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Recent growth and knock-on effects

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Executive summary

Addressing climate change requires a globally coordinated, long-term response across all economic sectors. The 2015 Paris Agreement provides the framework for limiting global warming to less than 2 degrees Celsius above pre-industrial levels and for pursuing efforts to limit it to 1.5 degrees Celsius. Early in this process, the European Union has adopted ambitious and binding climate and energy targets for 2020 and 2030. Member States have set the strategic objective of building an Energy Union, which aims to provide affordable, secure and sustainable energy (European Council, 2014) and which has a forward-looking climate policy at its core (European Council, 2015).

The most recent package of legislative measures, adopted by the European Commission in November 2016, aims to consolidate and match national climate and energy efforts, and facilitate the delivery of the 2030 targets for climate, energy efficiency and renewable energy sources (RES).

This report provides information about progress in RES in 2014 at the EU, country, energy market sector and RES technology levels. It also seeks to answer two key questions:

- Has the consumption of RES since 2005 contributed to lowering greenhouse gas (GHG) emissions and fossil fuel use across Europe?
- How does progress in European RES compare with developments in renewable energy in other parts of the world?

The current report also complements the EEA's *Trends and Projections in Europe 2016 — Tracking progress towards Europe's climate and energy targets* report (EEA, 2016d) with more specific information, including the approximated RES share estimates for 2015 published by the EEA in 2016 (EEA, 2016b) ([1]).

Key findings — the EU and its Member States

Today, RES have become a major contributor to the energy transition occurring in Europe. The speed at which renewable energy has grown since 2005 took many market actors by surprise, especially within the power sector. In 2015, renewable energy accounted for the majority (77 %) of new EU generating capacity for the eighth consecutive year. While fossil fuel capacity needs to be decommissioned at a faster rate to ensure that the EU avoids stranded assets or a lock-in of carbon-intensive power plants by 2030 (EEA, 2016c), the rate of replacement of carbon-intensive energy sources by RES to date has already resulted in GHG emissions reductions in the EU electricity sector, in the consumption of energy for heating and cooling, and in transport.

Steady RES progress since 2005 enabled the EU to meet its interim RES targets in 2015

The EU-wide share of renewable energy in final EU energy use increased from 15 % in 2013 to 16 % in 2014. As shown by the EEA in November 2016 (EEA, 2016b), this figure continued to grow in 2015. Final information from Eurostat, available since March 2017, illustrates that the official EU-wide RES share reached 16.7 % in 2015 — a number close to the EEA's early RES share estimate for that year (16.4 %). Steady progress in RES enabled the EU to meet the indicative trajectory for 2014 and 2015 set out in the Renewable Energy Directive (RED), and the expected trajectory set out in the National Renewable Energy Action Plans (NREAPs) adopted by countries.

- Today, the shares of RES in final energy use continue to vary widely between countries, ranging from over 30 % of gross final energy consumption in Finland, Latvia and Sweden, to 5 % or less in Luxembourg and Malta.

([1]) In March 2015, Eurostat released officially reported RES share data for 2015.

- In absolute terms, **renewable heating and cooling** remains the dominant RES market sector in Europe. At the EU level, RES made up about 18 % of all final energy consumed for heating and cooling in 2014. In 17 Member States, renewable heating and cooling represented over half of the national gross final consumption of renewables in 2014 (Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovenia and Sweden). Since 2005, despite biogas and heat pumps having the fastest compound annual growth rates, solid biomass-based technologies have remained dominant in this market sector.
- In absolute terms, **renewable electricity** is the second largest RES market sector in the EU. It continues to grow, driven by growth in onshore and offshore wind power and solar photovoltaic (PV) electricity generation. About 28 % of all electricity consumed in the EU in 2014 originated from renewable sources. In only four countries, however, did the share of renewable electricity represent over half of all gross final consumption of renewables in 2014 (Ireland, Portugal, Spain and the United Kingdom).
- In the **EU transport sector**, renewable energy made up around 6 % of all energy use in 2014. Renewable energy in this sector comes overwhelmingly from biofuels (close to 90 %), with electricity still playing only a limited role. The share of renewable energy in transport varied across countries, from a maximum of 40 % of all RES consumption (Luxembourg) to close to 0 % (Estonia and Spain).

The EU needs to make further efforts until 2020 to sustain progress in RES in the energy market sectors

A compound annual growth rate (i.e. geometric progression) is used to compare the historic progress in RES in the three energy market sectors with the annual growth needed by 2020 to meet NREAP targets for these sectors.

This comparison illustrates that the use of biofuels in transport grew fastest over the 2005-2014 period (at 18 % per year, on average) as it increased from a very low level in 2005. Although somewhat lesser efforts are needed in this market sector in the run-up to 2020, the necessary growth rate remains considerable (14 % per year, on average) to reach 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 second highest rate of growth took place in the EU's renewable electricity sector (7 % per year, on average). Efforts to date will need to be maintained to realise NREAP expectations for renewable electricity by 2020 (an annual 6 % growth rate is necessary).

Over the 2005-2014 period, the compound annual growth rate of the EU's renewable heating and cooling market sector was 3 % per year. In order to realise NREAP expectations for 2020, a growth rate of 4 % per year is needed until 2020.

RES progress since 2005 allowed the EU to cut its fossil fuel use by 11 % and its GHG emissions by 10 % in 2015

In 2015, most climate mitigation policies and measures reported by Member States under the Monitoring Mechanism Regulation aimed to improve the energy efficiency of buildings and to increase the RES share (EEA, 2015d). Progress towards national and EU RES targets since 2005 has allowed renewables to effectively displace fossil fuels and reduce GHG emissions across Europe (EEA, 2016a). The additional consumption of renewable energy, compared with the level of consumption in 2005, allowed the EU to cut its demand for fossil fuels by 130 million tonnes of oil equivalent (Mtoe) in 2015 (i.e. more than one tenth of the EU's fossil fuel consumption, which is comparable to the fossil fuel consumption of Italy).

Coal was the most substituted fuel across Europe (representing roughly one half of all avoided fossil fuels), followed by natural gas (roughly 28 % 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.

The growth in the consumption of renewable energy after 2005 helped the EU achieve an estimated gross reduction in CO_2 emissions of 8 % in 2014. In 2015, this increased further, resulting in a gross reduction of 436 Mt CO_2 emissions (a 10 % gross reduction in total EU emissions or, in absolute terms, 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 contributed roughly three quarters of the estimated total reductions attributed to RES use.

National RES deployment since 2005 has led to the largest reductions in domestic fossil fuel use and avoided GHG emissions in Germany, Italy and the United Kingdom in both 2014 and 2015. In relative terms, Sweden, Denmark and Finland were the top three ranked countries in terms of substituting fossil fuels and avoiding greenhouse gas emissions in proportion to their domestic fossil fuel use and emissions.

As a result of statistical conventions, the increase in the RES share since 2005 resulted in a 2 % reduction in 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. As the latter is part of the EU 20-20-20 climate and energy package, understanding the interactions between different RES technologies and their statistical impacts on primary energy is useful to policymakers.

The increase in the RES share since 2005 resulted in a 2 % EU-wide reduction in primary energy consumption in 2015, due to accounting rules in use in European energy statistics.

Some RES technologies led to a relatively large statistical decrease in primary energy use (e.g. wind power and solar PV). Others led to a statistical increase (especially solid biomass use, but also geothermal energy) that may have dampened national efforts to reduce the domestic primary energy indicator.

Key findings — RES in a global perspective

Global RES electricity generating capacity has doubled since 2005

Global investments in renewables have shown steady growth for more than a decade. This led to a doubling of global renewable electricity capacity between 2005 and 2015. During this time, RES capacity increased across most parts of the world, i.e.:

- In countries where electricity consumption was, and is expanding rapidly and generation from both renewable energy and fossil fuels is deployed to meet growing demand (Asia and Oceania, including OECD Asia and Oceania, Brazil, China and India).
- In countries experiencing slow growth or a decline in electricity consumption (EU-28 and the United States), where renewable energy is increasingly displacing existing generation and disrupting traditional energy markets and business models.
- In countries where renewable electricity developments are positive, but relatively slow, despite growing electricity consumption (Africa, the Americas — excluding the United States and Brazil, the Middle East and Other Europe and Commonwealth of Independent States).

Investment in RES capacity is spreading globally, with activity fast becoming visible outside Europe

In 2015, the EU ranked second after China in installed and grid-connected domestic renewable electricity capacity. Although Europe still had the largest installed solar PV capacity in 2015, China has quadrupled its installed RES capacity since 2005, and in 2015 it became the world leader in annual solar PV and wind power capacity additions.

In 2015, global developments in RES were dominated by record investments in solar and wind energy for electricity generation. Together, these technologies accounted for over 90 % of total global investment in RES (Frankfurt School-UNEP, 2016). At the other end of the scale, investment in biofuels used mainly in transport was lower in 2015 than in 2005, possibly because interest in first-generation biofuel capacity is levelling off and because there are still delays in overcoming technical and financial obstacles related to second-generation biofuel technologies.

The EU has recorded high annual shares of new global investment in renewable energy capacity. However, viewed over time, Europe's investment share declined from 46 % in 2005 to 17 % in 2015. On the one hand, this highlights Europe's pioneering role in developing renewable energy. On the other hand, it indicates 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 one of the key global players in terms of employment in the renewable energy sector. In 2014, it came second to Brazil in terms of the share of renewable energy jobs per capita in the labour force. In 2015, however, the EU ranked fifth, having been overtaken by Japan, the United States and China.

The largest employers in the EU renewables sector remain the wind, solar PV and solid biomass industries, despite more recent job losses experienced in the solar PV industry and the wind power sector, as competition from other producers, including China, continued to grow.

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

As the EU strives to become a sustainable, low-carbon economy by 2050, developing a competitive edge in renewables is essential. Currently, Member States need to overcome a number of important challenges to do so. In the short term, these range from formulating adequate policy responses that deliver climate and energy targets nationally to agreeing on a functional EU system for monitoring, cooperation and adjustment of efforts. In addition, the EU and its Member States need to improve their innovation capabilities, as a way to increase benefits from the ongoing energy transition in Europe. Given the situation where more than 150 non-EU countries have set national RES targets intended to reduce greenhouse gas emissions, and where most of these countries have also adopted policies to catalyse national RES investments (IRENA, 2017), the EU and its Member States must find solutions to focus and coordinate their efforts and to learn from each other, in order to remain leaders in low-carbon energy transitions.

1 Introduction

Guided by the long-term vision of a low-carbon and resource-efficient European economy by 2050 and supported by short-term (2020) and medium-term (2030) targets for climate and energy, the EU has embarked on a major transformation extending over the next 20-30 years (see Box 1.1). The energy sector is at the heart of this transformation. In the last decade it has witnessed the effective uptake of clean energy solutions – especially renewables. Although the sector is still heavily dependent on long-lived, carbon-intensive infrastructure (EEA, 2016c), it is currently shifting from a centralised, supply-based system dominated by few technologies owned by a small number of large players to a more decentralised and evenly distributed one.

Renewable energy has an important role to play in the energy transition, as it offers the opportunity to contribute to several sustainable development goals (Edenhofer et al., 2012): (1) social and economic development; (2) access to energy; (3) energy security;

Box 1.1 EU renewable energy policies for 2020 and 2030

A combination of GHG emissions reduction, energy savings and renewable energy consumption targets and objectives have 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, of 10 % by 2020, is divided equally into 10 % national transport targets for all countries, 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 provides a set of options for cooperation in order 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 in 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.

Photo: © Rawpixel (istockphoto.com)

For 2030, the EU's binding renewable energy target is to reach 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, 2016c).

and (4) climate change mitigation and the reduction of impacts on the environment and health. The key role of renewable energy is also recognised by the European Commission, as it is an integral part of the Energy Union action plan and the Juncker plan, designed to unlock the investments in the renewable energy sector.

A significant challenge for the next 35 years is therefore to enable rapid growth in renewable energy and energy efficiency investments so that they can become the backbones of our future energy system, while at the same time cutting our reliance on fossil fuels (EEA, 2016c; IEA-IRENA, 2017). A structural shift in the current energy system is required to move renewable energy from technology development to mass production and deployment, from small scale to larger scale, integrating local and more remote sources, and from subsidised to competitive.

In line with legal requirements under the Renewable Energy Directive (RED, 2009/28/EC) (EU, 2009), the European Commission formally assesses the EU and Member States' progress in their promotion and use of renewable energy sources (RES) against the interim trajectories and the 2020 RES targets. The European Commission publishes its assessments every 2 years in the form of a Commission renewable energy progress report. The most recent Communication on this topic was adopted in February 2017 (EC, 2017). 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 EEA and Öko-Institut (see EEA, 2016d)).

Since 2015, monitoring of progress towards the EU 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, 2015a).

1.2 About this report

This EEA report provides a detailed, annual assessment of changes in energy from renewable sources (RES) in Europe since 2005, at the level of individual technologies and countries, embedding in this way the long-term developments in renewable energy in the EU in the context of the ongoing transition in the energy sector. Another aim of the report is to illustrate the benefits of growing RES consumption in Europe – notably the replacement of fossil fuels and the reduction of greenhouse gas (GHG) emissions associated to their use. Last but not least, the report outlines global developments to put Europe's progress in its uptake of renewable energy in perspective.

The data presented in this publication was largely extracted during the second part of 2016, when this assessment was completed. The report uses Eurostat data for the period 2005-2014, complemented by EEA estimates regarding key RES developments in 2015. Since March 2017, officially reported RES data is available from Eurostat, but it was not included in the present assessment.

1.2.1 Report structure

This report is divided into three 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 and highlights certain benefits arising from the increase in RES consumption since 2005. Finally, Chapter 3 outlines selected global RES developments to put the EU's progress in its uptake of RES into context.

1.2.2 Scope of the report

Geographical scope

Owing to the limited availability of primary data for non-EU countries, this assessment focuses on the 28 EU Member States (EU-28). In Chapter 3, 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 2015 RES shares are, ultimately, estimated values developed for use in the *Trends and projections in Europe 2016* report (EEA, 2016d). Accordingly, the cut-off date for most data sources incorporated in the calculation of approximated RES shares was 31 July 2016**.** Although the 2015 RES shares proxies formed the basis of a specific EEA country consultation, in September 2016 ([2]), these values are not a substitute

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

for the official RES data that countries report to Eurostat. Official RES share data for 2015 were not available in time for this assessment; these data were released by Eurostat in March 2017.

The methodology applied for approximating RES values in the year t-1 was described in a previous EEA report (EEA, 2015a) — 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

Section 2.3 estimates the gross effects of renewable energy consumption on GHG emissions based on primary data available from Eurostat. For that, it is assumed that the increase in renewable energy consumption has substituted an equivalent amount of energy that would have been supplied by other sources. The term **'gross avoided GHG emissions'** illustrates the theoretical character of the GHG effects estimated in this way, as these contributions do not necessarily represent **'net GHG savings per se'** nor are they based on life-cycle assessment or full carbon accounting ([3]). Taking into account life-cycle emissions could lead to substantially different results. It is important to note that, due to the base year of this analysis (2005), the development of renewable energy from only that point in time is considered. Section 2.3 also estimates the effects on fossil fuel consumption and primary energy consumption. A detailed description of the methodology applied for approximating these effects was described in a previous EEA report (EEA, 2015a).

Renewable energy investments

The authors of this report have been unable to identify a central, publicly available source of information on global RES technology investments. The most comprehensive source of information regarding RES investments is *Global trends in renewable energy investment 2015* (Frankfurt School-UNEP, 2016). The period covered is 2005-2015 and the focus is on new renewable energy investments per region. Investment figures were originally supplied in nominal billion US dollars. A full comparability across regions and time remains limited, as nominal values include inflation ([4]). For the purpose of this report, figures in US dollars have been converted to euros using the Eurostat data set on exchange rates (Eurostat, 2015).

Renewable energy employment

Renewable energy deployment requires specific skills and value chains, which leads to the creation of new jobs. Jobs can be estimated using various methods with different levels of detail (see IRENA, 2016a). As data availability varies across regions and data differ in how they are generated and in their quality, a consistent time-series is not available to date. For these reasons, only a snapshot of the recent past (2015), by available region and technology, can be shown. Direct and indirect jobs related to renewable energy per region for 2015 are presented below and stem from IRENA (2016a).

Other observations

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, 2015a).

([3]) 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 CO_2 emission factor** is applied to all energy uses of biomass. This approach was chosen due to the absence of specific information about the GHG emissions performance of current bioenergy systems, and should not be interpreted as an endorsement of default biomass sustainability. The GHG emissions from the combustion of biomass are comparable to those of fossil fuels, but can be compensated over time by reduced emissions or increased sinks resulting from the production of the biomass used. It should be noted that, according to the United Nations Framework Convention on Climate Change (UNFCCC) Reporting Guidelines, emissions from biomass combustion have to be reported separately in GHG inventories as a memorandum item (mainly to avoid double counting emissions with LULUCF).

([4]) 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-28 share of renewable energy increased from 15.0 % in 2013 to 16.0 % in 2014. Approximated RES share estimates presented by the EEA and its European Topic Centre for Air Pollution and Climate Change Mitigation (ETC/ACM) in November 2016 (EEA, 2016d) indicated that the RES share in the EU continued to grow in 2015 and reached 16.4 % ([5]). Official RES share values reported by Eurostat in March 2017 confirm this positive development, with the EU renewable energy share increasing to 16.7 % at the end of 2015. As such, in both 2014 and 2015, the EU was on track with its trajectory, according to the RED.

The current report also estimates the gross effects of renewable energy deployment on GHG emissions, fossil fuel consumption and primary energy 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 436 Mt CO_2 equivalent to about 10 % of total EU GHG emissions;
- cut its demand for fossil fuels by 130 Mtoe (million tonnes of oil equivalent), or roughly 11 % of total EU fossil fuel consumption;
- reduce its primary energy consumption by 36 Mtoe, equivalent to a 2 % reduction in primary energy consumption across the EU.

2.1 Actual and approximated recent progress

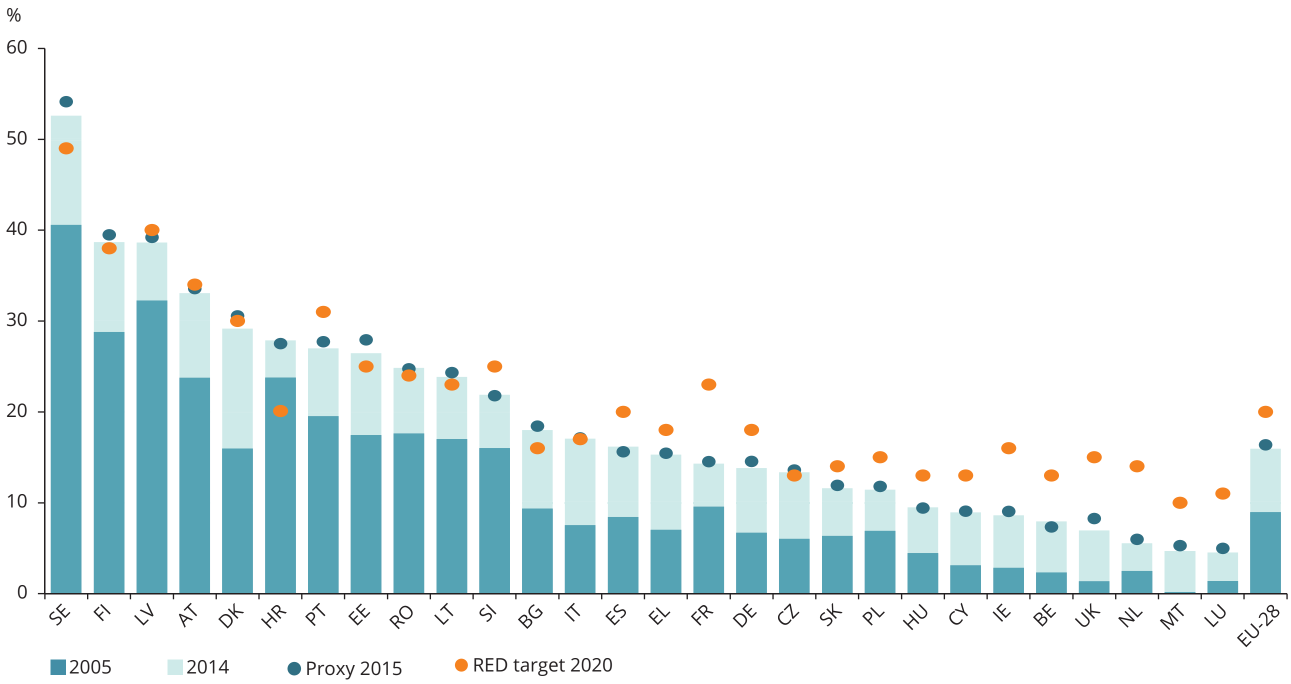
2.1.1 Renewable energy shares at the EU-28 level and in individual Member States

Progress towards the 2020 target was assessed by comparing it with the interim trajectories in the RED. The RED sets minimum indicative trajectories for each country, which end in the binding national RES share targets for 2020. Recent EEA assessments show that in both 2014 and 2015 the EU was on track compared with both trajectories to achieve its target share of gross final renewable energy consumption (EEA, 2016d). The indicative RED target for the EU for the years 2013 and 2014 is 12.1 %. For the years 2015 and 2016, it is 13.8%. Having achieved a RES share of 16.0 % in 2014, it has already surpassed the target level.

Figure 2.1 shows the actual RES shares in the EU Member States and EU-28 for 2005 and 2014 and the approximated RES shares for 2015. The RES share varies widely between countries. In 2014, the highest shares of renewable energy were attained by Sweden (52.6 %), Finland (38.7 %) and Latvia (38.7 %). Luxembourg (4.5 %), Malta (4.7 %) and the Netherlands (5.5 %) 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.

([5]) 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 frame of an Eionet consultation in 2015. For details, see Section 1.2.4 and Annexes 1 and 2.

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



Note: 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 2014. The country codes are defined in Table A3.1.

Sources: EEA; Eurostat, 2016b; RED (2009/28/EC).

Box 2.1 Renewable energy cooperatives — shared and collective value creation

Renewable energy cooperative refers to a business model whereby citizens jointly own and participate in renewable energy projects. These cooperatives are also referred to as community power or community energy initiatives.

Cooperatives contribute to the transition of a centralised energy market, dominated by large utilities, to a decentralised market, with a large number of 'prosumers' (producing consumers). These new ways of organising the energy system fit well not only with discourses on sustainability but also with ideas of self-reliance and independence.

Illustration: © SaimonSailent (istockphoto.com)

The European Federation of Renewable Energy Cooperatives represents 1 240 initiatives and 650 000 citizens. Its members have jointly invested EUR 2 billion in installations to produce renewable energy. These installations have a production capacity of 1 GW. The combined annual turnover is as high as EUR 950 million and the cooperatives provide sustainable jobs for a considerable number of European citizens. Renewable energy cooperatives are most popular in Germany and Denmark. The popularity of renewable energy cooperatives in these countries can be explained by favourable national energy policy frameworks and the local sharing of benefits from renewable energy projects.

More information: https://rescoop.eu.

2.2 RES contributions by energy market sector and technology

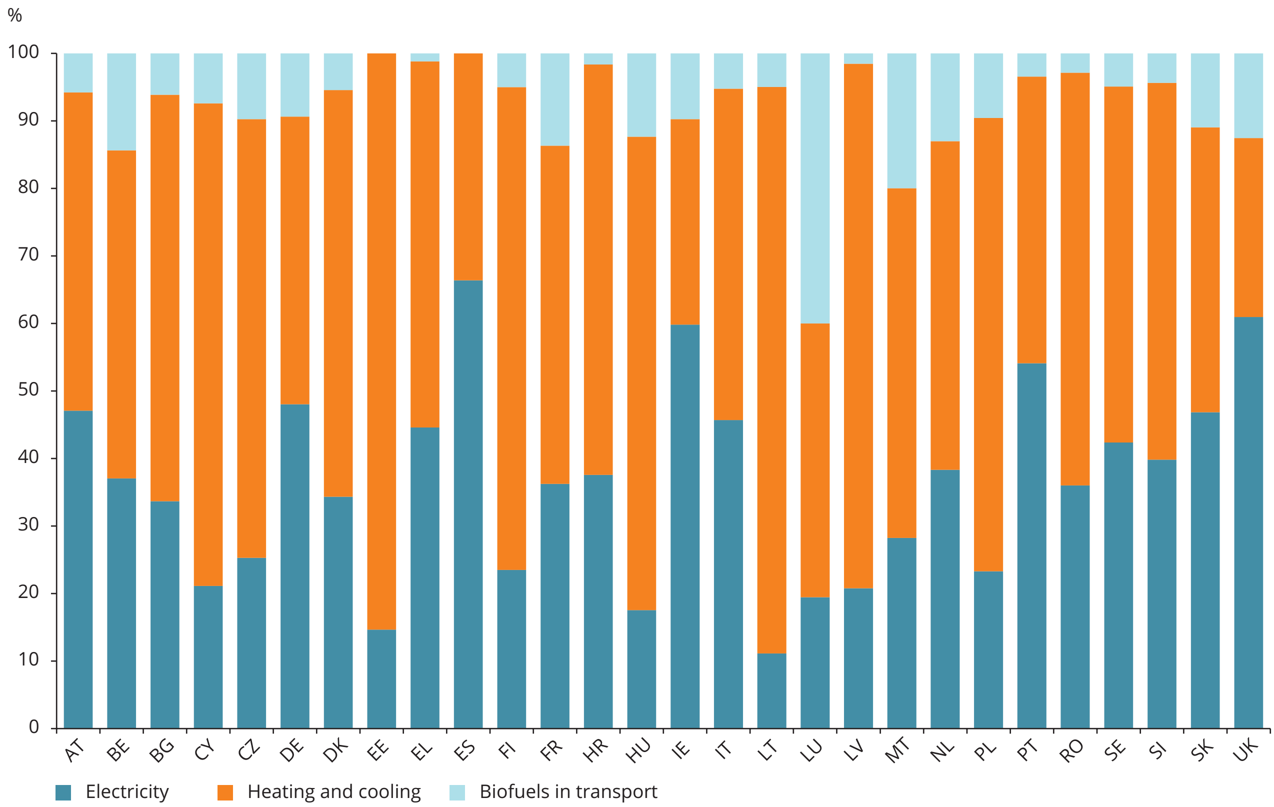
In this section, we show the progress achieved by renewable electricity, renewable heating and cooling and renewable transport fuels and make comparisons with their expected trajectories in the NREAPs.

The NREAPs that Member States submitted in mid-2010 describe the indicative national paths to meet the 2020 RES targets and include separate estimated trajectories for electricity, heating and cooling, and transport. They are, on the whole, more ambitious than the indicative RED trajectories. The indicative and estimated trajectories enable progress to be monitored, but they become increasingly outdated as conditions and policies change ([6]). As a result of steep learning curves, the rapid development and consequent cost reductions achieved by some renewable energy technologies imply that the shares of these technologies will be higher in 2020 than those anticipated in the NREAPs. Therefore, the NREAP trajectories should be seen as 'expected pathways', rather than national targets for particular RES technologies.

2.2.1 Breakdown of RES share into energy market sectors

We distinguish the following market sectors: electricity, heating and cooling, and transport. At the country level, the significance of each renewable market sector differs considerably. Figure 2.2 shows the relative weight of each sector in terms of total gross renewable final energy consumption in Member States in 2014.

Figure 2.2 Breakdown of 2014 RES consumption into renewable electricity, renewable heating and cooling and biofuels in transport (%)



Notes: This figure shows how the realised final renewable energy consumption in 2014 is distributed over renewable electricity, renewable heating and cooling and biofuels in transport. Wind power and hydropower are normalised ([7]). The consumption of RES accounts for only biofuels complying with the RED sustainability criteria. The country codes are defined in Table A3.1.

Source: Compiled from data from Eurostat, 2016b.

([6]) Some countries have since updated their NREAPs. The most recent versions were used for this report.

([7]) 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).

In 2014:

- **Renewable heating and cooling** represented more than half of all gross final consumption of renewables in 17 Member States (Estonia, Lithuania, Latvia, Finland, Cyprus, Hungary, Poland, the Czech Republic, Romania, Croatia, Denmark, Bulgaria, Slovenia, Greece, Sweden, Malta and France).
- **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 40 % of all RES consumption (Luxembourg) to 0 % (Estonia and Spain). Spain did not implement the legal framework for certification (EurObserv'ER, 2015c).

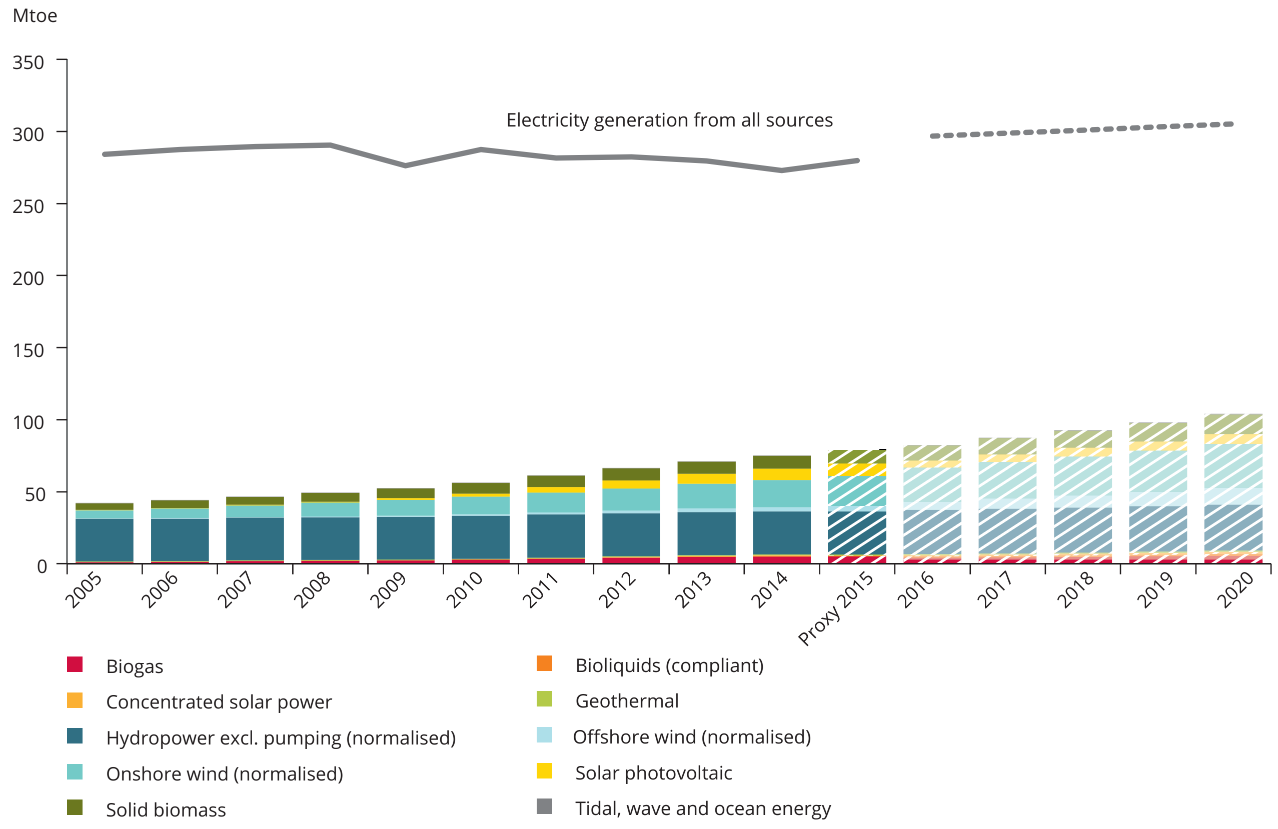
The variations observed across countries in the relative importance of each market sector are due to specific national circumstances, including different starting points in terms of the deployment of renewable energy sources, different availability of low-cost renewables, country-specific demand for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

2.2.2 Renewable electricity

In 2014, the EU-wide share of electricity from renewable sources (RES-E) amounted to 27.5%. Figure 2.3 and Table 2.1 show the consumption of RES-E up to 2014, approximated estimates for 2015 and the expected developments based on the NREAPs.

- The gross final energy consumption (GFEC) of RES-E increased to 74.9 Mtoe in 2014. This was 4 Mtoe higher than in 2013.
- In 2014 the largest contributions came from hydropower (30.0 Mtoe, or 40 % of all RES-E),

Figure 2.3 RES-E in the EU-28



Notes: This figure shows the realised final RES-E consumption for 2005-2014, approximated estimates for 2015 and the expected realisations in the energy efficiency scenario of the NREAPs for 2016-2020. Wind power and hydropower are normalised. The consumption of RES accounts for only biofuels complying with the RED sustainability criteria.

Sources: EEA; Eurostat; NREAP reports.

onshore wind ([8]) (18.9 Mtoe, or 25 % of all RES-E), solid biomass (9.0 Mtoe, or 12 % of all RES-E) and solar photovoltaic (PV) systems (7.9 Mtoe, or 11 % of all RES-E). All the other technologies made smaller contributions, ranging from 1 % to 7 % (biogas).

- Over the 2005-2014 period, the compound annual growth rate of RES-E consumption was 7 %. To realise the expectations for 2020 in the NREAPs, a growth rate of 6 % per year will be required over the 2014-2020 period. The compound annual growth rate was the highest for solar PV systems (59 %), offshore wind (29 %), biogas (18 %) and onshore wind (14 %). Hydropower had the lowest growth rate (0 %).

According to proxy estimates, total RES-E generation increased in 2015 to 79 Mtoe, while total electricity consumption increased to 280 Mtoe, resulting in a share of RES-E consumption of 28 %. Most of the increase in RES-E generation was due to the greater contribution of wind energy (+ 3.0 Mtoe), solar energy (+ 0.7 Mtoe) and energy from solid biomass (+ 0.5 Mtoe). In 2015, electricity consumption increased again following the decrease in 2014. This may be explained, according to the European Network of Transmission System Operators for Electricity (ENTSO-E), by a lower average temperature at the beginning of the year and a higher average temperature in the summer and by an increase in gross domestic product (GDP) compared with 2014 (ENTSO-E, 2016).

Table 2.1 RES-E in the EU-28: breakdown by RES technology

	Final energy (ktoe)					Annual growth rate (%)		
Technology	**2005**	**2013**	**2014**	**Proxy 2015**	**NREAP 2020**	**2005-2014**	**2013-2014**	**2014-2020**
Hydropower excl. pumping (normalised)	29 682	30 040	29 966	29 858	31 786	0 %	0 %	1 %
Onshore wind (normalised)	5 670	17 044	18 889	20 843	30 303	14 %	11 %	8 %
Solid biomass ([a])	4 756	8 527	8 971	9 469	13 460	7 %	5 %	7 %
Solar photovoltaic	126	6 956	7 941	8 669	7 062	59 %	14 %	– 2 %
Biogas	1 102	4 631	4 967	5 096	5 493	18 %	7 %	2 %
Offshore wind (normalised)	273	2 405	2 750	3 784	11 740	29 %	14 %	27 %
Geothermal	464	510	535	544	943	2 %	5 %	10 %
Concentrated solar power	0	410	469	469	1 633	n.a.	14 %	23 %
Bioliquids (compliant)	0	346	406	466	1 096	n.a.	18 %	18 %
Tidal, wave and ocean energy	41	36	42	41	559	0 %	15 %	54 %
Total renewable electricity (normalised, compliant biofuels)	42 114	70 905	74 937	79 238	104 075	7 %	6 %	6 %
Total renewable electricity (normalised, including non-compliant biofuels)	42 266	70 927	74 948	79 191	104 075	7 %	6 %	6 %

Notes: This table shows the realised final renewable energy consumption for 2005, 2013 and 2014, approximated estimates for 2015 and the expected realisations in the energy efficiency scenario of the NREAPs for 2020. The growth rates are the realised compound annual growth rates in 2005-2014, the growth from 2013 to 2014 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.

Sources: EEA; Eurostat; NREAP reports.

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

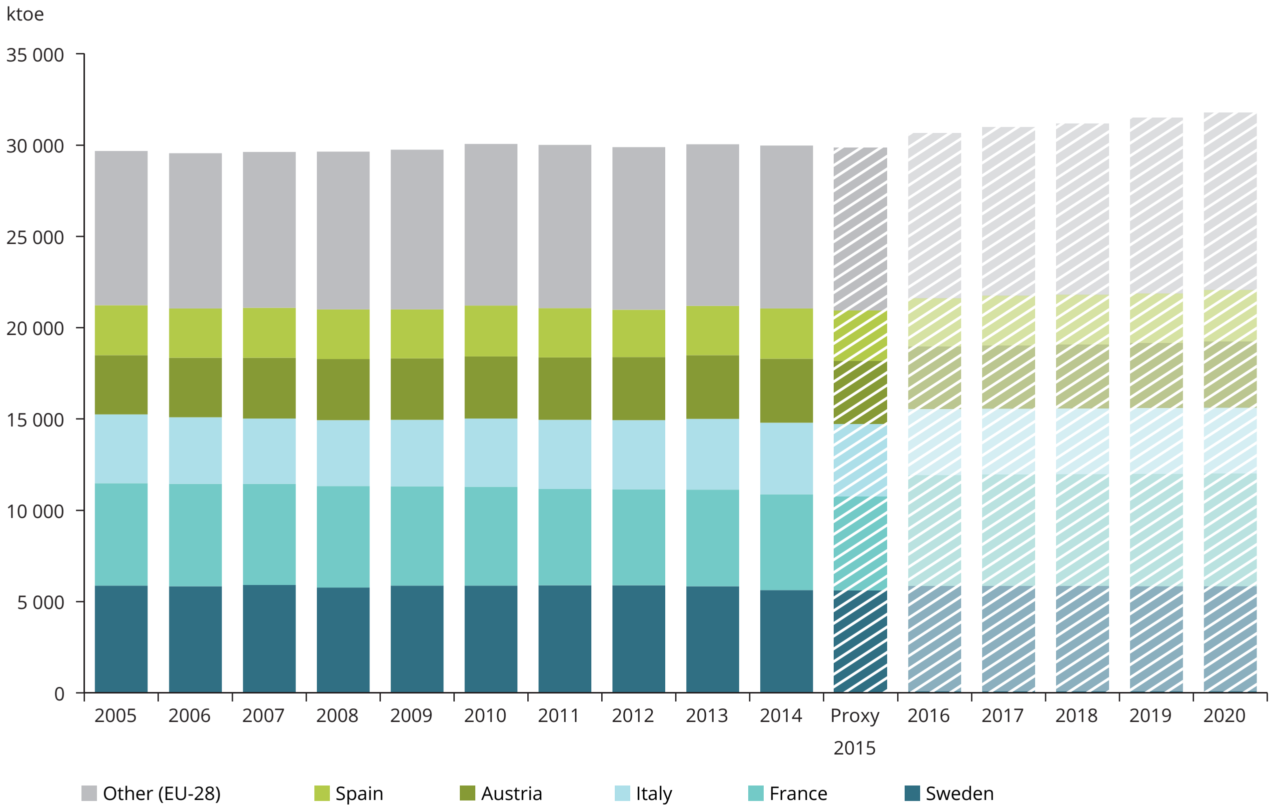
Hydropower

The normalised production of hydroelectric power remained quite stable over the 2005-2014 period, as illustrated in Figure 2.4. According to the NREAPs, limited growth from 30.0 to 31.8 Mtoe is expected for 2014-2020. In 2014, the five countries with the most hydropower (Sweden, France, Italy, Austria and Spain) had a share of 70 % of all hydropower in the EU-28. We estimate that, in 2015, the normalised production of hydroelectricity decreased slightly to 29.9 Mtoe. Hydropower capacities evolve only a little across Europe, therefore rainfall patterns are a determinant factor for annual changes in hydroelectricity production.

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 (Ecofys, 2014a). Most of the best sites have already been developed, amounting to half of the technically feasible potential (Peza, 2014). In addition, for small and medium run-of-river hydro plants (< 10 MW) there is a substantial technical potential that could allow hydropower to make a more significant contribution to future energy needs, provided that new projects do not conflict with the objectives of nature- and water-related legislation (as reflected by i.a. the Water Framework Directive, 2000/60/EC and the EU 2020 Biodiversity Strategy, COM(2011) 244 final).

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 hydro) can provide energy storage and load balancing functions, which contributes to the flexibility necessary to integrate high levels of renewable energy from intermittent sources. A recent study investigated how Norwegian hydropower, along with the necessary grid enhancement, could be used for large-scale balancing of the German power system (Moser, 2015).

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



Notes: This figure shows the realised final RES-E consumption for 2005-2014, approximated estimates for 2015 and the expected realisations in the energy efficiency scenario of the NREAPs for 2015-2020. 'Other (EU-28)' refers to the 23 Member States not displayed individually in the graph.

Sources: EEA; Eurostat; NREAP reports.

Onshore wind

Onshore wind power generation increased from 5.7 Mtoe in 2005 to 18.9 Mtoe in 2014. The largest contributions came from Germany (4.7 Mtoe) and Spain (4.4 Mtoe).

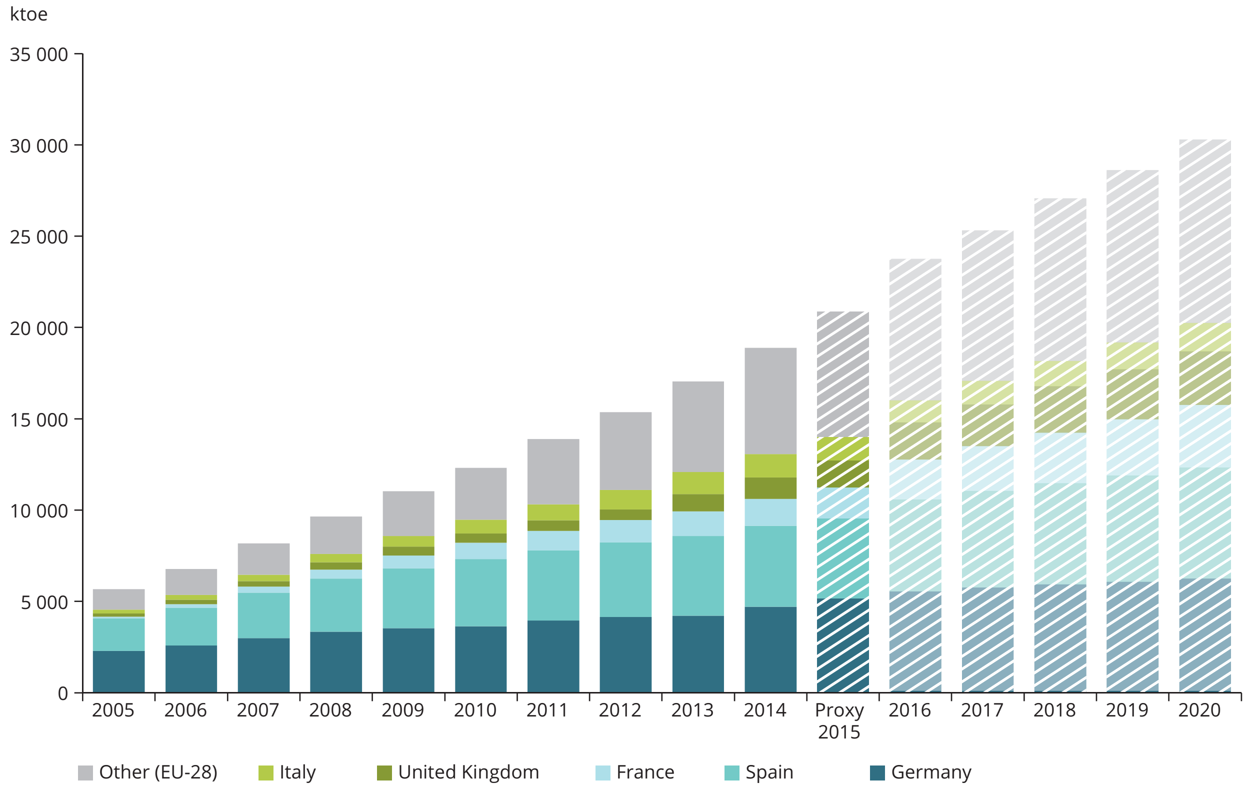
In 2015, the normalised onshore wind production of electricity was estimated to be 20.8 Mtoe (Figure 2.5). The greatest increase in normalised onshore wind production at the Member State level was in Germany, which corresponds to an additional installed onshore capacity of 3.5 GW. Other Member States with large absolute additions to capacity were Poland (+ 1.3 GW), France (+ 1.0 GW) and Sweden (+ 0.6 GW). Furthermore, the Netherlands, Finland and Austria added more than 0.3 GW in 2015 (EurObserv'ER, 2016b).

Onshore wind is a rather mature and lower cost RES technology. 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 2005-2014 period. 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, 2014a). Recently the markets have been more restrained. However, in some countries there was a rush in onshore wind installation in 2014-2015 due to fears over changing future support systems.

There is new growth in the installation of low-wind turbines. The technological development of these wind turbines has progressed rapidly, allowing for 10-25 % higher yields than the previous generation of turbines. These new wind turbines are generally taller and have much longer blades (EurObserv'ER, 2016a).

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



Notes: This figure shows the realised final RES-E consumption for 2005-2014, approximated estimates for 2015 and the expected realisations in the energy efficiency scenario of the NREAPs for 2016-2020. 'Other (EU-28)' refers to the 23 Member States not displayed individually in the graph.

Sources: EEA; Eurostat; NREAP reports.

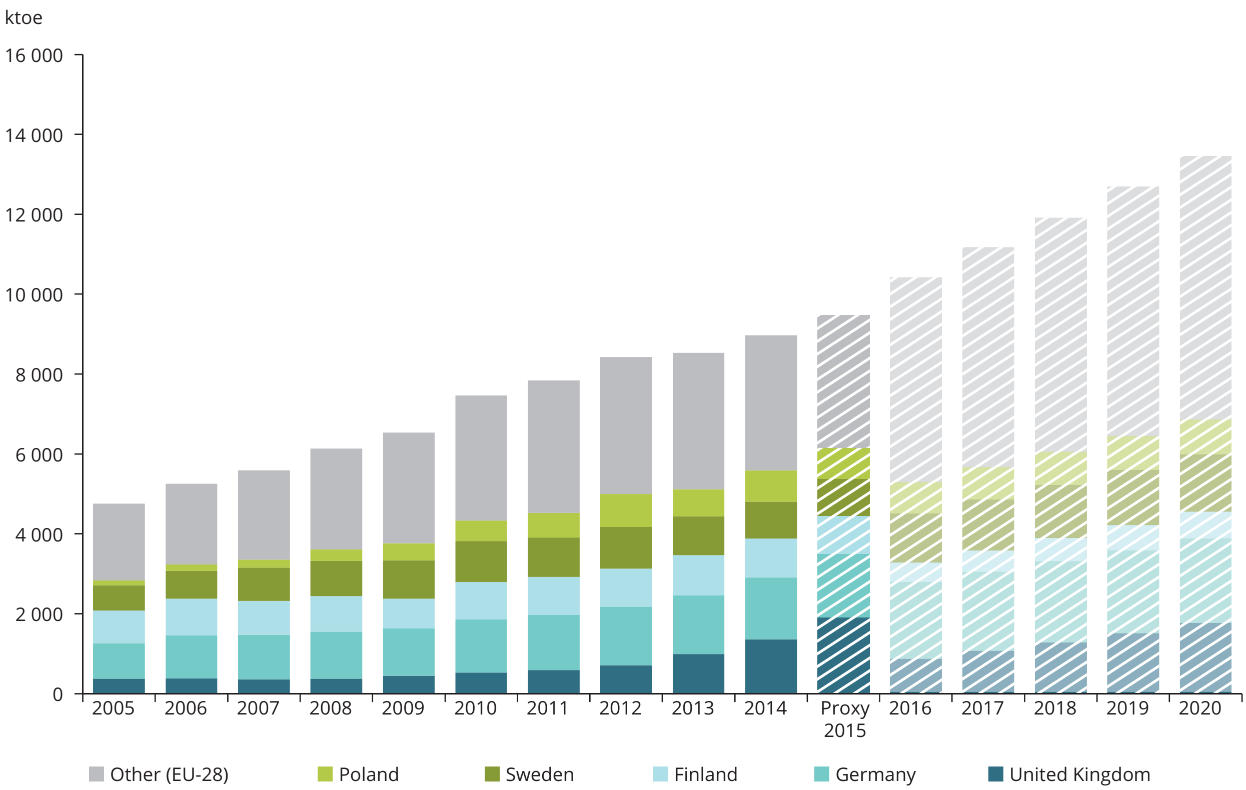
Solid biomass

Electricity generation from solid biomass grew from 4.8 Mtoe in 2005 to 9.0 Mtoe in 2014 ([9]). The growth rate over the 2005-2014 period was 7 % (Figure 2.6). In 2014, Germany's share of the total electricity generated from solid biomass was 17 %. The United Kingdom and Finland had shares of 15 % and 11 %, respectively. In 2015, electricity generation from solid biomass increased again compared with 2014 due to the expansion of biomass cogeneration and the conversion of coal-fired power plants to biomass installations. Again, in the United Kingdom there was a sharp increase in solid biomass electricity generation due to the conversion of a further, third, coal-fired power plant (EurObserv'ER, 2015b).

The implementation of sustainability criteria could influence future growth in solid biomass fuel. However, the harmonised criteria proposed by the European Commission will not become effective before 2020 (EC, 2016a). For now, it is left up to Member States whether or not they introduce sustainability criteria for solid biomass and gain experience with these requirements on a national level (Kampman et al., 2015). Moreover, the new renewable energy package that the Commission proposed in 2017 would allow Member States to implement more stringent national environmental criteria for solid biomass than the harmonised EU minimum.

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

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



Notes: This figure shows the realised final RES-E consumption for 2005-2014, approximated estimates for 2015 and the expected realisations in the energy efficiency scenario of the NREAPs for 2016-2020. 'Other (EU-28)' refers to the 23 Member States not displayed individually in the graph.

Sources: EEA; Eurostat; NREAP reports.

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

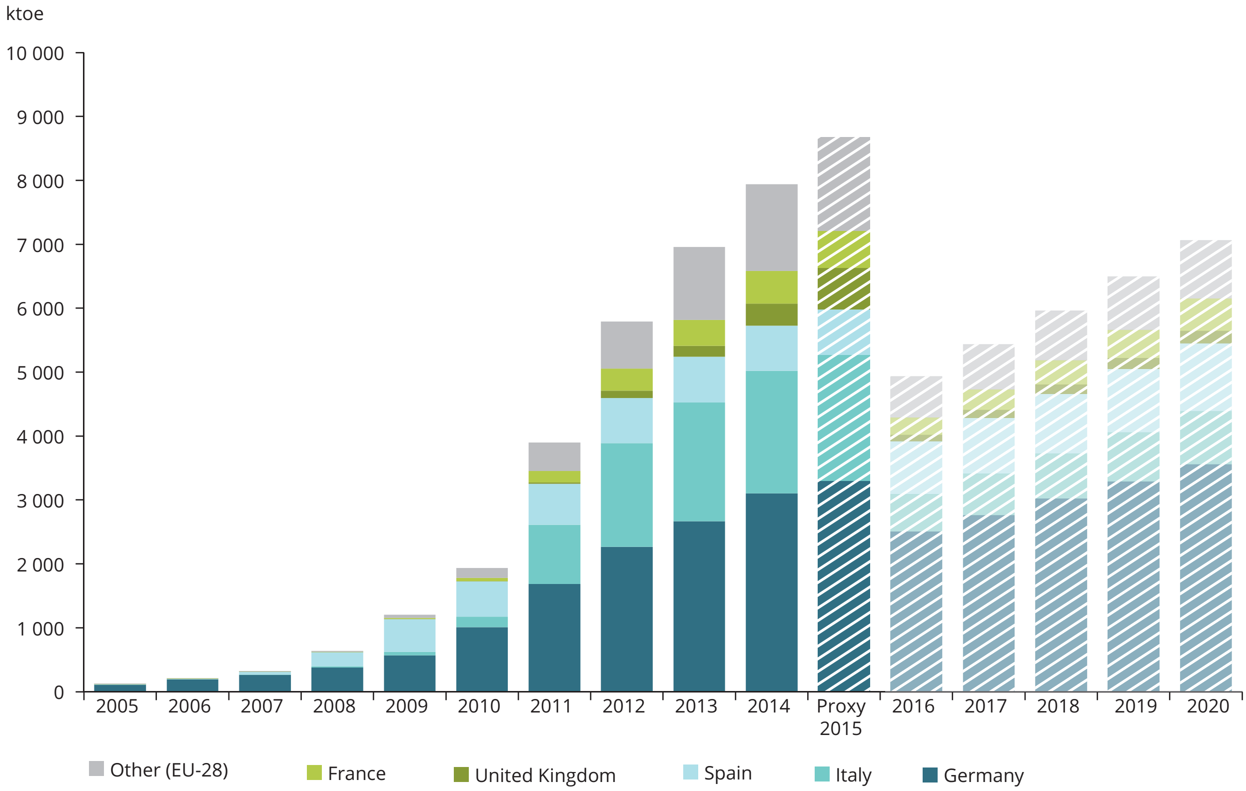
Solar photovoltaic systems

Solar PV electricity production reached 7.9 Mtoe in 2014 (Figure 2.7), which exceeds by almost 0.9 Mtoe the level that was expected for 2020, according to the NREAPs (7.1 Mtoe). In 2014, 39 % of the solar PV electricity was produced in Germany. Italy and Spain also had large shares, 24 % and 9 %, respectively.

In 2015, approximated estimates suggest that the production of solar PV electricity increased again, further overtaking the expected NREAP levels for 2020 and reaching 8.7 Mtoe. The greatest increase in solar PV electricity production at the Member State level was in the United Kingdom, which corresponded to an additional installed capacity of 3.5 GW ([10]). Other Member States with substantial absolute capacity additions were Germany (1.4 GW) and France (0.9 GW). A further four Member States (Austria, Denmark, Italy, Netherlands) added more than 0.1 GW in 2015. (EurObserv'ER, 2016a)

The considerable growth in solar PV electricity has been driven by rapid technological progress, cost reductions and the relatively short project development times (Ecofys, 2014a). In 2013 and 2014, the installation of new solar PV capacity slowed down compared with its peak years (2011 and 2012) because of increased taxes on electricity self-consumption and new policies reducing financial support. In 2015 the market recovered but its recovery has been hampered by the small number of operators in the European PV market. Currently, the European market is in transition from a market driven by guaranteed production-related support to a market with prosumers that use solar electricity for self-consumption and production and sale to the market. Many countries have already made provisions for developing self-consumption. The measures taken to promote or manage this development can slow down the development of solar PV systems (EurObserv'ER, 2016a).

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



Notes: This figure shows the realised final RES-E consumption for 2005-2014, approximated estimates for 2015 and the expected realisations in the energy efficiency scenario of the NREAPs for 2016-2020. 'Other (EU-28)' refers to the 23 Member States not displayed individually in the graph.

Sources: EEA; Eurostat; NREAP reports.

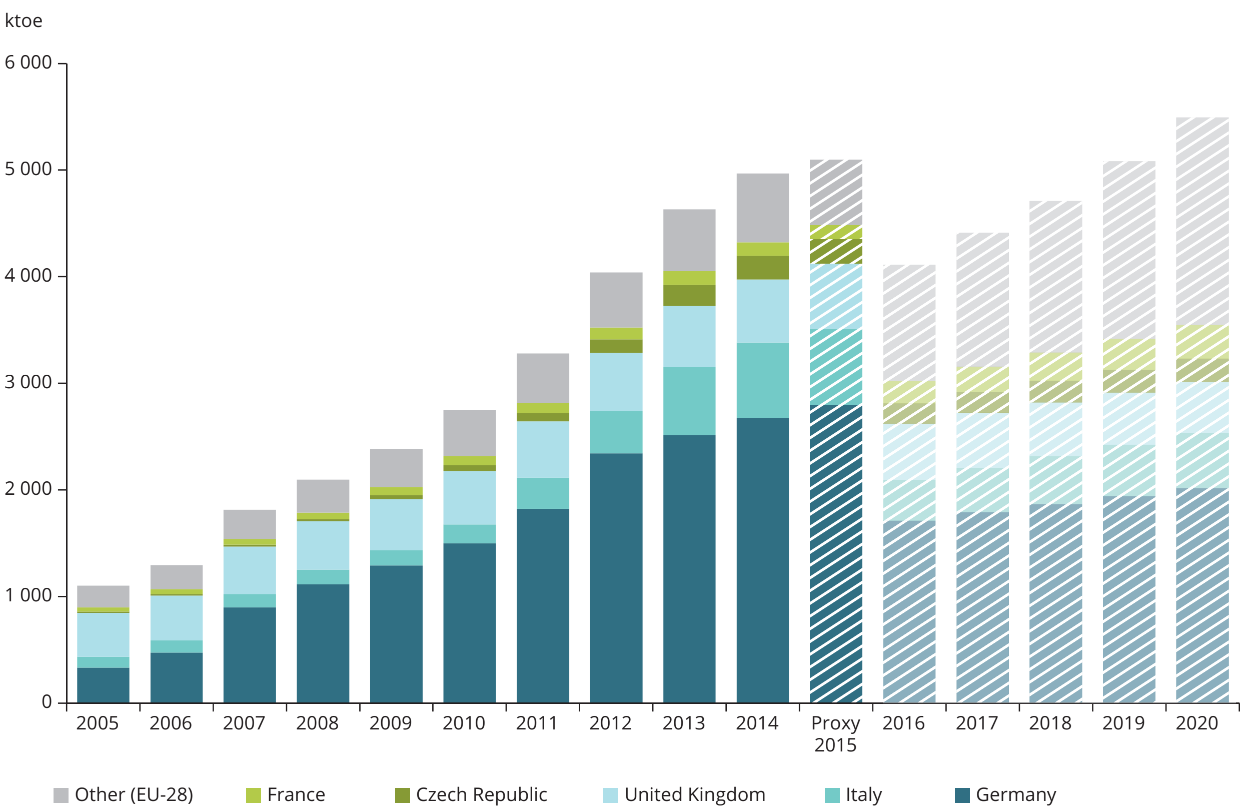
([10]) Data for all Member States are taken from EurObserv'ER and in some cases they might vary slightly from national data. Concerning the United Kingdom, it reported a 3.8 GW increase during the Eionet consultation.

Biogas

Electricity generation from biogas grew from 1.1 Mtoe in 2005 to 5.0 Mtoe in 2014 (Figure 2.8). The compound annual growth rate for biogas was 18 % over the period 2005-2014. Germany's share of electricity generation from biogas was 54 % of the total in the EU-28. Italy and the United Kingdom had shares of 14 % and 12 %, respectively. In 2015, electricity generation from biogas increased slightly to 5.1 Mtoe, according to the EEA estimate.

As such, the generation of electricity from biogas has grown faster than expected. However, slower growth could be observed in 2013 and 2014, due to policy changes in Germany and Italy, (EurObserv'ER, 2015a, annual overview 2015). At the European level, the discussions on sustainability criteria were similar to those about solid biomass and biofuels. The European Commission *State of play* report (EC, 2014) highlighted, specifically for biogas, the environmental issues stemming from the use of energy crops such as maize, which involved a significant expansion of these crops, often at the expense of grassland and/or food production, and the significant variations in the performance of biogas in terms of GHG emissions, depending on the biomass feedstock used. To realise the required levels of electricity generation from biogas by 2020, as anticipated in the NREAPs, a growth rate of only 2 % per year would be sufficient for the remaining period.

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



Notes: This figure shows the realised final RES-E consumption for 2005-2014, approximated estimates for 2015 and the expected realisations in the energy efficiency scenario of the NREAPs for 2016-2020. 'Other (EU-28)' refers to the 23 Member States not displayed individually in the graph.

Sources: EEA; Eurostat; NREAP reports.

Offshore wind energy

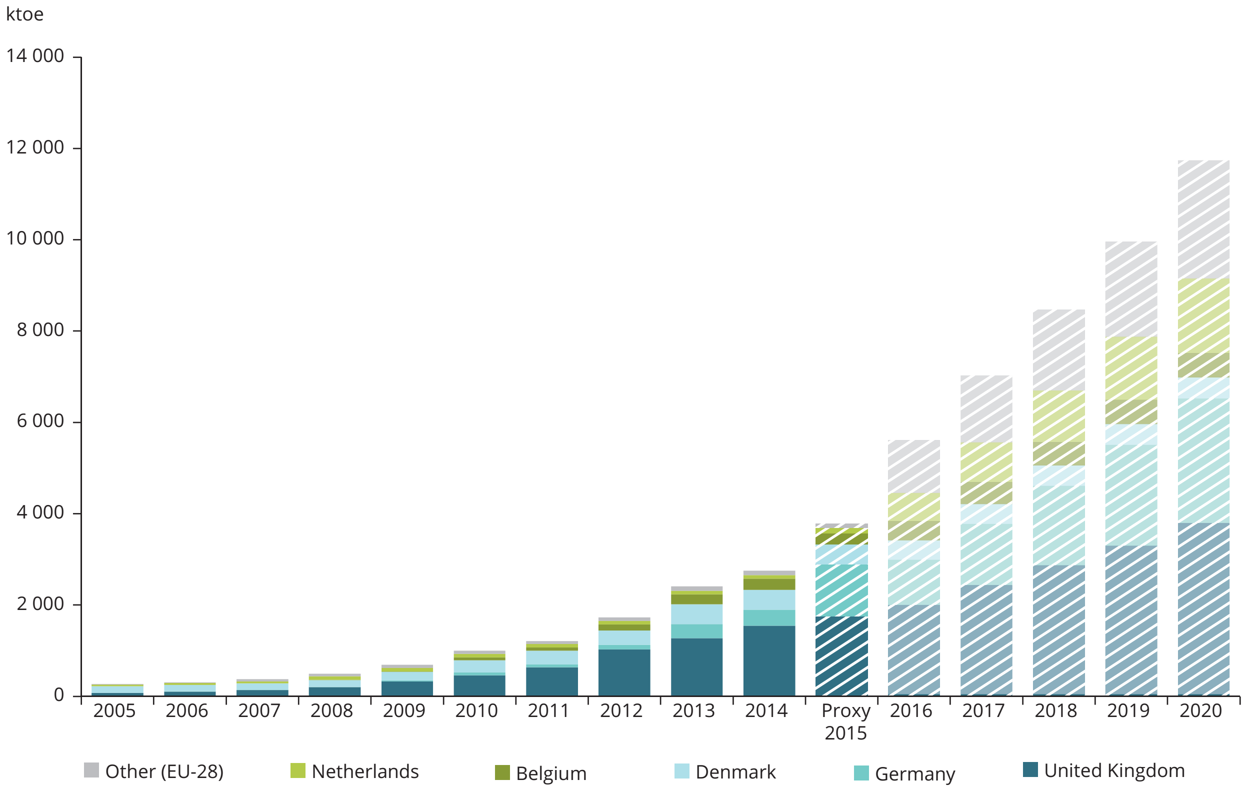
Offshore wind power grew from 0.3 Mtoe in 2005 to 2.8 Mtoe in 2014 (Figure 2.9). In 2015, the normalised generation of electricity from offshore wind rose to 3.8 Mtoe. The largest increase in normalised offshore wind power at the Member State level occurred in Germany, which corresponded to an additional installed offshore capacity of 2.3 GW. Further additions to offshore capacity were recorded in the United Kingdom (+ 0.6 GW) and the Netherlands (+ 0.1 GW) The United Kingdom is still the frontrunner, with a share of 46 % of the total normalised electricity generation from offshore wind power in the EU-28 in 2015, but Germany has increased its share from 13 % in 2014 to 30 % in 2015 (EurObserv'ER, 2016b).

Offshore wind power would need to grow to 11.7 Mtoe in 2020 to reach the expected realisations in the NREAPs. This corresponds to a compound annual growth rate of 27 % per year.

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 2014, and no change was expected in 2015, as no new large CSP plants were commissioned.
- Geothermal electricity grew by only 2 % per year over the 2005-2014 period to reach 0.5 Mtoe, and no significant change was expected in 2015.
- Electricity generation from tidal, wave and ocean energy was still only 42 ktoe in 2014, and no significant change was expected in 2015.
- Electricity production from compliant bioliquids was 0.4 Mtoe in 2014, and EEA estimates anticipate a slight increase to 0.5 Mtoe in 2015.

Figure 2.9 RES-E in the EU-28: offshore wind (normalised)



Notes: This figure shows the realised final RES-E consumption for 2005-2014, approximated estimates for 2015 and the expected realisations in the energy efficiency scenario of the NREAPs for 2016-2020. 'Other (EU-28)' refers to the 23 Member States not displayed individually in the graph.

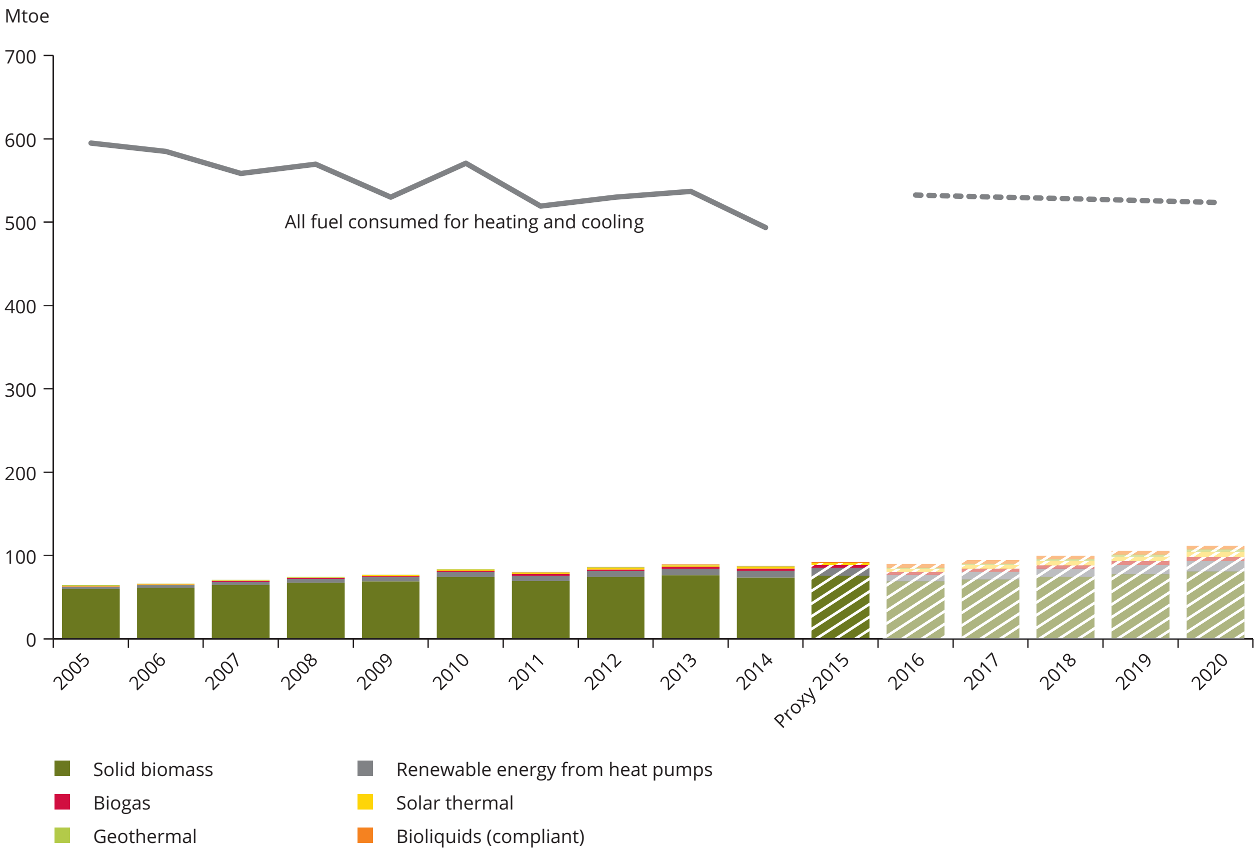
Sources: EEA; Eurostat; NREAP reports.

2.2.3 *Renewable heating and cooling*

The share of heating and cooling from renewable sources (RES-H&C) in the EU-28 was 17.7 % in 2014. Figure 2.10 and Table 2.2 show the development of RES-H&C from 2005 to 2014, approximated estimates for 2015 and its expected development up to 2020, based on the NREAPs.

- The gross final consumption of RES-H&C was 87.5 Mtoe in 2014, which corresponds to a decrease of 1.8 Mtoe compared with 2013.
- In 2014, the largest contributions came from solid biomass (73.5 Mtoe, or 84 % of all RES-H&C), heat pumps (8.2 Mtoe, or 9 % of all RES-H&C) and biogas (2.9 Mtoe, or 3 % of all RES-H&C).
- Over the 2005-2014 period, the compound annual growth rate of RES-H&C was 3 % per year. To realise the expectations in the NREAPs for 2020, a growth rate of 4 % per year would be required over the period 2014-2020.
- According to early proxy estimates, RES-H&C increased from 87.5 Mtoe in 2014 to 91.8 Mtoe in 2015, while the amount of fuel consumed for heating and cooling increased from 493 Mtoe to 508 Mtoe, resulting in a renewable share of heating and cooling consumption of 18.1 % in 2015. Climate conditions — especially the very mild winter — had a strong impact on the demand for heating and cooling in 2014.

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



Notes: This figure shows the realised final RES-H&C for 2005-2014, approximated estimates for 2015 and the expected realisations in the energy efficiency scenario of the NREAPs for 2016-2020. The consumption of RES accounts for only biofuels complying with the RED sustainability criteria.

Sources: EEA; Eurostat; NREAP reports.

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

	Final energy (ktoe)					Annual growth rate (%)		
Technology	**2005**	**2013**	**2014**	**Proxy 2015**	**NREAP 2020**	**2005-2014**	**2013-2014**	**2014-2020**
Solid biomass ([a])	60 033	76 547	73 510	75 927	80 886	2 %	– 4 %	2 %
Renewable energy from heat pumps	2 315	7 384	8 175	9 697	12 289	15 %	11 %	7 %
Biogas	714	2 611	2 908	3 183	5 108	17 %	11 %	10 %
Solar thermal	701	1 813	1 927	2 004	6 455	12 %	6 %	22 %
Geothermal	557	647	689	700	2 646	2 %	7 %	25 %
Bioliquids (compliant)	0	248	274	274	4 416	n.a.	10 %	59 %
Total renewable heat (compliant biofuels)	64 320	89 249	87 483	91 784	111 801	3 %	– 2 %	4 %
Total renewable heat (including non-compliant biofuels)	64 485	89 434	87 617	91 930	111 801	3 %	– 2 %	4 %

Notes: This table shows the realised final RES-H&C for 2005, 2013 and 2014, approximated estimates for 2015 and the expected realisations in the energy efficiency scenario of the NREAPs for 2020. Also shown are the realised compound annual growth rates from 2005 to 2014, the growth from 2013 to 2014 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.

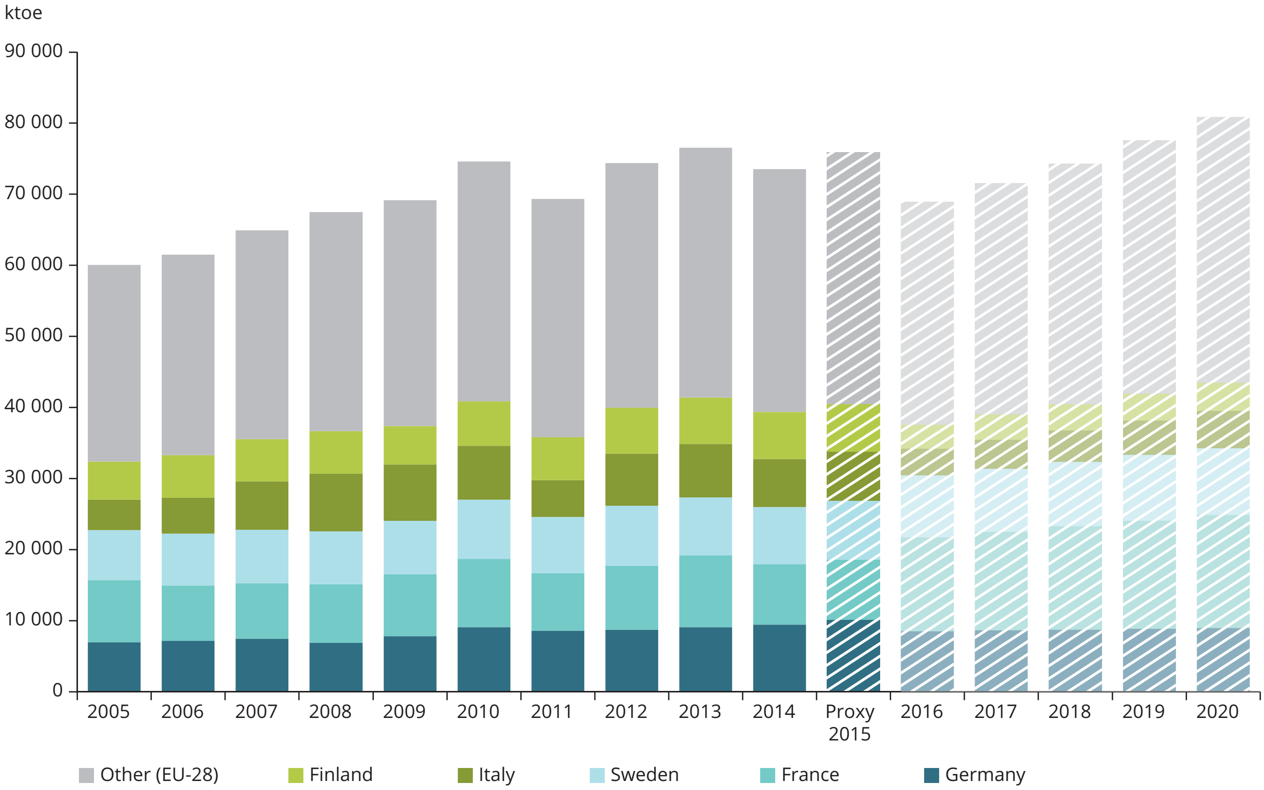
([a]) Renewable municipal waste has been included in solid biomass.

Sources: EEA; Eurostat; NREAP reports.

Solid biomass

Solid biomass remains the most important source of renewable energy for heating (Figure 2.11). The consumption of renewable heat originating from solid biomass decreased from 76.5 Mtoe in 2013 to 73.5 Mtoe in 2014. This decrease was mainly due to a mild winter in 2014, which reduced the demand for heating. The compound annual growth rate for heat from solid biomass was 2 % over the period from 2005 to 2014. In 2015, the consumption of solid biomass for renewable heat increased to 75.9 Mtoe, according to an EEA estimate. To realise the expected NREAP levels of solid biomass for 2020, a growth rate of 2 % per year over the remaining period would be sufficient.

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



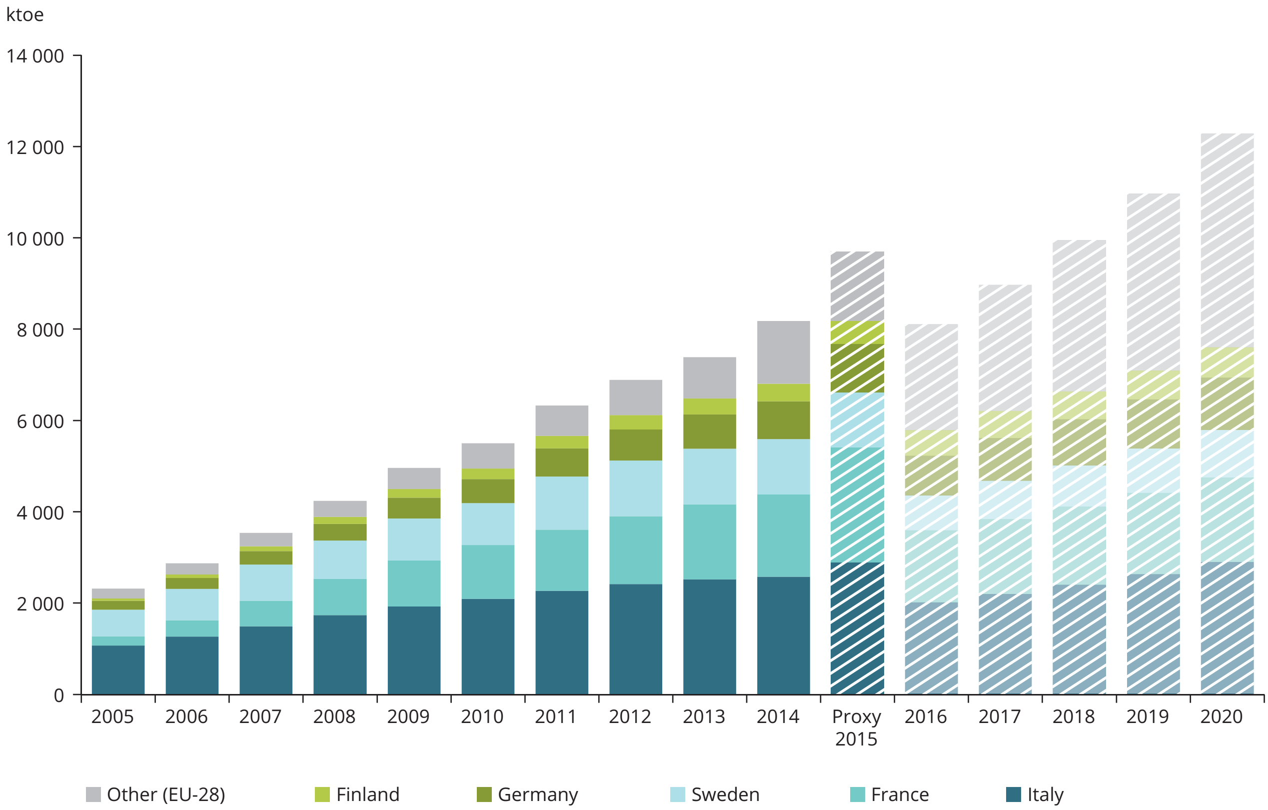
Notes: This figure shows the realised final RES-H&C for 2005-2014, approximated estimates for 2015 and the expected realisations in the energy efficiency scenario of the NREAPs for 2016-2020. 'Other (EU-28)' refers to the 23 Member States not displayed individually in the graph.

Sources: EEA; Eurostat; NREAP reports.

Heat pumps

Renewable energy from heat pumps grew from 2.3 Mtoe in 2005 to 8.2 Mtoe in 2014 (Figure 2.12). In northern Europe, most heat pumps are used for heating, but there is also a market for cooling. In 2014, Italy contributed 32 % to the final EU-wide RES consumption from heat pumps. France (22 %) and Sweden (15 %) also made significant contributions. In 2014, the heat pump market contracted, mainly due to the Italian and French markets (EurObserv'ER, 2015c). In 2015, renewable heat from heat pumps increased to 9.7 Mtoe, according to an EEA estimate. With a total growth rate over the 2005-2014 period of 15 % per year, the expectations in the NREAPs had already been exceeded by 2015. A 7 % compound annual growth rate would be sufficient to meet the expected contribution from heat pumps by 2020, according to the NREAPs.

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



Notes: This figure shows the realised final RES-H&C for 2005-2014, approximated estimates for 2015 and the expected realisations in the energy efficiency scenario of the NREAPs for 2016-2020. 'Other (EU-28)' refers to the 23 Member States not displayed individually in the graph.

Sources: EEA; Eurostat; NREAP reports.

Solar thermal energy

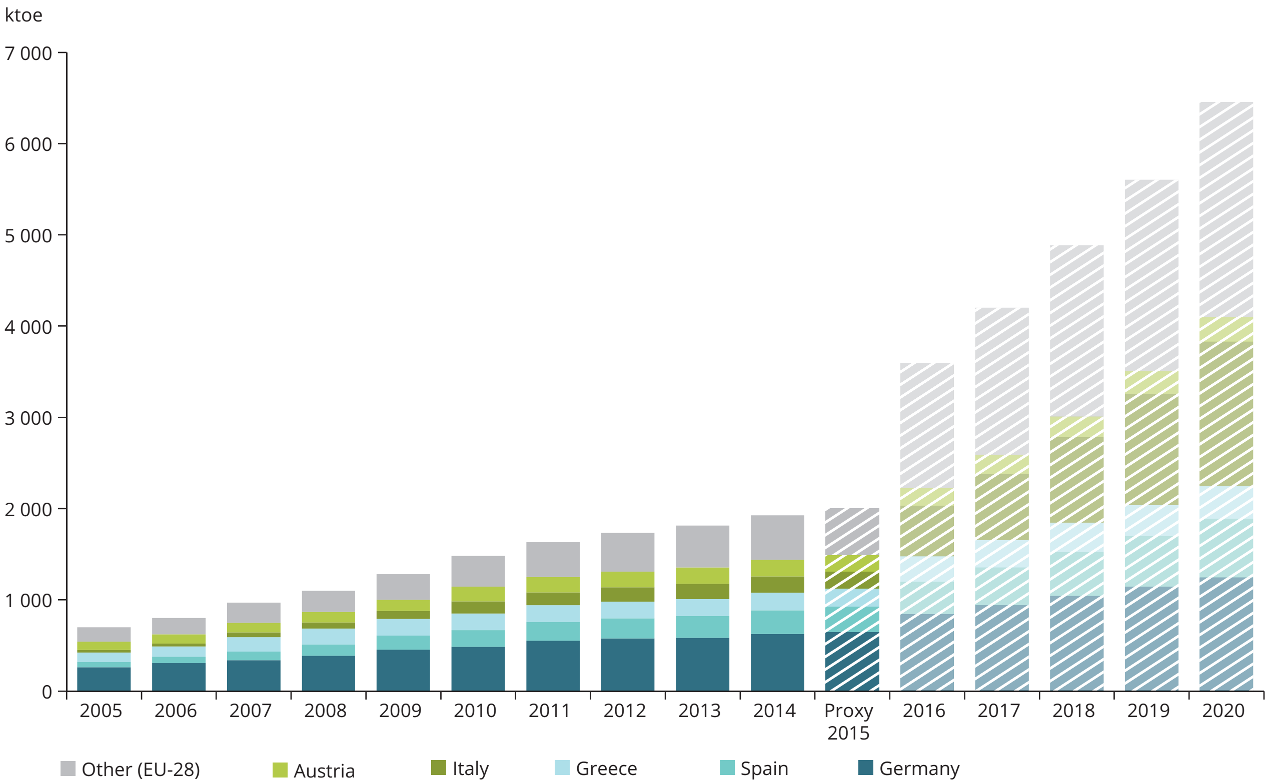
The production of renewable heat from solar thermal technology increased by 12 % per year over the 2005-2014 period, growing from 0.7 Mtoe to 1.9 Mtoe (Figure 2.13). However, despite an estimated increase to 2.0 Mtoe in 2015, solar thermal energy has not been able to meet the expectations of the NREAPs.

Solar thermal collectors 'harvest' heat from the sun for hot water or space heating. The European solar thermal market has been contracting since 2008 (EurObserv'ER, 2015c). The EurObserv'ER attributes this to a drop in house sales and competition from alternative technologies. A growth rate of 22 % 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 2.9 Mtoe in 2014. According to EEA estimates, it reached 3.2 Mtoe in 2015.
- Geothermal heat will have to bridge a large gap if it is to achieve the target anticipated for 2020 — 2.6 Mtoe. In 2014, the production of geothermal heat was 0.7 Mtoe.
- The production of heat from liquid biofuels was 0.3 Mtoe in 2014.

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



Notes: This figure shows the realised final RES-H&C for 2005-2014, approximated estimates for 2015 and the expected realisations in the energy efficiency scenario of the NREAPs for 2016-2020. 'Other (EU-28)' refers to the 23 Member States not displayed individually in the graph.

Sources: EEA; Eurostat; NREAP reports.

2.2.4 Renewable transport fuels

The share of renewable fuels consumed in transport (RES-T) in the EU-28 was 5.9 % in 2014. Figure 2.14 and Table 2.3 show the development of the use of biofuels in transport up to 2014, approximated estimates for 2015 and their expected development based on the NREAPs.

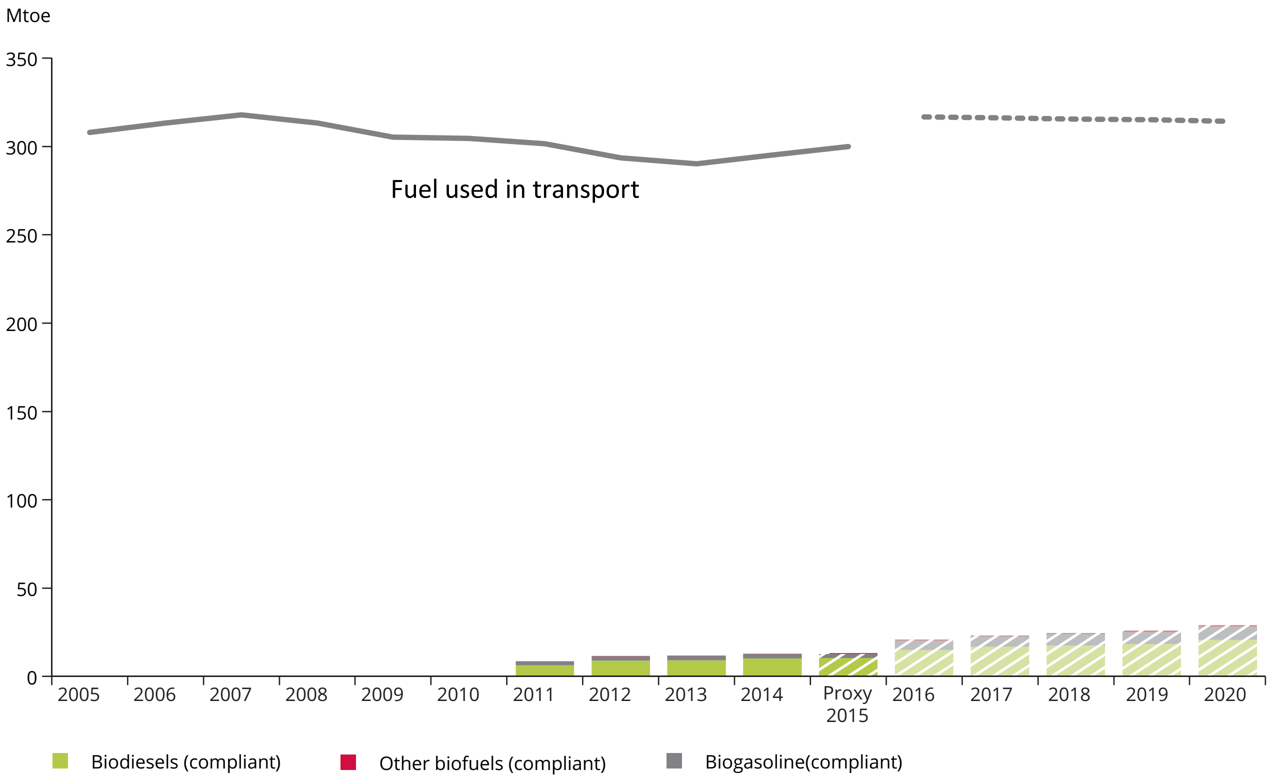
- The gross final consumption of compliant biofuels was 12.9 Mtoe in 2014, which corresponds to an increase of 1.2 Mtoe compared with 2013.
- According to 2015 proxy estimates, the RES-T share grew in 2014 to 6.0 %.
- To realise the expectations in the NREAPs for 2020, a growth rate of 14 % per year would be required over the remaining 2014-2020 period.

The use of renewable electricity in road transport in the EU-28 was 17 ktoe in 2014 and estimated to be 20 ktoe in 2015. The amount of renewable electricity used in other transport modes was 1.5 Mtoe ([11]) in 2014 and estimated to be 1.7 Mtoe in 2015.

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). 2013 was the first year in which the total consumption of biofuels decreased compared with the previous year. In 2014, there was an increase again to 14.1 Mtoe. The EEA estimates that the use of biofuels in transport was 14.2 Mtoe in 2015. Most countries' consumption of biofuels is below the expected realisations in their NREAPs, but there is no clear EU-wide trend.

The renewable energy transport sector has a separate RES target for 2020, which is equal to 10 % for each Member State. Because of concerns about the sustainability and benefits in terms of reductions in GHG emissions of first-generation biofuels, this target was controversial (Kampman et al., 2015).

Figure 2.14 RES-T in the EU-28: biofuels



Notes: This figure shows the realised final renewable energy consumption in transport for 2005-2014, approximated estimates for 2015 and the expected realisations in the energy efficiency scenario of the NREAPs for 2016-2020. The consumption of RES accounts for only biofuels complying with the RED sustainability criteria.

Sources: EEA; Eurostat; NREAP reports.

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

Furthermore, Member States have made different choices for the development of second-generation biofuels because of delays in adopting an EU directive with clear targets. In 2015, the EU Parliament and Council adopted the Directive to reduce indirect land use change for biofuels and bioliquids (ILUC Directive; EU, 2015b), which attempts to tackle — among other things — these concerns: the Directive 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 %. Besides these provisions, the Directive also harmonises the list of feedstocks across the EU whose contribution would count double towards the 2020 target of 10 % for renewable energy in transport (Annex IX); increases the multiplier factors for electricity produced from RES consumed by electric road vehicles and rail transport for calculating the market share of renewable energy in transport; increases the minimum reduction threshold for GHG emissions applied to biofuels produced in new installations; and obliges fuel suppliers to report annually the provisional mean values of the estimated indirect land use change emissions from biofuels traded ([12]).

In recent years, a significant volume of biofuels could not be demonstrated to be compliant with the sustainability criteria for inclusion in the calculation for the RED ([13]).

Table 2.3 RES-T in the EU-28: biofuels

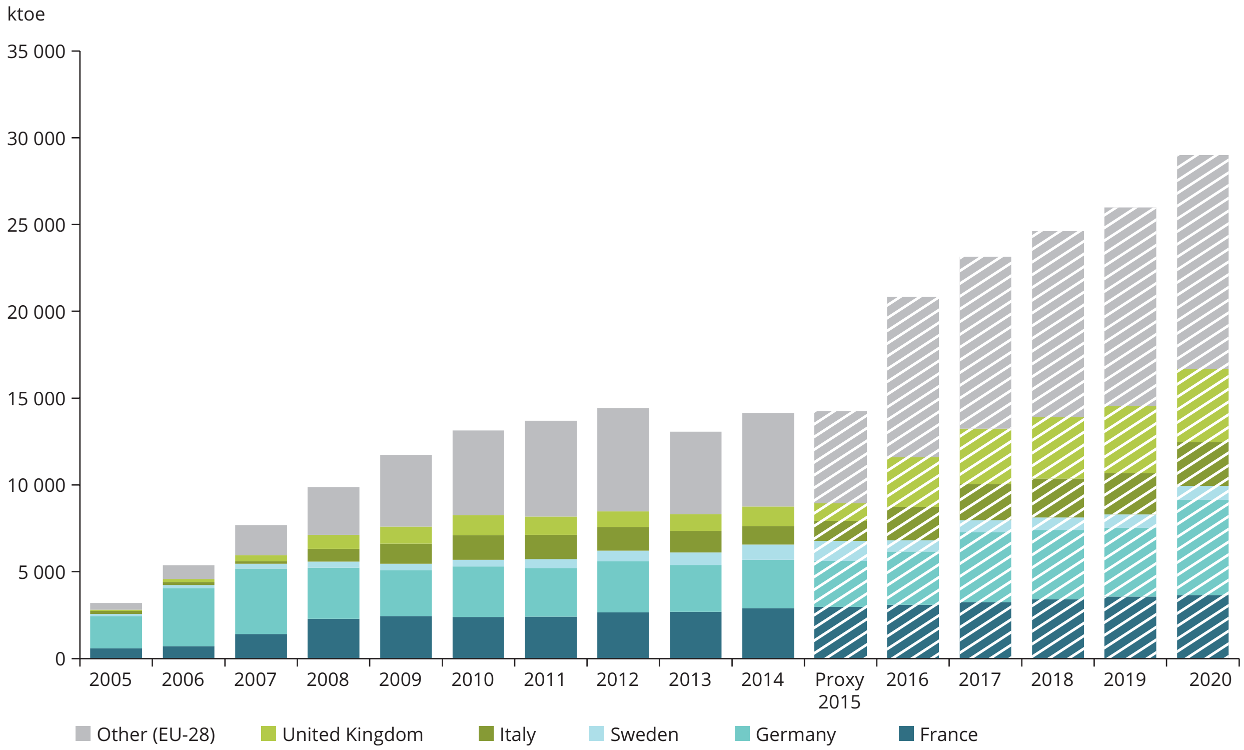
	Final energy (ktoe)					Annual growth rate (%)		
Technology	**2005**	**2013**	**2014**	**Proxy 2015**	**NREAP 2020**	**2005-2014**	**2013-2014**	**2014-2020**
Biodiesels (all)	2 470	10 276	11 342	11 427	20 920	18 %	10 %	11 %
Biogasoline (all)	574	2 659	2 657	2 622	7 324	19 %	0 %	18 %
Other biofuels (all)	155	126	142	168	746	– 1 %	13 %	32 %
Compliant biofuels	0	11 727	12 886	13 104	28 989	n.a.	10 %	14 %
All biofuels	3 198	13 060	14 141	14 217	28 989	18 %	8 %	13 %

Notes: This table shows the realised final renewable energy consumption in transport for 2005, 2013 and 2014, approximated estimates for 2015 and the expected realisations in the energy efficiency scenario of the NREAPs for 2020. Also shown are the realised compound annual growth rates for 2005-2014, the growth from 2013 to 2014 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; NREAP reports.

([12]) Directive (EU) 2015/1513.
([13]) Roughly 8 % of all biofuels consumed in transport in 2014 were not demonstrated to be compliant with the sustainability criteria in the RED.

Figure 2.15 RES-T in the EU-28: biofuels including non-compliant biofuels



Notes: This figure shows the realised final renewable energy consumption in transport for 2005-2014, approximated estimates for 2015 and the expected realisations in the energy efficiency scenario of the NREAPs for 2016-2020. 'Other (EU-28)' refers to the 23 Member States not displayed individually in the graph.

Sources: EEA; Eurostat; NREAP reports.

2.3 Effects on energy consumption and greenhouse gas emissions

The EU's renewable energy targets are one important part of the combined efforts to decarbonise the energy system. Although the RES targets are expressed in relative terms (i.e. as a share related to the future levels of energy consumption), progressing towards them can effectively displace fossil fuels and complement policies for the energy system that reduce GHGs. As energy efficiency improvements — another key dimension of the EU's decarbonisation efforts — gradually reduce our total energy needs, the growing share of renewable energy results in a progressively larger displacement of non-renewable alternatives.

To date, the consumption of RES has steadily increased, both as a relative 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 ([14]) of renewable energy on fossil fuel consumption and its associated GHG emissions and then — statistically — on primary energy consumption. The estimates were made by comparing actual growth in renewable energy since 2005 with a counter-factual scenario in which this growth would be delivered 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 or carbon accounting. The method is described in detail in the EEA report *Renewable energy in Europe — Approximated recent growth and knock-on effects* (EEA, 2015a).

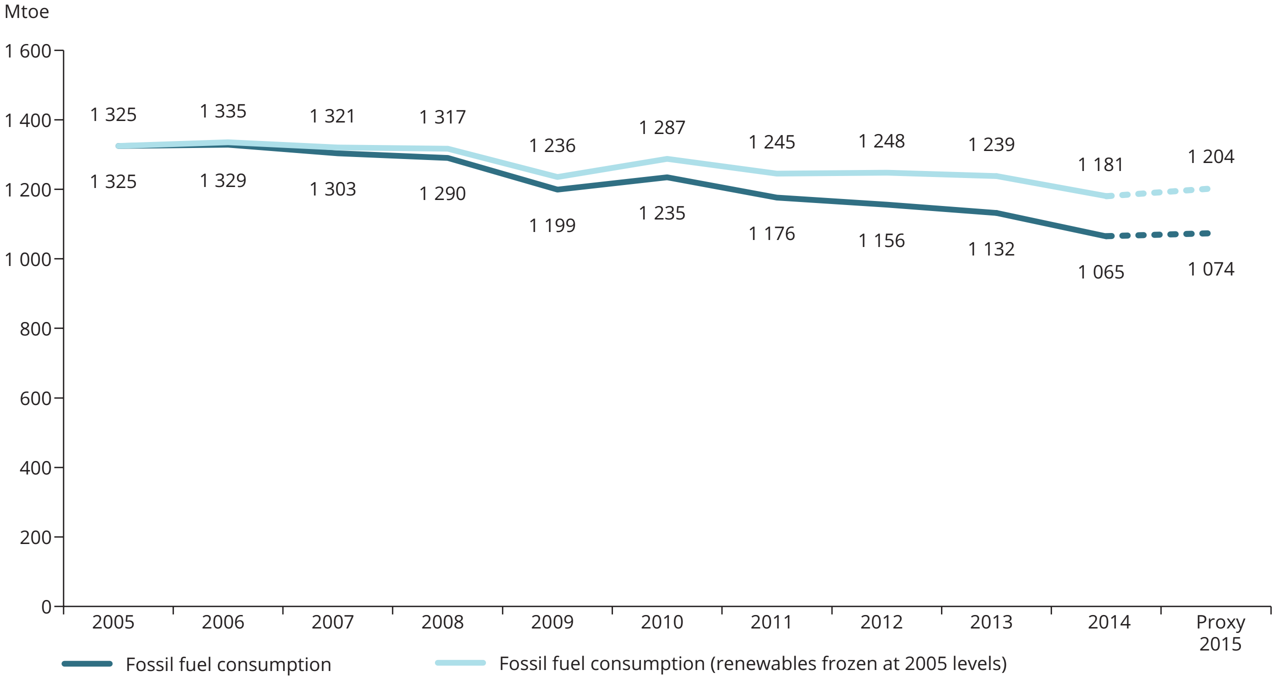
([14]) The term 'gross' describes the theoretical character of the effects estimated in this way. The potential interactions between renewable energy deployment, on the one hand, and the need to reduce GHG emissions under the EU-wide cap set by the Emissions Trading System (EU ETS), as well as wider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

2.3.1 *Effects at the EU-28 level*

Avoided fossil fuel use

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 130 Mtoe in 2015 (approximately 11 % of total fossil fuel consumption), as shown in Figure 2.16 and Table 2.4. This amount is comparable to the fossil fuel consumption of Italy. The largest reductions were realised in the consumption of solid fuels (62 Mtoe, or roughly 48 % of all avoided fossil fuels) and gaseous fuels (36 Mtoe, representing about 28 % of all avoided fossil fuels).

Figure 2.16 Estimated effect on fossil fuel consumption in the EU-28



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

Source: EEA; Eurostat.

Table 2.4 Estimated effect on fossil fuel consumption in the EU-28 (Mtoe)

Fuel type	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Proxy 2015
Solid fuels	0	– 3	– 7	– 11	– 13	– 19	– 27	– 40	– 48	– 55	– 62
Gaseous fuels	0	– 2	– 6	– 11	– 16	– 23	– 22	– 27	– 31	– 31	– 36
Petroleum products	0	– 1	– 4	– 5	– 7	– 11	– 10	– 13	– 15	– 14	– 17
Petrol	0	0	0	0	0	0	– 2	– 2	– 2	– 2	– 2
Diesel	0	0	0	0	0	0	– 6	– 9	– 9	– 10	– 11
Non-renewable waste	0	0	0	0	0	– 1	– 1	– 1	– 1	– 2	– 2
Total	**0**	**– 7**	**– 17**	**– 27**	**– 36**	**– 53**	**– 69**	**– 92**	**– 107**	**– 115**	**– 130**

Notes: This table shows the estimated effect on fossil fuel consumption of the increase in renewable energy consumption since 2005.

Source: EEA; Eurostat.

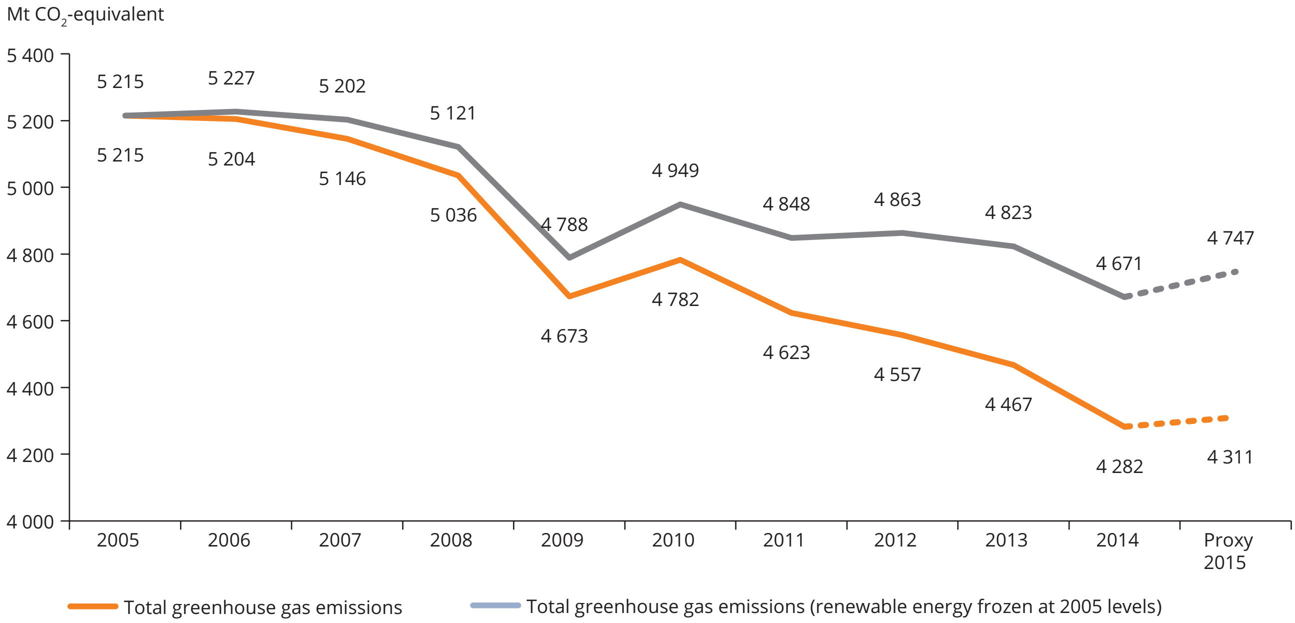
Gross avoided GHG emissions

According to the EEA, the growth in the consumption of renewable energy after 2005 resulted in an estimated 436 Mt of gross avoided CO_2 emissions at the EU level in 2015 — a 12 % increase compared with 2014 (Figure 2.17). This amount is comparable to the GHG emissions of Italy. The contribution from RES-E (330 Mt CO_2, or 76 % of all gross avoided emissions) was considerably larger than that of RES-H&C (66 Mt CO_2, or 15 % of all gross avoided emissions) and biofuels in transport (40 Mt CO_2, or around 9 % of total gross avoided emissions). This is because the increase in RES-E has reduced the need for solid fossil fuels — the most carbon-intensive fossil fuels — in the power sector.

In 2015, total GHG emissions (excluding international aviation and LULUCF) in the EU-28 were 4 311 Mt CO_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 10 % of EU's total GHG emissions in 2015.

As shown in Figure 2.18 and Table 2.5, the gross avoided emissions within the Emissions Trading Scheme (ETS) were estimated to be approximately 345 Mt CO_2 in 2015. The gross avoided emissions in non-ETS sectors were estimated to be approximately 92 Mt CO_2 ([15]).

Figure 2.17 Estimated gross effect on GHG emissions in the EU-28

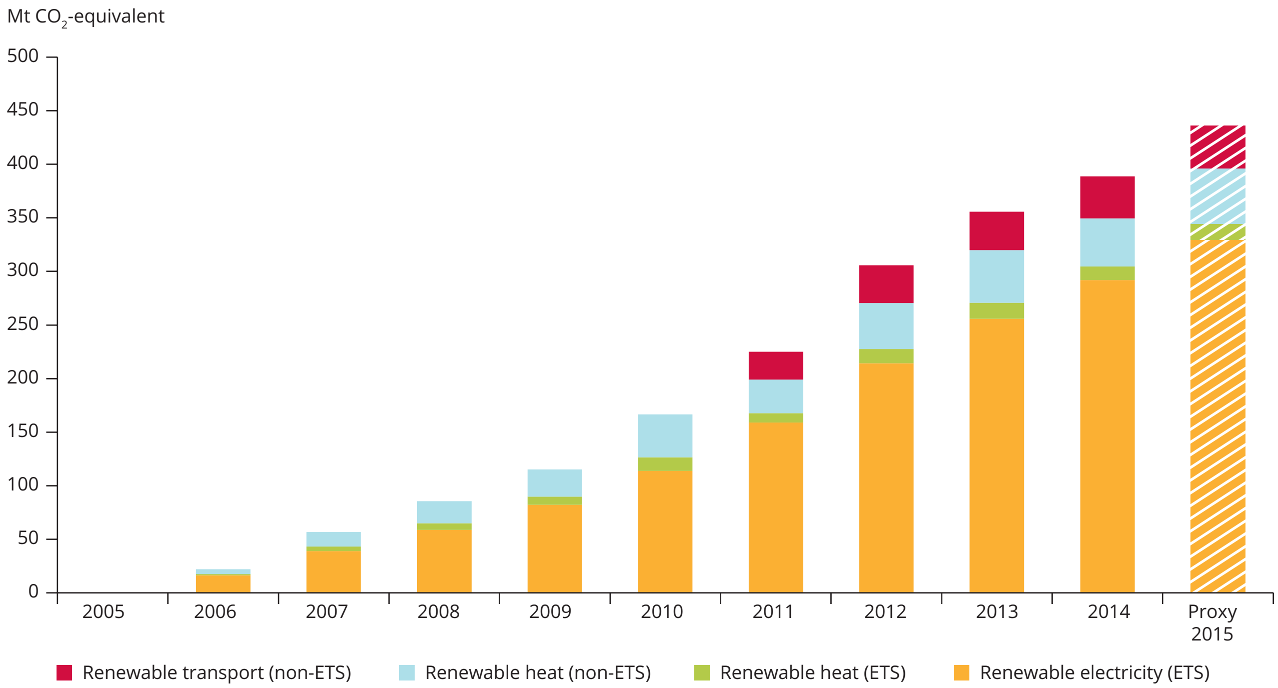


Notes: This figure shows the estimated gross reduction in GHG emissions (excluding international aviation) due to the increase in renewable energy consumption since 2005.

Source: EEA; Eurostat.

([15]) 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 either heat that is produced in sectors falling under the ETS or heat that is produced in non-ETS sectors. We assume that the share of ETS emissions in the industry sector is an indicator for the share of renewable heat production in the industry that takes place under the ETS.

Figure 2.18 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; Eurostat.

Table 2.5 Estimated gross reduction in GHG emissions in the EU-28 (Mt CO_2)

		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Proxy 2015
ETS	Electricity	0	16	39	59	82	114	159	214	256	292	330
	Heating and cooling	0	1	4	6	8	13	9	13	15	13	15
	Transport	0	0	0	0	0	0	0	0	0	0	0
	All renewables	0	18	43	65	90	126	168	228	271	305	345
Non-ETS	Electricity	0	0	0	0	0	0	0	0	0	0	0
	Heating and cooling	0	4	13	21	25	40	31	43	49	45	52
	Transport	0	0	0	0	0	0	26	35	36	39	40
	All renewables	0	4	13	21	25	40	57	78	85	84	92
Total	Electricity	0	16	39	59	82	114	159	214	256	292	330
	Heating and cooling	0	6	18	27	33	53	40	56	64	57	66
	Transport	0	0	0	0	0	0	26	35	36	39	40
	All renewables	0	22	57	86	115	167	225	306	356	389	436

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

Source: EEA; Eurostat.

Statistical impacts of RES on primary energy consumption

Primary energy consumption measures a country's total energy demand ([16]). Whereas the RED sets forth binding targets for 2020 for the share of renewable energy in GFEC, some energy policies put forward targets and objectives expressed in **primary** energy. This is the case for the recast Energy Performance of Buildings Directive (EPBD ([17])) and the Energy Efficiency Directive (EED ([18])). As the latter is part of the EU 20-20-20 climate and energy package ([19]), an assessment of interactions between different RES technologies and their statistical impacts on primary energy is presented further below. The methodology underpinning these findings was described in a previous EEA report (EEA, 2015a) ([20]).

At the EU level, primary energy consumption has been decreasing almost constantly since 2005 (EEA, 2015c). 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. For example, 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);
- an increasing share of certain renewable energy, such as hydro- and wind power, in electricity generation.

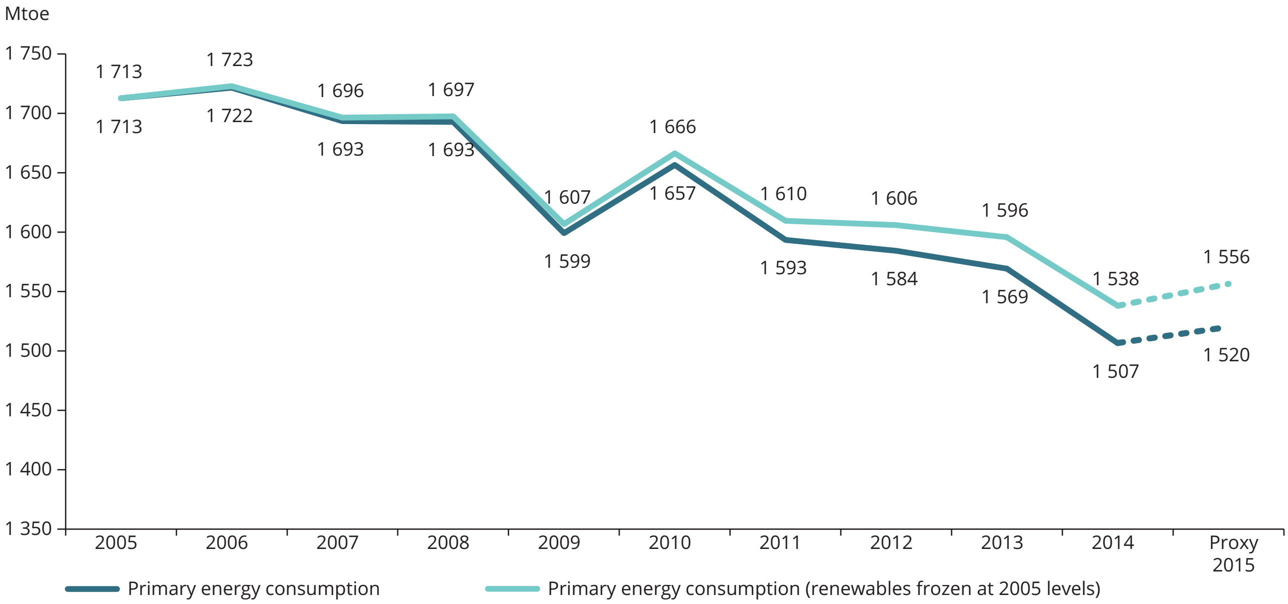
This is because the statistical methodologies in use follow the common physical principle of the first measurable primary equivalent energy in order to estimate the primary energy of certain technologies or sources. For nuclear and geothermal energy, the first measurable primary equivalent energy is 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.

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 the 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 2.19 and Table 2.6). The estimated reduction in primary energy consumption in 2014 was 31 Mtoe. Without the growth of renewable energy since 2005, primary energy consumption in the EU-28 in 2014 could have been 2 % higher.

([16]) Primary energy consumption is the gross inland consumption, excluding all non-energy use of energy carriers.
([17]) Directive 2010/31/EU.
([18]) Directive 2012/27/EU.
([19]) 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.
([20]) 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.

Figure 2.19 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.

Source: EEA; Eurostat.

Table 2.6 Estimated effect on primary energy consumption in the EU-28 (Mtoe)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Proxy 2015
Renewable electricity (normalised, compliant biofuels)	0.0	– 1.2	– 3.5	– 5.2	– 8.3	– 11.3	– 16.4	– 22.6	– 27.7	– 31.5	– 36.2
Renewable heating and cooling (compliant biofuels)	0.0	0.1	0.6	0.6	0.8	1.7	0.3	1.1	1.3	0.0	– 0.1
Renewable transport fuels (compliant biofuels)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
All renewables (normalised, compliant biofuels)	0.0	– 1.1	– 3.0	– 4.5	– 7.5	– 9.6	– 16.1	– 21.6	– 26.5	– 31.5	– 36.3

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

Source: EEA; Eurostat

Knock-on effects by renewable energy technology

Table 2.7 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 (133 Mt CO_2), solar PV energy (78 Mt CO_2) and heat from solid biomass (51 Mt CO_2) ([21]). Onshore wind and solar PV energy are also the most important contributors to avoided fossil fuel consumption and avoided primary energy consumption. In contrast, heat from solid biomass increased primary energy consumption by 3.4 Mtoe.

The use of solid biomass for electricity and heating leads to a gross reduction in GHG emissions and fossil fuel consumption ([22]), but it drives up the primary energy consumption.

Owing to statistical conventions followed by Eurostat, consumption of concentrated solar power and geothermal energy can also increase primary energy consumption.

Table 2.7 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 (Mt CO_2)		Effect on fossil fuel consumption (ktoe)		Effect on primary energy consumption (ktoe)	
	2014	Proxy 2015	2014	Proxy 2015	2014	Proxy 2015	2014	Proxy 2015
Renewable electricity								
Biogas	3 865	3 994	– 37	– 38	– 9 603	– 9 947	– 400	– 438
Bioliquids (compliant)	406	466	– 3	– 4	– 956	– 1 096	– 36	– 42
Concentrated solar power	469	469	– 4	– 4	– 1 159	– 1 159	248	248
Geothermal	71	80	– 1	– 1	– 169	– 190	538	606
Hydropower excl. pumping (normalised)	285	176	– 4	– 3	– 938	– 669	– 653	– 493
Offshore wind (normalised)	2 477	3 511	– 20	– 30	– 5 971	– 8 493	– 3 493	– 4 982
Onshore wind (normalised)	13 219	15 173	– 116	– 133	– 32 165	– 36 779	– 18 946	– 21 606
Solar photovoltaic	7 815	8 543	– 71	– 78	– 19 344	– 21 106	– 11 529	– 12 563
Solid biomass	4 215	4 713	– 36	– 40	– 10 020	– 11 200	2 754	3 082
Tidal, wave and ocean energy	0	0	0	0	0	0	0	0
Renewable heat								
Biogas	2 194	2 470	– 7	– 8	– 2 456	– 2 764	– 17	– 20
Bioliquids (compliant)	274	274	– 1	– 1	– 306	– 306	1	1
Geothermal	131	143	0	0	– 147	– 160	116	126
Renewable energy from heat pumps	5 860	7 382	– 3	– 3	– 2 798	– 3 420	– 2 798	– 3 420
Solar thermal	1 226	1 303	– 4	– 4	– 1 372	– 1 458	– 146	– 155
Solid biomass	13 477	15 894	– 43	– 51	– 15 105	– 17 812	2 865	3 379
Biofuels in transport								
Biodiesels (compliant)	10 294	10 512	– 32	– 33	– 10 294	– 10 512	0	0
Biogasoline (compliant)	2 451	2 424	– 7	– 7	– 2 451	– 2 424	0	0
Other biofuels (compliant)	140	168	0	– 1	– 140	– 168	0	0
Total renewables (normalised, compliant biofuels)	68 872	77 693	– 389	– 436	– 115 394	– 129 664	– 31 496	– 36 277

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; Eurostat.

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

([22]) 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.

Effects at EU 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 2014, the largest relative reductions in the consumption of fossil fuels were realised by Sweden (24 %), Denmark (22 %) and Finland (15 %), in proportion to their domestic fossil fuel use. In absolute terms, the greatest quantities of fossil fuels were avoided in Germany and Italy (Figure 2.20).

In terms of gross avoided GHG emissions in 2014, the countries with the largest estimated gross reductions were Germany (111 Mt CO_2), Italy (47 Mt CO_2) and the United Kingdom (39 Mt CO_2) (Figure 2.21). In relative terms, significant GHG emission reductions (of 10 % or more of the total national GHG emissions, excluding international aviation and LULUCF) were recorded in eight countries in 2014 (Sweden, Denmark, Finland, Austria, Portugal, Germany, Spain and Italy), as illustrated in the figure below. 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.

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 (– 8 %, – 7 % and – 5 %, respectively), whereas in Latvia and Finland the statistical conventions in place resulted in a slight increase in primary energy consumption due to their prevalence of biomass-based renewable energy. The effect of renewable energy on GHG emissions and energy consumption in 2014 are summarised by country in Annex 1.

Box 2.2 Finland — a successful cleantech cluster

Finland's climate and lack of fossil fuel resources has forced industry and society to minimise energy consumption and innovate and made Finland a leading cleantech, or clean technology, country. In 2014, Finland ranked second in the world, according to the Global Cleantech Innovation Index. The index ranks countries according to their potential to produce entrepreneurial cleantech start-ups that will commercialise clean technology innovations over the next 10 years. Five additional EU Member States were ranked among the top 10 countries globally (Denmark, Germany, Ireland, Sweden and the United Kingdom).

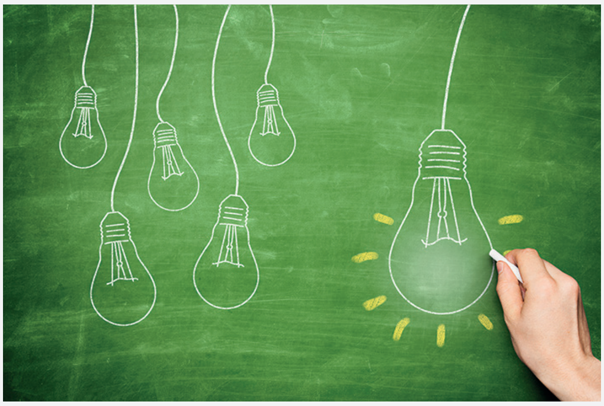
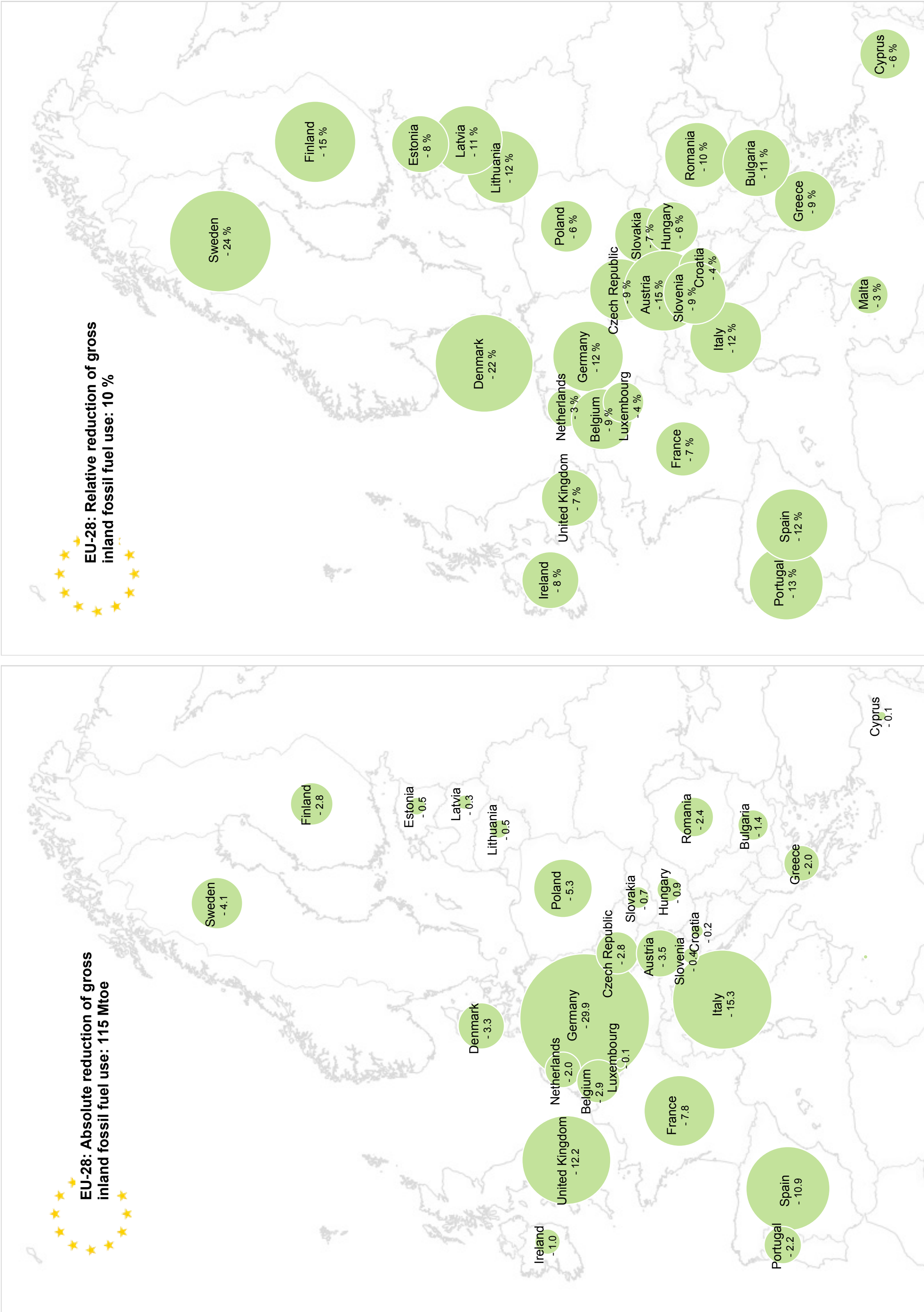


Photo: © StockFinland (istockphoto.com)

The case of Finland illustrates how dedicated research and development (R&D) budgets and strategic programmes can accelerate innovation. More than 40 % of Finnish public R&D funding goes into the energy and environment sector, and more than one third of public R&D investments are in cleantech. The Finnish government aims to raise the turnover of Finnish cleantech companies to EUR 50 billion and create 40 000 new jobs by 2020.

More information: http://www.cleantech.com/indexes/the-global-cleantech-innovation-index.

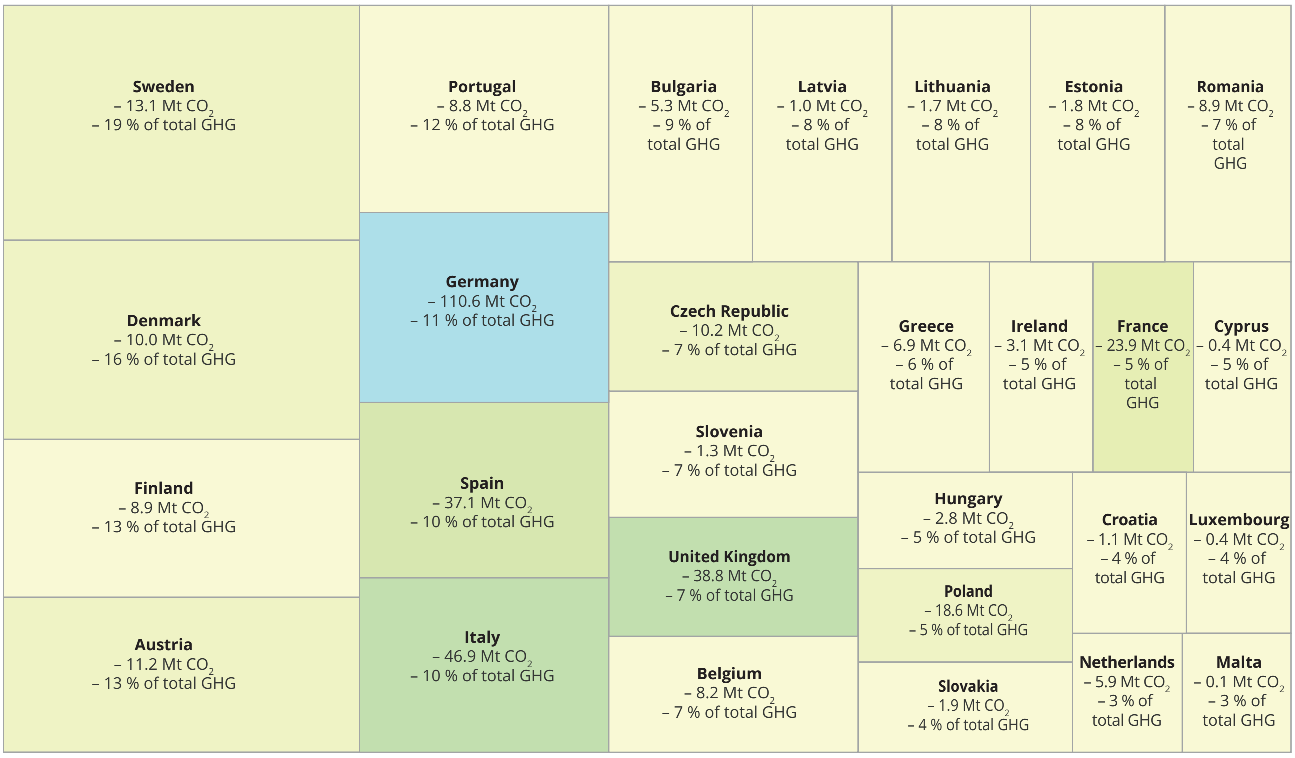
Figure 2.20 Total and relative reduction in gross inland fossil fuel use (per year in 2014)



Notes: Left panel: absolute reduction in gross inland fossil fuel use (Mtoe) due to the increase in renewable energy use per country since 2005. Right panel: 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.

Figure 2.21 Total and relative gross avoided GHG emissions (per year in 2014)



Note: The area of the 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 CO2 within its total national GHG emissions (excluding international aviation and 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; Eurostat.

3 RES developments: a global perspective

Chapter 2 presented actual and approximated recent progress at the EU level and in the 28 EU Member States. This chapter focuses on global RES developments, as a way of contrasting European developments with the changes in renewable energy occurring in other parts of the world.

The Renewable Energy Policy Network for the 21st Century (REN21, 2016) estimates that RES provided 19.2 % of global final energy consumption in 2014. On a global scale, it is important to realise that traditional biomass is still an important source of energy for the majority of the world's population, despite the associated health and environmental impacts ([23]). The available global data on gross renewable energy consumption do not make it possible for traditional biomass fuels to be excluded. The aggregate numbers thereby obscure underlying trends in modern RES, which offer the most relevant points of comparison for European developments. Therefore, this chapter focuses only on the global development of RES-E, such as installed RES-E capacities and investments.

The analysis in this chapter shows that:

- In terms of installed RES-E capacity per world region, the EU-28 (409 GW) comes in second after China (520 GW). The EU-28 has the largest solar PV capacity in the world, and in 2015 was surpassed only by China, which already is world leader in wind power capacity.

- The EU-28 was the region exhibiting the highest new investments in renewable energy every single year

Box 3.1 The energy–water–food nexus

By 2050, the demand for energy worldwide will have nearly doubled, while the demand for water and food are estimated to increase by more than 50 % (IRENA, 2015b). To overcome these increasing constraints, we need to fundamentally rethink how we produce and consume energy in relation to the water and food sector. Currently, energy supply already accounts for approximately 15 % of global freshwater withdrawals annually, linked to activities such as fuel extraction, processing and power generation, for fossil fuels, cooling, in nuclear power generation, and feedstock production, in the case of dedicated energy crops (IEA, 2012). The availability and accessibility of water resources are vital for energy security, and water stress could be exacerbated also in specific EU regions by the increase of irrigated energy crops over time (Vandecasteele, 2016). Thus, saving water would allow energy savings (through the energy needed to extract, transport and treat water).

Photo: © PeopleImages (istockphoto.com)

Conversely, disruptions in energy provision services can also have direct impacts on water security. As water scarcity and droughts and fluctuations in the energy price can affect food production, affordability and accessibility, pressures on the supply of water and energy can alternatively pose critical risks for food security. Consequently, rapid upscaling of low-carbon energy technologies can have substantial spill-over effects in the water and food sectors (IRENA, 2015b) or can increase other problems related to pollution, land appropriation and nutrient cycles (van den Bergh, 2015).

([23]) 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 countries in 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 (IRENA, 2016b).

from 2005 to 2012, but was surpassed by China in 2013, a country that has established itself as the clear leader in renewable energy investments since then.

- Of the world regions with sufficient available data, the EU-28 came in fifth regarding the share of renewable energy-related jobs in the total workforce in 2015 (after Brazil, China, Japan and the United States). In the EU-28, Germany, which had 0.9 % of its labour force working in jobs related to renewable energy, played a leading role.

3.1 RES-E capacities by region and main source

3.1.1 RES-E development by region

On a global scale, the installed RES-E capacity doubled (from 993 GW to 1 985 GW) between 2005 and 2015, while total electricity consumption grew by only approximately 57 % over the same time period (IRENA, 2016b; REN21, 2016). According to Frankfurt School and the United Nations Environment Programme (Frankfurt School-UNEP, 2016), in 2015, for the first time ever more than half of all newly installed power capacity was accounted for by renewable energy, as renewables (excluding large hydropower schemes) accounted for 53.6 % of net additions to global power-generating capacity. As a result, the share of RES-E in global electricity production rose to an estimated 23.7 % by the end of 2015 (of which 16.6 % was provided by hydropower).

Figure 3.1 illustrates the development of installed RES-E capacity between 2005 and 2015 for different world regions. Three groups of regions can be distinguished. In the first group of countries (ASOC, Brazil, China, India,), electricity consumption is expanding rapidly, and generation from both renewable energy and fossil fuels is being deployed to meet growing demand. The second group (EU-28 and the United States) experienced a slow growth or decline in electricity consumption. In these countries, renewable energy is increasingly displacing existing generation and disrupting traditional energy markets and business models. For the third group of countries (Africa, the Americas, excluding the United States and Brazil, the Middle East, OE-CIS), RES-E development has been relatively slow, despite growing electricity consumption.

The prime example of the first group of countries is China. With 520 GW of RES-E capacity installed, China managed to more than quadruple its renewable energy capacity over the 2005-2015 period, maintaining a staggering compound annual growth rate of 15.7 %. With 296 GW installed, large-scale hydropower is still by far the largest source of RES-E ([24]), with wind power (145 GW) coming in a distant second. However, with 30 GW of wind capacity and 15 GW of solar PV capacity added in 2015, China was the world leader for both technologies. Nevertheless, looking at new fossil-fuelled capacities that became operational in 2015, China also accounted for approximately half of the 85 GW of new coal-fired capacity, with India representing another 25 %, and the rest of Asia another 10 % ([25]).

Box 3.2 The importance of land use

Just as the fossil fuel-based energy system has profound impacts on land use and the associated ecosystem functioning (e.g. Gorissen et al., 2010), an energy system based predominantly on renewable sources, especially because of its decentralised nature, can also provoke land system change. For example, solar PV and wind energy are more land use-intensive energy production techniques (in terms of the area used per unit of energy produced) than coal, nuclear and natural gas (EEA, 2016b). Energy crop biomass for biofuels is the most land use-intensive energy production technique in use (EEA, 2016b). Therefore, renewable energy projects need to be tailored to local and regional contexts in a way that takes into account and reduces their potential negative social and environmental impacts.

([24]) In 2015, China added 16.1 GW of hydropower capacity; the country is aiming to add 350 GW by 2020 and 510 GW by 2050, all capacities excluding pumped storage (International Hydropower Association, 2015). This is equivalent to building between 17 and 25 more dams the size of China's Three Gorges Dam (currently the largest in the world) in 2020 and 2050, respectively.

([25]) The authors of REN 21 (2016), however, report that the Chinese government has announced plans to close coal mines and reduce coal's share of electricity production in 2016, due to a near-zero growth in electricity consumption. The interest for coal power in other South Asian countries remains high, however.

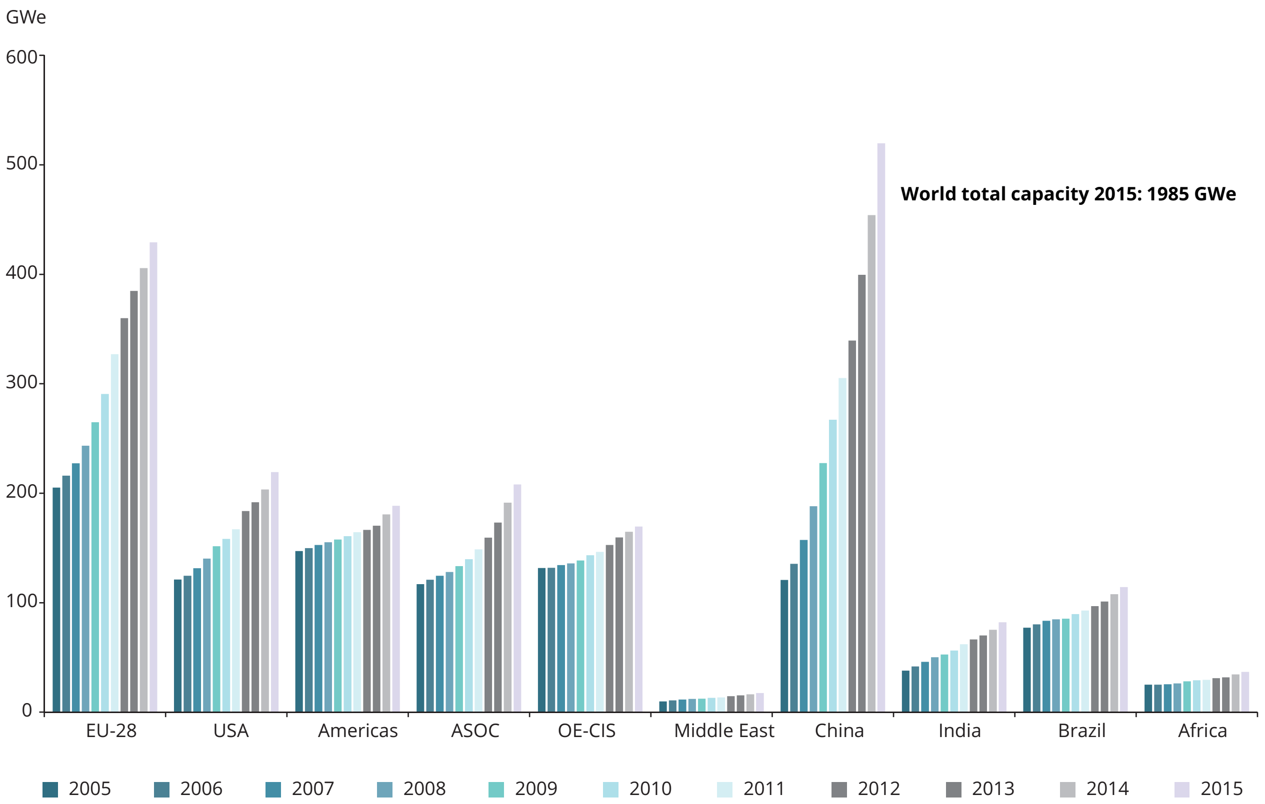
As far as gas-fired generation is concerned, China accounted for approximately 15 % of the 44 GW of new capacity coming into service (while the United States accounted for some 25 %) (Frankfurt School-UNEP, 2016). Of the other countries in the ASOC region, India also more than doubled its RES-E capacity over the 2005-2015 period (from 38 to 82 GW), and has established itself as the top country in terms of additions of wind, solar PV and hydropower capacity (REN21, 2016). According to REN21 (2016), other countries such as Malaysia, Pakistan, the Philippines, South Korea, Thailand and Vietnam are emerging as important markets for more than one RES-E technology.

In the second group of countries, the EU more than doubled its RES-E capacity over the 2005-2015 period, from 205 to 409 GW installed. As a result, the share of renewables in the EU's total power capacity increased to 44 % in 2015, and, with a 27.5 % share of electricity generated in 2014, renewables were Europe's largest source of electricity (REN21, 2016; IRENA, 2016b).

With 142 GW installed, wind power is the EU's largest renewable power source, followed by hydropower (126 GW) and solar PV energy (95 GW). According to REN21 (2016), renewables accounted for the majority (77 %) of new EU generating capacity for the eighth consecutive year, and the EU continues to decommission more capacity from conventional sources than it installs. Even so, markets appear to have slowed down in most EU Member States due to reduced levels of financial support and to an increased focus on the integration of variable renewable generation. In the United States, the installed RES-E capacity amounted to 219 GW in 2015, accounting for nearly 13.7 % of electricity generation (REN21, 2016). Hydropower is still the largest renewable power source (80 GW), closely followed by wind power (73 GW). However, with nearly 8 GW of wind capacity added in 2015, wind power is poised to overtake hydropower as the United States' leading RES-E source.

In a third group of countries, RES-E development has faced more difficulties. In the Middle East, relatively little RES-E capacity has been deployed. Nevertheless, there is a growing interest in solar PV energy and concentrated solar power in the region (REN21, 2016). Despite being one of the most promising markets for

Figure 3.1 RES-E capacities in selected world regions, 2005-2015



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 list of abbreviations.

Sources: IRENA, 2016b; REN21, 2016.

Box 3.3 Solar sharing — co-production of food and energy in Japan

In Japan, solar PV panels are mounted above ground and arranged at certain intervals to allow enough sunlight for photosynthesis and space for agricultural machinery. In April 2013, the Ministry of Agriculture, Forestry and Fisheries in Japan approved the installation of solar PV systems on crop-producing farms, which had been previously prohibited under the Agricultural Land Act. Farmers are required to report their annual area under crop cultivation and, if it falls below 80 %, they will be required to dismantle the PV system. Farmers in Fukushima also take part in a solar-sharing scheme. They grow crops such as oilseed rape — which absorbs radiation — to decontaminate their farmland, and hope to make up for the income losses by selling the electricity produced. The solar-sharing projects illustrate that careful design and choice of site for energy infrastructure can limit or reduce spill-over effects and provide opportunities for the combined use of arable land.

Photo: © albertogagna (istockphoto.com)

More information: http://www.i-sis.org.uk/Japanese_Farmers_Producing_Crops_and_Solar_Energy.php.

renewable energy (because of the combination of a growing population, an urgent need for new generation capacity, a lack of access to electricity in remote areas and abundant natural resources), RES-E development in Africa has been modest so far. Furthermore, RES-E investments in the continent have been highly uneven, with much of the development taking place in South Africa, and recently also Morocco (Frankfurt School-UNEP, 2016).

The Americas (excluding the United States and Brazil) have experienced relatively limited growth in RES-E capacity over the 2005-2015 period (from 147 to 189 GW), although it has to be noted that some of the countries with the highest share of RES-E generation are located in the region ([26]). Concerning the OE-CIS, although there is a sizeable solar PV and onshore wind development potential throughout the region, the deployment of RES-E capacity is still mainly dominated by hydropower (the Ukraine is a notable exception) ([27]). A large part of the region is hampered by considerable regulatory and investment barriers, as well as a lack of awareness about renewable energy and energy efficiency. Market entry remains challenging in countries that have not fully liberalised their energy markets and/or are still subsidising fossil fuels to a large extent. Furthermore, entrenched interests in conventional energy resources in many countries represent a significant barrier to effective legislation and policy implementation (REN21, 2016).

3.1.2 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 (2016), wind and solar PV technologies together made up about 77 % of the renewable power capacity added in 2015. With realistic global wind and solar electricity potentials ranging between 730 and 3700 EJ per year, the long-term contribution of wind and solar power to the world's energy needs could be vast and outstrip our energy needs (Deng et al., 2015). Only a small part of this vast potential has been realised to date, as deployment of these progressive renewable energy

([26]) For example, Costa Rica generated 99 % of its electricity with renewable sources in 2014, while Uruguay generated 92,8 % (REN21, 2016).
([27]) REN21 (2015) discusses the following countries: Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Montenegro, the Russian Federation, Serbia, Tajikistan, the former Yugoslav Republic of Macedonia, Turkmenistan, Ukraine and Uzbekistan.

technologies started only relatively recently. As a result, the estimated share of wind (3.7 %) and solar PV power (1.2 %) in global electricity production at the end of 2015 was still relatively small (REN21, 2016).

By far the largest installed solar PV capacity in 2015 was in the EU-28 (Figure 3.2; more than double the installed capacity in China), followed by China, Japan and the United States. Together, the EU, China, Japan and the United States account for 88 % of the total installed solar PV capacity worldwide (Section 3.2). Through its clear leadership since 2005, the EU-28 has contributed significantly to the demonstration and commercialisation of solar PV and wind power worldwide (Sections 3.2 and 3.3).

These developments occurred essentially because of the implementation of various market-pull policy support instruments. The growth rates in solar PV capacity between 2014 and 2015 in China (53 %), Japan (43 %) and the United States (40 %), however, by far surpassed the EU growth rate (8 %). It is also worth noticing that, since 2010, solar PV deployment has taken place at an increasing speed in other parts of the world, with Australia, India, South Korea, Canada, Thailand and South Africa contributing significantly to that growth.

In 2015, China overtook the EU as the region with the largest total installed wind power capacity (both onshore and offshore) (see Figure 3.3). The EU, China, the United States and India together accounted for 89 % of the total installed wind power capacity worldwide in 2015. Significant additions to wind power capacity were also realised by Canada, Brazil, Australia, Mexico, Japan and Chile.

The total global installed solar PV and wind power capacities in 2015 illustrate that only a very small share of the realistic potentials of these two technologies has been exploited to date.

Box 3.3 Cost reduction potential of onshore wind

Historically, the installed costs of onshore wind power have declined by 7 % every time global installed capacity has doubled. By 2025, the total installed costs of onshore wind farms could have declined by around 12 %.

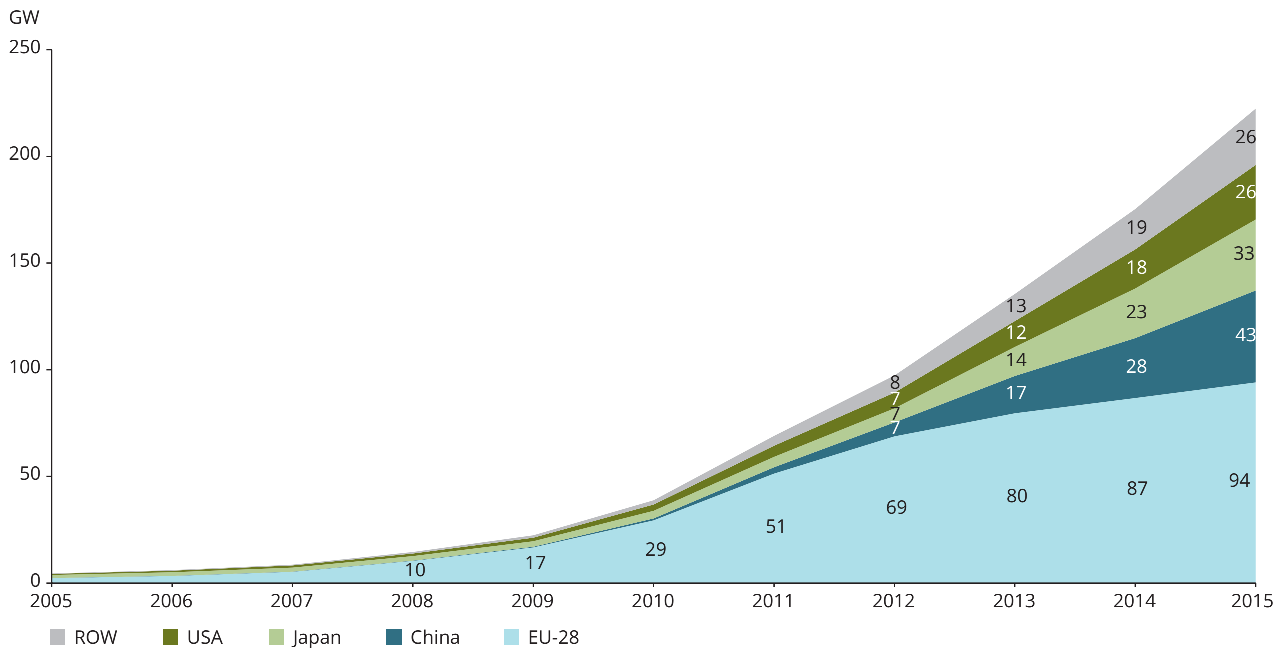
The combination of lower total installed and operational and maintenance costs, as well as rising capacity factors, means that the levelised cost of electricity of onshore wind could fall by 26 % by 2025. The levelised cost of electricity will fall more rapidly than investment costs, as ongoing technological improvements from improved design, larger turbines and increased hub heights and rotor diameters unlock greater capacity for the same wind resource.

Global onshore wind learning curve analysis, 1983-2014

Note: Circles represent individual projects in IRENA's renewable cost database or country averages for data prior to 2000. The centre of the circle indicates the value to be read on the y-axis and the diameter of the circle is the size of the project.

Source: IRENA, 2016c.

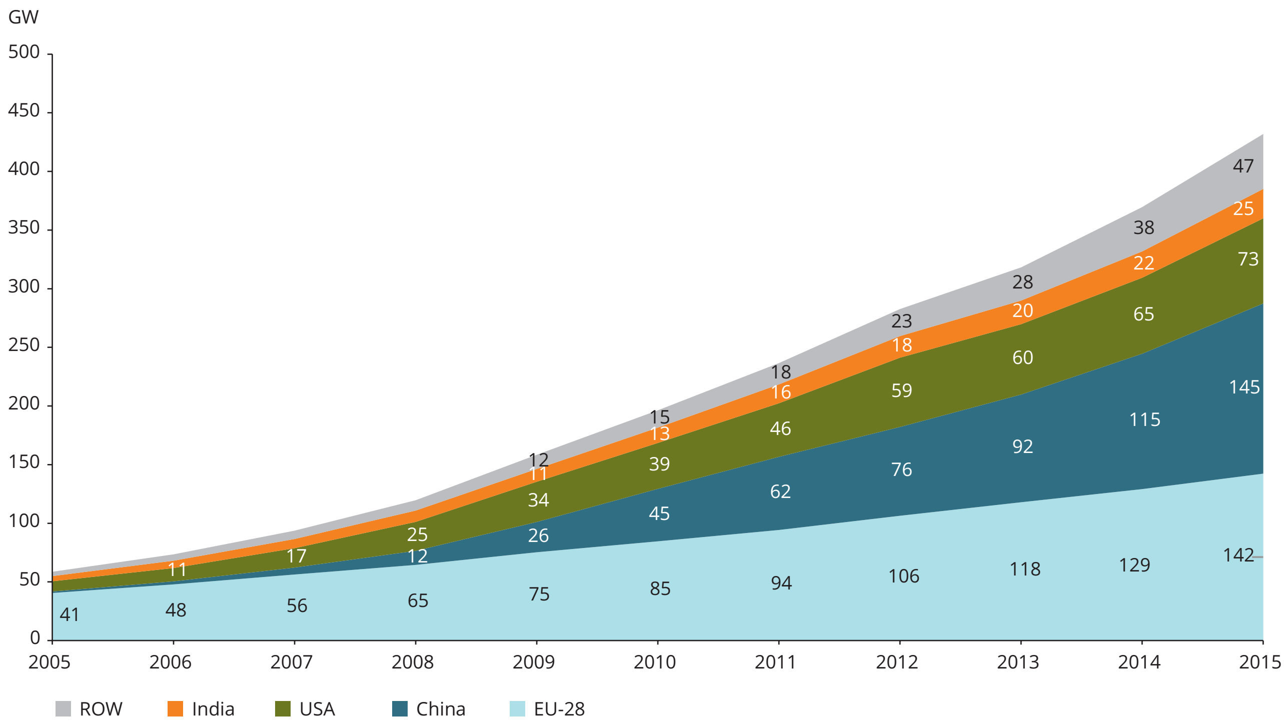
Figure 3.2 Growth in total solar PV capacity (GW) in the EU-28, the top three non-EU countries and the rest of the world (ROW), 2005-2015



Note: The figure shows the maximum net generation capacity installed and connected.

Sources: IRENA, 2016b; REN21, 2016.

Figure 3.3 Growth in total wind power capacity (GW) in the EU-28, the top three non-EU countries and the rest of the world (ROW), 2005-2015



Note: The figure shows the maximum net generation capacity installed and connected.

Sources: IRENA, 2016b; REN21, 2016.

3.2 Renewable energy investments

3.2.1 Share in global renewable energy investments

Throughout the 2005-2015 period, Europe (including CIS) exhibited high shares of global new investments in renewable energy (Table 3.1). However, investment activity spread rapidly to new markets. Viewed over time, Europe's investment share declined from 46 % to 17 % between 2005 and 2015, highlighting its pioneering role in developing renewable energy. In 2013, for the first time, Europe came second in terms of its share in global new investments in renewable energy, with the largest shares in new investments being taken by China (27 %), while ASOC came in third (19 %). Since then, China (36 % of global investments in 2015) and ASOC (17 % of global investments in 2015) have consolidated their positions. Together, China, Europe (including CIS) and ASOC accounted for approximately 70 % of global new investments in renewable energy technologies in 2015. There are also signs of emerging markets in Africa, the Middle East, and the Americas. The share of investments in the United States has fluctuated around 15 % over the last 5 years.

3.2.2 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 they had 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 policy uncertainties did not feature, the strongest average annual growth in renewable energy investments was distributed as follows: China (32 %), United States (25 %), India (24 %). After the difficult years 2012-2013 (with declining growth or even shrinkage in most regions), investments in renewable energy have taken a positive turn again since 2014. The year 2015 was noteworthy in two ways. Firstly, with EUR 257.7 billion invested worldwide (a 27 % increase compared with 2014), a new record level in global investments was achieved. Secondly, for the first time, investments in developing countries outweighed investments in developed countries. Many regions realised a strong growth in investments over the 2014-2015 period, especially Brazil (48 %), China (40 %) and India (38%). The Middle East and Africa also appeared as emerging markets, with 31 % growth. In contrast, investments in Europe (including CIS) did not recover from the decline during the years 2012-2013. Despite these growth rates, the absolute numbers speak for themselves (Figure 3.4): in every single year between 2005 and 2012 Europe (including CIS) has been the region with the highest new renewable energy investments. Since 2013, China has taken over and, with a EUR 92.7 billion investment (more than double the amount spent in Europe) in 2015, established itself as the clear world leader in renewable energy investments.

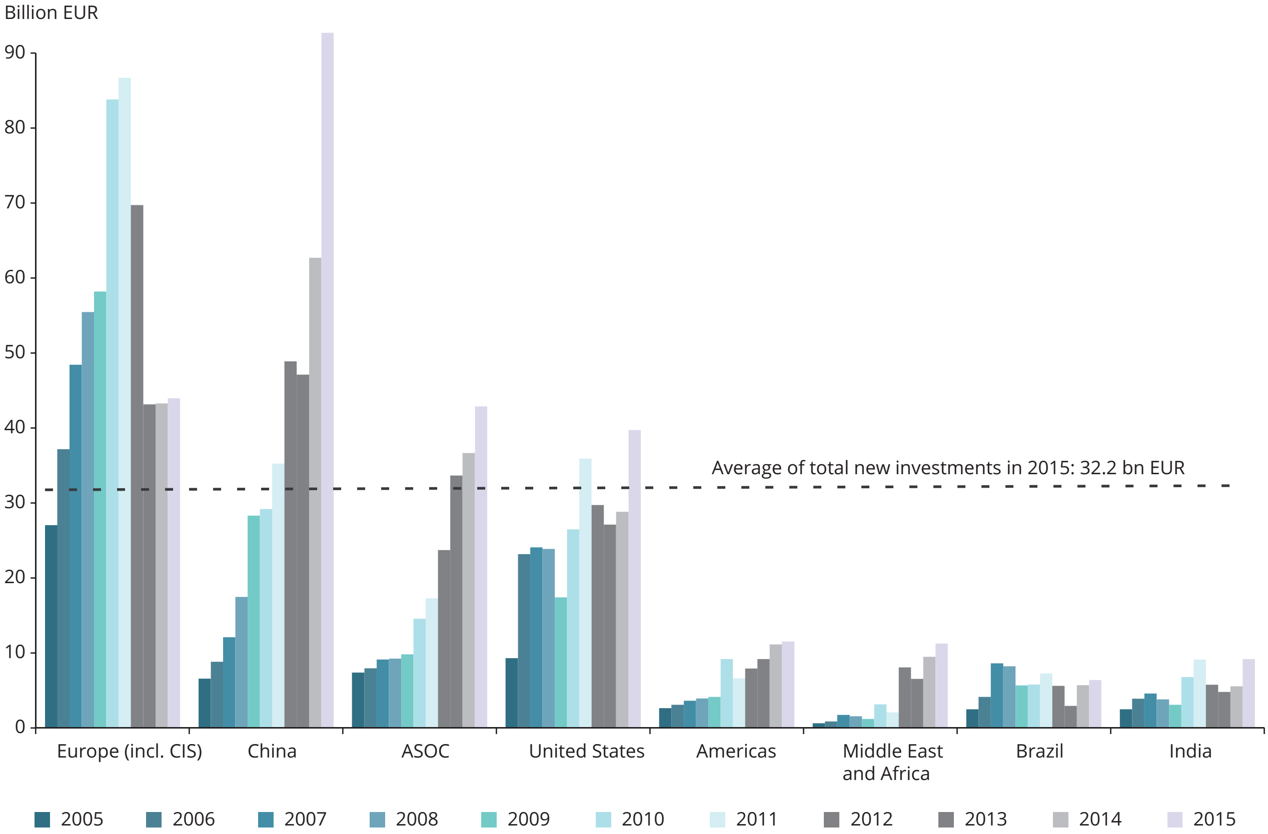
Table 3.1 Share of global new investments (%) in renewable energy per region, 2005-2015

World region	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Europe (including CIS)	46	42	43	45	46	47	43	35	25	21	17
China	11	10	11	14	22	16	18	25	27	31	36
ASOC (excl. China and India)	13	9	8	7	8	8	9	12	19	18	17
United States	16	26	21	19	14	15	18	15	16	14	15
Americas (excl. United States and Brazil)	5	3	3	3	3	5	3	4	5	5	4
Middle East and Africa	1	1	2	1	1	2	1	4	4	5	4
Brazil	4	5	8	7	4	3	4	3	2	3	2
India	4	4	4	3	2	4	5	3	3	3	4

Notes: 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 list of abbreviations. Dark green indicates the band of the highest shares; white denotes the band of the lowest; yellow illustrates the midpoint percentile.

Source: Frankfurt School-UNEP, 2016.

Figure 3.4 Total new investments by region, 2005-2015, in billion euros



Notes: Figures converted to euros using annual exchange rates from Eurostat. Information about the geographical coverage and regional aggregations is provided in the list of abbreviations.

Sources: Frankfurt School-UNEP, 2016; Eurostat 2016a.

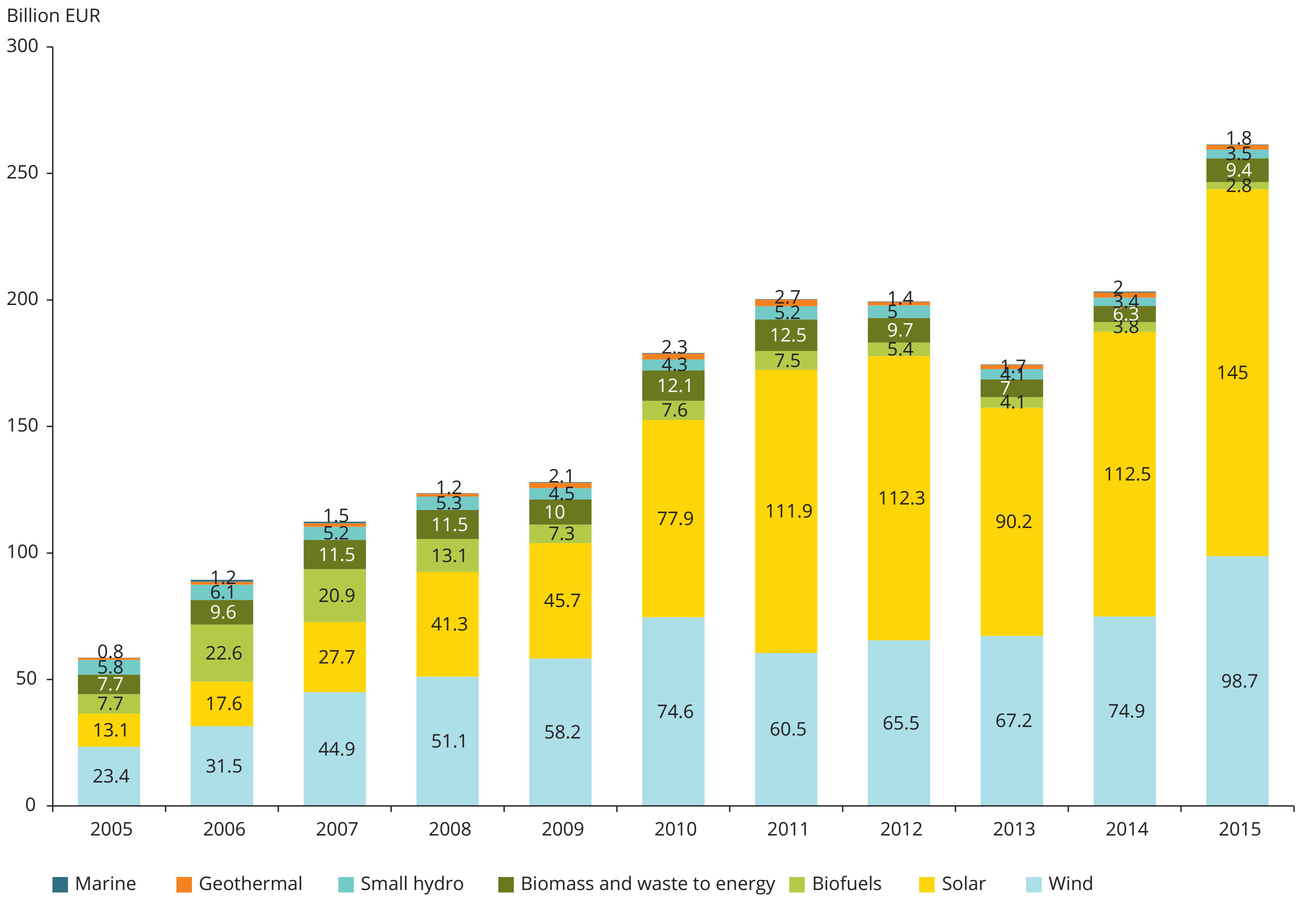
Nevertheless, according to a joint 2017 assessment by the International Energy Agency and the International Renewable Energy Agency, worldwide renewable energy investments are currently still not on a trajectory that will ensure limiting global warming to 2 °C (IEA-IRENA, 2016). To meet that target, a 1.2 % increase per year of the global RES share in total primary energy supply is needed – a sevenfold acceleration compared to recent years (IEA-IRENA, 2016). In essence, it requires shifting the global energy supply investments away from fossil fuels and into to low-carbon alternatives. This, in the context were oil and gas today still account for over 45 % of global energy investments.

While meeting the 2 degrees Celsius target will require a fundamental transformation of the way we produce and consume energy so that by 2050, amongst other things, up to 95 % of the global electricity would be low-carbon and 70 % of the new cars would be electric, the additional net total investment relative to the current climate pledges assumed under the Paris Agreement would represent only about 0.3 % of the global GDP in 2050 (IEA-IRENA, 2016). For systems in which variable renewables will account for large shares of the power generation mix, investment in both electricity storage and smart demand-response solutions will need to expand substantially (IEA, 2016).

3.2.3 Total new investments by technology

In 2015, the market was dominated by record investments in solar and wind energy, which, together, accounted for 93 % of the total global RES investments (Frankfurt School-UNEP, 2016). Total new investments in technology grew fastest for solar energy, as new investments were 11 times higher (in nominal terms) in 2015 than in 2005. Investments in solar energy as a share of total new investments became the largest in 2010, when they accounted for 44 % of total new investments (Figure 3.5). From 2005 to 2009, investments in wind power made up the largest share of total investments. In 2010, they moved into second place after solar energy, but their share was always between

Figure 3.5 **Total global new investment shares by technology, 2005-2015**



Source: Frankfurt School-UNEP, 2016.

37 % and 43 % of total new investments. 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.

Biofuels experienced a steady growth in new investment from 2005 to 2007, when first-generation biofuels were on the increase. After 2008, investments in biofuels started to decline and fluctuate at lower levels. In 2015, they were lower than in 2005. The 'plateauing' of first-generation biofuel capacity may explain this decline, including uncertainties over future legislation and the delayed development of second-generation biofuels and costs.

3.3 Renewable energy employment

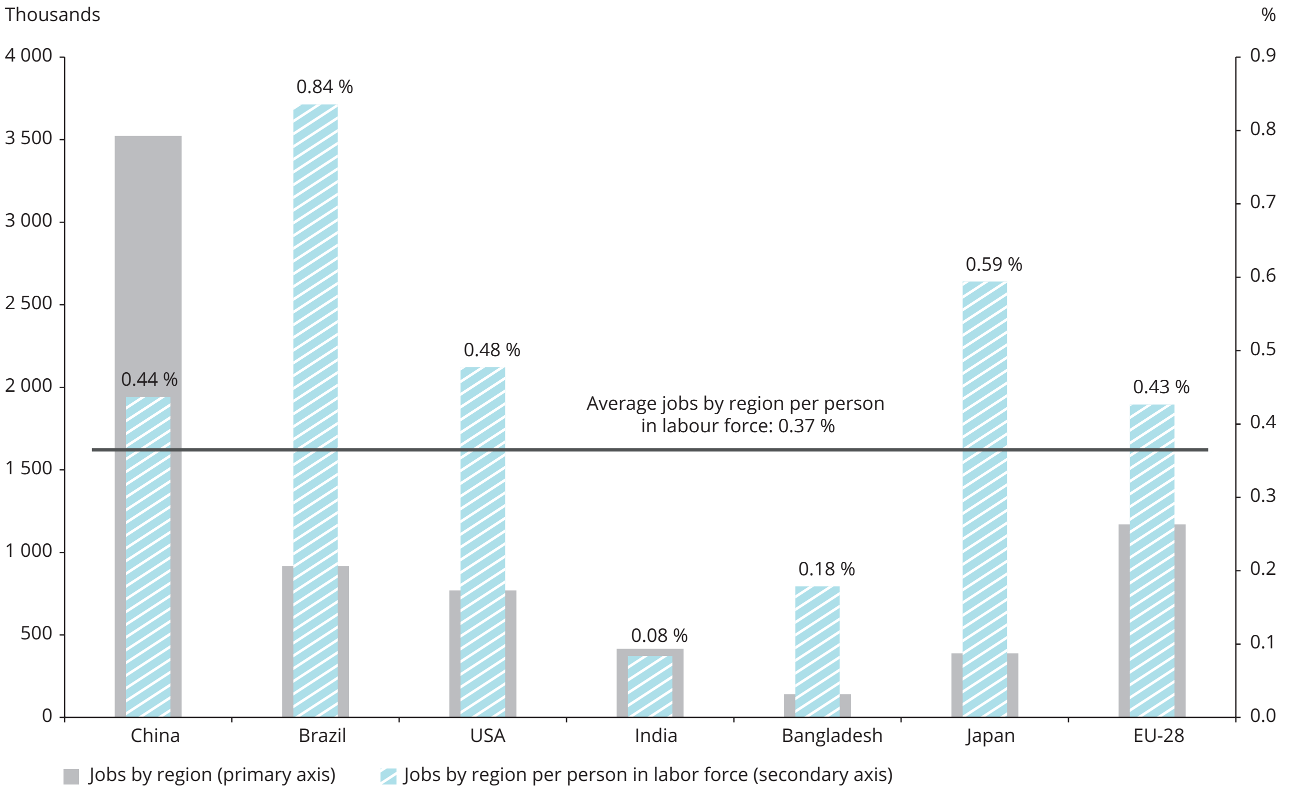
In 2014, a total of 7.7 million jobs (direct and indirect) were related to renewable energy, globally. In 2015, these had increased by 5 %, reaching a total of 8.1 million (IRENA, 2016a).

The regional distribution of these jobs is depicted in Figure 3.6. In absolute terms, in 2015 China, the EU-28 and Brazil were the largest employers, with the EU maintaining its second position, as in 2014. However, in relative terms (i.e. as share of renewable energy jobs in the total workforce — the blue-hatched bars in Figure 3.6) — the regional distribution in 2015 looks different:

- The EU came in in fifth place, just behind China. Brazil, Japan and the United States were the top three countries in terms of renewable energy-related jobs per capita in the labour force in 2015, with the latter two countries managing to outperform the EU compared to 2014.
- Within the EU, Germany was the number one (per capita, in labour force) employer (roughly one in 114 persons within the labour force was working in a job related to renewable energy), at the same level as Brazil.

In the EU, the largest employers are the wind, solar PV and solid biomass energy industries. However, the solar PV industry has experienced job losses over the past 5 years, including due to rising competition from China. Some job losses were also experienced in wind power, a sector which entered a consolidation phase in 2013 as competition from China continued to grow. In 2015, jobs per person in the workforce in the EU-28 were almost on the same level as in China.

Figure 3.6 Direct and indirect jobs related to renewable energy in 2015 split by region — absolute and per person in the labour force



Note: The primary y-axis displays absolute numbers (thousands of jobs) in 2015. 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 throughout the value chain. The data used to calculate jobs per person in the labour force were for 2014, as no data had been found for 2015 at the time of writing this report.

Source: Absolute jobs (IRENA, 2016a); jobs per person in workforce (World Bank, 2016).

Glossary and abbreviations

CCS	Carbon capture and storage
CHP	Combined heat and power
CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide equivalent – a metric measure used to compare the emissions from various greenhouse gases based upon their global warming potential.
CSP	Concentrated solar power
EEA	European Environment Agency
EED	Energy Efficiency Directive (Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC)
ENTSO-E	European Network of Transmission System Operators for Electricity
EPBD	Energy Performance of Buildings Directive (Directive 2010/31/EU on the energy performance of buildings)
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 as 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
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.

ktoe	Kilotonne of oil equivalent
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	Megatonne
Mtoe	Million tonnes of oil equivalent
MW	Megawatt
NREAP	National Renewable Energy Action Plan
PE	Primary energy: 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
R&D	Research and development
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 3

The presentation of the global picture in Chapter 3 follows as far as possible the geographic coverage and regional aggregation used by the IEA. For investments, the aggregation used by Bloomberg New Energy Finance (Bloomberg, 2015) 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)	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 2014, as discussed in Section 2.3 of this report.

Country	GHG emissions	Effect of renewables		Fossil fuel consumption	Effect of renewables		Primary energy consumption	Effect of renewables	
	Mton CO_2-eq	Mton CO_2	%	Mtoe	Mtoe	%	Mtoe	Mtoe	%
Austria	76.3	– 11.2	– 13 %	19.4	– 3.5	– 15 %	30.6	– 0.5	– 2 %
Belgium	113.9	– 8.2	– 7 %	30.7	– 2.9	– 9 %	45.0	– 0.3	– 1 %
Bulgaria	57.2	– 5.3	– 9 %	12.1	– 1.4	– 11 %	17.2	– 0.6	– 3 %
Croatia	24.5	– 1.1	– 4 %	5.3	– 0.2	– 4 %	7.7	– 0.2	– 3 %
Cyprus	8.4	– 0.4	– 5 %	2.1	– 0.1	– 6 %	2.2	0.0	– 2 %
Czech Republic	125.9	– 10.2	– 7 %	28.2	– 2.8	– 9 %	38.6	– 0.5	– 1 %
Denmark	51.2	– 10.0	– 16 %	11.6	– 3.3	– 22 %	16.6	– 1.4	– 8 %
Estonia	21.1	– 1.8	– 8 %	5.9	– 0.5	– 8 %	6.6	– 0.1	– 1 %
Germany	900.2	– 110.6	– 11 %	229.0	– 29.9	– 12 %	290.8	– 8.3	– 3 %
Greece	101.4	– 6.9	– 6 %	20.5	– 2.0	– 9 %	23.7	– 1.1	– 5 %
Finland	59.1	– 8.9	– 13 %	15.4	– 2.8	– 15 %	33.4	0.1	0 %
France	458.9	– 23.9	– 5 %	105.1	– 7.8	– 7 %	234.5	– 3.1	– 1 %
Hungary	57.2	– 2.8	– 5 %	13.9	– 0.9	– 6 %	21.1	0.0	0 %
Ireland	58.3	– 3.1	– 5 %	12.1	– 1.0	– 8 %	13.4	– 0.4	– 3 %
Italy	418.6	– 46.9	– 10 %	112.4	– 15.3	– 12 %	143.8	– 4.0	– 3 %
Latvia	11.3	– 1.0	– 8 %	2.5	– 0.3	– 11 %	4.4	0.0	0 %
Lithuania	19.0	– 1.7	– 8 %	3.7	– 0.5	– 12 %	5.6	0.0	– 1 %
Luxembourg	10.8	– 0.4	– 4 %	3.5	– 0.1	– 4 %	4.2	0.0	0 %
Malta	3.0	– 0.1	– 3 %	0.9	0.0	– 3 %	0.9	0.0	– 1 %
Netherlands	187.1	– 5.9	– 3 %	56.1	– 2.0	– 3 %	62.7	– 0.3	– 1 %
Poland	380.3	– 18.6	– 5 %	79.8	– 5.3	– 6 %	89.1	– 0.4	0 %
Portugal	64.6	– 8.8	– 12 %	14.9	– 2.2	– 13 %	20.7	– 1.5	– 7 %
Romania	109.8	– 8.9	– 7 %	22.2	– 2.4	– 10 %	30.8	– 1.0	– 3 %
Slovakia	40.6	– 1.9	– 4 %	9.5	– 0.7	– 7 %	15.3	0.0	0 %
Slovenia	16.6	– 1.3	– 7 %	3.9	– 0.4	– 9 %	6.5	– 0.1	– 1 %
Spain	328.9	– 37.1	– 10 %	80.1	– 10.9	– 12 %	112.6	– 4.7	– 4 %
Sweden	54.4	– 13.1	– 19 %	12.9	– 4.1	– 24 %	46.2	– 0.3	– 1 %
United Kingdom	523.7	– 38.8	– 7 %	151.4	– 12.2	– 7 %	182.4	– 2.6	– 1 %
All 28 Member States	**4 282.1**	**– 388.9**	**– 8 %**	**1 065.2**	**– 115.4**	**– 10 %**	**1 506.5**	**– 31.5**	**– 2 %**

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

Source: EEA; Eurostat.

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 (2015a) report, *Renewable energy in Europe — Approximated recent growth and knock-on effects*. The data have been updated to reflect the most up-to-date values by the end of October 2016, when no officially reported RES data for 2015 were available.

Some improvements in the methodology were also made:

- The whole calculation is now implemented in Eurostat's SHARES tool. This is an important step to improve the consistency of the RES proxies with both the methodology laid out in the RED and RES shares data published by Eurostat annually.
- A trend extrapolation is still the fall-back option if there are no data sources. But the methodology has changed from linear trend extrapolation to exponential trend extrapolation.
- The calculation is linked to the EEA's proxy estimate on primary and final energy consumption.

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

- EEA
    - — Final energy consumption estimate for 2015
        - Non-renewable energy consumption in heating and cooling
- ENTSO-E
    - — Monthly production
        - Electricity generation from gas
        - Electricity generation from biomass
- 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 2016
        - Consumption of liquid and gaseous biofuels in transport
        - Share of certified biofuels
    - — Photovoltaic barometer 2016
        - Electricity production from solar PV power
        - Cumulated PV capacity
    - — Solar thermal barometer 2016
        - Cumulated capacity of thermal solar collectors as proxy for solar thermal energy consumption in the heating and cooling sector
    - — Wind energy barometer 2016
        - Electricity production from wind energy
        - Cumulated wind power capacity
- Member State data
    - — Biofuels for heating and cooling for Austria, Germany, Lithuania, Poland, the Netherlands, Sweden and the United Kingdom
        - Non-renewable energy consumption in heating and cooling for the United Kingdom
        - Biofuels for electricity for Italy
        - Biofuels in transport for the United Kingdom
        - Electricity consumption for the United Kingdom
        - Total electricity production for the United Kingdom
        - Electricity imports and exports for the United Kingdom
        - Hydro and wind capacity for the United Kingdom
        - Renewable electricity production (hydro, wind, solar PV, marine, biofuels),

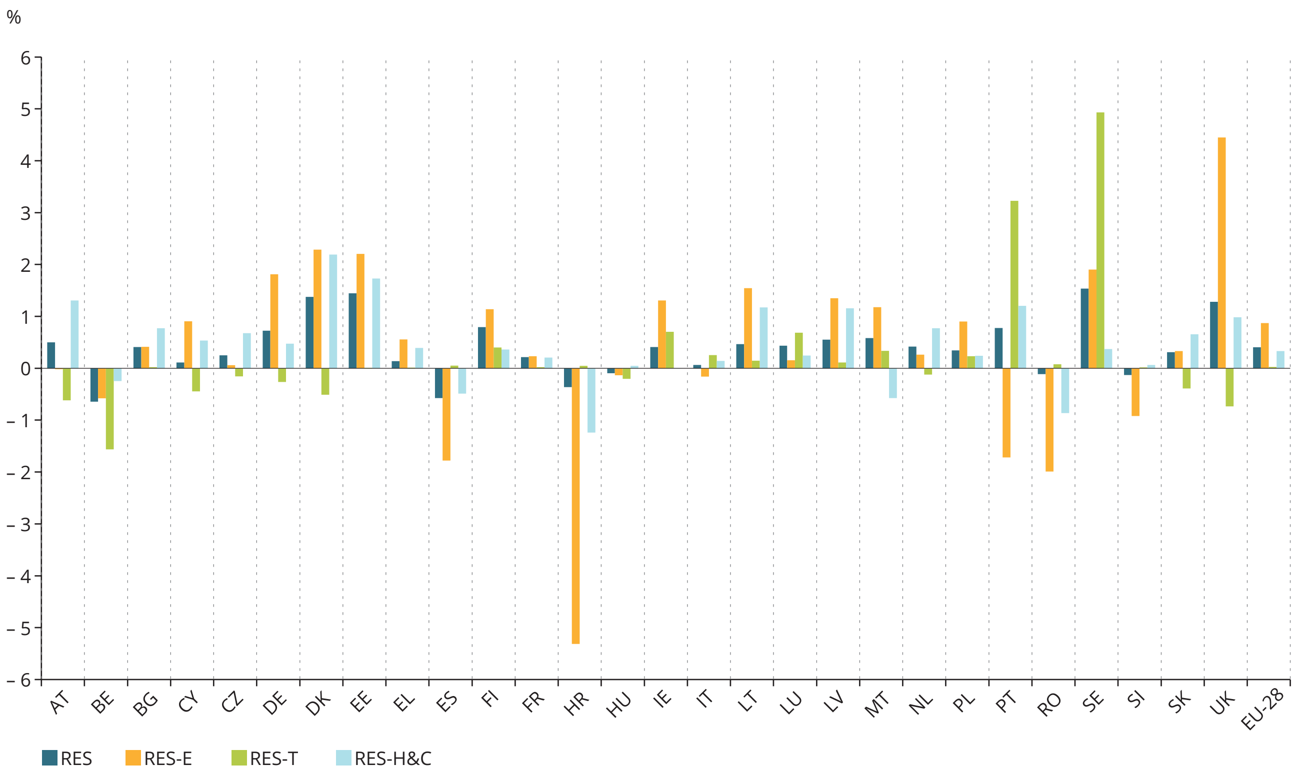
Annex 3 Discussion of main 2014/2015 changes by sector and country

As it is difficult to determine the uncertainties of the applied RES shares proxy methodology, it is likewise difficult to determine the uncertainties of this calculation. Therefore, changes in calculated RES shares proxies for the years 2014/2015 are compared with historically (2005-2014) observed changes in RES shares by way of descriptive statistics to determine statistically significant deviations from the historical changes.

If in 2014/2015, RES shares changes were significantly different but within the historically observed minima and maxima of RES shares changes, the results were considered plausible without further analysis. If 2014/2015 RES shares changes 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 in approximated 2015 RES shares to 2014 RES shares, while Table A3.1 provides detailed insights.

Figure A3.1 **Changes in approximated RES shares in 2015 compared with 2014 (in percentage points)**



Note: The country codes are defined in Table A3.1.

Source: EEA.

Table A3.1 Shares of renewable energy in 2014 and 2015

		RES (%)			RES-E (%)			RES-T (%)			RES-H&C (%)		
		2014	**2015**	**Delta**	**2014**	**2015**	**Delta**	**2014**	**2015**	**Delta**	**2014**	**2015**	**Delta**
Austria	AT	33.1	33.6	0.5	70.0	70.0	0.0	8.9	8.3	– 0.6	32.6	33.9	1.3
Belgium	BE	8.0	7.3	– 0.6	13.4	12.8	– 0.6	4.9	3.3	– 1.6	7.8	7.6	– 0.2
Bulgaria	BG	18.0	18.4	0.4	18.9	19.3	0.4	5.3	5.3	0.0	28.3	29.1	0.8
Cyprus	CY	9.0	9.1	0.1	7.4	8.3	0.9	2.7	2.2	– 0.4	21.8	22.3	0.5
Czech Republic	CZ	13.4	13.6	0.2	13.9	14.0	0.1	6.1	6.0	– 0.2	16.7	17.4	0.7
Germany	DE	13.8	14.5	0.7	28.2	30.0	1.8	6.6	6.4	– 0.3	12.2	12.7	0.5
Denmark	DK	29.2	30.6	1.4	48.5	50.8	2.3	5.8	5.3	– 0.5	37.8	40.0	2.2
Estonia	EE	26.5	27.9	1.4	14.6	16.8	2.2	0.2	0.2	0.0	45.2	46.9	1.7
Greece	EL	15.3	15.5	0.1	21.9	22.5	0.6	1.4	1.4	0.0	26.9	27.2	0.4
Spain	ES	16.2	15.6	– 0.6	37.8	36.0	– 1.8	0.5	0.5	0.1	15.8	15.3	– 0.5
Finland	FI	38.7	39.5	0.8	31.4	32.6	1.1	21.6	22.0	0.4	51.9	52.3	0.4
France	FR	14.3	14.5	0.2	18.3	18.5	0.2	7.8	7.8	0.0	17.8	18.0	0.2
Croatia	HR	27.9	27.5	– 0.4	45.3	40.0	– 5.3	2.1	2.1	0.0	36.2	35.0	– 1.2
Hungary	HU	9.5	9.4	– 0.1	7.3	7.1	– 0.1	6.9	6.7	– 0.2	12.4	12.4	0.0
Ireland	IE	8.6	9.0	0.4	22.7	24.0	1.3	5.2	5.9	0.7	6.6	6.6	0.0
Italy	IT	17.1	17.1	0.1	33.4	33.3	– 0.2	4.5	4.7	0.3	18.9	19.0	0.1
Lithuania	LT	23.9	24.3	0.5	13.7	15.2	1.5	4.2	4.3	0.1	41.6	42.8	1.2
Luxembourg	LU	4.5	5.0	0.4	5.9	6.1	0.2	5.2	5.9	0.7	7.4	7.6	0.2
Latvia	LV	38.7	39.2	0.6	51.1	52.4	1.3	3.2	3.3	0.1	52.2	53.3	1.2
Malta	MT	4.7	5.3	0.6	3.3	4.5	1.2	4.7	5.0	0.3	14.6	14.0	– 0.6
Netherlands	NL	5.5	6.0	0.4	10.0	10.2	0.3	5.7	5.6	– 0.1	5.2	5.9	0.8
Poland	PL	11.4	11.8	0.3	12.4	13.3	0.9	5.7	5.9	0.2	13.9	14.2	0.2
Portugal	PT	27.0	27.8	0.8	52.1	50.4	– 1.7	3.4	6.7	3.2	34.0	35.2	1.2
Romania	RO	24.9	24.7	– 0.1	41.7	39.7	– 2.0	3.8	3.9	0.1	26.8	25.9	– 0.9
Sweden	SE	52.6	54.1	1.5	63.3	65.2	1.9	19.2	24.2	4.9	68.1	68.4	0.4
Slovenia	SI	21.9	21.8	– 0.1	33.9	33.0	– 0.9	2.6	2.6	0.0	33.3	33.3	0.1
Slovakia	SK	11.6	11.9	0.3	23.0	23.3	0.3	6.9	6.5	– 0.4	8.7	9.4	0.7
United Kingdom	UK	7.0	8.2	1.3	17.8	22.3	4.4	4.9	4.2	– 0.7	4.5	5.5	1.0
European Union	**EU-28**	**16.0**	**16.4**	**0.4**	**27.5**	**28.3**	**0.9**	**5.9**	**6.0**	**0.0**	**17.7**	**18.1**	**0.3**

Sources: EEA; Eurostat, 2016b.

RES-E

The change in the RES-E shares proxy for 2015 compared with 2014 (+ 0.9 %) for the whole EU is smaller by 0.5 standard deviations than the average annual change in RES-E shares in the period from 2005 to 2014 (+ 1.2 %) (Figure A3.2). This is not a statistically significant deviation from the time series (*p* = 0.07) and still larger than, for example, the 2010/2009 change (+ 0.7 %).

The calculated changes in the RES-E shares proxies for 19 Member States are within one standard deviation of the average changes for the 2005-2014 period. In 12 Member States, the 2014/2015 change is significantly different from the 2005-2014 average at the 5 % level (Belgium, Croatia, Czech Republic, Finland, Italy, Lithuania, Malta, Portugal, Romania, Slovenia, Spain, United Kingdom). Of those, nine Member States showed changes in RES-E shares larger than the historically observed average plus or minus one standard deviation.

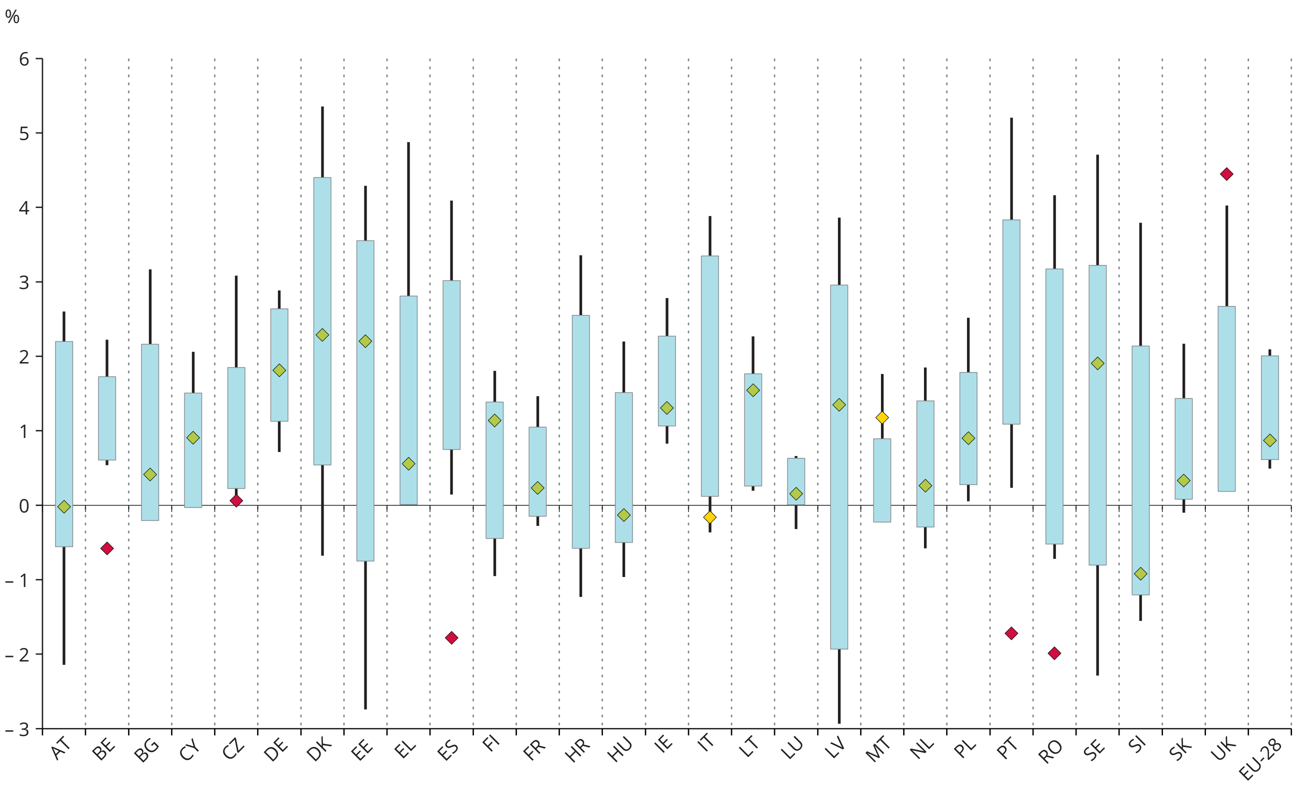
The following six Member States show larger changes in RES-E shares than have been historically observed.

Belgium: The absolute contribution of RES-E generation decreased by 4 % because decreases in electricity generation were stronger than increases from wind energy. In addition, electricity consumption increased by 1 % leading to a decreasing RES-E share for the first time in more than a decade.

Czech Republic: The absolute contribution of electricity generation increased, but electricity consumption also increased (+ 3 %), which overcompensated the growth in renewable energy. However, RES-E still grew in 2015 but more slowly than in previous years.

Portugal: The absolute contribution of RES-E generation was almost constant because normalised hydropower generation (which was the most important RES source in 2014) fell by almost 3 %, which was compensated by increases in other RES technologies (mainly wind energy

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



Note: Blue bars show the span from average of annual changes in RES-E shares between 2005 and 2014, 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 2015 compared with 2014. Green: change 2014/2015 within one standard deviation of changes from 2005 to 2014. Yellow: change 2014/2015 within minimum and maximum change in the period from 2005 to 2014. Red: change 2014/2015 larger than changes in the period from 2005 to 2014. The country codes are defined in Table A3.1.

Source: EEA.

but also solid biomass and solar energy). However, electricity consumption increased by almost 4 % leading to a decreasing RES-E share for the first time in more than a decade.

Romania: The absolute contribution of electricity generation increased but electricity consumption increased strongly (+ 9 %) which overcompensated the growth in renewable energy.

Spain: The absolute (normalised) contribution from renewable energy sources to electricity generation was almost constant, but electricity consumption increased strongly (+ 4 %).

United Kingdom: Most renewable energy sources for electricity generation increased strongly. Wind energy — which was already the most important renewable source — expanded by a further 19 %, the second most important, solid biomass, expanded by 40 %, and solar energy also increased strongly (+ 87 %), while electricity consumption increased only slightly (less than 1 %).

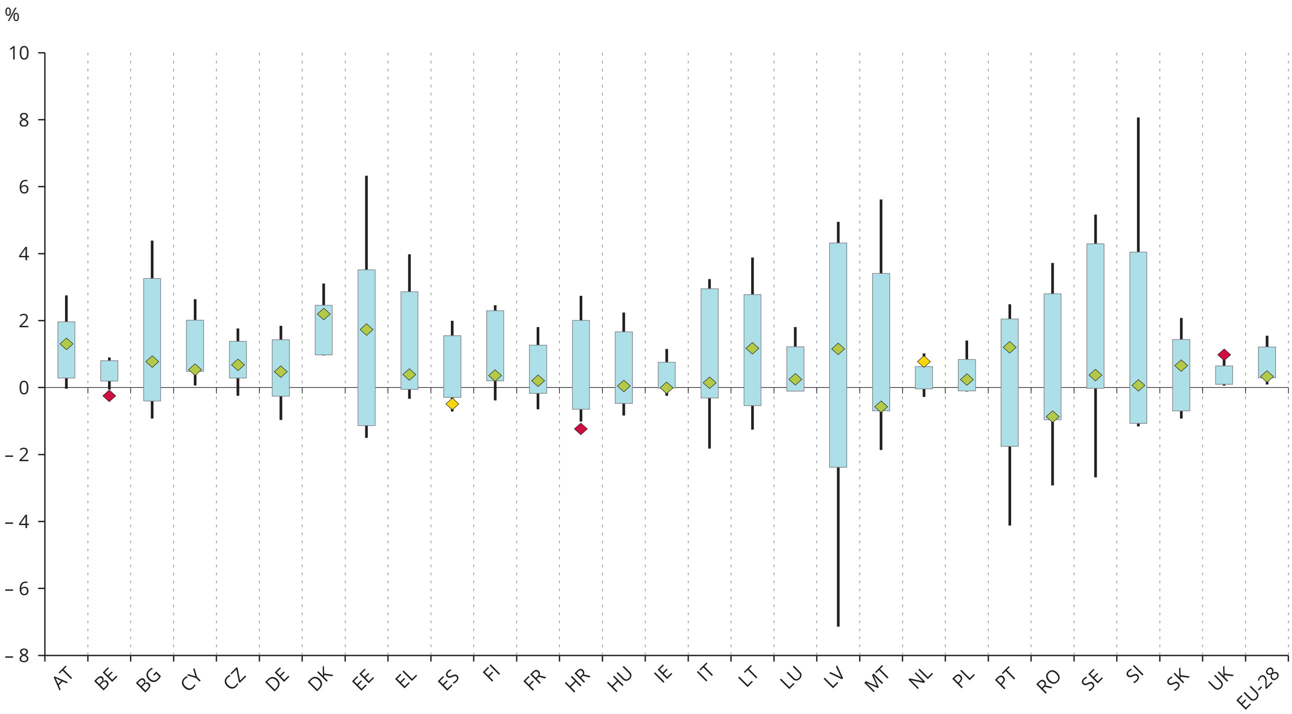
RES-H&C

The change in the RES-H&C shares proxy for 2015 compared with 2014 (+ 0.3 %) for the whole EU is lower by 0.9 standard deviations than the average annual change in RES-H&C shares in the 2005-2014 period (+ 0.8 %) (Figure A3.3). This deviation is significant at the 5 % level (p = 0.02).

The calculated changes in the RES-H&C shares proxies for 23 Member States are within one standard deviation of the average changes for the 2005-2014 period. In 12 Member States, the 2014/2015 change is significantly different from the 2005-2014 average at the 5 % level (Belgium, Croatia, Cyprus, Finland, Ireland, Italy, Malta, Netherlands, Romania, Spain, Sweden, United Kingdom). Of those, seven Member States showed changes in RES-E shares larger than the historically observed average plus or minus one standard deviation.

The following three Member States show larger changes in RES-H&C shares than have been historically observed.

Figure A3.3 Change in RES-H&C shares 2014/2015, compared with historically observed annual changes in RES-H&C shares (2005-2014), all in percentage points



Note: Blue bars show the span from average of annual changes in RES-H&C shares between 2005 and 2014, 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 2015 compared with 2014. Green: change 2014/2015 within one standard deviation of changes from 2005 to 2014. Yellow: change 2014/2015 within minimum and maximum change in the period from 2005 to 2014. Red: change 2014/2015 larger than changes in the period from 2005 to 2014. The country codes are defined in Table A3.1.

Source: EEA.

Belgium: Consumption of renewable energy sources in the heating and cooling sector was estimated to grow more slowly (+ 5 %) than the GFEC of all energy carriers for RES-H&C (+ 9 %). This might be a calculation artefact, as consumption of bioenergy — the predominant RES in the heating and cooling sector — was estimated using trend extrapolation due to a lack of data.

Croatia: Consumption of renewable energy sources in the heating and cooling sector was estimated to stay almost constant (+ 0.1 %) while the GFEC of all energy carriers for RES-H&C was estimated to grow by 4 %. This might be a calculation artefact, as consumption of bioenergy — the predominant RES in the heating and cooling sector — was estimated using trend extrapolation due to a lack of data.

United Kingdom: Consumption of wood, the most important energy carrier in this sector, increased very strongly by 23 % and other biofuels increased significantly, while total consumption in this sector increased by only 2 %.

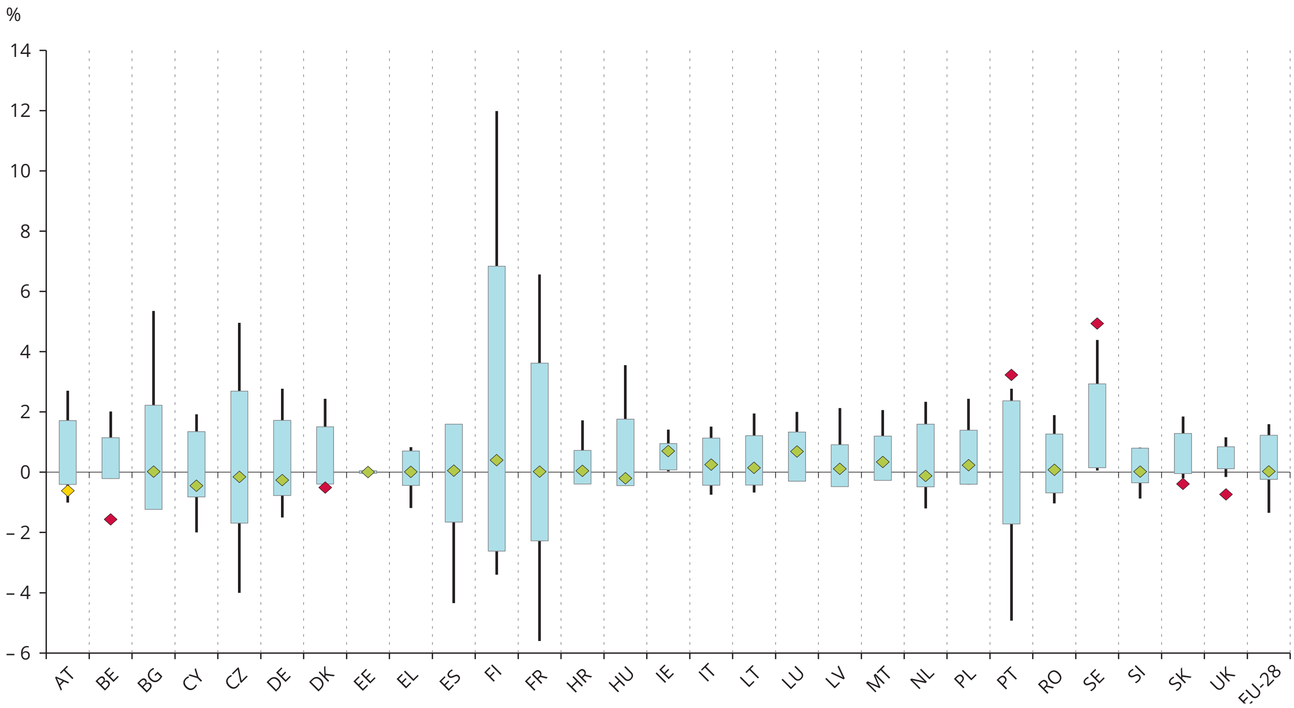
RES-T

At the EU level, the RES-T shares proxy for 2015 was almost the same as that in 2014 (+ 0.02 %). This slight increase is lower by 0.6 standard deviations than the average annual change in RES-T shares over the period from 2005 to 2014 (+ 0.5 %), but not significantly different at the 5 % level (p = 0.07) because the 2011/2010 change (– 1.67 %) even showed a decrease in the RES-T share (Figure A3.4).

The calculated changes in the RES-T shares proxies for 21 Member States are within one standard deviation of the average changes for the 2005-2014 period. In eight Member States, the 2014/2015 change was significantly different from the 2005-2014 average at the 5 % level (Austria, Belgium, Denmark, Hungary, Portugal, Sweden, Slovakia, United Kingdom). Of those, seven Member States showed changes in RES-E shares 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.

Figure A3.4 Changes in RES-T shares 2014/2015, compared with historically observed annual changes in RES-T shares (2005-2014), all in percentage points



Note: Blue bars show the span from average of annual changes in RES-T shares between 2005 and 2014, 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 2015 compared with 2014. Green: change 2014/2015 within one standard deviation of changes from 2005 to 2014. Yellow: change 2014/2015 within minimum and maximum change in the period from 2005 to 2014. Red: change 2014/2015 larger than changes in the period from 2005 to 2014. The country codes are defined in Table A3.1.

Source: EEA.

Belgium: The main reason for the strong decline in RES-T share in Belgium was a strong decrease in biodiesel consumption (– 39 %).

Denmark: Consumption of liquid biofuels (data split into bioethanol and biodiesel was unavailable) decreased by 10 %, which led to a decreasing RES-T share for the first time in more than a decade.

Portugal: Consumption of liquid biofuels in transport increased by 24 %, and at the same time the share of sustainable biofuels expanded from 52 % to 100 %, leading to almost doubling of the RES-T share (from 3.4 % to 6.7 %).

Sweden: Consumption of liquid biofuels increased by 18 % and consumption of biogas by 13 %, leading to a strong growth in the RES-T share.

Slovakia: Consumption of biofuels and other renewable energy sources for transport increased much more slowly (+ 1 %) than the total energy consumption for transport (+ 7 %), leading to a decrease in the RES-T share.

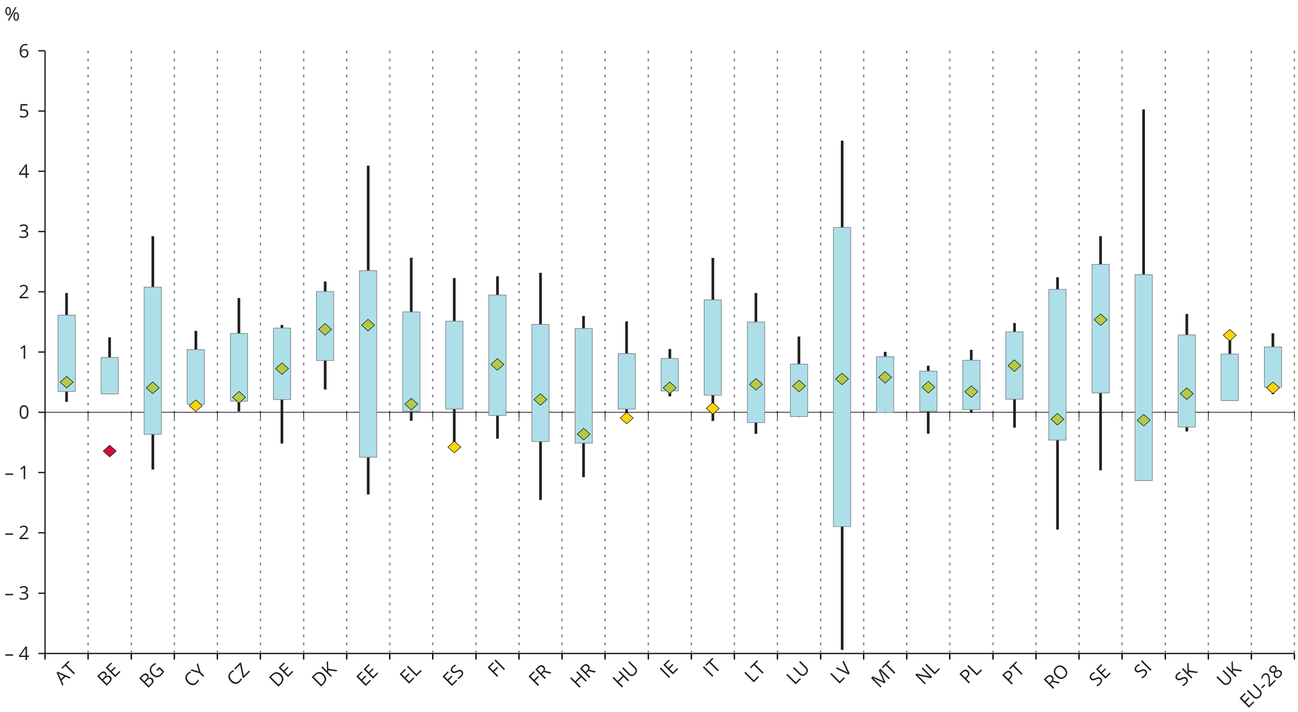
United Kingdom: The decrease in the RES-T share was mainly due to a strong decrease in biodiesel consumption (– 31 %) but also lower bioethanol consumption (– 3 %) and higher total consumption for transport (+ 1 %).

Total RES

The change in the RES shares proxy for 2015 compared with 2014 (+ 0.4 %) for the whole EU was lower than the observed average annual change in RES shares in the period from 2005 to 2014 (+ 0.8 %) (Figure A3.5). This is significantly different at the 5 % level (p = 0.02).

The calculated changes in the RES shares proxies for 22 Member States are within one standard deviation of the average changes in the period from 2005 to 2014. In 12 Member States, the 2014/2015 change was significantly different from the 2005-2014 average at the 5 % level (Austria, Belgium, Croatia, Cyprus, Czech Republic, Greece, Hungary, Ireland, Italy, Romania, Spain, United Kingdom). Of those, six Member States showed changes in RES-E shares larger than the historically observed average plus or minus one standard deviation.

Figure A3.5 **Change in RES shares 2014/2015, compared with historically observed annual changes in RES shares (2005-2014), all in percentage points**



Note: Blue bars show the span from average of annual changes in RES shares between 2005 and 2014, 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 2015 compared with 2014. Green: change 2014/2015 within one standard deviation of changes from 2005 to 2014. Yellow: change 2014/2015 within minimum and maximum change in the period from 2005 to 2014. Red: change 2014/2015 larger than changes in the period from 2005 to 2014. The country codes are defined in Table A3.1.

Only one Member State (Belgium) showed larger changes than have been historically observed: RES shares in all three sectors (electricity, transport, heating & cooling). Consequenctly, the total RES share decreased for the first time in more than a decade. The reasons for decreasing sectoral RES shares have already been explained.

Proxy 2014 versus RES shares 2014

Table A3.2 provides insights into the difference between approximated 2014 RES shares (calculated last year) and realised 2014 RES shares (available for the first time this year).

At the EU-28 level, approximated RES shares differed by 0.8 percentage points for the total RES share, – 0.6 percentage points for the RES-E share, 0.4 percentage points for the RES-T share and 1.2 percentage points for the RES-H&C share.

Deviations of more than 1 percentage point can be found in seven Member States for RES shares, in eight Member States for RES-E shares, in six Member States for RES-T shares but in 18 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

Table A3.2 2014 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	AT	33.1	33.2	0.2	70.0	69.8	– 0.3	8.9	7.7	– 1.2	32.6	34.4	1.8
Belgium	BE	8.0	8.5	0.6	13.4	13.6	0.3	4.9	4.8	0.0	7.8	8.8	0.9
Bulgaria	BG	18.0	18.0	0.0	18.9	19.4	0.6	5.3	3.0	– 2.4	28.3	27.6	– 0.7
Cyprus	CY	9.0	8.2	– 0.7	7.4	8.0	0.6	2.7	1.0	– 1.6	21.8	20.4	– 1.4
Czech Republic	CZ	13.4	13.2	– 0.2	13.9	13.2	– 0.7	6.1	6.7	0.5	16.7	16.3	– 0.4
Germany	DE	13.8	13.4	– 0.4	28.2	29.0	0.8	6.6	7.0	0.4	12.2	11.3	– 0.8
Denmark	DK	29.2	28.5	– 0.7	48.5	44.9	– 3.6	5.8	6.7	0.9	37.8	36.3	– 1.5
Estonia	EE	26.5	26.1	– 0.4	14.6	13.4	– 1.2	0.2	0.2	0.0	45.2	43.6	– 1.6
Greece	EL	15.3	15.4	0.1	21.9	22.2	0.2	1.4	1.1	– 0.3	26.9	27.5	0.6
Spain	ES	16.2	15.1	– 1.0	37.8	37.1	– 0.7	0.5	0.5	0.0	15.8	13.9	– 2.0
Finland	FI	38.7	36.8	– 1.8	31.4	31.8	0.4	21.6	9.9	– 11.7	51.9	50.6	– 1.3
France	FR	14.3	14.3	0.0	18.3	18.3	0.0	7.8	7.7	– 0.1	17.8	18.4	0.6
Croatia	HR	27.9	19.1	– 8.7	45.3	42.1	– 3.2	2.1	2.2	0.1	36.2	20.2	– 16.0
Hungary	HU	9.5	10.5	1.0	7.3	6.6	– 0.7	6.9	5.4	– 1.6	12.4	14.9	2.5
Ireland	IE	8.6	8.6	0.0	22.7	22.2	– 0.5	5.2	5.3	0.2	6.6	6.6	0.0
Italy	IT	17.1	17.1	0.0	33.4	32.7	– 0.8	4.5	4.5	0.0	18.9	19.1	0.2
Lithuania	LT	23.9	23.9	0.0	13.7	13.4	– 0.3	4.2	5.0	0.8	41.6	40.2	– 1.4
Luxembourg	LU	4.5	4.0	– 0.6	5.9	5.8	– 0.2	5.2	4.5	– 0.8	7.4	5.6	– 1.7
Latvia	LV	38.7	36.9	– 1.8	51.1	47.9	– 3.2	3.2	3.0	– 0.2	52.2	49.5	– 2.7
Malta	MT	4.7	4.6	– 0.1	3.3	2.8	– 0.5	4.7	3.9	– 0.8	14.6	23.8	9.2
Netherlands	NL	5.5	5.0	– 0.5	10.0	10.5	0.5	5.7	5.4	– 0.4	5.2	4.1	– 1.0
Poland	PL	11.4	11.8	0.3	12.4	11.7	– 0.7	5.7	5.9	0.2	13.9	14.5	0.5
Portugal	PT	27.0	25.0	– 2.0	52.1	51.1	– 1.0	3.4	0.7	– 2.7	34.0	32.0	– 1.9
Romania	RO	24.9	24.0	– 0.9	41.7	42.2	0.5	3.8	4.7	0.9	26.8	24.7	– 2.0
Sweden	SE	52.6	51.1	– 1.5	63.3	63.4	0.1	19.2	18.4	– 0.8	68.1	65.2	– 2.9
Slovenia	SI	21.9	21.9	0.0	33.9	32.3	– 1.6	2.6	2.0	– 0.6	33.3	34.4	1.1
Slovakia	SK	11.6	9.8	– 1.8	23.0	21.1	– 1.9	6.9	5.3	– 1.6	8.7	7.4	– 1.3
United Kingdom	UK	7.0	6.2	– 0.8	17.8	16.0	– 1.8	4.9	4.7	– 0.3	4.5	3.3	– 1.2
European Union	**EU-28**	**16.0**	**15.2**	**– 0.8**	**27.5**	**26.9**	**– 0.6**	**5.9**	**5.5**	**– 0.4**	**17.7**	**16.6**	**– 1.2**

Sources: EEA; Eurostat 2016b.

data sources are unavailable there; (2) on the other hand, GFEC 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 2014 is considerable. Deviations of more than 5 percentage points can be found in three: Croatia, Finland and Malta. For Croatia, the main reason for the strong deviation in the RES-H&C and RES shares is not the proxy itself but a strong recalculation of the whole time series for 2004-2014 because of updated data for bioenergy consumption.

In Finland, the contribution of liquid biofuels in the final data set increased very strongly, while the data source used in the proxy calculations (EurObserv'ER biofuel barometer) showed a decrease. In addition, for Malta the main reason for the strong deviation in the RES-H&C share is not the proxy itself but a strong recalculation of the whole time series for 2004-2014 because of updated data for total energy consumption in the heating and cooling sector.

In general, the approximated 2014 RES shares underestimated rather than overestimated realised RES shares in 2014.

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