Renewable energy in Europe – 2017 Update

Recent growth and knock-on effects

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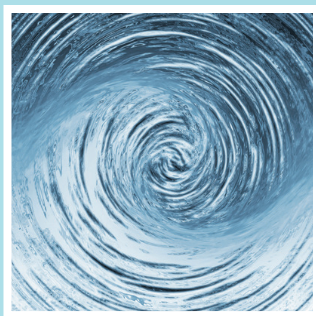

European Environment Agency

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Executive summary

This report outlines the progress renewable energy sources (RES) made in 2015 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 regarding developments at all of these levels in 2016.

The report confirms that the EU remains on track to reach its 20 % RES share target for 2020, despite RES growth across the EU having recently slowed. It also highlights that the additional consumption of RES across Europe since 2005 has had a number of co-benefits thereby allowing 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 remained at 2005 levels. It also helped the EU and its Member States reduce primary energy consumption.

The report also shows that EU is progressing slightly better overall, in terms of RES deployment, than other parts of the world. Today, the EU is a global leader in terms of renewable power capacity per capita; between 2005 and 2015, the speed at which the EU has transformed the energy resource base supporting its economic activity has outpaced that of other world regions. Moreover, European developments have significantly contributed to the initial development and roll-out of renewable energy technologies.

Within these selected perspectives, this report complements the EEA's recent assessment in its report, *Trends and Projections in Europe 2017 — Tracking progress towards Europe's climate and energy targets* (EEA, 2017a).

Key findings — EU and its Member States

Today, RES are a major contributor to the energy transition in Europe. The speed at which renewables have grown since 2005 took many market actors by surprise, especially within the power sector. In fact, the rapid development of some renewable energy technologies and consequent cost reductions have already led to RES technologies achieving high market shares. Today, for solar photovoltaic electricity, as well as biogas electricity and solid biomass use for heating and cooling, these shares are at, or close to the levels anticipated to be reached by 2020 in the National Renewable Energy Action Plans drafted by countries in 2010.

In 2016, renewable energy accounted for the overwhelming majority (86 %) of new EU electricity-generating capacity for the ninth consecutive year. 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 in transport.

The EU remains on track to reach its 20 % RES share target for 2020, but the pace of RES growth is slowing down

The EU is currently on track to meet its renewable energy target for 2020. The EU-wide share of renewable energy in final EU energy use increased from 16.1 % in 2014 to 16.7 % in 2015 and to an expected 16.9 % in 2016, according to the EEA's early estimates. This gradual increase has occurred despite an uptick in energy consumption from all sources, observed over the past two years across the EU (EEA, 2017a). Steady RES progress indicates the EU has met its indicative trajectory for 2015-2016, as set out in the Renewable Energy Directive (RED), and the expected trajectory path for both years resulting from the National Renewable Energy Action Plans (NREAPs) adopted by countries. However, the average yearly growth of the RES share slowed down in 2015 (to 6.4 %) and 2016 (to 5.9 %) compared with the average annual pace of growth recorded between 2005 and 2014 (6.7 %).

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, the Netherlands and the United Kingdom.

- In absolute terms, **renewable 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 (18.6 % in both 2015 and 2016, according to reported data and early EEA estimates). The sector grew by 4 % each year, on average, over the period 2005-2015 — a growth rate that must be maintained in order to realise NREAP expectations for 2020. In 18 Member States, renewable heating and cooling represented over half of the national gross final consumption of renewables in 2015 (Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Greece, Hungary, Italy, Latvia, Lithuania, the Netherlands, Poland, Romania, Slovenia and Sweden). 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. It grew at the second highest rate of 7 % per year, on average, between 2005 and 2015. This was driven especially by growth in onshore and offshore wind power and solar photovoltaic (PV) electricity generation, but also by other RES, such as an increase in solid biomass combustion for electricity purposes. About 29 % of all electricity consumed in the EU in 2015, and an estimated 30 % in 2016, originated from renewable sources. Efforts to date will need to be maintained to realise the NREAP expectations for renewable electricity by 2020 (an annual 5 % growth rate is necessary). In only four countries, however, did the share of renewable electricity represent over half of all gross final consumption of renewables in 2015 (Ireland, Portugal, Spain and the United Kingdom).

- In the **EU transport sector**, renewable energy made up around 7 % of all energy use in both 2015 and 2016, 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. Transport biofuels grew fastest over the period 2005-2015 (at 16 % 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, requiring a compound annual growth rate of 17 % to reach the NREAP targets for 2020. 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 share of renewable energy in transport varied across countries, from a maximum of 43 % of all RES consumption (Luxembourg) to close to 0 % (Estonia and Spain).

RES progress since 2005 allowed the EU to cut its fossil fuels use and the associated GHG emissions by about a tenth in 2015

In 2017, most climate mitigation policies and measures reported by the Member States under EU reporting requirements (the Monitoring Mechanism Regulation (MMR)) were aimed at the energy consumption (29 %), transport (21 %) and energy supply (15 %) sectors. The objective of such policies and measures was often to increase the RES share (EEA 2018, forthcoming). Progress towards national and EU RES targets since 2005 has allowed renewables to effectively substitute fossil fuels and reduce GHG emissions across Europe. The additional consumption of renewable energy, compared with 2005 levels, allowed the EU to cut its demand for fossil fuels by 135 million tonnes of oil equivalent (Mtoe) in 2015 (see Figure ES.1). This is equivalent to one tenth of the EU's gross inland consumption of fossil fuels and more than the fossil fuel consumption of Italy.

Coal was the most substituted fuel across Europe (representing 44 % of all avoided fossil fuels), followed by natural gas (roughly 30 % of all avoided fossil fuels). The reduction in petroleum products and related fuels was less pronounced because of the lesser share of RES use in the transport sector. In 2016, the amount of substituted fossil fuels is estimated to have increased by 10 Mtoe (to 145 Mtoe).

The growth in the consumption of renewable energy after 2005 helped the EU achieve an estimated gross reduction in CO_2 emissions of 9 % in 2015, compared with a counterfactual scenario in which RES consumption stayed at 2005 level. In 2016, the effect on CO_2 emissions increased further, resulting in a gross emission reduction of 483 $MtCO_2$ (an 11 % gross reduction in the EU), which represents more than the annual GHG emissions of Italy. Most of these changes took place in energy-intensive industrial sectors under the EU Emissions Trading Scheme (ETS), as the increase in renewable electricity decreased the 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 reduction in domestic fossil fuel use and avoided GHG emissions in Germany, Italy and the United Kingdom in both 2015 and 2016. In relative terms, however, the Nordic countries (Denmark, Finland and Sweden) remained the top three countries in the EU in 2015 in terms of their overall effectiveness in substituting fossil fuels and reducing GHGs by increasing their RES deployment.

Increasing the RES share since 2005 resulted in a 2 % reduction of EU primary energy consumption in 2015

Whereas the Renewable Energy Directive (RED) sets binding targets for 2020 for the share of renewable energy in gross final energy consumption, the Energy Efficiency Directive puts forward targets expressed in primary energy. Understanding the interactions between different RES technologies and their impacts on primary energy use, from a statistical point of view, is useful to policy-makers.

By 2015, the increase in the RES share since 2005 had resulted in a 2 % EU-wide reduction in **primary energy** consumption, according to accounting rules in use in European energy statistics. Some RES technologies have led to a relatively large statistical decrease in primary energy consumption (especially wind power and solar PV in the renewable electricity market sector). This is because these RES technologies are deemed to have a 100 % conversion efficiency, while generating electricity from fossil fuels requires greater amounts of primary energy. Other RES technologies have led to a statistical increase in primary energy consumption (especially solid biomass use for heating and cooling, but also geothermal energy), which may have dampened national efforts to reduce domestic primary energy consumption.

Key findings — RES in a global perspective

More than half of all new power capacity installed worldwide in 2015 and 2016 was of renewable origin

Global investments in renewables have shown steady growth for more than a decade. This has led to a doubling of global renewable electricity capacity between 2005 and 2015. By 2016, for the second year in a row, more than half of all newly installed power capacity worldwide was of renewable origin, as RES accounted for an estimated 62 % of added net power generation capacity in that year (IRENA, 2017a; Frankfurt School-UNEP, 2017). In 2016, the EU still ranked second after China as regards total installed and grid-connected domestic renewable electricity capacity.

Seen by technology and market sector, global RES development in 2016 was dominated by high investment in solar and wind energy for electricity generation. Together, these technologies accounted for over 90 % of total global RES investments (Frankfurt School-UNEP, 2017). At the other extreme, 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 with delays while they overcome technical and financial obstacles.

The EU is a clear leader in renewable electricity capacity per capita and per GDP unit and performed well over the period 2005-2016, but fast activity is becoming visible outside Europe

With an average renewable electricity capacity of 0.83 kilowatt (kW) installed per person in 2016, the EU is the clear world leader on a per capita basis, ahead of the USA, Brazil and China. In addition, in 2016, Europe still had the largest solar PV and wind capacities in place globally. However, China has quadrupled its installed capacities since 2005 and is poised to overtake the EU as world leader in annual solar PV and wind power capacity additions in the near future, as the country strives to become a global leader in innovation, science and clean technology by 2050.

Over the period 2005-2016, the renewable electricity capacity installed per gross domestic product (GDP) unit in the EU grew at an average annual pace of 7 %, which is faster than the pace of growth in other world regions. This suggests the EU has outpaced other world regions during this period in terms of transforming the energy resource base of its economic activities. Growth in renewable electricity capacity installed per unit GDP in the EU has been particularly notable since 2009 (see Figure 4.3). This coincides with the adoption in 2009 of the EU climate and energy package.

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 35 % in 2012 (and 25 % in 2016), these high annual shares highlight Europe's pioneering role in developing renewable energy globally. Since 2013, however, China claims the highest annual shares of global new investments in renewable power capacity, reflecting the fact that global investment activity is spreading to more attractive, non-European markets.

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 one of the key global players in terms of employment in the renewable energy sector. In 2016, it came fourth, after Brazil, Japan and the United States, in terms of the share of renewable energy jobs per capita in the labour force. Within the EU, Germany was the number one employer per capita in the labour force, second only to Brazil.

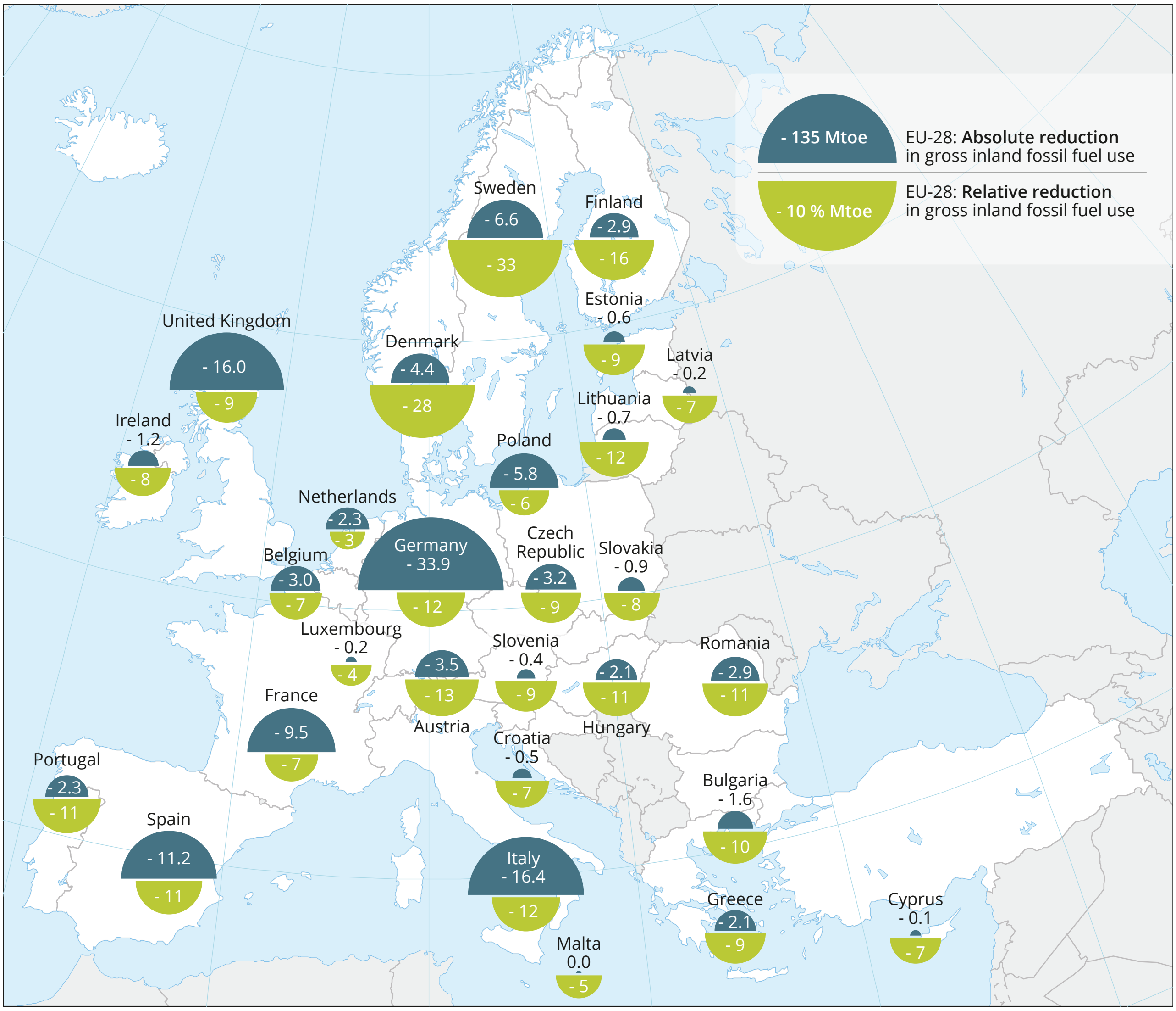
The largest employers in the EU renewables sector are the wind, solar PV and solid biomass industries. Over the past five years, job losses were experienced in the solar PV industry and in the wind power sector, as competition from other producing markets, including in China, continued to grow.

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

As the EU strives to become a sustainable, low-carbon economy by 2050, developing its global competitiveness in knowledge-intensive renewable energy is essential. Currently, Member States need to overcome a number of important challenges. In the short term, these range from formulating adequate policy responses that will meet national climate and energy targets, to agreeing on a functional EU system for the monitoring and adjusting of efforts, and for cooperation. In the medium term, Member States need to improve their national innovation capabilities as a way to increase benefits from the ongoing energy transition in Europe. In the context of 150 non-EU countries having set national RES targets intended to reduce GHG emissions — most of which have also adopted policies to catalyse national RES investments (IRENA, 2017b) — the EU and its Member States need to step up their efforts and remain leaders in low-carbon energy transitions.

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 knowledge-intensive, growing sectors. Together with the EU 2030 targets for energy and climate, the more systematic cooperation and coordination of national policies and measures between Member States — outlined by the European Commission in its legislative proposals of November 2016 — could represent a step in the right direction.

Figure ES.1 Total and relative reduction in gross inland fossil fuel use (per year, in 2015)



Notes: Absolute reduction in gross inland fossil fuel use (Mtoe) due to the increase in renewable energy use per country since 2005.
Relative reduction in gross inland fossil fuel use per country (expressed as absolute reductions over total gross inland consumption of fossil fuels).

Source: EEA, Eurostat, 2017b, 2017c.

1 Introduction

In the context of global efforts to mitigate climate change, the European Union (EU) set itself the objective of becoming a greener, resource-efficient and more competitive low-carbon economy and society by 2050. A keystone for achieving this goal is completing the transformation of the national energy sectors into a stronger, decarbonised, coordinated and resilient Energy Union that provides secure, sustainable, competitive and affordable energy for all (see Box 1.1). A significant challenge for the next 30 years is to enable rapid growth in renewable energy and energy efficiency solutions and to substitute carbon-intensive fossil fuels, and in this way to strengthen Europe's competitiveness.

Clean energy technologies have progressed remarkably within the current decade, as illustrated by the growth in renewable energy sources (RES) in Europe and elsewhere (see Chapters 2 and 3 of this report). Although carbon-intensive infrastructures are still predominant in many EU Member States (EEA, 2016a), a structural shift is under way across the EU, pushing renewables into the mainstream, from technological learning to industrial production, from subsidised to competitive and from small to larger scale, fostering their adoption by an early majority.

The European Commission assesses every two years the EU and Member States' progress in their promotion and use of RES, in line with legal requirements under the Renewable Energy Directive (RED, 2009/28/EC) (EU, 2009). The most recent Communication on this topic was adopted in February 2017 (EC, 2017a). It presents mainly historical RES developments up to 2014 (using data from Eurostat) and early RES estimates for 2015 (using methodology and data developed and provided by the European Environment Agency (EEA) and the European Topic Centre on Air Pollution and Climate Change Mitigation

Box 1.1 EU renewable energy policies for 2020 and 2030

A combination of targets and objectives on greenhouse gas (GHG) emissions reduction, energy savings and renewable energy consumption has been set for the EU as a whole, for 2020 and 2030. Together, they trace a pathway for the transition to a more sustainable, low-carbon European society.

The 20 % EU RES target for 2020 is split into binding national targets, 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 Renewable Energy Directive (RED; 2009/28/EC) 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 EU's binding renewable energy target is to achieve a share of at least 27 % of renewable energy in its gross final energy consumption. The European Commission's winter package of measures, of November 2016, includes a recast of the RED that reconfirms this minimum EU binding RES target. It includes measures to promote the better integration of electricity from renewable sources into the market and it updates the sustainability policy for bioenergy. In addition, the proposed Energy Union Governance Framework requires Member States to prepare integrated national climate and energy plans that set out individual national RES contributions post 2020, with a view to reaching the minimum 27 % EU RES target (EC, 2016b).

(ETC/ACM) (see EEA, 2016b)). Since 2015, monitoring of progress towards the EU's climate and energy objectives, including progress towards the RES targets, has been assessed under the European Commission's State of the Energy Union initiative (EC, 2015, 2017b).

The current report aims to support the work of the European Commission, the Member States and various stakeholders by providing a detailed overview of annual RES growth, broken down by country, technology and energy market sector.

1.1 About this report

This EEA report provides a detailed, annual assessment of changes in RES in Europe since 2005, at the level of individual technologies and countries. It also illustrates some of the indirect 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. Last but not least, it outlines key global developments to put Europe's renewable energy progress in perspective.

The assessment uses Eurostat data for the period 2005-2015, complemented by early EEA estimates regarding GHG emissions and energy developments in 2016.

1.1.1 Report structure

This report is divided into four parts. Chapter 1 sets the overall context; Chapter 2 gives an account of key RES developments at the EU level and in individual Member States; Chapter 3 highlights certain co-benefits arising from the increase in RES consumption since 2005; and Chapter 4 outlines selected global RES developments to put the EU's progress in its uptake of RES into context.

1.1.2 Scope of the report

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 electricity from renewable sources (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.

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

The EEA 2016 RES shares are, ultimately, estimated values. The cut-off date for most data sources incorporated in the calculation of approximated RES shares was 31 July 2017. Although the 2016 RES shares proxies formed the basis of a specific EEA country consultation in September 2017 ([1]), these values are not a substitute for data that countries officially report to Eurostat. During that country consultation, Germany and the United Kingdom submitted preliminary national data on an aggregate level, which were not sufficiently detailed to distinguish all of the specific RES technologies assessed within this report. These values are presented in footnotes throughout the report chapters when applicable. Official RES share data for 2016 were not available in time for this assessment — they will be published by Eurostat in 2018.

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 because the available data are more limited in this sector. Finally, the specific accounting rules in the RED concerning renewables consumed in transport are difficult to replicate. Despite these challenges, the estimation of RES share proxies yields plausible results in most cases and should be further improved, especially if 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 2016. The term 'gross avoided GHG emissions' illustrates the theoretical character of the GHG effects estimated

([1]) 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 2017, after the Eionet consultation.

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 ([2]). 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 most comprehensive information identified is from the Global trends in renewable energy investment annual report (Frankfurt School-UNEP, 2017). The period covered is 2005-2016 and the focus is on new renewable energy investments per region. Investment figures were originally supplied in nominal billions of US dollars. Full comparability across regions and time remains limited, as nominal values include inflation ([3]). For the purpose of this report, figures in US dollars have been converted to euros using the Eurostat data set on exchange rates (Eurostat, 2017a).

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 (2016), by available region and technology, can be shown. Direct and indirect jobs related to renewable energy per region for 2016 are presented below and stem from the International Renewable Energy Agency (IRENA, 2017c).

Other observations

For offshore wind, 2005-2016 data are calculated based on capacities reported by EurObserv'ER and based on an assumption of 4000 full load hours of operation. The offshore wind production is then subtracted from the total wind production reported by Eurostat (Eurostat, 2017b, 2017c) 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 NREAP table 10, where there is a 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 include also biogas and other liquid biofuels used in transport. Similarly, in the context of renewable electricity generation the term 'solid biomass' is understood to include also renewable municipal waste.

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]) 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.

([3]) 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.

2 RES developments in Europe

- The EU share of renewable energy increased from 16.1 % in 2014 to 16.7 % in 2015.
- Approximated RES share calculated by the EEA and the ETC/ACM indicate that the RES share in the EU continued to grow in 2016 and reached an estimated 16.9 % ([4]).
- Therefore, in both 2015 and 2016, the EU was on track, exceeding its biennial indicative trajectory under the RED (13.8 %).

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2.1 Actual and approximated recent progress

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

The Renewable Energy Directive (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. Having achieved a RES share of 16.7 % in 2015 and an estimated share of 16.9 % in 2016, 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' National Renewable Energy Action Plans (NREAPs), of 15.3 % and 16.1 %, respectively.

The RES share increased annually by 6.7 %, on average, between 2005 and 2014, with the pace of growth decreasing slowly in 2015 (to 6.4 %) and 2016 (to 5.9 %) compared with the average pace of growth recorded between 2005 and 2014. It is worth noting that gross final energy consumption decreased, on average, by 0.9 % per year between 2005 and 2015, (including by 1.4 % per year from 2010 to 2015). As shown elsewhere, the EU was on track to achieve its target share of a 20 % gross final renewable energy consumption by 2020 (EEA, 2017a).

Figure 2.1 shows the actual RES shares in the EU Member States and for the EU for 2005 and 2015, and the approximated RES shares for 2016. The RES shares vary widely among countries. In 2015, the highest shares of renewable energy were attained by Sweden (53.9 %), Finland (39.3 %) and Latvia (37.6 %). Luxembourg (5.0 %), Malta (5.0 %) and the Netherlands (5.8 %) 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.

([4]) 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.

Box 2.1 Progress of Member States towards 2015 RED and NREAP trajectories

In 2015, all Member States except France, Luxembourg and the Netherlands reported higher shares of renewables in their gross final consumption of energy than the minimum shares indicated in the RED for 2015-2016 (figure below). Concerning progress towards their own estimated renewable energy trajectories under the NREAPs, 20 Member States (all except France, Ireland, Luxembourg, Malta, the Netherlands, Poland, Portugal and Spain) reach or exceed their anticipated NREAP trajectories. However, in terms of national progress at the levels of RES market sectors only three Member States (Austria, Finland and Sweden) are at or above the anticipated NREAP consumption levels for renewables in all three sectors in 2015. Nineteen Member States reach or exceed their anticipated NREAP levels for gross final consumption of renewable energy in heating and cooling (all except Belgium, Cyprus, Greece, France, Ireland, Latvia, Portugal, Slovakia and the United Kingdom). Twelve Member States reach or exceed their NREAP levels for gross final consumption of renewable electricity (Austria, Belgium, Bulgaria, the Czech Republic, Germany, Denmark, Estonia, Finland, Croatia, Italy, Poland and Sweden). Five Member States are at or above their NREAP levels regarding the consumption of renewable energy sources in the transport sector (Austria, Finland, Luxembourg, Sweden and Slovakia).

A

- 2015 RES share compared with 2015 RED trajectory

  A black dot within the red-shaded columns indicates that the proportion between the actual RES share in a country in 2015 and the indicative level for that RES share in accordance with the RED is below 1 %

- National final RES consumption in proportion to EU final RES consumption in 2015 (circle size indicates the percentage in total EU-28 RES share)

B

Importance of national RES market sectors, as proportion to total national RES consumption in 2015

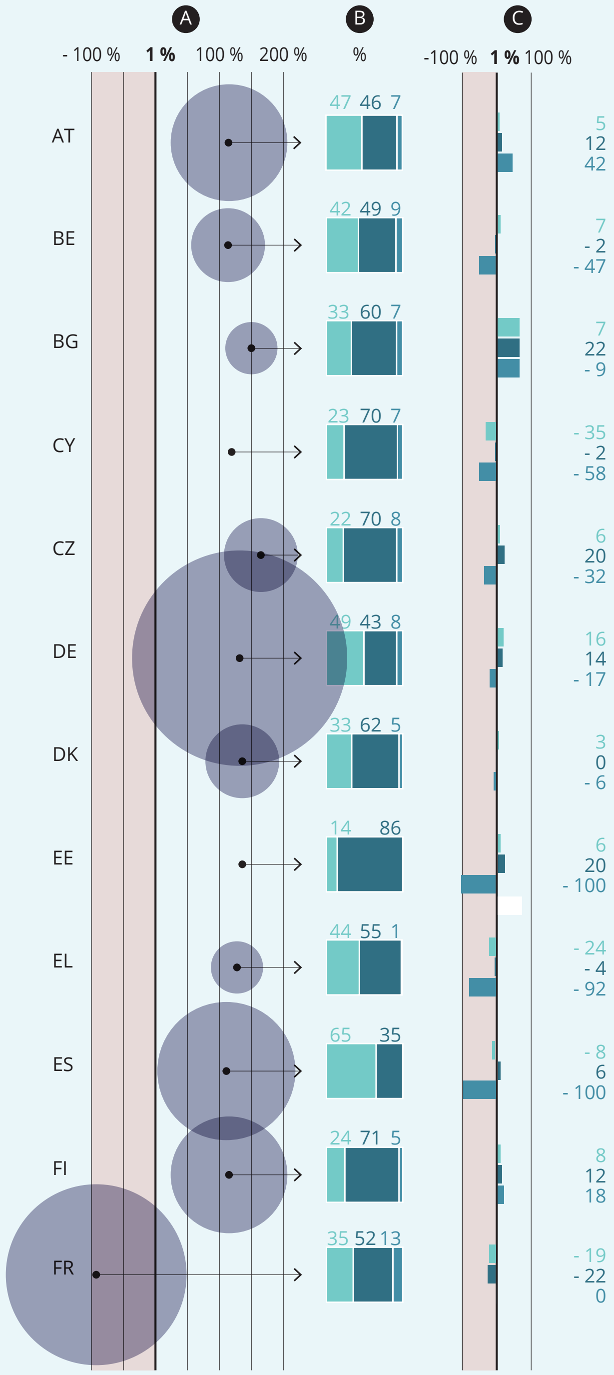
- Renewable electricity (RES-E)
- Renewable heating and cooling (RES-H&C)
- Biofuels in transport

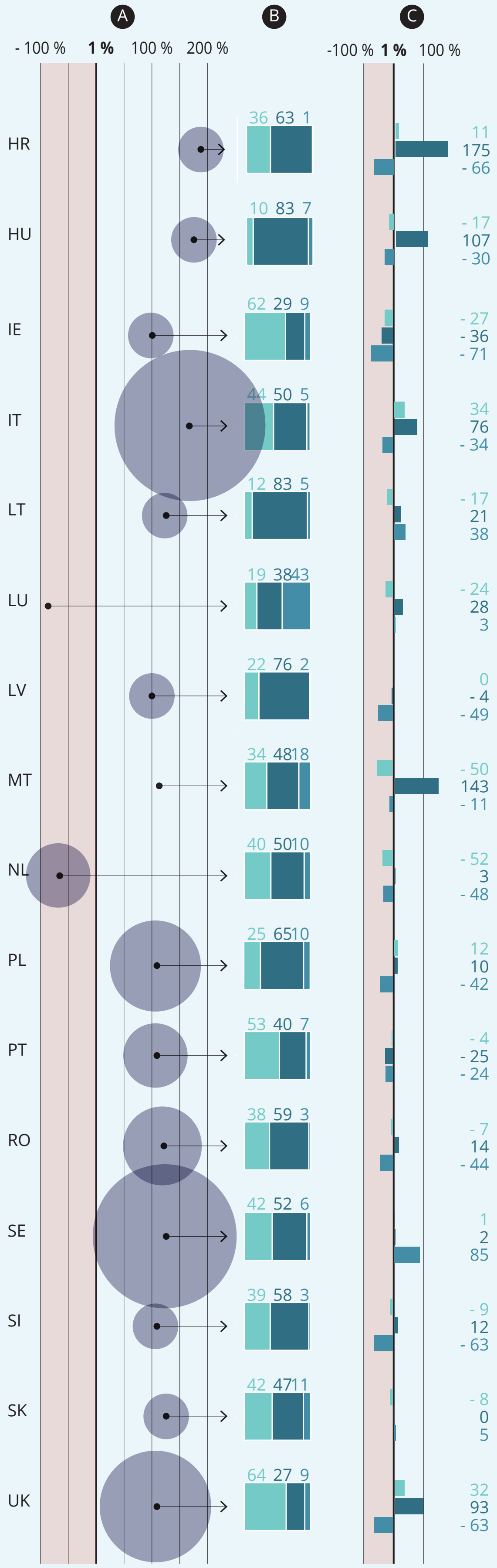
C

Final national consumption in RES market sectors compared with expected 2015 NREAP levels in these sectors

- RES-E
- RES-H&C
- Biofuels in transport

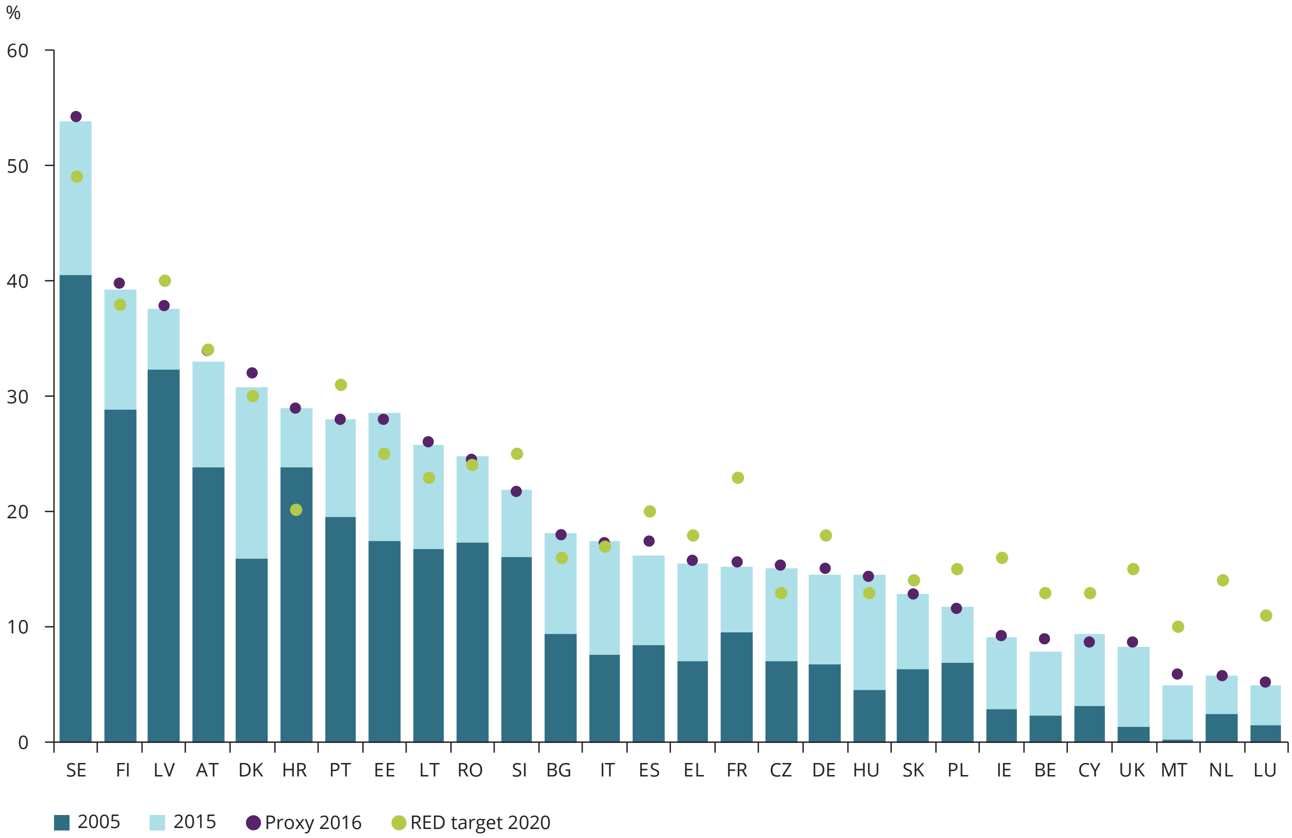
A bar within the red-shaded column indicates that the proportion between gross final consumption of renewable energy at sectoral level in 2015, and the anticipated absolute level of RES consumption in that sector according to the NREAPs is less than 1 %





Source: EEA; RED (2009/28/EC); Eurostat, 2017b, NREAP reports.

Figure 2.1 Actual and approximated RES shares in the EU-28



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 2015.

Sources: EEA, 2017a; Eurostat, 2017b; RED (2009/28/EC).

2.2 RES contributions 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 renewable electricity, renewable heating and cooling, and renewable energy consumption in the transport sector. The expected paths in the NREAPs are, on the whole, more ambitious than the indicative RED trajectories.

This section shows the progress achieved by RES within the specific energy market sectors — electricity, heating and cooling, and transport — and makes comparisons with the expected evolution in these market sectors in the NREAPs.

The expected (NREAP) trajectories of individual technologies enable progress to be monitored, but they become increasingly outdated as conditions and policies change ([5]). In fact, as a result 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 be reached by 2020 in the NREAPs.

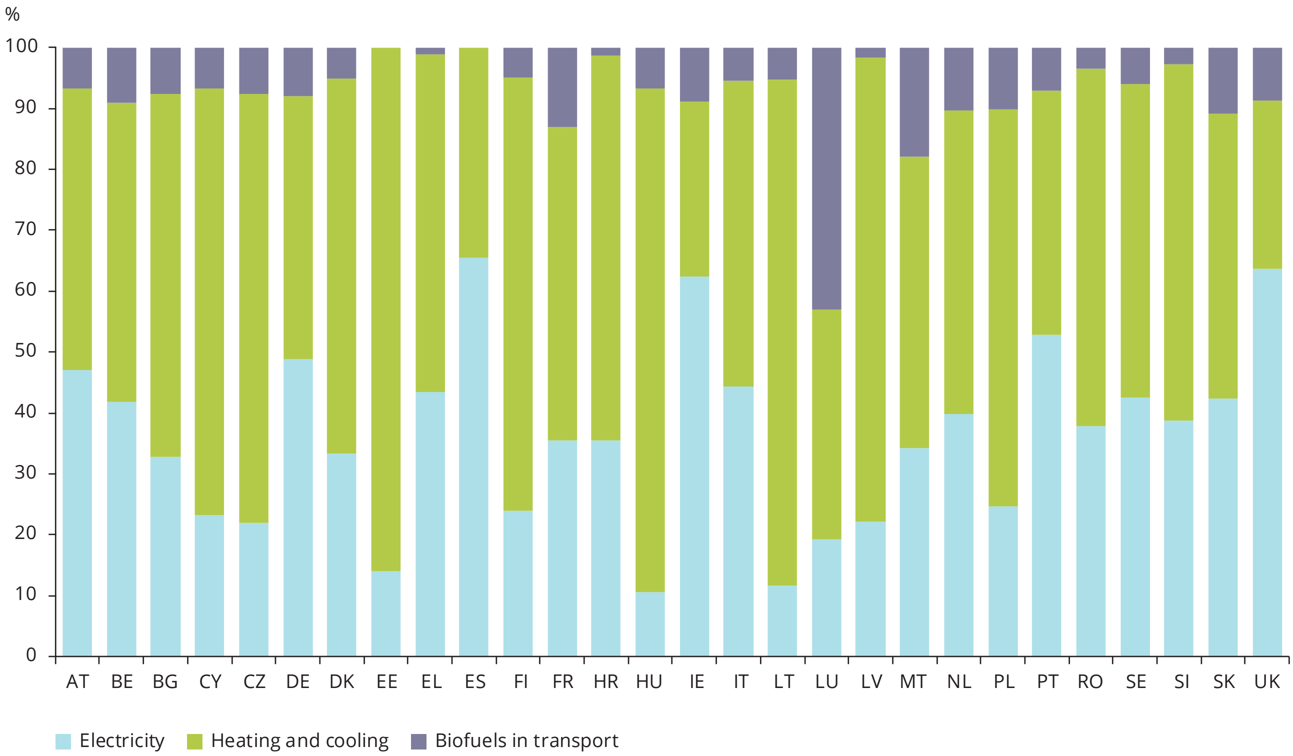
2.2.1 Breakdown of RES share by energy market sectors

At the country level, the significance of each energy market sector, and the role renewable energy plays therein, differs considerably. Figure 2.2 illustrates these differences by showing the relative weight of gross final renewable energy consumption in each national market sector. In 2015:

- **Renewable heating and cooling** represented more than half of all gross final consumption of

([5]) Some countries have updated their NREAPs since 2010. The most recent versions were used for this report. Austria, Bulgaria, Czech Republic, Denmark, Estonia, Ireland, Malta, 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.

Figure 2.2 **Shares in 2015 RES consumption of renewable electricity, renewable heating and cooling, and biofuels in transport**



Notes: This figure shows how actual final renewable energy consumption in 2015 is distributed over renewable electricity, renewable heating and cooling, and biofuels in transport. Wind power and hydropower are normalised [6]. The consumption of RES accounts for only biofuels complying with the RED sustainability criteria.

Source: Compiled from data from Eurostat, 2017b.

renewables in 18 Member States (Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Greece, Hungary, Italy, Latvia, Lithuania, the Netherlands, Poland, Romania, Slovenia and Sweden).

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

- The contribution of **renewable transport fuels** varied from a maximum of 43 % of all RES consumption (Luxembourg) to 0 % (Spain). In 2015, Spain had not implemented the legal framework for certification, but a royal decree has been passed to enforce compliance with the sustainability criteria laid down in the RED (EurObserv'ER, 2015a)

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.

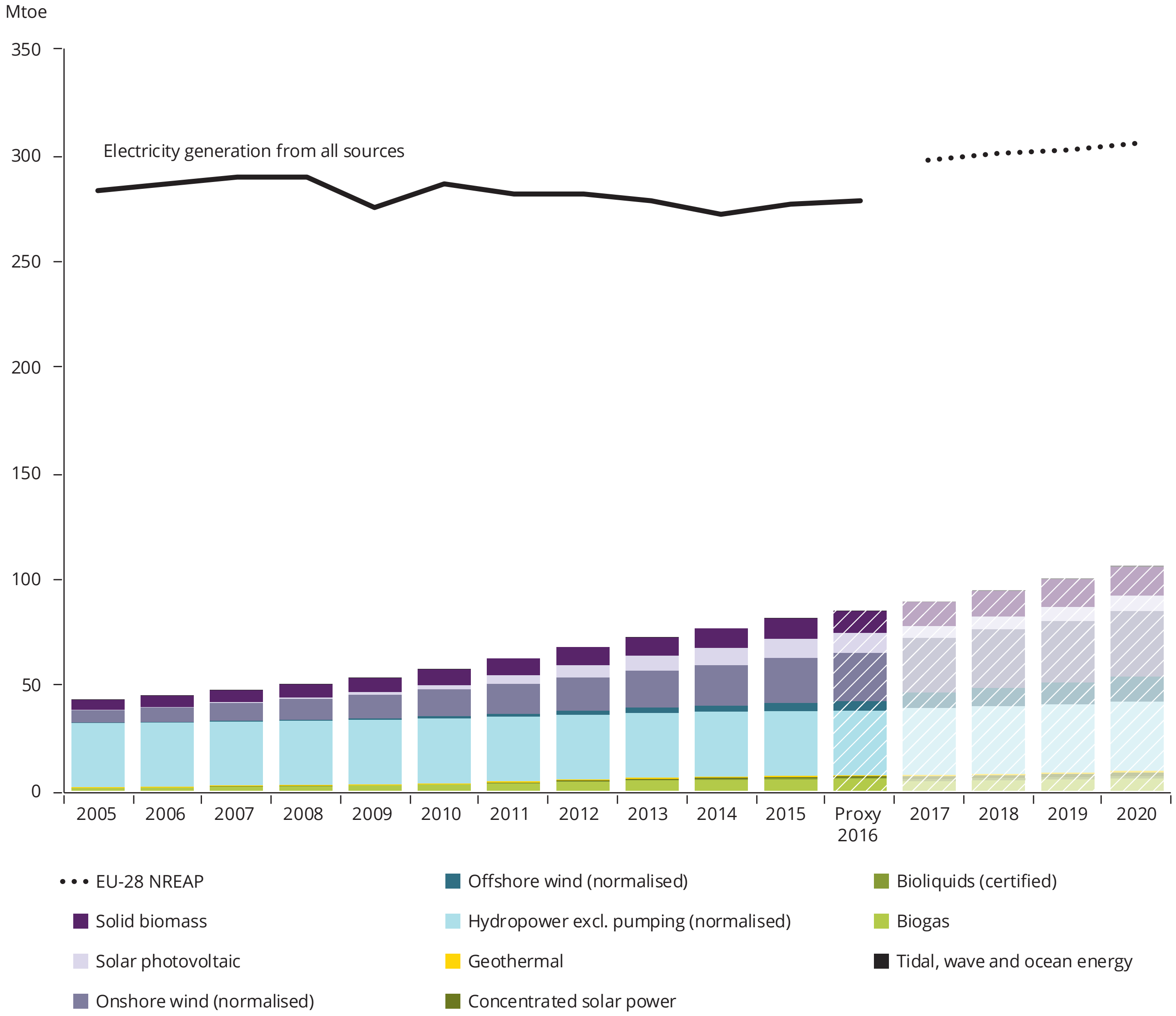
2.2.2 Renewable electricity

In 2015, the EU-wide share of electricity from renewable sources (RES-E) amounted to 28.8 %. Figure 2.3 and Table 2.1 show the consumption of RES-E up to 2015, approximated estimates for 2016 and the expected developments based on the NREAPs.

(6) 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). For details of the normalisation rule, please see the SHARES manual provided by Eurostat (2015b).

- The gross final energy consumption (GFEC) of RES-E increased to 79.7 Mtoe in 2015. This was 4.8 Mtoe higher than in 2014.
- In 2015, the largest contributions came from hydropower (30.1 Mtoe, or 38 % of all RES-E), onshore wind ([7]) (20.7 Mtoe, or 26 % of all RES-E), solid biomass (9.6 Mtoe, or 12 % of all RES-E) and solar photovoltaic (PV) systems (8.8 Mtoe, or 11 % of all RES-E). All the other technologies made smaller contributions, ranging from 0.1 % to 7 % (biogas).
- Over the period 2005-2015, the compound annual growth rate of RES-E consumption was 7 %. To achieve the expectations for 2020 in the NREAPs, a growth rate of 5 % per year will be required over

Figure 2.3 RES-E in the EU-28



Notes: This figure shows the actual final RES-E consumption for 2005-2015, approximated estimates for 2016 and the expected realisations in the energy efficiency scenario of the NREAPs for 2017-2020. Wind power and hydropower are normalised. The consumption of RES accounts for only biofuels complying with the RED sustainability criteria.

Sources: EEA; Eurostat 2017b; NREAP reports.

([7]) 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.

the period 2015-2020. The compound annual growth rate was highest for solar PV systems (53 %), offshore wind (30 %), biogas (17 %) and onshore wind (14 %). Hydropower had the lowest growth rate (0 %).

According to proxy estimates, RES-E generation increased in 2016 to 83.2 Mtoe, while total electricity generation from all sources increased to 278 Mtoe, resulting in a RES-E share of 29.9 % ([8]). Most of the increase in RES-E generation in 2016 was due to the greater contribution of wind energy (+ 2.1 Mtoe), energy from solid biomass (+ 0.7 Mtoe) and solar energy (+ 0.5 Mtoe). In 2016, electricity consumption in Europe increased in the second consecutive year following the decrease in 2014.

Table 2.1 RES-E in the EU-28, by RES technology

	Final energy (ktoe)					Annual growth rate (%)		
Technology	**2005**	**2014**	**2015**	**Proxy 2016 ([9])**	**NREAP 2020**	**2005-2015**	**2014-2015**	**2015-2020**
Hydropower excluding pumping (normalised)	29 588	29 975	30 053	29 881	31 786	0	0	1
Onshore wind (normalised)	5 670	18 884	20 708	22 337	30 303	14	10	8
Solid biomass ([a])	4 756	8 983	9 583	10 310	13 460	7	7	7
Solar PV systems	126	7 938	8 799	9 279	7 062	53	11	- 4
Biogas	1 104	4 985	5 249	5 526	5 493	17	5	1
Offshore wind (normalised)	273	2 750	3 784	4 267	11 740	30	38	25
Geothermal energy	464	535	561	573	943	2	5	11
Concentrated solar power	0	469	481	481	1 633	n.a.	3	28
Bioliquids (certified)	0	406	467	467	1 096	n.a.	15	19
Tidal, wave and ocean energy	41	42	42	42	559	0	1	68
Total RES-E (normalised, certified biofuels)	**42 023**	**74 967**	**79 726**	**83 163**	**104 075**	**7**	**6**	**5**
Total RES-E (normalised, including all biofuels) ([b])	**42 175**	**74 977**	**79 732**	**83 251**	**104 075**	**7**	**6**	**5**

Notes: This table shows the actual final renewable energy consumption for 2005, 2014 and 2015, approximated estimates for 2016 and the expected realisations in the energy efficiency scenario of the NREAPs for 2020. The growth rates are the actual compound annual growth rates in 2005-2015, the growth from 2014 to 2015 and the compound annual growth rates required to reach the expected realisation 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.

Sources: EEA; Eurostat 2017b; NREAP reports.

([8]) Based on preliminary data submitted by Germany and the United Kingdom, 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 2016 data from Germany and the United Kingdom, the total RES-E generation was 82.8 Mtoe, the total electricity generation 299.3 Mtoe and the resulting RES-E share 29.6 % in 2016.

([9]) Based on preliminary data submitted by Germany and the United Kingdom, aggregate RES-E values differ slightly from the detailed, technology-level assessment carried out in this report. Taking into account the preliminary 2016 data from Germany and the United Kingdom, the EEA 2016 estimates would change for hydropower (29 816 ktoe), wind power (onshore & offshore: 26 714 ktoe), solar PV systems (9 101 ktoe) and for total RES-E (82 761 ktoe). Concerning other RES technologies, the preliminary data submitted by Germany and the United Kingdom cannot be used for calculating specific consumption levels because of their higher level of aggregation.

Hydropower

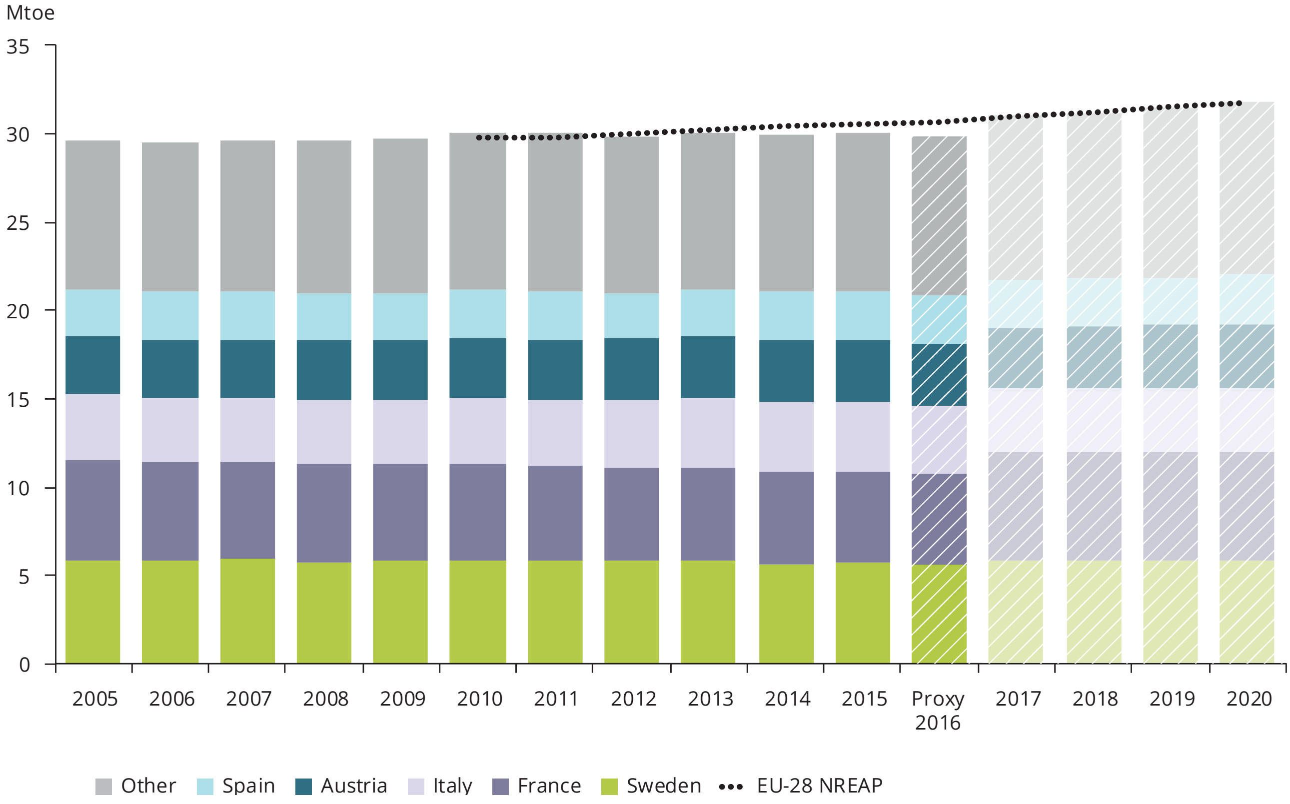
The normalised (6) production of renewable hydroelectric power remained quite stable over the period 2005-2015, as illustrated in Figure 2.4. According to the NREAPs, limited growth from 30.0 to 31.8 Mtoe is expected for 2015-2020. In 2015, the five countries with the most hydropower (Sweden, France, Italy, Austria and Spain) had a share of 70 % of all hydropower in the EU. In 2016, the normalised production of hydroelectricity is likely to have decreased slightly to 29.9 Mtoe (10).

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, provided that new projects do not conflict with the objectives of nature- and water-related legislation (as reflected by, inter alia, EU, 2000, EC, 2011).

Despite the low total growth rate anticipated up to 2020 at the EU level, the importance of hydropower may increase. 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 concerning Norwegian hydropower (Moser, 2015).

Figure 2.4 RES-E in the EU-28: hydropower excluding pumping (normalised)



Notes: This figure shows the actual final RES-E consumption for 2005-2015, approximated estimates for 2016 and the expected realisations in the energy efficiency scenario of the NREAPs for 2017-2020.

Sources: EEA; Eurostat 2017b; NREAP reports.

(10) Based on the preliminary data submitted by Germany and the United Kingdom, aggregate RES-E values differ slightly from the detailed, technology-level assessment carried out in this report. When taking into account preliminary 2016 data from Germany and the United Kingdom, the normalised hydropower generation declined to 29.8 Mtoe in 2016.

Onshore wind

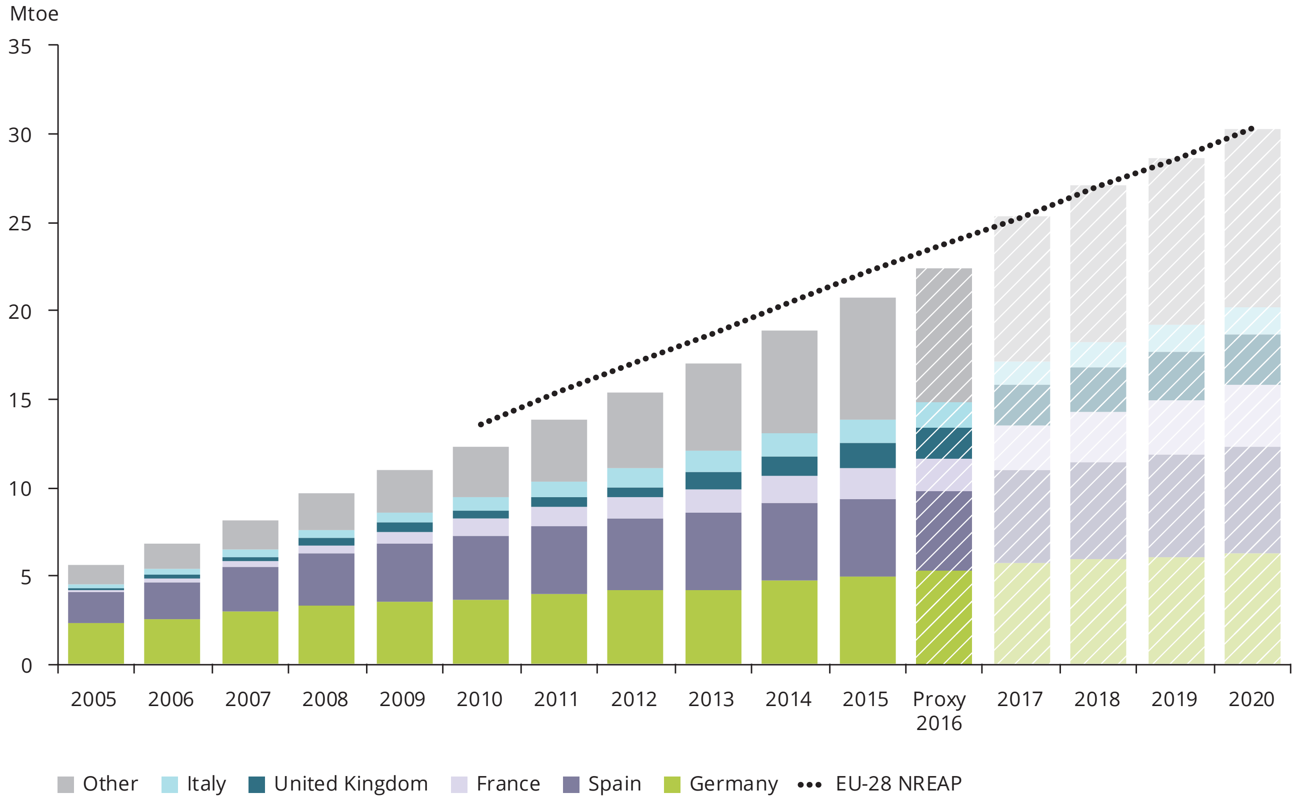
Onshore wind power generation increased from 5.7 Mtoe in 2005 to 20.7 Mtoe in 2015. The largest increases came from Germany (5.0 Mtoe) and Spain (4.4 Mtoe).

In 2016, the normalised onshore wind production of electricity was estimated to be 22.3 Mtoe (Figure 2.5). The greatest increase in normalised onshore wind production at the Member State level was recorded in Germany, followed by the United Kingdom and France. Germany installed additional onshore capacity of 4.6 GW, an increase of 4.3 GW net capacity, taking into account decommissioning of 0.7 GW (EurObserv'ER, 2017a).

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 30.3 Mtoe in 2020. The compound annual growth rate for onshore wind was 14 % over the period 2005-2015. Although a growth rate of 8 % in the period up to 2020 would be sufficient to meet the 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). In 2015, despite lower remuneration, high growth was observed in Germany due to higher yields of turbines, lower installation costs and lower interest rates. France relaunched its market by simplifying measures adopted under the energy

Figure 2.5 RES-E in the EU-28: onshore wind (normalised)



Notes: This figure shows the actual final RES-E consumption for 2005-2015, approximated estimates for 2016 and the expected realisations in the energy efficiency scenario of the NREAPs for 2017-2020.

Sources: EEA; Eurostat 2017b; NREAP reports.

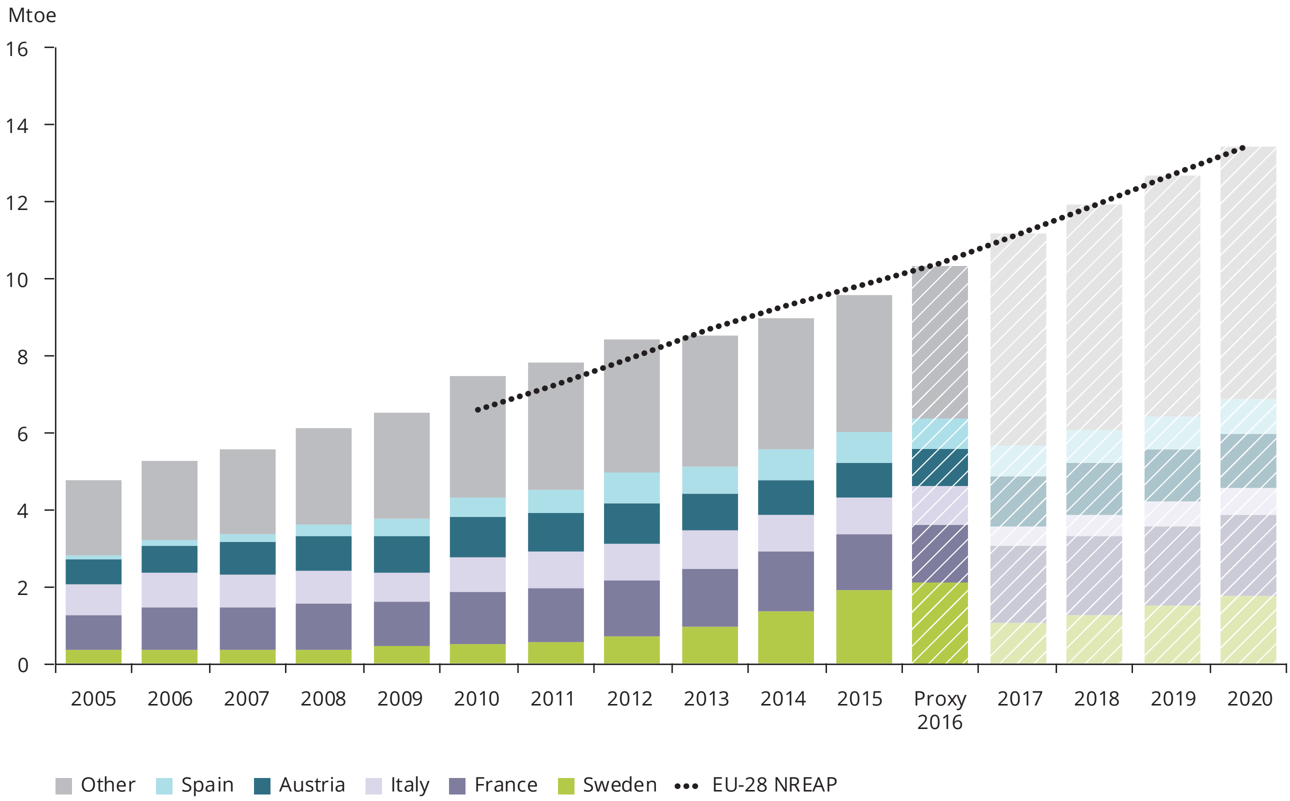
transition law and taking advantage of innovations and lower installation costs. Newly installed capacities also increased sharply in Finland, Netherlands, Poland, Sweden and the United Kingdom. In other European countries, growth was rather moderate (EurObserv'ER, 2017a).

Solid biomass

Electricity generation from solid biomass grew from 4.8 Mtoe in 2005 to 9.6 Mtoe in 2015, driven by, inter alia, the expansion of biomass cogeneration and the conversion of coal-fired power plants to biomass installations ([11]). The growth rate over the period 2005-2015 was 7 % (Figure 2.6). In 2015, the United Kingdom surpassed Germany in total electricity generated from solid biomass, with growth from 1.4 Mtoe in 2014 to 1.9 Mtoe in 2015. In 2015, the United Kingdom accounted for 20 % of total electricity generated from solid biomass and Germany accounted for 15 %. Finland and Sweden each had shares of 10 %. In 2016, electricity generation from solid biomass increased by 0.7 Mtoe, compared with 2015, to 10.3 Mtoe, a 7.6 % growth rate. The highest increase occurred in the United Kingdom with 0.2 Mtoe growth, further widening the gap between it and the other Member States of the EU. In comparison, Germany, the second largest generator of electricity from solid biomass, increased its output by 0.1 Mtoe.

Until 2020, the European Commission has left it up to Member States whether or not they 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 cover the conversion of biomass and biogas to heat and power in plants with a capacity of at least 20 MW (EC, 2016a). To safeguard the complete accounting of GHG emissions, the criteria require that GHG emissions and removals from land

Figure 2.6 RES-E in the EU-28: solid biomass



Notes: This figure shows the actual final RES-E consumption for 2005-2015, approximated estimates for 2016 and the expected realisations in the energy efficiency scenario of the NREAPs for 2017-2020.

Sources: EEA; Eurostat 2017b; NREAP reports.

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

use, land-use change and forestry (LULUCF ([12])) 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 RES progress, and that the 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.

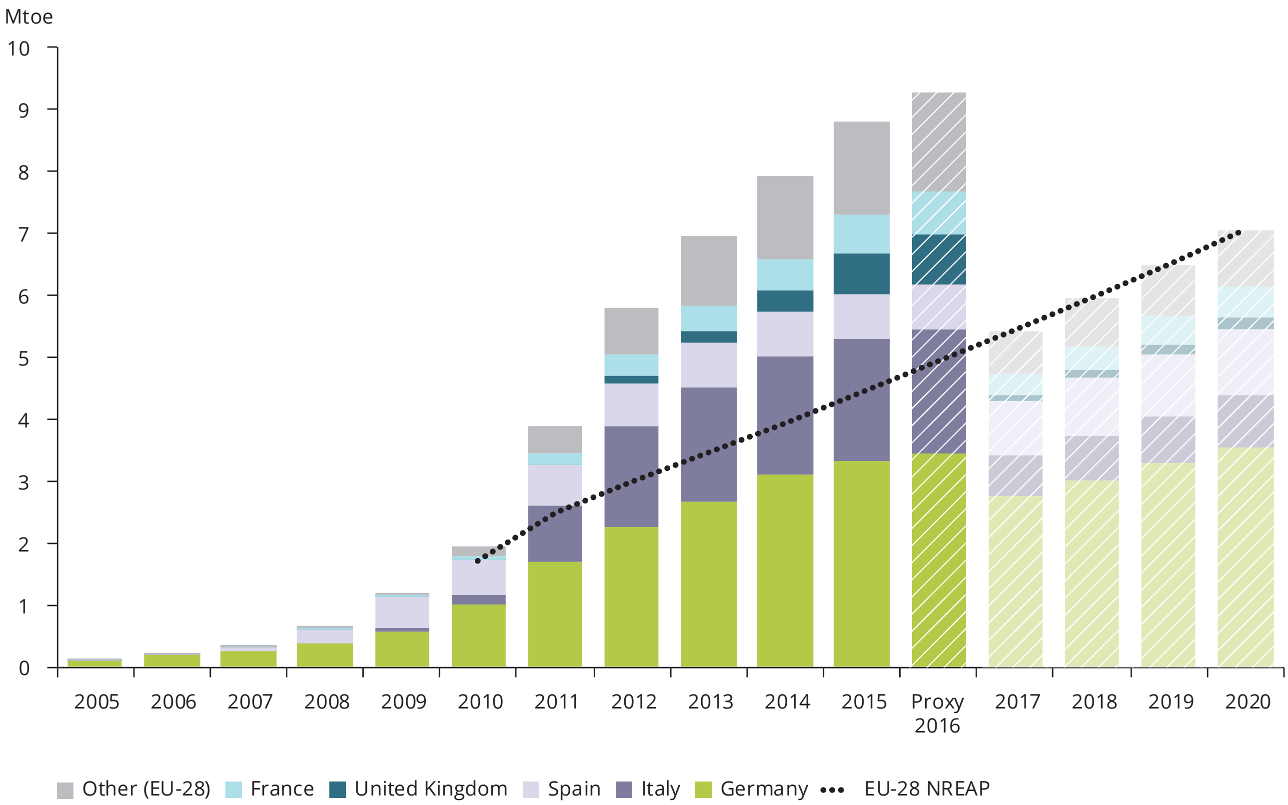
To meet NREAP expectations, a compound annual growth of 7 % over the period remaining up to 2020 would be necessary.

Solar photovoltaic systems

Solar PV electricity production reached 8.8 Mtoe in 2015 (Figure 2.7), exceeding by more than one fifth (1.7 Mtoe) the level that was expected for 2020, according to the NREAPs (7.1 Mtoe). In 2015, 38 % of solar PV electricity was produced in Germany. Italy also had a large share, 22 %, followed by Spain and the United Kingdom with shares of 8 % and 7 %, respectively.

In 2016, approximated estimates suggest that the production of solar PV electricity increased again, overtaking the NREAP levels for 2020 by 31 % and reaching 9.3 Mtoe ([13]). The greatest increase in solar PV electricity production at the Member State level was in the United Kingdom, which resulted from an additional installation of solar PV capacity of 3.8 GW ([14]) in 2016. Other Member States with substantial absolute capacity additions were Germany (1.6 GW) and France (1.1 GW). A further four Member States (Austria, Denmark, Italy and the Netherlands) added more than 0.1 GW in 2015 (EurObserv'ER, 2016a).

Figure 2.7 RES-E in the EU-28: solar PV energy



Notes: This figure shows the actual final RES-E consumption for 2005-2015, approximated estimates for 2016 and the expected realisations in the energy efficiency scenario of the NREAPs for 2017-2020.

Sources: EEA; Eurostat 2017b; NREAP reports.

([12]) Proposal for a Regulation of the European Parliament and of the Council on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry into the 2030 climate and energy framework (COM(2016)0479 final of 7 January 2016).

([13]) Based on preliminary data submitted by Germany and the United Kingdom, RES-E values differ slightly from the detailed, technology-level assessment carried out in this report. When taking into account the preliminary 2016 data submitted by Germany and the United Kingdom, the electricity generation from solar PV (excluding concentrated solar) increased to 9.1 Mtoe.

([14]) For 2016, data for all Member States are taken from EurObserv'ER and, in some cases, they might vary slightly from national data.

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, the annually installed solar PV capacities have also slowed down since 2011.

The European electricity market has witnessed a number of recent changes. The revised guidelines for environmental protection and energy of 2014, established public tendering in the electricity system, as of 1 January 2016, as the new norm for medium- and high-capacity facilities (> 500 kW installations) ([15]). 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 for consumers. At the same time, the guaranteed production-related support is becoming the preferred option to support small PV panels (as well as other small-scale variable renewables). This addresses consumer needs for at least the next few years, as the electricity generation market in many Member States is shifting from a system of relatively stable and continuous, centralised supply towards a system with more numerous, decentralised small-scale renewable sources used by prosumers for self-consumption and sale to the market (EurObserv'ER, 2017b).

Biogas

Electricity generation from biogas grew from 1.1 Mtoe in 2005 to 5.2 Mtoe in 2015 (Figure 2.8), only a few percentage points below the level expected for 2020 in the NREAPs (5.5 Mtoe). The compound annual growth rate for biogas was 17 % over the period 2005-2015. At the EU level, over half of the electricity sourced from biogas is recorded in Germany (54 %). Italy and the United Kingdom accounted for 13 % and 12 % of the EU total, respectively.

In 2016, electricity generation from biogas increased further, to 5.52 Mtoe, according to early EEA estimate, 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 2013-2015 due to policy changes in Germany and Italy. For a number of years, most of the EU's primary biogas 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, 2016b). 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 3.8 Mtoe in 2015, adding approximately 1 Mtoe from 2014 to 2015 (Figure 2.9). The largest increase in normalised offshore wind power generation at the Member State level occurred in Germany, which recorded an increase of 0.8 Mtoe from 2014 to 2015. Together, Germany, the United Kingdom and the Netherlands connected over 3 GW of offshore wind power capacity to the grid in 2015 (EurObserv'ER, 2017a). At the EU level, almost half of the total normalised electricity generation from offshore wind power in 2015 was recorded in the United Kingdom (46 %), but Germany has increased its share significantly, from 13 % in 2014 to 30 % in 2015.

According to early EEA estimates, European offshore wind generation in 2016 was 4.3 Mtoe, an increase of 13 % compared with 2015. Three large offshore wind projects were connected to the grid in 2016: Gemini in the Netherlands with 600 MW and Gode Wind 1 and 2 in Germany, with 330 and 252 MW capacity, respectively.

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 25 % per year from 2015 to 2020.

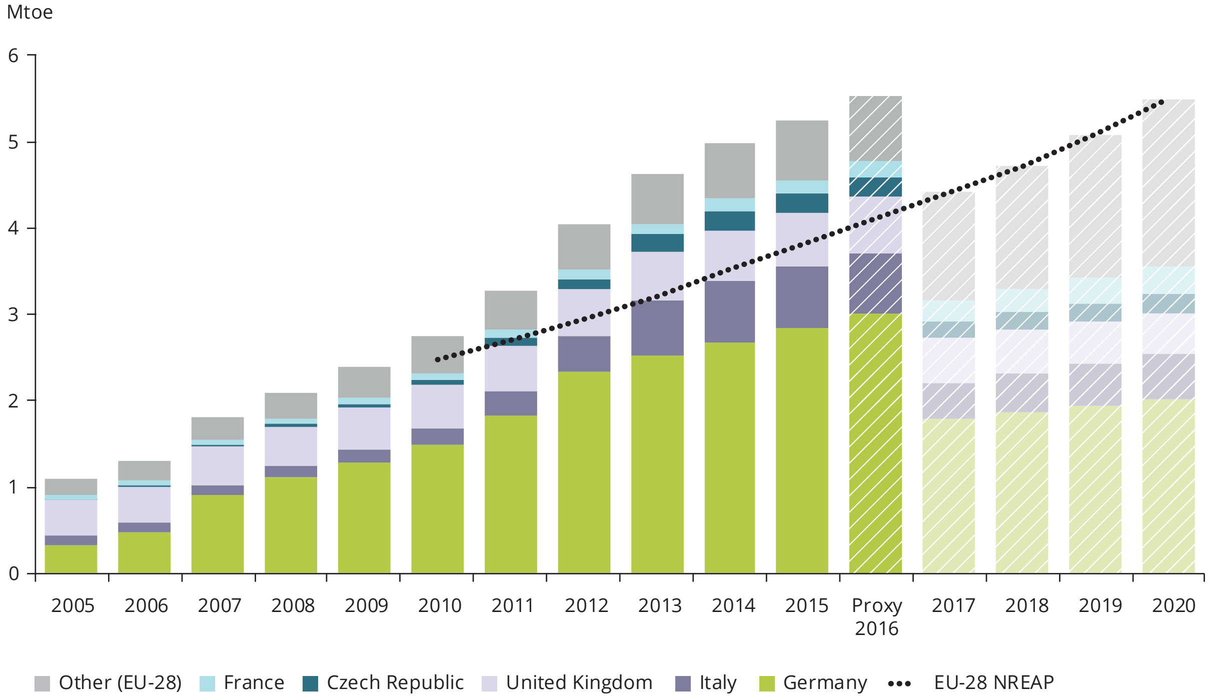
Other sources of renewable electricity

- Concentrated solar power (CSP) technology is currently only realistically applicable in southern Europe. CSP provided 0.5 Mtoe of renewable energy in 2015, and no change was expected in 2016. New CSP installations with approximately 500 MW capacity are under development in Europe, of which over 50 % are located in Italy (EurObserv'ER, 2017c).

- Geothermal electricity grew by only 2 % per year over the period 2005-2015, with a slight increase

([15]) Communication from the Commission — Guidelines on State aid for environmental protection and energy 2014-2020 (2014/C 200/01).

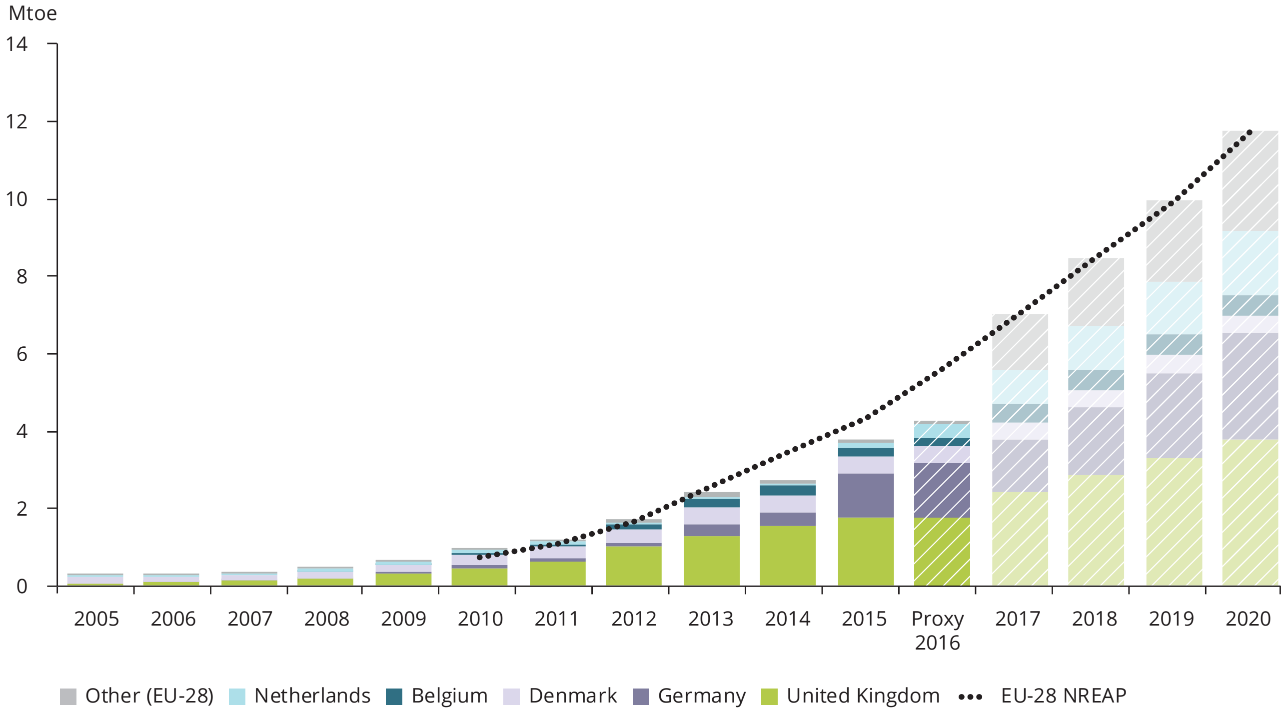
Figure 2.8 RES-E in the EU-28: biogas



Notes: This figure shows the actual final RES-E consumption for 2005-2015, approximated estimates for 2016 and the expected realisations in the energy efficiency scenario of the NREAPs for 2017-2020.

Sources: EEA; Eurostat 2017b; NREAP reports.

Figure 2.9 RES-E in the EU: offshore wind (normalised)



Notes: This figure shows the actual final RES-E consumption for 2005-2015, approximated estimates for 2016 and the expected realisations in the energy efficiency scenario of the NREAPs for 2017-2020.

Sources: EEA; Eurostat 2017b; NREAP reports.

of 5 % from 2014 to 2015 to reach 0.6 Mtoe in 2015. No significant change was expected in 2016.

- Electricity generation from tidal, wave and ocean energy remained at only 42 ktoe in 2015, and no significant change was expected in 2016.

- Electricity production from certified bioliquids rose by 15 % from 2014 to 2015, but remained at a moderate level of 0.5 Mtoe in 2015, and the EEA estimates the same generation in 2016.

2.2.3 *Renewable heating and cooling*

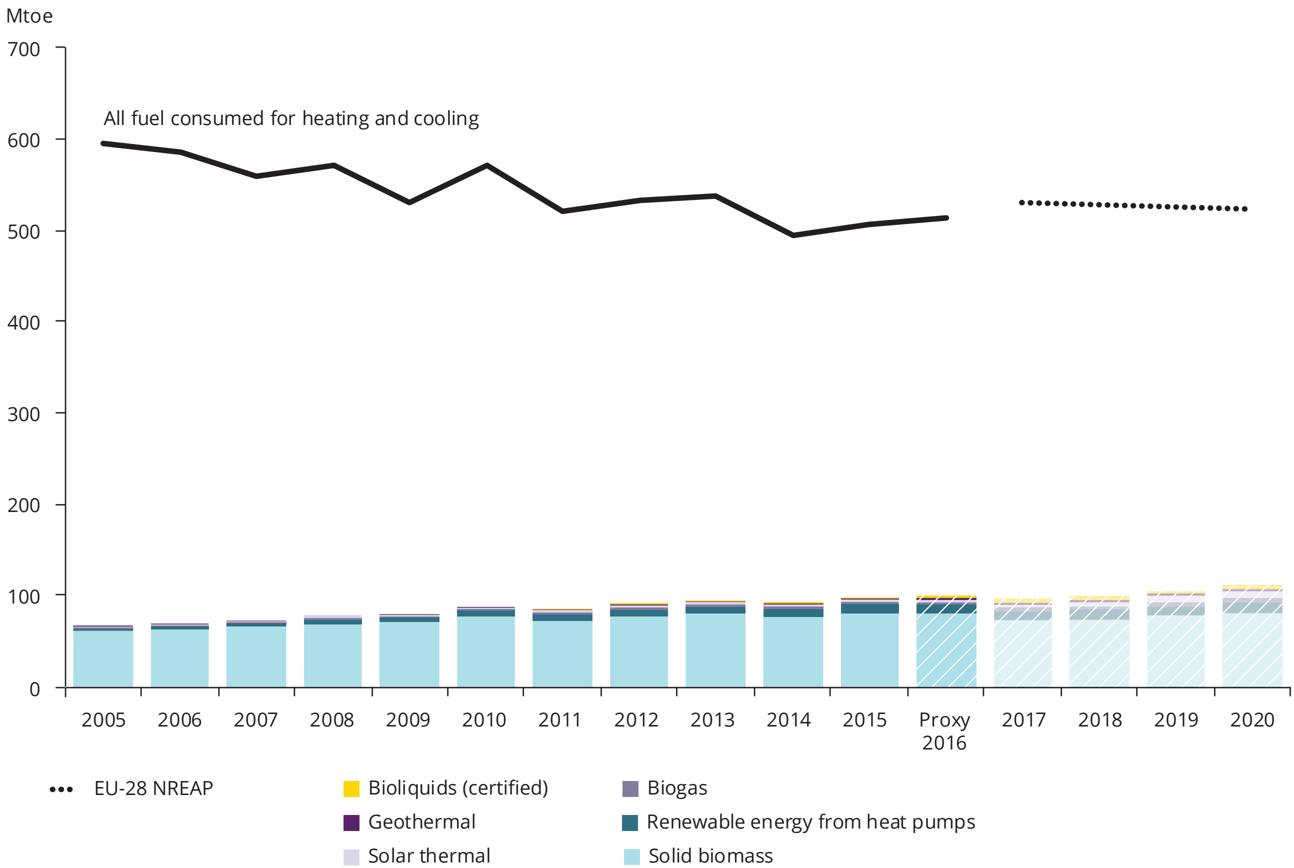
At the EU level, the gross final consumption of renewable energy in the heating and cooling market sector (RES-H&C) reached a share of 18.6 % in 2015. Figure 2.10 and Table 2.2 show the development of RES-H&C from 2005 to 2015, approximated estimates for 2016 and expected development up to 2020, based on the NREAPs.

- The gross final consumption of RES-H&C was 94.2 Mtoe in 2015, which corresponds to an increase of 5.0 Mtoe compared with 2014.

- In 2015, the largest contributions came from solid biomass (79.4 Mtoe, or 84 % of all RES-H&C), heat pumps (8.6 Mtoe, or 9 % of all RES-H&C) and biogas (3.2 Mtoe, or 3 % of all RES-H&C).

- Over the period 2005-2015, 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 2015-2020.

Figure 2.10 RES-H&C in the EU-28



Notes: This figure shows the actual final RES-H&C for 2005-2015, approximated estimates for 2016 and the expected realisations in the energy efficiency scenario of the NREAPs for 2017-2020. The consumption of RES accounts for only biofuels complying with the RED sustainability criteria.

Sources: EEA; Eurostat 2017b; NREAP reports.

- According to early proxy estimates, RES-H&C increased from 94.2 Mtoe in 2015 to 95.8 Mtoe in 2016, while the amount of fuel consumed for heating and cooling increased from 506 Mtoe to 515 Mtoe, resulting in a renewable share of heating and cooling consumption of 18.6 % in 2016 ([16]).

Solid biomass

Solid biomass remains the largest source of renewable energy for heating (Figure 2.11). The consumption of renewable heat originating from solid biomass increased from 75.2 Mtoe in 2014 to 79.4 Mtoe in 2015. This steep increase follows a mild winter in 2014, which reduced the demand for heating in that year. The compound annual growth rate for heat from solid biomass was 3 % over the period 2005-2015. In 2016, the consumption of solid biomass for renewable heat increased to 80.5 Mtoe, according to the early EEA estimate, almost reaching the expected NREAP level for 2020 of 80.9 Mtoe. A growth rate of below 1 % per year over the remaining period would be sufficient to reach the NREAP levels expected for 2020 for this category.

Heat pumps

Renewable energy from heat pumps grew from 2.3 Mtoe in 2005 to 8.6 Mtoe in 2015 (Figure 2.12). In northern Europe, most heat pumps are used for heating, but elsewhere there is also a market for cooling. In 2015, Italy contributed 30 % to final EU-wide RES consumption from heat pumps. France (23 %), Sweden (14 %) and Germany (10 %) also made significant contributions.

Table 2.2 RES-H&C in the EU-28

			Final energy (ktoe)				Annual growth rate (%)	
Technology	**2005**	**2014**	**2015**	**Proxy 2016 ([17])**	**NREAP 2020**	**2005-2015**	**2014-2015**	**2015-2020**
Solid biomass ([a])	60 274	75 196	79 379	80 511	80 886	3	6	0
Renewable energy from heat pumps	2 315	8 175	8 607	8 930	12 289	14	5	7
Biogas	725	2 938	3 191	3 273	5 108	16	9	10
Solar thermal	703	1 943	2 055	2 130	6 455	11	6	26
Geothermal energy	557	650	687	700	2 646	2	6	31
Bioliquids (certified)	0	274	278	278	4 416	n.a.	1	74
Total RES-H&C (certified biofuels)	**64 574**	**89 177**	**94 197**	**95 821**	**111 801**	**4**	**6**	**3**
Total RES-H&C (including all biofuels) ([b])	**64 739**	**89 311**	**94 324**	**95 959**	**111 801**	**4**	**6**	**3**

Notes: This table shows the actual final RES-H&C for 2005, 2014 and 2015, approximated estimates for 2016 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 2015, the growth from 2014 to 2015 and the compound annual growth rates required to reach the expected realisation 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.

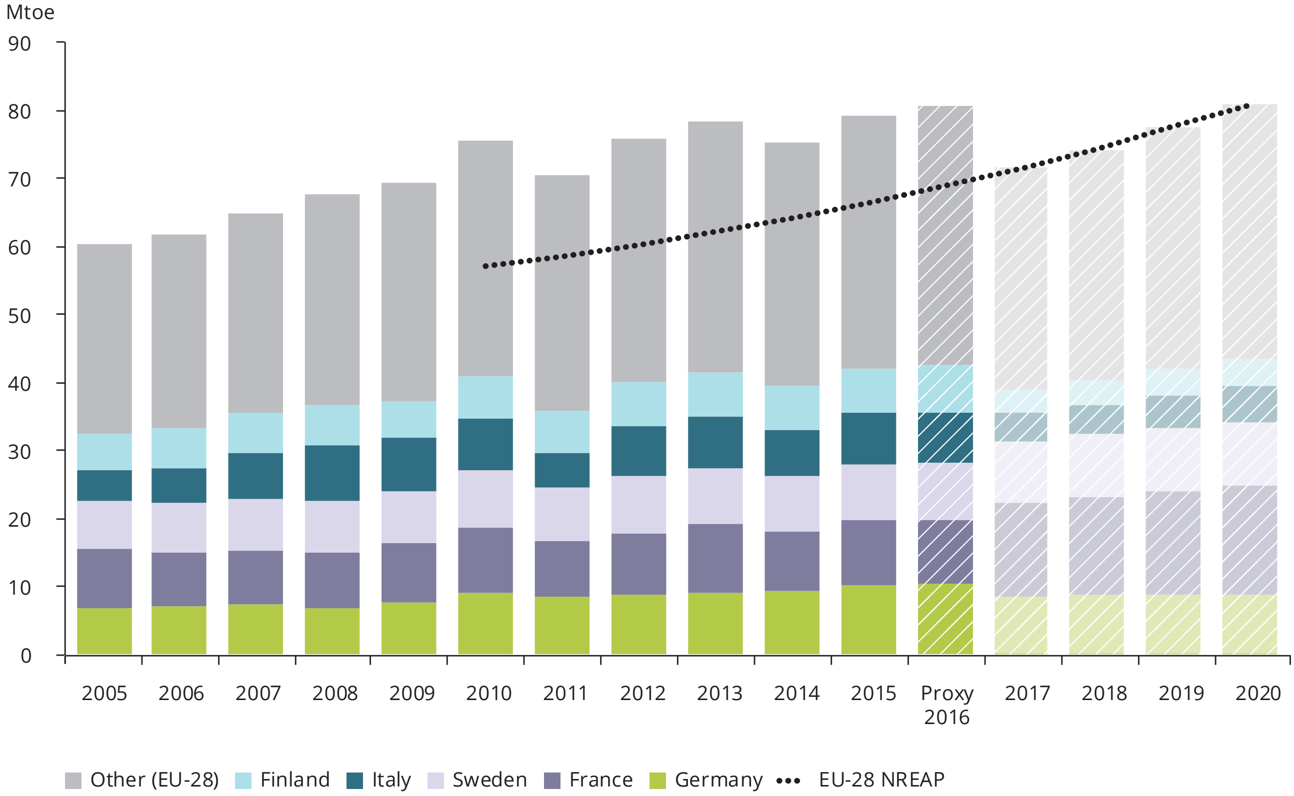
([b]) The series includes all biofuels and bioliquids consumed for heating and cooling, including uncertified ones after 2011.

Sources: EEA; Eurostat 2017b; NREAP reports.

([16]) Based on preliminary data submitted by Germany and the United Kingdom, RES-H&C values differ slightly from the detailed, technology-level assessment carried out in this report. When taking into account the preliminary 2016 data submitted by Germany and the United Kingdom, the total RES-H&C consumption was 96.3 Mtoe, all fuels consumed for heating and cooling 515.1 Mtoe and the resulting RES-H&C share 18.7 % in 2016.

([17]) See footnote ([16]) for 2016 proxy for 'Total renewable heat (certified biofuels)'. For the other values the preliminary data from Germany and the United Kingdom are not sufficiently detailed to allow a calculation of technology-specific consumption levels.

Figure 2.11 RES-H&C in the EU-28: solid biomass



Notes: This figure shows the actual final RES-H&C for 2005-2015, approximated estimates for 2016 and the expected realisations in the energy efficiency scenario of the NREAPs for 2017-2020.

Sources: EEA; Eurostat 2017b; NREAP reports.

The use of heat pumps increased considerably in 2015, with a 20 % growth in sales being recorded that year in the European market. Air-to-air heat pumps led the sales, being preferred in renovation works due to their lower installation costs and easier installation. Most of the air-to-air heat pumps sold in the European market today are reversible ([18]) and the strong demand for them is also driven by cooling needs. Market sales were boosted by high summer temperatures in southern Europe. The air-to-air heat pump market also continued to increase in parts of northern Europe, such as Sweden and Denmark, where products better suited to colder climates are in demand (EurObserv'ER, 2016b).

In 2016, renewable heat from heat pumps increased to 8.9 Mtoe, according to the early EEA estimate.

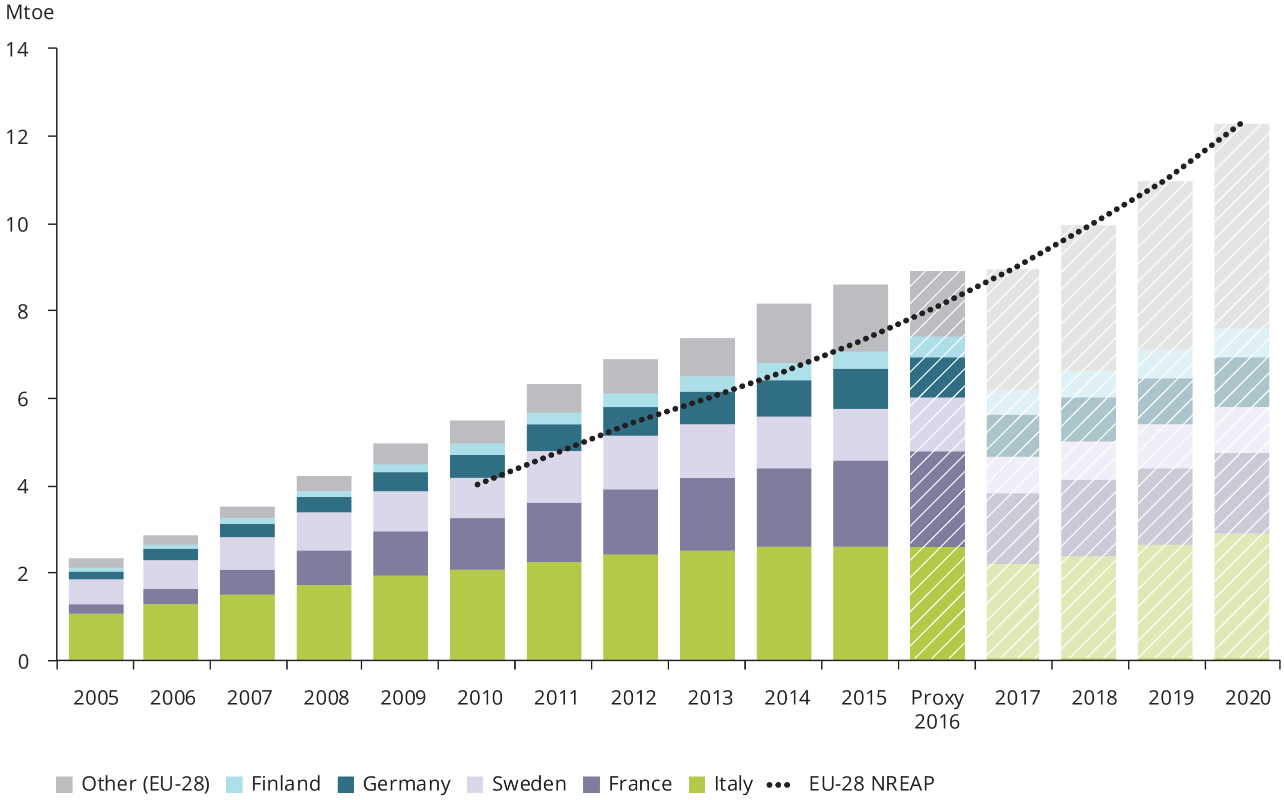
With a total growth rate over the period 2005-2015 of 14 % per year, the expectations in the NREAPs for 2015 and 2016 had already been exceeded. A 7 % compound annual growth rate would be sufficient to meet the expected contribution from heat pumps by 2020, according to the NREAPs.

Solar thermal energy

The production of renewable heat from solar thermal technology increased by 11 % per year over the period 2005-2015, growing from 0.7 Mtoe to 2.05 Mtoe (Figure 2.13). However, despite a further, estimated increase to 2.13 Mtoe in 2016, solar thermal energy has not been able to meet the expectations of the NREAPs.

([18]) Reversible pumps work in either direction to provide heating or cooling to a given internal space.

Figure 2.12 RES-H&C in the EU-28: renewable energy from heat pumps



Notes: This figure shows the actual final RES-H&C for 2005-2015, approximated estimates for 2016 and the expected realisations in the energy efficiency scenario of the NREAPs for 2017-2020.

Sources: EEA; Eurostat 2017b; NREAP reports.

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, 2017c). EurObserv'ER attributes this to the low price of natural gas, which affects solar heat's ability to compete by giving the advantage to the condensing gas boiler market, stop-start and degressive subsidy policies operating in some countries and 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, 2017c).

A growth rate of 26 % per year would be needed to reach the NREAP expectations for 2020.

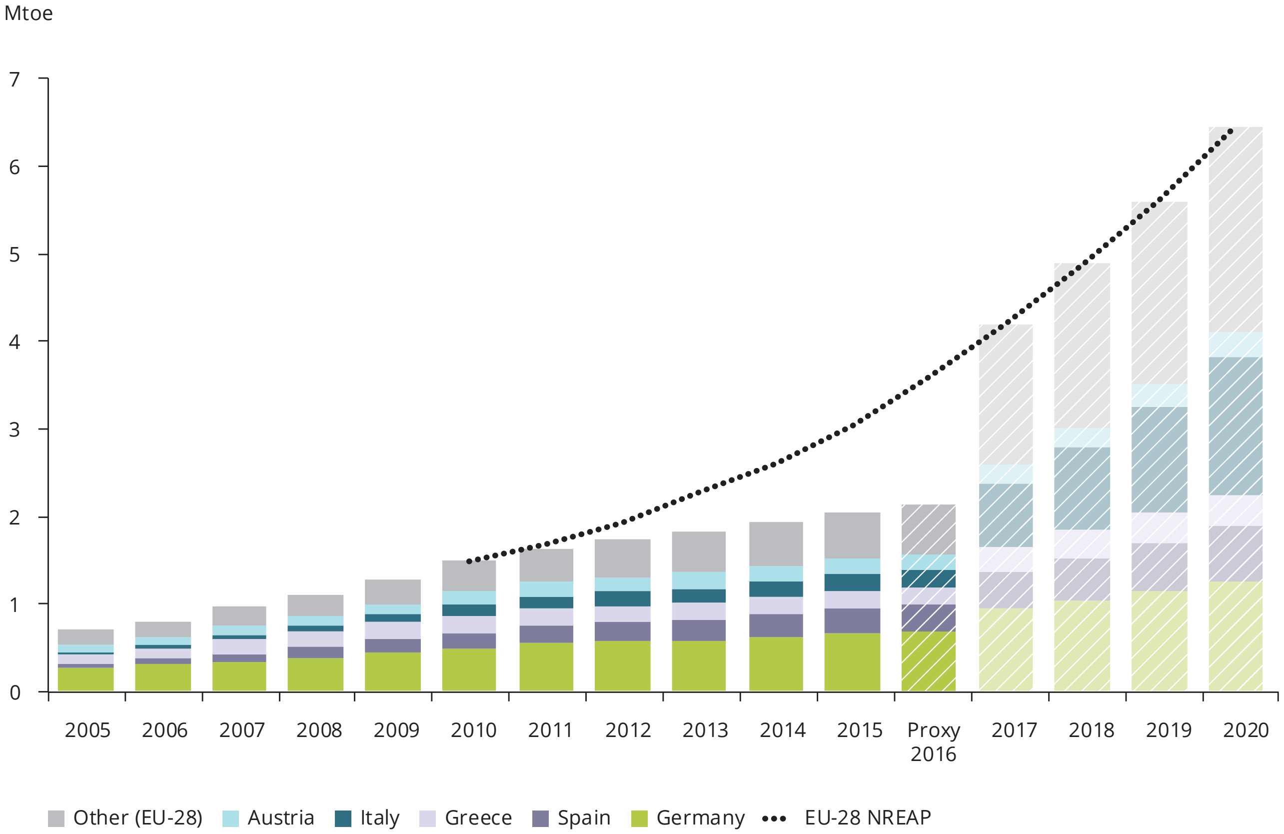
Other sources of RES-H&C

- Renewable heat from biogas grew from 0.7 Mtoe in 2005 to 3.2 Mtoe in 2015. According to EEA estimates, it reached 3.3 Mtoe in 2016.
- Geothermal heat will have to bridge a large gap if it is to achieve the target anticipated for 2020 — 2.6 Mtoe. In 2015, the production of geothermal heat was 0.7 Mtoe.
- The production of heat from liquid biofuels was 0.3 Mtoe in 2015, unchanged from 2014.

2.2.4 Renewable transport fuels

The share of renewable fuels consumed in transport (RES-T) in the EU was 6.7 % in 2015. Figure 2.14 and

Figure 2.13 RES-H&C in the EU-28: solar thermal energy



Notes: This figure shows the actual final RES-H&C for 2005-2015, approximated estimates for 2016 and the expected realisations in the energy efficiency scenario of the NREAPs for 2017-2020.

Sources: EEA; Eurostat 2017b; NREAP reports.

Table 2.3 shows the development of the use of biofuels in transport up to 2015, approximated estimates for 2016 and their expected development based on the NREAPs.

- The gross final consumption of certified biofuels was 13.1 Mtoe in 2015, which is a marginal increase compared with 2014.
- According to proxy estimates, the RES-T share grew from 6.7 % in 2015 to 7.1 % in 2016.
- To realise the expectations in the NREAPs for 2020, a growth rate of 17 % per year would be required over the remainder of the period 2015-2020.

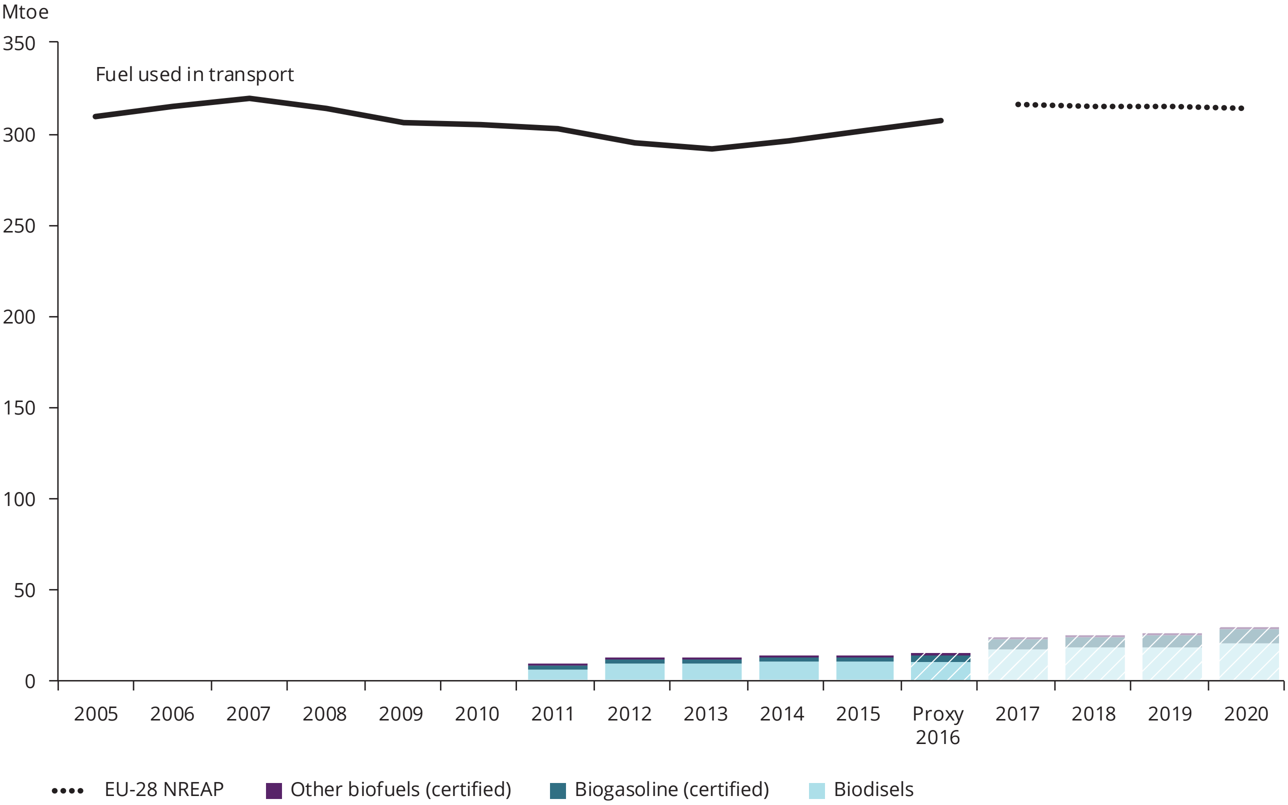
The use of renewable electricity in road transport in the EU was 64.4 ktoe in 2015, a significant increase from 19.0 ktoe in 2014, and is estimated to be 68.3 ktoe in 2016 ([19]). The amount of renewable electricity used in other transport modes was 1.6 Mtoe ([20]) in 2015 and is estimated to be 1.8 Mtoe in 2016.

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 2.15). In 2013, the total consumption of biofuels decreased compared with the previous year. In 2015, there was a stable consumption of 14.2 Mtoe (all biofuels). The EEA estimates that the use of biofuels in transport was 14.6 Mtoe in 2016. Most countries' consumption

([19]) Based on preliminary data submitted by Germany and the United Kingdom, RES-T values differ slightly from the detailed, technology-level assessment carried out in this report. When taking into account the preliminary 2016 data submitted by Germany and the United Kingdom, the consumption of renewable electricity in road transport increased to 70.0 ktoe in 2016.

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

Figure 2.14 Renewable transport in the EU-28: biofuels



Notes: This figure shows the actual final renewable energy consumption in transport for 2005-2015, approximated estimates for 2016 and the expected realisations in the energy efficiency scenario of the NREAPs for 2017-2020. The consumption of RES accounts for only biofuels complying with the RED sustainability criteria.

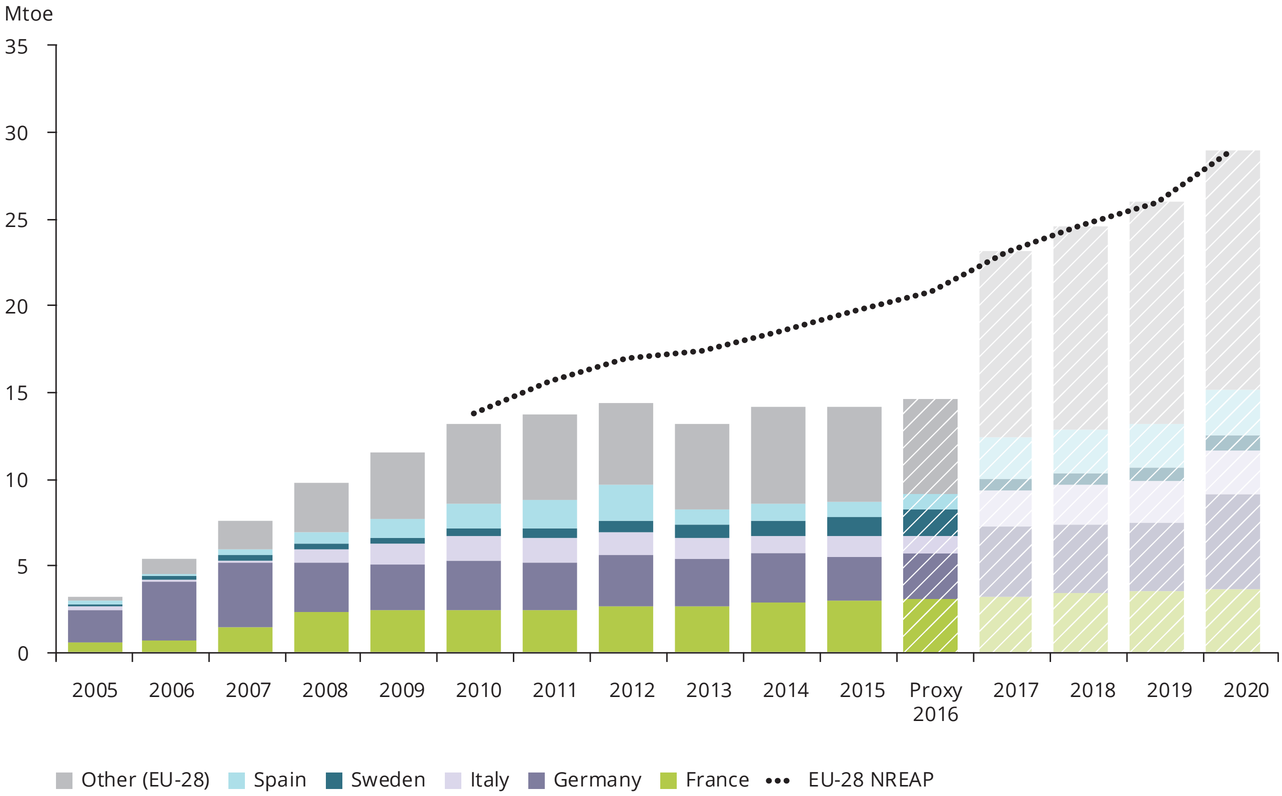
Sources: EEA; Eurostat 2017b; NREAP reports.

of biofuels is below the expected realisations in their NREAPs, but there is no clear EU-wide trend.

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, 2015b) 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 %. The Directive also harmonises the list of feedstocks whose contribution would count double towards the 2020 national target of a 10 % share of renewable energy consumption in transport (RED, Annex IX). For electricity produced from RES and consumed by electric road vehicles and rail transport, the Directive increases the multiplier factors for calculating the market share of renewable energy use in transport. 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 ([21]). In recent years, a significant volume of biofuels could not be demonstrated to be certified with the sustainability criteria for inclusion in the calculation for the RED ([22]).

([21]) Directive (EU) 2015/1513.
([22]) Roughly 8 % of all biofuels consumed in transport in 2015 were not certified in accordance with the sustainability criteria in the RED.

Figure 2.15 Renewable transport in the EU-28: biofuels including also non-certified biofuels



Notes: This figure shows the actual final renewable energy consumption in transport for 2005-2015, approximated estimates for 2016 and the expected realisations in the energy efficiency scenario of the NREAPs for 2017-2020.

Sources: EEA; Eurostat 2017b; NREAP reports.

Table 2.3 Renewable transport in the EU-28: biofuels

			Final energy (ktoe)				Annual growth rate (%)	
Technology	**2005**	**2014**	**2015**	**Proxy 2016**	**NREAP 2020**	**2005-2015**	**2014-2015**	**2015-2020**
Biodiesels (all)	2 470	11 397	11 345	11 662	20 920	16	0	13
Biogasoline (all)	573	2 657	2 680	2 741	7 324	17	1	22
Other biofuels (all)	155	143	132	164	746	- 2	- 7	41
Certified biofuels	0	12 934	13 058	13 404	28 989	n.a.	1	17
All biofuels	**3 198**	**14 197**	**14 158**	**14 566**	**28 989**	**16**	**0**	**15**

Notes: This table shows the actual final renewable energy consumption in transport for 2005, 2014 and 2015, approximated estimates for 2016 and the expected realisations in the energy efficiency scenario of the NREAPs for 2020. Also shown are the actual compound annual growth rates for 2005-2015, the growth from 2014 to 2015 and the compound annual growth rates required to reach the expected realisation in the NREAPs. The consumption of RES accounts for only biofuels complying with RED sustainability criteria.

Sources: EEA; Eurostat 2017b; NREAP reports.

3 Estimated effects of RES consumption

In 2015, the additional consumption of renewable energy, compared with the level of gross final RES consumption in 2005, allowed the EU to:

- reduce total GHG emissions by 447 $MtCO_2$, equivalent to 9 % of total EU GHG emissions;
- cut its demand for fossil fuels by 135 Mtoe, or roughly 10 % of the gross inland consumption of fossil fuels at the EU level;
- reduce its primary energy consumption by 36 Mtoe, equivalent to a 2 % reduction in primary energy consumption across the EU.

This chapter estimates several indirect effects related to the increased consumption of RES at the EU level and in the Member States, notably with regard to fossil fuel consumption and associated GHG emissions, and primary energy consumption.

The EU's renewable energy targets are one important part of the combined efforts to decarbonise the energy system. Progressing towards them can effectively displace fossil fuels and complement other climate mitigation efforts. As energy efficiency improvements 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 ([23]) 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 ([24]) 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 does not take into account 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).

([23]) 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.

([24]) 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 for primary and gross inland energy consumption are provided in the glossary.

3.1 Avoided fossil fuel use

3.1.1 Effects at the EU level

The additional use of renewable energy compared with the level of RES consumption in 2005 allowed the EU to cut its demand for fossil fuels by 135 Mtoe in 2015 (approximately 10 % of the EU's gross inland consumption of fossil fuels and 11 % of the EU's primary fossil fuel consumption) ([25]). This amount is more than the gross inland consumption of fossil fuels of Italy in 2015. Figure 3.1 illustrates the estimated reduction of fossil fuel use in primary energy consumption, as for the latter EEA developed early estimates (EEA, 2017c). Accordingly, the largest reductions were made in the consumption of solid fuels (60 Mtoe, or roughly 45 % of all avoided fossil fuels) and gaseous fuels (40 Mtoe, representing about 30 % of all avoided fossil fuels).

Estimates by the EEA show that avoided fossil fuel consumption will further increase from 135 Mtoe in 2015 to 145 Mtoe in 2016, which is approximately 12 % 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 2015, the largest relative reductions in the consumption of fossil fuels were made by Sweden (33 %), Denmark (28 %) and Finland (16 %), 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 (Figure 3.2).

3.2 Gross avoided GHG emissions

3.2.1 Effects at the EU level

According to the EEA, the growth in the consumption of renewable energy after 2005 resulted in an estimated 447 Mt of gross avoided CO_2 emissions at the EU level in 2015 — a 13 % increase compared with 2014 (see Figure 3.3). This amount is comparable to the GHG emissions of Italy in 2015. The contribution from RES-E (331 $MtCO_2$, or 74 % of all gross avoided emissions) was considerably larger than that of RES-H&C (76 $MtCO_2$, or 17 % of all gross avoided emissions) and biofuels in transport (40 $MtCO_2$, or around 9 % of total gross avoided emissions). This is because the increase in RES-E has reduced the need for solid fuels — the most carbon-intensive fossil fuels — in the power sector.

In 2015, total GHG emissions (including international aviation, but excluding LULUCF) in the EU were 4 452 $MtCO_2$. It is estimated that the additional use of renewable energy compared with the level of RES consumption in 2005 delivered a gross reduction of 9 % of the EU's total GHG emissions in 2015.

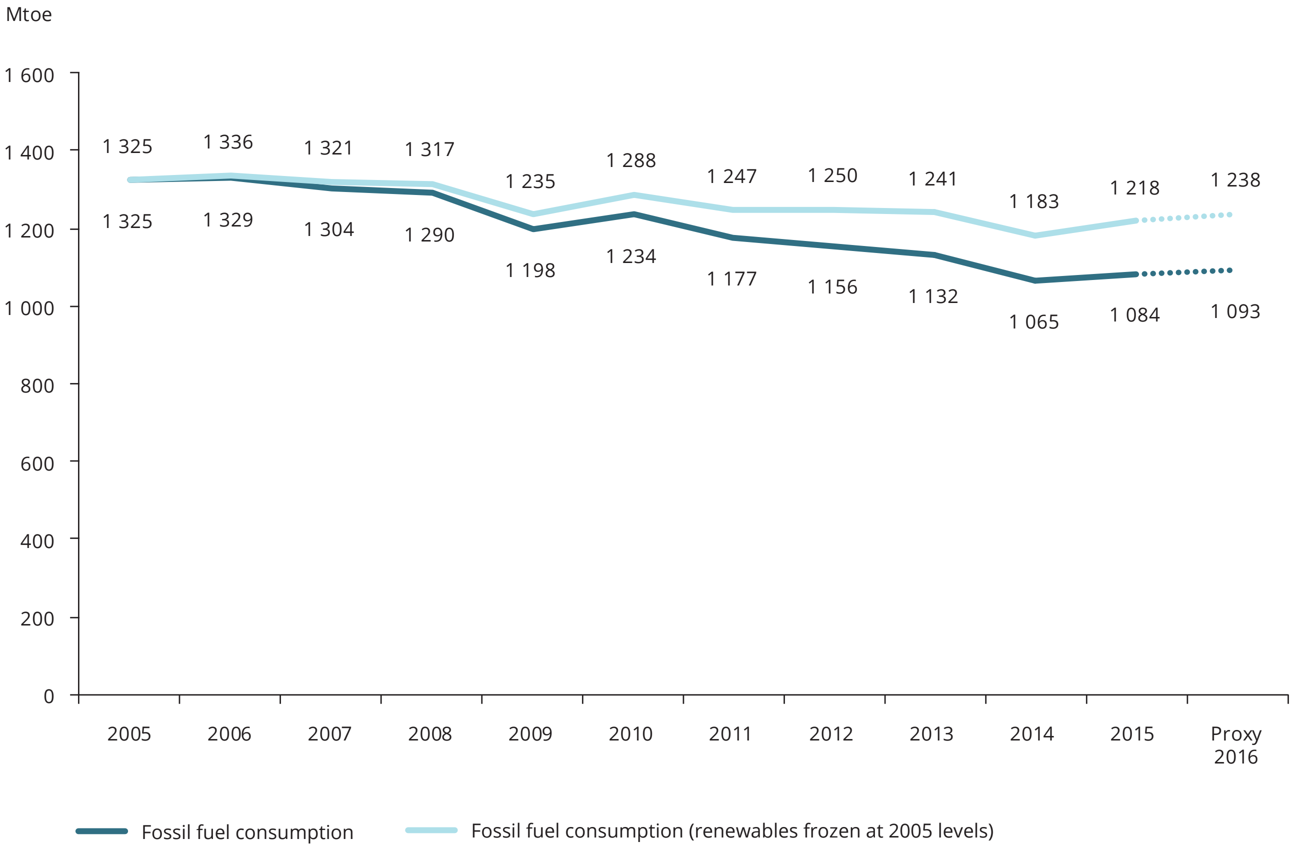
As shown in Figure 3.4 and Table 3.2, the gross avoided emissions within the Emissions Trading Scheme (ETS) were estimated to be approximately 349 $MtCO_2$ in 2015. The gross avoided emissions in non-ETS sectors were estimated to be approximately 98 $MtCO_2$ ([26]).

Estimates by the EEA for 2016 show an increase in gross avoided GHG emissions of approximately 8 %

([25]) 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.

([26]) 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 either in sectors falling 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 3.1 Estimated effect on fossil fuel consumption in the EU-28



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, 2017b, 2017c.

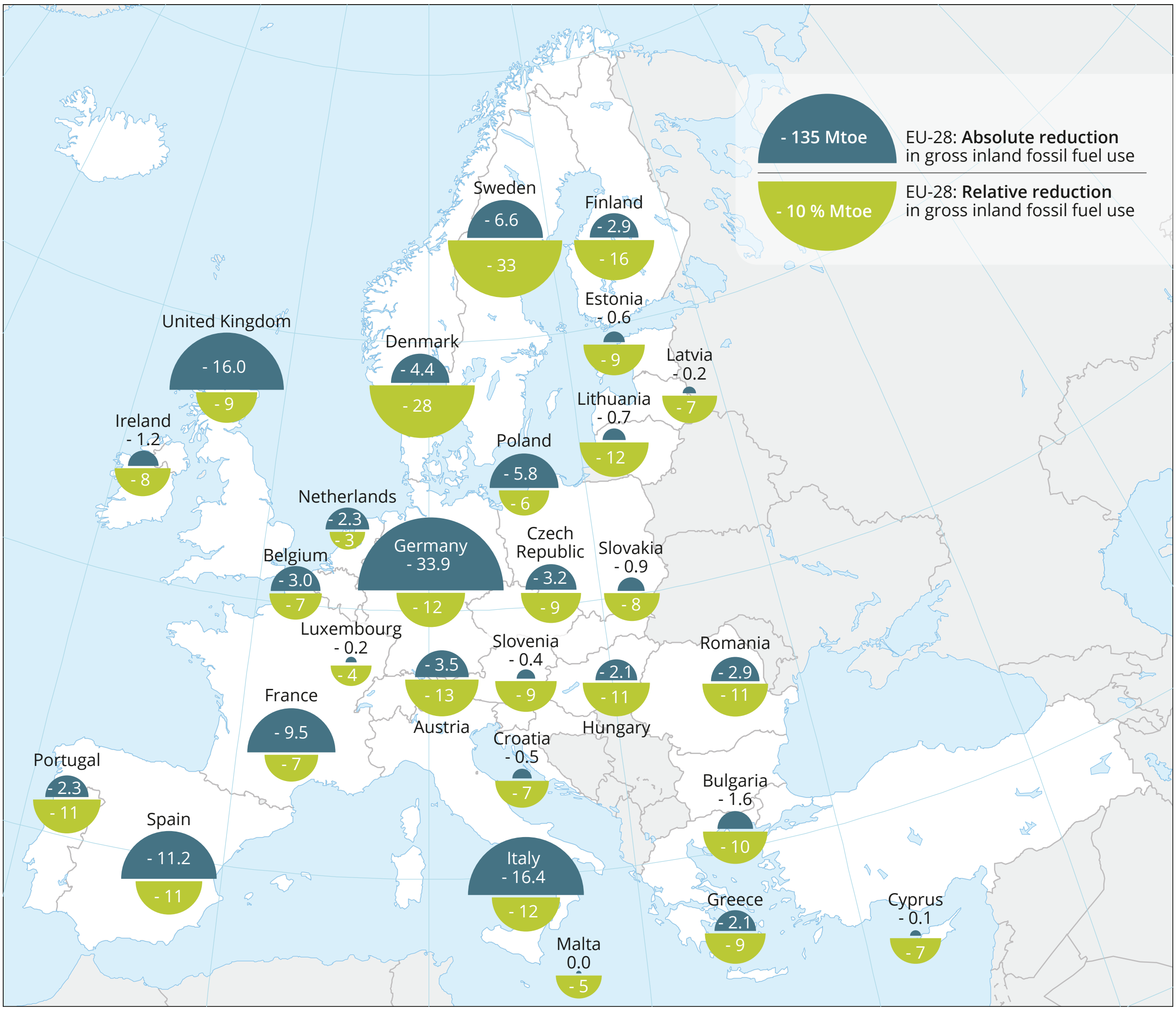
Table 3.1 Estimated effect on fossil fuel consumption in the EU-28 (Mtoe)

Fuel type	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Proxy 2016
Solid fuels	0	- 4	- 8	- 11	- 14	- 19	- 28	- 40	- 49	- 56	- 60	- 65
Gaseous fuels	0	- 2	- 6	- 11	- 16	- 23	- 23	- 28	- 32	- 32	- 40	- 43
Petroleum products	0	- 1	- 4	- 5	- 7	- 11	- 11	- 13	- 15	- 15	- 19	- 21
Gasoline	0	0	0	0	0	0	- 2	- 2	- 2	- 2	- 2	- 2
Diesel	0	0	0	0	0	0	- 6	- 9	- 9	- 10	- 11	- 11
Non-renewable waste	0	0	0	0	0	- 1	- 1	- 1	- 1	- 2	- 2	- 2
Total	**0**	**- 7**	**- 17**	**- 27**	**- 37**	**- 54**	**- 71**	**- 94**	**- 109**	**- 118**	**- 135**	**- 145**

Notes: This table shows the estimated effect on primary energy consumption from fossil fuels (excluding non-energy uses) of the increase in renewable energy consumption since 2005.

Sources: EEA; Eurostat, 2017b, 2017c.

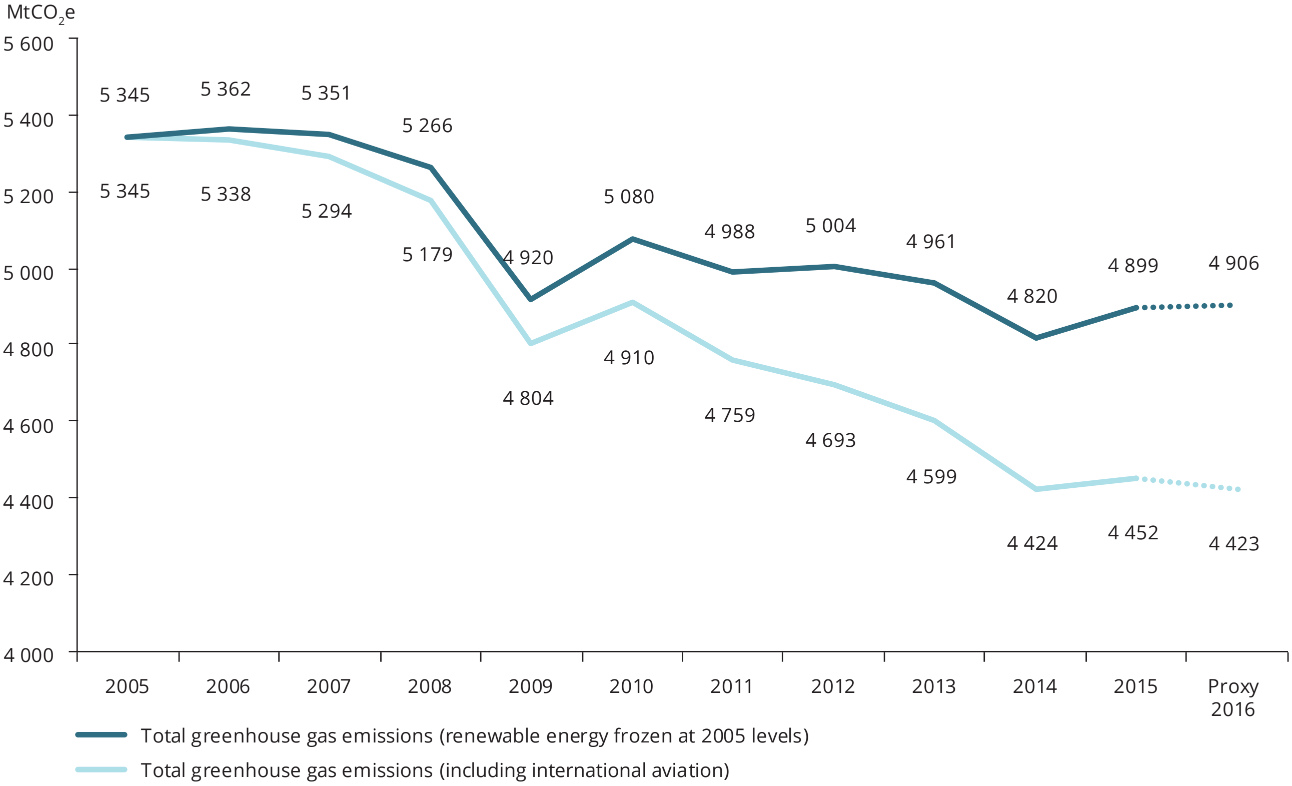
Figure 3.2 Total and relative reduction in gross inland fossil fuel use (per year, in 2015)



Notes: Absolute reduction in gross inland fossil fuel use (Mtoe) due to the increase in renewable energy use per country since 2005.
Relative reduction in gross inland fossil fuel use per country (expressed as absolute reductions over total gross inland consumption of fossil fuels).

Source: EEA, Eurostat, 2017b, 2017c.

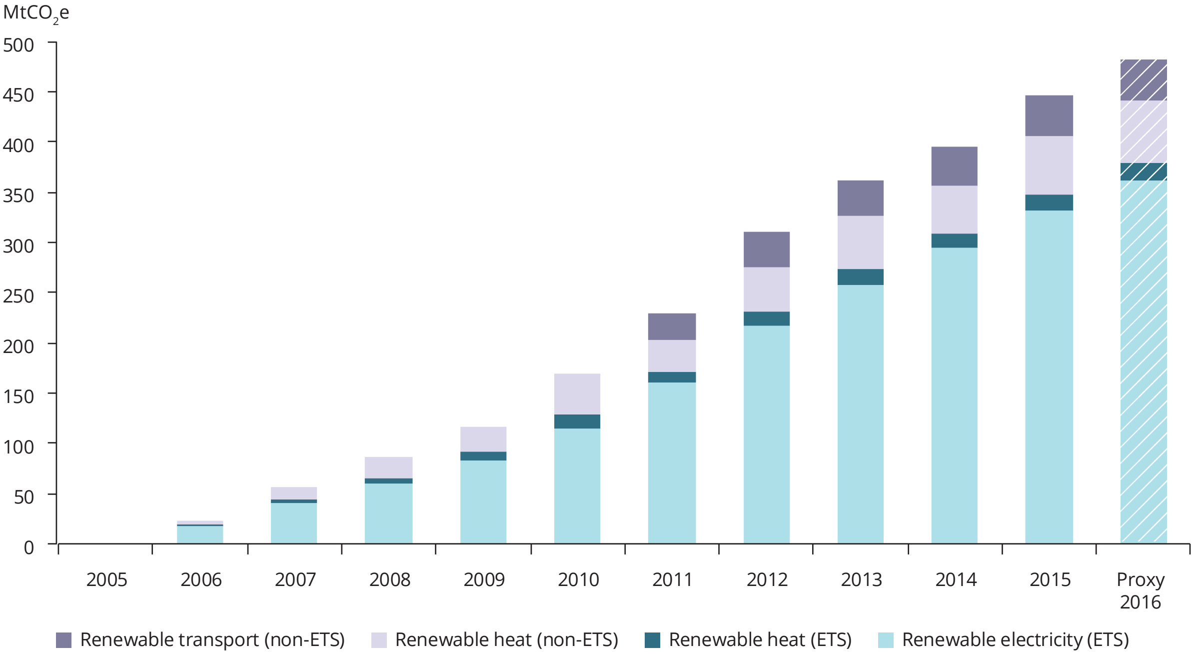
Figure 3.3 Estimated gross effect on GHG emissions in the EU-28



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.

Source: EEA, Eurostat, 2017b, 2017c.

Figure 3.4 Estimated gross reduction in GHG emissions in the EU-28, 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-28 ($MtCO_2$)

		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Proxy 2016
ETS	Electricity	0	17	40	60	84	115	161	217	258	295	331	361
	Heating and cooling	0	1	4	6	8	13	10	14	16	14	17	18
	Transport	0	0	0	0	0	0	0	0	0	0	0	0
	All renewables	0	19	44	66	91	128	171	231	274	309	349	380
Non-ETS	Electricity	0	0	0	0	0	0	0	0	0	0	0	0
	Heating and cooling	0	4	13	21	25	42	33	45	52	48	58	62
	Transport	0	0	0	0	0	0	26	35	36	40	40	41
	All renewables	0	4	13	21	25	42	59	80	88	87	98	103
Total	Electricity	0	17	40	60	84	115	161	217	258	295	331	361
	Heating and cooling	0	6	17	27	33	55	43	59	69	62	76	80
	Transport	0	0	0	0	0	0	26	35	36	40	40	41
	All renewables	0	23	57	87	117	170	229	311	362	396	447	483

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.

from 2015 to 2016. The total avoided GHG emissions in Europe in 2016 are estimated to be 483 Mtoe, roughly 11 % of the total GHG emissions (including international aviation).

3.2.2 *Effects at Member State level*

In terms of gross avoided GHG emissions in 2015, the countries with the largest estimated gross reductions were Germany (126 $MtCO_2$), Italy and the United Kingdom (both 50 $MtCO_2$) (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 nine countries in 2015 (Sweden, Denmark, Finland, Germany, Austria, Portugal, Estonia, Italy, 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 not reflected in this methodology.

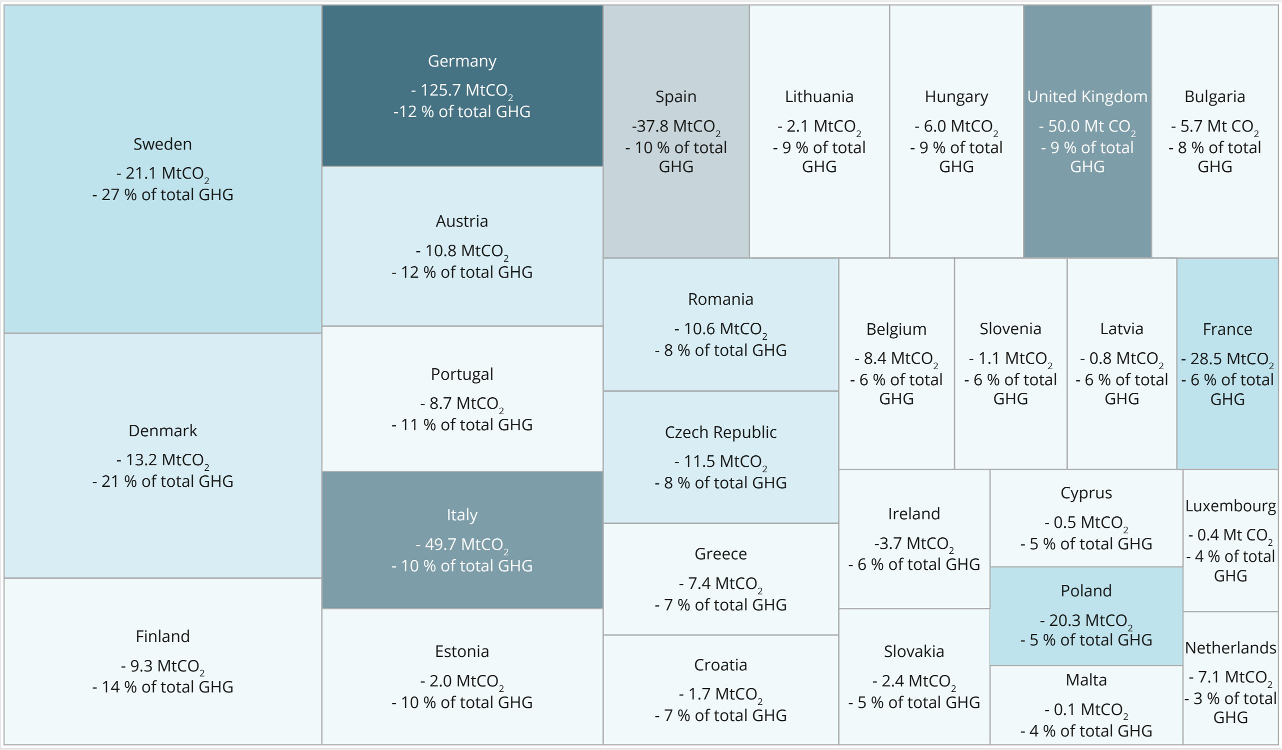
3.3 Statistical impacts of RES on primary energy consumption

3.3.1 *Effects at EU level*

Whereas the RED sets binding targets for 2020 for the share of renewable energy in gross final energy consumption, some energy policies put forward targets and objectives expressed in **primary energy** (defined as gross inland energy consumption minus non-energy use; see glossary). This is the case for the recast Energy Performance of Buildings Directive (EPBD) ([27]) and the Energy Efficiency Directive (EED) ([28]). As the latter is part of the EU 20-20-20 climate and energy package ([29]), an assessment of interactions between different

([27]) Directive 2010/31/EU.
([28]) Directive 2012/27/EU.
([29]) The three key EU climate and energy targets to be achieved by 2020 are: a 20 % reduction in EU GHG emissions compared with 1990; a 20 % share of renewable energy in final EU energy consumption; and a 20 % improvement in energy efficiency.

Figure 3.5 Total and relative gross avoided GHG emissions (per year in 2015)



Notes: The area of each rectangle illustrates the relative RES impacts on total national GHG emissions. The larger the area, the more significant the share of a country's estimated gross avoided CO_2 within its total national GHG emissions (including international aviation and excluding LULUCF). The colour scheme illustrates total gross avoided GHG emissions. The deeper the shading, the higher the absolute RES effects (Mt gross avoided GHG emissions).

Source: EEA.

RES technologies and their statistical impacts on primary energy is presented below. The methodology underpinning these findings was described in a previous EEA report (EEA, 2015) ([30]).

At the EU level, primary energy consumption has been decreasing, on an annual average, since 2005 (EEA, 2017a). This downwards trend is the result of a number of interacting factors, sometimes with opposing effects in terms of statistical accounting rules and definitions in use.

- Typically, general factors driving the accounting of primary energy consumption downwards include a decreasing share of nuclear energy and thermal generation (excluding combined heat and power, CHP), and an increasing share of certain renewable energy, such as hydro- and wind power, in electricity generation. This is because the statistical methodologies in use follow the common physical principle of the first measurable primary equivalent energy in order to estimate the primary energy of certain technologies or sources. For nuclear and geothermal energy, the first measurable primary equivalent energy is the heat that is being converted to electricity. 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 and thereby improves the overall conversion efficiency of the energy system.

([30]) 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 gasoline 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.

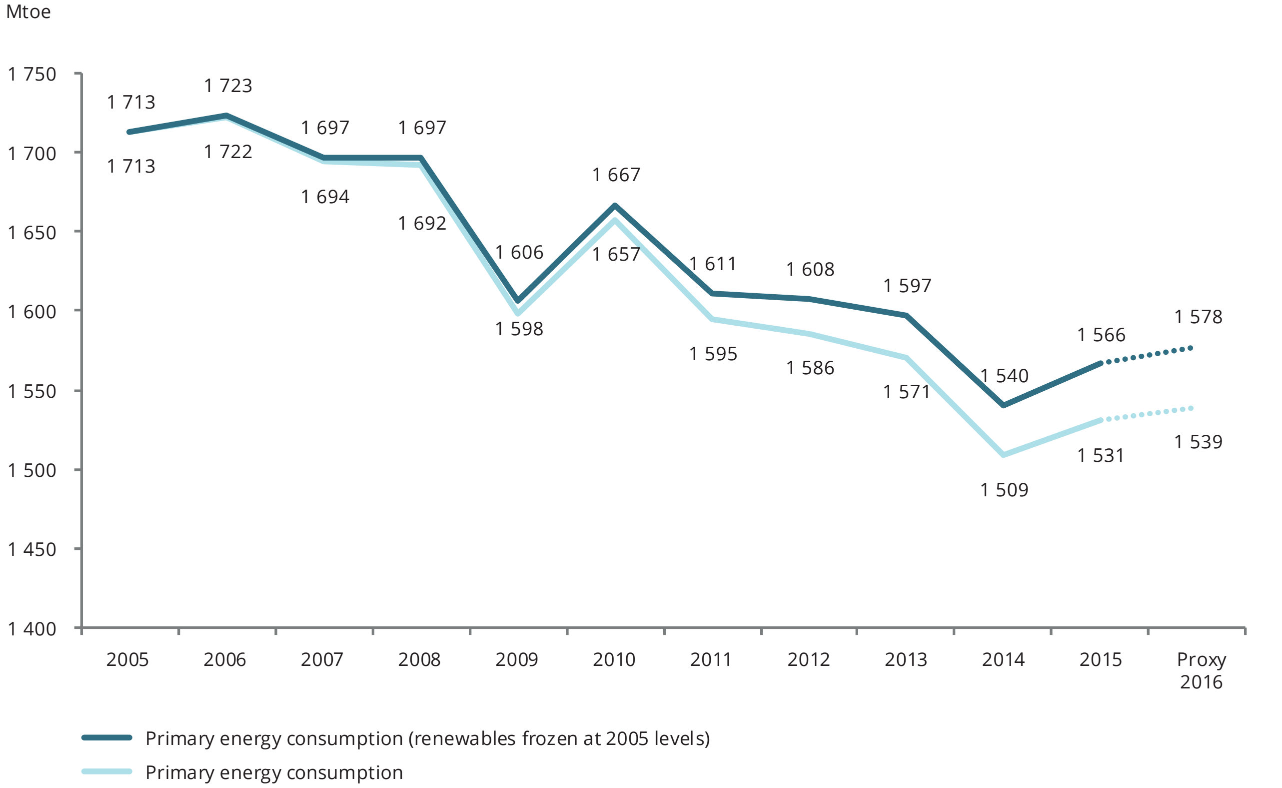
- General factors driving the accounting of primary energy consumption upwards include an increasing share of specific renewable energy technologies, such as biomass-based electricity production. This is because the efficiency of electricity generation from biomass is, on average, lower than that from 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 the deployment of renewable energy since 2005 reduced primary energy consumption by 36 Mtoe in 2015 (see Figure 3.6 and Table 3.3). The estimated reduction in primary energy consumption in 2016 was 39 Mtoe. Without the growth of renewable energy since 2005, primary energy consumption in the EU in 2015 could have been 2.3 % higher.

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 (– 11 %, – 6 % and – 4 %, 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

Figure 3.6 Estimated effect on primary energy consumption in the EU-28



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

Sources: EEA; Eurostat, 2017b, 2017c.

Table 3.3 Estimated effect on primary energy consumption in the EU-28 (Mtoe)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Proxy 2016
Renewable electricity (normalized, certified biofuels)	0.0	- 1.4	- 3.7	- 5.4	- 8.5	- 11.5	- 16.8	- 23.1	- 28.1	- 32.1	- 36.9	- 39.9
Renewable heating and cooling (certified biofuels)	0.0	0.0	0.5	0.6	0.8	1.9	0.6	1.4	1.6	0.3	1.3	1.3
Renewable transport (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
All renewables (normalized, certified biofuels)	0.0	- 1.3	- 3.2	- 4.8	- 7.7	- 9.7	- 16.2	- 21.7	- 26.5	- 31.8	- 35.7	- 38.6

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

Source: EEA, Eurostat, 2017b, 2017c.

these countries. The effects of renewable energy on GHG emissions and energy consumption in 2015 are summarised by country in Annex 1.

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 2015, the largest amounts of gross avoided GHG emissions were attributable to onshore wind energy (132 $MtCO_2$), solar PV energy (77 $MtCO_2$) and heat from solid biomass (60 $MtCO_2$) ([31]). 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 4.1 Mtoe in 2015.

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.

For 2016, preliminary estimates by the EEA show that the amount of avoided GHG emissions will further increase to 483 Mtoe. This is mainly driven by additional renewable energy consumption originating from onshore wind technologies, with additional avoided GHG emissions of 14 $MtCO_2$, followed by solid biomass, offshore wind and solar PV energy.

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

Table 3.4 Effect of renewable energy on GHG emissions and energy consumption by technology in the EU-28

Source of renewable energy	Increase in renewable energy consumption since 2005 (ktoe)		Effect on GHG emissions ($MtCO_2$)		Effect on fossil fuel consumption (ktoe)		Effect on primary energy consumption (ktoe)	
	2015	Proxy 2016	2015	Proxy 2016	2015	Proxy 2016	2015	Proxy 2016
Renewable electricity								
Biogas	4 144	4 421	- 39	- 41	- 10 130	- 10 821	- 262	- 294
Bioliquids (certified)	467	467	- 4	- 4	- 1 075	- 1 075	- 18	- 18
Concentrated solar power	481	481	- 4	- 4	- 1 196	- 1 196	247	247
Geothermal	97	108	- 1	- 1	- 225	- 252	743	833
Hydropower excluding pumping (normalised)	465	293	- 4	- 3	- 1 096	- 652	- 631	- 359
Offshore wind (normalised)	3 511	3 994	- 30	- 35	- 8 726	- 9 849	- 5 215	- 5 855
Onshore wind (normalised)	15 038	16 667	- 132	- 146	- 37 401	- 41 433	- 22 363	- 24 766
Solar PV energy	8 673	9 153	- 77	- 81	- 20 984	- 22 116	- 12 311	- 12 963
Solid biomass	4 827	5 554	- 41	- 47	- 11 733	- 13 583	2 893	3 248
Tidal, wave and ocean energy	1	1	0	0	- 2	- 2	- 1	- 1
Renewable heat								
Biogas	2 466	2 547	- 8	- 8	- 2 759	- 2 851	- 20	- 20
Bioliquids (certified)	278	278	- 1	- 1	- 311	- 311	1	1
Geothermal	130	143	0	0	- 145	- 160	114	126
Renewable energy from heat pumps	6 292	6 615	- 2	- 3	- 2 761	- 2 919	- 2 761	- 2 919
Solar thermal	1 352	1 427	- 4	- 4	- 1 513	- 1 597	- 161	- 170
Solid biomass	19 106	20 237	- 60	- 64	- 21 397	- 22 665	4 078	4 318
Biofuels in transport								
Biodiesels (certified)	10 441	10 864	- 32	- 34	- 10 441	- 10 864	0	0
Biogasoline (certified)	2 487	2 446	- 7	- 7	- 2 487	- 2 446	0	0
Other biofuels (certified)	132	195	0	- 1	- 132	- 195	0	0
Total renewables (normalised, certified biofuels)	**80 388**	**85 893**	**- 447**	**- 483**	**- 134 514**	**- 144 989**	**- 35 667**	**- 38 591**

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 RES developments: a global perspective

- RES provided 19.3 % of global final energy consumption in 2016 (REN21, 2017).
- Every year from 2005 to 2012, the EU was the region with the most new investments in renewable energy, as a proportion of global investment. However, it was surpassed by China in 2013, a country that, despite a drop from a share of 37 % in 2015 to 32 % of global investments in 2016, has established itself as the clear market leader since then.
- In terms of installed RES-E capacity per world region in 2016, the EU, with 422 GW installed comes second after China (545 GW). The EU has the largest solar PV and wind capacity in the world. China, however, is poised to overtake the EU as the leader in wind energy capacity. With 0.83 kW RES-E capacity installed per person, the EU is the clear world leader on a per capita basis. The annual average compound growth rate of 7.4 % in RES-E capacity per unit gross domestic product (GDP) over the period 2005-2016 shows that the EU is outpacing other regions in transforming the energy resource base of its economic activities.
- Of world regions with sufficient available data, the EU came fourth for per capita employment in the area of renewable energy in 2016, with 0.47 % of its labour force working in jobs related to renewable energy sources. In the EU, Germany, with 0.78 % of its labour force working in jobs related to RES, 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 ([32]). 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 renewable electricity 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.

4.1 RES-E capacities by region and main source

4.1.1 RES-E development by region

On a global scale, the installed RES-E capacity saw its largest increase ever in 2016, with an estimated 161 GW capacity added (IRENA, 2017a; REN21, 2017). For the second year in a row, more than half of all newly installed power capacity worldwide was of renewable origin, as RES accounted for an estimated 62 % of added net power generation capacity in 2016. As a result, the share of RES-E in global electricity generation rose to an estimated 24.5 % by the end

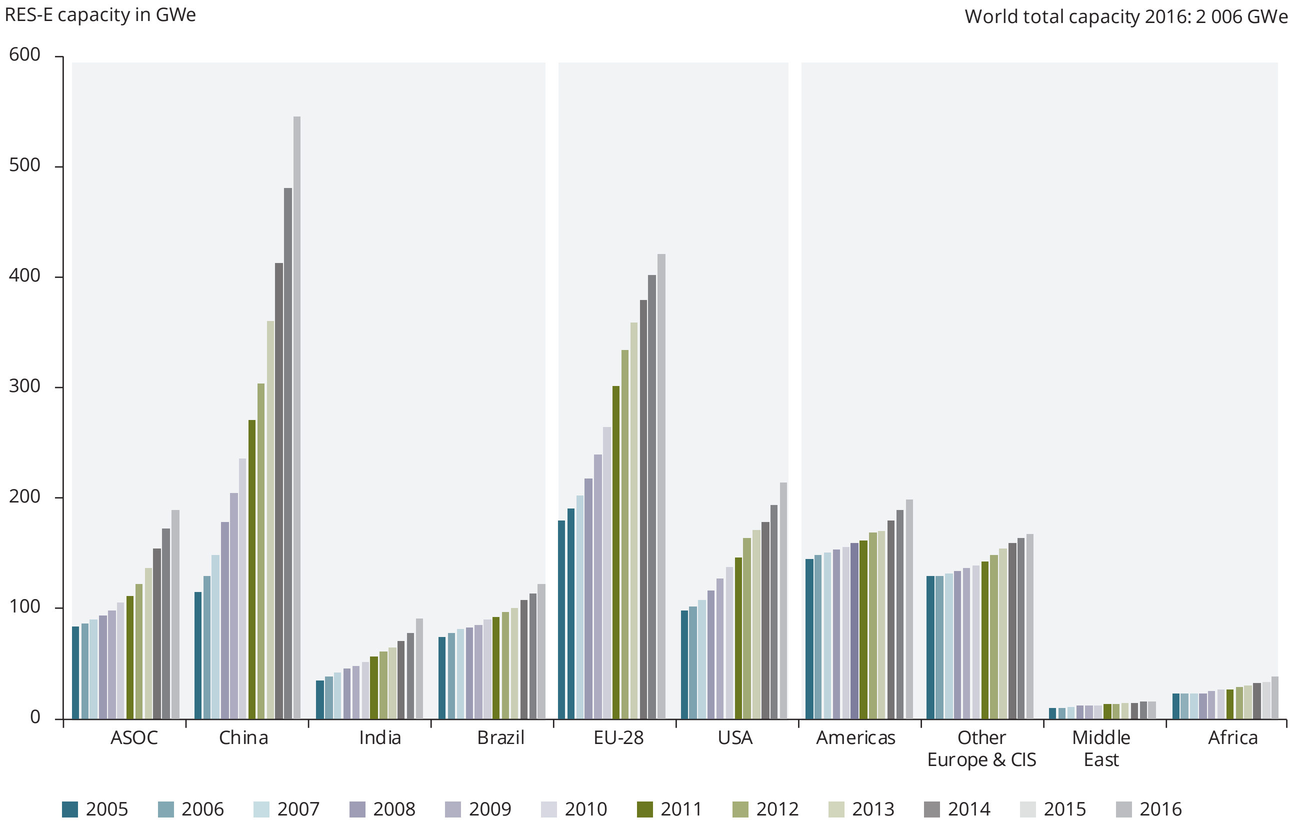
([32]) Traditional biomass energy refers to the burning of fuel wood, charcoal, agricultural and forest residues, or dung on open fires for cooking and heating. It is associated with considerable health and environmental impacts and it is still dominant in Africa (especially in sub-Saharan Africa) and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

of 2016 (of which 16.6 % is provided by hydropower). Meanwhile, however, the total global net capacity of coal-fired power stations also went up by 54 GW in 2016 and that of gas-fired generators by 37 GW. These figures represent the difference between the new assets coming on stream in 2016 and old ones being shut down. In general, most of the new coal assets are being installed in developing countries (most notably China and India), while most of the closures are in developed economies (Frankfurt School-UNEP, 2017).

World regions can be clustered into **three groups of countries** on the basis of their RES-E capacity developments between 2005 and 2016 (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, Asia and Oceania (ASOC) — excluding Brazil, China and India), electricity consumption is expanding rapidly, and both renewable energy and fossil fuel generation are being deployed to meet growing demand.
- The second group (EU 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 — Middle East, Other Europe and Commonwealth of Independent States (OE-CIS)), RES-E

Figure 4.1 RES-E capacities in selected world regions, 2005-2016



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

In the 2017 edition of the renewable electricity capacity statistics (IRENA, 2017a), pumped storage is no longer included in the total RES-E capacity. Data on wind and solar energy capacities were also revised (see footnote 29 in IRENA, 2017a). This causes slight differences from the total global RES-E capacities reported in the 2016 edition of the EEA report on renewable energy (EEA, 2017b).

Source: IRENA, 2017a.

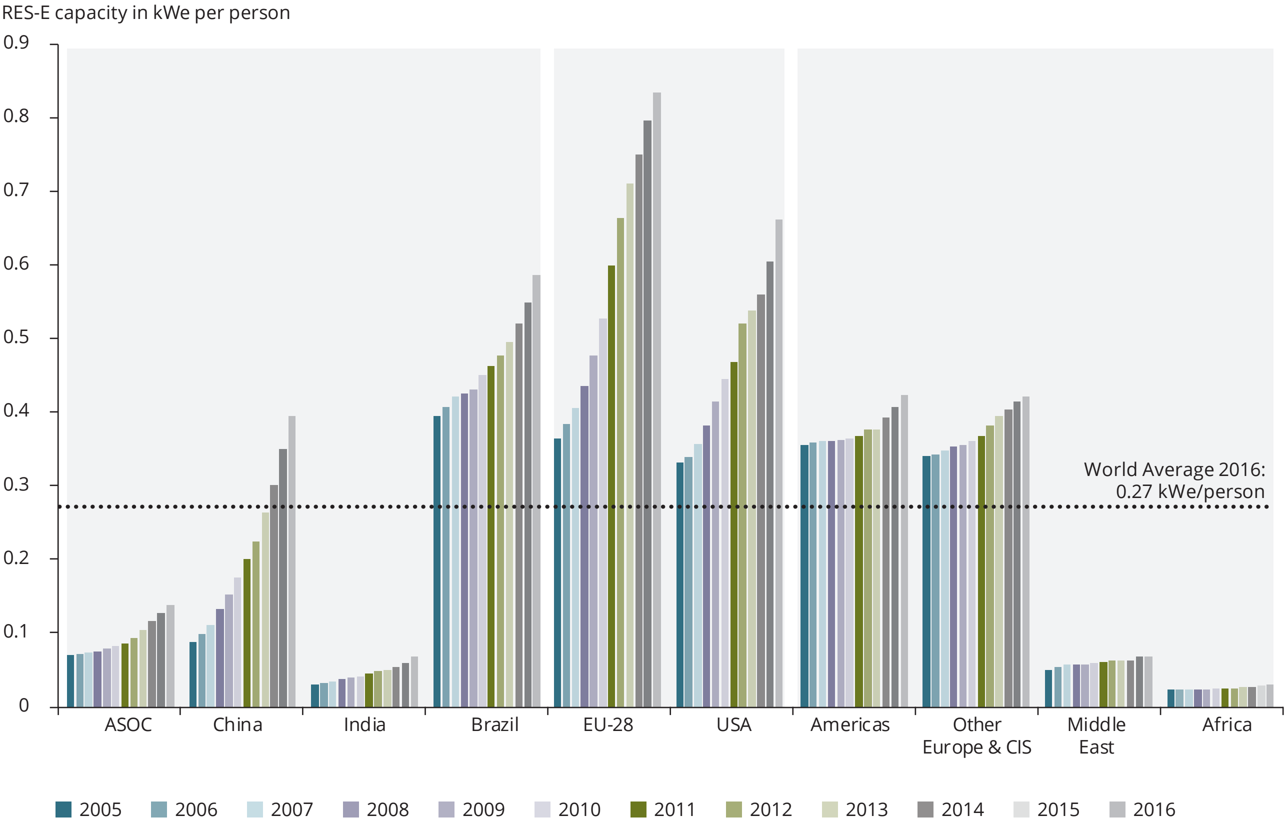
development has been relatively slow, despite growing electricity consumption.

The prime example of the **first group of countries** is China. With 545 GW of RES-E capacity installed and grid-connected, China managed to more than quadruple its RES-E capacity over the period 2005-2016, maintaining a strong compound annual growth rate of 15.2 %. With 307 GW installed (not including pumped storage), hydropower is by far the largest RES-E source, with wind power (149 GW) coming in a distant second. However, with 34.5 GW of solar PV capacity and 19.3 GW of wind capacity added in 2016, China was the world leader in terms of deployment of both technologies. Of the other countries in the ASOC region, India also more than doubled its RES-E capacity over the period 2005-2016 (from 35 to 91 GW) and has established itself as one of the top countries for wind, solar PV and hydropower capacity additions (IRENA, 2017a; REN21, 2017). Starting from a strong base in installed hydropower (71.0 GW or 95 % of the total RES-E capacity of 74.4 GW in 2005), Brazil has also experienced strong growth and diversification of its RES-E asset base. In 2016, hydropower accounted for 80 % (98 GW) of the total installed capacity of 123 GW.

In terms of RES-E development per capita or per GDP, the picture looks slightly different:

- With 47 kW/million EUR 2010 (2010 euro value at purchasing power parity) installed in 2016, Brazil is the best performing region, even though growth over the period 2005-2016 was relatively modest (14 % in total, or 1.2 % per year on average). In per capita terms (0.59 kW/person in 2016), growth has been stronger (49 %, or 3.7 % per year on average).

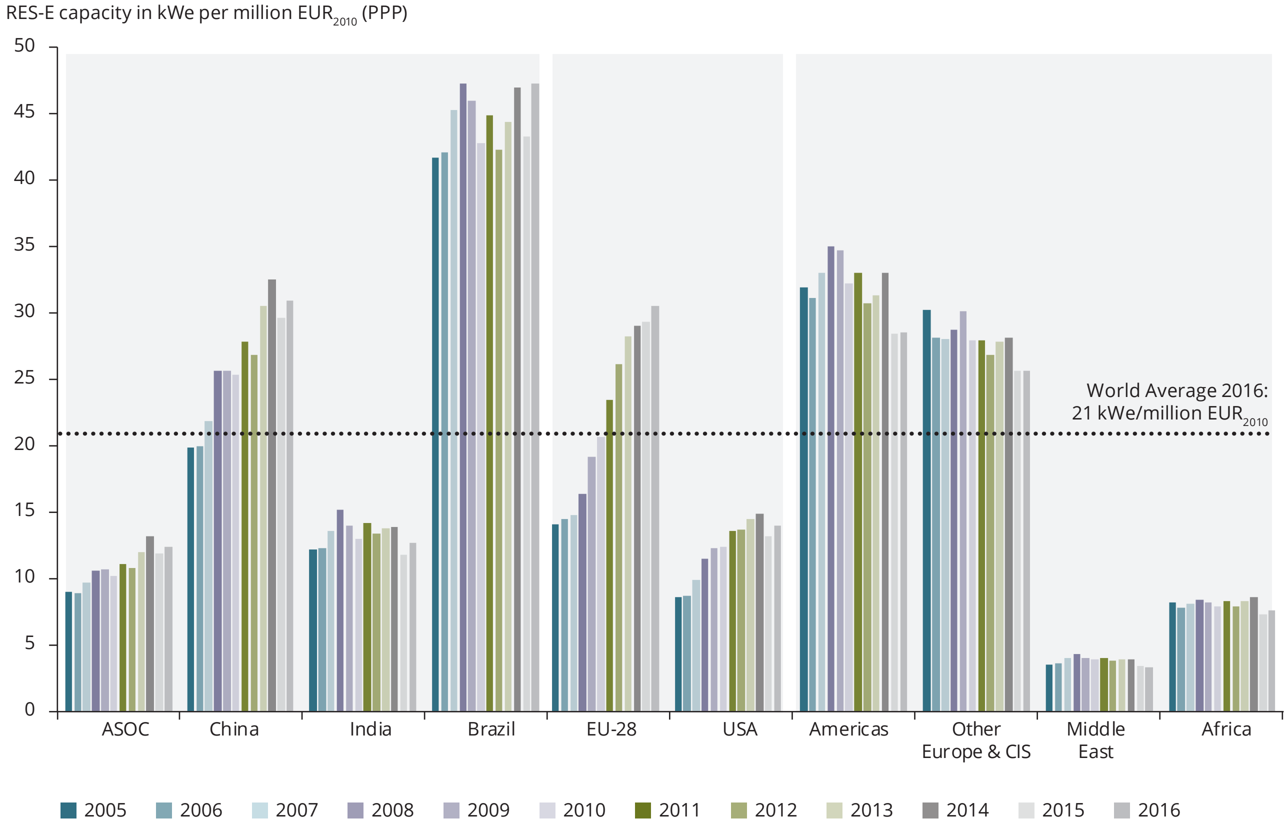
Figure 4.2 RES-E capacities per capita in selected world regions, 2005-2016



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

Sources: IRENA, 2017a; UN, 2017.

Figure 4.3 RES-E capacities per GDP in selected world regions, 2005-2016



Notes: ASOC refers to Asia and Oceania; OE-CIS refers to Other Europe and the Commonwealth of Independent States; information about the geographical coverage and regional aggregations is provided in the glossary. GDP expressed in constant 2010 euro value (EUR 2010) at purchasing power parity (PPP). Data for the EU, members of the EEA and accession countries were retrieved from the AMECO database. Data for other countries were retrieved from the World Bank. Exchange rates were retrieved from Eurostat.

Sources: EC DG Economic and Financial Affairs, 2017; Eurostat, 2017a; IRENA, 2017a; World Bank, 2017b.

- Due to its population control policies, China also experienced strong growth (14.6 % per year on average) in RES-E capacity per capita (0.39 kW/person in 2016), scoring well above the world average, but still lagging behind world leaders such as the EU (0.83 kW/person in 2016), the United States (0.66 kW/person in 2016) and Brazil (0.59 kW/person in 2016). With an average compound annual growth rate of 4.1 % in capacity per unit GDP, RES-E developments in China have even outpaced the strong economic growth over the period 2005-2016, with 30.9 kW/million EUR 2010 establishing the country on more or less the same level as the EU (30.5 kW/million EUR 2010) and the Americas (excluding Brazil and the United States) (28.5 kW/million EUR 2010).

- Within this group, India performs least well in per capita terms (at 0.07 kW/person, well below the world average) and per unit GDP (12.6 kW/million EUR 2010 and remaining almost stable over the period 2005-2016).

In the **second group of countries**, the EU more than doubled its RES-E capacity over the period 2005-2016, from 180 to 422 GW installed. With 154 GW installed, wind power is the EU's largest renewable power source, followed by hydropower (129 GW, not including pumped storage) and solar PV energy (102 GW). Continuing an ongoing trend, RES-E accounted for a large majority (86 %) of all new power capacity installations in the EU, dominated by wind power and solar PV energy (IRENA, 2017a).

- By 2016, the EU had established itself as the clear world leader in per capita RES-E capacity (0.83 kW/person). With a compound annual growth rate of 7.3 % in RES-E capacity per unit GDP over the period 2005-2016, the EU is also clearly outpacing other regions in the transformation of the energy resource base of its economic activities.

- In the United States, the installed RES-E capacity amounted to 215 GW in 2016. Hydropower is still the largest renewable power source (84 GW, not including pumped storage), closely followed by wind power (81 GW). However, with 8.2 GW of wind capacity added in 2016, wind power is poised to overtake hydropower as the United States' leading RES-E. The United States also scores well in per capita terms (0.66 kW/person), but the country's performance per unit GDP (14.0 kW/million EUR $_{2010}$) was below the world average in 2016. Furthermore, most of the growth in this parameter has happened over the period 2005-2010, while remaining almost stable over the period 2011-2016.

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 of RES-E capacity over the period 2005-2016 (from 145 to 198 GW), even though some of the countries with the highest RES-E shares are located in this region ([33]). Concerning the OE-CIS, the deployment of RES-E capacity is still mainly dominated by hydropower (with the Ukraine a notable exception), even though potential for sizable solar PV and onshore wind development exists throughout the region (Deng et al., 2015).

- Comparing the RES-E resource base to the size of the Middle East's economy reveals this region's weak performance on this parameter (3.3 kW/million EUR 2010, 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. Compared with 2015, in 2016 a drop of 32 % in RES investments was recorded in the Middle East and Africa (with notable exceptions for Egypt, Jordan and Kenya) (Frankfurt School-UNEP, 2017).

- Seen from a per capita perspective, the figure of 0.03 kW/person recorded in Africa is well below the world average.

- The Americas' performance on a per capita or per GDP basis is well above the world average, even though it should be noted that installed RES-E capacity per unit GDP has witnessed a drop from 33.0 kW/million EUR 2010 in 2014 to 28.5 kW/million EUR 2010 in 2015-2016, bringing this parameter again below the 2005 value of 30.9 kW/million EUR 2010.

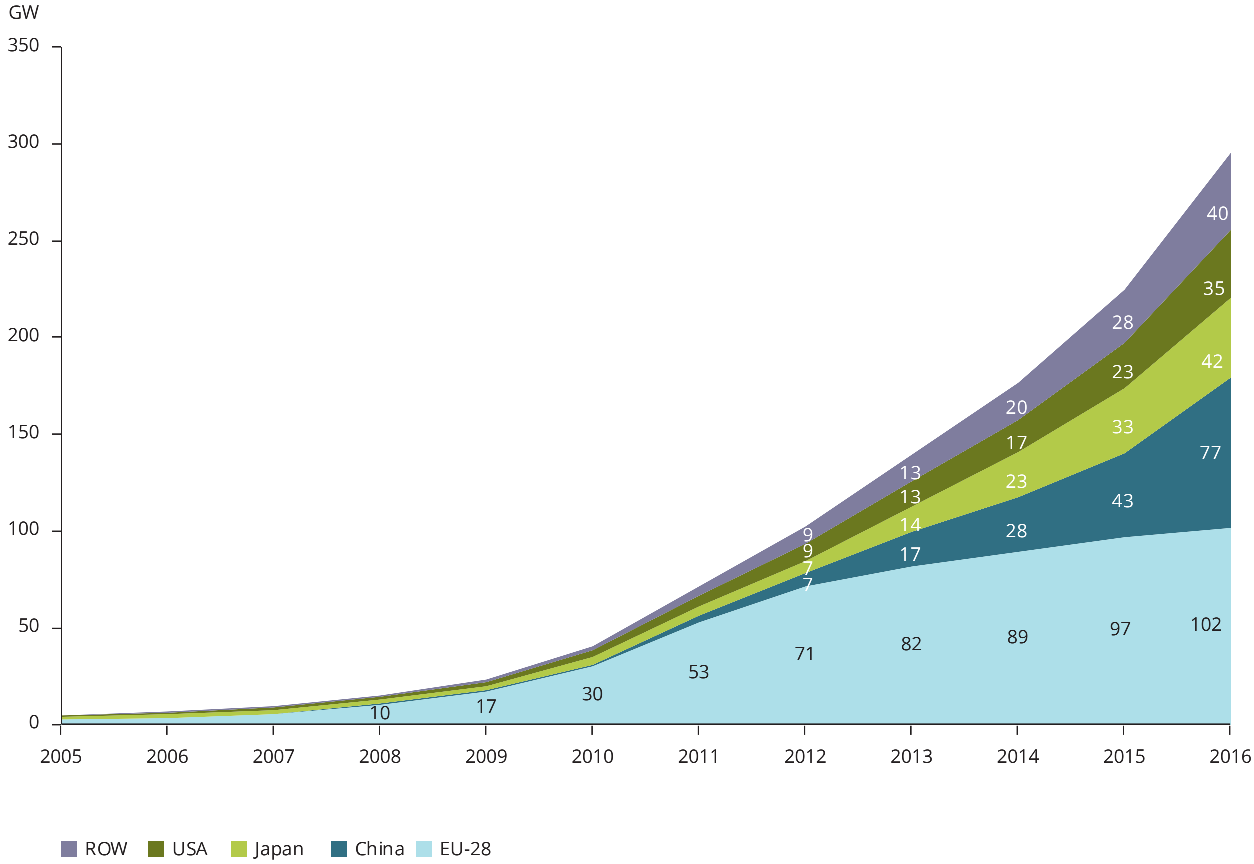
4.1.2 Wind and solar PV capacity deployment

Wind and solar PV energy are two of the progressive renewable energy technologies that are experiencing strong growth worldwide as a result of cost reductions achieved through innovation, technological learning and economies of scale. According to REN21 (2017), wind and solar power together made up about 81 % of the renewable power capacity added in 2016. 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 be vast, outstripping our energy needs (Deng et al., 2015). Despite impressive growth figures, only a small fraction of this vast potential has been realised to date. As a result, at the end of 2016, the estimated share of wind power (4.0 %) and solar PV energy (1.5 %) in global electricity production is still relatively small (REN21, 2017).

Through its clear leadership since 2005, the EU has contributed significantly to the demonstration and commercialisation of solar PV and wind power worldwide (Figure 4.4, Figure 4.5). These developments occurred essentially because of the implementation of various market-pull policy support instruments. As a result, by far the largest installed solar PV capacity in 2016 was in the EU (102 GW), followed by China (77 GW), Japan (42 GW) and the United States (35 GW). Together, the EU, China, Japan and the United States account for 86 % of the total installed solar PV capacity worldwide (Figure 4.4). Growth rates for solar PV energy between

([33]) For example, Costa Rica generated 98 % (74% from hydropower) of its electricity from renewable sources in 2015, while Uruguay generated 94.5 % (REN 21, 2017).

Figure 4.4 Growth in total solar PV capacity in the EU-28, the top three countries and the rest of the world (ROW), 2005-2016



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

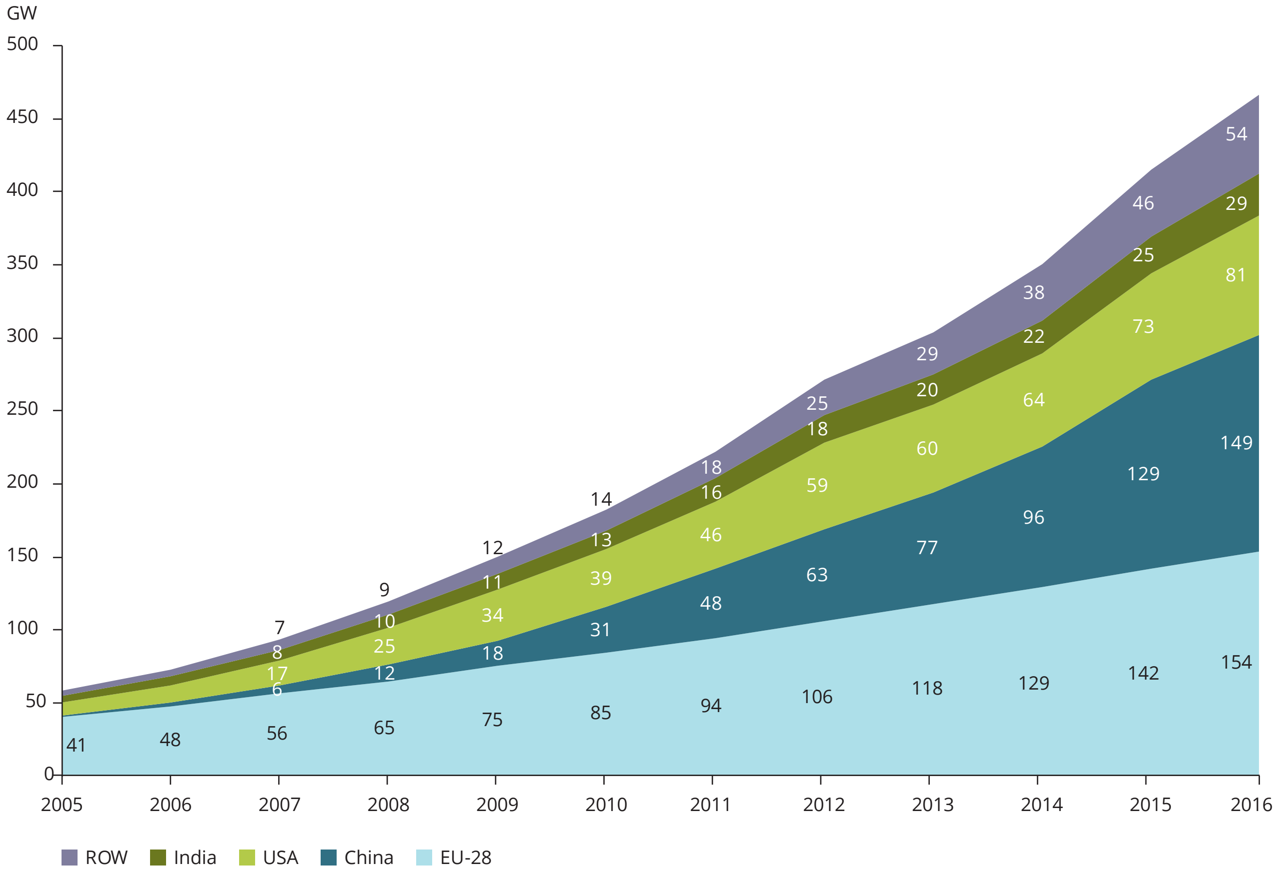
In the 2017 edition of the renewable electricity capacity statistics (IRENA, 2017a), data on the solar PV capacity installed in China and the United States have been revised. Previous data were based on data reported by the Global Solar Council, whereas 2017 data are based on data reported by official bodies. The main difference between the data sets is that the Global Solar Council adds up the direct current (DC) rating of solar panels, while the official bodies report the alternating current (AC) capacities (which are approximately 5 % lower than the DC rating). AC capacity reporting for solar PV energy is consistent with reporting for all other RES-E technologies.

Source: IRENA, 2017a.

2015 and 2016 in China (79 %), the United States (48 %) and Japan (25 %), however, by far surpassed the EU growth rate (5 %). It is also worth noting that, since 2010, solar PV deployment has taken place at increasing speed in other parts of the world, with Australia, Canada, India, South Africa, South Korea and Thailand having contributed significantly to that growth.

With 154 GW installed in 2016, the EU was still the region with the largest total installed wind power capacity (both onshore and offshore), closely followed by China (149 GW), the United States (81 GW) and India (29 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 2016. With a 15 % growth rate in 2016, China is poised to overtake the EU (8 % growth in 2016) as the world leader in wind energy. Significant additions to wind power capacity were also realised by Australia, Brazil, Canada, Chile, Japan and Mexico.

Figure 4.5 **Growth in total wind power capacity in the EU-28, the top three countries and the rest of the world (ROW), 2005-2016**



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

In the 2017 edition of the renewable electricity capacity statistics (IRENA, 2017a), 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 both 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 causes a downward revision of historical data.

Source: IRENA, 2017a.

4.2 Renewable energy investments

4.2.1 Share in global renewable energy investments

Throughout the period 2005-2016, Europe (including CIS) ([34]) had large shares of global new investments in renewable energy (see Table 4.1). However, investment activity spread rapidly to new markets. Viewed over time, Europe's investment share declined from 46 % to 25 % between 2005 and 2016 (19 % at its lowest in 2015), highlighting its 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 by China (27 %). Since then, China (32 % of global investments in 2016) has consolidated its position, although investments in 2016 went down by 32 % compared with 2015 (see also Figure 4.6). The share of investments in the United States has fluctuated by around 15 % over the last 5 years, rising to 19 % in 2016 (mainly due to a sharper decline in investments in other regions).

([34]) CIS refers to the Commonwealth of Independent States. For details, please see geographical notations in the list of abbreviations.

Table 4.1 Share of global new investments (%) in renewable energy per region, 2005-2016

World region	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Europe (including CIS)	46	42	42	45	46	47	44	35	25	23	19	25
China	12	10	10	14	21	17	16	23	27	31	37	32
ASOC (excluding China & India)	12	9	8	7	8	8	9	12	19	18	15	11
United States	16	26	25	20	13	14	18	16	14	14	16	19
Americas (excluding USA & Brazil)	5	3	3	3	3	5	3	4	5	5	4	3
Middle East & Africa	1	1	1	1	1	2	1	4	4	3	4	3
Brazil	4	5	6	6	4	3	4	3	2	3	2	3
India	4	5	4	3	2	4	5	3	3	3	3	4

Notes: ASOC refers to Asia and Oceania; CIS refers to the Commonwealth of Independent States; information about geographical coverage and regional aggregations is provided in the glossary. Dark green indicates the band of the highest shares; red denotes the band of the lowest; yellow illustrates the midpoint percentile.

Source: Frankfurt School-UNEP, 2017.

Together, China, Europe (including CIS) and the United States accounted for approximately 76 % of global new investments in renewable energy technologies in 2016.

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 investments in renewable energy. This took place against the backdrop of progress 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.

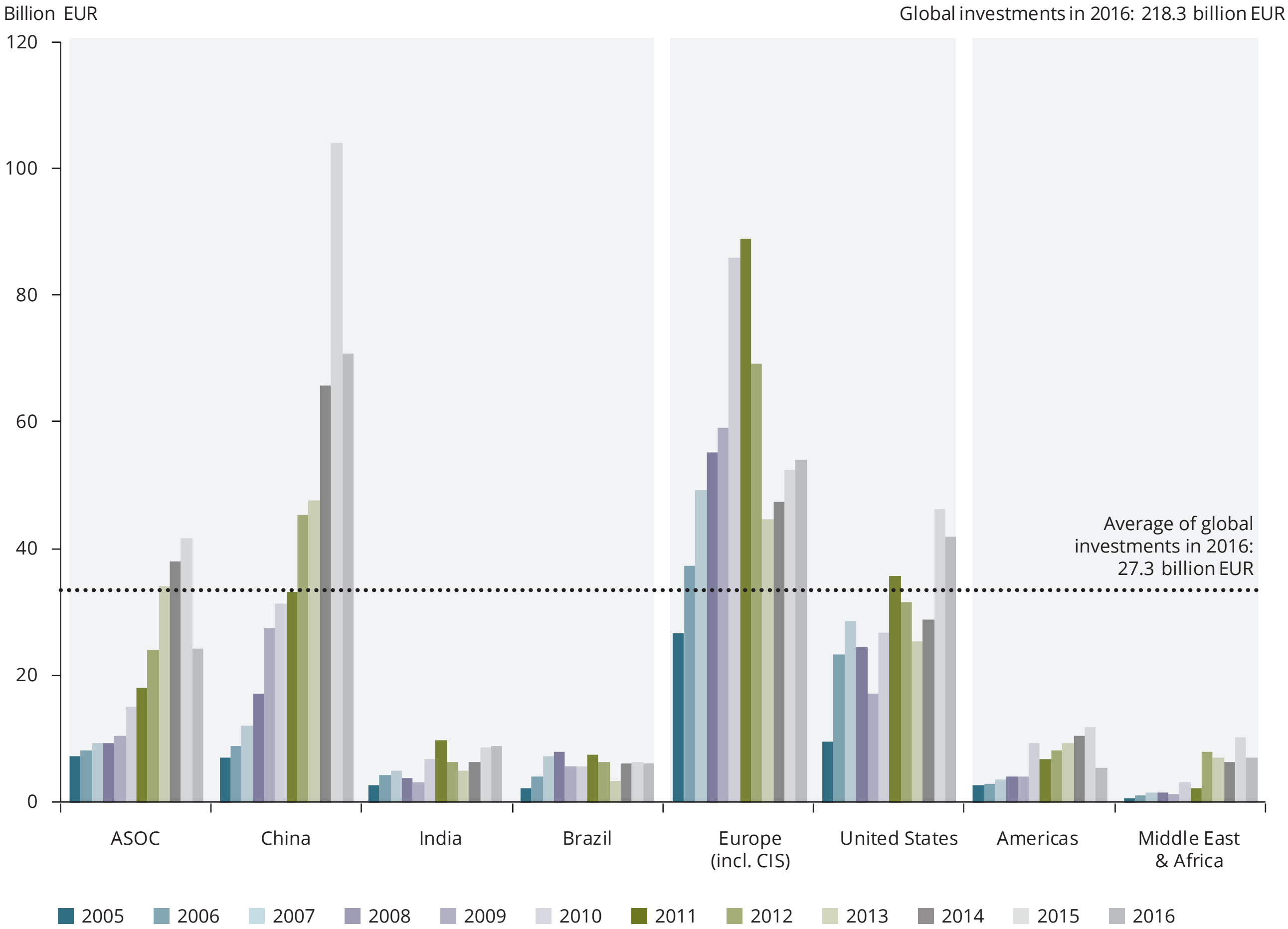
Taking into account the period from 2005 to 2011, in which there were no considerable policy uncertainties, the strongest average annual growth in renewable energy investments was distributed as follows: China (30 %), United States (25 %) and India (25 %). After difficult years in 2012-2013 (with declining 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 22 %), despite the fact that a new record in capacity addition (161 GW) was achieved (see Section 3.1.1). There are two main reasons for the decline in global investment in renewable energy during 2016 (Frankfurt School-UNEP, 2017). The first is the slowdown in investments in China (- 32 %), ASOC (- 42 %, mainly caused by a slowdown in investments in Japan), and some other emerging countries (Americas - 53 %; 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.

Overall, Figure 4.6 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 RES investments.

4.2.3 Total new investments by technology

New investment in renewable energy in 2016 continued to be dominated by solar (mostly solar PV) and wind power, which each accounted for roughly 47 % of total investment (Frankfurt School-UNEP, 2017). Over the period 2005-2016, total new investments in technology grew fastest for solar energy, as new investments were approximately eight times higher (in nominal

Figure 4.6 **Total new investments in renewable energy by region, 2005-2016**



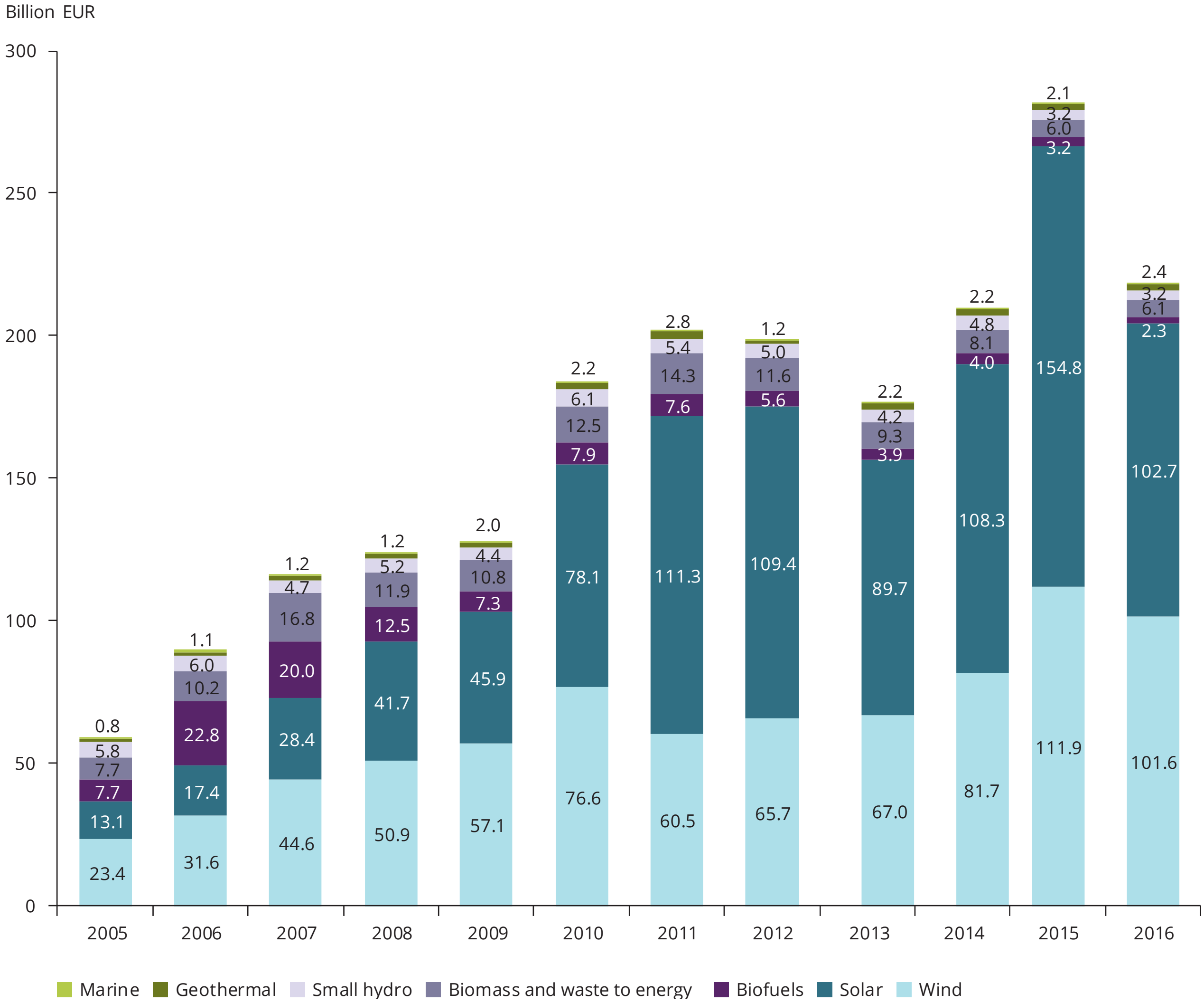
Notes: Figures converted to euros using annual exchange rates from Eurostat. ASOC refers to Asia and Oceania; CIS refers to the Commonwealth of Independent States; information about the geographical coverage and regional aggregations is provided in the glossary.

Sources: Frankfurt School-UNEP, 2017; Eurostat, 2017a.

terms) in 2016 than in 2005. Investments in solar energy as a share of total new investments became the largest in 2010, when they accounted for 43 % of total new investments (see Figure 4.7). From 2005 to 2009, investments in wind power made up the largest share of total investments. In 2010, they moved to second place after solar energy, but between 2011 and 2016, the share of investments in wind power again steadily increased almost up to the level of solar PV energy in 2016 (EUR 101.6 billion invested in wind power vs EUR 102.7 billion in solar PV). 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. 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. Investment in wind power was up 13 % in developed countries compared with 2015, but down 27 % compared with 2015 in developing countries (Frankfurt School-UNEP, 2017). Solar power investment declined in developed, and in developing and emerging countries, down 33 % and 35 %, respectively, compared with 2015. Significant cost reductions played a large role in these falling investment numbers, particularly for solar PV energy, which saw a global capacity addition of 32 % relative to 2015.

Investment in biomass/waste-to-energy and small-scale hydropower remained relatively stable over the period 2005-2016. The largest relative increase

Figure 4.7 Total global new investment by technology, 2005-2016



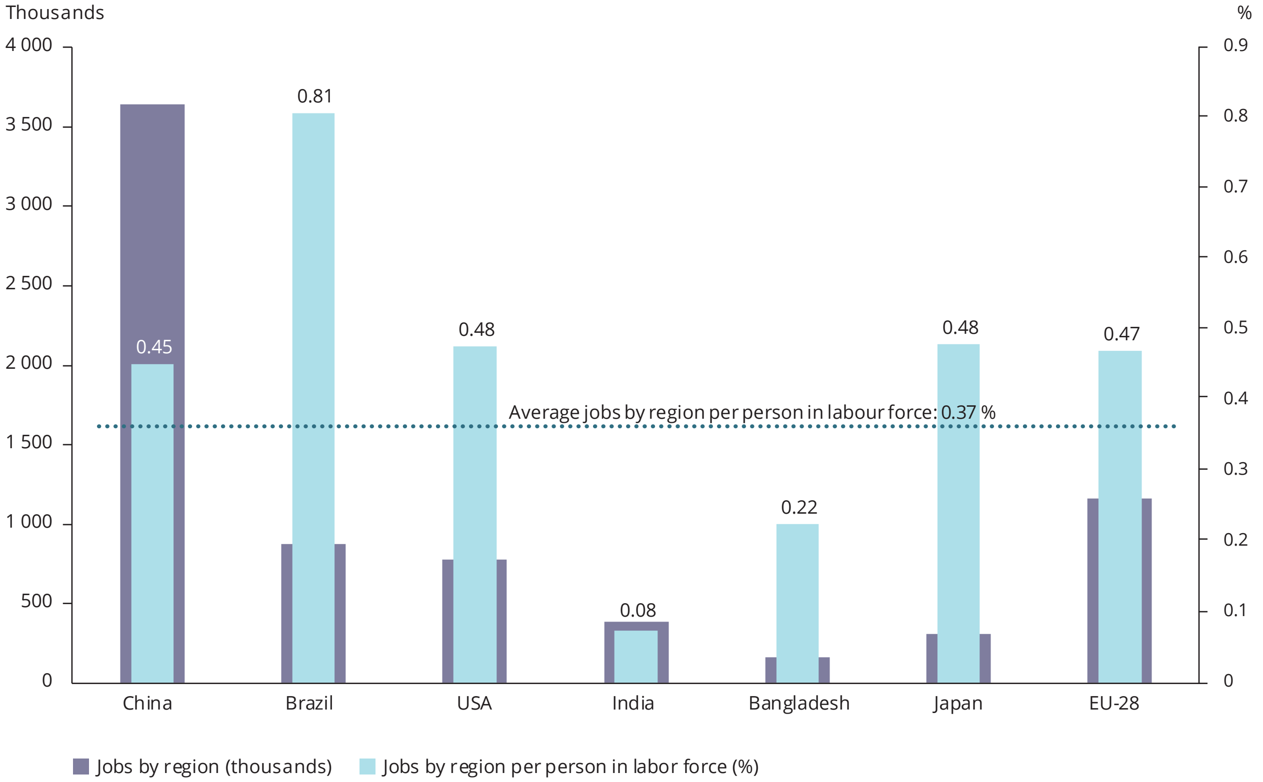
Source: Frankfurt School-UNEP, 2017.

in new investment in 2016 was for geothermal power, which was up 18 % compared with 2015 to EUR 2.4 billion. 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 2016, they were lower than in 2005. Plateauing of first-generation capacity may explain this decline, including uncertainties over future legislation and the delayed development of second-generation biofuels and costs.

4.3 Renewable energy employment

In 2016, a total of 8.3 million jobs (direct and indirect) were related to renewable energies globally (IRENA, 2017c). The regional distribution of these jobs is depicted in Figure 4.8. In absolute terms, China, the EU and Brazil were the largest employers. However, in relative terms (i.e. as a share of renewable energy jobs in the total workforce — the blue-hatched bars in Figure 4.8), the regional distribution looks different:

Figure 4.8 Direct and indirect jobs related to renewable energy in 2016, by region



Notes: The primary y-axis displays absolute numbers (thousands of jobs) in 2016. The secondary y-axis relates the absolute number of jobs to the total labour force of each region, thus displaying jobs per person in the labour force. The jobs displayed include both direct and indirect jobs along the value chain. All EU data are from 2015, as the 2016 data were not yet available.

Sources: Absolute jobs (IRENA, 2017c); jobs per person in the labour force (World Bank, 2017a).

- Brazil, Japan and the United States are the top three countries with respect to renewable energy-related jobs per person in the labour force in 2016, with the EU coming in just behind in fourth place.
- Within the EU, Germany was the number one per capita (labour force) employer (with 0.78 % of the total labour force working in the renewables sector), only slightly behind Brazil.

In the EU, the largest employers are the wind, solar PV and solid biomass industries. The number of renewable energy jobs in the EU fell slightly in 2015 to 1.16 million. Reductions in solar PV installations and module manufacturing resulted in a 22 % decrease in jobs in solar PV energy (IRENA, 2017c). At the same time, employment increased in geothermal, wind and solid biomass power.

Glossary and abbreviations

CHP	Combined heat and power
CSP	Concentrated solar power
CO_2e	Carbon dioxide equivalent — a measure used to compare the emissions from various greenhouse gases based upon their global warming potential
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)
EJ	Exajoule (one quintillion joules)
ENTSO-E	European Network of Transmission System Operators for Electricity
EPBD	Energy Performance of Buildings Directive (Directive2010/31/EU on the energy performance of buildings)
ETC/ACM	European Topic Centre on 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 Scheme
EU	European Union
EU-28	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, 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). With this, 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
IRENA	International Renewable Energy Agency
ktoe	Kilotonne 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
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)
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. 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 Bloomberg New Energy Finance (Bloomberg, 2017) 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. * 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). * 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 in order 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); Cook Islands; Fiji; French Polynesia; Kiribati; Laos; Macau, China; 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. * Under United Nations Security Council Resolution 1244/99.
Middle East	Bahrain; Islamic Republic of Iran; Iraq; Jordan; Israel; West Bank Gaza; Kuwait; Lebanon; Oman; Qatar; Saudi Arabia; Syrian Arab Republic; United Arab Emirates; and Yemen.

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Annex 1 Effect of renewable energy

The table below summarises the effect of the deployment of renewable energy since 2005 on GHG emissions and energy consumption by country in 2015, as discussed in Section 2.3 of this report.

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	81.0	- 10.8	- 12	22.7	- 3.5	- 13	31.3	- 0.4	- 1
Belgium	121.6	- 8.4	- 6	42.0	- 3.0	- 7	45.7	- 0.2	0
Bulgaria	62.0	- 5.7	- 8	13.4	- 1.6	- 10	17.9	- 0.6	- 3
Croatia	23.9	- 1.7	- 7	6.0	- 0.5	- 7	8.0	- 0.2	- 3
Cyprus	9.2	- 0.5	- 5	2.1	- 0.1	- 7	2.2	0.0	- 2
Czech Republic	128.8	- 11.5	- 8	32.3	- 3.2	- 9	39.9	- 0.5	- 1
Denmark	51.0	- 13.2	- 21	11.5	- 4.4	- 28	16.5	- 2.0	- 11
Estonia	18.1	- 2.0	- 10	5.4	- 0.6	- 9	6.2	- 0.1	- 2
Germany	926.5	- 125.7	- 12	256.3	- 33.9	- 12	292.9	- 9.7	- 3
Greece	98.6	- 7.4	- 7	20.8	- 2.1	- 9	23.7	- 1.1	- 4
Finland	57.5	- 9.3	- 14	15.3	- 2.9	- 16	31.9	- 0.1	0
France	474.6	- 28.5	- 6	123.5	- 9.5	- 7	239.3	- 3.2	- 1
Hungary	61.6	- 6.0	- 9	16.9	- 2.1	- 11	23.3	0.2	1
Ireland	62.4	- 3.7	- 6	13.0	- 1.2	- 8	14.0	- 0.5	- 3
Italy	442.8	- 49.7	- 10	125.9	- 16.4	- 12	149.6	- 3.6	- 2
Latvia	11.6	- 0.8	- 6	2.7	- 0.2	- 7	4.3	0.0	0
Lithuania	20.3	- 2.1	- 9	4.9	- 0.7	- 12	5.8	0.0	- 1
Luxembourg	11.7	- 0.4	- 4	3.5	- 0.2	- 4	4.1	0.0	0
Malta	2.6	- 0.1	- 4	0.6	0.0	- 5	0.8	0.0	- 2
Netherlands	206.7	- 7.1	- 3	72.1	- 2.3	- 3	64.6	- 0.5	- 1
Poland	387.7	- 20.3	- 5	86.5	- 5.8	- 6	90.0	- 0.6	- 1
Portugal	72.1	- 8.7	- 11	17.8	- 2.3	- 11	21.7	- 1.4	- 6
Romania	117.8	- 10.6	- 8	24.0	- 2.9	- 11	31.3	- 1.4	- 4
Slovakia	41.4	- 2.4	- 5	10.7	- 0.9	- 8	15.4	0.0	0
Slovenia	16.9	- 1.1	- 6	4.1	- 0.4	- 9	6.5	- 0.1	- 1
Spain	350.4	- 37.8	- 10	90.0	- 11.2	- 11	117.1	- 4.6	- 4
Sweden	55.9	- 21.1	- 27	13.7	- 6.6	- 33	43.7	- 1.8	- 4
United Kingdom	536.9	- 50.0	- 9	156.1	- 16.0	- 9	183.0	- 3.1	- 2
All 28 Member States	**4 452**	**- 447**	**- 9**	**1 194**	**- 135**	**- 10**	**1 531**	**- 36**	**- 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 September 2017, when no officially reported RES data for 2016 were available.

Some improvements in the methodology were made for the estimation of 2015 RES shares:

- The calculation is implemented 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 revoked:

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

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

- EEA
  - Final energy consumption estimate for 2016 in the industry sector
  - Final energy consumption estimate for 2016 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
  - Supply of electricity [nrg_105m]
    - Consumption of electricity
    - Total gross production
    - Electricity imports and exports
    - Gross production from hydro and pumped storage
- EurObserv'ER
  - Biofuels barometer 2017
    - Consumption of liquid and gaseous biofuels in transport
    - Share of certified biofuels
  - Photovoltaic barometer 2017
    - Electricity production from solar PV power
  - Solar thermal barometer 2017
    - Total heat production from solar thermal installations
  - Wind energy barometer 2017

  - Electricity production from wind energy

- Member State data (not included by default, but received during Eionet consultation)
  - France: actual electricity generation by technology (RTE)
  - Germany: final energy consumption in industry and tertiary sectors (UBA)
  - Malta: total generation of PV electricity (government)
  - Spain: share of certified biofuels (MAPAMA)
  - United Kingdom: SHARES summary sheet with no further comment (BEIS).

Annex 3 Discussion of main 2015/2016 changes by sector and country

Changes in calculated RES shares proxies for the years 2015/2016 are compared with historically (2005-2015) observed changes in RES shares by way of descriptive statistics to determine statistically significant deviations from the historical changes.

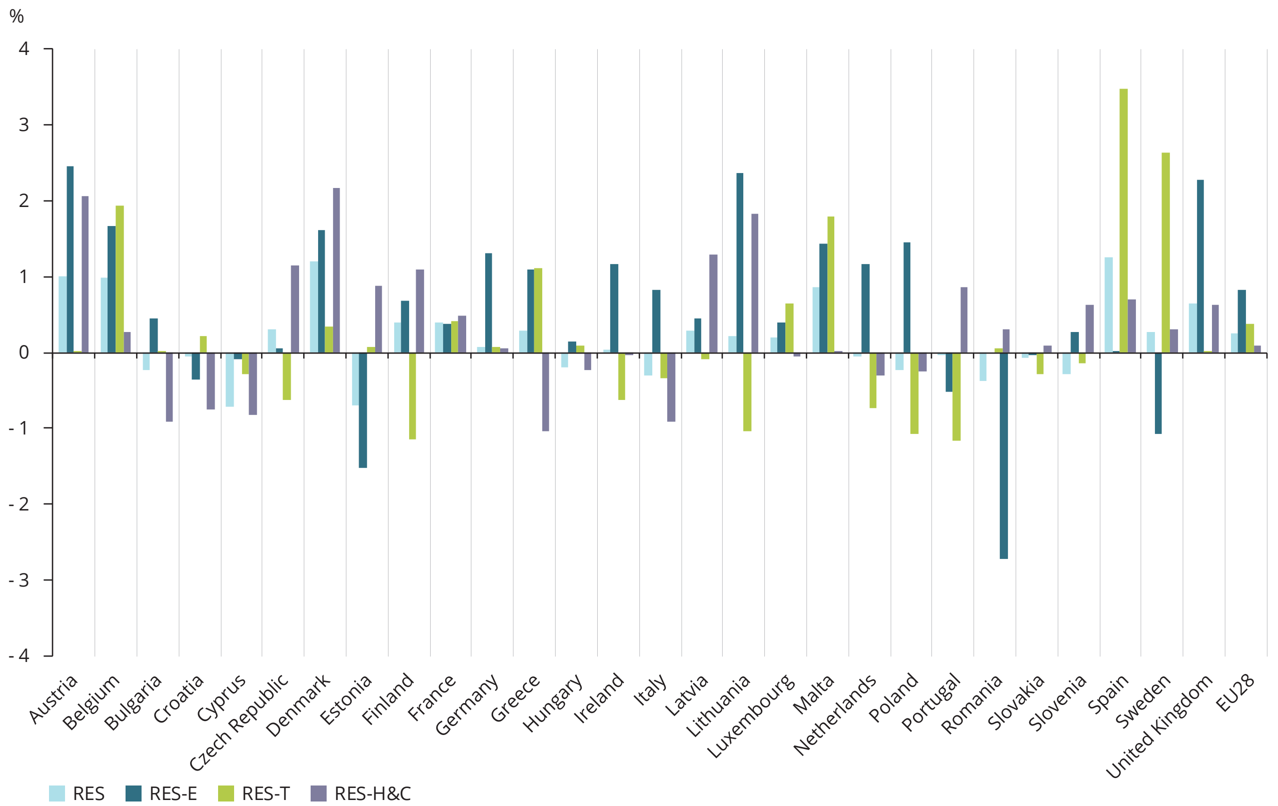
If, in 2015/2016, changes in RES shares were significantly different but within the historically observed minima and maxima, the results were considered plausible without further analysis. If the 2015/2016 changes in RES shares were higher or lower than historically observed changes, further in-depth 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 2016 RES shares and 2015 RES shares, while Table A3.1 provides detailed insights.

RES-E

The change in the RES-E shares proxy for 2016 compared with 2015 (+ 0.9 %) for the whole EU is smaller by 0.7 standard deviations than the average annual change in RES-E shares in the period from 2005 to 2015 (+ 1.5 %). This is a statistically significant deviation from the time series (p=0.04) but still larger than, for example, the 2010/2009 change (+ 0.7 %).

Figure A3.1 Changes in approximated RES shares in 2016 compared with 2015, in percentage points



Source: EEA.

Table A3.1 Shares of renewable energy in 2015 and 2016

	RES (%)			RES-E (%)			RES-T (%)			RES-H&C (%)		
	2015	2016	Delta	2015	2016	Delta	2015	2016	Delta	2015	2016	Delta
Austria	33.0	34.0	1.0	70.3	72.7	2.4	11.4	11.4	0.0	32.0	34.1	2.1
Belgium	7.9	8.9	1.0	15.4	17.1	1.7	3.8	5.8	1.9	7.6	7.9	0.3
Bulgaria	18.2	18.0	- 0.2	19.1	19.6	0.4	6.5	6.5	0.0	28.6	27.7	- 0.9
Croatia	29.0	29.0	- 0.1	45.4	45.1	- 0.4	3.5	3.8	0.2	38.6	37.8	- 0.8
Cyprus	9.4	8.7	- 0.7	8.4	8.4	- 0.1	2.5	2.2	- 0.3	22.5	21.7	- 0.8
Czech Republic	15.1	15.4	0.3	14.1	14.1	0.1	6.5	5.8	- 0.6	19.8	21.0	1.1
Denmark	30.8	32.0	1.2	51.3	52.9	1.6	6.7	7.0	0.3	39.6	41.8	2.2
Estonia	28.6	27.9	- 0.7	15.1	13.6	- 1.5	0.4	0.5	0.1	49.6	50.5	0.9
Finland	39.3	39.7	0.4	32.5	33.1	0.7	22.0	20.8	- 1.2	52.8	53.8	1.1
France	15.2	15.6	0.4	18.8	19.1	0.4	8.5	8.9	0.4	19.8	20.2	0.5
Germany	14.6	14.7	0.1	30.7	32.0	1.3	6.8	6.9	0.1	12.9	12.9	0.0
Greece	15.4	15.7	0.3	22.1	23.2	1.1	1.4	2.5	1.1	25.9	24.9	- 1.0
Hungary	14.5	14.3	- 0.2	7.3	7.4	0.1	6.2	6.3	0.1	21.3	21.0	- 0.2
Ireland	9.2	9.2	0.0	25.2	26.4	1.2	6.5	5.9	- 0.6	6.4	6.4	0.0
Italy	17.5	17.2	- 0.3	33.5	34.3	0.8	6.4	6.1	- 0.3	19.2	18.3	- 0.9
Latvia	37.6	37.8	0.3	52.2	52.7	0.4	3.9	3.8	- 0.1	51.8	53.1	1.3
Lithuania	25.8	26.0	0.2	15.5	17.9	2.4	4.6	3.5	- 1.0	46.1	47.9	1.8
Luxembourg	5.0	5.2	0.2	6.2	6.6	0.4	6.5	7.1	0.6	6.9	6.9	- 0.1
Malta	5.0	5.9	0.9	4.2	5.7	1.4	4.7	6.5	1.8	14.1	14.1	0.0
Netherlands	5.8	5.8	- 0.1	11.1	12.3	1.2	5.3	4.5	- 0.7	5.5	5.2	- 0.3
Poland	11.8	11.5	- 0.2	13.4	14.9	1.4	6.4	5.4	- 1.1	14.3	14.0	- 0.3
Portugal	28.0	27.9	0.0	52.6	52.1	- 0.5	7.4	6.2	- 1.2	33.4	34.2	0.9
Romania	24.8	24.4	- 0.4	43.2	40.4	- 2.7	5.5	5.5	0.1	25.9	26.2	0.3
Slovakia	12.9	12.8	- 0.1	22.7	22.6	0.0	8.5	8.2	- 0.3	10.8	10.9	0.1
Slovenia	22.0	21.7	- 0.3	32.7	33.0	0.3	2.2	2.1	- 0.1	34.1	34.7	0.6
Spain	16.2	16.3	0.1	36.9	36.9	0.0	1.7	1.8	0.0	16.8	17.5	0.7
Sweden	53.9	54.2	0.3	65.8	64.7	- 1.1	24.0	26.6	2.6	68.6	68.9	0.3
United Kingdom	8.2	8.6	0.4	22.4	24.8	2.5	4.4	4.5	0.0	5.5	5.5	- 0.1
European Union	**16.7**	**16.8**	**0.1**	**28.8**	**29.7**	**0.9**	**6.7**	**6.8**	**0.1**	**18.6**	**18.6**	**0.0**

Sources: EEA; Eurostat, 2017b.

The calculated changes in the RES-E shares proxies for 17 Member States are within one standard deviation of the average changes for the 2005-2015 period. In 16 Member States, the 2015/2016 change is significantly different from the 2005-2015 average at the 5 % level (Austria, Belgium, Croatia, Cyprus, Czech Republic, Estonia, Germany, Ireland, Lithuania, Malta, Netherlands, Portugal, Romania, Spain, Slovakia and Sweden). Of those, 11 Member States showed changes in RES-E shares that were larger than the historically observed average plus or minus one standard deviation.

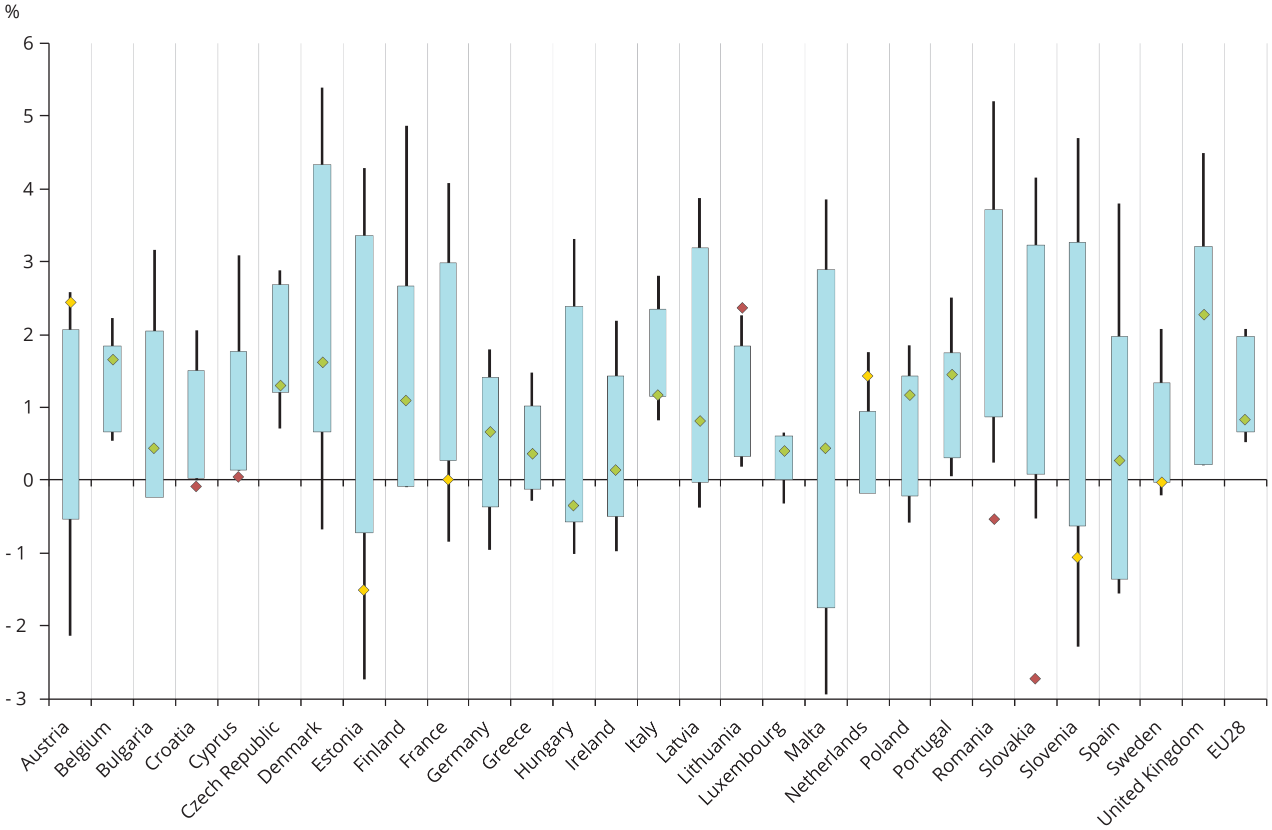
The following five Member States show larger changes in RES-E shares than have been historically observed.

Cyprus: The absolute contribution of electricity generation increased (+ 6 %), but electricity consumption also increased (+ 8 %), which overcompensated for the growth in renewable energy leading to a decreasing RES-E share.

Czech Republic: The absolute contribution of electricity generation increased (+ 2 %), but electricity consumption also increased (+ 2 %), which partly overcompensated for the growth in renewable energy. However, the RES-E share still grew in 2016 but more slowly than in previous years.

Lithuania: All types of renewable electricity generation increased. Wind energy, already the most significant

Figure A3.2 **Changes in RES-E shares 2015/2014, compared with historically observed annual changes in RES-E shares (2005-2015), in percentage points**



Notes: Blue bars show the range of average annual changes in RES-E shares between 2005 and 2015, 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 2016 compared with 2015. Green: change 2015/2016 within one standard deviation of changes from 2005 to 2015. Yellow: change 2015/2016 within minimum and maximum change from 2005 to 2015. Red: change 2015/2016 larger than changes from 2005 to 2015.

Source: EEA.

renewable energy source in the electricity sector, had the strongest absolute increase in the whole time series.

Portugal: The absolute contribution of electricity generation increased (+ 2 %), but electricity consumption also increased (+ 3 %), which overcompensated for the growth in renewable energy leading to a decreasing RES-E share for the first time in more than a decade.

Romania: The absolute contribution of electricity generation increased (+ 3 %), but electricity consumption also increased (+ 10 %), which overcompensated for the growth in renewable energy leading to a decreasing RES-E share for the first time since 2010.

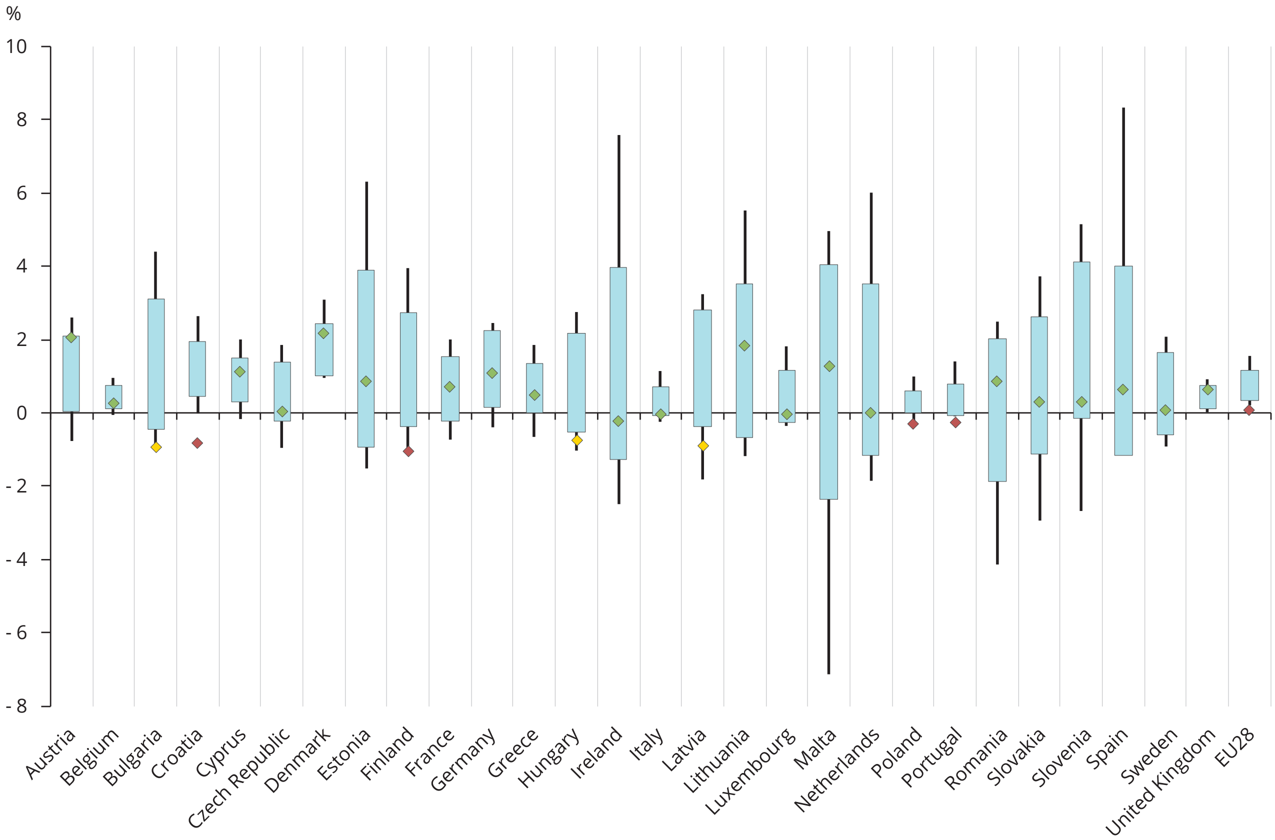
RES-H&C

At the EU level, the RES-H&C shares proxy for 2016 was almost the same as that in 2015 (+ 0.02 %). This slight increase is lower, by 1.8 standard deviations, than the average annual change in RES-H&C shares in the period 2005-2015 (+ 0.8 %). This deviation is significant at the 5 % level (p=0.0001).

The calculated changes in the RES-H&C shares proxies for 20 Member States are within one standard deviation of the average changes for the period 2005-2014. In 13 Member States, the 2015/2016 change is significantly different from the 2005-2015 average at the 5 % level (Belgium, Bulgaria, Croatia, Cyprus, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Poland, Sweden and United Kingdom). Of those, eight Member States showed changes in RES-E shares that are larger than the historically observed average plus or minus one standard deviation.

The following four 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.

Figure A3.3 Change in RES-H&C shares 2015/2016, compared with historically observed annual changes in RES-H&C shares (2005-2015), in percentage points



Notes: Blue bars show the range of average annual changes in RES-H&C shares between 2005 and 2015, 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 2016 compared with 2015. Green: change 2014/2016 within one standard deviation of changes from 2005 to 2015. Yellow: change 2015/2016 within minimum and maximum change from 2005 to 2015. Red: change 2015/2016 larger than changes from 2005 to 2015.

Source: EEA.

Cyprus: It is estimated that the energy consumption for heating and cooling increased by 2 % in 2016, while renewable H&C decreased by 1 %. This led to a decrease in the RES-H&C share.

Greece: It is estimated that the energy consumption for heating and cooling increased by 3 % in 2016, while renewable H&C decreased by 1 %. This led to a decrease in the RES-H&C share.

Netherlands: Renewable energy consumption in the heating and cooling sector is expected to stay almost constant, despite an increase in total energy consumption for heating and cooling. This would lead to a slight decrease in the RES-H&C share.

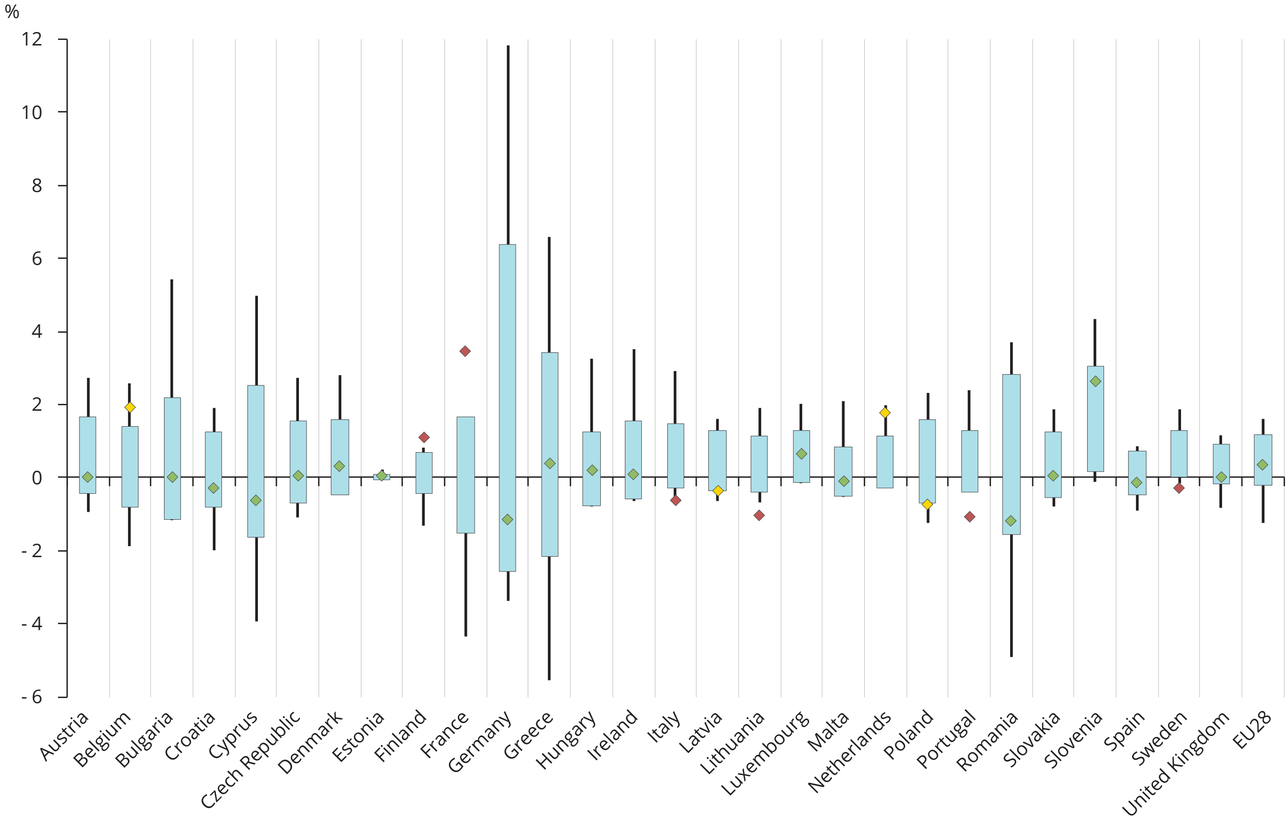
Poland: Renewable energy consumption in the heating and cooling sector is expected to decrease slightly, despite an increase in total energy consumption for heating and cooling. This would lead to a slight decrease in the RES-H&C share.

RES-T

At the EU level, the RES-T shares proxy for 2016 increased only slightly compared with 2015 (+ 0.06 %). 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 2015 (+ 0.5 %), but it is not significantly different at the 5 % level (p=0.07) because the 2011/2010 change (– 1.2 %) showed a decrease in the RES-T share.

The calculated changes in the RES-T shares proxies for 19 Member States are within one standard deviation of the average changes for the 2005-2015 period. In 12 Member States, the 2015/2016 change was significantly different from the 2005-2015 average

Figure A3.4 Changes in RES-T shares 2015/2016, compared with historically observed annual changes in RES-T shares (2005-2015), in percentage points



Notes: Blue bars show the range of average annual changes in RES-T shares between 2005 and 2015, 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 2016 compared with 2015. Green: change 2015/2016 within one standard deviation of changes from 2005 to 2015. Yellow: change 2015/2016 within minimum and maximum change from 2005 to 2015. Red: change 2015/2016 larger than changes from 2005 to 2015.

Source: EEA.

at the 5 % level (Belgium, Finland, Greece, Ireland, Italy, Lithuania, Malta, Netherlands, Poland, Portugal, Sweden and Slovakia). Of those, nine Member States showed changes in RES-T shares that are larger than the historically observed average plus or minus one standard deviation.

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

Greece: The main reason for the strong increase in RES-T share is a doubling in the share of certified biofuels, while total biofuel consumption is almost constant. In addition, there was a slight increase in renewable electric transport and a decrease in gasoline and diesel fuel consumption in transport.

Ireland: Consumption of (certified) biofuels decreased by 7 %, while consumption of gasoline and diesel fuel increased by 3 %.

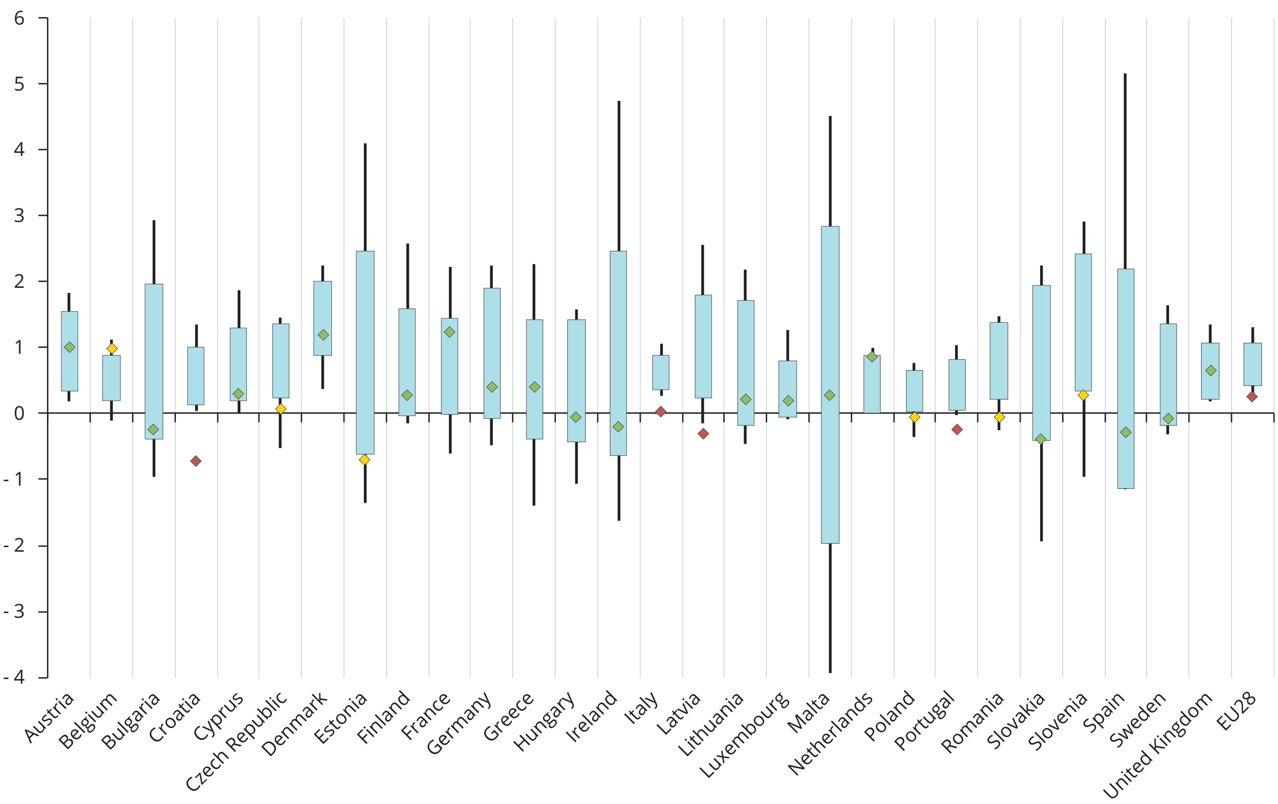
Lithuania: Consumption of (certified) biofuels decreased by 16 %, while consumption of gasoline and diesel fuel increased by 10 %.

Poland: Consumption of (certified) biofuels decreased by 9 %, while consumption of gasoline and diesel fuel increased by 13 %.

Slovakia: Consumption of (certified) biofuels was constant, while consumption of gasoline and diesel fuel increased by 5 %.

Spain: Spain implemented a sustainability certification system starting in 2016. While its total quantity of biofuels consumed in transport changed only slightly, the share of certified biofuels that can be accounted towards the RES-T target jumped from 0 % in 2015 to 100 % in 2016. Biofuels account for about two thirds of all renewables consumed in Spain's transport sector in 2016.

Figure A3.5 Change in RES shares 2015/2016, compared with historically observed annual changes in RES shares (2005-2015), in percentage points



Notes: Blue bars show the range of average annual changes in RES shares between 2005 and 2015, 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 in 2016 compared with 2015. Green: change 2015/2016 within one standard deviation of changes from 2005 to 2015. Yellow: change 2014/2016 within minimum and maximum change from 2005 to 2015. Red: change 2014/2016 larger than changes from 2005 to 2015.

Source: EEA.

Total RES

The change in the RES shares proxy for 2016 compared with 2015 (+ 0.14 %) for the whole EU was lower than the observed average annual change in RES shares in the period from 2005 to 2015 (+ 0.8 %). This is significantly different at the 5 % level (p=0.0001).

The calculated changes in the RES shares proxies for 18 Member States are within one standard deviation of the average changes in the period from 2005 to 2014. In 17 Member States, the 2014/2015 change was significantly different from the 2005-2015 average at the 5 % level (Belgium, Bulgaria, Cyprus, Czech Republic, Estonia, Germany, Hungary, Ireland, Italy, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Spain and Sweden). Of those, 10 Member States showed changes in RES shares that are larger than the historically observed average plus or minus one standard deviation.

In four Member States, progress in renewable energy was poorer than in any year in the period 2004-2015: In Cyprus, Italy and Poland, RES shares even decreased and the very small increases in Ireland are lower than any previous progress.

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 2015 versus RES shares 2015

Table A3.2 provides insights into the difference between approximated 2015 RES shares (calculated last year) and actual 2015 RES shares (available for the first time this year). For some countries, these differences can be larger, especially when looking at the amount of renewables consumed in transport. These differences can stem from different methodologies used by countries following the adoption of the ILUC Directive (EU, 2015a), as well as due to the difficulty to replicate the specific accounting rules in the RED concerning very specific shares of renewables consumed in transport (see also Section 1.2.2 Scope of the report).

Table A3.2 2015 RES shares by sector compared with approximated RES shares by sector

	RES (%)			RES-E (%)			RES-T (%)			RES-H&C (%)		
	Final	Proxy	Delta	Final	Proxy	Delta	Final	Proxy	Delta	Final	Proxy	Delta
Austria	33.0	33.6	0.6	70.3	70.0	- 0.3	11.4	8.3	- 3.1	32.0	33.9	1.9
Belgium	7.9	7.3	- 0.6	15.4	12.8	- 2.6	3.8	3.3	- 0.5	7.6	7.6	- 0.1
Bulgaria	18.2	18.4	0.2	19.1	19.3	0.2	6.5	5.3	- 1.2	28.6	29.1	0.5
Croatia	29.0	27.5	- 1.5	45.4	40.0	- 5.4	3.5	2.1	- 1.4	38.6	35.0	- 3.6
Cyprus	9.4	9.1	- 0.3	8.4	8.3	- 0.2	2.5	2.2	- 0.3	22.5	22.3	- 0.2
Czech Republic	15.1	13.6	- 1.5	14.1	14.0	- 0.1	6.5	6.0	- 0.5	19.8	17.4	- 2.4
Denmark	30.8	30.6	- 0.3	51.3	50.8	- 0.6	6.7	5.3	- 1.4	39.6	40.0	0.4
Estonia	28.6	27.9	- 0.7	15.1	16.8	1.7	0.4	0.2	- 0.2	49.6	46.9	- 2.7
Finland	39.3	39.5	0.2	32.5	32.6	0.1	22.0	22.0	0.0	52.8	52.3	- 0.5
France	15.2	14.5	- 0.7	18.8	18.5	- 0.2	8.5	7.8	- 0.7	19.8	18.0	- 1.8
Germany	14.6	14.5	0.0	30.7	30.0	- 0.7	6.8	6.4	- 0.4	12.9	12.7	- 0.2
Greece	15.4	15.5	0.0	22.1	22.5	0.4	1.4	1.4	- 0.1	25.9	27.2	1.3
Hungary	14.5	9.4	- 5.1	7.3	7.1	- 0.2	6.2	6.7	0.5	21.3	12.4	- 8.8
Ireland	9.2	9.0	- 0.1	25.2	24.0	- 1.2	6.5	5.9	- 0.6	6.4	6.6	0.2
Italy	17.5	17.1	- 0.4	33.5	33.3	- 0.2	6.4	4.7	- 1.7	19.2	19.0	- 0.1
Latvia	37.6	39.2	1.6	52.2	52.4	0.2	3.9	3.3	- 0.6	51.8	53.3	1.6
Lithuania	25.8	24.3	- 1.4	15.5	15.2	- 0.3	4.6	4.3	- 0.2	46.1	42.8	- 3.3
Luxembourg	5.0	5.0	0.0	6.2	6.1	- 0.1	6.5	5.9	- 0.6	6.9	7.6	0.7
Malta	5.0	5.3	0.3	4.2	4.5	0.3	4.7	5.0	0.3	14.1	14.0	- 0.1
Netherlands	5.8	6.0	0.1	11.1	10.2	- 0.8	5.3	5.6	0.4	5.5	5.9	0.4
Poland	11.8	11.8	0.0	13.4	13.3	- 0.1	6.4	5.9	- 0.5	14.3	14.2	- 0.1
Portugal	28.0	27.8	- 0.2	52.6	50.4	- 2.3	7.4	6.7	- 0.7	33.4	35.2	1.8
Romania	24.8	24.7	0.0	43.2	39.7	- 3.5	5.5	3.9	- 1.6	25.9	25.9	0.0
Slovakia	12.9	11.9	- 1.0	22.7	23.3	0.6	8.5	6.5	- 2.0	10.8	9.4	- 1.4
Slovenia	22.0	21.8	- 0.2	32.7	33.0	0.3	2.2	2.6	0.4	34.1	33.3	- 0.7
Spain	16.2	15.6	- 0.6	36.9	36.0	- 0.9	1.7	0.5	- 1.2	16.8	15.3	- 1.5
Sweden	53.9	54.1	0.2	65.8	65.2	- 0.6	24.0	24.2	0.2	68.6	68.4	- 0.2
United Kingdom	8.2	8.2	0.0	22.4	22.3	- 0.1	4.4	4.2	- 0.2	5.5	5.5	0.0
European Union	**16.7**	**16.4**	**- 0.3**	**28.8**	**28.3**	**- 0.5**	**6.7**	**6.0**	**- 0.7**	**18.6**	**18.1**	**- 0.5**

Sources: EEA; Eurostat 2017b.

At the EU level, approximated RES share was estimated to be 0.3 percentage points lower than the final RES share published by Eurostat. Sectoral RES shares were underestimated for all sectors; transport by 0.7 percentage points and electricity for heating and cooling by 0.5 percentage points each.

Deviations of more than one percentage point can be found in five Member States for RES shares, in six Member States for RES-E shares, in eight Member States for RES-T shares and in 12 Member States for RES-H&C shares. This shows again that 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 2015 is considerable. The largest deviations occurred for Croatia and Hungary. For Croatia, the RES-E share was underestimated by 5.4 percentage points. This was mainly due to an overestimation of total electricity production and an underestimation of electricity export, leading to a significantly overestimated electricity consumption. A 5.1 percentage point deviation in RES share and an 8.8 percentage point deviation in RES-H&C share can be found in Hungary. The main reason for the considerable deviation in the RES-H&C and RES shares is not the proxy itself but a significant recalculation of the whole time series for 2004-2014 because of updated data for bioenergy consumption being available.

In general, the approximated 2015 RES shares underestimated rather than overestimated actual RES shares in 2015.

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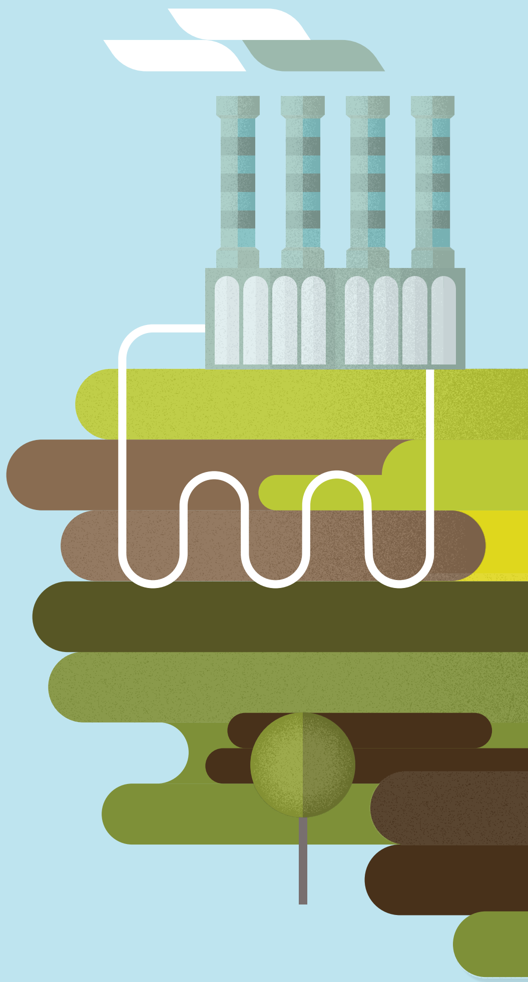

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