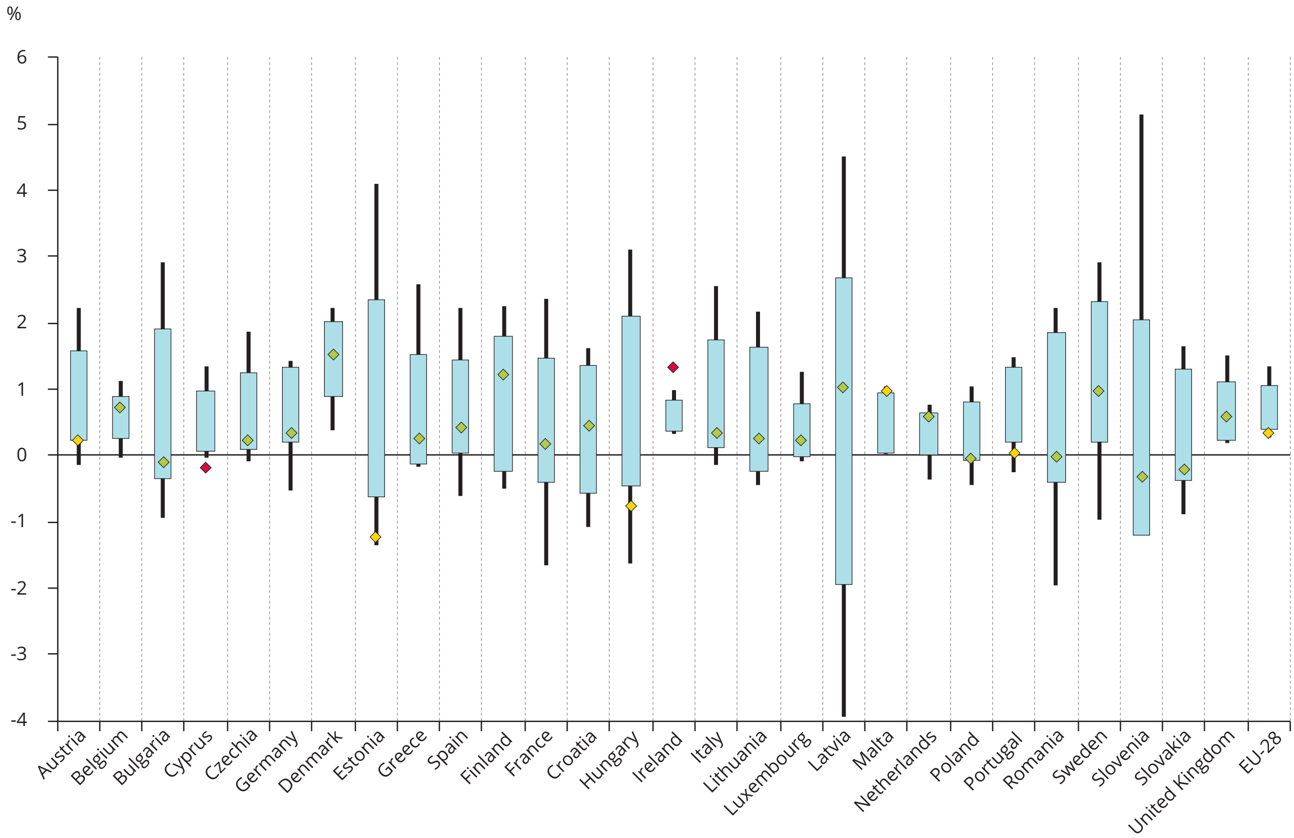
***Total renewable energy sources***

The change in the RES shares proxy for 2017 compared with 2016 (+0.3 %) for the whole EU was lower than the observed average annual change in RES shares in the period from 2005 to 2016 (+0.7 %). This is significantly different at the 5 % level (p = 0.002).

The calculated changes in the RES shares proxies for 20 Member States are within 1 standard deviation of the average changes in the period from 2005 to 2016. In 15 Member States, the change between 2016 and 2017 was significantly different from the 2005-2016 average at the 5 % level (Austria, Bulgaria, Cyprus, Czechia, Germany, Estonia, Hungary, Ireland, Italy, Malta, Netherlands, Poland, Portugal, Romania and Slovakia). Of those, two Member States showed changes in RES shares that are larger than the historically observed average ±1 standard deviation.

In Bulgaria, Cyprus, Estonia, Hungary, Poland, Romania, Slovenia and Slovakia, RES shares even decreased. While for Cyprus this was the first year it had a decreasing RES share, the other countries had already experienced years of decreasing RES shares in the period 2004-2016.

**Figure A3.5 Change in RES shares between 2016 and 2017, compared with historically observed annual changes in RES shares (2005-2016) in percentage points**




**Notes:** Blue bars show the range of average annual changes in RES shares between 2005 and 2016 ±1 standard deviation. Thin lines represent minimum and maximum year-to-year changes in this period. Diamonds show the change in proxy RES share for 2017 compared with 2016. Green: change between 2016 and 2017 within 1 standard deviation of changes from 2005 to 2016. Yellow: change between 2016 and 2017 within minimum and maximum change from 2005 to 2016. Red: change between 2016 and 2017 larger than changes from 2005 to 2016.

In contrast, Ireland's RES share grew more strongly in 2017 than in any year in the period 2004-2016.

However, it should be stressed that the RES proxy calculations have a tendency to underestimate RES shares. One reason is the lack of timely data available on bioenergy consumption in heating and cooling.

***Proxy 2016 versus RES shares 2016***

Table A3.2 provides insights into the difference between approximated 2016 RES shares (calculated in 2017) and actual 2016 RES shares (available for the first time in 2018). For some countries, these differences can be larger, especially when looking at the amount of RES-T. These differences can stem from different methodologies used by countries following the adoption of the ILUC Directive (EU, 2015), as well as from the difficulty of replicating the specific accounting rules in the RED concerning very specific shares of RES-T (see also Section 1.2.2).

At the EU level, approximated RES share was estimated to be 0.1 percentage points lower than the final RES share published by Eurostat. Sectoral RES shares were underestimated in transport by 0.1 percentage points and for heating and cooling by 0.4 percentage points.

**Table A3.2 2016 RES shares by sector compared with approximated RES shares by sector (all %)**

| | RES | | | RES-E | | | RES-T | | | RES-H&C | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Final** | **Proxy** | **Delta** | **Final** | **Proxy** | **Delta** | **Final** | **Proxy** | **Delta** | **Final** | **Proxy** | **Delta** |
| Austria | 33.5 | 34.0 | 0.5 | 72.6 | 72.7 | 0.1 | 10.6 | 11.4 | 0.8 | 33.3 | 34.1 | 0.7 |
| Belgium | 8.7 | 8.9 | 0.2 | 15.8 | 17.1 | 1.3 | 5.9 | 5.8 | -0.1 | 8.1 | 7.9 | -0.2 |
| Bulgaria | 18.8 | 18.0 | -0.8 | 19.2 | 19.6 | 0.3 | 7.3 | 6.5 | -0.7 | 30.0 | 27.7 | -2.3 |
| Cyprus | 9.3 | 8.7 | -0.7 | 8.6 | 8.4 | -0.2 | 2.7 | 2.2 | -0.4 | 23.0 | 21.7 | -1.3 |
| Czechia | 14.9 | 15.4 | 0.5 | 13.6 | 14.1 | 0.5 | 6.4 | 5.8 | -0.6 | 19.9 | 21.0 | 1.1 |
| Germany | 14.8 | 14.7 | -0.2 | 32.2 | 32.0 | -0.2 | 6.9 | 6.9 | 0.0 | 13.0 | 12.9 | -0.1 |
| Denmark | 32.2 | 32.0 | -0.1 | 53.7 | 52.9 | -0.8 | 6.8 | 7.0 | 0.2 | 41.7 | 41.8 | 0.1 |
| Estonia | 28.8 | 27.9 | -0.9 | 15.5 | 13.6 | -1.9 | 0.4 | 0.5 | 0.0 | 51.2 | 50.5 | -0.7 |
| Greece | 15.2 | 15.7 | 0.5 | 23.8 | 23.2 | -0.6 | 1.4 | 2.5 | 1.2 | 24.5 | 24.9 | 0.4 |
| Spain | 17.3 | 17.4 | 0.1 | 36.6 | 36.9 | 0.3 | 5.3 | 5.2 | -0.1 | 16.8 | 17.5 | 0.7 |
| Finland | 38.7 | 39.7 | 1.0 | 32.9 | 33.1 | 0.2 | 8.4 | 20.8 | 12.4 | 53.7 | 53.8 | 0.2 |
| France | 16.0 | 15.6 | -0.4 | 19.2 | 19.1 | -0.1 | 8.9 | 8.9 | 0.0 | 21.1 | 20.2 | -0.8 |
| Croatia | 28.3 | 29.0 | 0.7 | 46.7 | 45.1 | -1.6 | 1.3 | 3.8 | 2.5 | 37.6 | 37.8 | 0.3 |
| Hungary | 14.2 | 14.3 | 0.1 | 7.2 | 7.4 | 0.2 | 7.4 | 6.3 | -1.1 | 20.8 | 21.0 | 0.3 |
| Ireland | 9.5 | 9.2 | -0.3 | 27.2 | 26.4 | -0.7 | 5.0 | 5.9 | 0.8 | 6.8 | 6.4 | -0.4 |
| Italy | 17.4 | 17.2 | -0.2 | 34.0 | 34.3 | 0.3 | 7.2 | 6.1 | -1.2 | 18.9 | 18.3 | -0.6 |
| Lithuania | 25.6 | 26.0 | 0.4 | 16.8 | 17.9 | 1.1 | 3.6 | 3.5 | -0.1 | 46.5 | 47.9 | 1.4 |
| Luxembourg | 5.4 | 5.2 | -0.3 | 6.7 | 6.6 | -0.1 | 5.9 | 7.1 | 1.2 | 7.3 | 6.9 | -0.5 |
| Latvia | 37.2 | 37.8 | 0.7 | 51.3 | 52.7 | 1.4 | 2.8 | 3.8 | 1.1 | 51.9 | 53.1 | 1.2 |
| Malta | 6.0 | 5.9 | -0.2 | 5.6 | 5.7 | 0.1 | 5.4 | 6.5 | 1.0 | 15.3 | 14.1 | -1.2 |
| Netherlands | 6.0 | 5.8 | -0.2 | 12.5 | 12.3 | -0.3 | 4.6 | 4.5 | -0.1 | 5.5 | 5.2 | -0.2 |
| Poland | 11.3 | 11.5 | 0.3 | 13.4 | 14.9 | 1.5 | 3.9 | 5.4 | 1.4 | 14.7 | 14.0 | -0.7 |
| Portugal | 28.5 | 27.9 | -0.6 | 54.1 | 52.1 | -2.0 | 7.5 | 6.2 | -1.3 | 35.1 | 34.2 | -0.9 |
| Romania | 25.0 | 24.4 | -0.6 | 42.7 | 40.4 | -2.3 | 6.2 | 5.5 | -0.6 | 26.9 | 26.2 | -0.7 |
| Sweden | 53.8 | 54.2 | 0.4 | 64.9 | 64.7 | -0.2 | 30.3 | 26.6 | -3.7 | 68.6 | 68.9 | 0.3 |
| Slovenia | 21.3 | 21.7 | 0.4 | 32.1 | 33.0 | 0.9 | 1.6 | 2.1 | 0.5 | 34.0 | 34.7 | 0.7 |
| Slovakia | 12.0 | 12.8 | 0.8 | 22.5 | 22.6 | 0.1 | 7.5 | 8.2 | 0.7 | 9.9 | 10.9 | 1.0 |
| United Kingdom | 9.3 | 8.9 | -0.4 | 24.6 | 24.6 | 0.0 | 4.9 | 4.5 | -0.5 | 7.0 | 6.2 | -0.9 |
| **European Union** | **17.0** | **16.9** | **-0.1** | **29.6** | **29.6** | **0.0** | **7.13** | **7.08** | **-0.1** | **19.1** | **18.7** | **-0.4** |

**Sources:** EEA; Eurostat, 2018b.

Deviations in RES shares are less than 1 percentage point for all Member States. At sectoral level, deviations are larger than 1 percentage point in eight Member States for RES-E shares, in 11 Member States for RES-T shares and in six Member States for RES-H&C shares. Short-term proxy estimates are most difficult in the heating and cooling sector. This is mainly the result of two effects: (1) on the one hand, bioenergy is the predominant renewable energy source in this sector but useful data sources are unavailable there; (2) on the other hand, gross final energy consumption in the heating and cooling sector is hard to estimate due to the strong influence of climatic conditions.

For some Member States, the deviation between proxy and final data for 2016 is considerable. The largest deviations occurred for Finland and Sweden in the transport sector. For Finland the 68 % drop in compliant biofuels in Eurostat SHARES from 2015 to 2016 was not present in the data source used for calculation, leading to a strong overestimate of the RES-T share by 12.4 percentage points. In the case of Sweden, the underestimate of 3.7 percentage points is mainly due to different accounting rules: while all compliant biofuels increased in final SHARES data by 25 % (proxy estimate: 24 %), Annex IX biofuels, which are double counted, increased by 79 %. The RES proxy calculation does not differentiate between them, and therefore the same change as for all compliant biofuels, 24 %, was applied to Annex IX biofuels.

In general, the approximated 2016 RES proxy shares underestimated rather than overestimated actual RES shares in 2016.

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