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Renewable energy in Europe — approximated recent growth and knock-on effects

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Executive summary

Background and policy

To accomplish its transition to a low-carbon society by 2050, the European Union (EU) has adopted a set of intermediate climate and energy targets for 2020 and 2030. The energy sector will face particular challenges in the context of this ambitious transformation process, given the scale of change required in a relatively short period of time.

Renewable energy sources (RES) are important contributors to this transition, being able to mitigate emissions of greenhouse gases (GHGs), lower other environmental pressures associated with conventional energy production and overturn the dominance of fossil fuels. Therefore, progress in the deployment of renewables during this decade has profound implications for the future path towards 2050.

This report introduces several methods the European Environment Agency (EEA) has developed for assessing and communicating early RES growth and the important knock-on effects that RES growth has on the energy sector and related areas. The report provides specific information at EU and country level on estimated RES progress in 2013, estimated gross avoided carbon dioxide (CO_2) ([1]) emissions and avoided fossil fuel use due to the additional use of renewable energy since 2005, as well as an assessment of the statistical impacts of growing RES use on primary energy consumption.

Key findings

EEA calculations indicate that the share of gross final consumption of RES increased in all but one Member State in 2013 ([2]). According to EEA-approximated estimates, the EU-wide share of gross final consumption of renewables continued to increase, from 14.1 % in 2012 to 14.9 % in 2013. In 2013, this progress enabled the EU to meet the 12.1 % indicative target for 2013–2014 in line with the Renewable Energy Directive, as well as the 13.7 % expected EU-wide share for gross final renewable energy consumption in line with the National Renewable Energy Action Plans adopted by countries.

In 2013, the renewable heating and cooling market sector retained its dominance in the gross final consumption of all renewables in the EU. However, the renewable electricity sector grew faster and contributed the most to absolute growth in renewables use across all EU countries. By contrast, the use of RES in transport contracted in 2013 in about half of all Member States and also at EU level.

The increasing deployment of RES has positive impacts in a number of key areas such as climate change mitigation, energy security and energy efficiency.

Without the deployment of renewable energy since 2005, GHG emissions in 2012 could have been 7 % higher than actual emissions. The increase in renewable energy use since 2005 resulted in approximately 326 Mton of gross avoided CO_2 emissions at EU level in 2012, and 388 Mton in 2013, with most of these effects relating to sectors covered under the EU's Emissions Trading Scheme (ETS).

By reducing the demand for imported fossil fuels renewable technologies also increase energy security. Without the additional use of renewable energy since 2005, the EU's consumption of fossil fuels would have been about 7 % higher in 2012. Coal was the fuel most substituted by renewables across Europe (13 %). The substitution of natural gas (7 %) is especially relevant in the current geopolitical context and considering the decline of domestic gas resources, while the reduction of oil and related fuels was less pronounced, to some extent, given the lesser share of renewable energy use in transport.

([1]) The term 'gross avoided emissions' was chosen to describe the theoretical character of the GHG effects estimated on the basis of the additional gross final consumption of RES since 2005, and to clarify that these contributions do not necessarily represent 'net GHG savings per se'.
([2]) In Cyprus the RES share remained at 2012 levels (6.8 % of gross final consumption).

The EU's primary energy consumption has been decreasing almost constantly since 2005. The increasing consumption of renewables in Europe is one factor that has gradually driven down the accounting of EU primary energy consumption. The substitution effect resulting from the additional use of renewables since 2005 resulted in an estimated 2 % reduction in EU-wide primary energy consumption in the year 2012.

Fossil fuels continue to dominate the energy mix in most Member States as well as across the EU, giving rise to climate change, air pollution and other environmental pressures. Today, renewable energy is already a significant option for climate change mitigation and reduction of (often imported) fossil fuels. In line with adopted, binding EU targets, RES are expected to increase to 20 % of gross final EU energy consumption by 2020, increasing to a minimum of 27 % by 2030. For the EU to meet its ambitious decarbonisation targets, RES need to increase to between 55 % to 75 % or more of gross final EU energy consumption by mid-century, according to the European Commission's Energy Roadmap 2050 (EC, 2011b). It is therefore important for Member States and the EU to increase the focus on this growing sector, so as to find the best possible means of leveraging the social, economic and environmental benefits it can provide.

1 Introduction

1.1 Background

The EU has a regulatory framework that steers its energy and climate policies until 2020 towards a more integrated, secure and competitive low-carbon energy market. At the same time, the EU has adopted new climate and energy targets for 2030, and has set out a clear vision for low-carbon, sustainable growth in the run-up to 2050. Developing renewable energy is essential both until 2020 and beyond this date.

Over the past decade, the deployment of RES ([3]) increased strongly in the EU and in most Member States. Despite the commendable progress made, in 2012 public electricity and heat still remained the largest single source of GHG emissions in the EU ([4]), as fossil fuels account for three-fourths of the EU's gross inland energy consumption (GIEC ([5])) (Box 1.1).

Firm commitment is needed to significantly increase energy consumption from renewable sources until the middle of this century. This is the only way for Europe to achieve its 2050 decarbonisation objectives cost-efficiently (EC, 2011b). As renewable energy generally has a lower environmental impact per unit of energy produced compared to energy obtained from conventional sources (see Box 1.1), increasing the share of renewables in energy consumption will help reduce environmental pressures and benefit society at large.

1.2 About this report

1.2.1 Purpose

Access to early information on RES growth and RES share in gross final energy consumption is relevant for policymakers. The purpose of this report is to introduce several methods for approximating early (historical) RES shares at EU and Member State level (i.e. data that are so far not available from official public sources), and to assess and communicate the important knock-on effects that RES growth has on the energy sector and related areas.

The report provides specific information at EU and country level on:

- progress in RES in 2012, and approximated estimates (proxy estimates) for 2013;
- estimated gross avoided GHG emissions due to RES deployment;
- estimated avoided fossil fuel use due to RES deployment;
- estimated statistical impacts of RES on primary energy consumption (with implications for energy savings).

The current work contributes to the broader cross-sectoral analysis of GHG emission trends in Europe conducted regularly by the EEA and its ETC/ACM, and published in the annual EEA report *Trends and projections in Europe 2014 — Tracking progress towards Europe's climate and energy targets for 2020* (EEA, 2014a).

1.2.2 European Commission RES reporting context

In line with legal requirements under Directive 2009/28/EC on the promotion of the use of energy from renewable sources (known as the Renewable Energy Directive (RED)) ([6]), the European Commission (EC) formally assesses the EU's and Member States' progress in the promotion and use of renewable energy towards the 2020 RES targets. The EC publishes

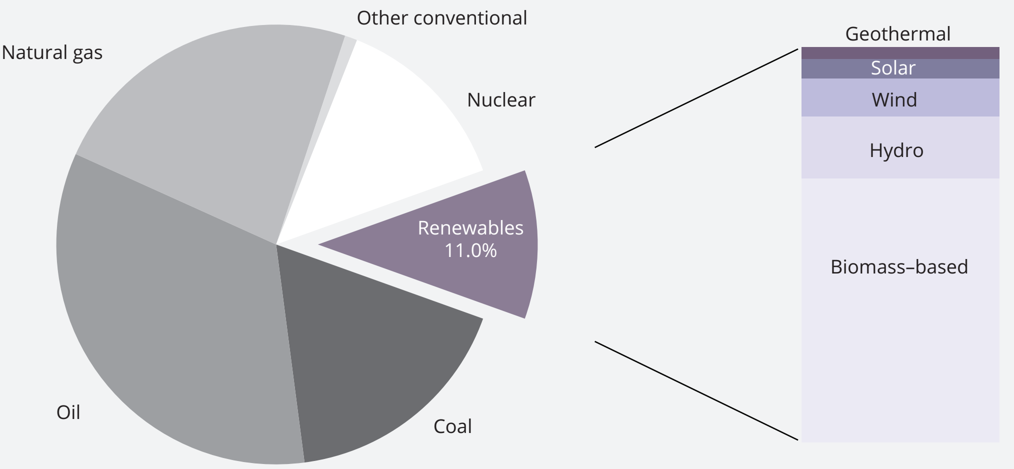
([3]) Energy from renewable sources means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases.
([4]) In 2012, public electricity and heat production was responsible for 27 % of EU total GHG emissions without land use, land use change and forestry.
([5]) GIEC and GFEC are defined in the list of acronyms, units and terms at the end of this report.
([6]) According to the RED, countries shall submit progress reports to the European Commission by end-2013.

Box 1.1 Benefits of renewable energy sources

Developing renewable energy offers several benefits, including: reduced GHG and air pollutant emissions; fewer environmental and health impacts; reduced reliance on fossil fuel imports; and improved competitiveness through boosting jobs, skills, innovation and green growth in cleantech sectors of the future.

Like other energy projects, renewable energy projects may also have negative impacts, for instance if they increase pressures on tropical forests, if they harm the environment and biodiversity through intense water and land use, or if they lead to additional air pollution and have a strong visual impact. To avoid and minimise such impacts, project developers and permitting authorities need to cooperate closely to ensure from the outset, through careful planning and project design, that only the right technologies are deployed in the right locations.

Figure 1.1 Shares in gross inland energy consumption (EU-28, 2012)



Note: Shares in the graph are presented against GIEC, in order to provide a snapshot of the EU energy system. By contrast, progress towards the 20 % RES target for 2020 is calculated against gross final energy consumption (GFEC), in accordance with provisions under the RED. GIEC and GFEC are defined in the list of acronyms, units and terms at the end of this report.

Source: Eurostat, 2014b.

its assessments every two years, in the form of a Communication on 'Renewable energy progress report'.

A forthcoming EC Communication on this topic is scheduled for adoption in early 2015. It is expected to present historical RES developments until 2012 (using the latest Eurostat data and Member States' renewable energy progress reports submitted to the Commission in 2013), complemented by a forward-looking assessment of RES progress (based on the EC's own research and research carried out on its behalf).

1.2.3 Structure

This report contains three distinctive chapters: the **introduction** (Chapter 1); the **data report** (Chapter 2) with detailed primary and secondary data for the four areas listed above; and the **methodological report** (Chapter 3), which describes the approaches developed for the purpose of conducting this assessment.

1.2.4 Data

This report presents both primary and secondary data, aggregated in figures and tables intended to facilitate an overall understanding of findings, as explained below.

Primary data: numbers directly taken from Eurostat (from the New Cronos database and the SHARES Results 2012 application), National Renewable Energy

Action Plans (NREAPs), country Progress Reports (PRs), data reported by countries under the Monitoring Mechanism Decision (EC, 2004) ([7]) and data obtained from other organisations and sources.

Secondary data: data derived from the primary data, at times using other parameters.

All data may have undergone changes of unit. Data sources and parameters are indicated in detail in relation to each assessment method as presented in Chapter 3.

1.2.5 Main limitations

Approximated estimates for the share of gross final RES consumption (RES shares proxies)
The 2013 RES shares are, ultimately, estimated values. These values cannot substitute data reported by countries (either via their biannual PRs under the RED, or as published by Eurostat).

Section 3.2 shows that a methodology could be developed and applied for approximating values of renewable energy shares in the year t-1. Confidence in the estimated RES share proxy values is highest in the electricity sector; data availability for the transport sector is sufficient, but replicating in the method the specific accounting rules in the RED for calculating the share of renewables used in transport is difficult and may result in some inaccuracy. Finally, dynamics in the renewable heating and cooling market sector might be underestimated due to more limited data availability for this sector.

Despite these challenges, this methodology yields plausible results in most cases, as explained under Section 3.2.4, and should be further improved, especially if more timely RES data become available.

Gross avoided GHG emissions
Section 3.3 describes two different methods to quantify the gross effects of renewable energy consumption on GHG emissions: (i) based on primary data available via Eurostat; and (ii) based on data reported by countries under the Monitoring Mechanism Decision (MMD).

For both of these methods, the term **'gross avoided GHG emissions'** was chosen to describe the theoretical character of the GHG effects estimated in this way, and to clarify that these contributions do not necessarily represent **'net GHG savings per se'**, nor have been based on life-cycle assessment or full carbon accounting ([8]), as explained further under Section 3.3.3.

Geographical scope
Due to limited primary data availability, this assessment focuses on the 28 EU Member States. Although data for other EEA member countries may, in certain cases, be available publicly, collecting these data has proved too demanding for this exercise.

Other limitations
The methods developed here are not suitable for assigning the effects of renewable energy consumption (such as on GHGs, fossil fuel use, or primary energy) to particular drivers, circumstances or policies, other than the deployment of RES itself. For instance, the reference emission factors (EFs) and the gross avoided GHG effects are calculated based on a set of assumptions pertinent to this retrospective assessment ([9]). These methodologies can provide useful insights, but it is important to bear in mind that the assumptions are static (i.e. the same set of assumptions is applied invariably for all years in the period), and therefore that the methods will be less accurate when the share of renewable energy in the energy mix becomes significant. This is because the more complicated interactions (in the energy system and with the economy) are not dynamically reflected in the current approaches.

([7]) Decision No 280/2004/EC, concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol (MMD). The Regulation (EU) 525/2013, on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change, repeals the MMD.

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

([9]) See Chapter 3, Methodological overview.

2 Renewable energy in the EU and its Member States

2.1 Introduction

This chapter complements the earlier EEA assessment of EU and Member State progress in renewable energy sources in 2012 (EEA, 2014a) as follows:

- it provides approximated estimates for the share of gross final RES consumption in 2013;
- it estimates gross avoided CO_2 emissions due to RES deployment;
- it estimates the avoided fossil fuel use due to RES deployment;
- it estimates effects on primary energy consumption of current RES statistical accounting methods (with implications for energy savings).

Representative sets of data for the areas listed above are presented in tables and graphically so as to facilitate an aggregate comprehension of findings and comparisons across Member States.

2.2 Policy framework in the run-up to 2020

The RED commits the EU to reaching a 20 % share of renewable energy in gross final energy consumption by 2020 and a 10 % share of renewable energy consumption in all transport fuels by the same year. The latter target translates to equal 10 % national transport targets for all countries. In 2012, to address indirect land-use change (ILUC) caused by biofuel production, the European Commission proposed limiting the contribution of food-based biofuels to a maximum of 5 %; the Council and Parliament are reviewing the Commission's proposal. The 20 % EU target for gross final consumption of renewable energy is split into binding national targets for 2020, as shown in Table 2.3 and elsewhere below. These national targets are set at different levels, to reflect national circumstances.

In the run-up to 2020, the following two interim trajectories are of particular interest in assessing 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 ([10]).
- **Expected trajectories** adopted by Member States in their National Renewable Energy Action Plans (NREAP), under the RED ([11]). These NREAP trajectories concern not only the overall RES share, but also the shares of renewables in electricity, heating and cooling, and transport sectors until 2020.

The Directive also provides options for cooperation in order to help countries achieve their targets cost effectively, and puts forward a set of sustainability criteria for biofuels.

The vital role renewable energy can play for European growth and competitiveness until 2020 is also highlighted by EU's 10-year growth strategy as set out in *Europe 2020 — A strategy for smart, sustainable and inclusive growth* (EC, 2010). A headline target for 2020 under this strategy is to increase the share of renewables to 20 % of gross final energy consumption. Two other headline targets for climate and energy until 2020 under this strategy are to achieve a 20 %

([10]) Annex I, Part B of Directive 2009/28/EC.
([11]) Under the RED, Member States were required to adopt and to publish in 2010 country NREAP reports that outline the expected trajectories for the national share of RES for the years starting with 2010 and until 2020. In addition, countries have to report biennially on national progress towards indicative RED and expected NREAP targets. National progress reports were submitted to the European Commission in 2011 and 2013, and a new round of reporting is due in 2015.

Box 2.1 EU climate and energy policies for 2020

A combination of national targets and objectives has been set for each Member State for GHG emission reductions, gross final consumption of renewable energy, and energy efficiency improvements.

- Meeting the 20 % binding EU-wide renewable energy target is mandated by the RED and hinges on each Member State's achievement of its national 2020 RES target.
- Meeting the 20 % binding EU-wide GHG reduction target hinges on two elements: first, on a division between emissions in industrial sectors covered by the EU Emissions Trading Scheme (ETS), where a single EU-wide cap is legally set, and then on reducing emissions from other sectors not covered by the EU ETS, where differentiated binding targets are set for each Member State and for each year of the period from 2013 to 2020 under Decision No 406/2009/EC (the Effort Sharing Decision (ESD)).
- Meeting the 20 % EU-wide energy savings objective (compared to a baseline scenario) rests on the indicative national targets for energy efficiency proposed by Member States in accordance with Directive 2012/27/EU (the Energy Efficiency Directive (EED)). The indicative national targets may be expressed either as primary or as final energy consumption reductions.

Targets and trajectories for GHG emission reductions and for RES shares were set jointly under the 2009 climate and energy package, so the expected emission reductions from RES in the run-up to 2020 were taken into account when setting the GHG targets.

reduction of the EU's GHG emissions compared to 1990, and a 20 % saving of the EU's primary energy consumption compared to baseline projections. These targets represent the EU's triple 20/20/20 objectives for climate and energy until 2020.

2.3 Longer-term framework

The EU has recently adopted three new EU-wide commitments for climate and energy for the year 2030 (European Council, 2014):

- a binding minimum 40 % domestic reduction of GHG emissions compared to 1990 levels;
- a binding minimum 27 % share of gross final renewable energy consumption;
- an indicative minimum 27 % improvement in energy efficiency.

Beyond 2030, the EU has a clear vision for the social and economic transitions needed in Europe to achieve low-carbon, sustainable growth: for 2050, EU leaders have endorsed the objective of reducing Europe's GHG emissions by between 80 % and 95 % below 1990 levels ([12]), in line with proposals from the European Commission (EC, 2011a and 2011c).

Taken together, the binding 2020 and 2030 targets and the objectives for 2050 represent a steady path for decarbonising the European energy system — a massive shift from fossil-based technologies to less polluting technologies.

Ensuring a cost-efficient transition towards this low-carbon architecture requires a diverse mixture of actions, addressing both energy supply and demand at the continental scale.

On the supply side, breaking the continuing dominance of fossil fuels in the energy system will require a strong commitment to improving energy efficiency, deploying renewable energy and continuous climate- and environment-proofing of energy projects. Substantial investments and regulatory change will be needed to integrate electricity, heat and gas networks and make energy markets fit for further growth of renewables.

On the demand side, the transition to a low-carbon energy system will require a profound transformation

([12]) The European Council endorses these GHG reductions as part of efforts by developed countries as a group to reduce their emissions by a similar degree.

of the social fabric. Changes in energy consumption practices can be facilitated by providing better information to end users about their energy consumption, and by improving access to financing energy savings for households. Smart meters, coupled with appropriate market incentives, energy-saving appliances and high-performance standards for buildings can all together deliver these needed behavioural changes.

Renewable energy is expected to play a central role amongst all mitigation options and scenarios, increasing to a minimum of 55 % and up to 75 % or more of gross final consumption by the middle of this century (EC, 2011b). Fully exploiting the potential of renewables will help the EU reduce environmental pressures associated with conventional energy processes, improve energy security and seize a unique chance for green growth in key sectors of the future.

2.4 2012 RES shares and approximated progress in 2013

2.4.1 Approximated interim EU progress

In recent years, the deployment of RES increased strongly in the EU, from an 8.7 % share in gross final consumption in 2005 ([13]), to 14.1 % in 2012. In absolute terms, final renewable energy use increased by 58 Mtoe over this period, at an average annual growth rate of 6.4 % (6.6 % per year if only biofuels complying with the RED sustainability criteria are taken into account) ([14]). From 2011 to 2012, the EU's RES consumption increased by 6.8 %, or roughly 10 Mtoe (Table 2.1). This positive development was stimulated by national targets under the RED, the introduction of specific national support framework for renewables, and substantial cost reductions recorded by some modern RES technologies, especially solar PV. As such, renewables (mostly solar PV and wind) accounted in 2012 for almost 70 % of new electrical capacity added in Europe (REN21, 2013).

Recent EEA assessments shows that in 2012 the EU was considered to be on track in relation to its two interim trajectories for the share of gross final RES consumption (EEA, 2014a):

- at 13.5 %, the EU's average RES share for the years 2011 and 2012 is higher than the 11.0 % indicative target for these two years from the RED ([15]);
- at the same time, the EU's RES share in 2012 is higher than the 13.0 % target for 2012 resulting from Member States' NREAPs ([16]).

2013 EEA-approximated estimates (in the present text called **proxies**) ([17]), indicate that the EU-wide share of gross final RES consumption continued to increase between 2012 and 2013, albeit by less than the increase recorded between 2011 and 2012. Compared to the RES consumption of 2012, the gross final consumption of renewable energy in 2013 is 6 Mtoe higher — an increase by 4 % over 2012 levels.

Based on the EEA proxy estimates, the total EU RES share was 14.9 % in 2013, i.e. 0.8 percentage points higher than in 2012 (see Table 2.3).

Despite slower growth from 2012 to 2013, the estimated 14.9 % RES share for 2013 would still keep the EU on track with its two interim trajectories (see Figure 2.1):

- the 12.1 % indicative average share for the years 2013 and 2014, resulting from the RED;
- the 13.7 % expected share for 2013 resulting from the NREAPs.

The drop in the pace of growth in 2013 occurred against the backdrop of less renewables used in transport (RES-T) across 12 Member States, along with slower growth in the renewable electricity (RES-E) and renewable heating and cooling (RES-H/C) market sectors. This slow-down is attributed to a slower growth of solar PV in the electricity sector, and of solid

([13]) This is 8.5 % if it is assumed that biofuels consumed in transport before 2011 would not be able to comply with sustainability criteria under the RED.

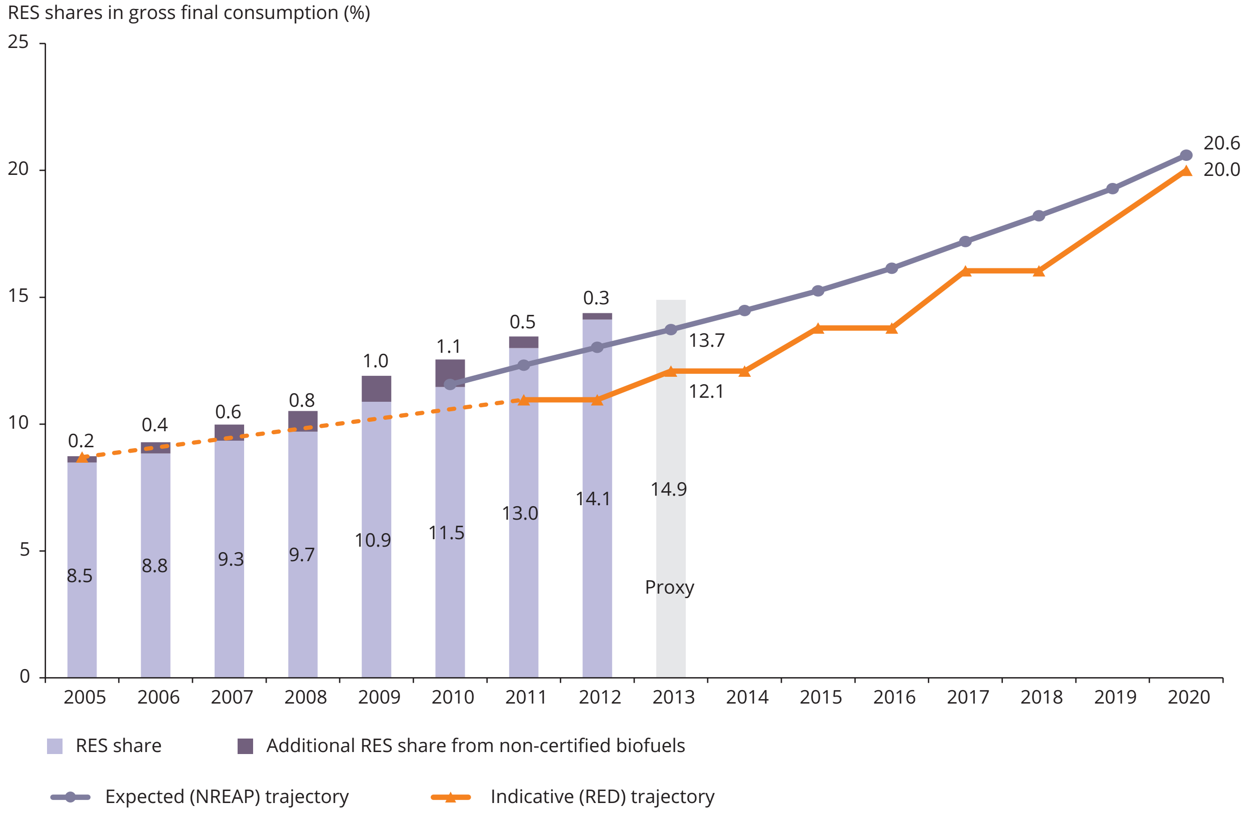
([14]) Compliant biofuels can only be identified and counted towards the target since 2011, when sustainability requirements kicked in under the RED. Because of that, the amount of sustainable biofuels consumed in transport before 2011 is artificially set to 'zero'. This results in a steeper growth curve for compliant biofuels, compared to the growth curve for 'all biofuels'.

([15]) For each Member State,the RED sets a mandatory national overall target for 2020 and an indicative trajectory for the period from 2011 until 2018, intended to ensure that each Member State achieves its 2020 target. An interim indicative RED target for the EU can be derived from the minimum indicative trajectories of the Member States in the run-up to 2020 (RED, Annex I Part B).

([16]) The NREAPs adopted by Member States in 2010 outline expected trajectories for the share of RES in gross final energy consumption towards the legally binding national 2020 RES targets. The cumulative expected realisations (according to Member States' NREAPs) show a European renewables path towards 2020 that is more ambitious than the indicative RED trajectory.

([17]) For reference, see the methodology presented in Section 3.2.

Figure 2.1 EU actual and approximated progress to interim and 2020 targets



Note: The EU's indicative RED trajectory is calculated from all national indicative RED trajectories. The NREAP trajectory represents cumulative expected realisations according to Member States' NREAPs.
For a consistent comparison across years, this figure separately provides the RES shares accounting only for biofuels complying with RED sustainability criteria, and the additional RES shares due to the other biofuels consumed in transport. By contrast, the RES share series reported by Eurostat, 2014a (SHARES Results 2012) takes into account all biofuels consumed in transport for the period from 2005 to 2010, and only biofuels complying with RED sustainability criteria for the years following 2011.

Source: EEA, 2014 (authors' work based on: Eurostat, 2014a; NREAP reports ([18]) using gross final energy consumption after reduction for aviation in the energy efficiency scenario).

biomass in electricity and heating and cooling sectors, compared to the period 2011 to 2012.

These 2012 to 2013 developments accompanied the restructuring of many national RES support frameworks (sometimes retroactively), changes in the national levels of ambition (including for the use of biofuels in transport) and the recent economic crises. These factors negatively affected liquidities and longer-term prospects for investment in renewable energy projects.

2.4.2 Contributions by energy market sector and technology

From 2012 to 2013, a number of changes occurred at EU level and nationally within the three energy market sectors (**renewable electricity** (RES-E), **renewable heating and cooling** (RES-H/C), **and renewable energy used in transport** (RES-T)), in which renewable energy sources compete with conventional sources. The relative importance of these sectors in 2012 and 2013 is summarised below, along with the most important changes in 2013 compared to 2012.

EU level
In 2012, RES-H/C contributed the most towards the gross final consumption of all renewable energy sources in the EU (52 %), followed by RES-E (40 %); RES-T had a significantly smaller contribution than the other two sectors (8 %).

In 2013, according to EEA calculations, RES-H/C still retained its dominance in the gross final consumption of all renewables in the EU (50 %), albeit decreasing by two percentage points compared to its relative

([18]) National Renewable Energy Action Plans: see http://ec.europa.eu/energy/renewables/action_plan_en.htm.

weight in the previous year, as the renewable electricity market sector edged up two percentage points. The relative weight of RES-T has not changed in 2013 (8 %).

Compared to 2012, gross final consumption in the RES-E and RES-H/T sectors increased at a slower rate in 2013; at the same time, the RES-T sector decreased (see Table 2.1).

The expansion of the RES-E sector in 2013 contributed most to absolute RES growth at EU level (+ 4.6 Mtoe). The renewable electricity sector benefited from an increase in onshore wind in 2013, a somewhat lower growth in the solar PV segment than in 2012, a small increase in hydropower output compared to 2012, and lower growth in other renewable energy technologies.

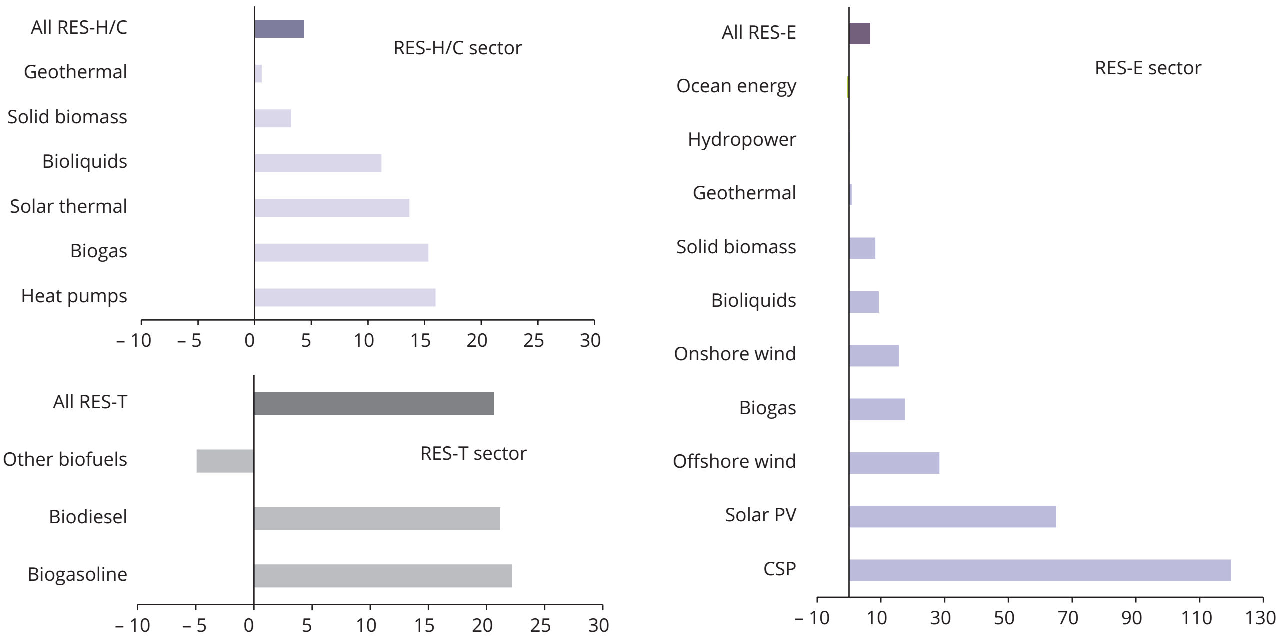
Table 2.1 Breakdown by RES technologies for electricity (E), heating and cooling (H/C) and transport (T) for EU-28

RES technology	Actual contribution			Proxy share	NREAP targets	Annual growth				
	2005	2011	2012	2013	2020	2005–2013	2011–2012	2012–2013	2012–2020	2013–2020
	Mtoe			Mtoe	Mtoe	%				
Electricity	**42.17**	**61.12**	**66.40**	**71.04**	**103.48**	**6.7**	**8.6**	**7.0**	**5.7**	**5.5**
Hydropower	29.58	29.97	29.83	30.28	31.22	0.3	– 0.5	1.5	0.6	0.4
Geothermal	0.46	0.51	0.50	0.50	0.94	0.8	– 2.0	0.0	8.4	9.6
Solar photovoltaic	0.13	3.90	5.78	6.87	7.06	64.9	48.4	18.8	2.5	0.4
Concentrated solar power	0.00	0.17	0.32	0.38	1.63	119.9	92.8	17.9	22.4	23.0
Tidal, wave and ocean energy	0.04	0.04	0.04	0.04	0.56	– 0.5	– 3.4	0.0	39.2	45.9
Onshore wind	5.80	14.45	16.15	18.60	30.30	15.7	11.8	15.2	8.2	7.2
Offshore wind	0.15	0.66	0.93	1.07	11.74	28.4	40.7	15.2	37.2	40.7
Solid biomass	4.76	7.89	8.54	8.97	13.43	8.2	8.3	5.0	5.8	5.9
Biogas	1.10	3.25	3.99	4.01	5.49	17.5	22.7	0.5	4.1	4.6
Bioliquids	0.15	0.28	0.31	0.31	1.10	9.4	9.4	0.0	17.0	19.7
Heating and cooling	**61.11**	**78.69**	**82.94**	**85.70**	**111.80**	**4.3**	**5.4**	**3.3**	**3.8**	**3.9**
Geothermal	0.58	0.57	0.61	0.61	2.65	0.6	7.2	0.0	20.1	23.3
Solar thermal	0.70	1.71	1.84	1.95	6.46	13.7	7.6	5.8	17.0	18.7
Solid biomass	56.65	67.67	71.04	73.00	80.89	3.2	5.0	2.8	1.6	1.5
Biogas	0.75	2.21	2.29	2.36	5.11	15.3	3.6	2.8	10.5	11.7
Bioliquids	0.17	0.40	0.39	0.39	4.42	11.2	– 4.7	0.0	35.6	41.6
Renewable energy from heat pumps	2.26	6.12	6.78	7.40	12.29	16.0	10.7	9.3	7.7	7.5
Transport	**3.03**	**13.71**	**14.61**	**13.61**	**28.88**	**20.6**	**6.5**	**– 6.9**	**8.9**	**11.4**
Biogasoline	0.56	2.89	2.85	2.76	7.32	22.2	– 1.2	– 3.0	12.5	14.9
Biodiesel	2.31	10.73	11.64	10.73	20.98	21.2	8.5	– 7.8	7.6	10.1
Other biofuels	0.17	0.10	0.12	0.11	0.57	– 4.9	20.5	– 7.8	21.3	26.2
Total (wind and hydro not normalised and including non-compliant biofuels)	103.65	150.64	163.55	172.79	n.a.	6.6	8.6	5.7	n.a.	n.a.
Total (normalised and including non-compliant biofuels)	106.31	153.53	163.96	170.34	244.16	6.1	6.8	3.9	5.1	5.3

Note: The table shows normalised data, including non-compliant biofuels, except for 'Total (wind and hydro not normalised)'. Annual growth rates for concentrated solar power (CSP) are calculated for the period starting with 2007.

Source: EEA, 2014 (authors' work based on: Eurostat 2014a and 2014b; NREAP reports).

Figure 2.2 2005-2013 average annual growth rates by technology and sector



Note: Annual growth rates for CSP are calculated for the period starting with 2007.

Source: EEA, 2014 (authors' work based on Eurostat 2014a and 2014b).

In the RES-H/C sector, the expansion in 2013 (+ 2.8 Mtoe) resulted mainly from growth in the solid biomass and heat pumps segments.

The contraction of the RES-T sector in 2013 (by 1.0 Mtoe) was mostly due to a cross-country reduction of biodiesel consumption, although biogasoline and other liquid biofuels used in transport decreased as well.

The overall development of RES in the EU in terms of average growth rates by technology and sector are shown in Figure 2.2 and Table 2.1.

Member State level

At country level, the significance of each renewable market sector differs considerably. Figure 2.3 and Figure 2.4 show the relative weight of each sector in the Member States in 2012 and in 2013, respectively.

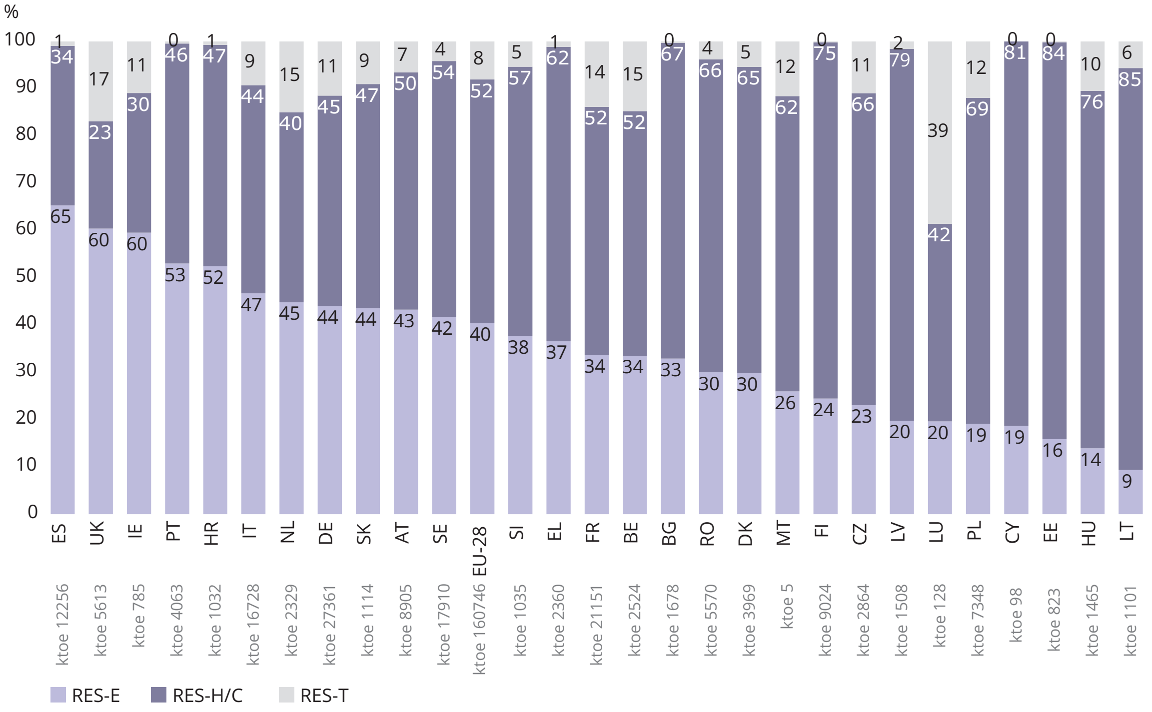
In 2012:

- renewable heating and cooling represented more than half of all gross final consumption of renewables in 18 Member States (Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovenia and Sweden);
- renewable electricity represented over one-half of all RES consumption in five countries only (Croatia, Ireland, Portugal, Spain and the United Kingdom);
- the contribution of renewable transport fuels varied from a maximum of 39 % of all RES consumption (Luxembourg) to 1 % or less (Bulgaria, Croatia, Cyprus, Estonia, Finland, Greece, Portugal and Spain).

The observed variations across countries in the relative importance of each market sector are due to specific national circumstances, including different starting points in 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 deployment.

The splits in the relative importance of RES market sectors were largely preserved in 2013, with RES-H/C predominating in 17 Member States (Austria, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovenia and Sweden), RES-E continuing to represent more than half of all gross final consumption of renewables in five Member States (Croatia, Ireland, Portugal, Spain and the United Kingdom), and the significance of the RES-T sector varying strongly, from a relative weight of 40 %

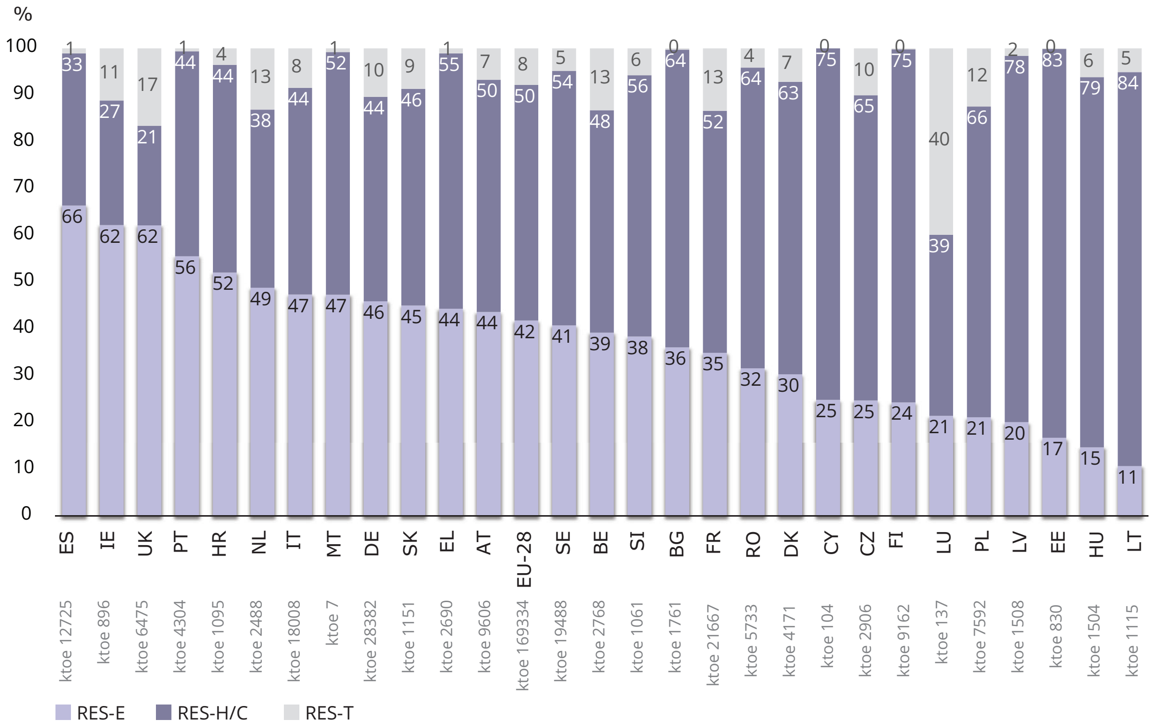
Figure 2.3 RES-E, RES-H/C, RES-T (%) and total RES (ktoe), 2012



Note: For country codes please refer to the list of acronyms, units and terms at the end of this report.

Source: EEA, 2014 (authors' work based on Eurostat, 2014a).

Figure 2.4 Proxy RES-E, RES-H/C, RES-T (%) and total RES (ktoe), 2013



Note: For country codes please refer to the list of acronyms, units and terms at the end of this report.

Source: EEA, 2014 (authors' work).

(Luxembourg) to less than 1 % of all RES (Bulgaria, Cyprus, Estonia, Finland, Greece, Malta, Portugal and Spain).

Discussion of main 2013/2012 changes by sector and country

As it is difficult to determine the uncertainties of the applied RES shares proxy methodology, (especially in the first year of application, when no comparison of estimated proxy values with subsequently published final values was possible), it is likewise difficult to determine the uncertainties of this calculation.

Therefore, changes of calculated RES shares proxies for the years 2013/2012 are compared to historically (2004–2012) observed changes in RES shares.

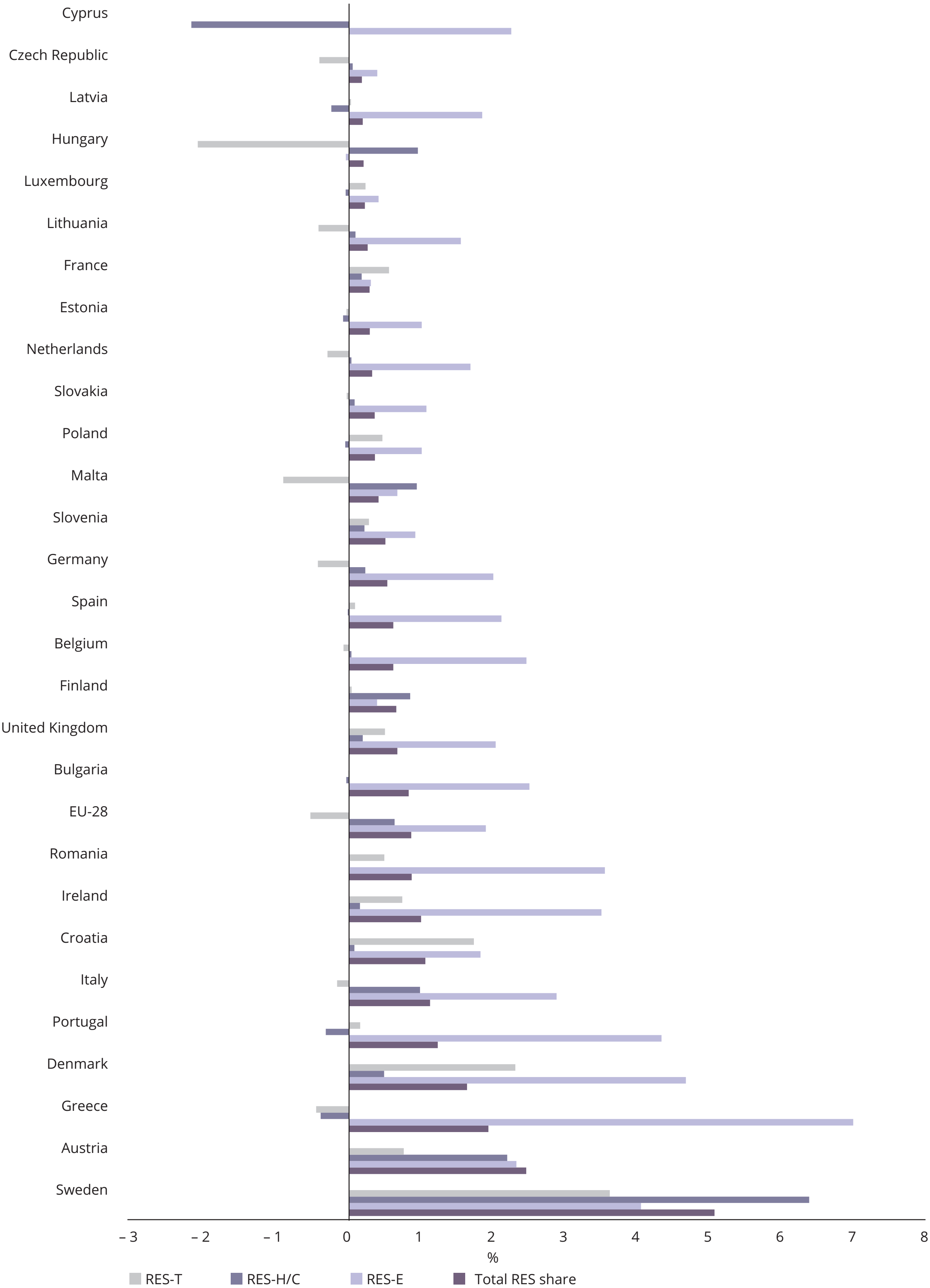
If 2013/2012 RES shares changes were within the historically observed minima and maxima of RES shares changes, results were considered plausible without further analysis. If 2013/2012 RES shares changes were higher or lower than historically observed changes, further in-depth analysis was performed. In all but one case, plausible reasons for these strong decreases or increases were found and are described below.

Table 2.2 Shares of renewable energies in 2012 and 2013 (%)

Country	Total RES share			RES-E			RES-H&C			RES-T		
	2012	2013	Delta	2012	2013	Delta	2012	2013	Delta	2012	2013	Delta
Belgium	6.8	7.4	0.6	11.1	13.6	2.5	6.6	6.7	0.0	4.5	4.4	– 0.1
Bulgaria	16.3	17.2	0.8	17.0	19.5	2.5	27.5	27.5	0.0	0.3	0.3	0.0
Czech Republic	11.2	11.4	0.2	11.6	12.0	0.4	13.6	13.7	0.0	5.6	5.2	– 0.4
Denmark	26.0	27.6	1.6	38.7	43.4	4.7	33.3	33.8	0.5	5.8	8.1	2.3
Germany	12.4	12.9	0.5	23.6	25.6	2.0	11.1	11.3	0.2	6.9	6.4	– 0.4
Estonia	25.8	26.1	0.3	15.8	16.8	1.0	43.1	43.0	– 0.1	0.3	0.2	0.0
Ireland	7.2	8.2	1.0	19.6	23.1	3.5	5.1	5.3	0.2	4.1	4.8	0.7
Greece	13.8	15.8	1.9	16.5	23.5	7.0	24.4	24.0	– 0.4	1.1	0.6	– 0.5
Spain	14.3	14.9	0.6	33.5	35.6	2.1	14.0	14.0	0.0	0.4	0.5	0.1
France	13.4	13.7	0.3	16.6	16.9	0.3	16.9	17.1	0.2	7.1	7.6	0.6
Croatia	16.8	17.9	1.1	35.5	37.3	1.8	18.3	18.3	0.1	0.4	2.1	1.7
Italy	13.5	14.6	1.1	27.6	30.4	2.9	12.8	13.8	1.0	5.8	5.7	– 0.2
Cyprus	6.8	6.8	0.0	4.9	7.2	2.2	21.2	19.0	– 2.2	0.0	0.0	0.0
Latvia	35.8	36.0	0.2	44.9	46.7	1.8	47.4	47.1	– 0.2	3.1	3.1	0.0
Lithuania	21.7	22.0	0.3	10.9	12.4	1.5	35.5	35.5	0.1	4.8	4.4	– 0.4
Luxembourg	3.1	3.3	0.2	4.6	5.0	0.4	5.0	4.9	0.0	2.2	2.5	0.2
Hungary	9.6	9.8	0.2	6.1	6.0	0.0	13.6	14.5	1.0	4.6	2.5	– 2.1
Malta	1.4	1.8	0.4	1.1	1.7	0.7	13.0	13.9	0.9	1.0	0.1	– 0.9
Netherlands	4.5	4.8	0.3	10.5	12.2	1.7	3.4	3.4	0.0	5.0	4.7	– 0.3
Austria	32.1	34.5	2.5	65.5	67.8	2.3	32.8	35.0	2.2	7.7	8.5	0.8
Poland	11.0	11.4	0.4	10.7	11.7	1.0	13.7	13.6	– 0.1	6.1	6.5	0.5
Portugal	24.6	25.8	1.2	47.6	51.9	4.3	33.0	32.7	– 0.3	0.4	0.6	0.2
Romania	22.9	23.8	0.9	33.6	37.1	3.5	25.7	25.8	0.0	4.1	4.6	0.5
Slovenia	20.2	20.7	0.5	31.4	32.3	0.9	30.6	30.8	0.2	2.9	3.2	0.3
Slovakia	10.4	10.7	0.4	20.1	21.1	1.1	8.7	8.8	0.1	4.8	4.8	0.0
Finland	34.3	34.9	0.7	29.5	29.9	0.4	48.1	49.0	0.8	0.4	0.5	0.0
Sweden	51.0	56.0	5.1	60.0	64.0	4.0	65.6	72.0	6.4	12.6	16.3	3.6
United Kingdom	4.2	4.9	0.7	10.8	12.8	2.0	2.3	2.4	0.2	3.7	4.2	0.5
EU-28	**14.1**	**14.9**	**0.9**	**23.5**	**25.4**	**1.9**	**15.6**	**16.3**	**0.6**	**5.1**	**4.5**	**– 0.5**

Source: EEA, 2014 (authors' work); Eurostat, 2014a.

Figure 2.5 Changes of RES shares in 2013 compared to 2012 (in percentage points)



Source: EEA, 2014 (authors' work).

RES-E

The change of the RES-E shares proxy for 2013 compared to 2012 (+ 1.9 %) for the whole EU is 1.1 standard deviations larger than the average annual change of RES-E shares in the period from 2004 to 2012 (+ 1.2 %), but still smaller than the 2011/2010 change (+ 2.0 %).

Of the 22 Member States with changes of RES-E shares larger than the historically observed average, 12 showed sharp changes (i.e. larger than average plus one standard deviation). No Member State recorded changes lower than one standard deviation below the historically observed average.

The developments at Member State level explain why the change for the whole EU-28 is the second largest in the time series, after the 2012/2011 change.

Denmark: already having installed the most wind-power capacity per capita, Denmark increased its capacity of installed wind power by 15 % (offshore wind capacity + 38 %), yielding in 8 % increase of electricity generation from wind power (EurObserv'ER, 2014d).

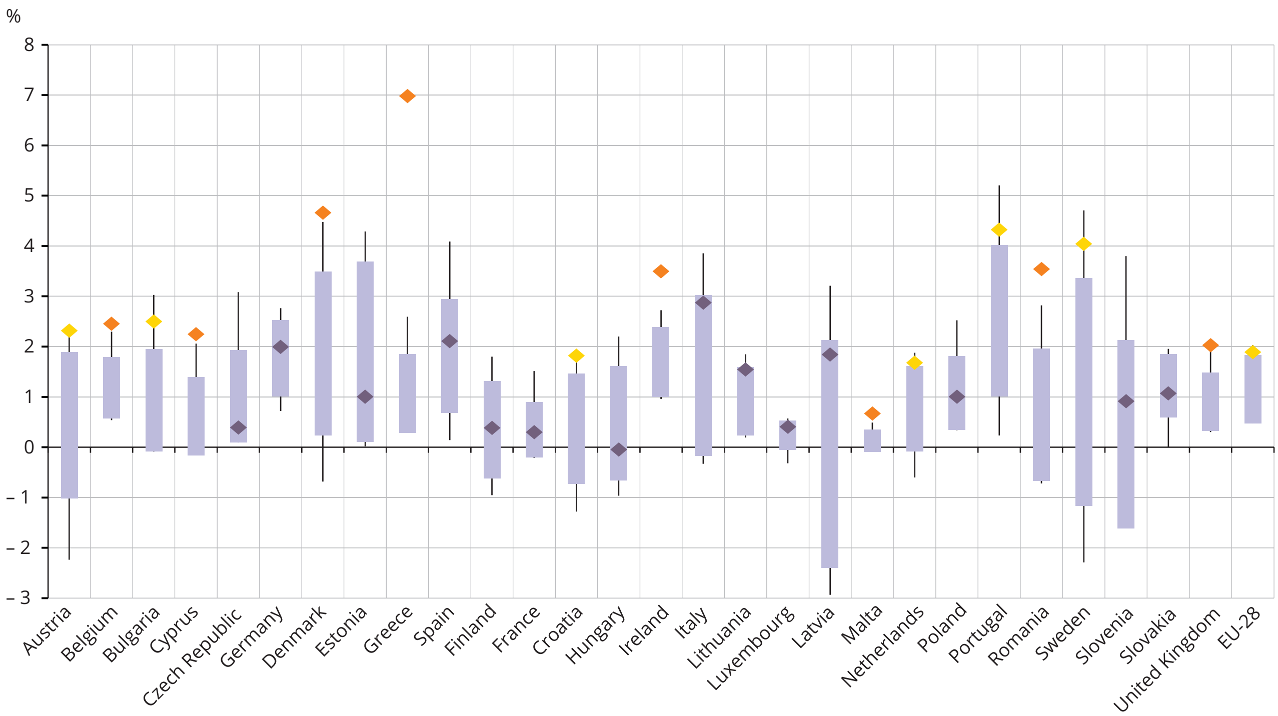
Greece: increased installed photovoltaic (PV) capacity by 68 % and electricity generation almost tripled (EurObserv'ER, 2014b).

Ireland: increased capacity of installed wind power by 8 %, resulting in a 25 % increase of electricity generation from wind power (EurObserv'ER, 2014d).

Malta: increased capacity of installed PV power by 32 %, resulting in a 121 % increase of electricity generation from solar PV (EurObserv'ER, 2014b).

Romania: the main contributor to strongly increased RES-E was a reduction of electricity consumption by 4 % (ENTSO-E, 2014). Installed wind capacity increased by 35 %, leading to an increase of 38 % of wind power electricity generation (EurObserv'ER, 2014d). In 2013, installed PV capacity increased dramatically from 49 MW to 1022 MW (increase by a factor of 21), leading

Figure 2.6 Change of RES-E shares 2013/2012, compared to historically observed annual changes in RES-E shares (2004–2012), all in percentage points



Note: Purple bars show the span from average of annual changes in RES-E shares between 2004 and 2012, plus and minus one standard deviation. Thin lines represent minimum and maximum year-to-year changes in this period. Diamonds show the change of proxy RES share 2013 compared to 2012. Dark purple: change 2013/2012 within one standard deviation of changes from 2004 to 2012. Yellow: change 2013/2012 within minimum and maximum change in the period from 2004 to 2012. Orange: change 2013/2012 larger than changes in the period from 2004 to 2012.

Source: EEA, 2014 (authors' work).

to an increase of PV electricity generation from 8 GWh to 398 GWh (factor of 53) (EurObserv'ER, 2014b) ([19]). This more than compensated for a 1 % reduction of hydroelectricity generation (ENTSO-E, 2014).

United Kingdom: electricity consumption was reduced by 2 % (EurObserv'ER, 2014b), and capacity of installed wind power was increased by 21% (offshore wind capacity + 22 %), generating a 31 % increase of electricity generation from wind power (EurObserv'ER, 2014d).

RES-H/C

The change of the RES-H/C shares proxy for 2013 compared to 2012 (+ 0.6 %) for the whole EU is 0.2 standard deviations smaller than the average annual change of RES-H/C shares in the period 2004 to 2012 (+ 0.7 %).

The calculated changes of the RES-H/C shares proxies for 23 Member States are within one standard deviation of the average changes of the period from 2004 to 2012. For one Member State, changes are within the historical minimum and maximum.

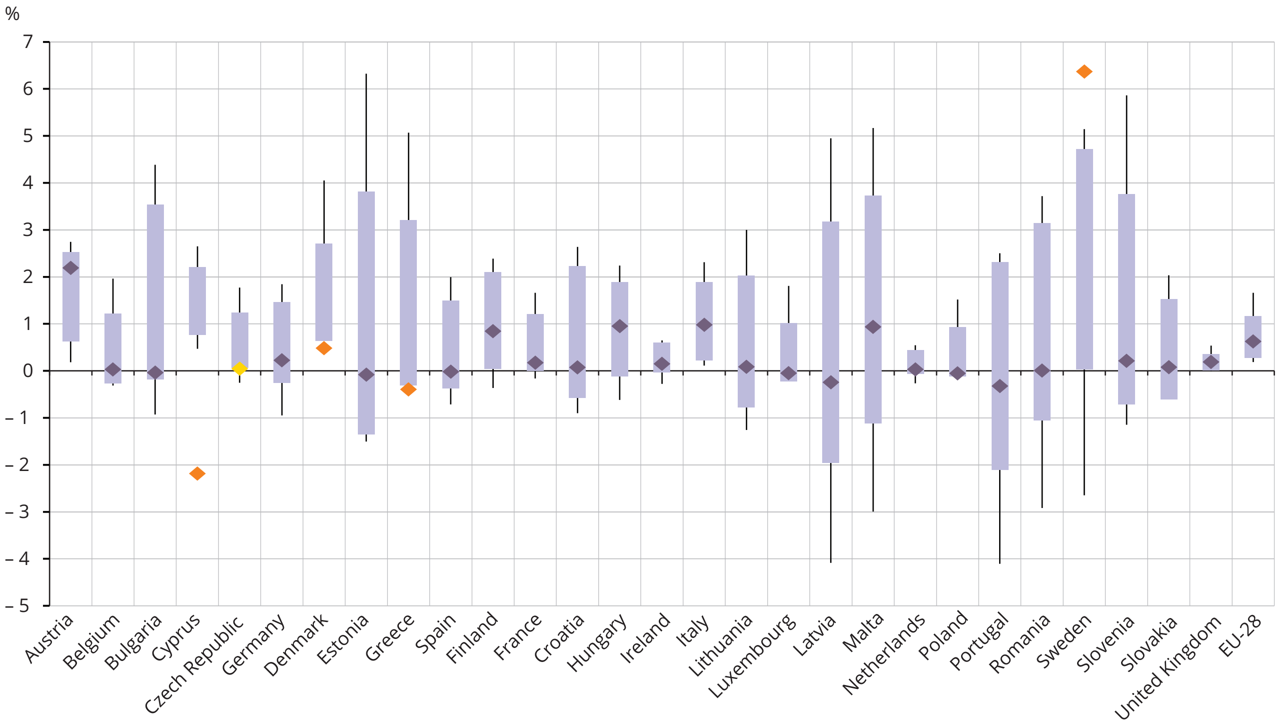
The following four Member States show larger changes than historically observed.

Cyprus: installed solar thermal collector area, and consequently the equivalent thermal power, decreased by 2 %. As Cyprus is the Member State with the largest installed collector area per capita (0.787 m²/capita) (EurObserv'ER, 2014c), this decrease has a strong impact on the RES-H/C share.

Denmark: there is no clear reason for this outlier. The most likely explanation is poor data availability on biomass for heating and cooling.

Greece: the observed reduction in renewables used in the heating and cooling sector can be explained by poor data availability on biomass for this sector, and in

Figure 2.7 Change of RES-H/C shares 2013/2012, compared to historically observed annual changes in RES-H/C shares (2004–2012), all in percentage points



Note: Purple bars show the span from average of annual changes in RES-H/C shares between 2004 and 2012, plus and minus one standard deviation. Thin lines represent minimum and maximum year-to-year changes in this period. Diamonds show the change of proxy RES shares in 2013, compared to 2012. Dark purple: change 2013/2012 within one standard deviation of changes for 2004 through 2012. Yellow: change 2013/2012 within minimum and maximum change in the period from 2004 to 2012. Orange: change 2013/2012 larger than changes in the period from 2004 to 2012.

Source: EEA, 2014 (authors' work).

([19]) Another data source (European Photovoltaic Industry Association, 2014) suggests an increase by 1.1 GW, so this impressive increase of installed PV capacity in Romania seems to be plausible.

the context of reported increases in informal biomass consumption during the economic crisis.

Sweden: Poor data availability on biomass use for heating and cooling could account for this outlier.

Under the applied methodology, only one Member State (Austria) shows an increase larger than the historically observed average of annual change of the RES-H/C shares. The changes in three Member States (Hungary, Sweden and the United Kingdom) show an increase of the RES-H/C shares similar to the historically observed average. For all other 24 Member States, the calculated change of RES-H/C share is lower than the historical average. Therefore, a logical conclusion is that the applied methodology might underestimate dynamics in the heating and cooling sector (see discussion in Section 3.2.4).

RES-T

At EU level, the change of the RES-T shares proxy for 2013 compared to 2012 shows a decrease (− 0.5 %). This decrease is a 1.2 standard deviation below the average annual change of RES-T shares over the period from 2004 to 2012 (+ 0.5 %). Yet the 2011/2010 change (− 1.4 %) was an even stronger drop in the RES-T share.

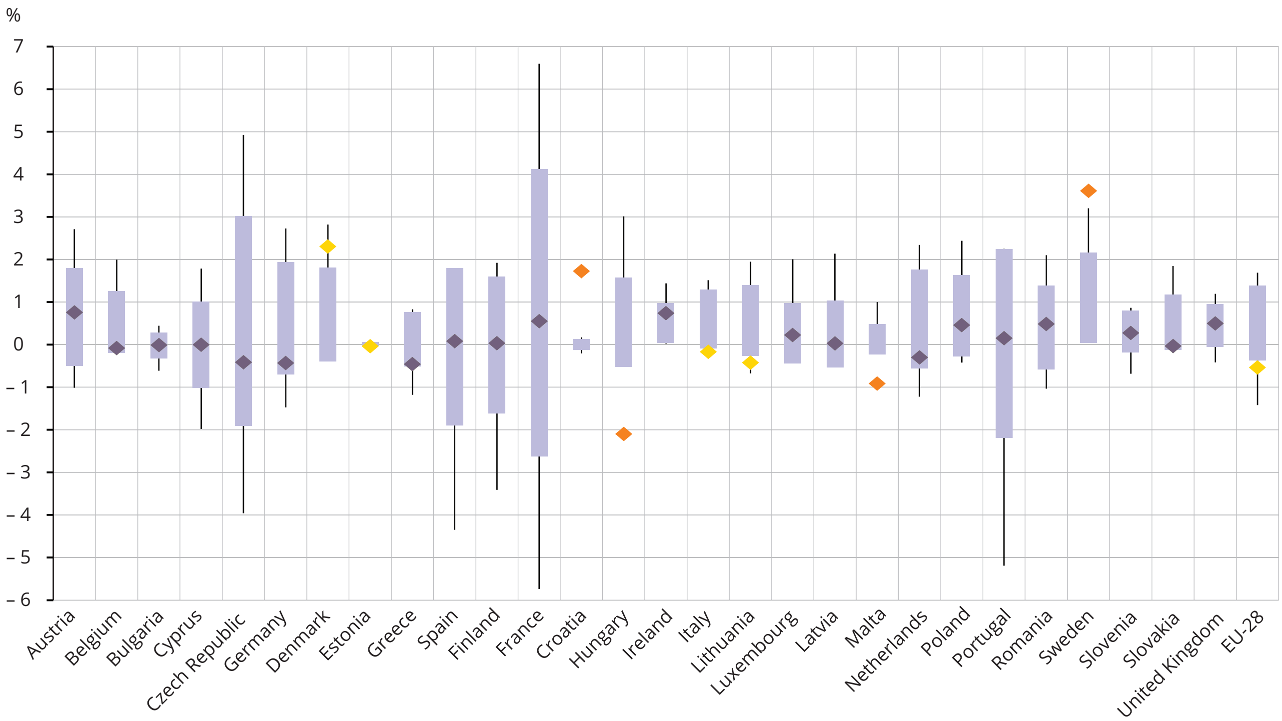
The calculated changes of the RES-T shares proxies for 20 Member States are within one standard deviation of the average changes for the 2004 to 2012 period. For another four Member States, changes are within the historical minimum and maximum.

The following four Member States recorded changes greater than historically observed.

Croatia: while in 2012 no certified biofuels were used, compliance rose to 100 % in 2013 (EurObserv'ER, 2014a).

Hungary: bioethanol consumption declined by 52 % and biodiesel consumption by 14 % (EurObserv'ER, 2014a). Together with a reduction of the share of certified biofuels from 100 % in 2012 to 85 % in 2013 (EurObserv'ER, 2014a), this results in a decrease of the consumption of compliant biofuels by 28 %.

Figure 2.8 Change of RES-T shares 2013/2012, compared to historically observed annual changes in RES-T shares (2004–2012), all in percentage points



Note: Purple bars show the span from average of annual changes in RES-T shares between 2004 and 2012, plus and minus one standard deviation. Thin lines represent minimum and maximum year-to-year changes in this period. Diamonds show the change of proxy RES shares in 2013, compared to 2012. Dark purple: change 2013/2012 within one standard deviation of changes from 2004 through 2012. Yellow: change 2013/2012 within minimum and maximum change in the period from 2004 to 2012. Orange: change 2013/2012 larger than changes in the period from 2004 to 2012.

Source: EEA, (authors' work).

Malta: the calculated reduction of the RES-T shares is attributable to the application of European versus national share of electricity from renewable energy sources in the RES share methodology.

Sweden: bioethanol consumption declined by 9 %, but biodiesel consumption increased by 60 %, generating an increase of 30 % for all biofuels (EurObserv'ER, 2014a). Together with an increase for the RES-E share from 56.0 % in 2010 to 59.9 % in 2011, which is the period considered for the electric transportation ([20]), the resulting RES used in the transport sector reached 28 %.

In total, 9 Member States show decreases of RES-T shares. 14 Member States show a contraction of absolute RES-T use, while RES-T absolute consumption increased in the other 14 Member States. This latter factor notwithstanding, the result was a decrease in the RES-T share across the whole EU.

Total RES

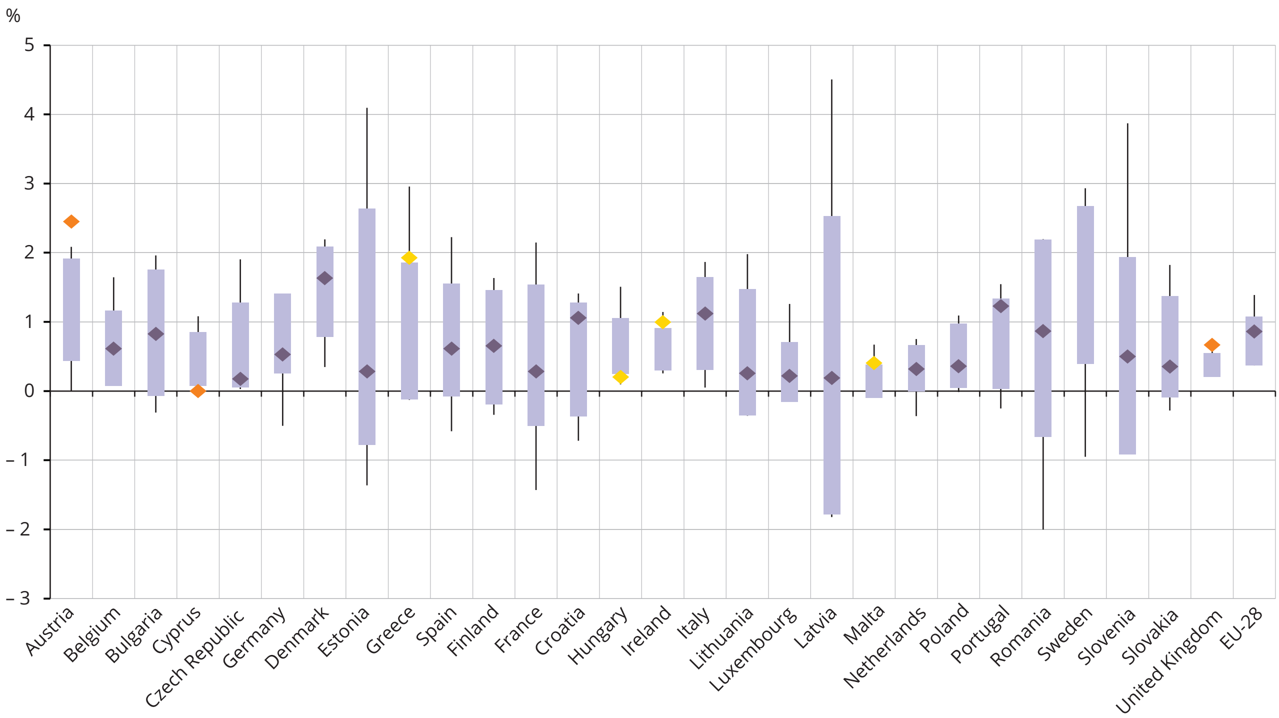
The change of the RES shares proxy for 2013 compared to 2012 (+ 0.9 %) for the whole EU is higher than the observed average annual change of RES shares in the period from 2004 to 2012 (+ 0.7 %).

The calculated changes of the RES shares proxies for 20 Member States are within one standard deviation of the average changes of the period from 2004 to 2012. For another four Member States, changes are within the historical minimum and maximum.

The following four Member States show larger increases than historically observed.

Austria: because RES shares strongly increased in the electricity sector (+ 2.3 %) and the heating and cooling sector (+ 2.2 %), even an almost average RES share increase in the transport sector (+ 0.8 %) was enough

Figure 2.9 Change of RES shares 2013/2012, compared to historically observed annual changes in RES shares (2004–2012), all in percentage points



Note: Purple bars show the span from average of annual changes in RES shares between 2004 and 2012, plus and minus one standard deviation. Thin lines represent minimum and maximum year-to-year changes in this period. Diamonds show the change of proxy RES shares in 2013 compared to 2012. Dark purple: change 2013/2012 within one standard deviation of changes from 2004 through 2012. Yellow: change 2013/2012 within minimum and maximum change in the period from 2004 to 2012. Orange: change 2013/2012 larger than changes in the period from 2004 to 2012.

Source: EEA, (authors' work).

([20]) According to Article 3, Number 4b of the RED, 'for the calculation of the contribution from electricity produced from renewable sources and consumed in all types of electric vehicles [...] the share of electricity from renewable energy sources [...] as measured two years before the year in question' shall be applied.

to generate a 2.5 % increase of the renewable energy share in gross final energy consumption, from 32.1 % in 2012 to 34.5 % in 2013.

Cyprus: because Cyprus is the Member State with the largest installed collector area per capita, the decrease in this market segment has a strong impact on the overall RES share.

Sweden: because RES shares strongly increased in the heating and cooling sector (+ 6.4 %), the electricity sector (+ 4.0 %) and the transport sector (+ 3.6 %), the renewable energy share in gross final energy consumption increased from 51.0 % in 2012 to 56.0 % in 2013.

United Kingdom: RES shares strongly increased in the electricity sector (+ 2.0 %), so despite almost average increases in the transport sector (+ 0.5 %) and heating and cooling sector (+ 0.2 %), it was enough overall to yield a 0.7 % increase of the renewable energy share in gross final energy consumption, from 4.2 % in 2012 to 4.9 % in 2013.

Three Member States show larger RES shares changes in 2013 than in any year-to-year change in the whole 2004 to 2012 period (see the red diamond shapes in Figure 2.9). Only one Member State shows changes in RES shares in 2013 that are lower than any historically 2004 to 2012 observed change. Three additional Member States show increases of more than one standard deviation above the historical average; only one Member State shows increases lower than one standard deviation below average (see the yellow diamond shapes in Figure 2.9). This results in an increase of the RES share of the whole EU above the historical average, despite only 12 Member States showing changes larger than the historical average, and 16 Member States showing smaller changes. It is also notable that no Member State has a RES share decrease.

2.4.3 Approximated interim progress in the Member States

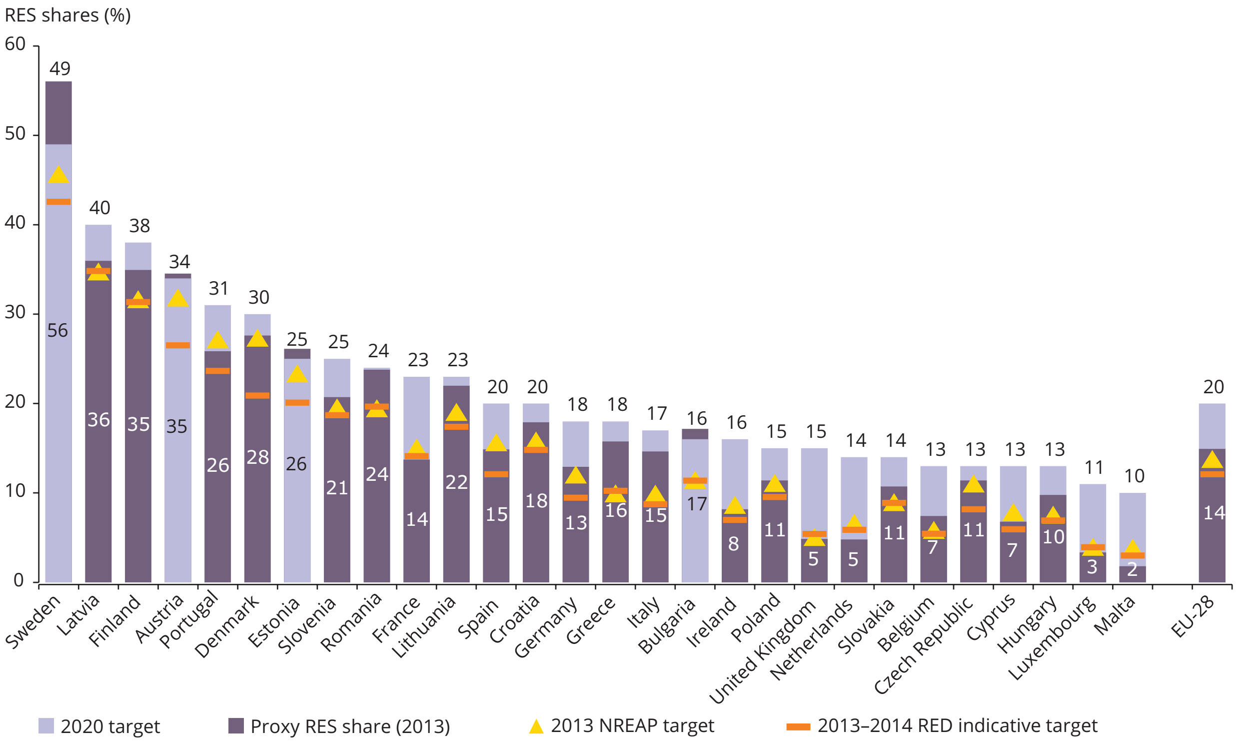
For 2013, the results of the RES share proxy calculation indicate that the share of gross final RES consumption has increased in all but one Member State ([21]). Approximated estimates for 2013 and interim trajectories are presented in Table 23 and Table 2.4. As such, it appears that the EEA's earlier assessment of country progress towards interim 2012 RES targets applies also in 2013 for the most part (EEA, 2014a).

According to the approximated estimates for 2013, the only changes compared to the 2012 assessment concern the United Kingdom and Cyprus. For the United Kingdom, the share of gross final renewable energy consumption in 2013 was slightly lower than the indicative average RES share for the years 2013 and 2014 under the RED. For Cyprus, the share of gross final RES consumption in 2013 was slightly lower than the expected NREAP target for 2013 ([22]). Nevertheless, the current methodology might underestimate the actual dynamics in the heating and cooling sector (see discussion in Section 3.2.4). Moreover, it is difficult to determine the uncertainties of the applied RES shares proxy methodology, especially in the first year of application, for which no comparison is possible of estimated proxy values with later published final values (see Section 3.2).

([21]) In Cyprus, the RES share calculated without the RED-derogation was 6.8 % both in 2012 and in 2013.

([22]) With regard to Cyprus, gross final energy consumption values for 2011 and 2012 were calculated using the derogation provided for under the RED, in line with the notification EEA received from Cyprus. The derogation allows Cyprus to consider the amount of energy consumed in aviation, as a proportion of its gross final consumption of energy, to be no more than 4.12 %. For the calculation of the approximated RES estimate in 2013, implementation of the above derogation was not implemented.

Figure 2.10 Proxy shares of renewable energy in gross final energy consumption and targets (EU countries), 2013



Note: The 2020 targets are set in the RED. Details on the normalisation applied to hydro and wind are presented in Section 3.2.

Source: EEA, 2014 (authors' work).

Table 2.3 EU and Member States' trajectories and progress towards targets (%)

Country	Reference	RES share		RES Proxy share	RES share (average)	Indicative RED trajectory (2-year averages)				Expected NREAP trajectory				Binding RED target
	2005	2011	2012	2013	2011–2012	2011–2012	2013–2014	2015–2016	2017–2018	2011	2012	2013	2020	2020
Belgium	2.3	5.2	6.8	7.4	6.0	4.4	5.4	7.1	9.2	4.4	5.2	5.8	13.0	13.0
Bulgaria	9.5	14.6	16.3	17.2	15.5	10.7	11.4	12.4	13.7	10.7	10.7	11.4	16.0	16.0
Czech Republic	6.0	9.3	11.2	11.4	10.3	7.5	8.2	9.2	10.6	9.8	10.5	11.0	14.0	13.0
Denmark	15.6	24.0	26.0	27.5	25.0	19.6	20.9	22.9	25.5	23.4	24.2	27.3	30.4	30.0
Germany	6.7	11.6	12.4	12.9	12.0	8.2	9.5	11.3	13.7	10.8	11.4	12.0	19.6	18.0
Estonia	17.5	25.6	25.8	26.1	25.7	19.4	20.1	21.2	22.6	21.2	22.0	23.3	25.0	25.0
Ireland	2.8	6.6	7.2	8.2	6.9	5.7	7.0	8.9	11.5	6.7	7.6	8.6	16.0	16.0
Greece	7.0	10.9	13.8	16.0	12.3	9.1	10.2	11.9	14.1	8.8	9.5	9.9	18.0	18.0
Spain	8.4	13.2	14.3	14.9	13.7	11.0	12.1	13.8	16.0	14.4	15.1	15.6	20.8	20.0
France	9.5	11.3	13.4	13.7	12.4	12.8	14.1	16.0	18.6	13.5	14.0	15.0	23.0	23.0
Croatia	12.8	15.4	16.8	17.9	16.1	14.3	15.0	16.1	17.6	14.2	15.1	15.8	20.1	20.0
Italy	5.9	12.3	13.5	14.6	12.9	7.6	8.7	10.5	12.9	8.7	9.2	9.9	17.0	17.0
Cyprus	3.1	6.8	7.8	6.8	7.3	4.9	5.9	7.4	9.5	6.8	7.1	7.8	13.0	13.0
Latvia	32.3	33.5	35.8	36.0	34.7	34.1	34.8	35.9	37.4	33.8	34.3	34.7	40.0	40.0
Lithuania	17.0	20.2	21.7	21.9	21.0	16.6	17.4	18.6	20.2	17.0	18.0	19.0	24.0	23.0
Luxembourg	1.4	2.9	3.1	3.4	3.0	2.9	3.9	5.4	7.5	2.9	2.9	3.9	11.0	11.0
Hungary	4.5	9.1	9.6	9.7	9.3	6.0	6.9	8.2	10.0	7.3	7.4	7.5	14.7	13.0
Malta*	0.3	0.7	1.4	1.5	1.1	2.0	3.0	4.5	6.5	2.3	2.6	3.8	10.2	10.0
Netherlands	2.3	4.3	4.5	4.8	4.4	4.7	5.9	7.6	9.9	4.6	5.6	6.6	14.5	14.0
Austria	24.0	30.8	32.1	34.5	31.4	25.4	26.5	28.1	30.3	31.4	31.6	31.8	34.2	34.0
Poland	7.0	10.4	11.0	11.4	10.7	8.8	9.5	10.7	12.3	10.1	10.6	11.1	15.5	15.0
Portugal	19.5	24.5	24.6	26.0	24.6	22.6	23.7	25.2	27.3	25.2	26.9	27.1	31.0	31.0
Romania	17.6	21.2	22.9	23.8	22.1	19.0	19.7	20.6	21.8	18.0	19.0	19.4	24.0	24.0
Slovenia	16.0	19.4	20.2	20.7	19.8	17.8	18.7	20.1	21.9	18.2	18.7	19.5	25.3	25.0
Slovakia	5.5	10.3	10.4	10.7	10.3	8.2	8.9	10.0	11.4	8.2	8.2	8.9	14.0	14.0
Finland	28.9	32.7	34.3	34.7	33.5	30.4	31.4	32.8	34.7	30.1	31.0	31.6	38.0	38.0
Sweden	40.5	48.8	51.0	54.4	49.9	41.6	42.6	43.9	45.8	44.2	44.9	45.6	50.2	49.0
United Kingdom	1.4	3.8	4.2	4.8	4.0	4.0	5.4	7.5	10.2	4.0	4.0	5.0	15.0	15.0
EU-28	**8.7**	**12.9**	**14.1**	**14.9**	**13.5**	**11.0**	**12.1**	**13.8**	**16.0**	**12.3**	**13.0**	**13.7**	**20.6**	**20.0**

Note: For Malta, data for 2012 are estimated by Eurostat, based on the national data transmission under Regulation (EC) No 1099/2008 on energy statistics. For Cyprus, see footnote (22).

Source: EEA, 2014 (authors' work based on Eurostat, 2014a; EC, 2009).

Table 2.4 EU and Member States' trajectories and progress towards targets (ktoe)

Country	Reference	Gross final consumption of RES		RES Proxy	Expected NREAP trajectory				Expected *
	2005	2011	2012	2013	2011	2012	2013	2020	2020
Belgium	865 (873)	1 974 (2 000)	2 524 (2 544)	2 711	1 793	2 124	2 390	5 374	41 301
Bulgaria	1 048 (1 048)	1 514 (1 531)	1 678 (1 763)	1 755	1 197	1 296	1 406	2 059	10 738
Czech Republic	1 661 (1 664)	2 420 (2 721)	2 864 (2 864)	2 872	2 898	3 119	3 268	4 180	29 803
Denmark	2 546 (2 561)	3 731 (3 748)	3 969 (3 997)	4 150	3 849	4 017	4 534	4 989	16 346
Germany	13 194 (15 124)	25 094 (25 130)	2 7361 (2 7381)	27 916	24 033	25 233	26 152	38 557	197 178
Estonia	548 (548)	793 (797)	823 (827)	830	682	714	763	863	3 451
Ireland	362 (363)	738 (759)	785 (805)	896	1 028	1 145	1 357	2 269	14 142
Greece	1 520 (1 520)	2 097 (2 180)	2 360 (2 460)	2 685	2 341	2 590	2 856	4 870	24 114
Spain	8 269 (8 525)	11 814 (13 506)	12 256 (14 343)	12 962	13 901	14 533	15 081	20 525	98 693
France	15 444 (15 834)	17 157 (19 561)	21 151 (21 128)	21 481	21 856	22 913	24 362	36 121	155 268
Croatia	844 (844)	987 (991)	1 032 (1 069)	1 087	927	970	1 027	1 469	7306
Italy	7 900 (8 077)	15 574 (15 575)	16 728 (16 743)	17 736	11 406	12 184	13 031	21 490	133 042
Cyprus	44 (44)	94 (110)	98 (114)	103	119	126	142	263	2 023
Latvia	1 374 (1 377)	1 362 (1 362)	1 508 (1 508)	1 504	1 384	1 432	1 471	1 918	4 796
Lithuania	848 (851)	1 001 (1001)	1 101 (1 101)	1 114	864	930	1 022	1 474	6 084
Luxembourg	61 (61)	121 (121)	128 (130)	138	76	99	127	391	4 396
Hungary	840 (843)	1 528 (1 532)	1 465 (1 484)	1 498	1 387	1 439	1 490	2 879	19 644
Malta *	1 (1)	3 (4)	5 (7)	6	10	12	18	55	534
Netherlands	1 088 (1 223)	2 221 (2 224)	2 329 (2 345)	2 451	2 328	2 845	3 319	7 340	50 532
Austria	6760 (6827)	8 570 (8 663)	8 905 (8973)	9 402	8 027	8 106	8 191	9 266	27 109
Poland	4 183 (4 232)	6 961 (6 962)	7 348 (7 348)	7 562	6 233	6 614	6 949	10 725	69 200
Portugal	3 792 (3 792)	4 372 (4 675)	4 063 (4 345)	4 264	4 719	5 054	5 122	6 044	19 467
Romania	4 601 (4 601)	5 176 (5 308)	5 570 (5 609)	5 693	4 768	5 147	5 335	7 268	30 278
Slovenia	814 (814)	1 007 (1 007)	1 035 (1 034)	1 055	904	939	993	1 344	5 323
Slovakia	645 (656)	1 140 (1 140)	1 114 (1 114)	1 125	1 061	1 122	1 188	1 715	11 226
Finland	7 502 (7 502)	8 500 (8 734)	9 024 (9 307)	9 091	7 930	8 250	8 500	10 700	28 170
Sweden	14 204 (14 423)	17 057 (17 139)	17 910 (18 000)	18 718	16 097	16 498	16 899	19 709	39 231
United Kingdom	2 004 (2 084)	4 969 (5 048)	5 613 (5 616)	6 447	5 200	6 032	6 856	20 510	136 700
EU-28	**102 962 (106 312)**	**147 976 (153 525)**	**160 746 (163 959)**	**168 312**	**147 018**	**155 483**	**163 849**	**244 366**	**1 186 095**

Note: The table shows normalised data. Parentheses indicate the gross final consumption of RES, including biofuels not in compliance with RED sustainability requirements. For Malta, data for 2012 are estimated by Eurostat, based on the national data transmission under Regulation (EC) No 1099/2008 on energy statistics.

* Expected gross final energy consumption (NREAP)

Source: EEA, 2014 (authors' work based on Eurostat, 2014a; NREAP reports).

2.5 RES impacts on GHG emissions and on fossil fuel use

Energy production and use has numerous environmental and health impacts. Today, fossil fuels continue to dominate the energy mix in Europe, contributing to climate change and air pollution. Despite the rapid growth of RES in electricity, heat production and transport since 2005, the three sectors together are responsible for about half of all EU-wide GHG emissions due to their heavy reliance on fossil fuels ([23]). To combat climate change, Member States and the EU must rethink their energy systems and shift quickly to a low-carbon economy and society (see Section 2.2).

Renewable energy is already an important option for climate change mitigation and for curtailing dependence on (often imported) fossil fuels.

Interactions between climate policies and policies supporting the realisation of RES are increasingly well understood and taken into account in policymaking. For instance, European targets and trajectories for GHG emission reductions and RES shares were set jointly under the 2009 climate and energy package, so that the expected emission reductions from RES in the run-up to 2020 were taken into account when setting the GHG targets, including the decreasing EU ETS cap. This integrated approach underpins also the EC's proposal for a climate and energy framework for 2030 (EC, 2014).

This section summarises gross avoided GHG emissions and avoided fossil fuels by country and at EU level, as a consequence of deploying renewables. The term 'gross avoided GHG emissions' is used to illustrate the theoretical character of the contributions estimated in this way, which do not necessarily represent **net** GHG savings. Absolute values for the gross avoided emissions in a given year concern CO_2 emissions only ([24]), in that respective year. Relative values are expressed as a percentage between these absolute values, and the total hypothetical GHG emissions in the respective year ([25]).

The estimates were derived by comparing the recorded growth in renewable energy use after 2005 with a hypothetical scenario that froze the contribution of renewables at 2005 levels. Thus, the amounts of renewable energy consumed before and in 2005 are subtracted from later RES amounts. As explained in Section 3.3.1, it is assumed that the remaining renewable energy has substituted an equivalent amount of energy that would have been supplied by other sources. To prevent distortion of estimates, for electricity production from hydro and wind the actual generated power amounts were used as a basis, rather than those calculated by applying the normalisation rules prescribed by the RED ([26]). The methods underpinning this section are described in Sections 3.3 and 3.4. Country-specific EFs used for the calculations can be found in Annex 3.

2.5.1 Gross avoided GHG emissions

According to EEA calculations, the use of renewables in 2012 resulted in approximately 326 Mton of gross avoided CO_2 emissions at EU level. This includes approximately 250 Mton (77 %) in sectors covered by the EU ETS, and 75 Mton (23 %) attained in non-trading sectors ([27]). These gross avoided emissions correspond to roughly 7 % of the EU's total GHG emissions in 2012, as is shown in Figure 2.11.

Of all gross avoided emissions in 2012, by far the highest levels were attained in the electricity sector (72 %). The use of RES in transport and for heating and cooling led to considerably lower levels (11 % and 17 %, respectively).

At country level, the ratio of gross avoided emissions to total national emissions is higher than the EU ratio in 11 Member States in 2012 (Austria, Belgium, Denmark, Estonia, Finland, Germany, Italy, Latvia, Portugal, Spain and Sweden). In the case of Portugal, the gross increase of non-ETS emissions in 2012 compared to 2005 (+ 1 % of total 2012 emissions) resulted from reduced use of solid biomass for heating in this sector from 2005 to 2012. In Croatia and Romania, the observed gross

([23]) In 2012, public electricity and heat production was responsible for 27 % and transport for 20 % of EU total GHG emissions without land use, land use change and forestry (sectors 1–7, exluding sector 5 and LULUCF).

([24]) Unpublished work by the authors has shown that non-CO_2 GHGs play a marginal role in total emissions from the public electricity and heat sector. It was therefore decided to focus in the current report on CO_2 emissions only.

([25]) The total hypothetical GHG emissions in a year are obtained by adding the absolute values for the gross avoided CO_2 emissions in a year to the actual GHG emissions in that year.

([26]) Normalised electricity consumption, as defined in Annex II of Directive 2009/28/EC: the normalisation rule only applies to hydro and wind power, which may vary from one year to another due to climatic variations. Actual electricity generation has been calculated as follows: Electricity generation from renewables other than wind and hydro (excluding non-bio municipal waste and other biofuels) + Electricity generation from wind + Electricity generation from hydro + Electricity generation from biofuels complying with the RED sustainability criteria.

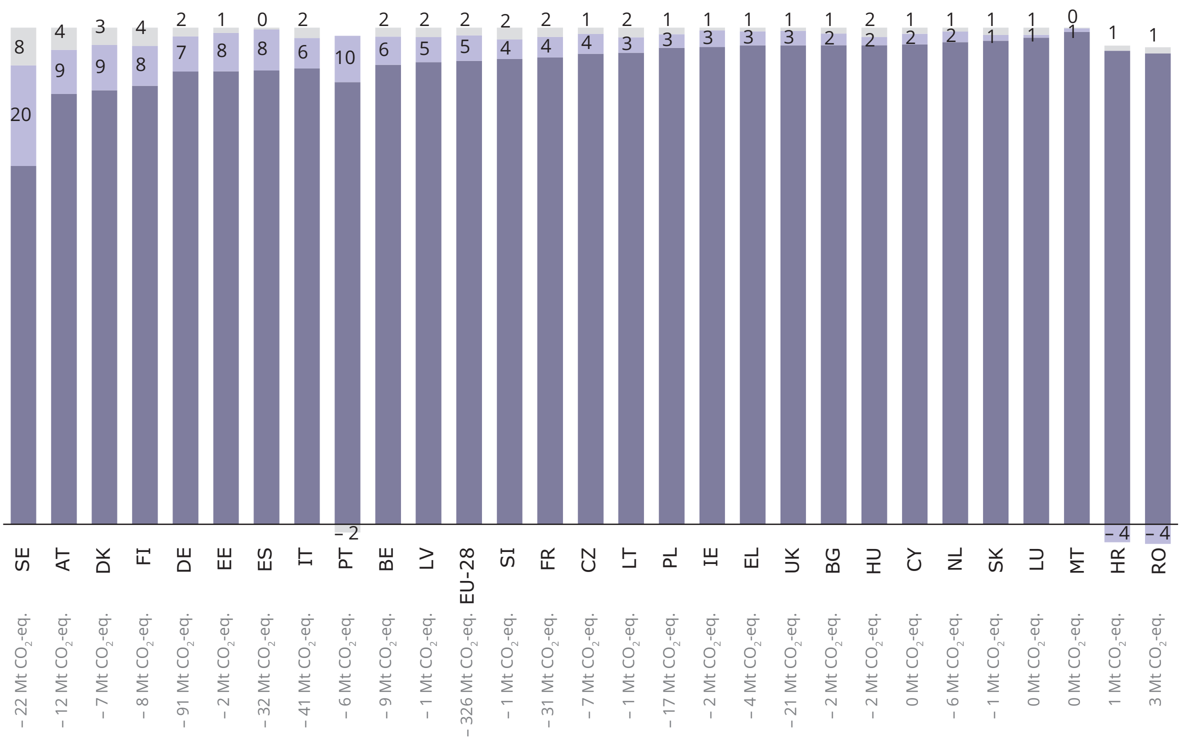
([27]) Non-trading sectors concern the sectors covered under the Effort Sharing Decision (Decision 406/2009/EC), in particular: transport (except aviation and international maritime shipping), buildings, agriculture and waste.

increase of ETS-sector emissions occurred due to reduced use of hydroelectricity from 2005 to 2012, which was offset in each country by an increase in fossil fuel use. Applying a normalisation of RES consumption values for hydropower and wind power would smooth out the results; this was, however, not the purpose for this current exercise.

In line with EEA RES proxy calculations, in 2013 the gross final consumption of renewables increased in Europe by roughly 5 % compared to the previous year. Gross avoided emissions at EU level increased by 19 %, to 388 Mton CO_2 ([28]). Compared to the previous year, an even higher proportion of the gross avoided emissions in 2013 occurred in the EU ETS sectors (80 %), as the proportion in non-trading sectors decreased by 3 percentage points. This corresponds to the observed contraction in the RES-T sector and a higher absolute increase recorded in the renewable electricity sector, compared to the renewable heating and cooling sector in 2013 (see discussion in Section 2.4). As such, of all gross avoided GHG emissions in Europe in 2013, 75 % were attained in the electricity sector, 16 % in the heating and cooling sector and 9 % in the transport sector.

At national level, the ratio of gross avoided emissions to total national emissions was above the EU ratio in 11 Member States in 2013 (Austria, Belgium, Croatia, Denmark, Estonia, Germany, Italy, Portugal, Slovenia, Spain and Sweden). As in 2012, for Portugal the gross **increase** in non-ETS emissions in 2013 can be explained through a reduced use of biomass in this sector compared to 2005. Romania saw a gross **increase** of ETS-sector emissions in 2013 compared to 2005 results, owing to lower hydropower use in 2013 than in 2005.

Figure 2.11 Gross avoided emissions compared to total emissions (%), 2012



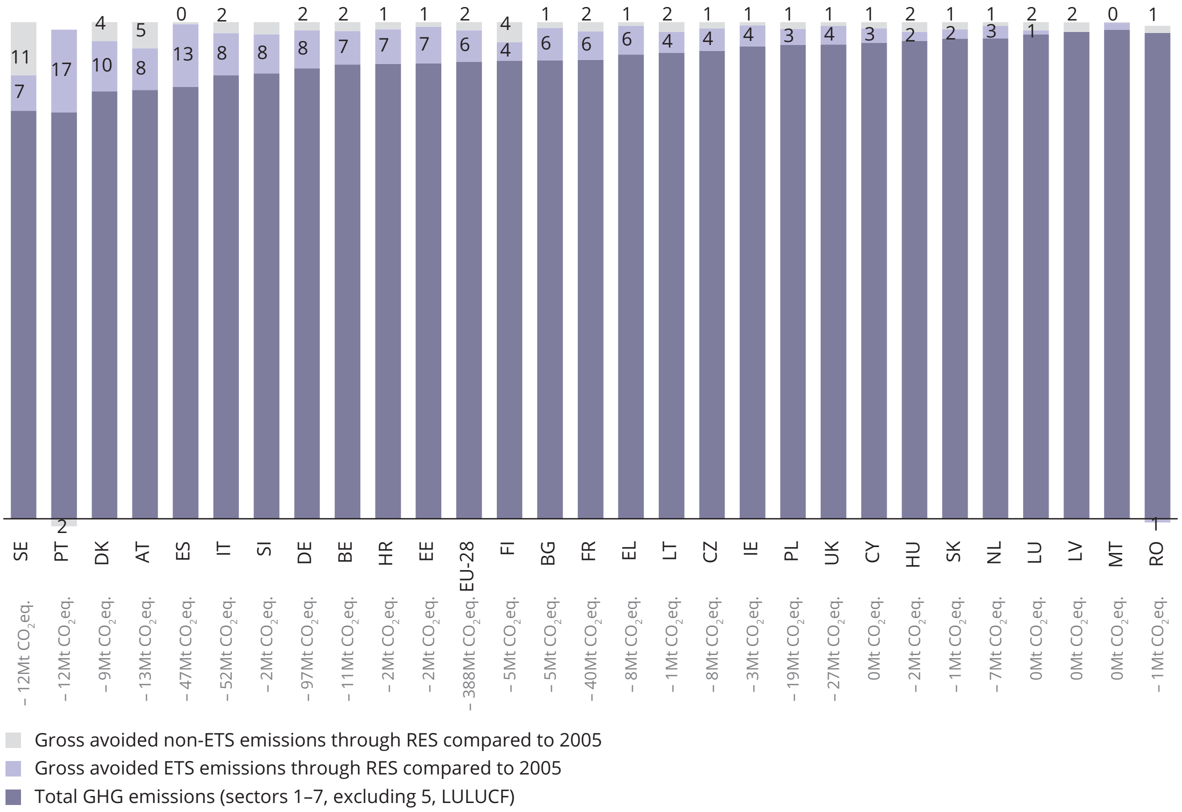
- Gross avoided non-ETS emissions through RES compared to 2005
- Gross avoided ETS emissions through RES compared to 2005
- Total GHG emissions (sectors 1–7, excluding 5, LULUCF)

Note: Figures in brackets show gross avoided emissions in million tonnes, in the respective year (i.e. not cumulated over the 2005-to-2012 period).

Source: EEA, 2014 (authors' work).

([28]) Gross avoided emissions are defined in relation to 2005 RES-use levels. Their increase is, therefore, not equivalent to the increase of gross final RES consumption over a given period.

Figure 2.12 Gross avoided emissions compared to total emissions (%), 2013



Note: Figures in brackets show gross avoided emissions in million tonnes, in the respective year (i.e. non-cumulative).

Source: EEA, 2014 (authors' work).

2.5.2 Avoided fossil fuel use

Based on EEA calculations, the additional use of renewable energy compared to the level of RES consumption in 2005 enabled the EU to cut its demand for fossil fuels by 98 Mtoe in 2012 and by 116 Mtoe in 2013, respectively. Without the additional use of renewable energy since 2005, the EU's gross inland consumption of fossil fuels would have been 7 % higher in 2012. At country level in 2012, 12 Member States saw reductions of their gross inland consumption of fossil fuels of 7 % or more, in response to RES increases since 2005 (Austria, Belgium, Denmark, Estonia, Germany, Finland, Italy, Latvia, Portugal, Slovenia, Spain and Sweden).

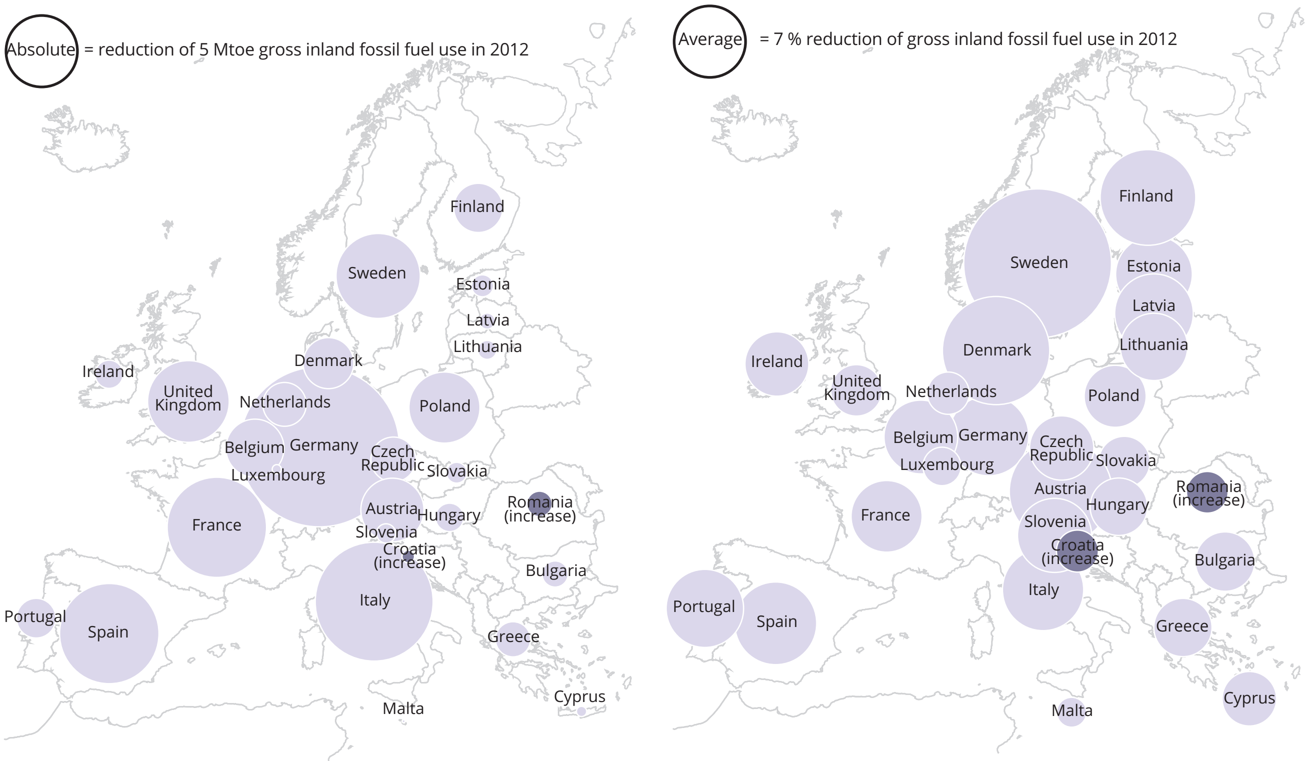
The increased use of renewables after 2005 triggered the strongest reduction of solid fuels (mainly coal) use in Europe, whose gross inland consumption in 2012 would otherwise have been 13 % higher. 43 % of all fossil fuels avoided in 2012 due to increased RES use are solid fuels, increasing to 47 % in 2013 (see Table 2.5). In 11 Member States, the gross inland consumption of coal was reduced by more than the 13 % EU-wide average reduction in 2012 (Austria, Belgium, Finland, France, Germany, Italy, Latvia, Lithuania, Portugal, Spain and Sweden).

Without the additional growth of renewable energy use that occurred after 2005, the EU's gross inland consumption of natural gas in 2012 would have been 7 % higher. This contribution is relevant in the current geopolitical context and Europe's diminishing natural gas resources. The substitution of natural gas makes up 28 % of all avoided fossil fuel use in 2012, and 30 % in 2013. In 2012, thanks to renewables, almost one-half of all Member States reduced their gross inland consumption of natural gas by at least 7 % (Austria, Belgium, Bulgaria, Denmark, Estonia, Finland, Greece, Ireland, Italy, Poland, Slovenia, Spain and Sweden).

For petroleum products, the substitution effects are somewhat less intense, given the lesser share of renewable energy use in transport: oil and transport fuels jointly make up 27 % of all avoided fossil fuels in 2012 and 22 % in 2013, respectively. Without the post-2005 growth in renewables, the EU-wide gross inland consumption of petroleum products in 2012 would have been 4 % higher. At country-level, the increased consumption of renewables has reduced the gross inland consumption of petroleum products by 4 % or more in 7 Member States (Austria, Denmark, Estonia, Finland, France, Slovenia and Sweden).

In terms of market sectors, the highest substitution effects at EU level are visible in the renewable electricity sector, which accounted for 67 % of all avoided fossil fuels in 2012 and rose to 71 % in 2013. According to EEA estimates, the effects in the other two sectors are smaller: RES-H/C contributed 21 % in 2012 and 19 % in 2013 towards total avoided fossil fuel use in the EU in the two corresponding years; the RES-T sector contributed 12 % in 2012 and 10 % in 2013 respectively.

Figure 2.13 Relative and absolute reduction of gross inland consumption of fossil fuels (p.a., in 2012)



Source: EEA, 2014 (authors' work).

Table 2.5 Estimated avoided fossil fuel use due to RES deployment, by type of fuel (Mtoe)

Country	Effects on solid fuel use		Effects on total oil use		Effects on gas use		Effects on diesel use		Effects on petrol use		Effects on other non– renewable fuel use		Effects on total non–renewable fuel use	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Belgium	– 0.5	– 0.5	– 0.2	– 0.2	– 2.1	– 2.5	– 0.3	– 0.3	– 0.1	– 0.1	– 0.2	– 0.3	– 3.3	– 3.9
Bulgaria	– 0.3	– 0.9	– 0.1	– 0.1	– 0.2	– 0.2	0.0	0.0	0.0	0.0	0.0	0.0	– 0.7	– 1.3
Czech Republic	– 1.3	– 1.5	0.0	0.0	– 0.3	– 0.3	– 0.2	– 0.2	– 0.1	– 0.1	0.0	0.0	– 2.0	– 2.1
Denmark	0.0	0.0	– 1.8	– 2.1	– 0.5	– 0.5	– 0.2	– 0.3	0.0	0.0	0.0	0.0	– 2.5	– 2.9
Germany	– 16.0	– 17.5	– 1.6	– 1.7	– 4.2	– 4.4	– 2.2	– 1.9	– 0.8	– 0.8	– 0.3	– 0.3	– 25.0	– 26.7
Estonia	– 0.3	– 0.3	– 0.1	– 0.1	– 0.1	– 0.1	0.0	0.0	0.0	0.0	0.0	0.0	– 0.5	– 0.5
Ireland	– 0.3	– 0.4	0.0	0.0	– 0.4	– 0.4	– 0.1	– 0.1	0.0	0.0	0.0	0.0	– 0.8	– 0.9
Greece	– 0.5	– 1.1	– 0.4	– 0.6	– 0.3	– 0.5	0.0	0.0	0.0	0.0	0.0	0.0	– 1.2	– 2.1
Spain	– 4.9	– 7.3	– 1.4	– 1.9	– 3.3	– 4.8	0.0	0.0	0.0	0.0	– 0.1	– 0.1	– 9.7	– 14.2
France	– 3.2	– 4.7	– 1.2	– 1.5	– 2.2	– 2.9	– 2.3	– 2.3	– 0.4	– 0.4	– 0.4	– 0.6	– 9.7	– 12.3
Croatia	0.3	– 0.4	0.0	– 0.1	– 0.1	– 0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	– 0.6
Italy	– 4.2	– 5.8	– 1.2	– 1.5	– 6.6	– 8.4	– 1.3	– 1.2	– 0.1	– 0.1	– 0.2	– 0.2	– 13.6	– 17.2
Cyprus	0.0	0.0	– 0.1	– 0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	– 0.1	– 0.1
Latvia	– 0.1	0.0	0.0	0.0	– 0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	– 0.3	– 0.1
Lithuania	– 0.1	– 0.2	0.0	0.0	– 0.1	– 0.1	– 0.1	– 0.1	0.0	0.0	0.0	0.0	– 0.4	– 0.4
Luxembourg	0.0	0.0	0.0	0.0	0.0	0.0	– 0.1	– 0.1	0.0	0.0	0.0	0.0	– 0.1	– 0.1
Hungary	– 0.2	– 0.2	0.0	0.0	– 0.5	– 0.5	– 0.1	– 0.1	– 0.1	0.0	0.0	0.0	– 0.8	– 0.8
Malta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	– 0.7	– 0.8	– 0.1	– 0.1	– 0.8	– 0.9	– 0.2	– 0.2	– 0.1	– 0.1	0.0	0.0	– 1.9	– 2.1
Austria	– 1.2	– 1.2	– 0.4	– 0.5	– 1.6	– 1.7	– 0.4	– 0.4	– 0.1	– 0.1	– 0.3	– 0.2	– 3.9	– 4.1
Poland	– 2.6	– 3.0	– 0.3	– 0.4	– 1.1	– 1.2	– 0.7	– 0.7	– 0.2	– 0.2	0.0	– 0.1	– 4.9	– 5.5
Portugal	– 1.6	– 2.8	0.3	0.1	– 0.2	– 0.6	0.0	0.0	0.0	0.0	– 0.1	– 0.1	– 1.5	– 3.3
Romania	1.1	0.2	– 0.1	– 0.1	– 0.2	– 0.4	– 0.1	– 0.1	– 0.1	– 0.1	0.0	0.0	0.6	– 0.4
Slovenia	– 0.2	– 0.4	– 0.1	– 0.1	– 0.1	– 0.1	– 0.1	– 0.1	0.0	0.0	0.0	0.0	– 0.4	– 0.6
Slovakia	– 0.1	– 0.1	0.0	0.0	– 0.3	– 0.4	– 0.1	– 0.1	0.0	0.0	0.0	0.0	– 0.4	– 0.6
Finland	– 1.1	– 0.3	– 1.0	– 1.0	– 0.3	– 0.3	0.0	0.0	0.0	0.0	0.0	0.0	– 2.4	– 1.6
Sweden	– 0.8	– 0.9	– 5.1	– 1.5	– 0.5	– 0.5	– 0.4	– 0.6	– 0.2	– 0.2	0.0	0.0	– 6.9	– 3.8
United Kingdom	– 3.4	– 4.3	– 0.2	– 0.2	– 2.1	– 2.6	– 0.5	– 0.6	– 0.4	– 0.4	0.0	– 0.1	– 6.5	– 8.1
EU– 28	**– 42.1**	**– 54.3**	**– 15.2**	**– 13.7**	**– 28.0**	**– 34.4**	**– 9.1**	**– 9.3**	**– 2.5**	**– 2.5**	**– 1.6**	**– 2.0**	**– 98.4**	**– 116.1**

Note: These yearly, non-cumulated estimates are calculated for all RES after 2005, without normalising hydro and wind power and without applying the RED-specific multipliers for certain RES consumed in transport.

Source: EEA, 2014 (authors' work).

2.6 Statistical impacts of renewable energy sources on primary energy consumption

Whereas the RED sets forth binding targets for 2020 for the share of renewables in gross **final** energy consumption (Section 2.2), other energy policies put forward targets and objectives expressed in **primary** energy. This is the case of Energy Performance of Buildings Directive (EPBD, ([29])) and the Energy Efficiency Directive (EED, ([30])). The latter is particularly relevant to this report, and an assessment of interactions between different RES and their statistical impacts on primary energy is presented further below. The methodology underpinning these findings is described in Section 3.5.

2.6.1 EU 20 % primary energy savings target

The EED commits the EU to meeting a primary energy savings target of 20 % for the period from 2005 to 2020. This is interpreted as a 20 % reduction of primary energy ([31]) by 2020, relative to a fixed baseline projection of the European Commission (EC, 2008) ([32]).

In absolute terms, and expressed against primary energy consumption, the 20 % energy savings target corresponds to a reduction of 368 Mtoe by 2020. This represents a 13.3 % reduction compared to the EU's primary energy consumption in 2005, and is equivalent to an average annual reduction of 0.9 % per year over the whole 2005 to 2020 period (EEA, 2014a). The target can be achieved by end-use energy efficiency improvements, as well as through more efficient energy conversion in the supply sector. In this sense, renewable energy also contributes to the efficiency target (Harmsen et al., 2011) due to the energy statistics currently being used ([33]).

2.6.2 Effects on primary energy consumption

As shown by the EEA in an earlier report, the EU's primary energy consumption has been decreasing almost constantly since 2005 (EEA, 2014a). This downward trend resulted from 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 downward include:

- a decreasing share of nuclear energy and thermal generation (excluding combined heat and power (CHP);
- an increasing share of certain renewables, such as hydro and wind power, in electricity.

This is because nuclear is considered to have a lower-than-average transformation efficiency, whilst renewables such as hydro, solar PV, wave and tidal, and wind, are considered to have a 100 % transformation efficiency, something which statistically improves the overall conversion efficiency of the system.

Factors driving the accounting of primary energy consumption upward 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 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 system, and thus drive the accounting of primary energy consumption upward.

Based on EEA calculations, the increase in consumption of renewables (such as wind, solar PV and hydro) in Europe since 2005 is estimated to have gradually contributed to the reduction of GIEC in Europe, as is shown in Table 2.6. With respect to the EED, the increase in EU-wide RES consumption since 2005 is estimated to have triggered a 2 % reduction of primary energy consumption in the year 2012 ([34]).

At country level, the additional use of RES since 2005 has reduced primary energy consumption by more than the 2 % EU-wide ratio in ten Member States (Austria, Belgium, Denmark, Germany, France, Ireland, Italy, Portugal, Spain and Sweden). In four Member States (Croatia, Romania, Slovakia and Finland), the change in renewable energy use in 2012 compared to 2005 resulted in an actual increase in their primary energy consumption. In Croatia and Romania, final hydropower shares in gross final energy consumption in 2012 were lower than in 2005 and the contribution from hydro sources was replaced by less efficient energy technologies.

([29]) Directive 2010/31/EU.
([30]) Directive 2012/27/EU.
([31]) Primary energy, in the context of the EED, means GIEC minus final non-energy use.
([32]) The baseline is the European Commission's PRIMES-2007 baseline scenario.
([33]) Both the IEA and Eurostat use the Primary Energy Method, where primary energy is defined as energy commodities that are either extracted or captured directly from natural resources (OECD/IEA, 2004).
([34]) In EEA, 2014a, blast furnace gas was included in the average emission factor for electricity. This lead to a slightly higher RES-induced reduction of primary energy consumption in 2012 (3 %). Subsequently, blast furnace gas was exluded from the method, as explained in Section 3.3.1.

Table 2.6 Effects of renewable energy sources on primary energy consumption

Country	RES effects on Gross Inland Energy Consumption (GIEC)								Primary Energy Consumption (Mtoe)	RES effects on Primary Energy Consumption
	(Mtoe)									
	2005	2006	2007	2008	2009	2010	2011	2012	2012	2012
Belgium	0.0	0.0	0.0	0.1	0.1	0.1	– 0.4	– 1.2	48.7	– 2.4 %
Bulgaria	0.0	0.0	0.3	0.3	0.1	– 0.2	0.2	– 0.1	17.8	– 0.4 %
Czech Republic	0.0	0.0	0.1	0.1	0.0	– 0.2	– 0.3	– 0.6	40.1	– 1.4 %
Denmark	0.0	0.1	0.1	0.1	0.2	0.0	– 0.7	– 0.8	17.9	– 4.2 %
Germany	0.0	– 0.5	– 1.9	– 2.0	– 1.7	– 1.7	– 6.5	– 8.5	297.6	– 2.8 %
Estonia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.1 %
Ireland	0.0	– 0.1	– 0.1	– 0.2	– 0.2	– 0.2	– 0.4	– 0.4	13.6	– 2.6 %
Greece	0.0	– 0.2	0.3	0.1	– 0.2	– 0.6	– 0.2	– 0.4	27.1	– 1.5 %
Spain	0.0	– 1.0	– 1.7	– 1.8	– 2.9	– 4.9	– 4.1	– 4.1	121.3	– 3.2 %
France	0.0	– 0.8	– 1.3	– 1.8	– 1.3	– 1.9	– 0.4	– 5.2	246.4	– 2.1 %
Croatia	0.0	0.1	0.3	0.2	– 0.1	– 0.3	0.2	0.2	7.6	3.0 %
Italy	0.0	0.2	0.7	– 0.2	– 1.2	– 1.5	– 2.9	– 3.6	155.3	– 2.3 %
Cyprus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	– 1.4 %
Latvia	0.0	0.1	0.1	0.0	0.0	0.0	0.0	– 0.1	4.4	– 1.4 %
Lithuania	0.0	0.0	0.0	0.0	0.0	0.0	– 0.1	– 0.1	5.9	– 1.5 %
Luxembourg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	– 0.1	4.4	– 1.1 %
Hungary	0.0	0.0	0.0	0.0	0.0	0.0	– 0.2	– 0.2	21.7	– 0.7 %
Malta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	– 0.3 %
Netherlands	0.0	– 0.1	– 0.1	– 0.1	0.0	0.1	– 0.2	– 0.3	67.1	– 0.5 %
Austria	0.0	0.1	0.1	0.0	– 0.1	0.2	0.1	– 1.0	31.8	– 3.0 %
Poland	0.0	0.0	0.0	0.1	0.1	0.2	– 0.8	– 0.8	93.3	– 0.8 %
Portugal	0.0	– 0.8	– 0.7	– 0.5	– 0.9	– 1.8	– 1.4	– 1.2	20.9	– 5.4 %
Romania	0.0	0.3	0.8	0.7	1.0	0.2	0.8	0.9	33.6	2.6 %
Slovenia	0.0	0.0	0.0	– 0.1	– 0.2	– 0.1	0.0	– 0.1	6.9	– 1.2 %
Slovakia	0.0	0.0	0.0	0.1	0.1	– 0.1	0.0	0.0	15.7	0.1 %
Finland	0.0	0.5	0.1	– 0.2	0.2	0.5	0.5	0.1	33.1	0.1 %
Sweden	0.0	1.6	1.6	0.7	1.2	1.2	0.4	– 2.0	48.0	– 4.0 %
United Kingdom	0.0	– 0.1	– 0.3	– 0.4	– 0.6	– 0.3	– 2.0	– 2.6	195.4	– 1.3 %
EU– 28	**0.0**	**– 0.5**	**– 1.6**	**– 4.9**	**– 6.2**	**– 11.4**	**– 18.4**	**– 31.9**	**1 584.8**	**– 2.0 %**

Note: The effects on GIEC are calculated by multiplying the amount of renewable energy in a given country with a country-specific average primary energy factor obtained using the approach described in Section 3.3.1. To calculate the effects on primary energy consumption defined according to the EED, final non-energy uses were subtracted from GIEC. The exclusion of blast furnace gas from the average emission factor for electricity (see Section 3.3.1) has reduced the RES impacts on primary energy consumption, from the 3.2 % (as presented in EEA, 2014a) to 3.04 % (as shown in this report).

Source: EEA, 2014 (authors' work based on Eurostat, 2014a and 2014b).

3 Methodological overview

3.1 Introduction

This chapter is directed at practitioners specialising in energy assessments, as well as researchers and other groups of specialised users. It presents the technical approaches developed by the EEA in collaboration with its ETC/ACM to produce the findings presented in Chapter 2.

Calculating RES shares of gross final energy consumption in line with the methodology prescribed in the RED (European Union, 2009) is a complex undertaking, based on data available from Eurostat or, every two years, from the countries' PRs under the RED. Every year, Eurostat provides detailed (renewable) energy statistics for the years 2005 till **t-2**, where t represents the present year. Eurostat primary data were therefore used for determining the amount of renewable energy consumption in each country and year up until 2012, by energy carrier and technology (see Section 3.3.1, The Eurostat-based method). EEA-approximated estimates (RES share proxies) were calculated and used for 2013.

Section 3.2 starts by describing the **methodology used to calculate RES shares proxies for the year t-1**. Section 3.3 introduces **two methodologies to estimate gross avoided GHGs from the deployment of RES**. The **estimation of avoided fossil fuel use due to RES deployment**, presented in Section 3.4, is a sub-step of the Eurostat-based method presented in Section 3.3.1. Finally, Section 3.5 describes the approach used to estimate the **effects on primary energy consumption of current RES statistical accounting methods**.

3.2 Methodology for the calculation of a RES shares proxy for the year t-1

This section presents an approach for estimating proxy RES shares for all EU Member States for the year **t-1**, while Eurostat energy balances only cover the time period **t-2**. Monthly Eurostat data on energy supply only contains liquid biofuels, but no data on other RES.

The methodology proposed in this report uses RES plant capacity data, energy production and consumption data and other annual studies published in time for a **t-1** assessment. Good statistical data are, however, not available for each and every variable in the RES shares calculation, according to the RED. Therefore, where no underlying data were published in time, simple time series analyses (i.e. linear trend extrapolations) were applied, or previous years' values were used, to derive missing values.

In calculating the proxy RES, the official methodology described in the RED was applied as far as possible. Some methodological differences (e.g. in the normalisation of hydro generation) occurred due to lack of data. Many variables are needed to calculate a RES share: not only RES energy production, but also conventional (fossil and nuclear) energy production and total energy consumption in different sectors. As the calculation of the RES share is a bottom-up calculation, a proxy value has to be estimated for each of these variables.

3.2.1 Calculation of proxy values for single variables

Proxy values can be estimated in different ways. Öko-Institut developed a proxy methodology for compiling a whole approximated GHG inventory for ([35]). This method is currently in use by the EEA. It features a bottom-up calculation, including hundreds of calculations per Member State, using driving data to estimate GHG emissions. Most of the mathematical methods developed for this purpose can be abstracted from GHG calculations and adapted to estimated energy data. Some of these methods can only be used if a driver is identified, or if data show a clear trend. Other methods are too complex or too specific on GHG estimates, and therefore were not taken into account in developing the RES shares proxy.

([35]) Latest report: *Approximated EU GHG inventory: proxy GHG estimates for 2013* (EEA, 2014b).

Direct use of other data sources
Eurostat publishes monthly energy data, but these do not include renewables. Detailed data on renewables are only included in the annual data ([36]), which are published too late to be used for the RES proxy.

Some RES production data exist from RES industry or from scientific organisations that publish data similar to those needed for the RES proxy calculations, as described further under Section 3.2.3. As no fully consistent and complete data source was identified, the methodological approach described below was used.

Trend change
If a variable shows for historical data a strong correlation to another data set , this second data set could be used as a driver to determine a new value, using the following formula:

$$x_{t-1} = \frac{y_{t-2}}{y_{t-1}} x_{t-2}$$

Where:

X_t-1 = value of the variable in the proxy year t − 1.

X_t-2 = value of the variable in the previous year t − 2.

X_t-1 = value of the driver in the proxy year t − 1.

X_t-2 = value of the driver in the previous year t − 2.

For instance, such a driver might be the installed CSP capacity in the proxy year and the previous year to calculate the proxy value for electricity generation from CSP. Also, sources containing similar, albeit not identical data as Eurostat's can be used here.

Linear trend extrapolation
If no driver for a variable can be identified, but the variable shows a clear linear trend, this trend can be extrapolated using the standardised method of least squares to calculate a proxy value for this variable. It is assumed that data only show a clear trend if the coefficient of determination . Otherwise, the methodology in the next section is applied.

Previous year value
For values for which year-to-year changes are quite small, using previous years' values is also a possible methodology for deriving proxy values. Especially when no other method gives plausible results, previous years' values can be used to estimate proxy values.

Variables needed for calculation
Table 3.1 shows the variables with non-trivial methods (i.e. all methods where not just previous year values were applied). The table also shows data sources used, but these data sources are described more in detail in Section 3.2.3.

3.2.2 Implementation

The RES shares proxy calculation is strongly linked to the EEA RES database: the applied methodology uses a lot of historical data, but it also uses external data sources, e.g. EurObserv'ER barometers. In this first stage of development and application of this new methodology, processing of the original data from different sources and parts of the calculation of the proxy variables for each Member State was performed outside the RES database.

3.2.3 Data sources

Table 3.2 shows data sources which could potentially be used to estimate the RES proxy. The crossed out entries in the list would be very useful, but unfortunately are published too late for the proxy calculation. For data sources marked with '(?)', a publishing date was not announced until now, but it is assumed that these data will be published in the same month as in 2013 ([37]).

EurObserv'ER
EurObserv'ER published four reports ('barometers') on capacity and/or energy data for different renewable energies technologies (EurObserv'ER 2014a, 2014b, 2014c and 2014d).

These reports contain the following data at Member State level.

Biofuels Barometer (EurObserv'ER, 2014a): biofuels consumption for transport disaggregated for bioethanol, biodiesel, biogas fuel and other biofuels; share of certified sustainable biofuels.

Photovoltaic Barometer (EurObserv'ER, 2014b): installed capacity at the end of the years 2012 and 2013, capacity installed and decommissioned in 2013 and electricity production from PV power 2012 and 2013.

Solar Thermal and Concentrated Solar Power Barometer (EurObserv'ER, 2014c): CSP for electricity production: list

([36]) For example, in the data tables supply, transformation, consumption — all products (nrg_100a), electricity (nrg_105a), heat (nrg_106a) and renewable energies (nrg_107a).
([37]) For example, 10/2014 (?) for EurObserv'ER*: Solid Biomass Barometer* means: in 2013, data were published in October, so it is expected that in 2014 data will be published in October as well.

Table 3.1 Variables with non-trivial methods

Variable	Method and used data
Electricity sector	
Hydro	Trend change on ENTSO-E. Additional normalisation over 8 years [38]
Wind	Trend change on wind energy electricity generation from *Wind Energy Barometer*
Photovoltaic	Trend change on photovoltaic electricity generation from *Photovoltaic Barometer*
Concentrated solar power	Trend change on Installed CSP capacity from *Solar Thermal and Concentrated Solar Barometer*
Solid biofuels	Linear trend extrapolation if $R^2 \geq 0.8$ else previous year values
Other renewables	Linear trend extrapolation if $R^2 \geq 0.8$ else previous year values
Gross electricity consumption	
Transportation sector	
Electricity in road transport	Linear trend extrapolation if $R^2 \geq 0.8$ else previous year values
Electricity in other transport	Linear trend extrapolation if $R^2 \geq 0.8$ else previous year values
Biogasoline	Trend change on bioethanol consumption from *Biofuels Barometer*
Biodiesel	Trend change on biodiesel consumption from *Biofuels Barometer*
Other liquid biofuels	Trend change on other biofuels consumption from *Biofuels Barometer*
Share of compliant biofuels	Direct use of shares of certified biofuels from *Biofuels Barometer*
Biofuels from waste	Trend change on total biofuels consumption from *Biofuels Barometer*
Heating and cooling sector	
Charcoal	Linear trend extrapolation $R^2 \geq 0.8$ if else previous year values
Geothermal Energy	Linear trend extrapolation $R^2 \geq 0.8$ if else previous year values
Municipal waste (renewable)	Linear trend extrapolation $R^2 \geq 0.8$ if else previous year values
Solid biofuels excluding charcoal	Linear trend extrapolation $R^2 \geq 0.8$ if else previous year values
Biogas	Linear trend extrapolation $R^2 \geq 0.8$ if else previous year values
Solar thermal	Trend change on solar collectors equivalent power from *Solar Thermal and Concentrated Solar Barometer*
Derived heat	Linear trend extrapolation if $R^2 \geq 0.8$ else previous year values on subsectoral level
Heat pumps	Linear trend extrapolation if $R^2 \geq 0.8$ else previous year values
Total	
Gross final consumption of energy	Previous year value +/- change of gross electricity consumption

Source: EEA, 2014 (authors' work).

of concentrated solar plants in operation at the end of 2013 with capacity and commissioning date.

Solar thermal for heating and warm water: annual installed solar thermal surface in 2012 and 2013; cumulated capacity of thermal solar collectors installed in 2012 and 2013.

Wind Energy Barometer (EurObserv'ER, 2014d): installed capacity at the end of the years 2012 and 2013, capacity installed and decommissioned in 2013, and electricity production from wind power for 2012 and 2013.

Additionally, EurObserv'ER publishes yearly reports on heat pumps and on solid biofuels. But these reports tend to become available too late for use in this RES shares proxy calculation.

ENTSO-E

ENTSO-E publishes monthly data on electricity consumption and production (ENTSO-E 2014). Production data are split for each country into the categories **nuclear, fossil fuels, hydro** (including run-off, river, storage and pump storage), **other renewables** (including wind, solar and biomass) and **not clearly**. Data on electricity consumption and on

(38) This normalisation method differs from the normalisation method described in Annex II of the RED. Considering data availability, the normalisation method in the RED was not applicable.

Table 3.2 Potential data sources

Data source	Type	Availability
~~AEBIOM: Statistical report 2014~~		12/2014 (?)
EPIA: Global Market Outlook For Photovoltaics 2014–2018	Capacity	06/2014
ENTSO-E monthly data	Total electricity production & consumption Nuclear, fossil, hydro and other renewable production	04/2014
~~Eurelectric: Power statistics & trends~~	~~Power consumption,~~	~~12/2014 (?)~~
EurObserv'ER: *Wind Energy Barometer*	Capacity, electricity production	02/2014
EurObserv'ER: *Photovoltaic Barometer*	Capacity, electricity production	04/2014
EurObserv'ER: *Solar Thermal and Concentrated Solar Power Barometer*	CSP: capacity ST: collector area, power equivalent	05/2014
EurObserv'ER: *Biofuels Barometer*	Consumption	07/2014
~~EurObserv'ER: *Heat Pump Barometer*~~	~~Installation numbers, renewable heat production~~	~~10/2014 (?)~~
~~EurObserv'ER: Solid Biomass Barometer~~	~~Heat consumption, electricity production~~	~~12/2014 (?)~~
~~Euroheat & Power~~		~~Not in time~~ (39)
Eurostat: Supply, transformation - oil - monthly data (nrg_102m)	Liquid biofuels	04/2014
EWEA: Wind in power – 2013 European statistics	Capacity	02/2014
USDA: EU Biofuels Annual 2014	Capacity, consumption	07/2014

Source: EEA, 2014 (authors' work).

hydro without pump storage were used in the RES shares proxy calculation.

USDA Foreign Agricultural Service

The Foreign Agricultural Service (FAS) of the U.S. Department of Agriculture (USDA) collects policy information and national data on production and consumption of biofuels of the EU Member States and publishes an annual report (USDA FAS, 2014) (40) This report contains data on bioethanol, biodiesel/hydrotreated vegetable oils, advanced liquid biofuels, wood pellets and biogas. There was an attempt to use the trend change of wood pellets consumption from this report to calculate proxy data on consumption of solid fuels in the heating and cooling sector. But as this data source does not differentiate between pellets consumption in the heating and cooling sector from pellets consumption in electricity production, this led to implausible results and these data were not used in the end (see discussion in Section 3.2.4).

Other data sources

The following data sources were published in time, but were not used for the reasons explained.

Annual data of the PV industry (European Photovoltaic Industry Association, 2014): this publication contains capacity data only, and not completely for all 28 EU Member States. The *Photovoltaic Barometer* (EurObserv'ER, 2014b) contains not only complete capacity data, but also data on PV electricity generation, so the latter data source was preferred.

Eurostat: Supply, transformation - oil - monthly data (nrg_102m): This data source contains information on total liquid biofuel consumption. The *Biofuels Barometer* (EurObserv'ER, 2014a) contains data on biofuels consumption in the transportation sector. So the latter data source is more specific and was therefore preferred.

Wind in power: 2013 European statistics (European Wind Energy Association 2014): This publication contains capacity data only, but the *Wind Energy Barometer* (EurObserv'ER, 2014d) also contains data on electricity generation from wind energy, so the latter data source was preferred.

(39) Every two years (on odd years), Euroheat & Power publishes a country-by-country survey, but the data are for t-2.
(40) The USDA FAS not only collects data on the EU but on a lot of countries all around the world as well.

3.2.4 Discussion of the method

This section shows that a methodology to approximate the share of gross final RES consumption (RES share proxy) can be developed. The proxy methodology is underpinned by different approaches for estimating missing data. The RES share proxy methodology yields plausible results in most cases, and should be further improved, especially if more timely RES data become available.

Confidence in the estimated RES shares proxy values is highest in the electricity sector, where data availability, especially for wind and solar energy, the most dynamic, growing RES technologies in most European countries, is excellent. Further improvements are possible in estimating electricity generation from biomass, and implementing a normalisation of electricity generation from wind energy and hydro that is closer to the normalisation method described in the RED.

Overall, data availability for the transport sector is sufficient. The specific accounting rules for the calculation of the RES-T share under the RED ([41]) caused difficulties in the development of the methodology. Although these challenges were finally solved, they still generated some inaccuracies in the estimated RES-T shares.

Especially in the heating and cooling sector, temperature effects play an important role in energy consumption, causing considerable year-to-year changes. This factor was not incorporated, as data were unavailable on energy consumption in this sector, and on heating degree days. In addition, data availability on biomass use specifically for heating and cooling is low. Only a few early data sources on biomass consumption are available, and none of them distinguishes between biomass consumption for electricity production and biomass consumption for heating and cooling. Similarly, no reliable data source suitable for calculating proxy values was identified on derived heat. Therefore, the whole estimation on derived heat is based on linear trend extrapolations and previous years' values.

3.3 Two methodologies to estimate gross avoided GHGs

This section describes two methods developed by the EEA to estimate gross avoided GHG emissions from the deployment of RES. The term 'gross avoided GHG emissions' reflects the theoretical character of the contributions estimated in this way; they do not necessarily represent net GHG savings (see discussion in Section 3.3.3).

The two distinct approaches described in this section were used to assess the effects of increasing shares of renewable energy consumption on climate mitigation efforts at national and EU level. These approaches are based on Eurostat data and on GHG projections reported by Member States under the MMD, respectively.

The main difference between the methods lies in the source of the energy data, and in certain differences in sector notations among the reported data sets used in each case, as well as in the years for which data need to be reported to Eurostat and the European Commission, in line with specific reporting obligations. Moreover, with the first (Eurostat-based) method it is possible to attribute the gross avoided GHGs to sectors covered by the EU ETS, and respectively, to non-ETS sectors. A similar allocation however cannot be performed with the second (MMD-based) method. Given these differences, a detailed, disaggregated comparison of results obtained from each method is not indicated.

The primary advantage of using two different methods at the same time lies in the potential for contrasting and comparing aggregated results per country, as well as with estimates reported by countries under Article 22 of the RED, in order to identify potential outliers requiring further investigation. However, in Chapter 2, only the results obtained using the Eurostat-based method are presented. It should be noted that neither method is suitable for assigning effects to particular drivers, circumstances or policies, other than the deployment of RES.

The first method (see Section 3.3.1) uses yearly energy data reported by countries to Eurostat for the years until t-2 and EEA RES proxy estimates for the year t-1 (i.e. 2013 in the current report). The second method (see Section 3.3.2) is based on energy data used by Member States as parameters to underpin their national projections of GHG emissions which were reported in 2013 under the MMD. The limitations of both methods are discussed in Section 3.3.3 of this chapter.

([41]) For example, the choice of application of national or European RES-E share in RES-T; double-counting of biofuels from waste; and applying a multiplying factor of 2.5 for electric road vehicles.

3.3.1 The Eurostat-based method

The Eurostat-based method consists of a relatively simple and organised set of steps to calculate gross avoided GHG emissions from the deployment of RES. The method is based on official statistical data reported by countries to Eurostat. GHG effects can be calculated for individual EU Member States, for Norway ([42]) and for the EU as a whole, for each year starting with 2005, and until t-2, where t represents the current year.

Description of the method
The method assumes that renewable energy (electricity, heating and transport fuels) replaces a set of **initial energy carriers** (electricity, heating and transport fuels) that would otherwise be supplied by other energy resources. Gross avoided emissions are calculated on an annual basis, against a counterfactual scenario. This scenario has been selected to highlight either absolute RES contributions in the energy system, or additional RES contributions from a certain year onwards (e.g. 2005; see definition of counterfactual scenarios under Sub-step 2.2: Calculation of gross avoided GHGs against counterfactual scenario).

There are three main steps to the method:

- **step 1:** determine the amount of renewable energy consumed in each country and year, by energy carrier and by technology;
- **step 2:** determine the reference emission factors of the initial energy carriers; then calculate the gross avoided GHG emissions per country and year;
- **step 3:** attribute the results from step 2 to ETS and to non-ETS sectors respectively.

(RES) energy consumption (step 1)

In this step, (RES) energy consumption is determined by country, energy carrier and technology.

Data sources
The Eurostat New Cronos database and SHARES Results provide detailed (renewable) energy statistics necessary to complete this step:

The New Cronos database is Eurostat's principal database containing high-quality macroeconomic and social statistical data. It also contains detailed information on energy balances, including information on transformation input, transformation output, primary production, final consumption and auto-consumption, per country and year, by energy carrier and energy technology ([43]). Energy balance data are reported by countries to Eurostat every year, in line with their obligations under the Energy Statistics Regulation ((EC) No 1099/2008).

The SHARES Results, also available from Eurostat, provide additional information on gross final consumption of renewable energy in the Member States and in the EU, in line with accounting rules set out in the RED ([44]).

The main renewable energy technologies (RETs) covered are hydropower, wind power, solar PV, solar thermal, concentrated solar power, geothermal, solid biomass, biogas, bioliquids, tidal, wave and ocean energy, renewable energy from heat pumps, and biofuels and renewable electricity consumed in transport. The renewable energy carriers considered are RES-E, RES-H/C and RES-T (see Figure 3.1 for a detailed breakdown).

In line with definitions in the Energy Statistics Regulation, contributions by individual RETs are attributed to specific renewable energy carriers RES-E, RES-H/C and RES-T (see Annex 1 for more information).

Figure 3.1 illustrates the type of statistical information (2005–2012) extracted during this step. It can be used to compare the historical evolution of individual RETs against their projected evolution outlined in the NREAPs adopted by countries in accordance with the RED.

Emission factors and gross avoided GHG emissions (step 2)

In the second step, it is assumed that the contributions from renewable energy carriers (RES-E, RES-H/C and RES-T) and/or from specific RETs to the overall energy mix have replaced contributions that would have otherwise been obtained from **initial energy carriers** (electricity, heating and transport fuels).

([42]) In line with data availability under Eurostat SHARES-Results.
([43]) For the breakdown of wind power into onshore and offshore wind, for which no data are provided by Eurostat, information from EurObserv'ER is used, as efforts to collect these data from individual countries would be disproportionate.
([44]) According to the RED, the share of renewable energy is calculated by dividing the gross final consumption of renewable energy by the total gross final energy consumption (GFEC). GFEC is defined in the list of acronyms, units and terms at the end of this report. RES data in the SHARES Results cover solar thermal and PV energy, hydro (including tide, wave and ocean energy), wind, geothermal energy and biomass (including biological waste and liquid biofuels). The contribution of renewable energy from heat pumps is also covered for the Member States for which this information is available.

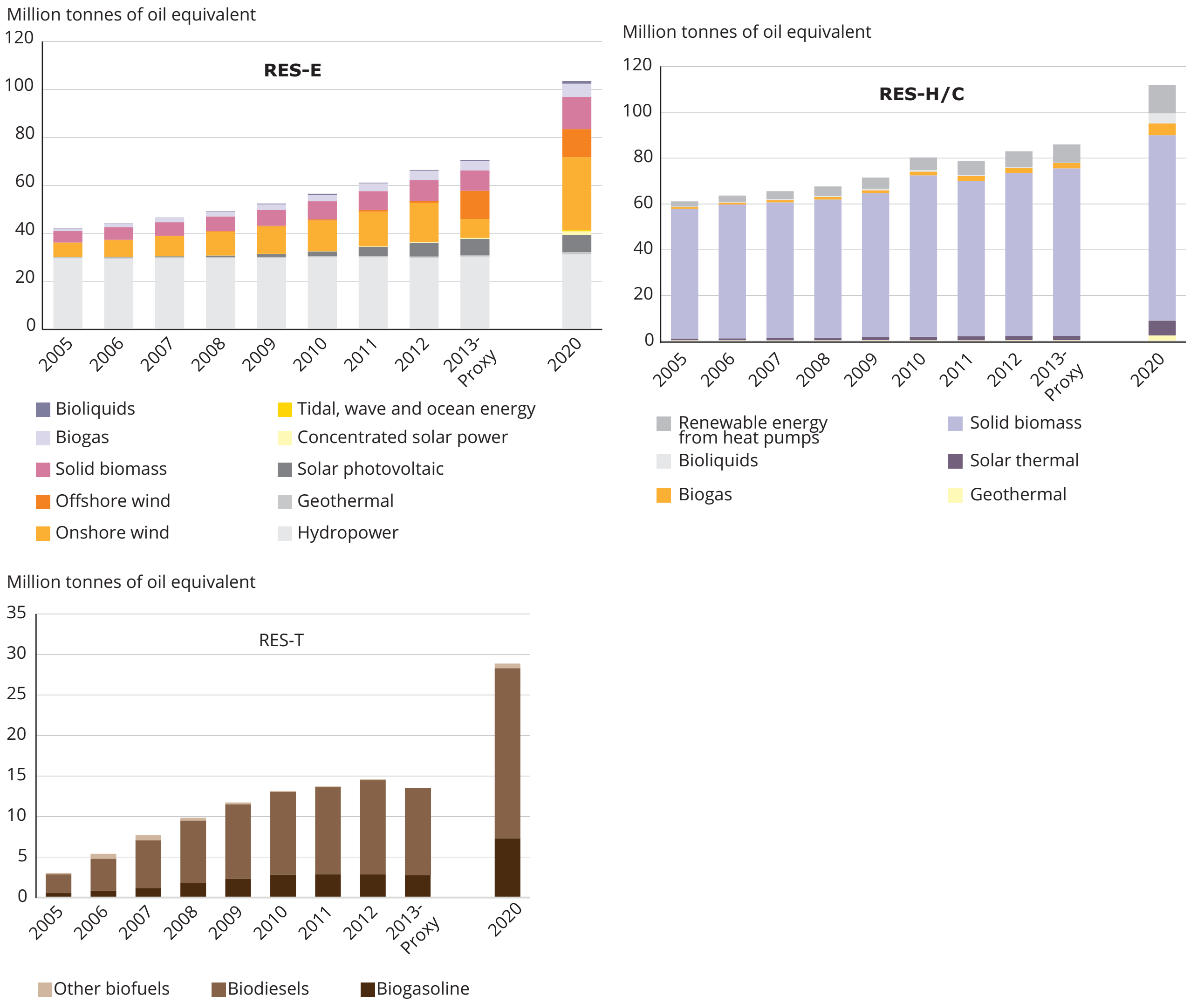
In sub-step 2.1, a sequence of stages is used to determine the reference EFs for each of the initial energy carriers assumed to have been replaced.

This enables the calculation of gross avoided GHG emissions from the use of renewable energy in sub-step 2.2. Assumptions with regard to the counterfactual scenario (i.e. the substitution of the initial energy carriers by renewable energy) are explained under this sub-step.

Sub-step 2.1: Calculation of reference emission factors per energy carrier

A. Electricity
A key challenge is that there are no generally accepted reference values or standard ways of calculating the amount of GHGs per unit of generated, used or saved electricity. These values can be calculated using different methods: some assume that new (power) capacity has an effect on the operation of current or future power plants; others assume that the new capacity is an alternative for investments in another specific new source of electricity ([45]); there are also mixed approaches. A review by the OECD and the International Energy Agency (IEA) of the most common methods in use reveals that their accuracy and feasibility is most often determined by data availability and constraints, respectively (see the summary in Annex 2 Overview of methods for calculating the amount of GHG emissions per unit of generated, used or saved electricity)

Figure 3.1 RES statistics obtained in step 1: realisations by RET and energy carrier (EU-28)



Source: EEA, 2014 (authors' work based on Eurostat 2014a and 2014b).

([45]) The former are 'operation margin methods'; the latter are 'build-margin methods'.

(i) *EEA approach*
For reasons of data availability and transparency, the EEA has chosen to calculate the reference emission factor for electricity (**EFe**) as a **generation-weighted average emission factor,** i.e. an emission factor weighed on the basis of the type of fuel used to produce electricity in each country, on an annual basis. Given the retrospective focus on the years from 2005 to 2012 (2013 including the RES shares proxy) the following assumptions are made.

Nuclear generation is excluded from the average, since nuclear plants are usually operated as must-run capacity. This is a simplified approach intended to reflect mainly the historical context; it is recognised, however, that growing shares of renewable electricity production will influence decisions on investment and abandonment of nuclear capacity in the longer run.

Renewable electricity generation is excluded from the average. In essence, this aims to reflect the current situation whereby renewable energy plants are unlikely to be displaced by new capacity, as that would make it more difficult for Member States to meet their renewable energy trajectories until and by 2020. A generation-weighted average over the total generation capacity (including renewable electricity) implies that even renewable capacity with low running costs is replaced by newly built renewable capacity. However, this is not supported by evidence from practice.

Blast furnace gas is excluded from the average. Blast furnace gas is considered a residue that can be utilised or flared. Since the production of blast furnace gas is linked to the production of iron and steel, its decline since 2005 should not be attributed to renewables.

(ii) *Primary energy use per unit of electricity (PEe)*
Primary energy factors (for electricity, in this case) need to be calculated to enable the equivalent substitution of one unit of energy from conventional sources by one unit of renewable energy, as seen in **Sub-step 2.2: Calculation of gross avoided GHGs against counterfactual scenario**. Eurostat provides statistics on the transformation input and output of thermal power stations per country. As the fuel consumption and electricity production are known, the primary energy use per unit of electricity in a given country (c) and year (yr) is calculated as follows:

$$PEe(yr,c) = \frac{\sum_{f_i} \text{Input\_e}(yr,c,f_i)}{\text{Output\_e}(yr,c,f_o)}$$

Where:

Input_e(yr,c,f_i) = Transformation input 'Main Activity Producer Electricity Plants' [B_101031] + Transformation input 'Autoproducer Electricity Plants' [B_101034].

f_i Input = All solid fuels [category 2000], oil total [3000], gas [4000], wastes- non ren. [7100] ([46]).

Output_e(yr,c, f_o) = Transformation output 'El. Gen. Main activity electricity only - Combustible Fuels' [15_107048] + Transformation output 'El. Gen. Autoproducer electricity only - Combustible Fuels' [15_107050] ([47]).

f_o Output = Electricity [6000]

Note that this average excludes the input and output of CHP plants. The operation of CHP plants is often driven by the heat demand.

(iii) *Reference emission factor (EFe) of the initial energy carrier 'electricity'*
By using CO_2 emission factors per type of fuel, **transformation input is converted to an amount of GHG emissions.** The required emission factors per fuel **EF(f_i)** are obtained from the EU ETS Monitoring and Reporting Regulation (EC, 2012a).

The reference emission factor for the initial energy carrier electricity **EFe(yr,c)** is calculated as follows:

$$EFe(yr,c) = \frac{\sum_{f_i} \text{Input\_e}(yr,c,f_i) \times EF(f_i)}{\text{Output\_e}(yr,c,f_o)}$$

Where:

EF(f_i) = CO_2 emission factors per fuel type (t CO_2/TJ; see Annex VI of Commission Regulation 601/2012).

As shown in the formula, the reference CO_2 emission factors for electricity is calculated at country level ([48]). The effects of cross-border electricity trade can be

([46]) Blast furnace gas [category 4220] was excluded.
([47]) In line with the assumptions, the following categories are excluded from 'Combustible fuels': 'Municipal waste (renew.)' [55431]', 'Solid biofuels excl. charcoal' [5541], 'Biogas (all)' [5542] and 'Other liquid biofuels [5548]'.
([48]) Blast furnace gas is excluded. See also Annex 3 Calculated reference emission factors (fossil fuels)Calculated reference emission factors (fossil fuels).

investigated too, for example by calculating reference CO_2 emission factors for electricity per geographic area.

Geographic zones can be determined comprising submarkets coupled through power exchanges, or within which no declared congestion exists (EC, 2012b). For example, the region 'Central-West Europe' represents six countries and the 'Nordic' region represents four countries. In these zones, hourly day-ahead power exchange prices show limited price divergences for extensive periods.

B. Heat
(i) *Country-specific emission factors for heat (EFh)* are calculated similarly to the approach applied to determine the reference values for the initial energy carrier electricity, so as to reflect the differences in the fuel mix between Member States.

(ii) *Primary energy use per unit of heat (PEh)*
Eurostat provides statistics on final energy use per country. Final energy consumption covers energy supplied to the final consumer for 'industry', 'transport' and 'other sectors'. Although the fuels in industry and other sectors are not used exclusively for heat production, this can be assumed to provide a reasonable approximation for the fuel mix for heat production [49].

The primary energy use per unit of heating (PEh) is shown as follows:

$$PEh(yr,c) = \frac{\sum_{f_i} \text{Input\_h}(yr,c,f_i)}{\text{Output\_h}(yr,c,f_o)} <=>$$

$$<=> \frac{\sum_{f_i} \text{Input\_h}(yr,c,f_i)}{\sum_{f_i} \text{Input\_h}(yr,c,f_i) \times \eta(f_i)}$$

Where:

Input_h(yr,c,f_i) = Final energy consumption: Industry [B_101800] + Final energy consumption: Other sectors [B_102000].

f_i = All solid fuels [category 2000], oil total [3000], gas [4000].

η(fi) = Fuel-dependent efficiency of heat production. It is assumed to be 87% for coal/solid fuels; 89% for oil/liquid fuels; and 90% for gas/gaseous fuels (based on Vatopoulos, et al.).

(iii) *Reference emission factor (EFh) of the initial energy carrier 'heating'*
By using CO_2-emission factors per type of fuel (EF(f_i)), **fuel use is converted to an amount of GHG emission.** The reference emission factor for the initial energy carrier heat EFh(yr,c) is calculated as follows:

$$EFh(yr,c) = \frac{\sum_{f_i} \text{Input\_h}(yr,c,f_i) \times \text{EF}(f_i)}{\sum_{f_i} \text{Input\_h}(yr,c,f_i) \times \eta(f_i)}$$

Where:

EF(f_i) = CO_2 emission factors per type of fuel (t CO_2/TJ; see Annex VI of Commission Regulation 601/2012).

Results of the calculated reference emission factors for heat are presented in Annex 3.

C. Transport fuels
Substitution rules are straightforward in the transport sector, due to the dominance of petrol and diesel in the sector and the comparable fuel efficiencies of vehicles (contrary to conditions for the other two energy carriers, electricity and heating). The assumption for this sector is therefore that renewable transport fuels (essentially biodiesel and bioethanol) replace the conventional transport fuels petrol and diesel on a one-to-one basis, according to their specific energy content. The fuel-specific emission factors for the conventional energy carriers petrol and diesel (EF(f_i)) are taken from Annex VI of the Commission Regulation 601/2012/EU. On this basis, primary energy use per unit of transport (PEt) and reference emission factors of the initial energy carriers petrol and diesel can be calculated.

Sub-step 2.2: Calculation of gross avoided GHGs against counterfactual scenario

With the reference emission factors (*EFs*) for the initial energy carriers (electricity, heating and transport fuels) determined, it is now possible to calculate gross avoided GHG emissions from the use of renewable energy. This requires setting an appropriate counterfactual scenario against which to measure the effects of renewable energy deployment.

(49) Final non-energy consumption is reported separately by Eurostat and therefore does not have to be accounted for in this calculation.

The following two counterfactual scenarios were identified as suitable for this report:

- 'Zero-RES contributions' counterfactual
- '2005-RES shares' counterfactual.

Chapter 2 presents results only in relation to the second ('2005-RES shares') counterfactual.

Calculation of effects against a 'zero-RES contributions' counterfactual
This counterfactual determines GHG effects for all RES consumed in a given year and country. In other words, the GHG effects are measured against a hypothetical case in which no renewable energy would have been generated in the energy system in that country and year. The assumption is that each renewable energy carrier (RES-E, RES-H and RES-T) has substituted an identical amount of energy of the initial energy carriers (electricity, heat and transport fuels) that would have otherwise been consumed in that country and year.

The total effects of renewable energy consumption on GHG emissions are calculated as shown in the formula below.

Where:

ΔEmissions(*yr c*)	= The gross avoided GHG emissions in a given year (yr) and country (c) [Mton CO_2];
FE(*ret, yr, c*)	= Gross final energy consumption of a renewable energy technology by RES carrier (RES-E, RES-H and RES-T) in a given year and country [ktoe];
e(*ret, yr, c*)	= Gross electricity production from renewable energy technologies [GWh/GWh gross final energy];
h(*ret, yr, c*)	= Gross heat production from renewable energy technologies [ktoe primary energy/ktoe gross final energy];
p(*ret, yr, c*)	= Petrol replacement from renewable energy technologies [ktoe primary energy/ktoe gross final energy];
d(*ret, yr, c*)	= Diesel replacement from renewable energy technologies [ktoe primary energy/ktoe gross final energy];
EFe(*yr, c*)	= Reference emission factor for electricity in a given year and country [kg CO_2/GJ];
EFh(*yr, c*)	= Reference emission factor for heat in a given year and country [kg CO_2/GJ];
EFp(*yr, c*)	= Reference emission factor for petrol in a given year and country [kg CO_2/GJ];
EFd(*yr, c*)	= Reference emission factor for diesel in a given year and country [kg CO_2/GJ];

Calculation of effects against a counterfactual that includes '2005-RES shares'
This counterfactual determines the GHG effects for the renewable energy that was added to the energy mix after the year 2005 (for RES-E, RES-H and RES-T individually). The amounts of renewable energy consumed before and in 2005 are subtracted from later RES amounts so that they do not count in the substitution.

Attribution of gross avoided GHG emissions to ETS or non-ETS sectors (step 3)

While previous steps determine overall gross GHG effects, understanding to what extent these effects occur in sectors falling under the EU ETS ([50]) and respectively in non-trading (national) sectors ([51]) can shed some light on the complicated interaction between renewable energy deployment at national level and national/EU-wide climate change mitigation efforts.

Step 3 proposes the allocation of gross GHG effects to ETS and respectively to non-ETS sectors in the following way.

$$\Delta\text{Emissions}(yr,c) = \sum_{ret} FE(ret,yr,c) * [-e(ret) * EFe(yr,c) - h(ret) * EFh(yr,c) - p(ret) * EFp(yr,c) - d(ret) * EFd(yr,c)]$$

([50]) Directive 2009/29/EC.
([51]) Non-trading sectors concern the sectors covered under the Effort Sharing Decision No 406/2009/EC, in particular transport (except aviation and international maritime shipping), buildings, agriculture and waste.

A. *Electricity*
For renewable electricity (RES-E): 100 % of GHG effects are attributed to the ETS

It is assumed that all renewable electricity generation (including shares accounted under RES-T) replaces centralised electricity generation that would have occurred in the energy system. Therefore, all gross avoided GHG emissions are attributed to sectors covered by the EU ETS.

B. *Heat*
For renewable heat (RES-H): technology- and country-specific attribution

Renewable heat can replace heat either produced centrally in sectors falling under the EU ETS, or generated and used in non-ETS sectors. To estimate the effects of renewable heat on GHG emissions, it is first necessary to define the characteristics of the concerned RETs ([52]) in line with definitions of the Energy Statistics Regulation (see Annex 1 for more details).

Secondly, among the concerned Eurostat sectors, it is mainly the final (renewable) energy in industry that can be attributed either to the ETS sectors, or to non-trading sectors. The Energy Balance of Eurostat contains the amount of (renewable) final energy consumed: (i) in industry [B101800]; and (ii) in all sectors ([53]), respectively. This allows the calculation of the share of final (renewable) energy consumption in industry over final (renewable) energy consumption in all sectors, at country level and for each renewable heat-producing technology.

Finally, it is assumed that the share of ETS emissions in the industry sector is an indicator for the share of renewable heat production in the sector that takes place under the EU ETS. Thus, the share of the RES (heat) that can be assigned to a country's industry is multiplied with a country-specific ratio of the ETS CO_2 emissions and the total CO_2 emissions of the industry sector (see Annex 1 for additional details).

C. *Transport fuels*
For renewable transport (RES-T): 100 % of GHG effects attributed to non-ETS sectors

For all use of biofuels in the transport sector, it is assumed that gross avoided GHG emissions occur within that sector and therefore outside the ETS.

3.3.2 The MMD-based method

This method is based on data reported by Member States as part of their biennial submission of GHG projections to the European Commission under the MMD/MMR ([54]) ([55]). As with the Eurostat-based method, GHG effects can be calculated for individual EU Member States and for the EU as a whole; for Norway, however, there is no formal obligation to report data under the above instruments.

Mandatory reporting years for GHG projections reported under the MMD in 2013 are, for example, 2010 and 2020, but not t-2 (i.e. 2012). For this reason, a comparison of results achieved using the MMD-based method against results from the Eurostat-based method is only possible for selected years. The MMD method thus provides a means of comparing gross results and identifying potential outliers requiring further investigation. This approach was developed with the help of the ETC/ACM in 2014.

Description of the method
Deriving avoided GHG emissions with the MMD-based method would ideally follow an approach that resembles the Eurostat-based method described in Section 3.3.1, as closely as possible. This requires assumptions on which emission factor is being used to determine the avoided GHG emissions. These assumptions are crucial to the process, and will explain some of the differences compared to results obtained with the previous method, if there are observed differences. As reporting on projections does not include explicit emission factors, but includes GHG emissions and energy inputs (or electricity and heat output on the supply side) for each Common Reporting

([52]) For example, geothermal, solar thermal, solid biomass and heat pumps.
([53]) Per country, for solar thermal [5532], solid biomass [5541], geothermal energy [5550], biogas [5542] and other liquid biofuels [5548].
([54]) Decision No 280/2004/EC concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol.
([55]) Following agreement by the Council and the European Parliament, the new Monitoring Mechanism Regulation (MMR) (EU Regulation No 525/2013) entered into force on 8 July 2013. The MMR (EU, 2013) repeals the MMD.

Format (CRF) sector (56), these data can be used to calculate emission factors for each reported year.

The structure of the reporting template (57) used by Member States to report the projection parameters underpinning their GHG projections resembles the CRF template. The calculation of gross avoided GHG emissions therefore needs to be split between:

- the energy **supply** sectors, which generate public electricity and heat (CRF sector 1.A.1.a - Public Electricity and Heat production (58));
- the energy **use** sectors, which generate their own energy through directly fossil fuel combustion (CRF sectors 1.A.2 – Manufacturing Industries and Construction, 1A3 – Transport and 1.A.4 Other sectors (Commercial/Institutional, Residential, Agriculture/Forestry/Fisheries).

(RES) energy consumption (step 1)

Data sources
In this step, (RES) energy consumption data by country and by energy supply and energy use sector are extracted from the national 2013 MMD projections.

The energy demands of **supply** sectors 1A2, 1A3 and 1A4 are reported by countries, distinguished as (59):

- liquid fuels
- solid fuels
- gaseous fuels
- renewables
- electricity
- heat
- other.

In order to account for avoided GHG emissions in electricity and heat, one can exclude the demand for electricity and heat in energy **use** sectors, and determine the avoided GHG emissions for electricity and heat separately, via the energy **supply** sectors, for which gross supplies of electricity and heat are reported together under the following categories:

- liquid fuels
- solid fuels
- gaseous fuels
- renewable
- nuclear
- other.

Calculating gross avoided GHG emissions can then follow the sequences described in step 2.

Emission factors and gross avoided GHG emissions (step 2)

Sub-step 2.1: Calculation of reference fossil emission factors by sector

Energy use sectors
Determine, for each GHG **(i)** and sector **(j)** the **reference (average) fossil emission factor per sector ($EF_{i,j}$)** by dividing the corresponding GHG emissions of that sector measured in $GgCO_2eq$ by its fossil fuel energy demands **(ED_{fos})** (60) measured in PJ:

$$EF_{fos,i,j} = \sum \frac{GHG_{i,j}}{ED_{fos,j}}$$

Where:

i = 1, . . . ,3 = GHG emissions (CO_2, CH_4, N_2O) measured in $GgCO_2eq$.

Note: Where a comparison with the Eurostat-based method is envisaged, only CO_2 emissions will be considered. This does not constitute a problem, since CH_4, N_2O emissions are minimal.

j = 1, . . . ,5 = energy use sectors (industry, commercial, residential, transport, agriculture)

Energy supply sectors
Determine the **reference emission factor for electricity & heat production** (EF**e&h**) excluding nuclear energy (61) in line with the previously described Eurostat-based method. Both supplies are reported

(56) National emissions reported to the United Nations Framework Convention on Climate Change and to the EU Greenhouse Gas Monitoring Mechanisms follow the classification of sectors provided by the Intergovernmental Panel on Climate Change.
(57) Article 3(2) of the MMD.
(58) The assumption is made that renewable energy does not contribute to avoiding emissions in sectors 1A1b (Petroleum Refining) and 1A1c (Manufacture of Solid Fuels and Other Energy Industries).
(59) Energy demands for transport (1A3) include gasoline (and of which biofuels), diesel (and of which biofuels), jet kerosene, other liquid fuels, gas (fossil), electricity, renewables and other.
(60) Demands for electricity and heat are **not** included here. The avoided emissions through electricity and heat are separately accounted for via an emission factor determined for the supply side.
(61) Nuclear energy is excluded in the first Eurostat-based method, and thus it is not included here, to keep comparability as large as possible. In the reporting templates, nuclear energy is only listed as an output to the electricity sector, or as an input to 'energy industries' that, however, includes more than only electricity and heat.

together, and thus a distinction is not possible. We suggest determining the corresponding emission factor related to output ([62]) as follows:

$$EF_{e\&h} = \frac{GHG_{e\&h}}{ELECGEN_{total} - ELECGEN_{nuclear} - ELECGEN_{RES}}$$

Where:

ELECGEN = electricity and heat generation measured in GWh.

Sub-step 2.2: Calculation of gross avoided GHGs against counterfactual scenario

Gross avoided GHG emissions can then be calculated via the following sequence:

1. **Calculation of GHG effects in the production of public electricity and heat**

The gross avoided GHG emissions through the use of RES in the production of electricity and heat are determined by multiplying the production of renewable electricity and heat (**$RES_{e\&h}$**) with the fossil emission factor of electricity and heat production:

$$RES_{e\&h} * EF_{e\&h}$$

2. **Calculation of GHG effects from the consumption of renewable energy in energy use sectors**

The gross avoided GHG emissions through end use of RES demands are determined by multiplying the RES demand of each energy **use** sector (**$RESD_j$**) with the fossil emission factor of that sector. This is accomplished for each sector and GHG and then the summed over all GHGs and sectors:

$$\sum_{i,j} RESD_j * EF_{fos,i,j}$$

3. **Counterfactual scenario and calculation of gross avoided GHGs**

Calculation of effects against a 'zero-RES contributions' counterfactual
Based on the previous information, total gross avoided GHG emissions from the deployment of renewable energy can then be expressed as follows:

In this way effects for all renewable energy produced and consumed in a country are determined. Thus, the gross avoided GHG effects calculated in this way are comparable to the effects obtained with the previous Eurostat-based method, under sub-step 2.2, 'zero-RES contributions' counterfactual.

Calculation of effects against a counterfactual that includes '2005-RES shares'
In order to determine gross avoided GHG emissions related to the second counterfactual scenario ('2005-RES shares') proposed for the Eurostat-based approach, the same methodology as reported above can be applied. However, one would compare the gross avoided GHG emissions through the use of RES against the status of historical RES contributions in 2005.

The relation to the counterfactual scenario can be approached in two ways, explained below.

- One may subtract the level of RES use in the counterfactual scenario from the level of RES use in the analysed scenario, and use this difference to determine the avoided GHG emissions for the analysed scenario.

- One may determine the avoided GHG emissions through the use of RES in the counterfactual and the analysed scenario against the 'zero-RES scenario', and then determine the difference between the two.

Instead of applying the emission factors to the level of RES deployment as reported under the MMD, the emission factors would be applied to the difference in RES deployment between the analysed scenario and the counterfactual scenario. The results would then not relate to the 'zero-RES scenario', but to the counterfactual scenario.

Data will need to be collected in the same categorical distinction as in the analysed scenario (e.g. With Existing Measures (WEM) scenario as reported under the MMD, or the scenarios under the RED) in order to allow for comparison.

Additional data sources for determining the difference between RES use in scenarios reported under the MMD and the 2005-RES share counterfactual are:

$$\Delta \text{Emissions}(\text{yr}, \text{c}) = RES_{e\&h} * EF_{e\&h} + \sum_{i,j} RESD_j * EF_{fos,i,j}$$

([62]) It is not completely clear whether heat is included in reported output. Sheet *ProjectionIndicators* rows 33–35 indicates this, but notation in Sheet *ProjectionParameters* does not explicitly note heat (starting row 33). The working hypothesis is that heat is included due to the notes in *ProjectionIndicators*.

- supply side: Public electricity & heat: Eurostat nrg105a
- demand side: Eurostat nrg100a.

Attribution of gross avoided GHG emissions to ETS or non-ETS sectors (step 3)

Whilst with the Eurostat-based method it is possible to attribute the gross avoided GHGs to sectors covered by the EU ETS and, respectively, to non-ETS sectors, a similar allocation cannot be performed using the MMD-based method.

3.3.3 Discussion of the methods

Gross avoided GHG emissions vs GHG 'savings'

Section 3.3 describes two different methods to quantify the gross effects of renewable energy consumption on GHG emissions: (i) based on primary data available via Eurostat, and (ii) based on data reported by countries under the MMD.

For both of these methods, the term **'gross avoided GHG emissions'** was chosen to describe the theoretical character of the GHG effects estimated in this way, and to clarify that these contributions do not necessarily represent **'net GHG savings per se'.** The potential interactions between policy frameworks supporting renewables, on the one hand, and the EU ETS, on the other hand, is an example.

The EU ETS puts forward a single EU GHG emissions cap for specific sectors, including the power generation, CHP and industry sectors, with the aim of achieving the most cost-effective GHG reductions across the covered sectors. The ETS cap until 2020 was set in a way that accounted for the expected GHG reduction effects induced by the binding RES targets until 2020. However, the overlap between establishing emission caps under the ETS and setting RES targets introduces an element of uncertainty: achieving a higher RES share in gross final energy consumption than the indicative RED target for a given period may result in additional gross avoided emissions, which, for the most part, occur in the EU ETS where they may free up more ETS allowances than initially anticipated, and further affect the carbon price signal in the EU ETS.

Assumption of full substitution of initial energy carrier

The described methods assume that an additional RES energy use will fully substitute an identical amount of energy that would have been provided by a set of initial energy carriers. It should be noted that this static approach does not capture the more complicated interactions in the energy system and with the economy; in real life, the substitution is unlikely to be 100 %: it may be more than 100 % if expensive RES force energy prices up, or less than 100 % if a subsidised addition of RES gives rise to rebound effects.

Life-cycle emissions

Although other (indirect) effects on GHG emissions may occur in practice, determining these effects, for example through life-cycle analysis, is outside the scope of the two methods. Whilst this does not mean that those indirect effects are unimportant ([63]), it is generally acknowledged that carbon and ecological footprints of wind power and solar PV are significantly smaller than those of fossil-based electricity (Granovskii et al., 2007; Weisser, 2007; Varun et al., 2009; IPCC, 2014). Life-cycle emissions of bioenergy systems tend to fall under a broad range, as they depend on numerous factors ([64]) (Cherubini et al., 2009). Typically, efficiencies of biomass combustion plants are lower than those of fossil fuel combustion installations. Therefore, end-of-pipe emissions from biomass combustion tend to be higher than those from fossil fuel installations if potential gains of stock in the LULUCF sector are not considered. However, in the absence of specific information on current bioenergy systems, on CO_2 emissions from the combustion of biomass (including biofuels/bioliquids), as well as on direct and indirect land use related emissions, which typically occur outside the energy sector and which were not included in national GHG emission totals in this report, and **a zero emission factor** was applied to all energy uses of biomass. This should not be interpreted as an endorsement of default biomass sustainability or carbon neutrality ([65]).

Renewable cooling

The effects of renewable cooling are not addressed in the Eurostat-based method. This is not really problematic, since today renewable cooling plays a marginal role in renewable energy statistics.

([63]) For example, emissions occur in the production chain of fossil fuels and biofuels. Use of renewable energy may have impacts on economic growth, carbon leakage and consumption. Emissions occur during the manufacturing of both conventional and renewable energy installations.

([64]) For instance, the type and management of the raw materials, conversion technologies, end-use technologies and system boundaries (especially the recognition of the biomass carbon cycle and carbon stock changes in biomass and soil over time, inclusion of nitrous oxide and methane emissions from agricultural activities, treatment of indirect land-use change, and allocation rules for multiple products).

([65]) It should be noted that according to UNFCCC Reporting Guidelines, these emissions have to be reported separately in GHG inventories as a Memorandum item (mainly to avoid double counting emissions from a reporting perspective), with the assumption being that unsustainable biomass production would show as a loss of biomass stock in the LULUCF sector.

3.4 Estimation of avoided fossil fuel use

Estimating the avoided gross inland consumption of fossil fuels due to the additional final consumption of RES is performed within the Eurostat-based method described in Section 3.3.1. By following the procedure in step 2 of that method, primary energy factors are calculated to enable the equivalent substitution of one unit of energy from conventional sources (in this case, specifically fossil fuels) by one unit of renewable energy.

The procedure leads to estimates for the amount and type of fossil fuel substituted by RES. The results presented in Section 2.5.2 of this report correspond to the '2005-RES shares' counterfactual.

3.5 Statistical impacts of renewable energy sources on primary energy consumption

Increasing the consumption of renewable energy can interact with the EU's 20 % energy savings target for 2020. Interactions result from the way renewable energy is dealt with in Europe's energy statistics, alongside the fact that the energy savings target is expressed in primary energy ([66]). This section describes a methodology to quantify the change of primary energy consumption that results from the use of various renewable energy technologies (RET).

3.5.1 Explanation of the methodology

The EU has set a primary energy savings target of 20 % for the period from 2005 to 2020. Under the EED, this is interpreted as a 20 % reduction of primary energy by 2020, relative to a fixed 2007 baseline projection ([67]) from the European Commission (EC, 2008). In absolute terms, the EED translates the 20 % energy savings target to a reduction by 368 Mtoe of the EU's primary energy consumption by 2020.

The target can be achieved by end-use energy efficiency improvements, as well as more efficient energy conversion in the supply sector. In this sense, renewable energy also contributes to the efficiency target (Harmsen et al., 2011) and different RET will affect primary energy differently, due to the current energy statistics in use.

A number of methods exist to account for the primary energy consumption of RET ([68]). Both the IEA and Eurostat use the **Primary Energy Method** to compile domestic energy consumption and GHG emission statistics reported by countries, where primary energy is defined as energy commodities that are either extracted or captured directly from natural resources (OECD/IEA, 2004).

For example, when electricity is generated with wind turbines, one unit of primary energy converts to one unit of electricity. On the other hand, when electricity is produced from fossil fuels, the amount of primary energy needed depends on the efficiency of converting the calorific value of the fuel into useful energy. When electricity is produced with an efficiency of 50 %, two units of primary energy are needed. This means that when wind electricity replaces fossil electricity, the consumption of primary energy is reduced. This helps to reach the energy savings target.

For other RET, however, the situation may differ. For example, when electricity is produced from biomass, the Primary Energy Method uses **actual** plant conversion efficiencies. Because the efficiency of electricity generation from biomass is on average lower than from fossil fuels, this will translate to an increase of primary energy, thus leading to **negative savings**. Increasing the contribution of biomass-based RET thus makes it harder to reach the energy savings target under the common energy statistics in use in Europe.

These effects are well-known. Harmsen et al. estimate that in the PRIMES-2007 baseline projection, the amount of energy savings due to renewable energy is 1.6 EJ between 2005 and 2020. Using alternative accounting methods, such as the **Substitution Method**, would lead to different results (Segers, 2008; EC, 2008).

To be able to determine the overall effects of renewable energy on the primary energy use, some assumptions must be made for all types of RET. These assumptions are based on energy statistics definitions and average conversion efficiencies in use. Table 3.3 below gives some examples; more information for all RET is provided in Annex 1.

(66) Primary energy, in the context of the EED, means GIEC minus non-energy use.
(67) The baseline is the European Commission's PRIMES-2007 baseline scenario.
(68) For example, the Direct Equivalent.

Section 3.3 explained how primary energy factors for heat and electricity can be calculated from Eurostat statistics. The information that is needed is shown in Table 3.4.

Let **F(ret, yr, c)** be the gross final energy consumption of a renewable energy technology (**ret**) in year (**yr**) and country (**c**). The total effects of renewable energy on primary energy consumption can then be calculated as in the formula below:

The RED prescribes normalisation rules, which mean that the share of renewable energy should not be calculated with the actual amount of wind and hydro energy, but rather with a normalised value (see also footnote 26).

$$\Delta \text{Primary energy}(yr, c) = \sum_{res} F(ret, yr, c) * [+i(ret) - e(ret) * Pe(yr, c) - h(ret) * Ph(yr, c) - p(ret) - d(ret)]$$

Table 3.3 Example of assumptions on primary energy input per renewable energy technology

Renewable energy source (res)	Abbreviation	Onshore wind	Solar thermal	Heat from solid biomass	...
Primary energy consumption [ktoe primary energy/ktoe gross final energy]	*i(ret)*	1	1	1.33	...

Table 3.4 Example of emission factors and primary energy factors

Country (c)	Abbreviation	Belgium	Belgium	...	United Kingdom
Year (yr)		**2005**	**2006**	**...**	**2012**
Primary factor electricity	*Pe (yr, c)*	...	...	...	...
Primary factor heat	*Ph (yr, c)*	...	...	...	...

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Annex 1 Attribution of renewable energy realisations to specific energy carriers

Annex 1 provides details on how contributions by individual RETs are attributed to specific energy carriers, based on the definitions in the Energy Statistics Regulation (see Table A1.1), and a number of additional assumptions and factors for the total ETS-share of emissions in industry.

Table A1.1 Most common abbreviations used in the formulas

Renewable energy source (RES)	Abbreviation
Gross electricity production from renewable energy technologies [GWh/GWh gross final energy]	**e(ret)**
Gross heat production from renewable energy technologies [ktoe/ktoe gross final energy]	**h(ret)**
Petrol replacement from renewable energy technologies [ktoe primary energy/ktoe gross final energy]	**p(ret)**
Diesel replacement from renewable energy technologies [ktoe primary energy/ktoe gross final energy]	**d(ret)**
Share of greenhouse gas effects in ETS [1=100 %]	**s(ret)**
Primary energy consumption [ktoe primary energy/ktoe gross final energy]	**i(ret)**

Table A1.2 Country-specific factors on the share of ETS-CO_2 emissions within the CRF sectors

Member State	AT	BE	BG	CY	CZ	DE	DK	EE	ES	FI	FR	GR	HR	HU
Comparison of total emissions between ETS and CRF (ETS/CRF, average 2008–2010, %)	76	90	88	93	87	89	87	93	83	88	88	95	88	94
Member State	**IE**	**IT**	**LT**	**LU**	**LV**	**MT**	**NL**	**PL**	**PT**	**RO**	**SE**	**SI**	**SK**	**UK**
Comparison of total emissions between ETS and CRF (ETS/CRF, average 2008–2010)	91	89	97	72	80	98	88	91	88	81	80	95	87	89

Note: Country codes (based on Eurostat country codes at 1 June 2012: see http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Country_codes): AT (Austria), BE (Belgium), BG (Bulgaria), CH (Switzerland), CY (Cyprus), CZ (the Czech Republic), DE (Germany), DK (Denmark), EE (Estonia), ES (Spain), FI (Finland), FR (France), GR (Greece), HU (Hungary), IE (Ireland), IS (Iceland), IT (Italy), LI (Liechtenstein), LT (Lithuania), LU (Luxembourg), LV (Latvia), MT (Malta), NL (the Netherlands), NO (Norway, PL (Poland), PT (Portugal), RO (Romania), SE (Sweden), SI (Slovenia), SK (Slovakia), TR (Turkey), UK (the United Kingdom).

For Croatia (HR), no direct calculation was possible. Therefore, the median value of the shares obtained for other countries was used to obtain the split for Croatia.

Table A1.3 Attributes of individual RETs

RES carriers	Renewable energy technologies (ret) contributing towards RES carrier	e	h	p	d	s	i
Renewable electricity	Hydropower ([a])	1([g])	-	-	-	1 ([b])	1 ([s])
	Geothermal	1 ([g])	-	-	-	1 ([b])	10 ([s])
	Solar photovoltaic	1 ([g])	-	-	-	1 ([b])	1 ([s])
	Concentrated solar power	1 ([g])	-	-	-	1 ([b])	3 ([s])
	Tidal, wave and ocean energy	1 ([g])	-	-	-	1 ([b])	1 ([s])
	Onshore wind	1 ([g])	-	-	-	1 ([b])	1 ([s])
	Offshore wind	1 ([g])	-	-	-	1 ([b])	1 ([s])
	Solid biomass	1 ([g])	-	-	-	1 ([b])	3 ([s])
	Biogas	1 ([g])	-	-	-	1 ([b])	2.4 ([s])
	Bioliquids	1 ([g])	-	-	-	1 ([b])	2.3 ([s])
Renewable heat	Geothermal	-	1 ([i])	-	-	([r])	2 ([s])
	Solar thermal	-	1 ([i])	-	-	([r])	1 ([s])
	Solid biomass	-	1 ([i])	-	-	([r])	1.3 ([s])
	Biogas	-	1 ([i])	-	-	([r])	1.1 ([s])
	Bioliquids	-	1 ([i])	-	-	([r])	1.1 ([s])
	Renewable energy from heat pumps	– 0.33 ([p])	1 ([p])	-	-	([r])	1 ([s])
Transport	Biogasoline	-	-	1 ([c])	0 ([c])	0 ([d])	0 ([s])
	Biodiesel	-	-	0 ([e])	1 ([e])	0 ([d])	0 ([s])
	Other liquid biofuels	-	-	0 ([f])	1 ([f])	0 ([d])	0 ([s])

Notes: ([a]) Excluding the production of electricity in pumped storage units from water that has previously been pumped uphill.

([b]) It is assumed that renewable electricity generation substitutes centralised electricity generation in the ETS.

([c]) It is assumed that 'biogasoline' replaces petrol.

([e]) It is assumed that 'biodiesel' replaces diesel.

([f]) It is assumed that 'other liquid biofuels' replace diesel.

([d]) It is assumed that transport emissions take place outside of the ETS.

([g]) The gross final energy is equal to the gross electricity production.

([i]) The gross final energy is equal to the gross heat production.

([p]) It is assumed that heat pumps have an average seasonal performance factor (SPF) of 3.0.

([r]) Country-specific value, calculated as follows: the Energy Balance of Eurostat contains the amount of (renewable) final energy that is consumed in the industry [B101800] (for solid biomass [5541], geothermal energy [5550], biogas [5542] and other liquid biofuels [5548]). The share of the RES that can be assigned to a country's industry (see Table A1.2) will be multiplied by the ratio of the ETS CO_2 emissions and the total CO_2 emissions of the EU-28 industry. In this way, one factor s(ret) per RET and carrier is calculated.

([s]) Assumptions are based on energy statistics definitions and average conversion efficiencies in use.

Table A1.4 Share of the contributions towards RES-H, by RET, that can be assigned to a country's industry ([69])

RET	Share assigned to industry
Solar thermal	1 %
Biogas (all)	13 %
Solid biomass (also municipal wastes (renew.) and charcoal)	50 %
Other liquid biofuels	26 %
Geothermal	1 %

([69]) Based on the Energy Balances of Eurostat for the EU-28, for 2012.

Annex 2 Methods for calculating the amount of GHG emissions per unit of generated, used or saved electricity

Table A2.1 Overview of methods based on a review of the OECD and the IEA (OECD/IEA, 2002)

Method	Type	Description
Generation-weighted average emission factor (average over total generation capacity)	Operation margin	The new capacity avoids a proportional fraction of all generating units in a system.
Generation-weighted average emission factor (average excluding must-run/low running cost facilities)	Operation margin	The average excludes resources that are unlikely to operate less, because they are 'must-run' capacity or have low running costs.
Dispatch decrement analysis	Operation margin	Actual dispatch data can provide empirical evidence of the mix of resources that are turned on and off in response to increasing or decreasing loads.
Dispatch model simulation	Operation margin	A dispatch modeling approach in which the complex operations of the electric system are simulated.
Average of recent capacity additions	Build margin	This method requires collecting data on the most recent construction activity and deriving a weighted average.
Single, proxy plant type	Build margin	A single technology, e.g. natural gas combined-cycle technology, is used as a proxy.
Combined margin	Combined margin	A combination of operation margin and build margin methods.

Annex 3 Calculated reference emission factors (fossil fuels)

As explained in Section 3.3.1, the Eurostat-based method uses primary data from the Eurostat Energy Balance as well as data obtained by applying the proxy methodology described in Section 3.2 as input, to calculate reference emission factors by country (or region) for electricity and heating for the reference period of this assessment. Emission factors for transport fuels are taken from Annex VI of the

Table A3.1 CO_2 emission factor electrical energy (ktonne/PJ) ([70])

Country	2005	2006	2007	2008	2009	2010	2011	2012	2013 proxy
Belgium	165	168	163	157	150	149	149	219	219
Bulgaria	329	334	332	314	319	318	305	310	310
Czech Republic	295	300	295	301	298	299	294	292	292
Denmark	256	241	271	312	355	252	270	258	258
Germany	237	241	239	230	234	229	228	238	238
Estonia	292	286	267	299	295	289	306	300	300
Ireland	178	171	164	155	152	152	154	165	165
Greece	245	233	224	221	232	244	225	227	227
Spain	191	182	183	157	154	148	171	188	188
France	226	223	222	212	212	205	207	215	215
Croatia	235	223	215	220	220	244	235	242	242
Italy	173	173	169	166	173	172	172	177	177
Cyprus	222	213	214	214	211	201	213	216	216
Latvia	207	207	204	195	196	194	199	214	214
Lithuania	207	207	204	195	196	194	199	214	214
Luxembourg	107	107	108	109	107	107	180	180	180
Hungary	249	221	214	215	237	227	229	230	230
Malta	291	268	284	238	239	245	249	255	255
Netherlands	182	159	153	153	152	147	143	170	170
Austria	155	163	169	153	145	151	158	186	186
Poland	207	207	204	195	196	194	199	214	214
Portugal	183	185	177	167	176	162	172	200	200
Romania	283	276	278	294	309	292	302	284	284
Slovenia	275	303	267	264	273	245	258	253	253
Slovakia	385	369	336	368	289	161	112	117	117
Finland	235	224	224	226	225	228	234	232	232
Sweden	185	193	284	180	194	234	249	234	234
United Kingdom	177	184	175	169	165	162	170	194	194

Source: EEA, 2014 (authors' work).

([70]) Because of the lack of available data on electricity generation by 'Main activity producer electricity plants' and 'Autoproducer electricity plants', the CO_2 emission factors for Latvia, Lithuania and Poland have been set equal to the value calculated for the EU-28.

European Commission Regulation No. 601/2012 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council (EC, 2012a).

The efficiency of heat generation is assumed to be 87 % for coal/solid fuels, 89 % for oil/liquid fuels and 90 % for gas/gaseous fuels, based on Vatopoulos et al. (2012).

Table A3.2 CO_2 emission factor heat (ktonne/PJ)

Country	2005	2006	2007	2008	2009	2010	2011	2012	2013 proxy
Belgium	76	75	75	76	73	73	73	72	72
Bulgaria	86	86	86	82	80	82	80	80	80
Czech Republic	82	83	81	80	81	80	81	80	80
Denmark	77	77	77	76	75	75	75	75	75
Germany	74	74	73	74	73	73	74	74	74
Estonia	81	79	82	83	81	79	83	80	80
Ireland	83	82	82	82	81	80	79	79	79
Greece	85	84	85	84	83	84	82	82	82
Spain	75	76	76	76	75	75	75	74	74
France	74	75	75	74	74	74	74	74	74
Croatia	76	76	76	75	74	74	74	74	74
Italy	72	72	72	72	70	70	71	70	70
Cyprus	91	91	90	91	90	89	87	87	87
Latvia	73	73	73	73	73	74	75	74	74
Lithuania	76	78	78	77	76	76	77	77	77
Luxembourg	72	72	72	71	72	71	71	71	71
Hungary	68	68	68	68	68	67	68	68	68
Malta	72	72	72	71	78	75	71	71	71
Netherlands	66	66	68	67	67	66	67	67	67
Austria	78	78	78	78	76	76	76	76	76
Poland	88	89	88	88	88	89	88	88	88
Portugal	80	80	78	78	77	76	75	74	74
Romania	75	74	74	73	71	71	71	71	71
Slovenia	76	76	75	76	75	74	74	74	74
Slovakia	78	79	78	79	82	79	80	79	79
Finland	85	85	85	85	85	85	85	85	85
Sweden	88	88	89	89	87	89	89	88	88
United Kingdom	69	69	70	69	69	68	69	68	68

Source: EEA, 2014 (authors' work).

Table A3.3 CO_2 emission factor transport fuels (ktonne/PJ)

CO_2 emission factor diesel	74.1
CO_2 emission factor gasoline	69.3

Analysis of emission factor findings

The following graphs show the results of the calculated reference emission factors for electricity, for the approach conditions 1 + 2 outlined in Section 3.3.1 under steps 2 and 3.

The variation in the reference emission factor for electricity is a combination of the variation in the use of different fuels for electricity production (and the corresponding emission factor) and the variation in the efficiency of the conversion of the fuels to electricity.

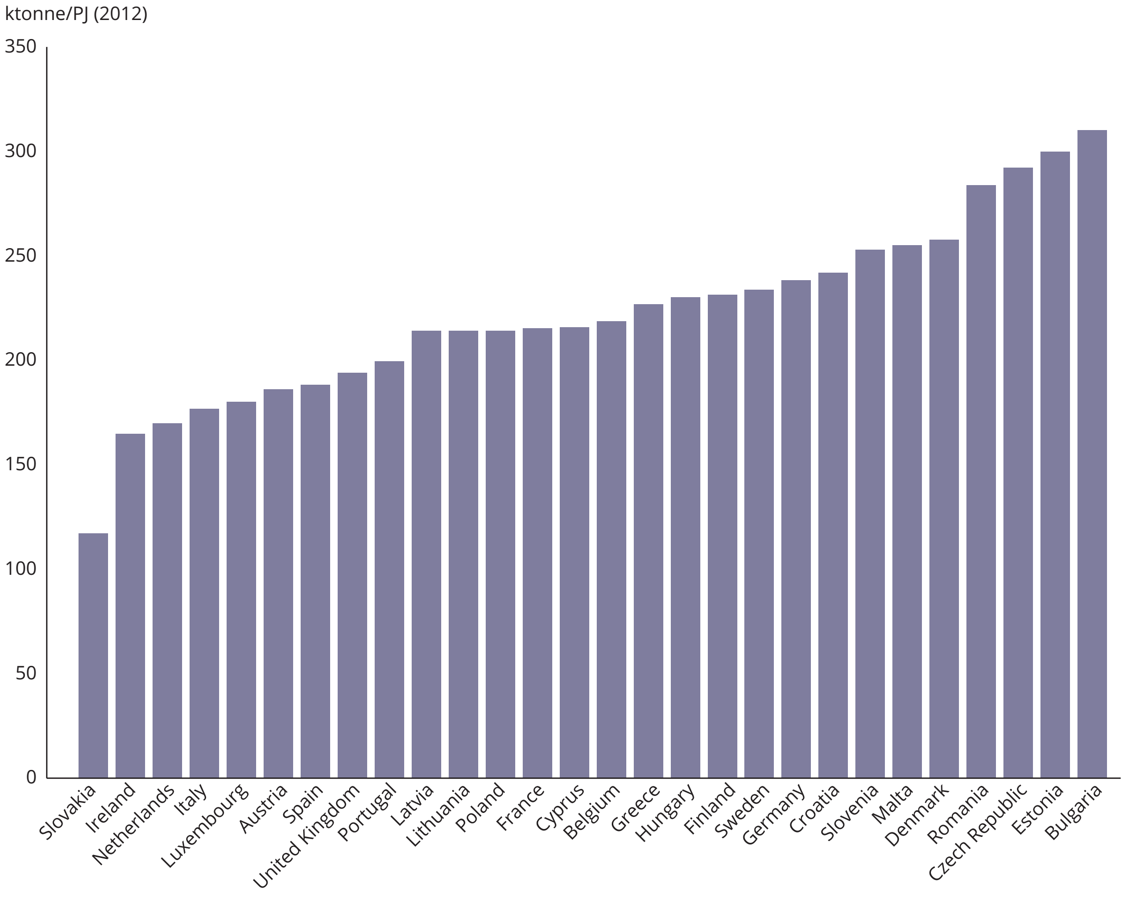
Blast furnace gas has been excluded from the average emission factor for the replaced electricity, in the same way as nuclear energy and renewable energy are excluded. This is justified by the fact that the production of blast furnace gas is linked to the production of iron and steel and therefore is not influenced by the increased consumption of renewables.

The following graphs show the results of the calculated reference emission factors for heat for the approach outlined under steps 2 and 3.

The variation in the reference emission factor for heat is directly linked to the variation in the use of different fuels for heat production.

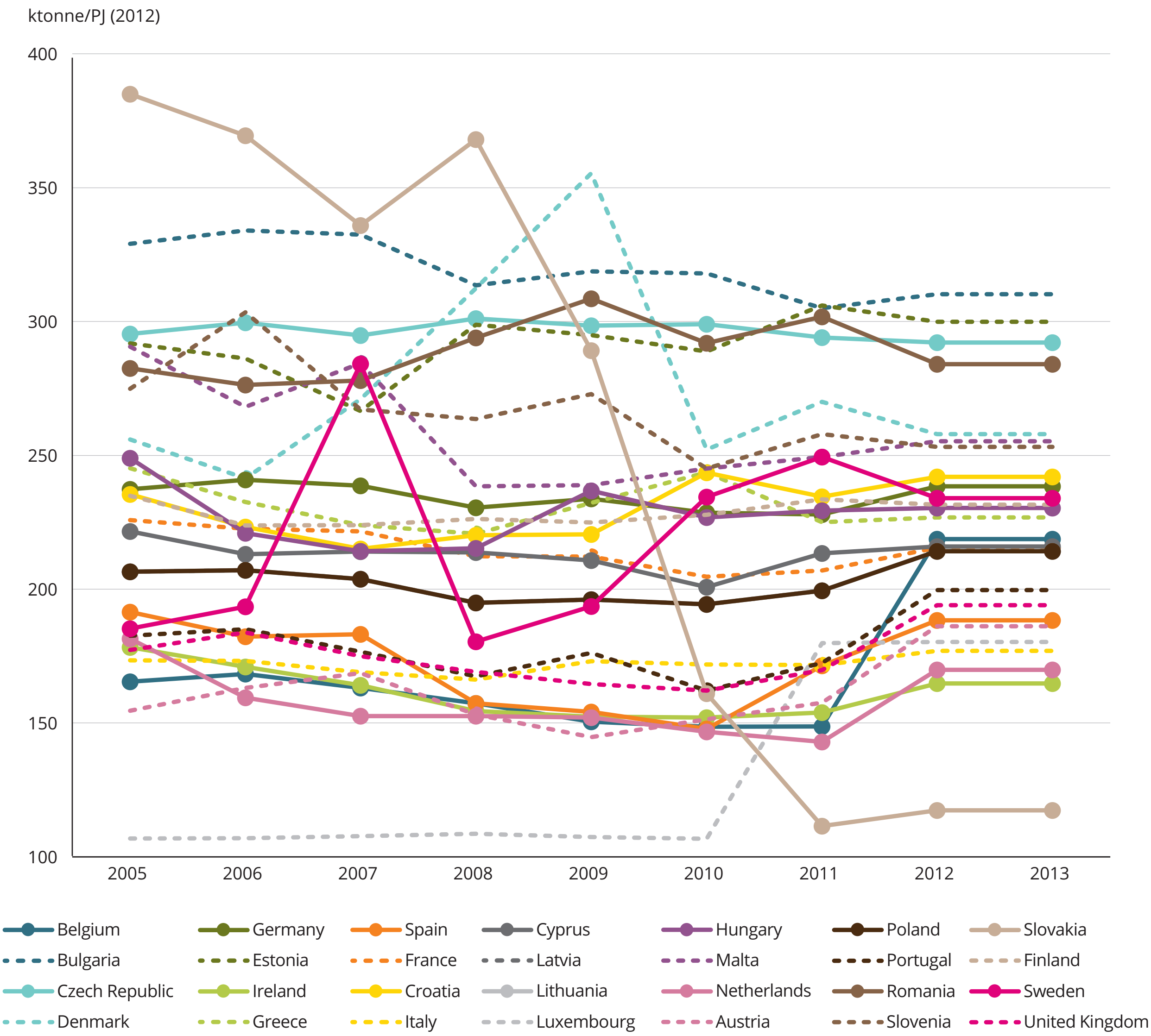
Due to the methodology used (fuel-dependent efficiency of heat production not varying in the period from 2004 to 2012) the variation in time of the reference factor for heat is fully attributable to the switch in fuels. Countries that have a declining reference emission factor converted to a considerable part their heat production from solid fuels with higher specific emission factors to gaseous fuels with lower specific emission factors.

Figure A3.1 Reference emission factor for electricity (ktonne/PJ, 2012)



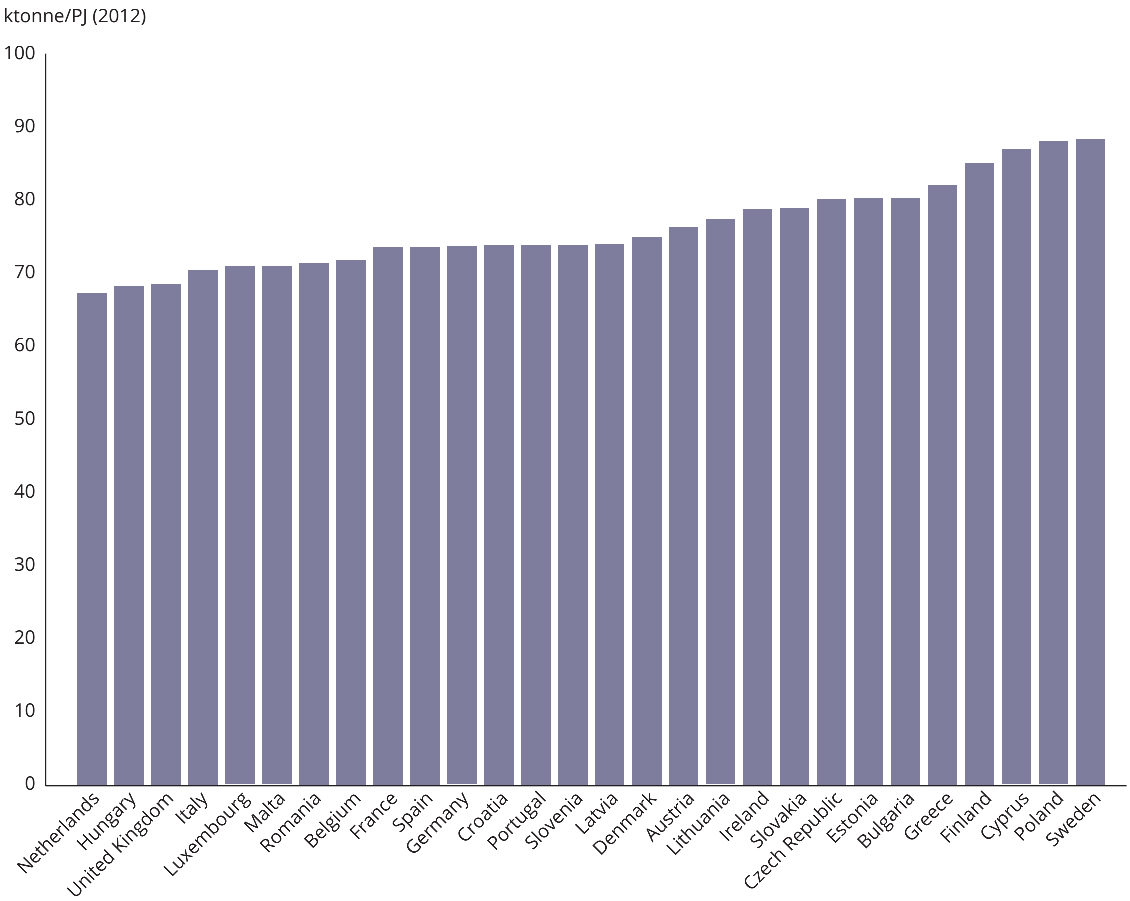
Source: EEA, 2014 (authors' work).

Figure A3.2 Evolution of reference emission factor for electricity (ktonne/PJ, 2004–2012)



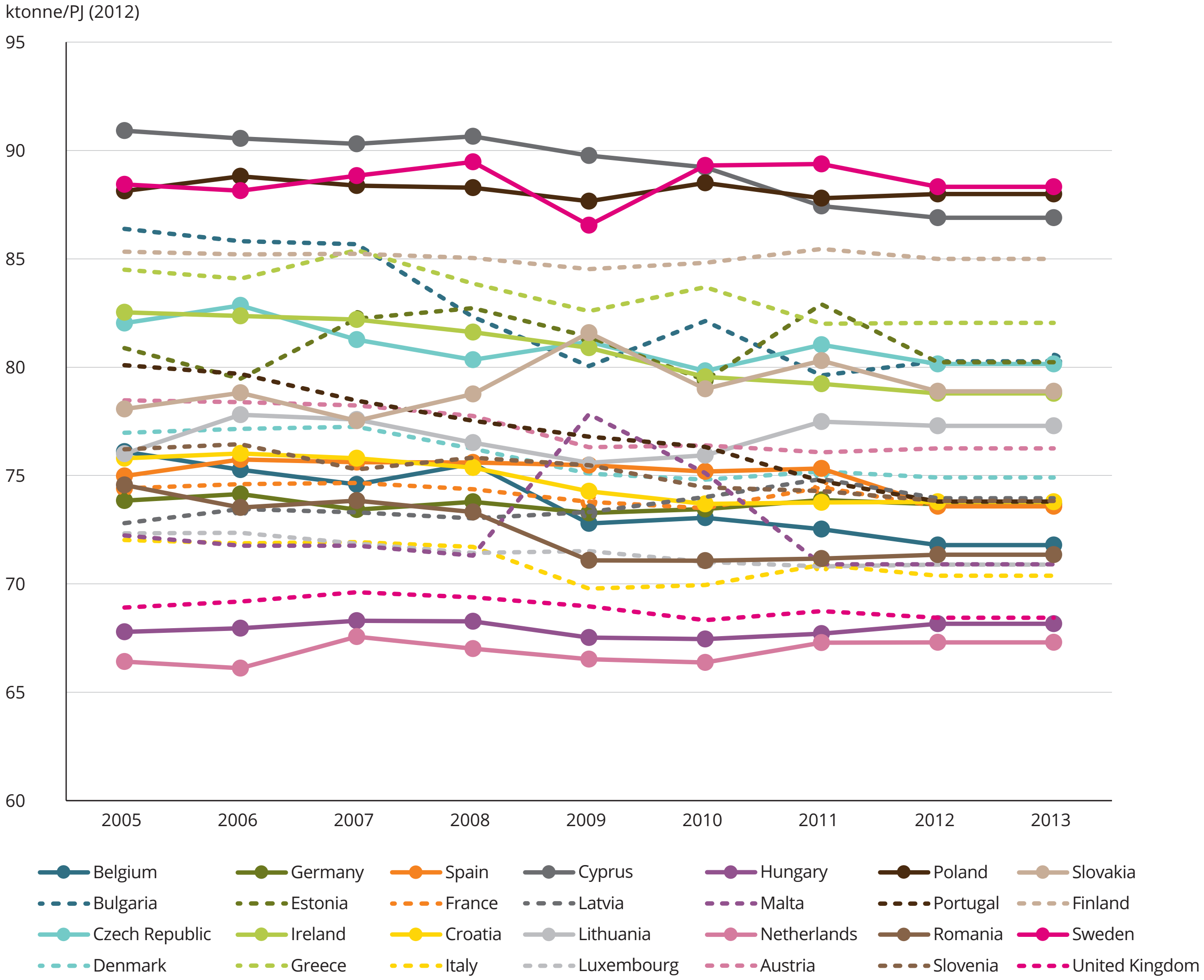
Source: EEA, 2014 (authors' work).

Figure A3.3 Reference emission factor for heat (ktonne/PJ, 2012)



Source: EEA, 2014 (authors' work).

Figure A3.4 Evolution of reference emission factor for heat (ktonne/PJ, 2004–2012)



Source: EEA, 2014 (authors' work).

Acronyms, units and terms

AEBIOM	European Biomass Association
CHP	Combined heat and power
Country codes	Based on Eurostat country codes at 1 June 2012: see http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Country_codes: AT (Austria), BE (Belgium), BG (Bulgaria), CH (Switzerland), CY (Cyprus), CZ (the Czech Republic), DE (Germany), DK (Denmark), EE (Estonia), ES (Spain), FI (Finland), FR (France), GR (Greece), HU (Hungary), IE (Ireland), IS (Iceland), IT (Italy), LI (Liechtenstein), LT (Lithuania), LU (Luxembourg), LV (Latvia), MT (Malta), NL (the Netherlands), NO (Norway, PL (Poland), PT (Portugal), RO (Romania), SE (Sweden), SI (Slovenia), SK (Slovakia), TR (Turkey), UK (the United Kingdom).
CRF	The Common Reporting Format sector classification and standardised tables containing mainly numerical information submitted electronically by Annex I Parties under the United Nations Framework Convention on Climate Change
CSP	Concentrated solar power
ECN	Energy research Centre of the Netherlands
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)
EF	Reference emission factor calculated in this paper
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)
EPIA	European Photovoltaic Industry Association
ESD	Effort Sharing Decision (Decision No 406/2009/EC on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020)
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 ETS	European Union Emissions Trading Scheme Directive (Directive 2009/29/EC amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community)
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, the United Kingdom
EWEA	European Wind Energy Association
FAS	Foreign Agricultural Service (of the United States)
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 (cf. Art. 2f of Directive 2009/28/EC). With this, it excludes transformation losses which are included in GIEC. In calculating a Member State's gross final energy consumption for the purpose of measuring its compliance with the targets and interim RED and NREAP trajectories, the amount of energy consumed in aviation shall, as a proportion of that Member State's gross final consumption of energy, be considered to be no more than 6.18% (4.12% for Cyprus and Malta).
GHG	Greenhouse gas
GIEC	Gross inland energy consumption, sometimes abbreviated 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
IEA	International Energy Agency
ILUC	Indirect land-use change
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
MMD	Monitoring Mechanism Decision (Decision 28/2004/EC of 11 February 2004 concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol)
MMR	Monitoring Mechanism Regulation (Regulation (EU) No 525/2013 of the European Parliament and of the Council of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC)
Mtoe	Million tonne of oil equivalent
MW	Megawatt
MWh	Megawatt-hour (1 million W-h)
NREAP	National Renewable Energy Action Plan

PE	Primary energy: in the context of the EED, this represents GIEC minus n on-energy use
PJ	Petajoule (10^{15} Joules)
PR	Progress Report
PRIMES	Price-driven and agent-based energy market equilibrium model
PV	Solar photovoltaic energy
RED	Renewable Energy Directive (Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC)
RES	Renewable energy sources
RES-E	Renewable electricity
RES-H/C	Renewable heating and cooling
RES-T	Renewable energy consumed in transport
RET	Renewable energy technology
SHARES	Short Assessment of Renewable Energy Sources. Tool developed by Eurostat and aimed at facilitating the calculation of the share of energy from renewable sources according to the RED
SPF	Seasonal performance factor
UNFCCC	United Framework Convention on Climate Change — an international environmental treaty concerning climate change
USDA	United States Department of Agriculture

European Environment Agency

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