THE STATE OF RENEWABLE ENERGIES IN EUROPE

EDITION **2018**

18th EurObserv'ER Report

This barometer was prepared by the EurObserv'ER consortium, which groups together Observ'ER (FR), ECN part of TNO (NL), RENAC (DE), Frankfurt School of Finance and Management (DE), Fraunhofer ISI (DE) and Statistics Netherlands (NL).

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EUROPE TRANSCENDS BORDERS

Vincent Jacques le Seigneur, president of Observ'ER

"If there is one project today which carries a positive vision for Europe, it is definitely the energy transition", *highlighted Jacques Delors and Enrico Letta in the* Notre Europe[1] *think tank manifesto. History appears to have proved them right. For the energy challenge that sparked off the European Coal and Steel Community (ECSC, 1951) followed by the atom (Euratom, 1957), is once again at the centre of all discussions in a spirit of openness and convergence, even though much remains to be accomplished.*

Today, the European Union is centre-stage of a two-pronged approach to set the course for the next decade. Firstly, with the penning of a climate strategy[2] for a carbon-neutral Europe by 2050, which will be debated by the European Council on 9 May 2019 at Sibiu. Secondly it is rolling out the new 2010 Climate-Energy package, the first of whose eight regulations has just been voted through. It has been a long road travelled since 2014 to convince the most stubborn Member States, but also to get the European Parliament to shift the Commission and the European Council from their initial stance. Now the results are there to be seen! The European Union's leadership role has been confirmed, the renewables share in final energy consumption, initially set at 27%, is now 32% and energy efficiency gains have been increased by more than five points. While the abandonment of binding targets on the Member States is a blow, the insistence on having national energy and climate plans[3] will enable the Commission to assess them and make recommendations if not demand corrective measures[4].

This political agenda is crucial on a number of counts. It gives visibility to all public and private investors and decision-makers. It is particularly timely for the economy because renewable energies that already employ more than 1.5 million people and generate sales worth some 155 billion euros are well and truly sources of growth. It also meets Europeans' expectations as 75 % of them would rather have a common energy policy than the economic or monetary union or unlikely new extensions[5]. It comes second only to free movement of persons in Europe at the top of their wish list.

Many initiatives have been taken without waiting for this European energy community that was so dear to Jacques Delors. The European Commission's Directorate-General for Competition which encourages the introduction of cross-border tenders to facilitate deployment of renewable energies in the most conducive areas, and at the same time bringing down costs faster. Another example is the requirement to harmonise support mechanisms enshrined in this new set of legislation that could affect the development pace of wind and solar photovoltaic energy but is far and away the best way to build tomorrow's Europe.

Governance has been fixed to stay on course. For the Member States this means the obligation to present a progress report on the Energy Union's five dimensions every two years: security of supply, internal market, energy efficiency, emissions reduction, research and competitiveness. For the Commission it entails the obligation to present an annual report on the state of the Energy Union to the European Parliament and Council. Let's leave it up to our two illustrious rapporteurs to conclude: *"The European Commission has done its part of the work by submitting ambitious proposals that must now be improved on. We would like our national and European leaders to be aware of the strategic importance of the Energy Union for our Europe, our nations and our way of life"*. Let them still and always be heard.

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1. *"Making the transition of energy a European Union success" Notre Europe, 2017*

2. *Communication presented at the end of November 2018: "A Clean Planet for all"*

3. *Submitted to the Commission before 1 October 2019*

4. *The legislative package, Franco-German Office for the Energy Transition (OFATE), December 2018*

5. *Eurobarometer No. 90, Oct 2017*

ENERGY INDICATORS

EurObserv'ER has been collecting data on the European Union's renewable energy sources for twenty years to describe the state and thrust of the various sectors in theme-based barometers. The first part of this assessment is a summary of the barometers published in 2018 for the wind energy, photovoltaic, solar thermal, concentrated solar power, biogas, biofuel, solid biomass and heat pumps sectors. The data drawn from these barometers has been consolidated with the official data available at the very end of the year.

The sectors that were not covered by individual barometers have also been analysed in detail and statistically monitored using data published in 2018. They cover small hydropower, heat pumps, geothermal energy, biogas, the incineration of renewable municipal waste and ocean energies.

This work offers a full synopsis of the energy dimension of the twelve renewable sectors now developed at an industrial scale within the European Union.

Methodological note

The tables reproduce the most recent figures available for each sector. In publishing this edition, the EurObserv'ER data was fully reconciled with the Eurostat data published on 31 January 2019 and the Indicator-specific data from the Renewable Energy Directive provided by the SHARES (Short Assessment of Renewable Energy Sources) tool published on 4 February 2019. This reconciliation covers the indicators for electricity output, electrical capacity, final energy consumption and derived heat from heating or cogeneration plants. In the case of market indicators not monitored by Eurostat, such as market data for different types of heat pumps or different types of solar thermal collectors, the EurObserv'ER source or indicators was exclusively used.

As for the "heat" data, a distinction is made between derived heat from the processing sector and final energy consumption in line with Eurostat definitions. Derived heat covers the total production of heat in heating plants and cogeneration plants (combined heat and power plants). It includes heat used by the auxiliaries of the installation which use hot fluid (space heating, liquid fuel heating, etc.) and losses in the installa tion/network heat exchanges. For auto-producing entities i.e. entities generating electricity and/or heat wholly or partially for their own use as an activity which supports their primary activity) the heat used by the undertaking for its own processes is not included.

Final energy consumption is the total energy consumed by end users, such as households, industry and agriculture. It is the energy which reaches the final consumer's door and excludes that which is used by the energy sector itself including for deliveries, and transformation. It also excludes fuel transformed in the electrical power stations of industrial auto-producers and coke transformed into blast-furnace gas where this is not part of overall industrial consumption but of the transformation sector. Final energy consumption in «households, services, etc.» covers quantities consumed by private households, commerce, public administration, services, agriculture and fisheries.

A distinction is also made with regard to electricity and derived heat production data between output from plants solely producing either electricity or heat and the output from cogeneration plants simultaneously producing heat and electricity. For French indicators, overseas departments are always included.

WIND POWER

NEW INSTALLATION RECORD

According to Eurostat, 168.9 GW of net maximum onshore and offshore wind electrical capacity (i.e. the maximum active capacity that can be continuously supplied) was in service in the European Union in 2017, 14.7 GW more than in 2016. It is the highest increase ever recorded by the sector, overtaking those of 2016 and 2015 (12.8 GW each). This installation record can be attributed to the positive thrust of the three biggest markets, and especially the leading market, Germany. It alone posted 6 126 MW of net additional capacity, taking its capacity to 55.7 GW by the end of 2017, which is almost a third of the European Union's wind energy capacity. In 2017 the UK also made a spirited comeback, boosted by its offshore segment, and posted 3 662 MW of additional capacity, which is almost double the amount it installed in 2016 (1 868 MW). France (including the overseas departments) also posted its best growth in 2017 to date by adding 2 GW (2 001 MW).

These three countries, through their market sizes, may account for the major share of newly-installed capacities in the European Union, but other countries have also been active. New records were set in Belgium (436 MW) and Ireland (532 MW). Sweden (177 MW), Austria (157 MW) and Greece (171 MW) lost steam. However, height Member States installed no additional capacity.

OFFSHORE EXPANDS

Having dimmed in 2016, offshore wind energy's sparkle returned in 2017 and was a factor in the wind energy sector's performance. According to EurObserv'ER, the maritime sector posted 3 228.6 MW of additional net capacity, taking the EU's offshore wind turbine capacity base to 15 821.5 MW. The sector now accounts for just under 10% (9.4%) of total EU wind energy capacity but benefitted from more than 22% of all the additional capacity installed in 2017.

If we take the French Floatgen floating wind turbine demonstrator out of the equation, 12 offshore wind farms were fully connected to the

grid in 2017. Four farms, all of them British, were partially connected: Race Bank, Walney, Rampion and Galloper. The fully-connected British wind farms were Dudgeon East (402 MW), Burbo Bank Extension (200 MW), Blyth (42 MW) and Hywind Scotland (30 MW). The latter is a special case because it is the world's first offshore farm (leaving aside demonstrators) to use floating foundations. Germany also has 5 new fully connected farms: Veja Mate (402 MW), Wikinger (350 MW), Nordsee One (332 MW), Nordergründe (111 MW) and Sandbank (52 MW). As for Belgium, it inaugurated the NobelWind farm (165 MW) and Finland commissioned its Pori Tahkoluoto farm (42 MW) and replaced all of its Kemis Ajos farm wind turbines (26.4 MW). The French floating wind turbine demonstrator Floatgen (2 MW) was inaugurated in October 2017 but although it produced its first kWh while in dock in December 2017, it was only connected to its real site off the Croisic coast early in 2018.

PRODUCTION IN 2017 WAS MORE LIKE BACK-TO-NORMAL

The poor winds along the British coasts, in the North and Baltic Seas and broadly over the Northern half of Europe in 2016 hit wind power production hard. But wind conditions in 2017 returned to normal. Eurostat reports that output reached 362.4 TWh in 2017, which is a 19.7% increase on 2016 (equivalent to an additional 59.6 TWh). Germany was the first country to pass the 100 TWh output threshold as it generated 105.7 TWh in 2017. The UK (50 TWh) beat Spain (49.1 TWh) by a hairs' breadth to second place in the EU producer rankings.

1

Wind power net capacity installed in the European Union at the end of 2017 (in MW)*

	2016	2017
Germany	49 592	55 718
Spain	22 990	23 100
United Kingdom	16 174	19 835
France	11 511	13 512
Italy	9 384	9 737
Sweden	6 434	6 611
Poland	5 747	5 759
Denmark	5 246	5 522
Portugal	5 124	5 124
Netherlands	4 257	4 202
Ireland	2 786	3 318
Romania	3 025	3 030
Austria	2 730	2 887
Belgium	2 370	2 806
Greece	2 370	2 624
Finland	1 565	2 044
Bulgaria	699	698
Croatia	483	576
Lithuania	509	518
Hungary	329	329
Estonia	310	312
Czechia	282	308
Cyprus	158	158
Luxembourg	120	120
Latvia	70	77
Slovenia	5	5
Slovakia	3	4
Malta	0	0
Total EU 28	154 272	168 934

* Net maximum electrical capacity. **Source: Eurostat**


EnBW

Obviously output improved in the countries that have major offshore capacity. An increasing number of offshore wind farms have annual load factors close to if not in excess of 50%. This rate can be even higher in winter, coinciding with electricity requirement peaks in many countries. The load factor of a wind turbine is the ratio between the energy effectively produced during a given timeframe and the potential energy it could have generated at nominal capacity during the same timeframe.

2

Installed offshore wind power net capacity in the European Union at the end of 2017 (in MW)*

	2016	2017
United Kingdom	5 293.4	6 987.9
Germany	4 152.0	5 427.0
Denmark	1 271.1	1 296.8
Netherlands	957.0	957.0
Belgium	712.2	877.2
Sweden	203.0	203.0
Finland	4.3	72.7
Total EU 28	12 593.0	15 821.5

* Net maximum electrical capacity. **Source: EurObserv'ER 2018**

EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2018 EDITION

THE LEVEL OF EUROPEAN COOPERATION IS PARTLY RESPONSIBLE FOR THE CHANGE

Projected European growth through to 2020 should generally stay on course to meet the national renewable energy action plan targets, but in the longer term, projections will be hazier. In fact, while the drop in the price of wind power and its competitiveness in relation to other technologies opens up new prospects for the sector, wind energy's future development pace will be constrained by the dearth of outlets in the European electricity market, unlike its American and Chinese counterparts. The European electricity market's overcapacity situation combined with the influx of "variable" renewable energies has led to a drop in the wholesale price of electricity and thereby undermined many historical operators that are thus asking for more time to decarbonise their production systems.

One solution advanced by the Directorate General for Competition of the European Commission entails cross-border tendering which would make the development of renewable energies easier in the most conducive areas at the lowest possible costs. The European Commission reckons that by opening up 10–15% of tenders to foreign capacities, support costs would drop by about 4–5% over the 2021–2030 period. The Commission also believes that cross-border tenders are the most effective way of harmonising support mechanisms. Lastly it feels that this move would enable a European renewable energy development target to be set linked to a "European" support mechanism. If that happens, the future development pace of wind energy will be closely linked to the level of European cooperation as part of a common energy vision, in addition to the efforts to combat climate warming that the Member States have agreed to make by the 2030 timeline. ■

3

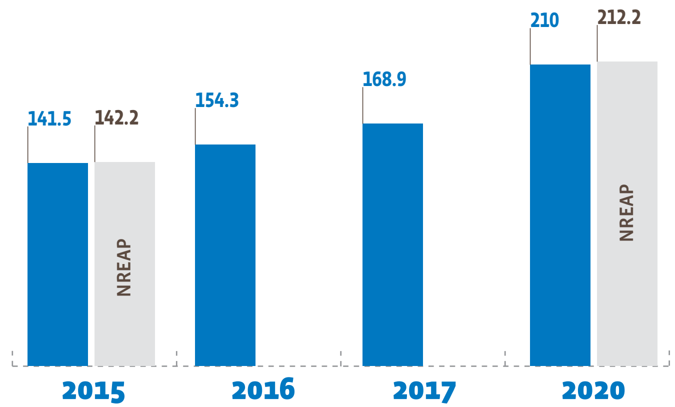
Electricity production from wind power in the European Union in 2016 and 2017 (in TWh)

	2016	2017
Germany	78.598	105.693
United Kingdom	37.263	50.004
Spain	48.905	49.127
France	21.473	24.711
Italy	17.689	17.742
Sweden	15.479	17.609
Poland	12.588	14.909
Denmark	12.782	14.780
Portugal	12.474	12.248
Netherlands	8.170	10.569
Ireland	6.149	7.445
Romania	6.590	7.407
Austria	5.232	6.574
Belgium	5.437	6.511
Greece	5.146	5.537
Finland	3.068	4.795
Bulgaria	1.425	1.504
Lithuania	1.136	1.364
Croatia	1.014	1.204
Hungary	0.684	0.758
Estonia	0.594	0.723
Czechia	0.497	0.591
Luxembourg	0.101	0.235
Cyprus	0.227	0.211
Latvia	0.128	0.150
Slovakia	0.006	0.006
Slovenia	0.006	0.006
Malta	0.000	0.000
Total EU 28	302.859	362.412

Source: Eurostat

4

Comparison of the current trend against the NREAP (National Renewable Energy Action Plans) roadmap (in GW)



Source: EurObserv'ER 2018

PHOTOVOLTAIC

Solar power's spectacular growth, which is based on solid industrial foundations, makes photovoltaic one of the cornerstones of global energy transition. During 2017, approximately 100 GW of photovoltaic capacity was installed all over the world and took global installed capacity to more than 400 GW (403.3 GW according to the IEA's PVPS report). China installed more than half of this new capacity (53 GW) The European Union has now dropped out of the top 5 global markets, for behind the top three represented by China (53 GW), the USA (10.7 GW) and India (9.6 GW), come Japan (7.5 GW) and Turkey (2.6 GW). Only three EU countries are left in the top 10 – Germany in 6th place (1.7 GW), ahead of Australia (1.3 GW) and South Korea (1.2 GW), with France (0.9 GW), the UK (0.9 GW) and Brazil (0.9 GW) – all tightly bunched. The 2017 global market amounted to a little less than the whole of the European Union's installed collector base, which Eurostat claims was 106.7 GW. It is clear that as the globalisation process of solar power picks up speed, the European Union market's relative share and installed base are gradually shrinking.

TRANSITION STILL DOMINATES THE EU MARKET

The 2017 data released by Eurostat in January 2019 confirms the trend decline in net capacity connection for the year. In 2011, the EU enjoyed an installation peak of 23.2 GW, then the annual net installed capacity decreased to 6.5 GW in 2014. After the 2015 spurt, additional annual installed capacity continued its downward slide to 5.7 GW in 2017.

Thus, the European Union market is still in transition, with less emphasis on fast development of big photovoltaic power plants which is now regulated by a tendering policy, and more on commercial and residential roof-mounted systems. Its focus is also driven by self-consumption systems that allow investors to benefit from the lower production costs of self-consumed solar power, rather than purchase more expensive power from the grid.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1

Installed solar photovoltaic net capacity in the European Union at the end of 2017 (in MW)*

	2016	2017
Germany	40 714	42 337
Italy	19 283	19 682
United Kingdom	11 912	12 776
France	7 702	8 610
Spain	4 716	4 725
Belgium	3 325	3 610
Netherlands	2 049	2 903
Greece	2 604	2 606
Czechia	2 068	2 070
Romania	1 372	1 374
Austria	1 096	1 269
Bulgaria	1 028	1 036
Denmark	851	906
Portugal	513	579
Slovakia	533	528
Hungary	235	344
Poland	187	287
Slovenia	233	247
Sweden	153	244
Luxembourg	122	128
Malta	93	112
Cyprus	84	110
Finland	35	74
Lithuania	70	74
Croatia	56	60
Ireland	6	16
Latvia	1	1
Estonia	0	0
Total EU 28	101 041	106 707

** Net maximum electrical capacity.* ***Source: Eurostat***

GERMANY REGAINS ITS EU LEADERSHIP

In 2017, Germany took back the European market reins after having left them in the UK's hands for three years in a row. According to Eurostat, Germany's installed photovoltaic capacity increased by 1 623 MW in 2017 (compared to 1 471 MW in 2016) rising to 42 337 MW, which equates to about 1.6 million on-grid installations. Photovoltaic electricity output rose to 39.4 TWh in 2017, (3.4% more than in 2016) and amounted to 6% of the country's brut electricity production. According to AGEE-Stat, the self-consumed share of electricity continued to rise, achieving 10% in 2017 (9.5% in 2016 and 9.1% in 2015). This self-consumption market is now supported by the solar power storage market. The Franco-German Office for the Energy Transition (OFATE) claims that 40 000 small photovoltaic battery systems were sold in Germany by 31 December 2017, and that 32 000 of them were subsidized through the KfW (development bank) programme for promoting stationary battery storage systems.

Solar photovoltaic power plants with capacities greater than or equal to 750 kWp are subject to tendering. The fourth tendering period for ground-mounted photovoltaic plants with minimum capacity of 750 kWp, published on 1 February 2018, saw prices continue to drop. There were 79 bids for a total volume of 546 MWp and 24 of them were successful for 200 MW of capacity. The reference value of these tenders was € 0.433 per kWh. The lowest bid made was € 0.386 per kWh. The reference value of the previous bid was € 0.491 per kWh. On 1 April 2018, the Federal Grid Agency released the results of the first bi-technology tender for solar energy and wind energy. All the successful bidders for this tender bid for photovoltaic power plants, which demonstrates the competitive advantage enjoyed by solar power in Germany. A total of 32 photovoltaic power plant projects were successful for total capacity of 210 MW. The average price was set at € 0.467 per kWh (a little higher than the last photovoltaic-specific tender), with the lowest bidding price at € 0.396 per kWh and the highest at € 0.576 per kWh.

2

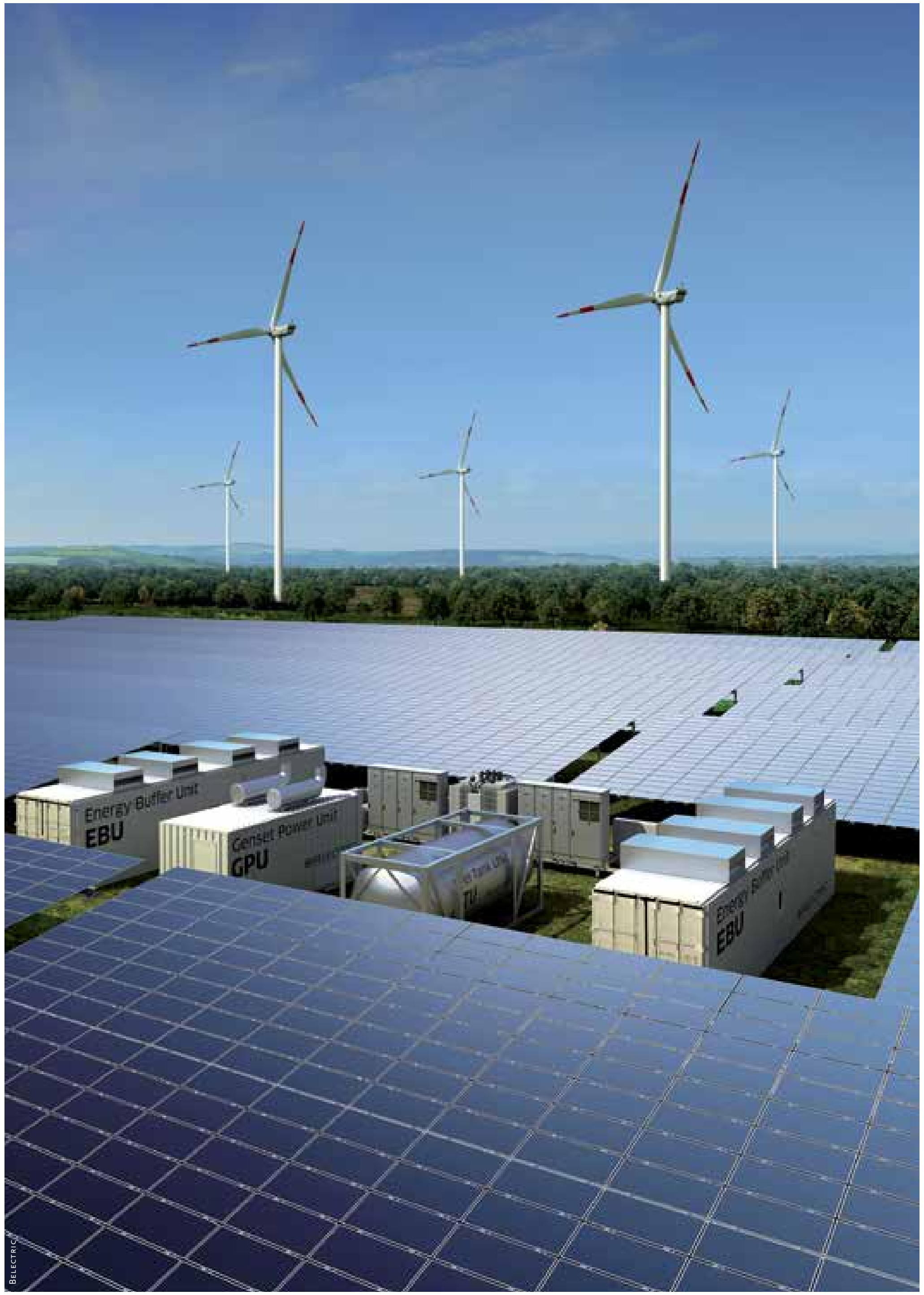
Electricity production from solar photovoltaic in the European Union in 2016 and 2017 (in TWh)

	2016	2017
Germany	38.098	39.401
Italy	22.104	24.378
United Kingdom	10.411	11.525
France	8.657	9.573
Spain	8.064	8.514
Greece	3.930	3.991
Belgium	3.092	3.288
Netherlands	1.602	2.204
Czechia	2.131	2.193
Romania	1.820	1.856
Bulgaria	1.386	1.403
Austria	1.096	1.269
Portugal	0.871	0.992
Denmark	0.744	0.751
Slovakia	0.533	0.506
Hungary	0.244	0.349
Malta	0.254	0.310
Slovenia	0.267	0.284
Sweden	0.143	0.230
Cyprus	0.146	0.172
Poland	0.124	0.165
Luxembourg	0.100	0.108
Croatia	0.066	0.079
Lithuania	0.066	0.068
Finland	0.019	0.044
Ireland	0.006	0.011
Latvia	0.000	0.000
Estonia	0.000	0.000
Total EU 28	105.975	113.665

Source: Eurostat

THE UK LARGE POWER PLANT MARKET COMES TO A STANDSTILL

Having held the European leadership for three years, the British large solar power plant market has gradually waned. According to the Department for Business, Energy and Industrial Strategy (BEIS), 864 MW of capacity went on-grid 2017 compared to 2 311 MW in 2016 (and to 4 073 MW in 2015). This additional capacity brings the net installed capacity at the end of 2017 to 12 776 MW. Most of the capacity installed in 2017 was on sites accredited under the old Renewable Obligation incentive system and was installed in the first quarter of the year before the mechanism was curtailed for good (720 MW installed in Q1, then 43 MW in Q2, 55 MW in Q3 and 45 MW in Q4). The few tens of MW installed over the last quarters were from the market for small installations that were still eli-



gible for Feed-in Tariffs. This situation has arisen because no solar energy project has qualified since the second Contract for Difference (CfD) auction was held.

THE EUROPEAN UNION PRODUCES 113.7 TWH OF PHOTOVOLTAIC ELECTRICITY

In terms of output, 2017 was much better than 2016, aided by slightly better sunshine conditions and a net additional capacity of 11.7 GW over the past two years. According to Eurostat, European Union output reached 113.7 TWh in 2017, which equates to annual growth of 7.3%. Solar power now amounts to 3.4% of the European Union's gross electricity output.

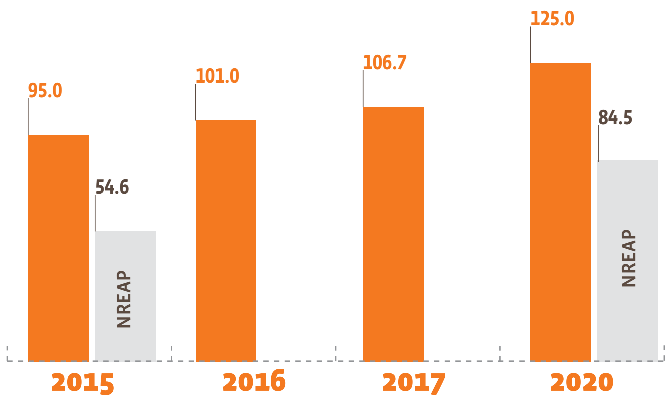
FINE PROSPECTS UNDER POLITICAL PRESSURE

Despite the further drop in the number of connections in the EU, the negative momentum should be broken at least for the next three years. Solaire photovoltaic has without a doubt become the most popular, cheapest and easiest renewable energy for economic stakeholders to access. Hence, many governments are banking on solar power to achieve their national targets for 2020. The latecomers, including France and the Netherlands, have responded to their wake-up call and this is already giving new impetus to the EU market, which is enjoying the very positive reduction in costs. Spain's tenders should also perk up the European market from 2019 onwards, aided by the implementation of new PPA (power purchase agreement) projects without public subsidies. Germany, helped by the implementation of a stable regulatory framework, should continue to be the mainstay of the European market with a target to install 2.5 GW per annum. As for the eleven EU countries that have already met their gross electricity consumption target shares of renewable energy, the European obligation to develop these sectors has been diluted and is only motivated by national political will. That may explain why markets that were formerly buoyant, such as the Czechia, Romania and Bulgaria, are now completely listless. EurObserv'ER reckons that the newly-installed capacity across the European Union could gradually rise to at least 10 GW by 2020.

Another positive factor is the increasing appetite of a variety of economic sectors (retail distribution, food-processing, agriculture, etc.) for the new self-consumption models. However, the area of collective solar power self-consumption is subject to friction between the stakeholders of the relevant countries, both over regulatory issues and the input of those installations to the development and maintenance of the distribution grid. ■

3

Comparison of the current trend of photovoltaic capacity installed against the NREAP (National Renewable Energy Action Plans) roadmap (in GW)



Source: EurObserv'ER 2018

SOLAR THERMAL

Solar thermal is certainly the very best form of energy for transferring heat to water from a physical point of view, as it neither emits GHG nor pollutants. Yet, the sector is struggling to make economic inroads into the hot water and heating production market. The European Union market experienced another sharp drop in the installed surface for hot water and heating production in 2017, its ninth hard year in a row since 2009. According to EurObserv'ER, the 16.6% drop was particularly sharp between 2016 and 2017 – when 2 175 546 m^2 of collector surface was installed, adding 1 523 MWth of thermal capacity (2 609 886 m^2 in 2016).

STRUGGLING TO FIND A GAP IN THE CLOUDS

All in all, Europe's solar thermal markets are finding it hard to stabilize (Spain, Austria, Poland) or are contracting (Germany, France, Italy and Belgium). Despite its patent energy efficiency and CO2 balance advantages, solar thermal heat is struggling to establish an economic foothold in the heating and domestic hot water production market. It faces particularly stiff competition in the renovation segment but also in new build, where it has never really taken off.

The solar thermal business is highly sensitive to government policies that may or may not create an obligation to install renewable heat in new build under the terms of its thermal regulations. Spain is a case in point. Thermal regulation specifications also have a strong impact on the market's momentum because, if there is no renewable obligation, minimum adherence to construction standards can be achieved by good insulation or by incorporating fossil or electrical technologies that have also made great strides in energy efficiency. Yet those thermal regulations that insist on the introduction of renewable technologies, or a minimum share of renewable energy in building energy consumption do not necessarily benefit solar thermal solutions. In actual fact, each regulation tends to bolster one heating or domestic hot water production solution over another. Competition from the other renewable heating technologies such as air-sourced heat pumps and thermodynamic hot water heaters is rife. These sectors are booming and are also boosted by the trend to electrify heating and cooling needs. Solar thermal is also caught up in internecine rivalry with solar photovoltaic where it competes not only for available roof space, but also, and this is new, for uses. The drive to achieve network parity in many countries is fuelling development of self-consumption, firstly to meet electricity needs, and increasingly by making recourse to systems directly linked to an immersion heater or a thermodynamic hot water heater to meet domestic hot water needs.

Installers' failure to recommend solar thermal in the individual family home renovation sector is compounding the situation. Installers often try to orient their customers towards cheaper, easier-to-install systems (which do not involve working on the roof). Energy labelling, which should be an asset for the solar thermal sector (as solar thermal systems are the top scorers) also tends to be played down. This is despite the efforts made to raise installers' awareness of energy labelling through the LabelPack A+ project coordinated by Solar Heat Europe and funded by the European Union's Framework Programme for Research and Innovation, Horizon 2020.

NEWS FROM AROUND THE MAIN EUROPEAN MARKETS

The German market has contracted considerably

Germany stayed at the top of the EU solar thermal market ranks in 2017. According to AGEE-Stat, the Working Group on Renewable Energy Statistics that works for the Federal Ministry for Economic Affairs and Energy (BMWi), Germany installed about 650 000 m^2 of collectors in 2017 (equating to 455 MWth of output). This data signals a 15.1% drop in newly-installed area over 2016 (766 000 m^2) and also confirms the observations made last year by the sector's players. The MAP incentive programme which was upgraded in 2015, and the new "Anreizprogramm Energieeffizienz (APEE)" energy efficiency stimulation programme set up on 1 January 2016, fell short of stemming solar thermal's decline. The industry blames the downward trend not only on the cost of gas-fired heating which is still very competitive but also on increasing competition from other renewable energy heating systems. Another grumble observed elsewhere, is installers' growing indifference to solar thermal solutions, in favour of solutions that are faster to install.


Wagner & Co Solartechnik GmbH

Upturn for the Greek market

The Greek market is on an upswing, unlike the other main European solar thermal markets.

1

Annual installed surfaces in 2016 per type of collectors (in m²) and power equivalent (in MWth)

	Glazed collectors		Unglazed collectors	Total (in m²)	Equivalent power (MWth)
	Flat plate collectors	Vacuum collectors			
Germany	677 000	67 000	22 000	766 000	536.2
Denmark	478 297			478 297	334.8
Greece	271 400	600		272 000	190.4
Spain	214 000			214 000	149.8
Italy	186 647	25 043		211 690	148.2
France*	114 894		5 500	120 394	84.3
Poland	116 000			116 000	81.2
Austria	109 600	1 440	760	111 800	78.3
Portugal	55 000			55 000	38.5
Belgium	39 000	7 500		46 500	32.6
Czechia	22 000	9 000		31 000	21.7
Netherlands	20 137	5 179	2 621	27 937	19.6
Ireland	23 305			23 305	16.3
Croatia	19 000	2 500		21 500	15.1
Hungary	13 050	5 592	188	18 830	13.2
Cyprus	18 000	600		18 600	13.0
Romania	6 800	11 000		17 800	12.5
United Kingdom	17 000			17 000	11.9
Bulgaria	10 000	0		10 000	7.0
Slovakia	8 000	1 600		9 600	6.7
Finland	5 000			5 000	3.5
Luxembourg	3 759			3 759	2.6
Sweden	2 763	336	75	3 174	2.2
Slovenia	2 300	400		2 700	1.9
Lithuania	800	1 400		2 200	1.5
Estonia	1 000	1 000		2 000	1.4
Malta	2 000			2 000	1.4
Latvia	1 500	300		1 800	1.3
Total EU 28	**2 438 252**	**140 490**	**31 144**	**2 609 886**	**1 827**

** Including 38 739 m² in overseas departments.* ***Source: EurObserv'ER 2018***

2

Annual installed surfaces in 2017 per type of collectors (in m²) and power equivalent (in MWth)*

	Glazed collectors		Unglazed collectors	Total (in m²)	Equivalent power (in MWth)
	Flat plate collectors	Vacuum collectors			
Germany	573 000	57 000	20 000	650 000	455.0
Greece	312 840	3 160		316 000	221.2
Spain	190 666	7 187	3 652	201 505	141.1
Denmark	173 387	0	0	173 387	121.4
Italy	159 666			159 666	111.8
France**	114 591		5 500	120 091	84.1
Poland	115 000			115 000	80.5
Austria	99 770	1 060	630	101 460	71.0
Portugal	55 105			55 105	38.6
Belgium	30 200	5 200	0	35 400	24.8
Netherlands	21 150	6 162	2 621	29 933	21.0
United Kingdom	28 000			28 000	19.6
Bulgaria	24 000			24 000	16.8
Czechia	16 500	7 500		24 000	16.8
Slovakia	24 000			24 000	16.8
Croatia	22 700			22 700	15.9
Ireland	11 254	9 049	0	20 303	14.2
Cyprus	18 000	860		18 860	13.2
Romania	6 800	11 000		17 800	12.5
Hungary	12 000	5 000	180	17 180	12.0
Finland	5 000			5 000	3.5
Luxembourg	3 600			3 600	2.5
Sweden	2 867	341		3 208	2.2
Slovenia	2 300	400		2 700	1.9
Lithuania	800	1 400		2 200	1.5
Estonia*	1 000	1 000		2 000	1.4
Latvia	1 500	300		1 800	1.3
Malta	518	130		648	0.5
Total EU 28	**2 026 214**	**116 749**	**32 583**	**2 175 546**	**1 522.9**

** Estimate. ** Including 39 220 m² in overseas departments.* ***Source: EurObserv'ER 2018***

3

Cumulated capacity of solar thermal collectors installed in the European Union in 2016 and 2017** (in m² and in MWth)*

	2016		2017	
	m²	MWth	m²	MWth
Germany	19 122 000	13 385	19 109 000	13 376
Austria	5 288 813	3 702	5 271 743	3 690
Greece	4 477 000	3 134	4 596 000	3 217
Italy	3 891 000	2 724	4 050 666	2 835
Spain	3 796 000	2 657	3 997 000	2 798
France	3 005 947	2 104	3 094 442	2 166
Poland	2 016 000	1 411	2 131 000	1 492
Denmark	1 368 997	958	1 542 384	1 080
United Kingdom	1 400 000	980	1 428 000	1 000
Portugal	1 176 000	823	1 231 105	862
Cyprus	1 025 000	718	1 043 860	731
Belgium	721 000	505	750 600	525
Netherlands	652 000	456	649 000	454
Czechia	569 000	398	593 000	415
Sweden	475 000	333	472 000	330
Bulgaria	354 000	248	378 000	265
Ireland	343 251	240	311 216	218
Hungary	292 000	204	308 000	216
Slovenia	239 000	167	238 750	167
Croatia	204 000	143	226 700	159
Slovakia	177 000	124	201 000	141
Romania	174 000	122	189 000	132
Malta	72 000	50	72 250	51
Luxembourg	59 550	42	63 150	44
Finland	55 000	39	60 000	42
Latvia	22 720	16	24 520	17
Lithuania	17 950	13	20 150	14
Estonia	14 120	10	16 120	11
Total EU 28	**51 008 348**	**35 706**	**52 068 656**	**36 448**

** All technologies including unglazed collectors. ** Estimate.* ***Source: EurObserv'ER 2018***

According to Costas Travasores, executive secretary of the EBHE (the Greek Solar Industry Association), the Greek market grew by 16.2% to 316 000 m² in 2017 compared to 272 000 m² in 2016. The EBHE ascribes this growth to the drop in the price of systems due to keen competition between players. Other factors are the increase in the number of distribution networks as e-business builds up, along with the emergence of new private labels working with OEM partners and a slight improvement in the Greek economy.

The Spanish market sags

According to the annual survey conducted by the Spanish Solar Thermal Association (ASIT), Spain installed 201 505 m² of collectors in 2017 (equating to 141 MWth of thermal capacity). The figure is slightly (5%) lower than last year's survey results. The installed base is put at 2 875 MWth, namely more than 4 million m² in area.

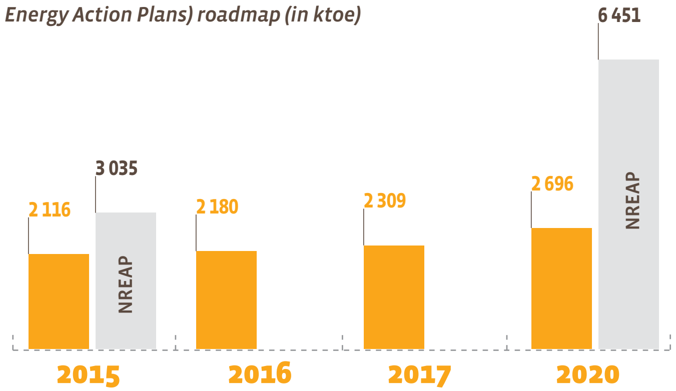
Spain's solar thermal market is closely linked to that of the new build market through the 2006 construction code (Technical Building Code) which made the installation of renewable hot water production systems obligatory in new buildings. The regulations propelled the sector to new heights in 2007 (641 419 dwellings built) and 2008 (615 072 dwellings built) only to plummet when the Spanish property bubble burst, compounded by the global financial crisis.

A QUESTION MARK HANGS OVER SOLAR HEAT'S CONTRIBUTION

The European market downturn observed since 2009 has deflected the sector's trajectory from the National Renewable Energy Action Plan (NREAP) targets. This decline begs the question of how solar heat's contribution to Europe's renewable energy targets can be kept up in the coming years, as older systems are decommissioned. The current market level is now very similar to 2003 (2.1 million m²). If proof of this trend is required, Austria, an erstwhile solar thermal pioneer with one of the highest equipment levels in Europe, saw solar heat's contribution drop slightly in 2017 after stabilizing in 2016.

4

Comparison of the current trend against the NREAP (National Renewable Energy Action Plans) roadmap (in ktoe)



Source: EurObserv'ER 2018

Nonetheless on paper, the intentions are clearly stated and likely to relaunch the sector in the next decade. The new European legislative package that defines the renewable energy trajectory to 2030 could encourage the member states to be much more proactive about solar heat. Article 23 of the new renewable energy directive states that each Member State must ensure that the renewable energy share of these uses increases every year, to facilitate the penetration of renewable energies in the heating and cooling sector. The indicative annual mean value adopted is 1.3 percentage points for the following periods: 2021–2025 and 2026–2030, starting from the baseline renewable energy share in the heat and cooling sector measured in 2020, expressed as the national share of final energy consumption.

Solar heat still has good prospects. Domestic hot water production in the collective sector has the most growth potential because of the huge reservoir of buildings requiring upgrading. Other growth opportunities such as solar heating networks and solar industrial heat should gradually develop and give the sector more room for manoeuvre. ■

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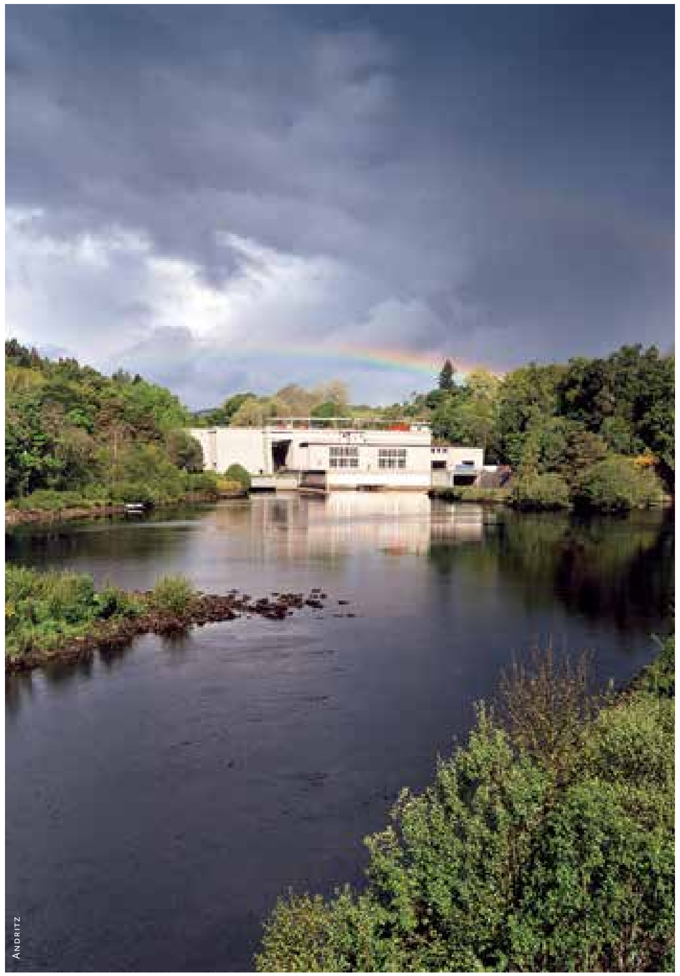
HYDROPOWER

Record rainfall deficit hit much of Europe in 2017. Hydropower generated by natural water flow, i.e. that does not take into account the electricity produced by pumping, generated just over 300 TWh in 2017 (300.7 TWh) in the European Union down from 351 TWh in 2016.

Only two of the major producer countries were spared, Sweden and Latvia. Sweden produced 3 TWh more than in 2016 with a total of 65.1 TWh, while Latvia produced an extra 1.9 TWh, with a total of 4.4 TWh in 2017.

The Southern and most westerly countries of Europe suffered the greatest losses. Spain's output was almost halved (by 48.4%) dropping from 36.4 to 18.8 TWh, while Portuguese hydropower output dropped 62.5% (losing 9.8 TWh) to just 5.9 TWh. French output was cut by 10.9 TWh (by 17.9%) down to 50 TWh, Italy lost 6.2 TWh (14.7%) of output to reach 36.2 TWh and Greece lost 1.6 TWh (28.5%) to generate 4 TWh. Germany and



1

Net capacity of pure hydro plants, mixed hydro plants and pure pumped hydro plants in the European Union in 2016 and in 2017 (in MW)*

	2016				2017			
	Pure hydro power	Mixed hydro power	Pumped hydro power	Total	Pure hydro power	Mixed hydro power	Pumped hydro power	Total
France	18 487	5 407	1 728	25 621	18 560	5 418	1 728	25 706
Italy	14 991	3 325	3 982	22 298	15 109	3 377	3 940	22 426
Spain	14 053	2 690	3 337	20 080	14 052	2 690	3 337	20 079
Sweden	16 367	99		16 466	16 403	99		16 502
Austria	8 493	5 623		14 116	8 506	5 644		14 150
Germany	4 573	1 187	5 540	11 300	4 449	1 178	5 493	11 120
Portugal	4 458	2 502		6 960	4 462	2 764		7 226
Romania	6 377	265	92	6 734	6 328	272	92	6 692
United Kingdom	1 835	300	2 444	4 579	1 874	300	2 444	4 618
Greece	2 693	699		3 392	2 693	699		3 392
Bulgaria	2 210	149	864	3 223	2 359	149	864	3 372
Finland	3 250			3 250	3 272			3 272
Slovakia	1 608		916	2 524	1 607		916	2 523
Poland	596	376	1 413	2 385	591	376	1 423	2 390
Czechia	1 090		1 172	2 262	1 093		1 172	2 265
Croatia	1 912	293		2 205	1 913	293		2 206
Latvia	1 564			1 564	1 564			1 564
Belgium	115		1310	1 425	113		1 310	1 423
Slovenia	1 113		180	1 293	1 167		180	1 347
Luxembourg	34		1296	1 330	35		1 296	1 331
Lithuania	117		760	877	117		760	877
Ireland	237		292	529	237		292	529
Hungary	57			57	57			57
Netherlands	37			37	37			37
Denmark	9			9	9			9
Estonia	6			6	7			7
Total EU 28	106 283	22 915	25 326	154 523	106 613	23 260	25 247	155 119

* Net maximum electrical capacity. **Source: Eurostat**

Austria suffered less with respective year-on-year drops of 0.4 TWh (1.9% to 20.2 TWh) and 1.5 TWh (3.8% to 38.4 TWh).

Hydropower output has been normalised over the last 15 years to mitigate the effects of variable runoff conditions. The Renewable Energy Directive has defined the methodology that the Member States must apply to their renewable energy target calculations. By using the SHARES statistical tool to calculate the targets, the normalised hydropower production adopted across the European Union was 348.9 TWh in 2017 – a 0.6% decrease over 2016 (351.0 TWh).

Turning to capacity, the statistical monitoring carried out by the official statistics institutes such as Eurostat and the International Energy Agency has been simplified. Since the 2017 annual "Renewable energies and waste" questionnaire, the official national statistics bodies no longer have to specify the conventional hydropower plant capacity (i.e. excluding pumping) by size (<1 MW, 1–10 MW and >10 MW). The conventional capacity that grouped these three power plant categories is now one single category, called "pure hydro plants". This groups together the hydropower plants that only use direct inputs of natural water and have no storage capacity for pumping to send the water upstream of the dam. The "mixed hydro plants" and "Pure pumped storage plants" classifications have not changed. Mixed hydro plants are those with natural water input where all or part of the facility can be used

2

Hydraulic gross electricity production (without pumping) in the European Union (in TWh) in 2016 and 2017

	2016	2017
Sweden	62.018	65.066
France	60.838	49.974
Austria	39.902	38.370
Italy	42.432	36.199
Germany	20.547	20.150
Spain	36.395	18.782
Finland	15.799	14.772
Romania	18.028	14.494
United Kingdom	5.390	5.928
Portugal	15.723	5.897
Croatia	6.853	5.307
Latvia	2.530	4.381
Slovakia	4.359	4.324
Greece	5.543	3.963
Slovenia	4.503	3.868
Bulgaria	3.942	2.828
Poland	2.140	2.560
Czechia	2.000	1.869
Ireland	0.681	0.692
Lithuania	0.454	0.602
Belgium	0.370	0.270
Hungary	0.259	0.220
Luxembourg	0.115	0.086
Netherlands	0.100	0.061
Estonia	0.035	0.026
Denmark	0.019	0.018
Total EU 28	350.976	300.707

Source: Eurostat

to pump the water upstream of the dam. This type of plant can thus produce power with natural water flow and also with water that has been previously pumped upstream of the dam. "Pure pumped storage plants" are not linked to a water course and do not use natural water flow. They comprise two impoundments at different altitudes and enable the energy to be stored by pumping the water from the lower impoundment to the upper impoundment when electricity demand is low.

According to Eurostat, the net maximum capacity of the European Union's pure hydro plants was measured at 106 613 MW in 2017 (106 283 MW in 2016), while the net maximum capacity of its mixed plants was 23 260 MW in 2017 (22 915 MW in 2016). If we only consider the pure hydro plants, the 5 most richly endowed countries (2017 data) are France (18 560 MW), Sweden (16 403 MW), Italy (15 109 MW), Spain (14 052 MW) and Austria (8 506 MW).

LAKE TO RUN-OF-RIVER HYDRO PLANTS

While the European Union's new statistical monitoring regulations make it harder to monitor "small hydro plant" capacities, which by definition comprise the <10 MW hydropower plants (excluding pumping), a new indicator has been proposed that differentiates "run-of-river plants" in the "pure hydro plants" category.

This new indicator is gradually being introduced. Not all the Member States have been able to use it so far. It makes the distinction between hydropower plants that use natural flow and the decrease in a river's height to produce electricity and "accumulating" or "lake" hydropower plants, whose water is stored in an impoundment (or lake) retained by a dam. Lake power plants enable seasonal storage to be made and production to be modulated to get through electricity load consumption peaks. Other hydropower plants said to be "pondage plants" have shorter accumulation periods and do not modulate their output more than daily or weekly. In the absence of storage capacity, the output of run-of-river plants must be used instantly at the time of production. While by number, they are mainly small power plants, bigger power plants (≥150 MW) are sited on the major European rivers like the Rhine. The net capacity of run-of-river hydro plants (2017 data) is particularly in high several countries, such as Italy (5 479 MW), Austria (5 272 MW) and Germany (4 097 MW). ■

GEOTHERMAL ENERGY

This form of energy is hot water or steam drawn from the subsoil. It is used for producing heat, electricity or to deal with cooling needs. Geothermal techniques and uses vary in line with the aquifer temperature (groundwater) from which the water is drawn. When it is in the range 30–150° C (from a depth of a few hundred to approximately 2 000 metres), geothermal heat can be used for district heating (heating networks) or be supplied directly to heat dwellings. The use of one or more very high capacity heat pumps (HP) may be envisaged to improve the performance of a geothermal heating network. Heat pumps increase the temperature range that can be harnessed by the network and thus make optimum use of available geothermal energy.

When the aquifer temperature ranges from 90 to 150° C, electricity can also be produced. In this case, the water drawn from the subsoil, transfers its heat to another liquid that vaporises at below 100° C. The steam obtained by this technique drives a turbine to generate electricity. These plants can be run as combined heat and power plants producing heat for heating networks and power at the same time. Water drawn from depths of more than 1 500 metres above 150° C (up to 250° C), reaches the surface as steam and can be used directly to drive electricity generating turbines. This is what is called high-energy geothermal power and is found in volcanic regions and along plate boundaries. Heat pump systems that extract the superficial heat from the soil and surface aquifers are dealt with specifically and by convention are excluded from official geothermal energy data.

1

Capacity installed and net usable capacity of geothermal electricity plants in the EU in 2016 and 2017 (in MWe)

	2016		2017	
	Capacity installed	Net capacity	Capacity installed	Net capacity
Italy	915.5	767.0	915.5	767.2
Germany	38.0	29.0	38.0	32.0
Portugal	28.8	25.0	34.3	29.1
France*	17.1	15.5	17.1	15.9
Hungary	0.0	0.0	3.4	3.0
Austria	1.0	0.9	1.0	0.9
Romania	0.0	0.0	0.05	0.05
Total EU 28	1 000.4	837.4	1 009.3	848.2

Net maximum electrical capacity. **Source EurObserv'ER 2018 (Capacity installed), Eurostat (Net capacity)*

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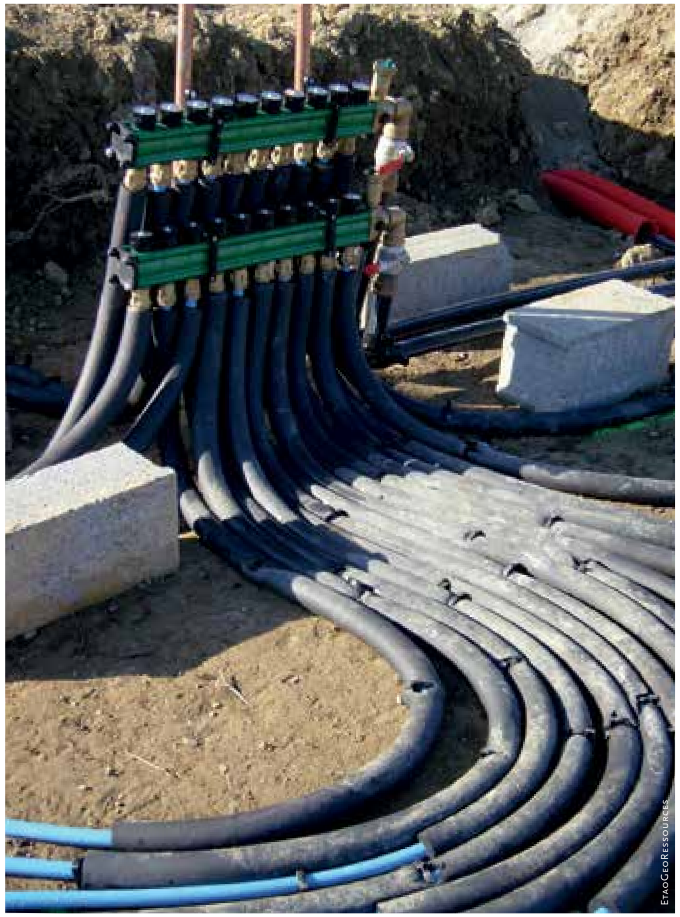
2

Gross electricity generation from geothermal energy in the European Union in 2016 and 2017 (in GWh)

	2016	2017
Italy	6 289.0	6 201.2
Portugal	172.0	216.7
Germany	175.0	163.0
France	97.6	133.1
Hungary	0.0	1.0
Austria	0.02	0.09
Total EU 28	6 733.6	6 715.0

Source: Eurostat



HEAT PRODUCTION

There are many applications for geothermal heat. The main use is for heating dwellings and commercial premises. Other uses are possible, primarily in agriculture (heating greenhouses, drying crops, etc.), fish-farming, industrial processes and heating pools. Refrigeration is another area of use. Faced with so many solutions, accurate and regular monitoring of the thermal capacity by the official statistical bodies can be dogged by shortcomings. In its annual market survey (EGEC Geothermal market report) EGEC (the European Geothermal Energy Council), provides data on European geothermal heating network capacities. The report states that at the end of 2017 the thermal capacity of the EU's geothermal heating networks was about 1 763 MW distributed over 198 heating networks. Most of the year's additional capacity was installed in France, the Netherlands and Italy. France commissioned three new networks in 2017, all of them in the Greater Paris region. A new doublet (a doublet is a double borehole, the first to draw water and the second to re-inject it into the water table) has been added to the Blanc Mesnil (1 MW) urban network and another to the Dammarie-Les-Lys (9 MW) network. France also inaugurated the new urban heating network at Grigny (10 MW). The Netherlands, together with France, is one of the most active geothermal players. It commissioned two new heating networks... one at Venlo/Grubbenvorst (10.6 MW) and the other at Ardwarmte Vogelaer (10.2 MW), while The Piancastagnaio-Siena (4.4 MW) project was commissioned in Tuscany, Italy for the "La Rota" industrial estate.

3

Capacity of geothermal district heating systems installed in the European Union in 2016 and 2017 (in MWth)

	2016	2017
France	493	509
Germany	336	336
Hungary	254	253
Italy	157	160
Netherlands	127	142
Romania	85	88
Poland	64	64
Austria	60	60
Sweden	48	44
Denmark	33	33
Croatia	20	20
Slovakia	16	16
Lithuania	14	14
Belgium	10	10
Czechia	7	8
Slovenia	4	4
United Kingdom	2	2
Total EU 28	1 730	1 763

Source: EGEC Market reports 2016 and 2017

Geothermal heat output data is regularly monitored by the national statistics bodies and Eurostat. The official data, that amalgamates the heat distributed by the networks and the heat used directly by final consumers, records 828.7 ktoe of output in 2017 (257.9 ktoe of derived heat and 570.8 ktoe of final energy consumption), which points to 6.5% growth over the twelve month period.

ELECTRICITY PRODUCTION

The geothermal power capacity of all the European Union countries taken together is slowly increasing. In 2017, 8.9 MW of new capacity was installed taking the total to 1009.3 MW. Net capacity, which is the maximum usable capacity, is put at 848.2 MW (10.7 MW). Gross geothermal power output changed very slightly (it was 0.3% less than in 2016) at 6.7 TWh. Lower output in Germany and Italy was made up for by the Portuguese and French increases. Italy dominates geothermal power production in the EU (6.2 TWh in 2017), and alone accounts for 92.3% of the total.

According to EurObserv'ER, two countries increased their geothermal power capacity in 2017. Hungary commissioned its first geothermal plant in November 2017 to become the 6th European Union country with a geothermal power sector. The Tura plant, owned by KS Orka, uses binary cycle technology and operates as a CHP plant with 3.35 MW of electrical capacity and 7 MW of thermal capacity. While the electrical part went on stream at the end of 2017, the plant will only start recovering heat once construction of the greenhouses due to be heated is completed in 2018. The project's second phase is now being prepared and could eventually take the site's power-generating capacity to more than 10 MW. Portugal also commissioned a plant in November 2017 – Pico Alto (an ORC type binary cycle plant) on Terceira Island in the autonomous region of the Azores. This 4.5 MW power plant is designed to produce 21 GWh of electricity per annum and cover 10% of the island's electricity requirements.

THE SECTOR CALLS FOR THE REMOVAL OF BARRIERS

While every year deep geothermal energy contributes more to meeting the climate targets, it falls far short of the trajectory planned in the national renewable energy action plans. The sector players complain that the dearth of public authority awareness of the technology or commitment constitute a major barrier to broader deployment of geothermal energy. They argue that a stable framework to provide project developers with security of investment must be set up if geothermal energy is

4

Heat consumption from geothermal energy in the European Union in 2016 and 2017

	2016			2017		
	Total heat consumption	of which final energy consumption	of which derived heat*	Total heat consumption	of which final energy consumption	of which derived heat*
France	145.2	40.2	105.0	170.1	40.2	130.0
Italy	144.1	124.7	19.3	149.8	130.8	18.9
Hungary	115.1	50.6	64.5	127.5	61.8	65.7
Germany	100.1	81.1	19.0	100.4	85.1	15.3
Netherlands	67.9	67.9	0.0	72.8	72.8	0.0
Slovenia	44.2	43.8	0.4	48.3	47.8	0.4
Bulgaria	34.6	34.6	0.0	34.6	34.6	0.0
Romania	31.7	25.6	6.1	32.5	26.2	6.3
Poland	22.2	22.2	0.0	22.6	22.6	0.0
Austria	21.2	7.2	14.0	21.7	7.5	14.1
Spain	18.8	18.8	0.0	18.8	18.8	0.0
Greece	10.1	10.1	0.0	8.8	8.8	0.0
Croatia	9.1	9.1	0.0	8.2	8.2	0.0
Slovakia	4.9	1.6	3.3	5.0	1.5	3.5
Denmark	2.7	0.0	2.7	1.8	0.0	1.8
Portugal	1.4	1.4	0.0	1.6	1.6	0.0
Cyprus	1.6	1.6	0.0	1.6	1.6	0.0
Belgium	1.6	0.0	1.6	1.5	0.0	1.5
United Kingdom	0.8	0.8	0.0	0.8	0.8	0.0
Lithuania	1.0	0.0	1.0	0.4	0.0	0.4
Total EU 28	**778.2**	**541.1**	**237.0**	**828.7**	**570.8**	**257.9**

** Essentially district heating (see Eurostat definition).* ***Source: Eurostat***

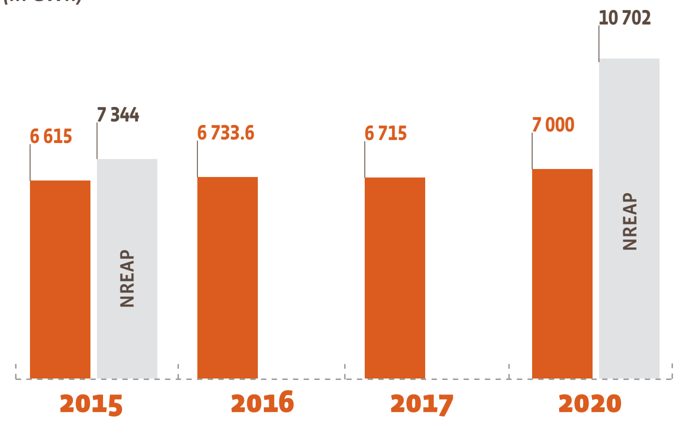
ever to expand. This should be achieved through support programmes, and suitable regulatory and operating conditions required by deep geothermal technologies. According to the EGEC, many projects launched will lead to a significant expansion in deep geothermal capacity for heating and cooling, and also for power. However, these new additions will fall short of meeting the 2020 targets, because to do so implies increasing the deep geothermal capacity installed for heating and cooling almost four-fold and increasing installed geothermal power capacity by 50% within the next two to three years. Furthermore, geothermal project lead times are fairly long. As a result, it is fairly unlikely that they will all be commissioned before 2020. Nevertheless, some countries can be quoted as positive examples. The Netherlands is one of the few EU Member States to have set up

a framework suitable for ambitious geothermal development, that will galvanise its geothermal industry into providing new renewable energy capacities.

In a joint statement sent to the European bodies and member countries in November 2018, the geothermal sector players also asked for stronger backing for research, development and innovation in geothermal energy, and the launching of a major European geothermal exploration campaign. Limited knowledge of the deep subsoil is viewed as a major barrier to the development of geothermal projects. They consider that the removal of these barriers is essential to enable the sector to make a meaningful contribution to the EU's climate targets by the 2030 and 2050 timelines. ■

5

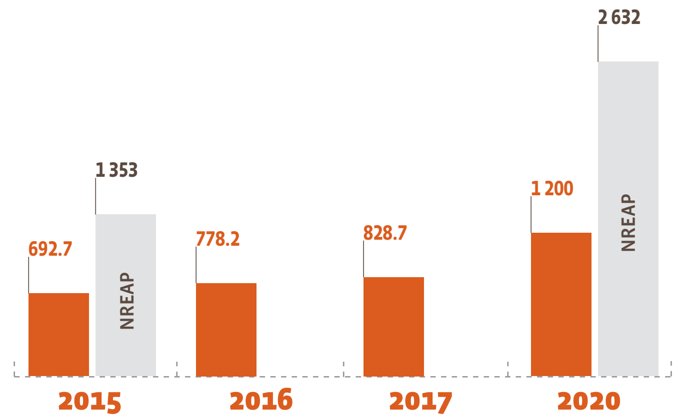
Comparison of the current geothermal electricity generation trend against the NREAP (National Renewable Energy Action Plan) roadmap (in GWh)



Source: EurObserv'ER 2018

6

Comparison of the current geothermal heat generation trend against the NREAP (National Renewable Energy Action Plan) roadmap (in ktoe)



Source: EurObserv'ER 2018

HEAT PUMPS

In order to understand heat pump (HP) market trends, you must first be able to identify the various types of systems. There are three main HP families differentiated by the heat source used. Air-sourced heat pumps (ASHP) use the air (ambient, extracted or indoor) as their heat source. Ground-source heat pumps (GSHP) extract their heat from the ground while hydrothermal HPs use heat from water (groundwater, rivers or lakes). EurObserv'ER amalgamates the hydrothermal family of HPs with ground-source HPs, in the interests of simplicity.

Heat from GSHPs is distributed via a heating circuit through underfloor heating or to low- or high-temperature radiators, the notion being that of water-based heat. ASHPs use various heat distribution methods. Some of them, like GSHPs use water as the vector and are known as air-water HPs. Others use systems that blow out hot air and are known as air-air HPs. Almost all of these air-air systems work reversibly, and their cooling function often makes air-conditioning the main use for them in hot climate countries. Reversible air-air HPs dominate HP system sales in the EU. Their unit capacity is generally much lower than that of water-based HPs.

Viessmann Werke GmbH & Co.

We should point out that the amount of renewable energy produced by heat pumps varies. Firstly, it depends on the auxiliary energy source used to run the compressor (the country's electricity system mix), the heat source used (ground, water, air), the mode used (heating versus cooling), the length of time used and the climate zone where they are installed. The European Commission published a methodological guide in March 2013 to help the Member States measure the renewable energy production generated by their heat pump bases, that set out guidelines for calculating the renewable energy share produced by the various heat pump technologies in compliance with Article 5 of the 2009/28/EC directive.

THE HP MARKET FOR HEATING IS IN FINE FETTLE

The European heat pump sector for heating and cooling applications has been based on strong markets for many years. According to EurObserv'ER, more than 3.5 million systems were sold in the European Union in 2017, which is a 4.4% increase over 2016. Growth could have been very much better had it not been for the downturn in the Italian market, the main European market, whose volume is heavily geared to cooling requirements. Approximately one third of the total sales were intended to cover heating requirements (1.1 million according to EHPA). The remaining two-thirds catered for cooling needs in warmer country climates (Italy, Spain, Portugal, and the South of France in particular). This ambivalence with regard to uses raises statistical comparison issues between the various EU markets, all the more so because reversible air-air HPs are used in heating mode in Northern Europe – in Sweden, Denmark and Finland.

Reversible air-air ASHPs still account for the majority of sales in the European market with 3.1 million systems sold in 2017, which is about 100 000 units more than in 2016 (3.3% growth). The only reason for the glitch in reversible air-air HP market growth is poorer performance by the Italian market (which slipped 7.2% on its 2016 sales). Given its size – 45% of the EU market for these HPs – this decline hit overall HP sales figures. Italy's market is very specific in that in volume it is essentially geared to cooling needs. The reason for the decline may be that the market was saturated after the sweltering summer of 2016 prompted a surge in sales (55.4%). The increase in summer comfort needs is now the main reversible air-air HP market driver in France, Spain and Portugal.

The air-water ASHP market specifically meets heating needs. Sales have steadily risen since 2013 and even accelerated in 2017 increasing by 18.3%, with more than 300 000 units sold (300 756 registered in 21 EU countries), after already having increased by 13% in 2016.

EurObserv'ER found the 2017 geothermal HP market (which in our study includes hydrothermal HPs) to be stable (it slipped 0.6%). However, performance was patchy across Europe. The market perked up in the UK, Belgium and the Netherlands, finally stabilized in France, Austria and Sweden, but appears to be contracting in Finland and Denmark, where geothermal HPs are already well established.

EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2018 EDITION

RENEWABLE ENERGY PRODUCTION IN 2017: 10.5 MTOE

While the Eurostat SHARES tool used to monitor progress on the renewable energy targets does not provide a market indicator, it does specify the capacity of national HP bases eligible for renewable energy production accounting in its detailed version. This data enables us to determine the amount of renewable energy delivered by HPs using the methodology and criteria defined by the Renewable Energy Directive. According to SHARES, this contribution was 10 467 ktoe in 2017, an increase of 537 ktoe over 2016. Therefore, HPs make a high contribution to the increase in renewable heat across the European Union. It is also the main renewable technology capable of meeting cooling needs.

THE ROUTE TO 2030 IS NOW MAPPED OUT

Major trends will contribute to a build-up of this technology for the next few years as regulatory and political signals encourage further electrification of heating needs.

The technological progress made over the last decade has opened up new growth opportunities. High-temperature heat pumps can now run efficiently when outdoor

1

Market of aerothermal heat pumps in 2016 and 2017 (number of units sold).*

	2016				2017			
	Aerothermal HP	of which air-air HP	of which air-water HP	of which exhaust air HP	Aerothermal HP	of which air-air HP	of which air-water HP	of which exhaust air HP
Italy	1 541 200	1 511 400	29 800	0	1 440 000	1 403 000	37 000	0
Spain	792 088	781 116	10 972	0	912 378	901 406	10 972	0
France	446 745	372 270	74 475	0	487 090	405 390	81 700	0
Portugal	129 136	128 611	525	0	144 666	144 141	525	0
Sweden	78 413	55 000	8 099	15 314	81 355	55 000	9 035	17 320
Netherlands	69 797	58 618	11 179	0	80 026	60 168	19 858	0
Germany	60 970	0	48 501	12 469	71 138	0	57 638	13 500
Belgium	37 812	32 350	5 462	0	55 528	49 190	6 338	0
Finland	51 672	45 742	3 709	2 221	54 141	47 281	4 138	2 722
Denmark	25 209	21 396	3 784	29	41 793	35 504	6 125	164
United Kingdom	16 058	0	16 058	0	19 260	0	18 935	325
Poland	8 756	3 546	5 160	50	16 370	8 280	8 080	10
Estonia	15 010	13 700	1 280	30	15 010	13 700	1 280	30
Czechia	10 862	0	10 827	35	13 778	0	13 718	60
Austria	12 131	0	12 076	55	13 764	0	13 689	75
Ireland	4 457	0	4 398	59	4 457	0	4 398	59
Slovenia	5 200	0	5 200	0	3 200	0	3 200	0
Slovakia	1 888	158	1 730	0	2 554	306	2 248	0
Lithuania	890	0	890	0	1 498	0	1 474	24
Hungary	180	70	105	5	650	320	325	5
Luxembourg	80	0	80	0	80	0	80	0
Total EU 28	**3 308 553**	**3 023 976**	**254 310**	**30 267**	**3 458 736**	**3 123 686**	**300 756**	**34 294**

*Note: Data from Italian, French and Portuguese aerothermal heat pump market are not directly comparable to others, because they include the heat pumps whose principal function is cooling. *Estimate. **Source: EurObserv'ER 2018***

2

Market of geothermal (ground source) heat pumps in 2016 et 2017** (number of units sold)*

	2016	2017
Sweden	22 843	22 641
Germany	20 789	20 170
Finland	8 491	7 986
Poland	5 390	5 660
Austria	5 228	5 230
Netherlands	4 065	4 806
France	3 095	3 100
United Kingdom	1 920	2 358
Denmark	2 248	2 143
Belgium	1 600	1 963
Estonia	1 750	1 750
Czechia	1 521	1 561
Italy	857	860
Lithuania	770	633
Slovenia	700	598
Ireland	371	291
Hungary	800	220
Slovakia	242	168
Luxembourg	116	116
Spain	77	95
Portugal	25	52
Bulgaria	0	0
Total EU 28	**82 898**	**82 401**

** Hydrothermal heat pumps included. ** Estimate. **Source: EurObserv'ER 2018***

3

*Total number of heat pumps in operation in 2016 and 2017**

	2016			2017		
	Aerothermal heat pumps	Ground source heat pumps	Total heat pumps	Aerothermal heat pumps	Ground source heat pumps	Total heat pumps
Italy	19 045 000	14 220	19 059 220	19 520 000	14 200	19 534 200
France	5 085 653	151 770	5 237 423	5 572 743	154 870	5 727 613
Spain	2 289 432	1 293	2 290 725	3 201 810	1 388	3 203 198
Sweden	1 057 666	514 038	1 571 704	1 136 341	525 678	1 662 019
Germany	551 958	339 946	891 904	616 569	358 181	974 750
Finland	629 480	102 995	732 475	683 621	110 981	794 602
Portugal	384 080	857	384 937	528 746	909	529 655
Netherlands	316 899	50 943	367 842	393 922	54 846	448 768
Denmark	272 470	60 691	333 161	290 254	61 204	351 458
Bulgaria	214 971	4 272	219 243	214 971	4 272	219 243
Austria	79 065	99 547	178 612	92 808	103 120	195 928
United Kingdom	130 852	29 183	160 035	150 112	31 541	181 653
Belgium	91 938	9 374	101 312	147 466	11 337	158 803
Estonia	116 717	12 375	129 092	131 727	14 125	145 852
Poland	45 361	41 995	87 356	61 731	47 655	109 386
Czechia	54 975	23 149	78 124	68 753	24 710	93 463
Slovenia	24 900	10 050	34 950	27 900	10 648	38 548
Ireland	13 484	3 824	17 308	17 941	4 115	22 056
Slovakia	8 495	3 315	11 810	11 049	3 483	14 532
Lithuania	2 760	4 463	7 223	4 258	5 096	9 354
Hungary	5 400	1 310	6 710	6 050	1 530	7 580
Luxembourg	1 309	555	1 864	1 389	671	2 060
Total EU 28	30 422 864	1 480 165	31 903 029	32 880 160	1 544 560	34 424 720

*Note: Data from italian, French and Portuguese aerothermal heat pump market are not directly comparable to others, because they include the heat pumps whose principal function is cooling. * Estimate.* ***Source: EurObserv'ER 2018***

temperatures are sub-zero. As a result, they can be used in many more buildings and tackle the renovation market head-on.

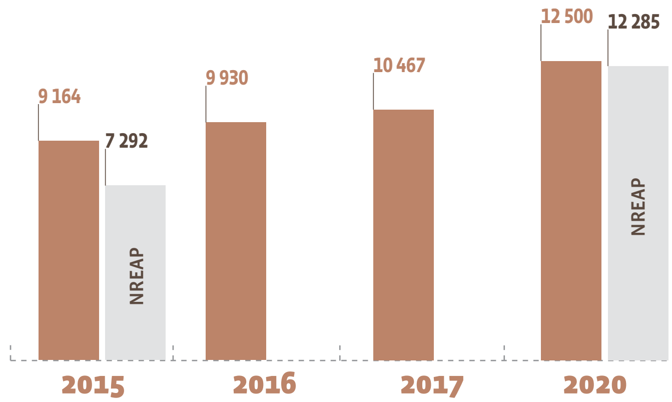
Heat pumps also benefit from a winning combination as individual and collective solar photovoltaic self-consumption takes off. The possibility of generating one's own power at lower cost than purchasing it from the grid has begun to influence the heating and domestic hot water market. As peaks in solar power production coincide directly with summer comfort needs, the move to solar photovoltaic power self-consumption is also a boon to the reversible ASHP market.

Article 23 of the new renewable energy directive 2018/2001 (December 11, 2018) will have a direct impact on the HP sector's development trajectory. This article specifies that to help renewable energy enter the heating and cooling sector, each Member State must keep up an annual increase in the renewable energy share of these uses. The proposed indicative annual mean value adopted is 1.3 percentage points for the following periods: 2021–2025 and 2026–2030, starting from the baseline renewable energy share measured in 2020, expressed as the national share of final energy consumption.

Generally speaking, the new European legislation that has been adopted sends an extremely positive signal to heat pumps industrials. The route to 2030 is now mapped out and it is up to the heat pump sector to rise to the challenge of the European Union's renewable energy ambitions. ■

4

Comparison of the current trend against the NREAP (National Renewable Energy Action Plans) roadmap (in ktoe)



Source: EurObserv'ER 2018

BIOGAS

Methanization is a natural biological process in which many micro-organisms (bacteria) break down organic matter in an oxygen-free environment. Methanization biogas produced by anaerobic fermentation is classified as three subsectors along the lines of the origin and treatment of the waste. They are methanization of wastewater treatment plant sludge ("sewage sludge gas"), non-hazardous waste storage facility biogas ("landfill gas") and the methanization of non-hazardous waste or raw plant matter ("other biogas"). A fourth biogas sector is also monitored in international nomenclatures. It is produced by applying a thermal treatment ("biogas from thermal treatments"), namely pyrolysis or gasification of solid biomass (wood, forest residue, solid and fermentable household waste). These processes produce hydrogen (H_2) and carbon monoxide (CO), which when combined can be transformed into synthetic biogas to substitute natural gas (CH_4). These processes have been identified in Finland, Spain, Denmark, Italy and Belgium, and new projects are underway, as in the Netherlands.

16.8 MILLION TOE PRODUCED IN THE EUROPEAN UNION

In 2017, primary energy output from biogas in the European Union slightly rose (0,4% more than in 2016). According to Eurostat, it amounted to 16 812 ktoe compared to 16 742 ktoe in 2016. This outcome is in keeping with the slower growth displayed by the sector since 2011. Primary energy output growth has steadily declined ever since it peaked in 2011 (with a year-on-year rise of 21.9%). The introduction of more stringent regulations governing the use of food crops (such as maize), limiting the capacities allocated to biogas tenders and much less attractive biogas electricity remuneration conditions accounts for the dwindling growth. While the general trend of the main producer countries is one of slowdown (the UK, Poland, Italy), and even lower output (Germany, Austria), biogas is still enjoying double-digit growth in four countries – Denmark (34.0%, at 389 ktoe), France (14.0%, at 899.5 ktoe) Finland (11.1%, at 124.5 ktoe) and Estonia (20.5%, at 12.9 ktoe). France increased its output more than any other country in 2017 (by 110.7 ktoe). It had introduced a more lucrative remuneration system which is starting to pay off (feed-in tariff for biogas injection, higher feed-in tariff for small plants of <500 kW, tenders for >500-kw plants), yet still limits the food crop input allowed in production. Non-hazardous waste or raw plant matter methanization plants may have food or energy crop inputs, grown as a main crop provided the maximum annual proportion of raw tonnage feedstock per annum does not exceed 15%.

According to Eurostat, non-hazardous waste and raw plant matter methanization biogas ("other biogas") now accounts three-quarters (75%) of biogas production (74.9% in 2016). This increase has been at the expense of landfill biogas (which fell from 16 to 15.4%). Sewage sludge biogas production rose slightly (from 8.2 to 8.3%) in 2017 while the thermal biogas share rose from 1.0 to 1.3%.

While primary energy output has not increased across the European Union, the same does

Bioconstruct

not apply to final energy output, which suggests fewer losses in the processing sector. According to Eurostat, biogas electricity output totalled 63.4 TWh in 2017 compared to 62.8 TWh in 2016, or a 1% increase. Its recovery as heat increased at a faster pace. Derived heat (from the processing sector) came to 757.2 ktoe by the end of 2017 (695.9 ktoe at the end of 2016), which equates to 8.8% growth. Final energy consumption (disregarding the processing sector), is put at 3 million toe at the end of 2017 (3.4% more than in 2016).

Biogas can also be purified for conversion into biomethane, which is then used in the same way as natural gas – namely as electricity in CHP plants, or also by natural gas vehicles (NGV) and alternatively can be injected into the natural gas grid. In recent years, biomethane injection has become a major outlet for the biogas market. The European Biomethane Observatory reports that at the end of 2017, the European sector had at least 542 biomethane

1

Primary energy production from biogas in the European Union in 2016 and 2017 (in ktoe)

	2016					2017				
	Landfill gas	Sewage sludge gas	Other biogas from anaerobic fermentation	Thermal biogas	Total	Landfill gas	Sewage sludge gas	Other biogas from anaerobic fermentation	Thermal biogas	Total
Germany	83.5	464.3	7547.2	0.0	8095.0	132.0	460.4	7252.1	0.0	7844.6
United Kingdom	1400.8	303.4	938.7	0.0	2642.9	1277.1	311.6	1130.2	0.0	2718.9
Italy	365.5	53.1	1449.9	6.6	1875.1	349.8	53.5	1488.0	6.4	1897.7
France	290.1	25.4	473.3	0.0	788.8	311.1	27.4	561.0	0.0	899.5
Czechia	25.4	41.5	534.0	0.0	601.0	23.1	43.1	541.4	0.0	607.7
Netherlands	16.2	57.6	244.9	0.0	318.6	16.9	57.6	246.4	0.0	320.8
Austria	3.7	15.1	287.6	0.0	306.4	2.4	14.5	229.1	0.0	246.1
Denmark	4.7	25.2	186.2	74.2	290.3	4.7	26.3	235.5	122.5	389.0
Poland	57.6	119.8	83.7	0.0	261.1	48.0	115.0	117.5	0.0	280.6
Spain	138.6	62.1	20.5	23.9	245.2	149.9	64.7	22.8	23.9	261.4
Belgium	21.9	26.3	179.8	5.9	233.9	20.0	24.9	174.1	5.3	224.3
Sweden	6.7	75.6	91.2	0.0	173.5	4.7	78.6	94.6	0.0	177.8
Slovakia	11.9	10.6	129.4	0.0	151.8	9.9	12.5	130.1	0.0	152.5
Finland	22.8	15.1	25.0	49.3	112.1	20.9	16.1	31.4	56.1	124.5
Greece	72.5	16.6	12.6	0.0	101.7	68.8	16.1	22.2	0.0	107.1
Latvia	7.8	2.6	79.5	0.0	89.9	8.1	2.4	82.7	0.0	93.2
Hungary	18.4	23.2	46.9	0.0	88.6	15.1	29.0	47.9	0.0	91.9
Portugal	68.2	2.7	9.4	0.0	80.3	73.5	3.0	8.6	0.0	85.1
Bulgaria	0.1	0.2	59.7	0.0	60.0	0.0	2.8	44.0	0.0	46.8
Ireland	38.9	8.4	7.5	0.0	54.8	38.1	9.2	7.2	0.0	54.6
Croatia	5.3	3.5	37.9	0.0	46.6	5.0	3.5	55.3	0.0	63.8
Lithuania	8.5	7.5	16.0	0.0	32.0	5.1	7.2	19.9	0.0	32.2
Slovenia	3.7	2.2	24.3	0.0	30.2	1.9	2.1	21.8	0.0	25.7
Luxembourg	0.0	2.3	17.6	0.0	19.9	0.0	1.8	18.7	0.0	20.5
Romania	0.0	0.0	17.7	0.0	17.7	0.0	0.0	18.0	0.0	18.0
Cyprus	0.0	0.6	11.1	0.0	11.8	0.0	0.7	11.4	0.0	12.0
Estonia	7.2	3.5	0.0	0.0	10.7	9.5	3.4	0.0	0.0	12.9
Malta	0.0	0.0	1.9	0.0	1.9	0.0	0.0	2.3	0.0	2.3
Total EU 28	2679.9	1368.5	12533.3	159.9	16741.6	2595.5	1387.4	12614.4	214.3	16811.6

Source: Eurostat

producing plants (528 in the European Union, 35 in Switzerland and 9 in Norway). The vast majority of these plants inject biomethane directly into the grid.

Germany, with 203, had the highest number of plants at the end of the year, followed by Sweden (67) and the UK (85). Biomethane injection into the grid is growing steadily in France. According to the SDES (Monitoring and Statistics Directorate) trend charts, 44 plants were injecting into the gas grid at the end of 2017 for maximum annual production capacity of 696 GWh, compared to 67 plants on 30 September 2018, with maximum annual production capacity of 1048 GWh. Sweden is a special case as only 27% of its plants inject into the grid, since most of the biomethane produced is used in the country's road transport. According to Statistics Sweden, 111 ktoe of biomethane was used directly in transport in 2017 compared to 98.9 ktoe in 2016.

THE 30-MTOE TARGET CAN BE ACHIEVED BY 2030

The main European biogas producer countries' decision to reduce or regulate the use of energy crops, has had a strong impact on the biogas sector's growth scenarios. They are now more closely linked to optimized recovery of digestate rather than the increased use of energy crops, at least until 2030.

In the long-term, rapid commitment to energy strategy choices will be required to set up a climate neutral economy in line

2

Gross electricity production from biogas in the European Union in 2016 and 2017 (in GWh)

	2016			2017		
	Electricity only plants	CHP plants	Total	Electricity only plants	CHP plants	Total
Germany	9 223.1	24 480.4	33 703.5	7 911.0	25 968.0	33 879.0
Italy	3 073.2	5 185.5	8 258.7	2 961.1	5 338.0	8 299.1
United Kingdom	7 024.6	711.1	7 735.7	6 937.2	784.6	7 721.8
Czechia	49.2	2 539.8	2 589.0	41.3	2 598.0	2 639.3
France	661.2	1 306.7	1 967.9	382.3	1 709.2	2 091.5
Poland	0.0	1 027.6	1 027.6	0.0	1 096.4	1 096.4
Spain	726.0	180.1	906.0	742.0	199.0	941.0
Belgium	93.0	893.0	986.0	72.3	866.0	938.3
Netherlands	34.0	958.8	992.8	29.7	893.6	923.3
Denmark	0.8	565.4	566.1	1.0	685.1	686.0
Austria	597.3	68.5	665.9	562.7	67.4	630.1
Slovakia	114.0	462.0	576.0	86.0	508.0	594.0
Finland	222.3	174.6	396.8	231.6	179.6	411.2
Latvia	0.0	396.9	396.9	0.0	405.4	405.4
Hungary	90.2	243.1	333.3	88.0	246.0	334.0
Croatia	26.4	211.0	237.3	24.1	285.6	309.7
Greece	32.8	236.9	269.6	51.0	249.2	300.2
Portugal	267.8	16.7	284.6	269.6	16.9	286.5
Bulgaria	96.4	94.4	190.8	93.0	122.8	215.8
Ireland	160.9	44.2	205.1	155.0	42.6	197.7
Slovenia	2.3	139.8	142.1	1.1	129.0	130.1
Lithuania	0.0	122.7	122.7	0.0	127.2	127.2
Luxembourg	0.0	72.7	72.7	0.0	72.4	72.4
Romania	35.9	29.0	64.9	38.1	28.6	66.7
Cyprus	0.0	52.0	52.0	0.0	51.8	51.8
Estonia	0.0	45.0	45.0	0.0	41.8	41.8
Sweden	0.1	11.0	11.1	0.0	11.0	11.0
Malta	0.0	8.3	8.3	0.0	9.7	9.7
Total EU 28	22 531.4	40 277.2	62 808.7	20 678.1	42 732.9	63 411.0

Source: Eurostat

3

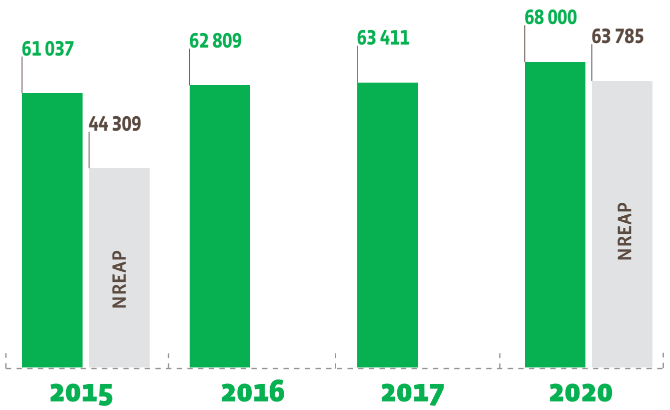
Gross heat production from biogas in the European Union in 2016 and in 2017 (in ktoe) in the transformation sector**

	2016			2017		
	Heat only plants	CHP plants	Total	Heat only plants	CHP plants	Total
Italy	0.2	207.8	208.0	0.1	225.9	226.0
Germany	68.8	153.8	222.5	60.0	154.7	214.7
Denmark	14.8	62.6	77.4	19.1	79.9	99.0
France	5.8	40.0	45.8	14.2	47.9	62.1
Latvia	0.0	22.7	22.7	0.0	23.9	23.9
Poland	0.3	13.8	14.1	0.3	21.0	21.3
Finland	7.0	12.9	19.8	6.0	15.1	21.2
Czechia	0.0	14.3	14.3	0.0	17.2	17.2
Slovakia	0.0	11.2	11.2	0.1	13.0	13.1
Sweden	3.1	3.5	6.5	7.1	3.3	10.4
Belgium	0.0	10.2	10.2	0.0	8.9	8.9
Croatia	0.0	6.8	6.8	0.0	7.8	7.8
Netherlands	0.0	6.5	6.5	0.0	6.4	6.4
Slovenia	0.0	6.6	6.6	0.0	5.3	5.3
Romania	0.4	3.5	3.9	1.6	3.3	4.9
Austria	1.6	4.2	5.9	1.2	2.5	3.7
Bulgaria	0.0	3.2	3.2	0.0	3.3	3.3
Luxembourg	0.0	2.0	2.0	0.0	2.0	2.0
Lithuania	0.0	2.2	2.2	0.0	2.0	2.0
Hungary	0.2	3.8	3.9	0.0	1.8	1.8
Cyprus	0.0	1.2	1.2	0.0	1.3	1.3
Estonia	0.0	0.6	0.6	0.0	0.6	0.6
Malta	0.0	0.2	0.2	0.0	0.4	0.4
Ireland	0.0	0.0	0.0	0.0	0.0	0.0
Greece	0.0	0.0	0.0	0.0	0.0	0.0
Spain	0.0	0.0	0.0	0.0	0.0	0.0
Portugal	0.0	0.0	0.0	0.0	0.0	0.0
United Kingdom	0.0	0.0	0.0	0.0	0.0	0.0
Total EU 28	102.1	593.8	695.9	109.7	647.5	757.2

** Corresponds to «Derived heat» (see Eurostat definition). **Source: Eurostat***

4

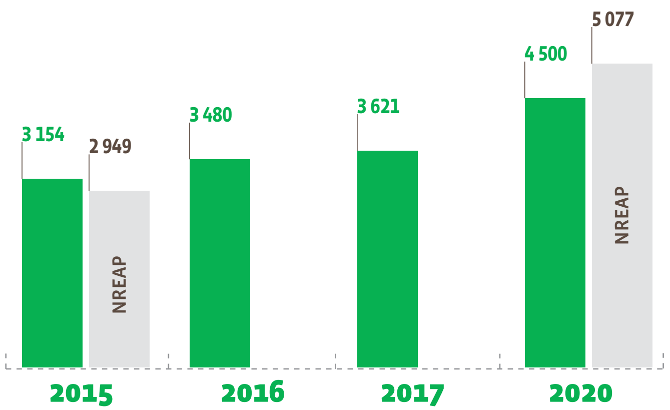
Comparison of the current trend of electricity biogas generation against the NREAP (National Renewable Energy Action Plans) roadmap (in GWh)



Source: EurObserv'ER 2018

5

Comparison of the current trend of biogas heat consumption against the NREAP (National Renewable Energy Action Plans) roadmap (in ktoe)



Source: EurObserv'ER 2018

with the Paris Agreement. The European Commission, at the request of the European Council, provided an initial response on 28 November 2018 in the form of a communiqué entitled "A Clean Planet for all", along with an in-depth analysis "Depth analysis in Support of the Commission". The Commission believes that achieving a climate neutral economy by 2050 is technologically, economically and socially achievable, but will call for societal and economic sea changes within a single generation. The Commission's "In depth Analysis" puts forward eight scenarios to enable the European Union to achieve its climate objectives. Each one has an important role to play for renewable gas. The Commission reckons that the contribution of methanization biogas could increase from 16 Mtoe in 2015 to 30 Mtoe by 2030 (including a small amount of "thermal" biogas), and according to the scenarios examined, could change by 2050 from 45 Mtoe (EE scenario) to 79 Mtoe (P2X scenario).

E-gas (biomethane produced by electrolysis), would add 91 Mtoe in 2050 and between 40 and 50 Mtoe according to the other scenarios that have considered its widescale use. The various renewable gas industry players have expressed their willingness to help the European Commission turn these scenarios into reality. They highlight the benefits of gas distribution networks for smoothing out renewable electricity production fluctuations. They emphasize the technical ease and storage capacities of the gas distribution networks, the advantages of a hybrid energy infras-

Andre Wipff / Agrivalor

tructure, based on stronger gas and electricity networks that in their view would form the backbone of a completely carbon-free European energy system. ■

BIOFUELS

The final settlement of the new renewable energy directive has at last ended the uncertainty over biofuel's future. Its deployment now has a more formal framework which should enable the sector to match the philosophy of the forthcoming climate-energy package, namely, to combat climate warming. Biofuel consumption figures in the transport sector reflect this expected outcome, for having been stable for several years, consumption picked up in 2017 (growing by 8.0%), to reach 15.4 Mtoe.

Time has been taken to reflect and consult on renewable energy's contribution in transport and the allowance made in that contribution for "agro-fuels" (produced from food crops). The new renewable energy directive 2018/2001 (RED II) dated 11 December 2018 enshrines the sector's development framework until at least 2030. By that timeline, each Member State must require fuel suppliers to supply a minimum of 14% share (minimum) of the final energy consumed in road and rail transport by 2030 as renewable energy according to its own indicative trajectory. A clause provides for upgrading the target by 2023. It has been decided to maintain the contribution of agro-fuels, biodiesel and bioethanol produced from feed crops capped at 7% for transport, which is the same level as it is for 2020 prescribed by the ILUC directive (2015/1513 directive) dated 9 September 2015. RED II has also set binding incorporation targets for advanced biofuels and biogas, not produced from food feedstocks, at a minimum of 0.2% in 2022, at least 1% in 2025 and at least 3.5% by 2030.

BIOFUEL CONSUMPTION INCREASES BY 8% IN THE EU

While the biofuel roadmap to the 2030 timeline is now highly regulated, the current consumption level, and confirmation of the 7% cap for biofuel produced from feed crops, open up new outlets to the sector.

After increasing slightly in 2016, total consumption of both sustainably-certified and other biofuel, put on a real spurt in 2017. Consumption of all biofuels taken together increased by 8.0% between 2016 and 2017 to reach 15 392.8 ktoe, which is 1 135.8 ktoe more than in 2016. All the main categories of biofuel profited. Of the two main types, it is biodiesel (which includes synthetic HVO biodiesel) whose consumption increased the most… by 991.8 ktoe or 8.6%. At the same time, bioethanol consumption only increased by 128.9 ktoe (4.9%). Biogas fuel consumption for NGVs (Natural Gas Vehicles), is recorded in five countries: Sweden, Germany, Finland, Austria and Denmark. This consumption also increased by 9.7% from 131.4 ktoe in 2016 to 150.4 ktoe in 2017.

Sustainably-certified biofuel consumption, the only consumption eligible for inclusion in the directive's renewable energy and transport target calculations, has been made public via the Eurostat SHARES tool that aims to harmonise calculation of the renewably-sourced energy share. The advantage of this tool is that all Member States must use exactly the same method to calculate the desired values.

1

Biofuels consumption for transport in the European Union in 2016 (in toe)

	Bioethanol	Biodiesel	Biogas fuel	Other biofuels*	Total consumption	% compliant**
France	476.0	2 639.2	0.0	0.0	3 115.3	100%
Germany	744.9	1 808.8	31.8	2.2	2 587.7	98%
Sweden	109.3	1 268.6	98.9	0.0	1 476.7	100%
Spain	134.1	1 029.8	0.0	0.0	1 163.9	100%
Italy	32.5	1 008.5	0.0	0.0	1 041.0	100%
United Kingdom	386.4	630.2	0.0	0.0	1 016.5	100%
Austria	57.1	481.1	0.4	0.0	538.6	97%
Poland	167.7	289.8	0.0	0.0	457.4	100%
Belgium	43.1	391.0	0.0	0.0	434.1	100%
Czechia	48.4	252.7	0.0	0.0	301.1	100%
Portugal	26.3	231.2	0.0	2.2	259.7	100%
Romania	81.3	175.9	0.0	0.0	257.2	100%
Netherlands	120.6	123.8	0.0	0.0	244.4	97%
Denmark	0.0	235.6	0.1	0.0	235.7	100%
Hungary	43.8	142.1	0.0	0.0	185.9	100%
Finland	67.6	110.3	0.2	0.0	178.1	100%
Bulgaria	32.9	127.3	0.0	0.0	160.2	100%
Greece	0.0	149.5	0.0	0.0	149.5	33%
Slovakia	15.5	129.2	0.0	0.0	144.8	98%
Ireland	31.6	86.8	0.0	0.0	118.5	100%
Luxembourg	8.8	78.2	0.0	0.1	87.1	100%
Lithuania	6.4	50.1	0.0	0.0	56.5	100%
Slovenia	4.3	13.8	0.0	0.0	18.2	100%
Latvia	8.3	2.0	0.0	0.0	10.3	100%
Cyprus	0.0	8.8	0.0	0.0	8.8	99%
Malta	0.0	6.1	0.0	0.0	6.1	100%
Estonia	2.6	0.0	0.0	0.0	2.6	0%
Croatia	0.0	1.0	0.0	0.0	1.0	100%
Total EU 28	2 649.6	11 471.5	131.4	4.5	14 257.0	99%

** Pure used vegetable oil and unspecified biofuel. ** Compliant with Articles 17 and 18 of Directive 2009/28/EC.*
Source: EurObserv'ER 2018, Shares 2017 for % compliant

2

Biofuels consumption for transport in the European Union in 2017 (in toe)

	Bioethanol	Biodiesel	Biogas fuel	Other biofuels*	Total consumption	% compliant**
France	537.3	2 797.7	0.0	0.0	3 335.0	100%
Germany	733.4	1 842.6	38.3	0.6	2 614.9	98%
Sweden	99.1	1 460.6	111.1	0.0	1 670.8	100%
Spain	138.0	1 231.5	0.0	0.0	1 369.5	100%
Italy	33.1	1 028.8	0.0	0.0	1 061.9	100%
United Kingdom	383.2	636.5	0.0	0.0	1 019.7	100%
Poland	176.2	428.7	0.0	0.0	604.9	100%
Austria	56.0	410.3	0.3	0.0	466.6	96%
Belgium	96.7	368.4	0.0	0.0	465.1	100%
Finland	80.7	311.0	0.3	0.0	392.1	99%
Czechia	59.3	254.5	0.0	0.0	313.8	100%
Netherlands	129.0	182.6	0.0	0.0	311.5	97%
Romania	91.1	206.1	0.0	0.0	297.2	100%
Portugal	3.1	239.0	0.0	0.0	242.1	100%
Denmark	0.0	218.2	0.3	0.0	218.5	100%
Greece	0.0	165.9	0.0	0.0	165.9	33%
Bulgaria	26.7	136.4	0.0	0.0	163.0	100%
Ireland	44.5	116.1	0.0	0.0	160.6	100%
Slovakia	19.6	129.9	0.0	0.0	149.5	100%
Hungary	40.0	108.0	0.0	0.0	148.0	100%
Luxembourg	6.7	103.5	0.0	0.0	110.3	100%
Lithuania	7.4	53.6	0.0	0.0	61.0	100%
Slovenia	8.6	15.7	0.0	0.0	24.3	99%
Latvia	7.9	1.2	0.0	0.0	9.2	100%
Cyprus	0.0	8.6	0.0	0.0	8.6	100%
Malta	0.0	7.4	0.0	0.0	7.4	100%
Estonia	1.0	0.0	0.0	0.0	1.0	0%
Croatia	0.2	0.3	0.0	0.0	0.5	100%
Total EU 28	2 778.6	12 463.2	150.4	0.6	15 392.8	99%

** Pure used vegetable oil and unspecified biofuel. ** Compliant with Articles 17 and 18 of Directive 2009/28/EC.*
Source: EurObserv'ER 2018, Shares 2017 for % compliant

Jean-Claude Moschetti_AlgoSolis_CNRS Photothèque

It prevents irregularities arising from the various parameters and rules used by different calculation methods. According to SHARES, sustainably-certified biofuel consumption in transport came to 15 191.6 ktoe in 2017 (14 081.3 ktoe in 2016), which equates to an increase of 1 110.3 ktoe.

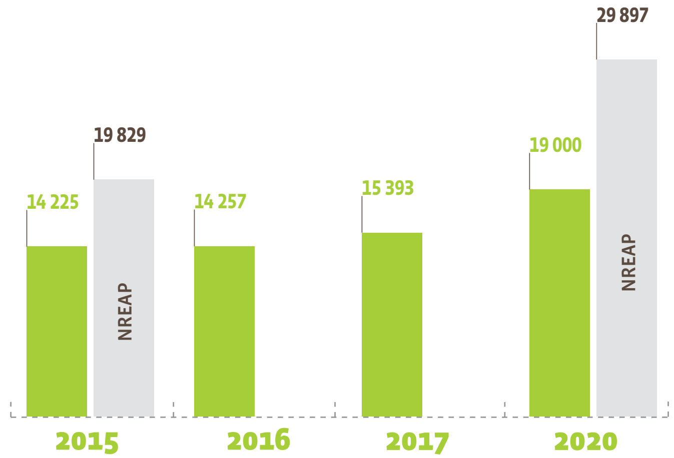
CONSUMPTION MAY WELL DOUBLE BY 2030

Consumption of conventional and advanced bioethanol and biodiesel will continue to grow across the European Union, driven by the increase in the incorporation rates provided for by each Member State. These rates are either set as energy content or incorporation volume and may or may not have specific targets for bioethanol and biodiesel. Most of the Member States have adopted double accounting for advanced biofuels as authorized by the European Directive (i.e. the possibility of applying a multiplying factor of 2 to consumption of this type of biofuel in the renewable energy target calculations for transport), thereby reducing the real incorporation level. Examples of biofuel incorporation rates defined by individual countries as energy content for 2020 are: 8.5% for Spain, 8.5% for Poland, 8.75% for Austria, 8.81% for Croatia, 10% for Greece, 10% for Italy, 10% for the Netherlands, 10% for Portugal, and 20% for Finland.

The annual GAIN Report data published by the USDA Foreign Agricultural Service concludes that the incorporation rate by energy content, excluding double accounting, could reach 5.2% in 2018, i.e. a 3.6% share for bioethanol and a 5.8% share for biodiesel. The food crop biofuel share is put at 4.1%, whereas the ILUC Directive caps this at 7% for the 2020 timeline and the RED II directive applies the same cap in the longer term from

3

Comparison of the current trend of biofuel consumption dedicated to transport against the NREAP (National Renewable Energy Action Plans) roadmap (in ktoe)



Source: EurObserv'ER 2018

2021–2030. The theoretical potential for conventional biofuels to improve is thus 2.9 percentage points by 2020. The blend and energy content share of advanced biofuels (not produced from food crops) is put at 1.2%, broken down as 1% from used cooking oil or animal fat (listed in Part B of Annex IX of the RED II) and 0.2% from farming and forestry by-products, primarily from cellulosic raw materials (listed in Part A of the same annex).

The authors of the GAIN report adopted a forward-looking approach. By taking into account the historical records of EU fuel consumption and the European Commission's projections for the use of fuels in transport (from its EU Reference Scenario 2016 Energy, transport and GHG emissions Trends to 2050 publication) and combining them with the 7% cap, they suggest that the maximum potential consumption of biofuels produced from food crops could in theory reach 23 Mtoe in 2022 then drop to 21 Mtoe in 2030. These consumption levels are theoretical and likely to be downgraded in line with the various Member States' policies. They also depend on the importance given by the various States to other energy sources that enable them to achieve the obligatory 14% share of renewable energy in transport, applying the various multiplying factors. These proposed multiplying factors are four for renewable energy used in electric vehicles, 1.5 for rail transport, 1.2 for biofuels used in air and maritime transport and two for advanced biofuels (Parts A and B). The RED II targets for advanced biofuels from Part A of the annex (cellulosic biofuel) are 0.2% in 2020, which is the same as the current level. However, this share should rise to 3.5% by 2030, which will raise the consumption level closer to 10 Mtoe. The construction of a hundred or more celullosic biofuel plants each with 200 000 litres of capacity will be required to achieve this. Consumption of advanced biofuels produced from the raw material listed in Part B (used vegetable oils and animal fats) could rise to a little over 5 Mtoe by 2022 and stabilise at 5 Mtoe in 2030. Thus, the maximum theoretical output of all biofuels taken together could rise to 35 Mtoe by 2030, which is more than double the consumption measured in 2017. EurObserv'ER projects that the consumption of biofuels used in transport will be 30 Mtoe in 2030.

However, these projections are still largely theoretical, because while the intentions are positive, in practice the targets set for RED II are not binding on each individual Member State. The European Commission will have the prerogative to verify that the Member States actually meet their commitments, so that the common target across the European Union is met by the combined total of their commitments. Country negotiations attest to the existence of a two-speed Europe split between those that are ready to step up their energy transition efforts and the Central European nations that intend to develop at their own pace. That is likely to produce a less ambitious common outcome and very certainly not enough to meet European commitments to limit the consequences of climate warming. ■

RENEWABLE MUNICIPAL WASTE

In 2017, European Union primary energy output from renewable municipal waste recovered by waste-to-energy incineration plants passed the symbolic threshold of 10 million tonnes oil equivalent (Mtoe). According to Eurostat, this output was 10 059.9 ktoe in 2017, which amounts to 2.5% growth (245.7 ktoe more than in 2016). These figures do not take into account all the energy recovered by these plants, but just the biodegradable part of the household waste. The energy recovered from non-renewable household waste (plastic packaging, water bottles, etc.) is slightly lower. Trends vary across the Member States, for while the energy recovered from renewable household waste increased in most countries, 5 countries saw their output level fall (see table).

The sector has a natural advantage in that incineration plants tend to be sited near major conurbations that both supply the waste but that are also major energy consumers. This proximity makes for optimum, local use of the energy, be it as heat, electricity, or more

often than not the two simultaneously through cogeneration. Thus, heat can be exported more easily to supply district heating systems or industrial sites in need of heat.

In 2017, electricity was the main energy recovery mode from incinerators. If we consider the renewable part of the waste only, incineration plants generated 22.2 TWh by the end of 2017, or nearly 975 GWh more than in 2016 (a 4.6% rise). The main recovery method used in these plants is cogeneration and the improved energy efficiency of incinerators constantly increases output, as demonstrated by the electricity output share which increased by 52.4% in 2015, by 53.4% in 2016 and by 56.2% in 2017.

The heat sold to heating networks also increased (by 4.1%) to 2 904.6 ktoe in 2017 (from 2 789.8 ktoe in 2016). The share of heat produced by cogeneration also increased, rising from 79.5% in 2015, to 80.0% in 2016 and 80.3% in 2017.

1

Primary energy production of renewable municipal waste in the European Union in 2016 and 2017 (in ktoe)

	2016	2017
Germany	3 102.0	3 216.9
France	1 369.7	1 390.9
United Kingdom	820.1	886.6
Italy	870.7	853.2
Sweden	832.0	779.1
Netherlands	793.6	764.3
Denmark	450.2	467.7
Belgium	370.6	375.1
Finland	306.2	326.9
Spain	235.2	259.7
Austria	199.0	176.7
Portugal	103.7	119.0
Ireland	63.9	103.1
Poland	61.0	92.5
Czechia	85.5	92.0
Hungary	66.1	46.1
Bulgaria	28.9	32.2
Lithuania	21.8	29.4
Slovakia	19.5	28.5
Luxembourg	12.6	14.1
Latvia	0.0	3.7
Romania	1.7	2.0
Cyprus	0.2	0.5
Total EU 28	**9 814.2**	**10 059.9**

Source: Eurostat

Urban waste-to-energy figures vary wildly within the EU. If we take primary energy output per inhabitant as our indicator, the Nordic countries are far and away the most heavily involved in recovering energy from their household waste (81.4 toe/1 000 inhab. for Denmark, 77.9 toe/1 000 inhab. for Sweden, and 59.4 toe/1 000 inhab. for Finland) and the Netherlands (44.7 toe/1 000 inhab.).

The sector is much less advanced in countries like France (with 20.8 toe/1 000 inhab.), where many older-generation plants were not specifically designed to produce energy but just to dispose of the waste by incineration. The Central European and some Southern EU countries like Spain have so far invested very little in recovering energy from their household waste, with ratios frequently below 10 toe/1 000 inhab.

Xavier Schwebel / Suez Environnement

2

Gross electricity production from renewable municipal waste in the European Union in 2016 and 2017 (in GWh)

	2016			2017		
	Electricity-only plants	CHP plants	Total	Electricity-only plants	CHP plants	Total
Germany	3 601.3	2 328.5	5 929.8	3 309.0	2 647.0	5 956.0
United Kingdom	1 892.3	847.4	2 739.8	1 949.2	1 436.4	3 385.6
Italy	1 217.8	1 197.6	2 415.4	1 160.1	1 223.6	2 383.6
France	1 177.2	1 005.8	2 183.0	1 236.8	1 025.0	2 261.8
Netherlands	0.0	2 005.1	2 005.1	0.0	1 903.7	1 903.7
Sweden	0.0	1 681.0	1 681.0	0.0	1 778.0	1 778.0
Belgium	452.0	497.0	949.0	473.9	498.3	972.2
Denmark	0.0	860.8	860.8	0.0	883.6	883.6
Spain	641.3	94.3	735.5	674.0	98.0	772.0
Finland	40.2	479.1	519.2	28.0	528.4	556.4
Portugal	304.8	0.0	304.8	360.3	0.0	360.3
Austria	250.4	82.8	333.2	247.9	70.2	318.1
Hungary	178.7	66.4	245.1	83.0	77.0	160.0
Ireland	75.8	0.0	75.8	150.7	0.0	150.7
Czechia	0.0	98.6	98.6	0.0	114.3	114.3
Poland	0.0	12.7	12.7	0.0	80.7	80.7
Lithuania	0.0	47.4	47.4	0.0	73.2	73.2
Luxembourg	42.2	0.0	42.2	46.9	0.0	46.9
Slovakia	0.0	26.0	26.0	0.0	22.0	22.0
Total EU 28	9 873.9	11 330.5	21 204.4	9 719.8	12 459.3	22 179.1

Source: Eurostat

The UK currently has one of the most active new incineration construction programmes underway. According to the Department for Business, Energy & Industrial Strategy (BEIS), energy output from renewable household waste increased by 8.1% between 2016 and 2017 (886.6 ktoe in 2017) and by 71.9% compared to the 2014 output level. Most of this energy has been recovered as electricity, whose output stood at 3.4 TWh in 2017 (a 23.6% annual rise). The reason for this strong growth is that several incinerators with energy recovery were commissioned during 2016 (including Teeside and Greatmore) and have now operated throughout 2017. According to the BEIS, the nett electrical capacity of the incineration plants rose from 930 MW in 2015, to 1028 MW in 2016 and 1 091 MW in 2017... and has more than doubled since 2012 (513 MW). British legislation is responsible for this trend, as the landfill tax has risen annually since 1996. The levy applied rose from £ 86.10 per tonne on 1 April 2017 to £ 88.95 on 1 April 2018.

Energy recovery from renewable municipal waste has increased the most in Germany, where the additional 115 ktoe for the year resulted in total output of 3 217 ktoe in 2017. This particular increase has contributed to driving up heat sales to district heating

3

*Gross heat production from renewable municipal waste in the European Union in 2016 and in 2017 (in ktoe) in the transformation sector**

	2016			2017		
	Heat only plants	CHP plants	Total	Heat only plants	CHP plants	Total
Germany	271.9	460.5	732.4	284.8	488.5	773.3
Sweden	56.3	509.8	566.1	56.4	528.0	584.4
France	147.4	279.5	427.0	149.1	285.4	434.5
Denmark	35.8	320.4	356.2	34.8	331.3	366.1
Netherlands	0.0	265.2	265.2	0.0	277.0	277.0
Finland	22.4	145.9	168.3	25.3	141.5	166.9
Italy	0.0	117.1	117.1	0.0	124.2	124.2
Austria	13.7	48.6	62.3	14.6	50.9	65.6
Czechia	0.0	35.9	35.9	0.0	40.6	40.6
Belgium	0.0	26.8	26.9	0.1	26.0	26.1
Lithuania	0.0	10.4	10.4	0.0	16.4	16.4
Poland	0.1	0.3	0.4	0.1	10.8	10.9
Hungary	0.0	12.1	12.1	0.0	10.9	10.9
United Kingdom	8.1	0.0	8.1	7.0	0.0	7.0
Slovakia	1.5	0.0	1.5	0.8	0.0	0.8
Romania	0.02	0.00	0.02	0.01	0.00	0.01
EU 28	**557.2**	**2 232.6**	**2 789.8**	**573.0**	**2 331.6**	**2 904.6**

** corresponds to «Derived heat» (see Eurostat definition).* ***Source: Eurostat***

networks. Heat from the processing sector increased by 40.8 ktoe to 773.3 ktoe in 2017. Final energy consumption, namely direct heat consumption on production sites increased at the same time from 364 to 413.4 ktoe.

THE TARGETS ARE WELL ON THEIR WAY TO BEING MET

All-in-all, the momentum for recovering energy from renewable municipal waste is positive. Increasing landfill taxes and the ban on dumping organic waste in landfills, have stimulated the sector. This is borne out by the increase in primary energy output from 8.1 Mtoe in 2010 to 10 Mtoe in 2017.

If the framework directive on waste which has established a " waste hierarchy" (prevention, preparation for reuse, recycling, recovery, disposal) is adhered to, an increasing share of recyclable waste will be deflected from the incineration plant chain (recycling of cartons, paper, packaging, milk cartons, etc.). In time, regulations will only allow the biodegradable fraction of waste to be incinerated, either because it is unsuitable for recycling or quality composting – which applies to soiled cartons or because it is too complicated to recycle –e.g. multi-layer packaging. Nonetheless, there is significant growth potential across the European Union. According to CEWEP, twelve Member States still bury most of their municipal waste. This has serious consequences for

GHG emissions such as methane and, in the case of poor management, generates potential leachate pollution, with the ensuing health problems. The association reckons that these countries will require financial support and aid from the European Union to achieve their targets.

Turning to the forecasts for 2020, CEWEP believes that the energy contribution from waste towards the renewable energy directive targets could realistically reach 67 TWh by 2020, with 25 TWh of electricity and 42 TWh (3.6 Mtoe) of heat. Total heat consumption (heat from the processing sector and final heat consumption) already stands at 3.8 Mtoe (including 2.9 Mtoe of heat sold to heating networks). The down-to-earth CEWEP heat target for 2020 could easily be outstripped. The forthcoming commissioning of new incineration plants in the UK, coupled with the improvements to the energy efficiency of existing plants should also result in meeting the 25 TWh target for 2020. ■

SOLID BIOMASS

Solid biomass is an umbrella term for all solid organic components to be used as fuels. They include wood, wood chips, timber industry by-products (offcuts, sawdust, etc.), black liquor from the paper industry, wood pellets, straw, bagasse, animal waste and other solid plant residues. Charcoal, which derives from solid biomass, has its own statistical processing, so it is excluded from the data we present. The same goes for renewable municipal waste which is also likened to solid biomass and recovered in incineration plants and is thus subject to specific statistical processing.

Solid biomass energy consumption trends are at the mercy of public policies encouraging its use, but when we look at the heating application, it also correlates to outdoor temperatures, which were fairly mild in 2017. According to the World Meteorological Organization it was the 5th hottest year ever recorded in Europe, which restrained its increase in heating requirements in the European Union. Last year, 2018, was also very warm, the hottest ever recorded in several European countries including France, since the first temperature readings were taken in 1900. The succession of mild years and winters in Europe – a measurable consequence of climate warming – effectively blurs out interpretation of the impact of the policies implemented to promote the use of solid biomass in high-efficiency heating appliances.

Another element that needs to be taken into consideration is that in some of the Northern European countries where the forestry industry is a major economic player, the availability of solid biomass likely to be converted into energy (wood offcuts, black liquors, forest residue) is also dependent on the European market needs for forestry products (construction, grinding, furnishings, etc.). Part of the available quantity of biomass energy is thus linked to the activity level of the forestry industry, even though another part of the activity is totally dedicated to supplying biomass to the energy sector.

Lastly improvements in monitoring through new surveys, especially surveys of household wood energy consumption, must also be taken into account when discussing trends and analysing the monitoring of solid biomass consumption. It also needs to be said that in addition to changing weather conditions, average wood consumption per dwelling is falling, particularly because of the improvements to wood-fired heating appliance performance and building insulation.

PRIMARY ENERGY CONSUMPTION APPROACHES THE 100-MTOE THRESHOLD

According to Eurostat, primary solid biomass energy consumption remained just below the 100-Mtoe threshold in 2017. Consumption grew by 1.9% to reach 99.8 Mtoe, which equates to a 1.9-Mtoe increase. The individual member states present a mixed picture, as a few of them saw their solid biomass consumption contract slightly. They include Poland (by 329 ktoe), France, including the Overseas Territories (218 ktoe), Sweden (72 ktoe) and Hungary (39 ktoe). In contrast, the most significant increases can be assigned to Italy (571 ktoe), the UK (423 ktoe), Denmark (401 ktoe), Finland (285 ktoe) and Germany (278 ktoe).


W. Simlinger

Primary energy production from solid biomass, exclusively sourced from European Union soil, increased at a slightly slower pace (1.3%) totalling 95 Mtoe (a 1.2 Mtoe increase between 2016 and 2017). Most of the difference, equating to net imports, can be put down to wood pellet imports from the USA and Canada. Over the last three years, the EU balance of net imports has been rising. It stood at 3.7 Mtoe in 2015, 4.1 Mtoe in 2016 and 4.8 Mtoe in 2017.

Final energy consumption equates to primary energy consumption minus all the energy losses along the industrial chain that converts the energy resources into energies used in final consumption, namely electricity and heat. Solid biomass heat is differentiated on the basis of whether it is directly used by the end user in heating appliances (boilers, stoves, inserts, etc.) or

1

Primary energy production and gross inland consumption of solid biomass in the European Union in 2016 and 2017 (in Mtoe)*

	2016		2017	
	Production	Consumption	Production	Consumption
Germany	12.169	12.169	12.011	12.447
France	11.012	11.012	10.794	10.794
Sweden	9.402	9.419	9.316	9.347
Italy	7.232	8.441	7.826	9.013
Finland	8.334	8.358	8.611	8.643
United Kingdom	3.715	6.245	4.253	6.668
Poland	6.415	6.620	6.161	6.291
Spain	5.327	5.327	5.473	5.473
Austria	4.457	4.555	4.593	4.590
Romania	3.579	3.607	3.564	3.639
Denmark	1.693	2.816	1.727	3.216
Czechia	2.970	2.906	2.997	2.962
Portugal	2.605	2.402	2.619	2.421
Hungary	2.402	2.413	2.360	2.374
Belgium	1.285	2.051	1.202	2.038
Latvia	2.076	1.300	2.040	1.428
Netherlands	1.366	1.209	1.434	1.264
Lithuania	1.203	1.209	1.306	1.263
Croatia	1.531	1.253	1.543	1.241
Bulgaria	1.121	1.057	1.123	1.066
Estonia	1.396	0.898	1.487	0.984
Greece	0.797	0.855	0.809	0.862
Slovakia	0.835	0.826	0.841	0.827
Slovenia	0.609	0.609	0.592	0.592
Ireland	0.227	0.270	0.246	0.275
Luxembourg	0.063	0.069	0.077	0.084
Cyprus	0.009	0.010	0.010	0.012
Malta	0.000	0.001	0.000	0.001
Total EU 28	93.830	97.906	95.015	99.815

** Excluding charcoal.* ***Source: EurObserv'ER 2018***

2

Gross electricity production from solid biomass in the European Union in 2016 and 2017 (in TWh)*

	2016			2017		
	Electricity-only plants	CHP plants	Total	Electricity-only plants	CHP plants	Total
United Kingdom	19.589	0.000	19.589	20.763	0.000	20.763
Finland	1.004	9.599	10.603	0.918	9.973	10.890
Germany	4.775	6.019	10.794	4.602	6.055	10.657
Sweden	0.000	9.750	9.750	0.000	10.250	10.250
Poland	2.052	4.861	6.913	1.415	3.893	5.309
Denmark	0.000	3.486	3.486	0.000	4.798	4.798
Spain	3.212	0.836	4.048	3.458	0.907	4.365
Italy	2.226	1.899	4.125	2.198	2.033	4.232
Belgium	2.156	1.315	3.471	2.491	1.326	3.816
Austria	0.875	2.816	3.691	0.877	2.816	3.692
France	0.419	3.032	3.450	0.419	2.922	3.341
Portugal	0.760	1.721	2.481	0.799	1.775	2.573
Czechia	0.014	2.053	2.068	0.004	2.209	2.213
Netherlands	1.116	0.791	1.907	1.099	0.674	1.772
Hungary	0.827	0.666	1.493	0.955	0.691	1.646
Slovakia	0.003	1.126	1.129	0.000	1.080	1.080
Estonia	0.127	0.713	0.840	0.140	0.856	0.996
Latvia	0.000	0.427	0.427	0.000	0.525	0.525
Romania	0.077	0.388	0.466	0.064	0.395	0.458
Ireland	0.379	0.016	0.395	0.366	0.016	0.381
Lithuania	0.000	0.269	0.269	0.000	0.303	0.303
Croatia	0.000	0.194	0.194	0.000	0.216	0.216
Bulgaria	0.003	0.160	0.163	0.014	0.167	0.180
Slovenia	0.000	0.137	0.137	0.000	0.155	0.155
Luxembourg	0.000	0.025	0.025	0.000	0.052	0.052
Greece	0.005	0.000	0.005	0.010	0.000	0.010
Total EU 28	39.619	52.300	91.918	40.590	54.086	94.675

** Excluding charcoal.* ***Source: Eurostat***

whether it is derived heat from the processing sector (from biomass boiler houses and biomass units operating in combined heat and power plants (CHP). Eurostat's data records an 1.6% increase (1.1 Mtoe) in the amount of heat consumed directly used by end users compared to 2016 by reaching 69.4 Mtoe in 2017. Gross solid biomass heat output sold to heating networks increased by 4.2% (by 445 ktoe), driven by increased heating needs. It reached 11 Mtoe in 2017, 60.2% of which was supplied by CHP plants. If we add these two elements together, total final biomass heat energy consumption increased by 2.0% between 2016 and 2017 to 80.3 Mtoe – an additional 1.6 Mtoe).

Hans Ekestang / Stockholm Exergi

European Union production of solid biomass electricity is less vulnerable to the vagaries of climate. It depends more on the policies of the few member states that promote its use instead of coal. Across the European Union, biomass electricity production increased by 3.0% year-on-year to 94.7 TWh in 2017 (adding 2.8 TWh). Most of this figure can be attributed to the growth in solid biomass' net maximum electrical capacity in the major producer countries. Electrical capacity in the UK, reached 3 191 MW at the end of 2017 (196 MW more than in 2016), that of Finland 1 966 MW (219 MW more) and Denmark 1 504 MW (472.6 MW more). Higher output in the other countries can be ascribed to better use of existing capacities. Examples of this are Sweden and Belgium whose solid biomass electrical capacities at the end of 2017 were 3 706 MW and 559 MW respectively. Four countries stand out as the clear leaders in the solid biomass electricity producer country rankings – the UK (20.8 TWh in 2017, 1.2 TWh more than in 2016), Sweden (10.3 TWh, 0.5 TWh more), Finland (10.9 TWh, 0.3 TWh more), and Germany (10.7 TWh, 0.1 TWh less). Taken together, the four account for 55.7% of the European Union's solid biomass electricity output in 2017. Across the European Union (EU of 28), cogeneration plants produce more than half (57.1% in 2017) of its solid biomass electricity. If we exclude the UK, the proportion is 73.2%.

ELECTRICITY PRODUCTION SHOULD SPEED UP BY 2020

Many states have put solid biomass at the centre of their national renewable energy action plan strategy and more generally in their climate warming control strategy, because of its available potential and technical capacity to replace fossil fuels for producing heat and electricity.

The EurObserv'ER forecasts put the input of biomass heat at 90 Mtoe by the 2020 timeline, breaking it down as 86 Mtoe from solid biomass and 4 Mtoe from renewable municipal waste. If biogas and liquid biomass heat are added to the equation, EurObserv'ER puts the combined biomass heat contribution at 95 Mtoe by 2020.

Turning to power, the solid biomass sector will also benefit from the conversion of Danish coal-fired power plants, the spread of biomass cogeneration in Sweden (an additional 500 MW is expected by 2023 according to the IEA) and the expected boom in biomass co-firing in the Netherlands (e.g. the Amer and Eemshaven plants). In the Netherlands, several large biomass co-firing projects in existing coal-fired plants have been awarded SDE+ subsidies. Output should be 7 TWh per annum by 2020. The UK, whose effective exit from the EU is due on 1 January 2021, following a transition period commencing on 29 March 2019, should also increase its bioenergy capacity by 2.1 GW by 2023. A sizeable part of this additional capacity will be up and running before 2020. These elements indicate that solid biomass electricity production should grow very significantly in the next three years. EurObserv'ER believes that

3

Gross heat production from solid biomass in the European Union in 2016 and in 2017 (in Mtoe) in the transformation sector***

	2016			2017		
	Heat only plants	CHP plants	Total	Heat only plants	CHP plants	Total
Sweden	0.711	1.765	2.477	0.709	1.808	2.518
Finland	0.668	1.092	1.760	0.711	0.995	1.706
Denmark	0.473	0.666	1.139	0.478	0.878	1.356
France	0.533	0.498	1.031	0.569	0.555	1.124
Austria	0.543	0.341	0.884	0.547	0.360	0.908
Germany	0.216	0.400	0.616	0.208	0.401	0.609
Lithuania	0.392	0.096	0.488	0.422	0.124	0.545
Italy	0.078	0.464	0.542	0.078	0.466	0.544
Estonia	0.157	0.150	0.308	0.165	0.132	0.296
Latvia	0.114	0.137	0.251	0.145	0.147	0.292
Poland	0.048	0.271	0.319	0.054	0.225	0.279
Czechia	0.023	0.138	0.161	0.032	0.139	0.171
Slovakia	0.048	0.077	0.125	0.049	0.083	0.133
Hungary	0.056	0.068	0.124	0.048	0.064	0.112
Netherlands	0.027	0.022	0.049	0.024	0.077	0.101
United Kingdom	0.080	0.000	0.080	0.086	0.000	0.086
Romania	0.031	0.041	0.072	0.018	0.047	0.065
Croatia	0.000	0.022	0.022	0.000	0.036	0.036
Slovenia	0.009	0.019	0.028	0.011	0.020	0.030
Luxembourg	0.004	0.009	0.013	0.004	0.019	0.024
Bulgaria	0.006	0.009	0.015	0.004	0.010	0.014
Belgium	0.000	0.006	0.006	0.000	0.007	0.007
Total EU 28	4.218	6.292	10.510	4.362	6.593	10.955

** Excluding charcoal. ** Correspond to "Derived heat" (see Eurostat definition). **Source: Eurostat***

4

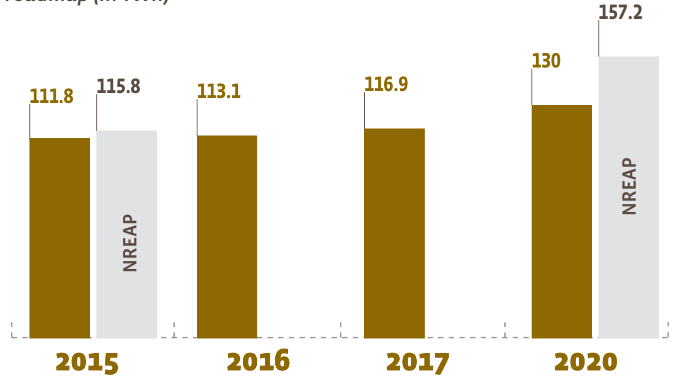
Heat consumption from solid biomass in the European Union in 2016 and 2017*

	2016	of which final energy consumption	of which derived heat**	2017	of which final energy consumption	of which derived heat**
Germany	9.566	8.949	0.616	9.853	9.244	0.609
France	9.965	8.934	1.031	9.777	8.653	1.124
Sweden	7.852	5.376	2.477	7.792	5.275	2.518
Italy	7.123	6.582	0.542	7.716	7.173	0.544
Finland	6.922	5.162	1.760	7.048	5.342	1.706
Poland	5.170	4.851	0.319	5.222	4.943	0.279
Spain	4.005	4.005	0.000	4.059	4.059	0.000
Austria	3.839	2.955	0.884	3.934	3.027	0.908
Romania	3.465	3.393	0.072	3.512	3.447	0.065
United Kingdom	2.888	2.808	0.080	3.002	2.917	0.086
Denmark	2.367	1.228	1.139	2.626	1.270	1.356
Czechia	2.438	2.278	0.161	2.446	2.275	0.171
Hungary	2.015	1.891	0.124	1.932	1.820	0.112
Portugal	1.773	1.773	0.000	1.772	1.772	0.000
Belgium	1.317	1.310	0.006	1.267	1.261	0.007
Latvia	1.121	0.870	0.251	1.232	0.940	0.292
Croatia	1.171	1.149	0.022	1.160	1.124	0.036
Lithuania	1.110	0.621	0.488	1.157	0.612	0.545
Bulgaria	1.007	0.993	0.015	1.037	1.023	0.014
Greece	0.849	0.849	0.000	0.857	0.857	0.000
Netherlands	0.712	0.662	0.049	0.820	0.719	0.101
Estonia	0.711	0.404	0.308	0.716	0.420	0.296
Slovenia	0.585	0.556	0.028	0.562	0.531	0.030
Slovakia	0.513	0.388	0.125	0.527	0.394	0.133
Ireland	0.190	0.190	0.000	0.197	0.197	0.000
Luxembourg	0.063	0.050	0.013	0.072	0.048	0.024
Cyprus	0.006	0.006	0.000	0.008	0.008	0.000
Malta	0.001	0.001	0.000	0.001	0.001	0.000
Total EU 28	78.744	68.234	10.510	80.306	69.351	10.955

** Excluding charcoal. ** Essentially district heating (see Eurostat definition).* ***Source: Eurostat***

5

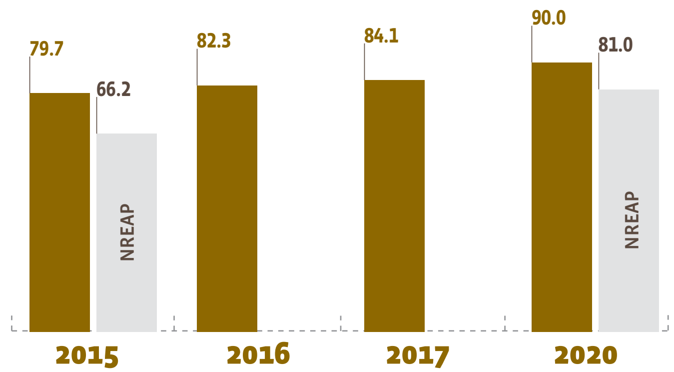
Comparison of the current trend of electricty production from solid biomass against the NREAP (National Renewable Energy Action Plan) roadmap (in TWh)



This data includes an estimate of renewable electricity from municipal waste incineration plants. ***Source: EurObserv'ER 2018***

6

Comparison of the current trend of heat consumption from solid biomass against the NREAP (National Renewable Energy Action Plan) roadmap (in Mtoe)



This data includes an estimate of renewable heat from municipal waste incineration plants. ***Source: EurObserv'ER 2018***

if the renewable municipal waste recovered in incineration plants as electricity is included, it could exceed 130 TWh in 2020.

Rapid growth in the number of large-scale biomass power plants also raises the issue of raw material procurement. It is vital that biomass needs are met responsibly and sustainably. The new renewable energies directive enforces sustainability requirements on biomass feedstocks to be included in the renewable energy share calculations of gross final energy consumption. The 6th and 7th paragraphs of Article 29 of the directive detail the criteria that must be met to reduce the risk of being produced in a non-sustainable manner. Biomass fuel derived from forestry work must come from countries that have implemented legislation that guarantees the lawfulness of forest operations, forest regeneration, and the maintenance or improvement of its capacity to produce biomass, the protection of classified areas under international or national law, the preservation of soil quality and biodiversity. Biomass fuels from forestry work must also fulfil land use, land-use change and forestry (LULUCF) criteria. In particular, they must be sourced from a signatory state to the Paris Agreements, that has made a defined national contribution to the United Nations Framework Convention on climate change and whose legislation or regulations guarantee that the emissions generated by the LULUCF sector do not exceed its emission reductions. The Commission has to decide how proof of compliance with these sustainability criteria will be demonstrated no later than 31 January 2021. ■

CONCENTRATED SOLAR POWER

Concentrated Solar Power plants include all the technologies that convert the energy from the sun's rays into very high-temperature heat and recover it as electricity or heat. The technologies used are tower plants where heliostats concentrate the radiation on a collector at the top of the tower, plants that use Fresnel collectors where rows of flat mirrors concentrate the radiation on a tube-shaped collector, parabolic trough collectors that concentrate the rays on a tube and parabolic collectors where a parabolic mirror reflects the sun's rays onto a convergence point.

5 079 MW OF CSP CAPACITY IN THE WORLD

Most of the current development work on CSP plants is going on in China, Australia, South Africa, the Gulf States and the Maghreb, whose sunshine conditions are particularly suitable for this application. According to the Protermosolar website, the global capacity of these plants was put at 5 079 MW at the end of 2018 (4 879 MW at the end of 2017). Two facilities were commissioned in 2017 – the Xina Solar One plant (100 MW) in South Africa and the Agua Prieta plant in Mexico (12 MW). In 2018, three new plants came on stream – Waad Al Shamal ISCC Plant in Saudi Arabia (50 MW), Kathu Solar Park (100 MW) in South Africa and the Delingha plant (50 MW) in China. Many more plants are currently under construction and should result in a significant increase in installed global capacity from 2019 onwards.

2 314 MW IN THE EUROPEAN UNION

The market slowed down substantially after a spate of installations concentrated in Spain between 2007 and 2014. At the end of 2017, the European Union capacity level inched up when the Ottana plant (0.6 MW) in Sardinia went on-grid. This took the EU's installed thermodynamic solar capacity to 2 314.3 MW including pilot projects and demonstrators, but 2018 saw no new developments. The eLLO plant in the French Eastern Pyrenees has been running since the end of October 2018 (when the collector field started up). However, it will not be connected to the power grid and therefore will not be included in the statistics until 2019. Four bigger projects (Solecaldo 41 MW at Aidone, Sicily, Reflex Solar Power 12.5 MW at Gela, Sicily, Lentini 55 MW, Sicily and the San Quirico 10-MW hybrid solar CSP project in Sardinia) are still slated for completion by 2020-2021 in Italy, although the investors are waiting for the decree that will set the remuneration conditions. Commercial commissioning is thus on hold.

CSP IS SIDE-LINED IN SPAIN

In 2012, the incumbent conservative government applied a moratorium on renewable energy grants, which put a stop to CSP development. The European sector leader, Spain, had completed and connected 49 commercially-operating CSP plants and one prototype (Puerto Errado 1) between 2007 and 2013, with a combined capacity of 2 303.9 MW. Since 2014, its CSP plants have operated solely using solar energy as the initial option of using a 15% natural gas top-up was called off. The move has had absolutely no effect on plant output, which has remained upwards of 5 TWh, without any operating problems. Eurostat says that output rose to 5 883 GWh in 2017, from 5 579.2 GWh in 2016 and 5 93.2 GWh in 2015. Protermosolar claims that, Spain's current CSP capacity can cover peaks of up to 10% of the country's electricity needs. Its mean input is around 8% in the summer. The Spanish situation is unlikely to change over the next few years. Despite the end of the moratorium, Spain's tenders for new "technologically neutral" renewable energy projects since 2017 have forced CSP to take a backseat vis-à-vis competitive technologies such as solar photovoltaic.

COMMISSIONING IN FRANCE MIS-TIMED

The eLLO project at Llo in the eastern Pyrenees, will be the first Fresnel-type plant to have a storage system. The site has been ready since the end of 2018 when the solar field was commissioned, and the heat storage system was installed. It will only be included

1

Concentrated solar power plants in operation at the end of 2017

Projects	Technology	Capacity (in MW)	Commisionning date
Spain			
Planta Solar 10	Central receiver	10	2007
Andasol-1	Parabolic trough	50	2008
Planta Solar 20	Central receiver	20	2009
Ibersol Ciudad Real (Puertollano)	Parabolic trough	50	2009
Puerto Errado 1 (prototype)	Linear Fresnel	1.4	2009
Alvarado I La Risca	Parabolic trough	50	2009
Andasol-2	Parabolic trough	50	2009
Extresol-1	Parabolic trough	50	2009
Extresol-2	Parabolic trough	50	2010
Solnova 1	Parabolic trough	50	2010
Solnova 3	Parabolic trough	50	2010
Solnova 4	Parabolic trough	50	2010
La Florida	Parabolic trough	50	2010
Majadas	Parabolic trough	50	2010
La Dehesa	Parabolic trough	50	2010
Palma del Río II	Parabolic trough	50	2010
Manchasol 1	Parabolic trough	50	2010
Manchasol 2	Parabolic trough	50	2011
Gemasolar	Central receiver	20	2011
Palma del Río I	Parabolic trough	50	2011
Lebrija 1	Parabolic trough	50	2011
Andasol-3	Parabolic trough	50	2011
Helioenergy 1	Parabolic trough	50	2011
Astexol II	Parabolic trough	50	2011
Arcosol-50	Parabolic trough	50	2011
Termesol-50	Parabolic trough	50	2011
Aste 1A	Parabolic trough	50	2012
Aste 1B	Parabolic trough	50	2012
Helioenergy 2	Parabolic trough	50	2012
Puerto Errado II	Linear Fresnel	30	2012
Solacor 1	Parabolic trough	50	2012
Solacor 2	Parabolic trough	50	2012
Helios 1	Parabolic trough	50	2012
Moron	Parabolic trough	50	2012
Solaben 3	Parabolic trough	50	2012
Guzman	Parabolic trough	50	2012
La Africana	Parabolic trough	50	2012
Olivenza 1	Parabolic trough	50	2012
Helios 2	Parabolic trough	50	2012
Orellana	Parabolic trough	50	2012
Extresol-3	Parabolic trough	50	2012
Solaben 2	Parabolic trough	50	2012
Termosolar Borges	Parabolic trough + HB	22.5	2012
Termosol 1	Parabolic trough	50	2013
Termosol 2	Parabolic trough	50	2013
Solaben 1	Parabolic trough	50	2013
Casablanca	Parabolic trough	50	2013
Enerstar	Parabolic trough	50	2013
Solaben 6	Parabolic trough	50	2013
Arenales	Parabolic trough	50	2013
Total Spain		**2303.9**	
Italy			
Archimede (prototype)	Parabolic trough	5	2010
Archimede-Chiyoda Molten Salt Test Loop	Parabolic trough	0.35	2013
Freesun	Linear Fresnel	1	2013
Zasoli	Linear Fresnel + HB	0.2	2014
Rende	Linear Fresnel + HB	1	2014
Ottana	Linear Fresnel	0.6	2017
Total Italy		**8.15**	
Germany			
Jülich	Central receiver	1.5	2010
Total Germany		**1.5**	
France			
La Seyne sur mer (prototype)	Linear Fresnel	0.5	2010
Augustin Fresnel 1 (prototype)	Linear Fresnel	0.25	2011
Total France		**0.75**	
Total EU 28		**2314.3**	

Continues overleaf

Parabolic trough plants, Central receiver plants, Dish Stirling systems, Linear Fresnel systems, HB (Hybride Biomass)
Source: EurObserv'ER 2018

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in the statistics starting in 2019. The plant occupies a 36-hectare site and is equipped with 95 200 mirrors assembled in 23 800 collectors that cover a 153 000-m² area. The output will be stored in nine 90-tonne, 120-m³ steam accumulators at 80 bar, which equates to four hours' storage. The plant's design capacity is 9 MW, which is enough to supply power to more than 6 000 households, namely about 20 GWh per annum. According to SUNCNIM, the project designer, the capacity level and storage technology are no longer suitable for the global electricity market. The operator has therefore switched focus to the plant's thermal production capacity, and aims to supply steam to industry, primarily the oil industry, in countries with high sunshine levels.

PROJECTS STILL BLOCKED IN ITALY

According to Emilio Conti, of Anest (the Italian National Association of Thermodynamic Solar Energy), the situation changed very little in 2017. The sector has been waiting for two years for a new decree covering the renumeration conditions of >5-MW plants, that should have been published at the end of 2017. The decree was due to take over elements of the decree dated 23 June 2016 prompting the start of construction work on 118.5 MW of capacity which had received permission. Three projects are involved in Sicily (55 MW at Carlentini, 41 MW at Aidone, 12.5 MW at Gela) and one in Sardinia (a 10-MW hybrid CSP/Biomass plant at San Quirico). Two other plants are still in the final licensing stage – the Flumini Mannu (55 MW) plant that straddles Villasor and Decimoputzu, Sardinia and the 10-MW 3QP plant at San Severo in Puglia.

As regards <5-MW plants, 8 projects have made it to the registers of the Italian Energy Services Operator (GSE). Seven of the projects are located in Sicily and one in Sardinia. According to Anest, construction is likely to start soonest on Calliope PV Srl at Trapani, Sicily (4 MW), Stromboli Solar Srl also at Trapani (4 MW), Solin Par SRL at Partanna (4.3 MW) and Bilancia PV Srl at Mezzojuso (4 MW) near Palermo. In the meantime, the sector has had to settle for connection of the small 600-kW Fresnel-type plant to the grid on 5 October (with 9 000 m² of mirrors) at Ottana, Sardinia, the first to use an Organic Rankine Cycle. A second 1-MW parabolic-trough demonstrator, also connected to an ORC system is under construction at Melilli, Sicily. The Feed-in tariff for 250 kW–5 MW installations is € 296 per MWh, to which "an integration factor" is added if the plant has its own storage system, which in the case of the Melilli CSP plant adds another € 45 per MWh (giving a total of € 341 per MWh).

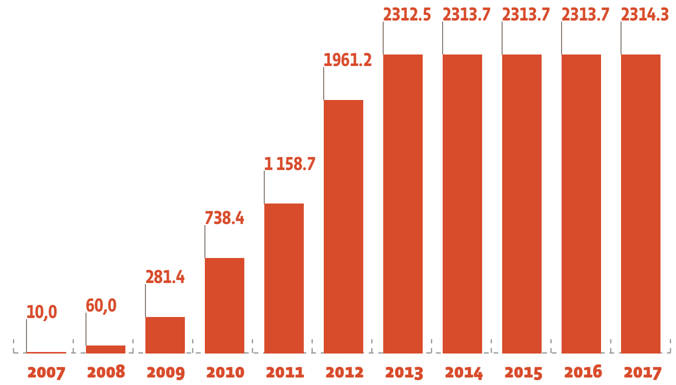
CSP IS LOOKING AT AN AMORPHOUS FUTURE IN EUROPE

By 2020, the sector's European growth prospects will be far below the targets set by the member states for their national renewable energy action plans. The trajectory for the next three years is still blurred because completion of the only current tangible projects – all in Italy – is on hold, pending the publication of decrees offering better remuneration conditions.

With the new renewable energy directive almost upon us, new major CSP projects could still be rolled out in Europe. The sector's representatives, such as Luis Crespo of Protermosolar reminds us of the important role CSP could play in the context of an increasingly interdependent and interconnected European grid. He highlights the sector's strengths stemming from the long-lasting storage capabilities that can secure part of the European countries' power supplies, especially in Central Europe, where only variable capacity technologies such as wind energy and solar photovoltaic are likely to be developed. Luis Crespo also points out that the new European renewable energy directive stresses the importance of cross-border exchanges encouraging investments to be made where resources are at their best. The future role for CSP in achieving the new targets for 2030 will depend on the countries' capacities to geographically coordinate their investments on the basis of the complementary features of all the renewable energies to give Europe a robust, cheap, emission-free electricity-generating system. ■

2

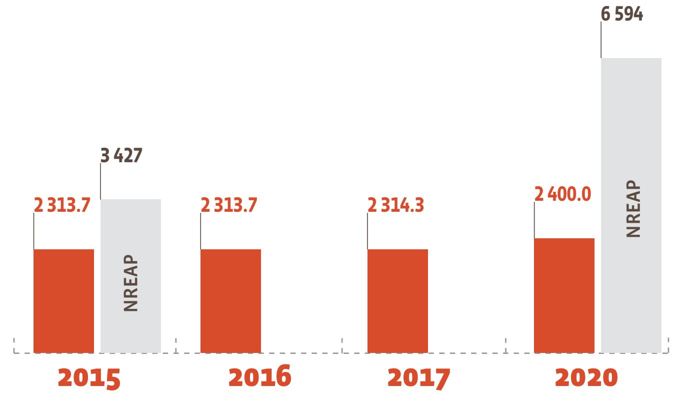
CSP plant capacity trend in the European Union (in MW)



Source: EurObserv'ER 2018

3

Comparison of the current trend against the NREAP (National Renewable Energy Action Plans) roadmap (in MW)



Source: EurObserv'ER 2018

OCEAN ENERGY

Seas and oceans offer an invaluable source of energy that can be harnessed as tidal energy, marine current power, wave energy, energy recovered from temperature and salt content differences between two bodies of water (thermal and osmotic energy respectively). Europe has considerable, diverse potential that makes it the ocean energy sector leader thanks to its many kilometres of continental and far-flung coastlines.

The European Horizon 2020 programme supports research and innovation. In 2018, it enabled a third MaRINET programme to be launched, that provides free access to a network of 57 leading-edge research facilities throughout Europe. Furthermore, the 3-year (2018 – 2021) European DTOcean+ project has been relaunched. It will set up an open source advanced design tool suite for marine current and wave energy system innovation, development and deployment that aims to reduce the LCOE from 6 to 8%.

Tidal energy has been commercially harnessed since 1966 at France's la Rance (Ille-et-Vilaine) tidal barrage (240 MW) installed in the Rance river estuary. As estuary barrages raise environmental and social acceptance issues, research work on artificial lagoon systems out at sea is underway. However, the UK government has dropped the most advanced project, a 320 MW prototype led by Tidal Lagoon Power in Cardiff, Wales.

Pilot projects have tested current and wave energy installations and should soon move on to the commercial stage. The United Kingdom has made the most progress in the sector, not only through small-scale experiments carried out at the European Marine Energy Centre (EMEC) in Scotland for more than a decade, but also through larger-scale projects that are about to come on stream. The most advanced is Australia's Atlantis Resources Meygen Corporation tidal turbine project for a 398-MW installation in the Pentland Firth strait. The first 6-MW phase was completed in 2017. The second phase – the Demotide project – also 6 MW is due to start operating commercially in 2019. However, as most of the marine energy projects receive European funding, the spectre of Brexit hangs over the country's efforts.

France's sector was dealt a blow when Naval Energies pulled out of the current energy development work. Nonetheless, Atlantis Resources Corporation announced its intention to install 10 x 2 MW tidal turbines at Raz Blanchard as a test facility, while river turbines are taking off in France. HydroQuest has commissioned four river turbines in the Rhone, near Lyon (320 kW in all) and in 2019 will immerse 39 x 40 and 80 kW (2 MW in all) turbines downstream of the Génissiat dam (Ain). Good progress has also been made in wave energy conversion with the launch of a 50 MW pilot wave energy converter in August in the port of La Rochelle by the Gironde start-up, Hydro Air Concept Energie (Hace). Ireland, Spain, Denmark, Sweden, Italy and

Emmanuel Donfut / Balao

Belgium are also working in this sector as well as Portugal where Finland's AW-Energy will shortly install a 350-kW WaveRoller prototype wave energy converter (off Peniche). The Netherlands is championing water current and osmotic energy development efforts.

The sector will need strong support if Europe is to maintain its lead in marine energies, according to a new marine energy market survey commissioned by the European Commission (EC). The survey suggests the establishment of a European investment platform for marine energies, to validate the 2016 Ocean Energy Roadmap recommendations made by the industry represented by OEE (Ocean Energy Europe). But the report's main recommendation is to introduce Feed-in Tariffs. ■

1

List of European Union plants harnessing ocean energy at the end of 2018

Projects	Capacity (in MW)	Commissioning date	Current state
United Kingdom			
SeaGen	1.2	2008	Connected
Wello Oy- Penguin WEC	0.6	2012	Connected
Minesto - Deep GreenOcean	0.03	2013	Connected
WaveNET	0.45	2016	Connected
Nova 30	0.03	2014	Connected
Nova 100	0.3	2016	Connected
Andritz TTG#1 – Meygen	4.5	2016-2017	Connected
Atlantis AR1500 – Meygen	1.5	2017	Connected
CorPower C3	0.05	2018	Connected
PLAT-O	1	2016	Connected
Minesto - Deep GreenOcean	0.5	2018	Connected
Total UK	**10.16**		
France			
La Rance Barrage	240	1966	Connected
Hydrotube Énergie H3	0.02	2015	Being tested
Sabella D10	1	2015	Connected
Bertin Technologies	0.018	2016	Connected
Guinard Énergie	0.004	2018	Connected
Seeneoh / Hydroquest	0.08	2018	Connected
Seeneoh/Design Pro	0.025	2018	Connected
Hydrowatt/Hydroquest	0.32	2018	Connected
Hydro Air Concept Energie (Hace)	0.05	2018	Connected
Total France	**241.52**		
Spain			
Mutriku OWC – Voith Wavegen	0.3	2011	Connected
Oceantec WEC MARMOK-A-5	0.03	2016	Connected
Total Spain	**0.33**		
Italy			
KOBOLD turbine	0.03	2000	Connected
H24	0.05	2015	Connected
REWEC3	0.02	2016	Being tested
OBREC	n.c	2016	Being tested
ISWEC	0.1	2016	Being tested
GEM	0.02	2014	Being tested
Total Italy	**0.22**		
Netherlands			
Tocardo T1	0.3	2015	Connected
Tocardo T2	0.25	2016	Connected
Eastern Scheldt Tocardo T2	1.25	2015	Connected
REDstack Afsluitdijk	0.05	2014	Connected
Total Netherlands	**1.85**		
Sweden			
Lysekil Project	n.c	2006	Connected
Seabased Sotenäs project	3	2016	Being tested
Total Sweden	**3**		
Denmark			
Wavepiston	0.012	2015	Being tested
Weptos	n.c	2017	Being tested
Crestwing	n.c	2018	Being tested
Total Denmark	**0.012**		
Portugal			
Evopod E1	0.001	n.c	Being tested
Total Portugal	**0.001**		
Greece			
SINN Power	n.c	2018	Connected
Total Greece	**n.c**		
Total EU	**257.1**		

Source: EurObserv'ER 2018

Continues overleaf

INTEGRATION OF RES IN THE BUILDING STOCK AND URBAN INFRASTRUCTURE

Currently, heating and cooling is mainly provided by onsite technologies integrated in buildings. For the further decarbonisation of the heating sector especially in highly populated areas, the integration of RES in district heating grids is gaining in importance. The consumption and market indicators on RES integration in the building stock and urban structure are designed to show the status quo of RES use and the development of RES deployment in this respect. Due to the large building stock and the long life cycle of heating systems, the consumption and market stock shares change slowly while the market sales shares reflects changes at the margin.

RES integrated in buildings or urban infrastructure comprises various technologies that are applied to provide heating, cooling and electricity. Decentralized technologies in buildings include heat pumps, biomass boilers, and solar thermal collectors. Relevant urban infrastructure for the integration of RES comprises mainly district heating plants including biomass CHP and heat only plants, geothermal plants, innovative applications such as solar thermal collector fields and large-scale heat pumps.

Methodological note

The consumption shares of RES in the building stock shows the significance of the respective RES in the building sector, and its use. It is the quotient of final renewable energy demand for heating and cooling in building and total final energy demand in buildings including electricity for heating and hot water preparation.

In addition, the market stock shares of RES are depicted. They show the installed heating units as a percentage of all dwellings. As solar power is mainly applied in combination with other technologies, it is not counted here as an alone standing system. In contrast, electric heating is included in the market stock share as an alone-standing system. It is an important technology for heating and hot water preparation in some countries.

In contrast to consumption shares of RES, market sales shares of RES depict the dynamics and development of RES at the edge. Market shares show the share of technologies sold in relation to the total of all sold heating units. They may vary from year to year in each country. As data on sales were not available for all technologies or countries, the number of system exchanges is assessed based on the average exchange rate of systems of those countries, for which data were available. Although solar thermal energy is mainly used in combination with other systems, it is separately listed here to show its significance and dynamics.

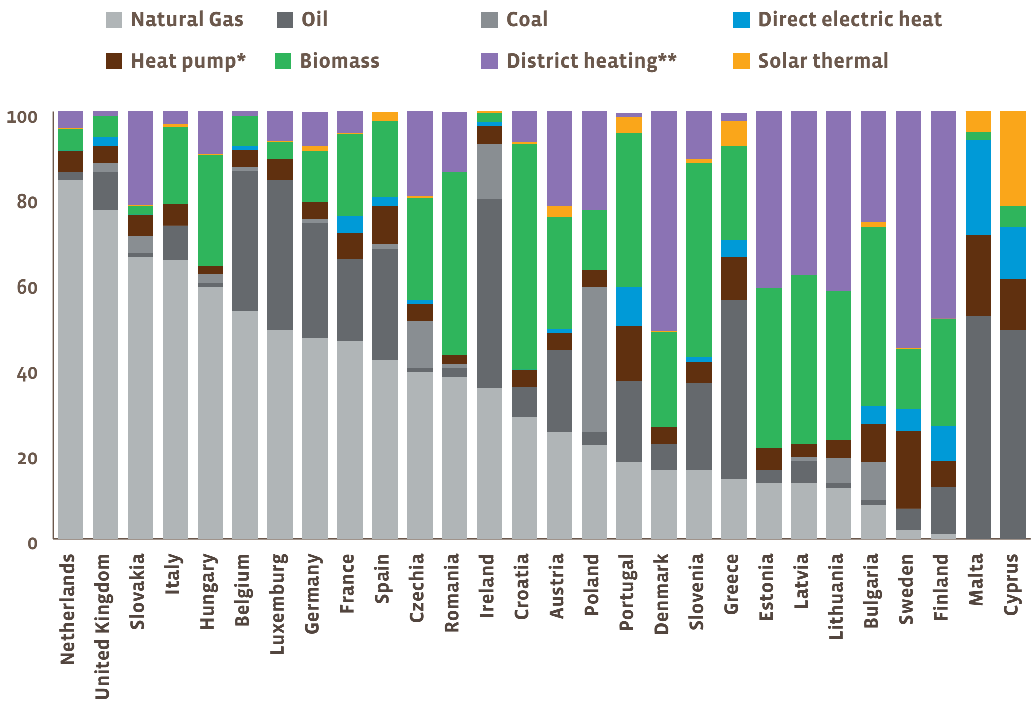
A more detailed description on the methodological approach of the market and consumption shares can be found on the project's website and on Eurostat's methodology on consumption shares see http://ec.europa.eu/eurostat/web/energy/data/shares. Because Eurostat data for 2017 were not published at that time, the shares are shown for 2016 only.

EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2018 EDITION

RESULTS AND INTERPRETATION

1

RES consumption shares in 2016



*Source: EurObserv'ER 2018 - own assessment based on diverse sources. *Heat pumps consider both ambient heat and electricity **District heating contains derived heat obtained by burning combustible fuels like coal, natural gas, oil, renewables (biofuels) and waste, or also by transforming electricity to heat in electric boilers or heat pumps.*

Figure 1 presents the consumption shares of heating and cooling with renewable energies in 2016 for residential buildings and services. Basically, this share is a combined indicator for the integration of renewable energies in buildings and urban infrastructure. It depicts the final renewable energy demand for heating and cooling as a share of total final energy demand for heating and cooling. Annual exchange rates for heating/cooling systems range around two to four percent, thus the consumption share shows only small changes from one year to the other. Thus, the situation in 2017 is expected to be similar to 2016.

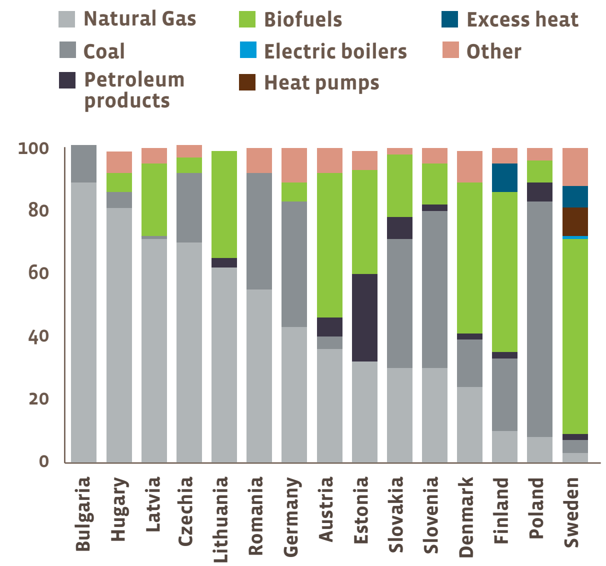
In the Netherlands and the United Kingdom, and to a smaller share in Slovakia, Italy, Hungary, Luxemburg and Belgium gas is still dominating the heating system. Oil boilers are mainly used in Malta, Cyprus, Ireland and in Luxemburg, Belgium, Greece, Slovenia, Portugal and Germany they still represent an important technology or source for heat.

Figure 2 depicts the existing supply mix in the countries where DH covers around 10% or more from the heating and hot water demand in 2016. From the arithmetic average, it can be concluded that the existing DH networks still rely on fossil fuels with natural gas and coal as predominant sources. Coal is mostly used in Poland, Slovenia, Slovakia, Germany and Romania. The oil DH consumption with exception of Estonia is almost phased out and presents an insignificant amount in the supply mix. In average, the biofuels such as biomass, biogas and renewable waste play a significant role with about 24% of all energy sources for DH.
The biofuels are a predominant DH heat source in the Scandinavian countries and Austria and has a substantial share in the Baltic countries and Slovenia. Excess heat and heat pumps are mostly used in Finland and Sweden.

District heating is strong especially in the Scandinavian countries as well as in the Baltic and other East European countries. In the latter countries, district heating has a long history and can rely on existing infrastructure.

2

District heating supply mix in 2016

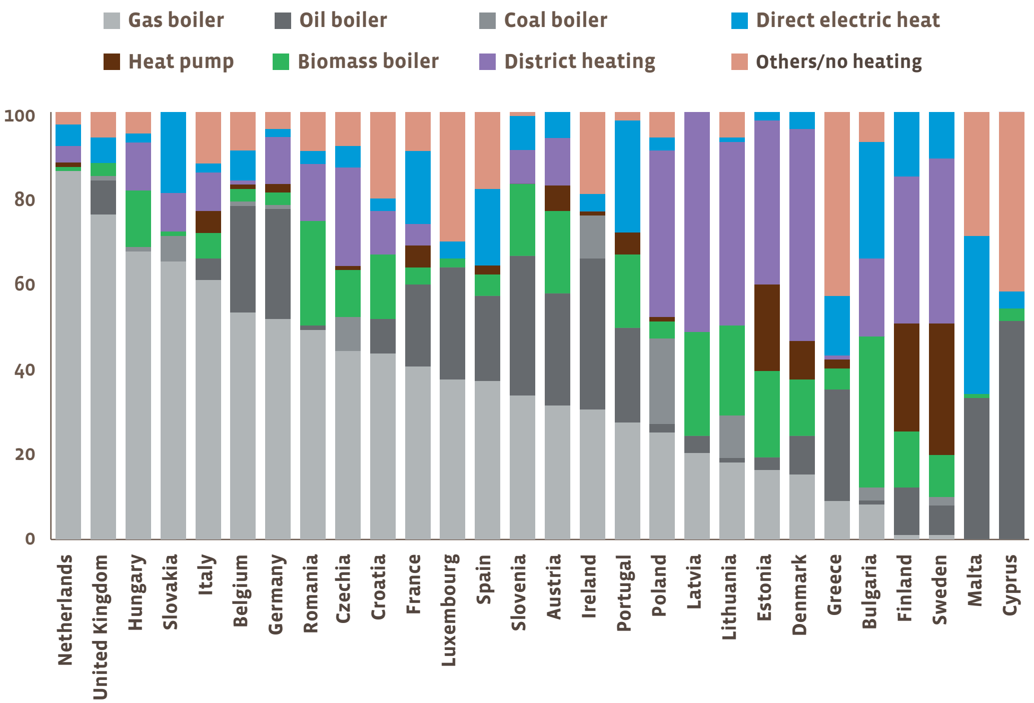


Source: EurObserv'ER 2018 - Based on 2016 data for: DK, DE, AT, FI ; Based on 2015 data for: PL, RO, SE ; Based on 2013 data for: LT, LV, EE, BG, SK, CZ, SI, HU

Back to figure 1, RES dominate in Croatia (54%), Slovenia (50%),and Bulgaria (49%). This domination is only due to the high use of biomass, which represents a rather cheap fuel for heating in these countries. It is also used in Romania (43%), Latvia (39%), and Portugal (36%). Albeit the growth of heat pumps in some countries, they display still a minor share apart from Sweden (18%), Portugal (13%) and other Southern European countries such as Malta (19%), Cyprus(12%), Greece (10%), and Spain (9%). Overall, solar thermal displays the smallest shares and is mainly used to a small extent in Southern European countries, where the solar radiation is stronger than in the north. It is highest in Cyprus (22%), and lowest in the Baltic States and Romania and Finland. In Poland a large share of coal (34%) is used for heating while electric heating plays a role in Malta, Portugal, Cyprus, and Finland but also in Sweden, France, Bulgaria and Greece.

Figure 3 depicts the technology shares in the building stock, i.e. for all dwellings. In contrast to Figure 1 above, it shows the share of households with another or unknown heating system or no heating system at all. This share is very high for Cyprus, Greece, and high for Malta and Luxemburg, and also considerable for Croatia, Ireland and Spain. Due to climatic conditions some dwellings might have only a small heater, stove etc., which is not accounted in the statistics. Further, the high share could reflect data problems in this group. As solar thermal is not included here as separate system, dwellings which use only solar thermal energy for heating are part of this group as well.
With respect to rising RES shares in

3
RES market stock shares in 2016



Source: EurObserv'ER 2018 - own assessment based on diverse sources. Note: solar is not counted as an alone standing system as it is used mainly in combination with other systems

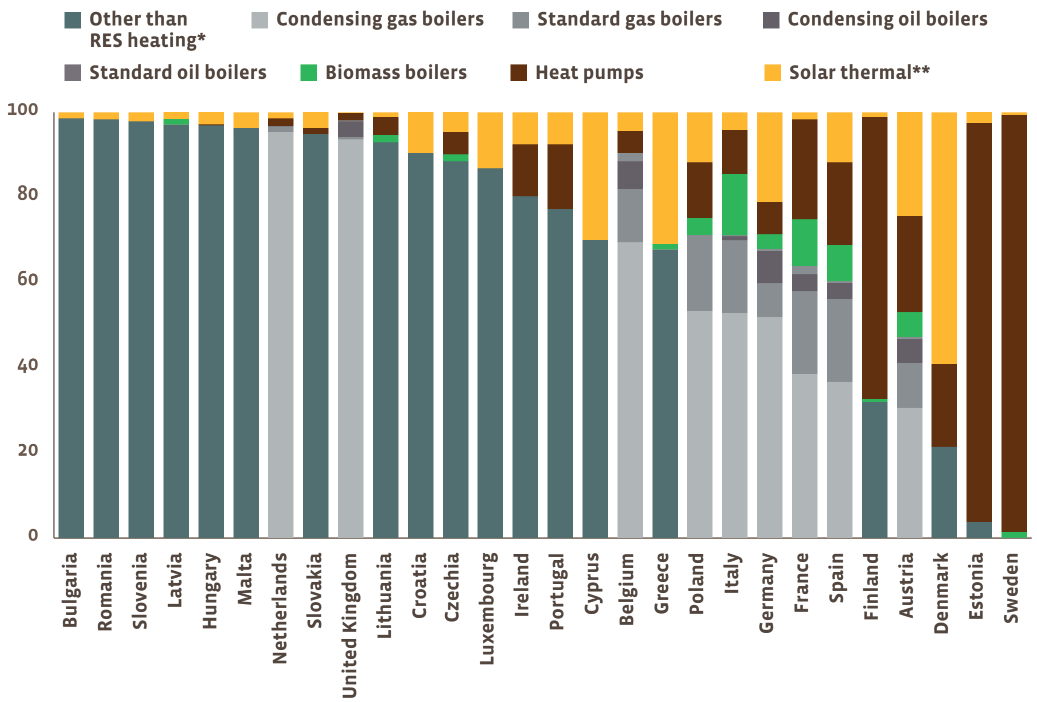
the power sector, electric heating gains in significance. In Bulgaria, Portugal and Malta the shares range significantly above ten percent, while in Spain, Slovakia, France, Finland, Greece and Sweden they are slightly above this threshold. This means a rising RES share in electricity contributes to low-carbon heating/cooling in these countries.

MARKET SALES SHARES OF RES

Figure 4 and Figure 5 depict the market sales share of RES technologies used for heating and cooling. In contrast to Figure 3 above, Figure 4 shows the recent developments in RES by illustrating the sales shares of RES heating/cooling in the respective year. Thus, it shows the dynamic in the market.

Heat pumps show a very high dynamic in Estonia, Finland, Sweden and France. Biomass boilers, although at a lower level than heat pumps, display a high dynamic in Italy, France, Spain and Austria. Despite the lack of market sales data for some countries, it can be assumed based on the consumption and market share that the sales of individual biomass technologies is also high in the Baltic countries, Bulgaria, Romania, Croatia and Slovenia. Solar thermal energy shows a high dynamic in countries where it has already a high share, such as Cyprus and Greece, but it displays the highest

4
RES-market sale shares in 2016



*Source: EurObserv'ER 2018 - own assessment based on diverse sources. * could comprise gas, oil and SEB_CHP, calculated for EU countries with missing data, based on average share of sales of AT, BE, FR, DE, IT, NL, PL, ES, UK; ** solar thermal system corresponds to 4 m² collector area*

dynamic in Denmark (solar district heating) while Austria, Germany, Poland and Spain reveal a moderate development.

Overall, in many EU countries, the dynamic of RES in the heating/cooling sector is low.

CONCLUSIONS

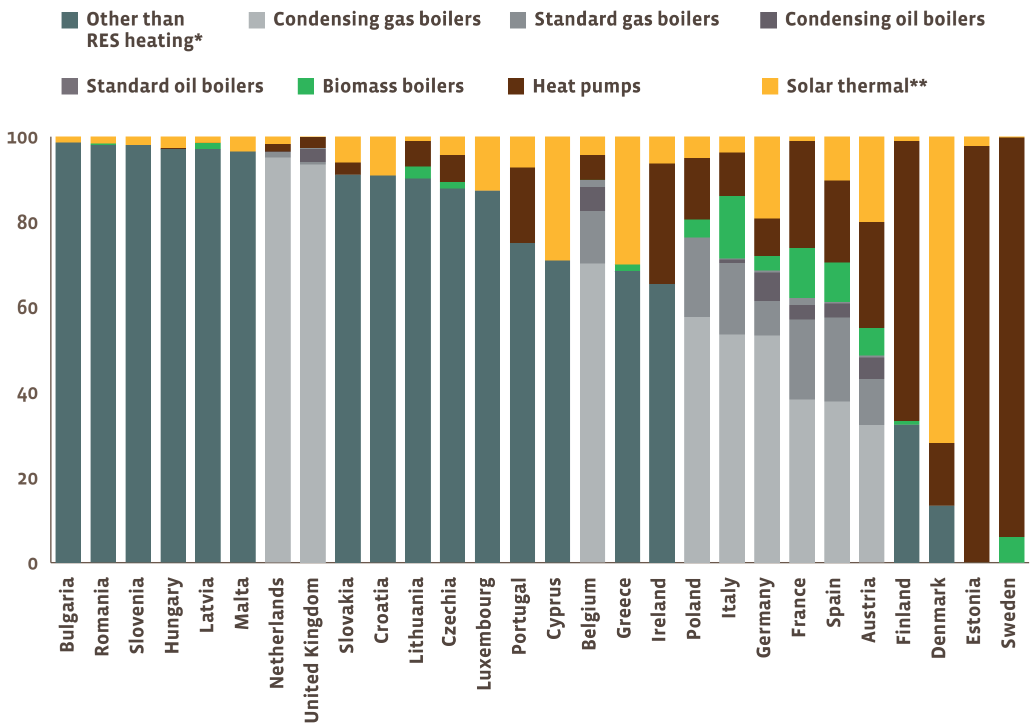
Overall, natural gas is the most commonly used heating system, followed by oil boilers, while coal boilers are slowly disappearing as the consumption shares as well as the market sale shares indicate. In addition, there is a high dynamic in sales of condensing gas and oil boilers, indicating that they will play a significant role in heating even in the future.

Albeit the relatively high dynamic of heat pumps in some of the countries, the consumption shares are small compared to fossil fuel based heating. Solar thermal power has quite some potential even in Northern countries as the case of Denmark shows but its dynamic as well as share in the stock is low.

In Table 1 an overview of the heating systems exchange rates for the selected EU MS is presented. It can be observed that in countries like Belgium, Italy, Netherlands, and the UK where the share of district heating is very low, the exchange rates are higher than in

5

RES-market sale shares in 2017



*Source: EurObserv'ER 2018 - own assessment based on diverse sources. * could comprise gas, oil and SEB_CHP, calculated for EU countries with missing data, based on average share of sales of AT, BE, FR, DE, IT, NL, PL, ES, UK; ** solar thermal system corresponds to 4 m² collector area*

the countries with high shares of households supplied by a district heating network.

In summary, in some countries RES consumption as well as the dynamic in sales of RES systems is high. In particular, heat pumps are increasingly employed in Scandinavian countries while biomass plays an increasingly role in some Eastern European countries. In Romania, Bulgaria and Hungary the dynamics in RES-H seems to be low, but traditionally heating relies already to a certain share on biomass. In light of the decarbonisation of heating and cooling, electricity is gaining in significance if it is based on renewable energy source. However, deployment rates of electric heating are still low. ■

1

Heating systems exchange rates as a percentage of households

Country	2016	2017
Austria	2.24%	2.33%
Belgium	5.47%	5.62%
France	3.38%	3.56%
Germany	1.73%	1.78%
Italy	4.60%	4.75%
Netherlands	5.34%	5.56%
Poland	1.53%	1.58%
Spain	2.11%	2.16%
Sweden	2.56%	3.04%
United Kingdom	6.18%	6.45%
Total	3.45%	3.59%

Source: own assessment based on diverse sources

HALF A PERCENTAGE POINT CLOSER TO THE 2020 TARGET IN 2017

Renewable energy output levels are by nature sensitive to climate conditions, both by prevailing on the demand made of them (e.g.: household wood consumption depends on winter temperatures, or the amount of time heat pumps are in use for winter heating or for their reversible function in the summer). Their variability also directly dictates output level at a given capacity – so annual rainfall levels affect hydroelectricity; average wind speeds affect wind energy and hours of sunshine affect solar installation output.

One of the conclusions we can draw from 2017, is that like 2016, agitated climate conditions affected the output of several renewable sectors, with contrasting and even reversed situations, depending on the member countries' geography. At the scale of the European Union two major electricity production sectors were particularly affected in 2017. On the downside, most of Europe suffered a record hydropower deficit, while on the upside wind energy production surged in 2017, in the wake of a year of particularly low winds in the Northern half of Europe. Current climate warming is probably to blame for these disturbances. According to the World Meteorological Organization, 2017 was the 5th hottest year ever recorded in Europe. Judging from the heat records broken from the North Sea to the Danube, many continental European countries experienced unheard-of mean annual temperatures in 2018.

THE NEW RENEWABLE SECTORS MAKE UP FOR THE RECORD HYDROPOWER DEFICIT

Gross real renewable electricity output (non-normalised), whose hydropower component derives from natural water flow (i.e., it excludes hydraulic pumping), crept up very slightly in 2017 to 975.2 TWh (graph 1), a 2.2% increase over 2016 (953.9 TWh). This equates to 21.3 TWh of additional output between 2016 and 2017, which betters the previous year's performance slightly (1.7% between 2015 and 2016) but was not as good as the 2015 (4%), 2014 (4.9%) and 2013 (11.7%) performance levels. If we factor in the hydropower output generated by pumping, which does not qualify as renewable energy by the European Renewable Energy Directive, then output came to 1 005.8 TWh in 2017 (983.9 TWh in 2016) – namely an increase of 2.2%.

Drought and record rainfall shortages characterized 2017 for much of Europe. Hydropower output from natural water flow, that excludes electricity produced by pumping, was 50.3 TWh lower than in 2016, dropping to an historic low of 300.7 TWh (351 TWh in 2016). Only two major producer countries were spared… Sweden and Latvia. The Southern and most westerly countries of Europe suffered the greatest losses, with output slashed by 48.4% in Spain, 62.5% in Portugal, 28.5% in Greece, 17.9% in France and 14.7% in Italy. Annual variations in "natural" hydropower output can be very significant. The 2017 level was a far cry from those of 2014 (375.9 TWh) and 2010 (376.9 TWh), which were particularly rainy years for the European Union as a whole.

The hydroelectricity deficit was offset by a huge surge in wind and solar power output. While in 2016 winds were particularly ill-disposed to wind power production along the British coasts, the North Sea, the Baltic and more generally over half of Northern Europe, more normal conditions prevailed in 2017. According to Eurostat, 362.4 TWh of wind power was generated in 2017, which is a 19.7% year-on-year rise (an increase of 59.6 TWh). Germany is the first country to have broken the 100-TWh wind power output barrier when it generated 105.7 TWh in 2017. The UK (50 TWh) beat Spain (at 49.1 TWh) to the finishing line to become the number two producer in the European Union. Naturally, output improved in the countries with major offshore wind turbine capacities. Increasing numbers of offshore wind farms have annual load factors approaching if not above 50%. The rate can be even higher during the winter which is when many countries experience peaks in electricity demand. The other factor that boosted development is the increase in wind turbine production capacities (onshore and offshore). Nett capacity rose by 14.7 GW (for a total of 169.8 GW), which is the highest increase in capacity the sector has ever recorded, outstripping those of 2016 and 2015 (12.8 GW each).

Solar photovoltaic also performed well in 2017, aided by more sunshine and 11.7 GW of nett newly-installed capacity over the past two years. According to Eurostat, European Union output rose to 113.7 TWh in 2017, or 7.3% year-on-year growth. Photovoltaic power now amounts to 3.4% of the European Union's gross electricity output. If we add the output of Spain's concentrated solar power plants (5.9 TWh), whose installed capacity has remained stable, solar power's total contribution was 119.5 TWh.

As for biomass energy taken as a whole, electricity output rose to 185.3 TWh in 2017… 4 TWh more or a 2.2% rise over its 2016 performance. The thrust of the growth in biomass electricity production is primarily provided by its solid biomass component that increased in twelve months by 3.0% to 94.7 TWh (thus adding 2.8 TWh). Most of this can be put down to an increase in solid biomass' net maximum electrical capacity in the countries that promote its use to replace coal and also via increased biomass cogeneration activity. The UK, Finland and Denmark are currently the most active countries in this area. Biomass electricity also benefits from an increase in the renewable electricity share from household waste incineration (by 1 TWh, for a total of 22.2 TWh).

The increase in biogas electricity output, whose political support is waning, was smaller (0.6 TWh, for a total of 63.4 TWh), while liquid biomass electricity output decreased by 0.3 TWh, to give a total of 5 TWh. The geothermal and ocean energy electricity sectors saw little change in their output. Geothermal electricity slid by 19 GWh (producing a total of 6.7 TWh) whereas ocean energy gained 25 GWh (producing a total of 526 GWh).

A MORE ADVANTAGEOUS DIRECTIVE MONITORING INDICATOR

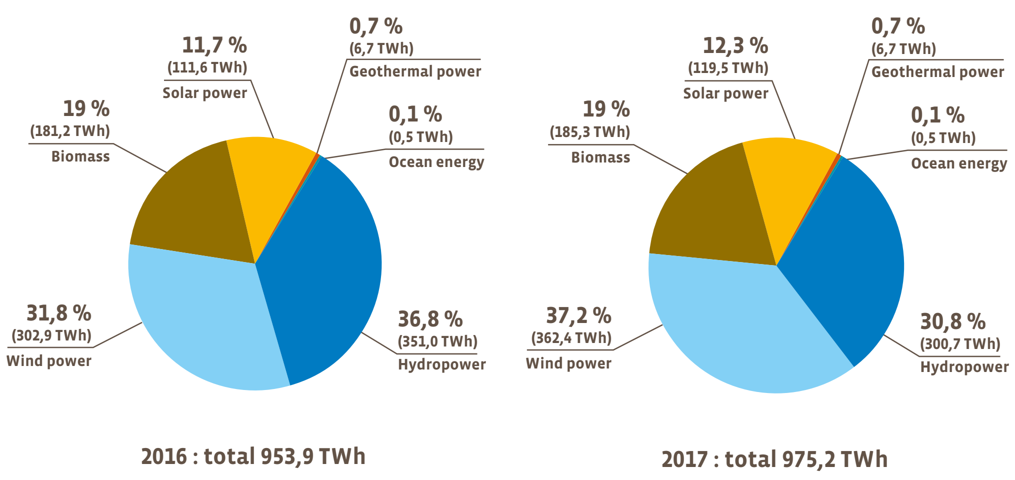
The renewable electricity production monitoring indicator used for calculating the Renewable Energies Directive (2009/28/EC) target differs in that it includes normalised production for hydropower and wind energy – the normalisation formula is defined in Annex II of the directive – to tone down the impact of climate vagaries, at least for rainfall and wind. The resulting indicator is more representative of the efforts made by each Member State. It is also more accurate because it factors in an estimate of the renewable electricity output produced by biomethane (refined biogas) that is injected into the natural gas grid and only includes the electricity output derived from sustainably-certified liquid biomass.

The normalised hydropower output figure finally adopted was 348.9 TWh in 2017 (351 TWh in 2016), that of wind energy 346.7 TWh (311.1 TWh in 2016). They take the renewable electricity output included in the European target calculations to 1 008.1 TWh in 2017 compared to 962.1 TWh in 2016. The total electricity output retained was 3 278.7 TWh in 2017, 0.7% more than in 2016 (3 255 TWh). This accounting change increases the renewable energy share from 29.6% in 2016 to 30.7% in 2017. The "normalised" renewable electricity share has more than doubled from its 2005 level (14.8%).

Turning to the reference period (2005–2017), we see that many EU countries have enjoyed considerable increases in their renewable electricity shares,

1

Share of each energy source in renewable electricity generation in the EU 28.



Note: Figures for actual hydraulic and wind generation (not normalised), pumped hydro excluded. Source : EurObserv'ER

accompanied by profound changes to the electricity production mix. The biggest increases can be credited to Denmark (35.7 percentage points), Portugal (26.5 pp), Germany (24 pp), the UK (24 pp), Ireland (22.9 pp), Italy (17.8 pp) and Spain (17.2 pp). This contrasts with meagre renewable electricity share growth in Hungary (3.1 pp), Slovenia (3.8 pp), Luxembourg (4.9 pp), Slovakia (5.6 pp), France (6.2 pp) and the Netherlands (7.5 pp).

Member States' renewable energy potential and support policies lead to wild divergences in the renewable electricity share as shown in Graph 2. Renewable output now dominates the mix in the top five countries – Austria (72.2% in 2017), Sweden (65.9%), Denmark (60.4%), Latvia (54.4%) and Portugal (54.2%). Yet, it is less than 10% in four straggling countries – Cyprus, Luxembourg, Hungary and Malta.

HEAT PASSES THE 100 MTOE THRESHOLD

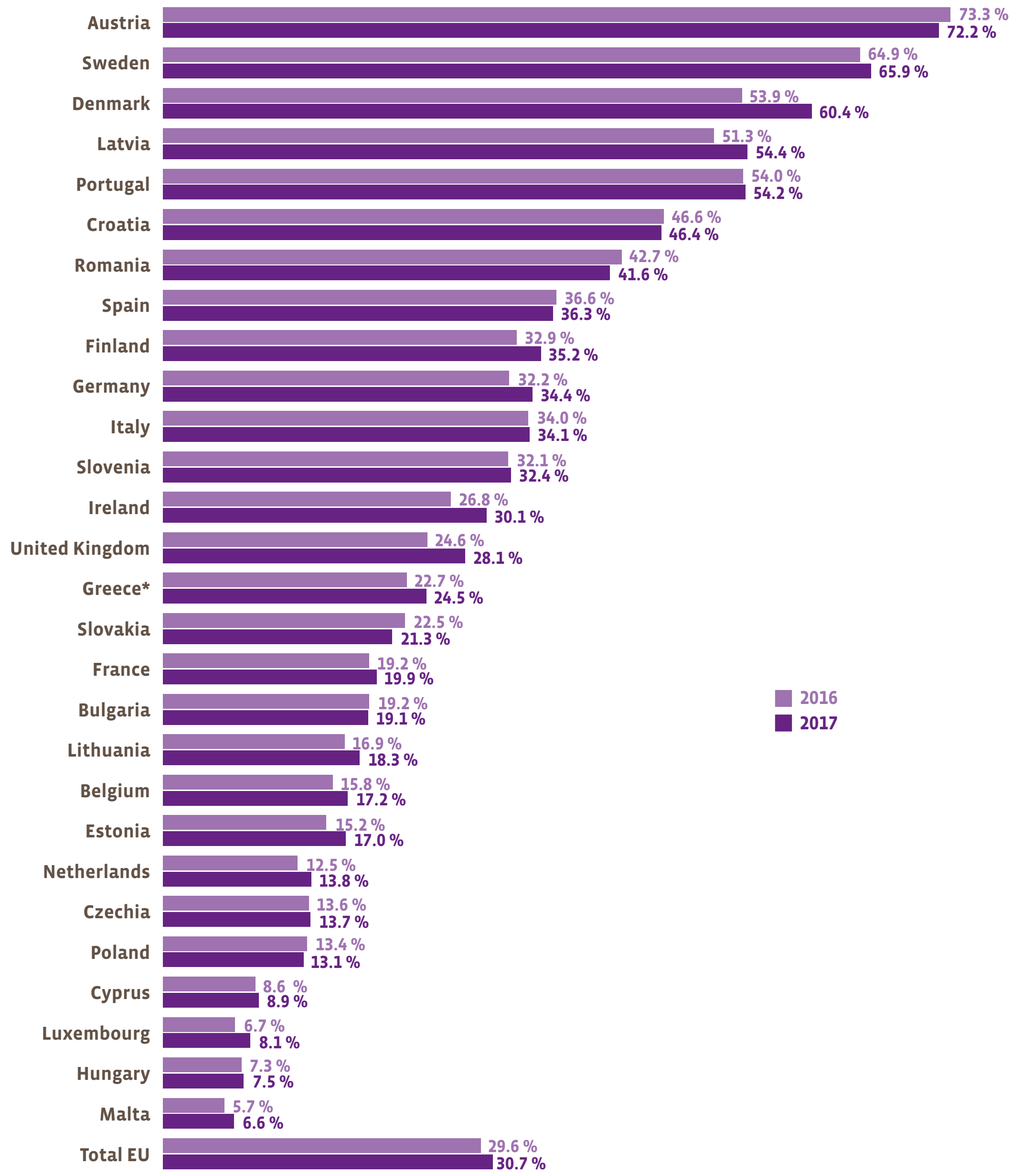
The Eurostat data released through its SHARES calculation tool shows that in 2017, renewable heat contributed less than renewable electricity to the increase in final renewable energy consumption, although the opposite was true in 2016. This indicator covers both the energy directly consumed by final users that is not produced by the processing sector (e.g.: household wood energy consumption that fuels domestic heating appliances), derived heat from heating and cogeneration plants and the renewable output recovered by heat pumps. Thus, heat output contributed up to 100.2 Mtoe in 2017 (99.5 Mtoe), which represents 2.7% growth over the 2016 level (an additional 2.7 Mtoe). This growth is less than the previous year's when 3.3 Mtoe was added (3.5%) or that of 2015 when 4.7 Mtoe was added (+5.1%).

Care needs to be taken when analysing renewable heat consumption variations. This is because the string of mild years and winters in Europe – a measurable consequence of climate warming – clouds the interpretation of the impact of renewable heat

1. SHARES 2017, update of 4 February 2019, downloaded from https://ec.europa.eu/eurostat/web/energy/data/shares

2

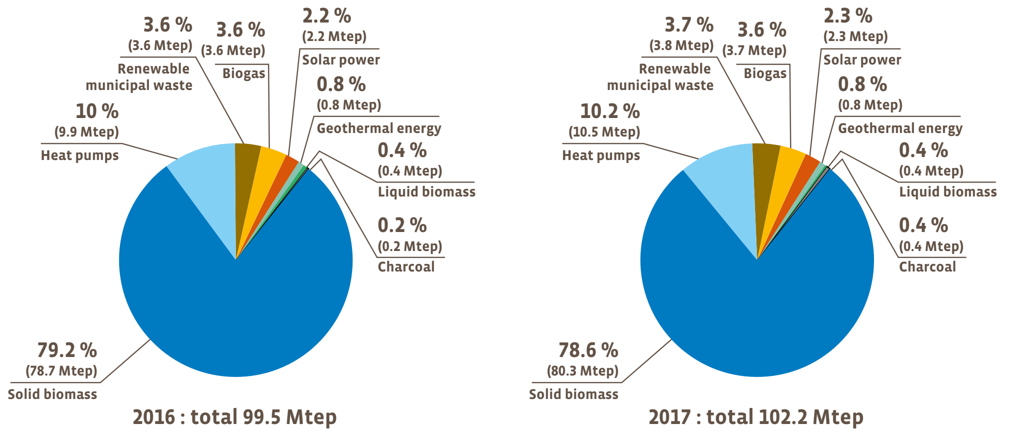
Share of renewable energy in the electricity generation of EU countries in 2016 and 2017



****estimated, provisional for Greece. Notes for calculation:** Hydro is normalised and excluding pumping. Wind is normalised. Solar includes solar photovoltaic and solar thermal generation. All other renewables include electricity generation from gaseous and liquid biofuels, renewable municipal waste, geothermal, and tide, wave & ocean. **Source: SHARES 2017 (updated 4 February 2019)***

3

Share of each energy source in renewable heat and cooling consumption in the EU 28



Source: EurObserv'ER

promotion policies, because heating requirements are directly correlated with average temperature levels. We should signal that over and above considerations of climate, energy efficiency efforts made possible by better building insulation and high performance heating appliances enable the full energy benefit of primary renewable energy to be drawn. The installation of a new wood heating system, replacing an older wood heating system, will have the effect of reducing the final renewable energy consumption, even more if insulation work has been done.

If we examine the individual sector trends, the increases can be largely ascribed to the additional input of solid biomass (1.6 Mtoe) and to a lesser extent the heat pump sector (0.5 Mtoe), renewable municipal waste (0.2 Mtoe), charcoal (0.2 Mtoe), solar thermal (0.1 Mtoe) and biogas (0.1 ktoe). The increased input of the geothermal sector was lower (0.05 Mtoe) and the liquid biomass input broadly remained stable.

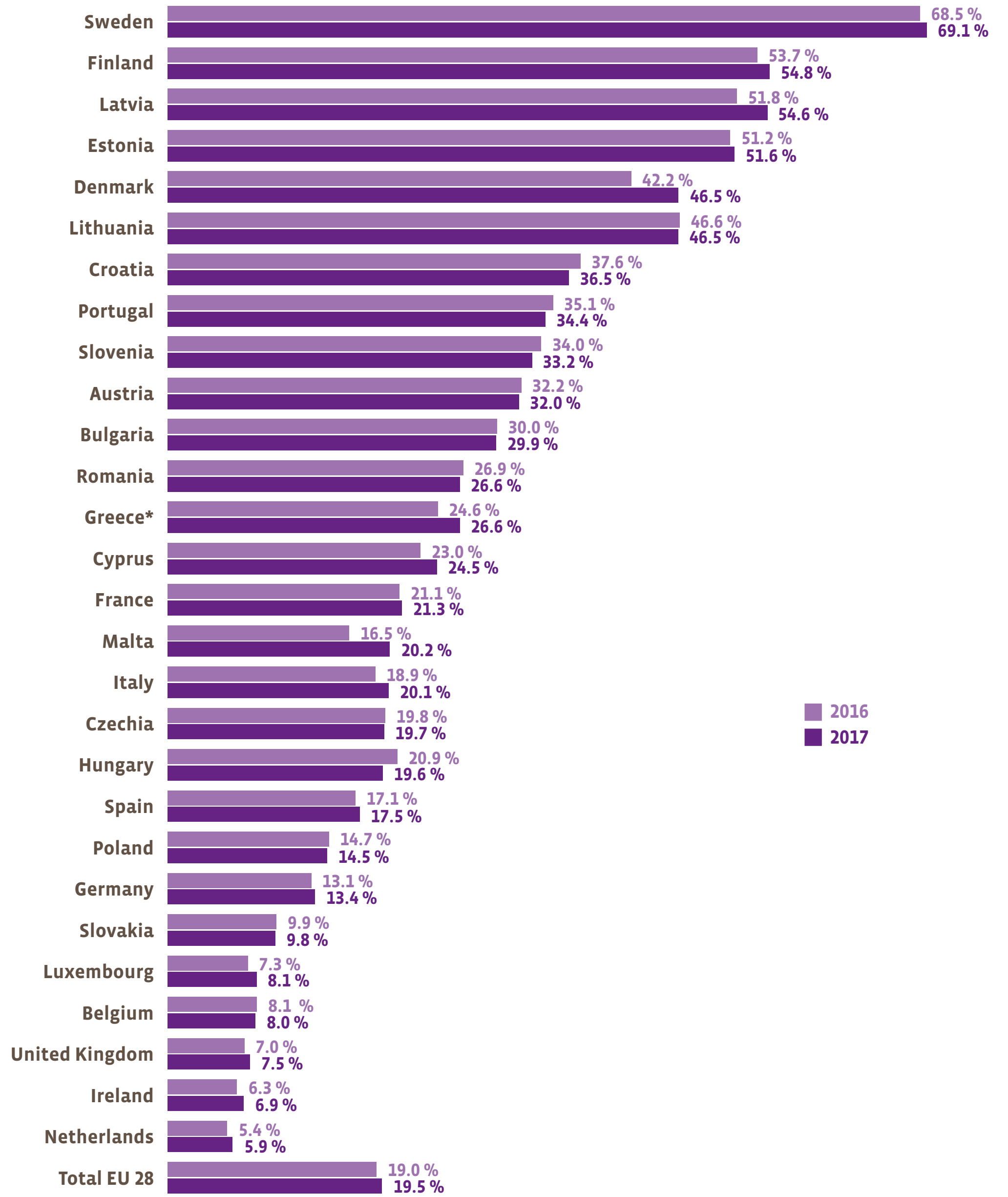
According to EurObserv'ER's calculations, the distribution between the various renewable heat sectors changed little between 2016 and 2017 (graph 3). Solid biomass is still the dominant renewable heat source (78.6% of the 2017 total) equating to 80.3 Mtoe of consumption. Heat pumps, be they air-sourced, hydrothermal or ground-sourced, provide the European Union with its second biggest source of renewable heat – a 10.2% share and output of 10.5 Mtoe. They are followed by renewable municipal waste (a 3.7% share and output of 3.8 Mtoe), biogas (3.6%, 3.7 Mtoe), solar (2.3%, 2.3 Mtoe), geothermal energy (0.8%, 0.8 Mtoe) and liquid biomass (0.4%, 0.4 Mtoe).

Given the total increase in heat consumption from 522.3 Mtoe in 2016 to 524.5 Mtoe in 2017 (0.4%), the renewable heat share rose to 19.5% (19.0% in 2016). If we take 2005 as the reference year (11.1%), we arrive at an 8.4 percentage point gain.

From 2005 to 2017, the highest renewable heat share growth can be credited to Denmark (23.7 pp), Estonia (19.5 pp), Malta (19.2 pp), Sweden (17.3 pp), Lithuania (17.2 pp), Finland (15.7 pp), Bulgaria (15.6 pp) and Slovenia (14.3 pp). They contrast with the countries with

4

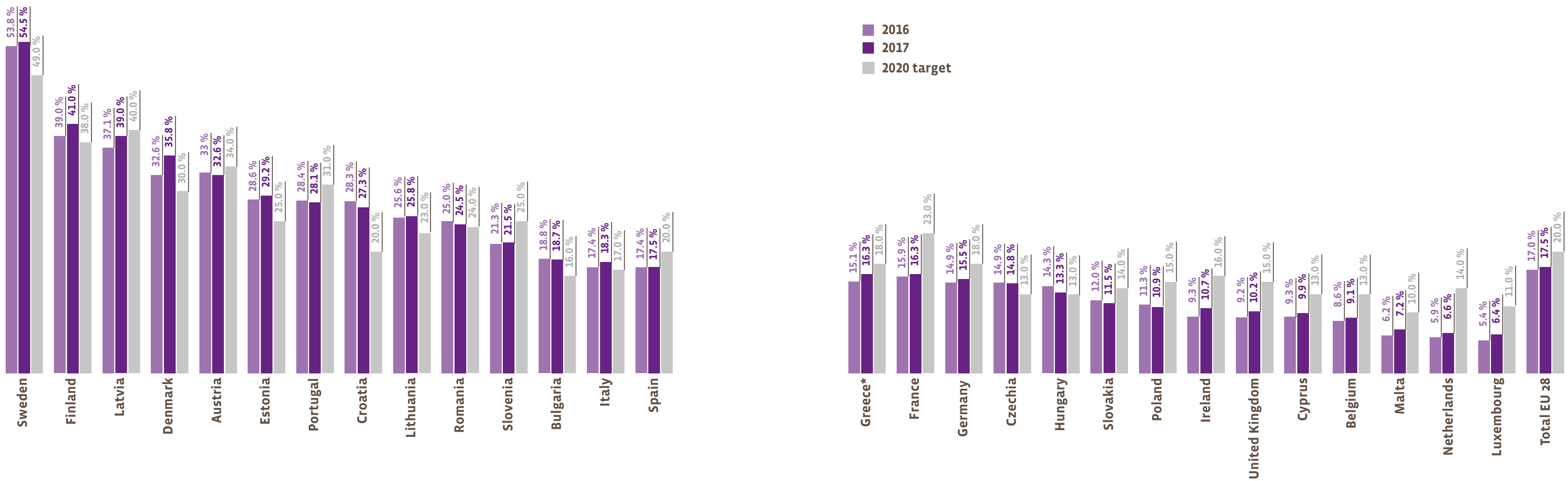
Share of renewable energy in heating and cooling of EU countries in 2016 and 2017



Source: SHARES 2017 (updated 4 February 2019)

5

Share of energy from renewable sources in gross final energy consumption in 2016 and 2017 and 2020 targets



**** estimated, provisional for Greece. Note:** SHARES tool version 2017 that takes into account specific calculation provisions as in place in Directive 2009/28/EC following its amendment by Directive (EU) 2016/1513 of the European Parliament and of the Council of 9 September 2016 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources. **Source: SHARES 2017 (updated 4 February 2019)***

the lowest growth increases – Portugal (2.3 pp), Ireland (3.4 pp), the Netherlands (3.5 pp), Poland (4.3 pp) and Luxembourg (4.5 pp).

Turning to the Member States, as biomass is patently the main renewable heat source, the biggest renewable heat share in total heat consumption naturally occurs in countries with forestry industries. It even dominates or almost dominates the heat mix in Northern Europe (68.6% in Sweden, 53.7% in Finland), and the Baltic States (54.6% in Latvia, 51.6% in Estonia and 46.5% in Lithuania). At the bottom of the scale, renewable heat has a tiny share of the heat mix in the Benelux (Luxembourg 8.1%, Belgium 8.0%, and 5.9% in the Netherlands) and the British Isles (6.9% in Ireland and 7.5% in the UK).

HALF A PERCENTAGE POINT CLOSER TO THE 2020 TARGET IN 2017

Eurostat has published its preliminary results for the renewably-sourced share of energy that meets the 2009/28/EC directive calculated by its SHARES (Short Assessment of Renewable Energy Sources) tool. The 4 February 2019 update confirms the December estimates made for the EurObserv'ER project across the whole of the European Union. The renewably-sourced share of gross final energy consumption was 17.5% in 2017, which is half a percentage point improvement (0.5 pp) on 2016.

The 2017 increase in the renewable energy share across the European Union was a little higher than that of 2016 when 0.3 pp was added between 2015 and 2016. Yet it is still below the gains made in 2012 (1.3 pp), 2013 (0.7 pp) and 2014 (0.8 pp). The current growth rate is too low to meet the 2020 target, for it needs to be at least 0.83 pp every year between 2018 and 2020. With collective effort the target still remains within the European Union's reach, primarily by implementing cooperation mechanisms that include "statistical transfers" from countries that expect to overshoot their targets to countries expecting to fall short of target.

Each EU Member State has its own 2020 target. The national targets make allowance for the starting point situation differences as well as the renewable energy potentials, ambitions and economic performances specific to the Member States. The major forestry countries and/or those with high hydropower potential are naturally at an advantage. This applies to Sweden whose renewably-sourced energy dominated its energy mix at 54.5% in 2017.

Four other countries produce a third or more of their final energy consumption from renewable sources – Finland (41.0%), Latvia (39.0%), Denmark (35.8%) and Austria (32.6%). At the other end of the scale five countries had renewable energy shares of less than 10% (i.e. two fewer than in 2016, as the UK and Ireland left the group in 2017). The five are Cyprus (9.9%), Belgium (9.1%), Malta (7.2%), the Netherlands (6.6%), and Luxembourg (6.4%).

An update on 2017 shows that a sizeable majority of the member countries are on course to make their targets, ergo, they have already achieved target, or are on track to do so by their indicative renewable energy directive trajectories. The provisional SHARES results show that 11 member countries had exceeded their 2020 targets in 2017. They are the same 11 as last year, i.e.: Sweden (by 5.5 pp), Finland (by 3 pp), Denmark by

6

Share of energy from renewable sources in gross final energy consumption in 2016 and 2017 and indicative trajectory

Countries	2016	2017	*Indicative trajectory 2017-2018*
Sweden	53.8%	54.5%	45.8%
Finland	39.0%	41.0%	34.7%
Latvia	37.1%	39.0%	37.4%
Denmark	32.6%	35.8%	25.5%
Austria	33.0%	32.6%	30.3%
Estonia	28.6%	29.2%	22.6%
Portugal	28.4%	28.1%	27.3%
Croatia	28.3%	27.3%	17.4%
Lithuania	25.6%	25.8%	20.2%
Romania	25.0%	24.5%	21.8%
Slovenia	21.3%	21.5%	21.9%
Bulgaria	18.8%	18.7%	13.7%
Italy	17.4%	18.3%	12.9%
Spain	17.4%	17.5%	16.0%
Greece*	15.1%	16.3%	14.1%
France	15.9%	16.3%	18.6%
Germany	14.9%	15.5%	13.7%
Czechia	14.9%	14.8%	10.6%
Hungary	14.3%	13.3%	10.0%
Slovakia	12.0%	11.5%	11.4%
Poland	11.3%	10.9%	12.3%
Ireland	9.3%	10.7%	11.5%
United Kingdom	9.2%	10.2%	10.2%
Cyprus	9.3%	9.9%	9.5%
Belgium	8.6%	9.1%	9.2%
Malta	6.2%	7.2%	6.5%
Netherlands	5.9%	6.6%	9.9%
Luxembourg	5.4%	6.4%	7.5%
Total EU 28	**17.0%**	**17.5%**	**-**

**** estimated, provisional for Greece. Note:*** *SHARES tool version 2017 that takes into account specific calculation provisions as in place in Directive 2009/28/EC following its amendment by Directive (EU) 2016/1513 of the European Parliament and of the Council of 9 September 2016 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources.* ***Source: SHARES 2017 (updated 4 February 2019)***

5.8 pp), Estonia by 4.2 pp), Croatia by 7.3 pp), Lithuania by 2.8 pp), Romania (by 0.5 pp), Bulgaria (by 2.7 pp), Italy (by 1.3 pp), the Czech Republic (by 1.8 pp) and Hungary (by 0.3 pp). The countries furthest off the mark are the Netherlands (7.4 pp under target), France (6.7 pp), Ireland (5.3 pp), the UK (4.8 pp) and Luxembourg (4.6 pp).

If we now focus on the indicative trajectory, whose percentage is identical for 2017–2018, only a handful of countries fell behind. The worst offenders are the Netherlands (3.3 pp off track) and France (2.3 pp off track). The shortfalls are smaller for Poland (by 1.4 pp), Luxembourg (by 1.1 pp), Ireland (by 0.8 pp) while Slovenia and Belgium are only very slightly off track (by 0.3 pp and 0.2 pp respectively).

Growth of the renewable share is not always linear and can slip from one year to the next. In 2017, the renewable share of about one third of the member countries (9 of the 28) contracted on its 2016 level, but this is an improvement on 2016, when 13 countries had slightly lower renewable shares than in 2015. In 2017, the nine countries with lower renewable shares were Austria, Portugal, Poland, Slovakia, Croatia, Romania, Bulgaria, the Czech Republic and Hungary. Leaving aside Hungary, the drop in the renewable share cannot be attributed to a drop in final renewable energy consumption but to higher growth in final consumption of non-renewable energy (oil, gas, coal and nuclear energy). For the third year running, and having approached its 2020 target in 2014, the EU's final energy consumption is increasing according to Eurostat. It was measured in the European Union of 28 at 1 122.3 Mtoe in 2017, which is a 1.1% annual rise (1 109.8 toe in 2016). The reason for this increase is the upturn in economic activity, as the European Union's GDP grew by 2.4% in 2017, which is the highest annual growth rate since the 2009 financial crisis.

But the additional energy needs of a country driven by economic growth in certain specific sectors relating to economic activity (such as industry and transport) have yet to be systematically filled by increased renewable energy development.

The European Union now has three years left in which to gain the missing 2.5 pp to reach its 2020 target and create the best foundations for meeting the new renewable energy directive 2018/2001 goals. This new directive that was finally adopted on 11 December 2018, makes it binding on the Member States to collectively ensure that the renewably-sourced energy share of the EU's gross final energy consumption in 2030 is at least 32%.

While quantified targets are important for the industry players involved in energy transition, as well as for the programming laws that will ensure their implementation at national level, it is crucial that the European Union gives its citizens a long-term strategic vision, a common goal, in order to reach a prosperous, modern and climate neutral economy by 2050.

The European Council, made up of Heads of State and governments, has asked the European Commission to present it with a climate strategy for 2050 by the first quarter of 2019. It must comply with the Paris Agreement and integrate the national climate-energy plans. A preliminary response was submitted by the European Commission on 28 November 2018 in the form of a communication entitled "A Clean Planet for All". It offers a strategic vision of the economic and social sea changes required to set up a climate-neutral economy. The underlying idea is not to set targets, but to ensure that the transition is socially fair, that it does not sideline Europeans or leave regions behind schedule but empower and strengthen the competitiveness of the European economy in global markets. According to the Commission, achieving a climate-neutral economy by 2050 is technologically, economically and socially achievable but will call for radical societal and economic transformations within a single generation. Thus, the Commission has listed its strategic priorities to achieve climate neutrality for the economy. Its first measure is full decarbonisation of the European energy procurement system, with large-scale electrification of the energy system coupled with significant deployment of renewables, maximising the benefits of energy efficiency, by almost halving energy consumption between 2005 and 2050, (and a target of 956 Mtoe in 2030), developing intelligent infrastructures and smart grids, spreading the benefits of bio-economy and creating a carbon sink by developing sustainable agriculture and land management, setting up carbon capture and storage systems, implementing clean, connected mobility and making industrial modernisation the flagship of a circular economy. ■

SOCIO-ECONOMIC INDICATORS

The following chapter sheds a light on the European renewable energy sectors in terms of socioeconomic impacts. All 28 members States are covered for 2016 and 2017.

Methodological note

For the socio-economic indicators, an important methodological change has been implemented as of the 2017 Edition of 'The State of Renewable Energy in Europe', by setting up a modelling environment that formalises the assessment procedure of employment and turnover. The model was developed by the Energy research Centre of the Netherlands (ECN), currently ECN part of TNO.

It is important to note that the indicators used in this methodology differ from those of previous years (up to and including Edition 2016); instead of determining the actual jobs that are present or revenues made in a certain year, the methodology determines the jobs and revenues that are related to the capacity of a technology (installed and already present) of a certain year. This subtle difference means that a sudden decline or increase in jobs as presented in this study does not necessarily correspond with what is observed by national sector associations, as during short periods in which less new technology capacity is installed, companies (and their employees) can still continue to hold on using their reserves.

The new methodological approach is based on an evaluation of the economic activity of each renewable sector covered, which is then expressed into full-time equivalent (FTE) employment. Note that from this point on the term 'job' will refer to a full-time equivalent. This new approach focuses on money flows from four distinct activities:

1. *Investments in new installations;*
2. *Operational and maintenance activities for existing plants including the newly added plants;*
3. *Production and trading of renewable energy equipment;*
4. *Production and trading of biomass feedstock.*

Proper characteristics of the economic sectors of each EU Member State are taken into account when determining the renewable employment and turnover effects by using input-output tables. ***The new methodology uses a consistent and mathematical approach to define the employment and turnover effects, allowing for a comparison between the European Union Member States.*** *Underlying used databases stem from Eurostat, JRC and EurObserv'ER. Employment related to energy efficiency measures is outside of the scope of the analysis. Below, some important methodological issues are briefly highlighted:*

- *Employment data presented in each RES chapter refers to* ***gross employment****, i.e. not taking into account developments in non-renewable energy sectors or reduced expenditure in other sectors.*
- ***Data include both direct and indirect employment.*** *Direct employment includes RES equipment manufacturing, RES plants construction, engineering and management, operation and maintenance, biomass supply and exploitation. Indirect employment refers to secondary activities, such as transport and other services.*
- *Socio economic indicators for the bioenergy sectors (biofuels, biomass and biogas)* ***include the upstream activities in the agricultural, farming and forestry sectors****.*
- *Turnover figures are expressed in current million euros (€M).*
- *Taking data accuracy into account, the socio-economic indicators have been rounded to 100 for employment figures and to € 10 million euro for turnover data.*

The employment and turnover data were obtained from a 'living model', still under development and open for comments and further improvement. One of the challenging issues when setting up a model is to incorporate the numerous remarks received from modelling experts, the renewable energy industry, policy makers and country representatives. In September 2018 selected experts from national statistics bodies and technology associations were invited to comment on the socio-economic indicators.

Answers to this questionnaire have resulted in valuable insights. Among others, a discrepancy was observed between the EurObserv'ER estimates and a report by WindEurope entitled 'Local Impact, Global Leadership, The impact of wind energy on jobs and the EU economy' *(2017)[1], which also assesses wind-related economic activity. The estimates in that report differ from the data reported in this section, which can be explained by the difference in methodology. The WindEurope report makes an inventory of direct employment by counting jobs reported in annual reports from companies active in wind power. Indirect employment is then estimated. By contrast, EurObserv'ER uses an input-output modelling approach to assess both direct and indirect employment in an integral modelling approach. One of the differences in the EurObsrv'ER work is that investments following from renewable energy technologies starting to generate energy in a certain year are allocated to the socio-economic activity in that particular year.*

Also for Italy deviations were observed in comparing the report 'La situazione energetica nazionale nel 2017' *(2018)[2]. These differences however were attributed to different boundary conditions applied in both studies (for heat pumps EurObserv'ER assesses also refrigerating heat pumps and for geothermal EurObserv'ER assesses heat-only installations next to electricity generation). This difference in approach is (at least partially) an explanation of the differences observed.*

The EurObserv'ER team would like to acknowledge all experts that shared their view in the consultation round.

In the 2017 Edition a new indicator was introduced: the employment effects in the fossil fuel chains based on the energy replaced by increased renewables production. This indicator only takes into account direct jobs in fossil sectors, not replaced investment or the indirect effects. Currently estimates for eighteen member states are reported.

For more information regarding the methodology used in this chapter, interested readers are referred to a separate methodology paper that explains the new approach in more detail. This paper can be downloaded from the EurObserv'ER project website.

1. https://windeurope.org/about-wind/reports/local-impact-global-leadership
2. https://www.mise.gov.it/images/stories/documenti/MiSE-DGSAIE_Relazione_energia_ed_appendici_2018.pdf

WIND POWER

Wind power sector remains an important contributor to employment within the EU's renewable energy market. According to the EurObserv'ER model, employment picked up in 2017 after a drop in turnover and employment in 2016, increasing from an estimated 309 000 to 356 700 FTE. The turnover increased from an estimated 39 250 M€ to 48 040 M€ . The top five countries in terms of wind energy related employment remains similar as in 2016, except for the Netherlands whose fifth place is claimed by France. Both the onshore and offshore wind sector has been assessed in this chapter.

The total additional installed wind turbines in 2017 increased, mainly due to offshore wind (3 228.6 installed MW in 2017 compared to 1 613.8 MW in 2016). The employment related to the wind energy sector increased significantly. The export of wind turbines and offshore foundations remains strong. In particular, the manufacturing sectors of wind turbine producers such as Denmark, Germany and Spain, profited from this. Vestas (Denmark), Siemens Gamesa (Germany and Spain) and Enercon (Germany) are the biggest players in the EU with their exports going to non-EU countries: India, USA, Argentina, Chile, Canada, Mexico, China, Egypt, Taiwan, Thailand and Vietnam.

In ***Germany***, the number of FTE jobs derived from wind power has reached 140 800 jobs as compared to 121 700 jobs in the past year with revenues surpassing € 20 billion. Germany secures its position as the EU leader in job creation within the wind power sector accounting for 39.5% of the total jobs in this sector. Job creation could be attributed towards Germany's impressive and record-breaking growth within this one-year period. According to Eurostat, Germany installed 6 126 MW worth of capacity in 2017 of which 4 431.5 MW accounted for onshore wind facilities and 1 694.5 MW accounted for offshore wind. Changes in support systems offered by the German government have boosted growth of the industry and incentivized developers to seize advantageous payment options, encouraged in part

by the move towards a tendering system and direct sales. Bidding values for the three tenders in 2017 showed a remarkable drop over the year. The Renewable Energy Office of the German Ministry for Economic Affairs and Energy (BMWi) concludes that if the tender results in offshore wind pricing continues on this downward trend in 2018, future bids at 0 euro cents per kWh are a possibility.

With an impressive year-on-year increase of 63% ***United Kingdom*** had the second highest number of FTE with a total of 69 900 jobs. Revenues derived from the sector followed a similar trend, totalling € 7.4 billion in 2017 (€ 4.5 billion in 2016). This number of FTE accounts for 19.6% of all wind related jobs in the EU.

Spain came in 3rd in terms of the number of FTE with 37 200 jobs, accounting for 10% of the total jobs within the wind sector in the EU. Revenues continue to increase from € 2.8 billion in 2016 to € 4.3 billion in 2017. Strong growth

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in € m)	
	2016	2017	2016	2017
Germany	121 700	140 800	16 060	20 040
United Kingdom	42 900	69 900	4 490	7 360
Denmark	26 600	34 200	4 600	6 310
Spain	23 500	37 200	2 820	4 340
Netherlands	21 500	5 800	2 680	830
France	18 800	18 500	2 790	2 860
Poland	11 400	8 000	790	660
Portugal	6 400	3 100	500	320
Italy	6 300	7 500	950	1 120
Sweden	4 900	2 700	1 010	620
Ireland	4 200	6 500	440	700
Greece	3 700	3 100	300	230
Finland	3 500	4 100	520	630
Romania	2 500	2 100	150	160
Belgium	2 300	5 500	450	1 100
Austria	1 700	2 000	280	350
Estonia	1 600	1 200	90	80
Lithuania	1 600	500	60	30
Czechia	900	900	60	70
Croatia	900	1 100	50	70
Hungary	800	800	50	50
Bulgaria	600	500	30	30
Luxembourg	200	100	30	20
Cyprus	<100	200	<10	20
Latvia	<100	<100	<10	<10
Malta	<100	<100	<10	<10
Slovenia	<100	<100	<10	<10
Slovakia	<100	<100	<10	<10
Total EU 28	309 000	356 700	39 250	48 040

Source: EurObserv'ER 2018

PNE WIND AG

in employment was fuelled by a surge of activity in the manufacturing sector and by wind farm developers (for instance Iberdrola Renovables that developed and operated 16 077 MW in 2017).

The number of FTE in **Denmark** rose by 28.7% from 2016 levels to attain 34 200 in 2017. Revenues for the year added up to € 6.3 billion. The increase is partly related to domestic realised wind energy projects, but the majority of the FTE are due to manufacturing of wind turbine equipment that is exported to other EU and non-EU countries. With a total of 5 522 MW of wind capacity developed and operated in 2017, Denmark also leads in terms of wind power capacity per 1 000 inhabitants with an astounding capacity of 960.3 kW/1000 inhabitants. In comparison, Germany, ranked fourth, has only 671.5kW/1000 inhabitants. Denmark has also achieved a cumulative capacity of 5 522 MW at the end of 2017 of which 1 296.8 MW in offshore wind capacity. This makes it the country with the third largest offshore energy sector in the EU (after the UK and Germany).

In **France**, the number of FTE fell slightly from 18 800 jobs in 2016 to 18 500 in 2017 even though the total installed capacity of onshore wind in France increased by 15.3% to reach 13 512 MW. The decline in jobs appears to be caused by a lower net export of wind turbine equipment compared to 2016. Favourable weather conditions resulted in an increase in electricity produced from the wind sector from 0.7% in 2016 to 15% in 2017. At the same time, the number of projects in the pipeline grew by 5%. A contributing factor was a more robust regulatory framework that enabled the shift towards top-up remuneration and a phasing out of feed-in tariffs. ■

PHOTOVOLTAIC

The Photovoltaics (PV) sector contracted by approximately 5% within the European Union in 2017. Despite this PV was responsible for more than 7% of the energy mix in Germany and Italy. Only 5.7 GW of additional capacity was added in 2017 within the EU, which is a 10.8% drop compared to 2016 added capacity levels. Overall, the European PV industry in 2017 still represented a € 11.2 billion market and a workforce of 90 800 people.

Germany boasted the greatest number of jobs within the EU PV sector in 2017, an estimated number of 29 300 FTE and revenues of € 4.01 billion. It surpassed the UK in this respect after the latter held the lead for three consecutive years. The number of German PV jobs is equivalent to 32.2% of all jobs within the PV sector in the EU. According to Eurostat, Germany connected 1 623 MW to the grid in 2017 compared to 1 492 MW in 2016 from PV, a 12.4% annual increase. Simultaneously, the domestic market of Germany is flourishing and is supported by the solar power storage market which manufactures small photovoltaic battery systems. Germany also boasts some of the largest photovoltaic developers in 2017 such as Juwi AG /MVV Energie AG and Enerparc which together have installed more than 4 300 MW. Although Germany experienced an overall increase in jobs, as the largest manufacturer and only net exporter of PV equipment in Europe the German growth in the PV sector was slightly hampered by the overall decrease in installed PV in Europe, which limited the export of PV equipment produced in Germany.

On the flip side, the ***United Kingdom*** has slid to the second spot in terms of FTE in the commercial PV sector. The estimation of the British job market contracted sharply by 55.4% from approximately 29 000 FTE to just over 12 900 in 2017 with revenues totalling € 1.31 billion. This drastic decline can be attributed to the slump in the amount of newly added PV capacity installed (864 MW in 2017 as compared to

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Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in € m)	
	2016	2017	2016	2017
Germany	27 100	29 300	3 400	4 010
United Kingdom	29 000	12 900	2 810	1 310
Italy	10 700	11 200	1 400	1 450
France	5 200	9 300	710	1 310
Netherlands	4 700	6 000	560	730
Spain	2 200	5 500	220	500
Belgium	2 400	3 000	440	570
Austria	1 300	1 600	190	260
Portugal	700	1 500	40	90
Hungary	2 000	1 300	90	60
Czechia	1 700	1 300	110	100
Greece	1 100	1 300	90	90
Poland	1 500	1 100	90	80
Denmark	1 200	1 100	200	190
Romania	1 800	900	90	60
Finland	400	700	80	120
Bulgaria	800	600	30	30
Sweden	300	500	60	90
Cyprus	<100	500	<10	30
Malta	100	300	<10	20
Slovakia	400	200	20	20
Lithuania	300	100	10	<10
Slovenia	300	100	20	10
Estonia	200	100	10	<10
Croatia	<100	100	<10	<10
Luxembourg	<100	100	10	10
Ireland	<100	<100	<10	10
Latvia	<100	<100	<10	<10
Total EU 28	95 900	90 800	10 730	11 190

Source: EurObserv'ER 2018

First Solar

2 364 MW in 2016). The downturn was induced by the fact that not a single solar project has qualified since the second auction under the Contract for Difference (CID) system. Nevertheless, the output from solar power has increased by 10.7% as compared to 2016 and currently accounts for 3.2% of the UK's electricity output.

Italy clinched the third place with 11 200 FTEs in 2017, a slight year-on-year growth of 4.6%. Revenues for 2017 amounted to € 1.45 billion. The total added capacity increased from 382 MW in 2016 to 399 MW in 2017 bringing the total connected and cumulated PV capacity to 19 682 MW at the end of the year. Employment in Italy could potentially be driven by the presence of solar PV developers such as Enerl Green Power, who installed 1 200 MWp of PV capacity in 2017, as well as the need for workers for both the installation of new PV panels as well as the repair and maintenance of older equipment.

The number of jobs in ***France*** has increased by an astounding 78.7% to reach 9 300 FTE with revenues amounting to € 1.3 billion. This rebound is in part facilitated by the positive traction that France is gaining after 2016's disappointing performance. With more than eight calls for tender in 2017, amounting to 1 503 MW, the sector is expected to display continued growth as well in 2018. This growth will be additionally driven by an increase in the tender volume for solar PV by 1 GW in the coming year. Unprecedented growth in the domestic market boosted employment numbers as the number of households producing their own electricity jumped from 8 000 to 20 000 in 2017. ■

SOLAR THERMAL

The solar thermal market in the EU once again contracted with a further decline of 17% for the 9th year running with a little more than 2 million m² installed surface area. European solar thermal markets are finding it challenging to stabilize and are struggling to stay afloat. Regulations curbing the installation of solar thermal collectors, restrictive political choices as well as competition from both 'fossil' and 'electric' technologies that are becoming more efficient and other renewables, are some of the factors that contribute to the deterioration of the market in the EU. In the concentrated solar power (CSP) sector, the EU market has slowed down with 2 314 MW of installed power capacity including pilot plants and demonstrators. New projects are expected to be completed in 2018, mostly in Italy, which should lead to an increase in employment for this country. Total solar thermal sector employment is estimated at 21 900 jobs in and turnover at € 2.4 billion in 2017 as compared to 29 000 jobs and € 3.4 billion in 2016.

Spain has maintained its title of the largest European player, with the number of FTE totalling 8 100 and revenues reaching € 970 million, a slight increase from 2016 levels. Most of these workers operate and do maintenance on the existing concentrated solar power (CSP) installations or provide related secondary activities. Although the growth of yearly newly added solar thermal installations has dipped by about 6%, growth is still anticipated in this sector. This is due to the obligation under the Technical Building Code (CTE) to provide between 30% and 70% of all new buildings' hot water needs from renewable hot water production systems. Although this had initially led to rapid growth in 2007, the Spanish property bubble burst just a year later leading to a plummet in the number of new properties being constructed and set the stage for declining developments since. This decline however began to reverse in 2017. Market growth resulting from the CTE scheme of 15% was perceived over the past year, although unsubsidised system sales fell. In the industrial and social service sector, installed collector area has doubled in 2017 to 4 000m², a clear indicator that the overall market decline can be attributed to the renovation market. Turning to CSP, the output achieved in Spain in 2017 reached 5 348 GWh as compared to 5 071 GWh 2016 according to Red Eléctrica de España. Although the temporary suspension to construct more CSP plants, due to refusal from the government to continue subsidies, has ended, Spain's CSP market has yet to pick up. The shift towards more "technologically neutral" tenders in 2017 has major implications for the CSP sector as other competing technologies such as solar photovoltaic can get the upper hand in the application for these tenders.


Deerns France

Our estimation of employment in ***Germany*** is sharply going down in 2017 (-30%) to 4 500 from 6 400. Revenues added up to € 580M, a downturn from € 760M compared to the previous year. This slump can be ascribed to various reasons. There is strong competition from gas-fired heating and many installers

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in € m)	
	2016	2017	2016	2017
Spain	8 000	8 100	980	970
Germany	6 400	4 500	760	580
Greece	1 500	2 000	110	130
Bulgaria	1 300	1 300	40	50
Austria	2 000	1 200	330	200
France	1 100	1 000	150	130
Italy	1 400	600	170	70
Portugal	200	500	10	30
Poland	1 100	300	70	20
Croatia	100	200	<10	10
Czechia	400	200	20	10
Denmark	3 200	200	530	30
Hungary	400	200	20	10
United Kingdom	200	200	10	10
Belgium	200	100	30	30
Cyprus	100	100	<10	10
Ireland	100	100	10	10
Malta	<100	100	<10	<10
Netherlands	100	100	10	10
Slovakia	<100	100	<10	<10
Slovenia	200	100	<10	<10
Estonia	<100	<100	<10	<10
Finland	<100	<100	<10	<10
Latvia	<100	<100	<10	<10
Lithuania	<100	<100	<10	<10
Luxembourg	<100	<100	<10	<10
Romania	200	<100	<10	<10
Sweden	<100	<100	20	10
Total EU 28	**29 000**	**21 900**	**3 380**	**2 410**

Source: EurObserv'ER 2018

are additionally discouraged by the time lag between installation procedures and seeing profits. These factors are so influential, that even the energy efficiency stimulation programme "Anreizprogramm Energieef¬fizienz" (APEE) has been unsuccessful in its efforts to stimulate growth in the sector. According to the German Economics and Energy Ministry (BMWi), the country installed about 650 000m² of collectors in 2017, a 15.1% drop compared to the previous year.

The estimation of FTE in **Greece** is going from 1 500 to 2 000, showing remarkable growth in stark contrast to the downturn of other main European markets. Revenues totalling € 130 million were attained over the last year. The Greek solar thermal market expanded by a striking 16.2% to reach 316 000m² installed surface area in 2017. Competition between players has driven prices down drastically. Development was further enhanced by the expansion of distribution grids, cyber-commerce as well as the emergence of do it yourself (DIY) chains in the market, and private labels working with original equipment manufacturers (OEM) partners- all amidst the backdrop of a recovering/ improving economy. Furthermore, sales from export, e.g. by the Greek company Dimas Solar has increased by 12% as a result of the booming demand from the North African market. In terms of CSP, several projects were in the pipeline in Greece amounting to about 125 MW at the start of 2018. These projects could also be a significant contributor to employment levels in the country.

The greatest fall in EurObserv'ER employment estimation related to solar thermal occurred in **Denmark**, mostly the result of a lack of newly installed solar thermal installations in Denmark in 2017 caused by changes in regulations. Note that there was a great increase in the number of solar thermal installations in 2016 whereas almost no new installations took place in 2017. This has a highly negative impact on the FTE derived using the methodology described earlier in this chapter. With both the demand from the domestic market as well as the export market dwindling, Denmark takes a big loss in FTE in both workers in the installation sector as well as in the manufacturing sector. ■

HYDROPOWER

Overall, the estimation of full time equivalent (FTE) jobs in the European Union hydropower sector has fallen from 75 900 to 70 700 with the total turnover declining from € 8 620 million to € 8 360 million. A vast majority of the hydropower infrastructure within the EU was installed between the 1960s and 1970s and is now in need for rehabilitation and modernisation[1]. Eastern Europe, particularly in the western Balkan, holds great promise for further development in the hydropower sector. With an emphasis on holistic planning approaches, the 2017 Regional hydro Master Plan stresses the need for increased synergies and transboundary planning for hydropower capacity growth in the region. Such an approach is also aimed at promoting services such as flood mitigation for all stakeholders. Nevertheless, there is widespread dissent amongst other stakeholders who condemn the construction of more dams due to their environmental impact, particularly in "No-go" zones that are crucial to the survival of rare flora and fauna as well as unique landscapes. Instead, NGOs such as Riverwatch and EuroNature are calling for more solar and wind development in the Balkans[2]. With such conflicting stances, the future of hydropower development in the EU remains to be seen.

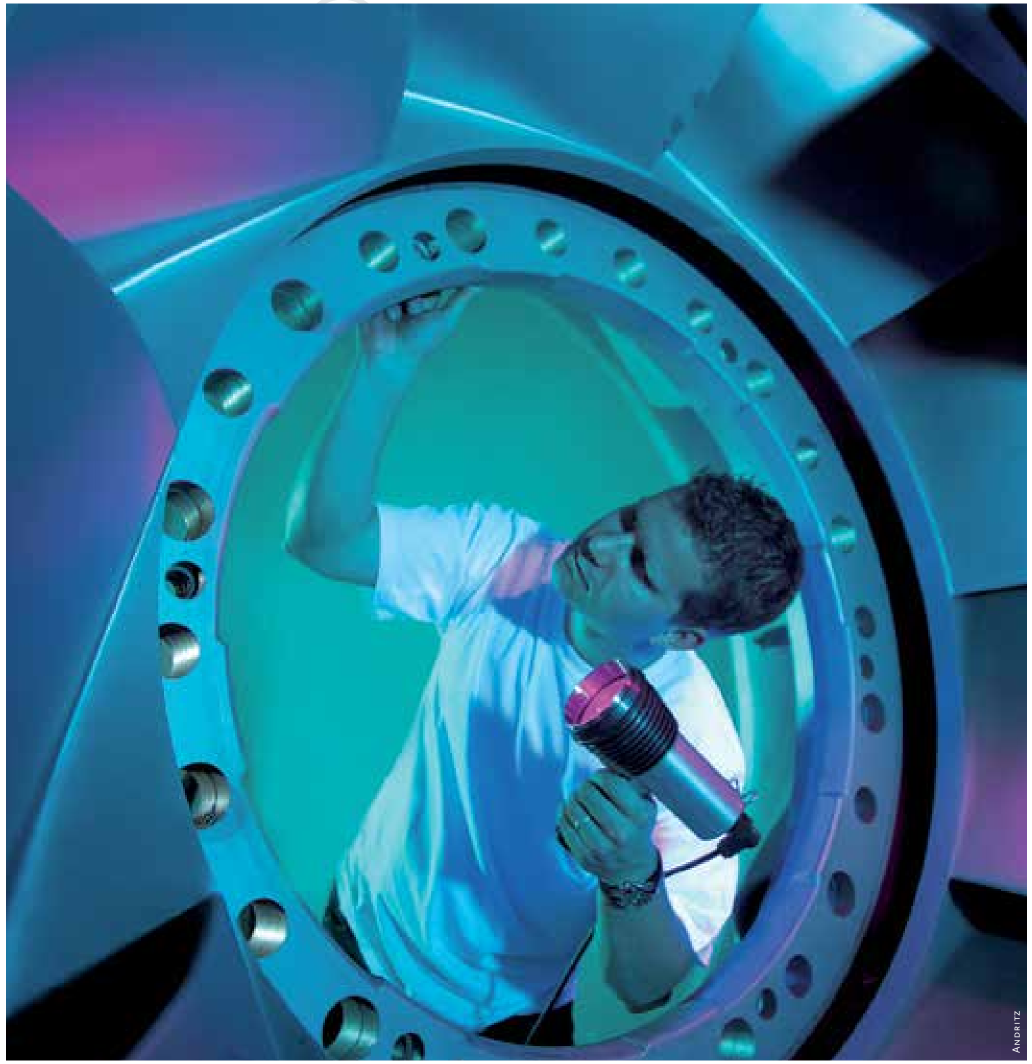
Spain has snatched the top spot from former frontrunner Italy with 11 200 jobs in the hydropower sector in 2017. This is coupled with a turnover of € 1 070 million, a slight decrease from the previous year. Note that between April and December 2017, droughts have plagued the Iberian Peninsula leading to extremely low water reserves. This has led to a dramatic decline of 37% in hydro reserves in comparison to 2016 levels. Accordingly, the run-of-river potential sunk by 53%. An increased frequency of droughts, and consequently lower hydro reserves, would mean that Spain might miss its 2020 renewable share targets despite the RES growth it experienced during the previous year. Small hydro capacity may have a part to play in achieving this target as well. These unfavourable weather conditions may impact the job market for hydro should they persist during the coming years.

Italy, who led the pack in 2016 with a grand total of 13 400 FTE, has seen a decline in the number of jobs retained in 2017 to 10 800 with a turnover of € 1 420 million. The future of hydropower in Italy has now shifted towards low-output micro-hydro plants, as an amalgamation of factors such as low economic and technical commitments, as well a call for less impact on the environment, loom in the background of the industry. However, the importance of hydropower in Italy should not be downplayed. In 2016, 67% of the energy derived from renewable sources was from hydropower and the total installed capacity stood at 22 298 MW. Thus, while most of the 'key sites' for hydropower are being utilized (leading according to some to the 'closure' of this sector), it remains a mainstay in the energy mix of the country.

Holding on to third place, ***France*** has managed to once again secure its spot in the top three countries for employment in the hydropower sector despite a 3% decline in the number of FTEs. France had 9 900 jobs within the hydropower sector. Its turnover was € 1 480 million, which is higher than that of Spain and Italy. The total installed capacity for France should remain stable over the years, around 25 000 to 26 000 MW. Hydropower plays a role in the country by balancing its energy supply; present-day energy supply garnered from hydropower is one that is flexible which allows for manipulation to meet fluctuating demand. In 2017, 85 MW of additional capacity was installed in France bringing the total installed capacity in the country to 25 706 MW. ■

1. https://www.hydropower.org/sites/default/files/publications-docs/iha_2018_hydropower_status_report_4.pdf

2. https://www.pveurope.eu/News/Markets-Money/More-PV-and-wind-to-save-Balkan-rivers?utm_source=newsletter&utm_medium=email&utm_campaign=20181214_New+business+models+for+O%26M%2C+push+for+storage+in+UK%2C+mo



Andritz

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in € m)	
	2016	2017	2016	2017
Spain	10 900	11 200	1 080	1 070
Italy	13 400	10 800	1 760	1 420
France	10 200	9 900	1 460	1 480
Sweden	4 800	4 700	940	950
Austria	4 800	4 600	770	790
Germany	5 200	4 600	650	650
Portugal	3 800	4 200	260	290
Romania	4 400	3 400	240	240
Bulgaria	2 900	2 300	120	120
United Kingdom	2 200	2 300	240	250
Greece	1 700	2 000	150	140
Czechia	1 700	1 500	110	110
Croatia	1 600	1 400	90	90
Finland	1 200	1 200	190	190
Slovakia	1 300	1 200	90	90
Poland	1 300	1 100	100	100
Latvia	1 100	1 000	50	50
Slovenia	900	800	60	60
Lithuania	800	700	30	30
Luxembourg	500	500	70	70
Belgium	400	400	80	80
Ireland	200	300	20	30
Hungary	< 100	100	< 10	<10
Cyprus	< 100	<100	< 10	<10
Denmark	< 100	<100	< 10	<10
Estonia	< 100	<100	< 10	<10
Malta	< 100	<100	< 10	<10
Netherlands	< 100	<100	< 10	<10
Total EU 28	75 900	70 700	8 620	8 360

Source: EurObserv'ER 2018

EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2018 EDITION

GEOTHERMAL ENERGY

Geothermal energy represents the smallest sector of renewable energy in the EU. Despite this, the size of its labour force has increased from 8 600 jobs to an estimated 10 900 jobs - a noteworthy 28% growth[1]. The main players involved have also shifted, with countries such as France and Slovakia displacing Germany and Hungary to clinch the second and third spot respectively. The total installed geothermal electricity capacity in the EU in 2017 was 1 009 MWe. In addition, nine new geothermal heating plants were inaugurated in 2017, amounting to a total of 75 MWth spread across France, Netherlands and Italy. Geothermal district heating accounts for 1.8 GWth in the EU. Individual heating systems, which form the bulk of the geothermal sector, also remains a key component of the German, Swedish and French markets. The cumulative number of geothermal plants in operation within the EU is 55 while the total additional installed capacity amounted to 9 MWe.

As in 2016, the frontrunner for employment in the geothermal sector is ***Italy*** with a total of 3 100 jobs, a 35% year-on-year growth mostly related to equipment manufacturing and construction of new geothermal plants, with a turnover of € 410 million. Additionally, over 40 areas are under investigation for the construction of new geothermal power plants. If the results of these investigations remain favourable, there is a strong chance that employment levels could be further positively impacted. The Italian Geothermal Union estimates that the use of geothermal heat will continue to rise in the country. It postulates that between 8 100 MWth and 11 350 MWth will be

1. *Note that renewable energy technologies that typically do not have a regular added capacity each year, can demonstrate sudden spikes in FTE and revenues, because the used methodology allocates all of the project cost of a new installation to one year (the year in which the installation is finished and appears in the statistics).*


Enel

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in € m)	
	2016	2017	2016	2017
Italy	2 300	3 100	310	410
France	600	2 500	90	360
Hungary	1 200	700	60	40
Slovakia	100	700	10	50
Denmark	300	600	50	100
Germany	1 200	500	150	70
Portugal	< 100	400	< 10	30
Belgium	< 100	200	< 10	40
Bulgaria	200	200	< 10	10
Romania	200	200	10	10
Croatia	< 100	100	< 10	10
Lithuania	< 100	100	< 10	10
Netherlands	500	100	70	10
Poland	200	100	10	10
Slovenia	100	100	< 10	10
Austria	< 100	<100	10	10
Cyprus	< 100	<100	< 10	<10
Czechia	< 100	<100	< 10	<10
Estonia	< 100	<100	< 10	<10
Finland	< 100	<100	< 10	<10
Greece	< 100	<100	< 10	<10
Ireland	< 100	<100	< 10	<10
Latvia	< 100	<100	< 10	<10
Luxembourg	< 100	<100	< 10	<10
Malta	< 100	<100	< 10	<10
Spain	< 100	<100	< 10	<10
Sweden	< 100	<100	< 10	10
United Kingdom	< 100	<100	< 10	<10
Total EU 28	**8 600**	**10 900**	**950**	**1 300**

Source: EurObserv'ER 2018

reached by 2050 in terms of overall installed capacity.

With 2 500 jobs, ***France*** has overtaken Germany to get the second top spot in terms of employment with a turnover valued at € 360 million. However, this promising development does not imply that the sector is performing at its optimal level. A study conducted by the International Conference on Mutual Economics (PIPAME) suggests that there is potential for more cohesion between French offices, ministries and associations.

Slovakia's geothermal market made an astounding leap with the level of employment in the industry jumping from 100 FTE in 2016 to 700 FTE in 2017. Turnover values also increased from € 10 to € 50 million within the same time period. This unprecedented growth is related to the gradual phase out of the coal and mining sector and political action taken to utilize the country's natural resources in an ecological way, resulting in a new geothermal energy installation coming online to supply heat to buildings in Velky Meder[2]. ■

2. *https://www.euroheat.org/news/new-geothermal-district-heating-system-started-operation-slovakia/*

HEAT PUMPS

STIEBEL ELTRON

The total heat pump (HP) market increased by 4.4% in 2017 with 34.4 million HP units sold in the EU. The number of units sold was, however, less than in 2016. Approximately a third of this was used to cover heating needs in countries with colder climates while the remaining two-thirds were used for cooling purposes in countries where hot summers are prevalent. The lower heat pump sales led to a plunge of nearly 24% in the number of jobs EU wide with the final number standing at 191 700 FTE. Growth could have been more significant if not for the slump in the Italian market- the biggest heat pump market in the EU. Correspondingly, revenues have also decreased from € 30 200 million in 2016 to € 22 730 million in 2017[1]. The demand for heat pump units for summer cooling needs is the main driver of HP sales in France, Spain and Portugal.

Making its way to 1st place, ***Spain*** snatched the title of the country with the greatest number of jobs from former frontrunner Italy. With 56 600 FTE in 2017, the country has seen a dip by about 7.4% as compared to the previous year, the result of less units domestically installed in comparison to 2016. It holds 28% of all the jobs in the HP sector in the EU. Turnover amounted to € 5 330 million in 2017, a comparatively small decrease from 2016 levels of € 5 800 million.

Sliding down to the second spot, ***Italy*** has encountered a decline in the number of jobs from 94 000 FTE in 2016 to 41 700 FTE in 2017. This was accompanied by a contraction in the turnover from € 12 280 million to € 5 490 million within the same time period. A reason for this could be that the Italian market has become saturated following record levels of growth in 2016 (55.4%). A 6.6% fall in the number of aerothermal HP[2] units sold and stable geothermal (ground source) HP sales in 2017 could be attributed to this[3].

Moreover, the higher investment costs of heat pumps compared to conventional electric heaters is a deterrent for growth- and it must be noted that the electricity-to-gas price ratio has fluctuated over the

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in € m)	
	2016	2017	2016	2017
Spain	60 800	56 600	5 800	5 330
Italy	94 000	41 300	12 280	5 440
France	32 800	36 200	4 630	5 310
Netherlands	3 600	6 800	450	870
Portugal	7 400	13 800	440	860
Germany	14 500	9 300	1 920	1 350
Sweden	10 400	5 100	2 110	1 030
Finland	4 500	4 700	700	740
Poland	2 200	3 000	140	220
Czechia	1 800	2 600	110	180
Estonia	2 100	1 700	120	120
United Kingdom	1 800	1 700	170	170
Denmark	2 100	1 500	340	270
Belgium	1 500	1 400	280	270
Austria	1 900	1 300	300	220
Greece	1 400	1 200	110	100
Slovenia	500	900	30	60
Bulgaria	3 900	700	130	40
Hungary	500	400	20	20
Ireland	400	300	40	40
Lithuania	400	300	10	10
Romania	300	200	10	10
Slovakia	100	200	<10	20
Croatia	<100	<100	<10	<10
Cyprus	<100	<100	<10	<10
Latvia	<100	<100	<10	<10
Luxembourg	<100	<100	<10	<10
Malta	<100	<100	<10	<10
Total EU 28	**249 400**	**191 700**	**30 200**	**22 730**

Source: EurObserv'ER 2018

course of the year. These factors coupled with a lack of knowledge in the supply chain, have led to end-users' hesitating to invest in HPs. The information gap implies that many remain unaware of the advantages of HPs that could be exploited. Nevertheless, the future for HP is not entirely bleak.

Currently, three mechanisms exist in Italy that should help boost the HP industry in the long run. These include grants such as "white certificates" which are distributed proportional to energy savings derived from HPs, tax rebates for replacing older systems, and cash grants for installing HPs in the place of older technologies. Hybrid systems which combine gas boilers and aerothermal heat pumps are a relatively new form of technology that is also gaining traction.

France, on the other hand, has attained a slight growth over the year with 36 500 FTE garnered in 2017, a 11.3% year-on-year increase. This positive change is also mirrored in the rise of turnover from € 4 630 million to € 5 350 million. According to EurObserv'ER, the 2017 French ASHP market was 9% up on its 2016 level (487 090 units sold in 2017), with 10% growth for air/water HPs (81 700 units sold in 2017) and 9% for air/ air HPs (405 390 units sold in 2017). Thermal regulations brought about in 2012 have proven advantageous for the 2017 construction market recovery. Increasing consumer awareness on the benefits of HPs has also motivated many to approach specialists and stable price levels have boosted confidence in the technology. ■

1. *It must be noted that the market data presented in this document from Italy, Spain and France are not directly comparable to other countries as they include heat pumps whose principal function is cooling. This approach is in line with the EU RES Directive*
2. *Aerothermal HPs include air-air, air-water and exhaust air HPs.*
3. *https://www.eurobserv-er.org/pdf/eurobserver-heat-pumps-barometer-2018-en/*
4. *https://www.eurobserv-er.org/pdf/eurobserver-heat-pumps-barometer-2018-en/*

BIOGAS

Within the EU, the estimation of the biogas job market marginally contracted by approximately 5% in 2017 as compared to 2016; going from 76 300 to 72 400 FTE. Likewise, the total turnover fell from € 7 640 million to € 7 520 million within the same time period. The main reason for this decline since 2011 is the apprehensiveness of many EU states to the use of energy crops. Consequently, investments in the biogas market have shrunk.

Germany takes the lead with its labour force of 35 000 FTE, a slight dip of 2% as compared to 2016 levels. Altogether, this accounts for 48% of the total FTE related to biogas in the EU in 2017. Turnover levels stood at € 4 190 million, a small rise from the previous year (€ 4 120 million in 2016). While the market appears to be stable, a threat looms in the distance for many German biogas operators. There are no flexible state regulations that allow for the feeding into the grid with biogas. As for equipment manufacturers, many local companies are beginning to rely on export of their products to keep their businesses afloat. Due to cutbacks for renewable energy, the number of biogas companies has shrunk dramatically from 400 in 2012 to 250 today. In 2018, only 137 biogas plants were built, in contrast to the 196 built in 2016. However, hope is not lost for the German biogas industry if measures are taken for the implementation of a more flexible compensation scheme and opportunities to diversify (e.g. by feeding biogas into the public gas network).

With 8 400 FTEs and a turnover of € 800 million, the ***United Kingdom*** has secured the second place in terms of employment in the EU. This, however, should not mask the fact that both the number of FTE and turnover has dropped by almost 30% in the period between 2016-2017 – a contrast to the 24% growth experienced between 2015 and 2016. There are 550 anaerobic digestion plants currently in operation in the UK, of which 85 directly inject biomethane into the grid. Like Germany, the future of biogas in the UK seems to be precarious, with less support expected from feed-in tariffs by April 2019.

Turning to more positive developments, Italy has enjoyed a stable biogas sector with the number of employed individuals reaching 8 100 FTE with a turnover of € 840 million ■

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in € m)	
	2016	2017	2016	2017
Germany	35 700	35 000	4 120	4 190
United Kingdom	11 800	8 400	1 120	800
Italy	8 000	8 100	880	840
Czechia	4 300	4 500	240	270
France	1 800	2 400	220	290
Poland	3 100	2 300	160	100
Spain	1 300	1 600	90	120
Greece	800	1 300	40	70
Latvia	800	900	40	40
Croatia	600	800	30	50
Denmark	300	700	50	120
Lithuania	800	700	20	30
Netherlands	800	700	120	110
Portugal	800	700	30	30
Bulgaria	800	600	30	30
Finland	400	600	50	80
Hungary	1 500	600	70	30
Belgium	400	500	100	130
Slovakia	600	500	40	40
Austria	500	400	80	60
Romania	200	300	<10	10
Ireland	300	200	30	20
Cyprus	<100	100	<10	10
Estonia	<100	100	<10	<10
Luxembourg	<100	100	10	10
Slovenia	200	100	20	10
Sweden	<100	100	<10	10
Malta	<100	<100	<10	<10
Total EU 28	**76 300**	**72 400**	**7 640**	**7 520**

Source: EurObserv'ER 2018

BIOFUELS

Employment within the EU in the biofuels sector has increased from 205 100 to 230 400 FTE, a 12% year-on-year growth[1]. The turnover increased from € 13 110 million in 2016 to € 13 810 in 2017. According to EurObserv'ER, the consumption of biofuels surged in 2017 even though regulations that placed a cap of 7% on the amount of biofuels obtained from food was implemented. Across the board, all biofuel sectors grew in 2017 but biodiesel (including HVO synthetic biodiesel) gained the most traction with 10% growth on its 2016 level. It must be noted that the methodology used to evaluate the biomass industry covers biomass supply activities, i.e. in the agricultural sector. Thus, the leading countries in terms of employment are not necessarily the largest biofuel consumers such as France and Germany, but more notably Member States with large share of agricultural areas such as Romania, Hungary, Lithuania and Poland.

Based on the modelling approach used, ***Romania's*** contribution to the biofuels sector has shown incredible growth in the past year. In 2017, the cumulative employment in Romania reached 34 300 FTE as compared to 2016 levels of 23 800 FTE. Turnover in 2017 reached € 960 million.

The number of FTE fell in ***Poland*** from 34 800 in 2016 to 31 400 in 2017 while the turnover dropped from € 1 310 million to € 1,110 million.

Spain has seen remarkable growth 2017 as compared to 2016. The number of FTE rose from 15 100 to 26 600 while the turnover went from € 900 million to € 1,590 million. Spain remains the 4th largest consumer of biofuels in the EU with a total consumption of 1 280 ktoe, a 15.4% rise. A reason for this is that distributors are legally obliged to 5% of biofuels in the energy mix in 2017 (4.3% in 2016). The share of energy content should gradually increase to 6% in 2018, then to 7% in 2019 and 8.5% in 2020.

Of interest, are ***France*** and ***Germany***. The former had the second highest employment rate in the biofuels sector in 2016. However, within the span of one year,

Maarten Feenstra / Neste Oil

the number of FTE in France has dropped from 33 200 to 24 400, caused by a lack of investments in new production capacity . Nevertheless, according to the Ministry for Ecological and Inclusive Transition's Statistics Office, biofuel consumption grew by 7.7% and reached 3 335 ktoe in 2017. In Germany, the biofuel consumption has remained stable for the past three years, with a slight increase in consumption by 1.2% in 2017, but employment dropped from 21 800 FTE in 2016 to 15 500 FTE in 2017. ■

1. *Please note that the results have to be interpreted with caution as the production capacity for biofuels were obtained from data from Epure and EBB instead of Eurostat. Because of this, production of bioethanol for industrial or for food purposes is now also included. For biodiesel, it is assumed that only half of the production capacity as provided by EBB is active, based on the total installed production capacity and actual production in 2016 according to EBB.*

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in € m)	
	2016	2017	2016	2017
Romania	23 800	34 300	750	960
Poland	34 800	31 400	1 310	1 110
Spain	15 100	26 600	900	1 590
France	33 200	24 400	3 160	2 350
Hungary	15 700	18 200	750	820
Germany	21 800	15 500	2 300	1 640
Greece	4 500	11 500	150	370
United Kingdom	4 500	10 100	370	820
Italy	6 500	9 000	630	780
Czechia	8 000	8 400	420	450
Sweden	7 600	8 300	330	350
Bulgaria	3 000	7700	110	280
Lithuania	9 200	4 500	290	150
Latvia	3 100	4000	130	130
Slovakia	4 000	3800	300	300
Netherlands	400	2800	70	440
Austria	2 900	2000	390	300
Croatia	1 900	2000	100	110
Finland	2 900	1600	300	150
Belgium	900	1500	240	420
Denmark	200	700	30	120
Estonia	200	700	<10	40
Slovenia	<100	500	<10	60
Portugal	400	400	20	20
Ireland	<100	200	<10	20
Cyprus	<100	100	<10	10
Luxembourg	<100	<100	<10	<10
Malta	<100	<100	<10	<10
Total EU 28	**205 100**	**230 400**	**13 110**	**13 810**

Source: EurObserv'ER 2018

RENEWABLE MUNICIPAL WASTE

Renewable municipal waste remains a small RE sector in the European renewable energy mix. According to the EurObserv'ER estimations presented here, the RMW sector is worth € 4 750 million and maintains 35 600 full time jobs.

Overall there has been a 30% increase in the number of full-time employment jobs in the EU from 2016 to 2017 in the waste-to-energy sector[1].

The ***UK*** clinched the top spot this year after expanding its capacity of waste-to-energy plants. With the number of FTE totalling 10 800, mostly due to the build of new plants in 2017, the industry gave rise to a turnover of € 1 140 million as compared to the previous year (€ 270 million). According to EurObserv'ER allocation method, 30% of FTE in the municipal solid waste market in the EU in 2017 could be found in the UK. This rapid growth knocked former leader Germany down to second place. A rise in the number of waste-to-energy plants (from 37 in 2016 to 40 in 2017) coupled with a focus on increasing efficiency of plants have enabled the UK to increase its renewable energy output in the municipal waste sector[2].

Sliding down to 2nd place with 18% of the municipal solid waste jobs in the EU, ***Germany*** has managed to retain 6 300 FTE, a slight downturn from the 7 000 jobs in 2016. The turnover within the same timeframe was € 1 020 million, a slight drop from the previous year (€ 1 030 million in 2016).

The municipal waste industry has not invested in new capacity in 2017 in ***Italy***. While the country held the 3rd place in 2016 with 15% of all RMW jobs in the sector in the EU, this has since changed, and the number of FTEs have dropped to 2 500 in 2017, accounting for only 7% of all RMW jobs in the EU. The sudden decrease in FTE should be interpreted carefully, as the losses occurred due to a lack of construction related activities in 2017 as opposed to 2016. The employment in operational and maintenance activities or in the supply chain of municipal waste did not change. ■

1. *Note that renewable energy technologies can demonstrate sudden spikes in FTE and revenues, because the used methodology allocates the project costs of a new installation to one year (the year in which the installation is finished and appears in the statistics).*
2. *http://www.tolvik.com/wp-content/uploads/Tolvik-UK-EfW-Statistics-2017.pdf Bear in mind that the statistics here do not only talk about MSW but also residual waste.*

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in € m)	
	2016	2017	2016	2017
United Kingdom	2 300	10 800	270	1 140
Germany	7 000	6 300	1 030	1 020
Belgium	300	3 200	60	590
France	4 000	2 600	550	350
Italy	3 800	2 500	500	320
Austria	200	1 600	30	270
Netherlands	2 000	1 500	290	230
Spain	700	1 100	80	120
Sweden	900	800	160	160
Czechia	200	700	10	50
Ireland	< 100	700	< 10	70
Poland	< 100	700	< 10	50
Denmark	500	600	110	130
Portugal	500	500	40	40
Finland	700	400	120	70
Hungary	1 000	400	40	20
Greece	< 100	100	< 10	10
Lithuania	300	100	< 10	<10
Luxembourg	< 100	100	< 10	10
Romania	< 100	100	< 10	<10
Slovakia	< 100	100	< 10	<10
Bulgaria	< 100	<100	< 10	<10
Croatia	< 100	<100	< 10	<10
Cyprus	< 100	<100	< 10	<10
Estonia	< 100	<100	< 10	<10
Latvia	< 100	<100	< 10	<10
Malta	< 100	<100	< 10	<10
Slovenia	< 100	<100	< 10	<10
Total EU 28	**25 700**	**35 600**	**3 430**	**4 750**

Source: EurObserv'ER 2018

SOLID BIOMASS

According to EurObserv'ER, solid biomass heat consumption increased by 1.1 Mtoe in 2017, 1.4% more than in 2016, to reach a 79.9 Mtoe . On the other hand, the demand for electricity derived from solid biomass grew by 2.9% and was fuelled, in particular, by converted coal-fired power plant in countries such as the UK, Finland and Denmark. The number of FTE in the EU related to biomass increased by approximately 4% in 2017 and stood at 364 800 at the end of the year while the turnover recorded (€ 34 550 million) increased by 8% as compared to 2016 levels[1].

Germany retained the top spot in terms of employment in the biomass sector with 44 900 FTE, with an increase in employment of around 6% when compared to the 42 500 FTE in 2016. A total of 10.7 TWh of electricity was produced from solid biomass by Germany in 2017, a year-on-year decline of 0.1 TWh. The primary energy production of solid biomass in the country amounting to 12.0 Mtoe in 2017, a small increase from 11.9 Mtoe in 2016. Major operators of biomass plants based in Germany include E.on and Zellstoff Stendal. The biomass sector has encountered lukewarm responses to the biomass tendering process. New facilities are said to be hindered by a lack of financial support while legal constraints placed on older facilities made bidding on them 'unattractive'[2].

1. The sector solid biomass comprises different technologies that cover different end-user sectors: energy (biomass CHP, co-firing), industry (boilers), and households (pellet boilers and stoves). Note that the available data for biomass consumption by households was very limited, which resulted in unrealistic 2017 estimates for FTE related to biomass stoves and boilers for some countries. For these countries the FTE results for employment related to biomass stoves and boilers of 2016 were used.

2. https://www.endswasteandbioenergy.com/article/1445017/poor-response-germanys-first-biomass-tender

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in € m)	
	2016	2017	2016	2017
Germany	42 500	44 900	5 110	5 630
Italy	32 600	35 800	2 540	2 550
France	35 400	33 900	4 090	3 990
Finland	25 400	26 800	4 320	4 860
Poland	26 100	25 900	1 010	1 000
Spain	18 400	20 800	770	1 030
Latvia	21 800	20 700	720	770
Sweden	18 700	20 700	4 090	4 460
United Kingdom	12 600	15 000	1 090	1 230
Croatia	15 000	14 400	380	280
Hungary	12 000	13 300	350	420
Czechia	11 400	12 300	690	840
Romania	11 400	11 400	330	320
Denmark	8 500	10 500	1 450	1 890
Slovakia	8 700	9 000	340	350
Austria	8 600	8 700	1 740	1 630
Bulgaria	9 600	8 700	270	280
Portugal	6 500	8 000	580	670
Estonia	10 000	8 000	560	490
Netherlands	3 900	4 800	480	550
Lithuania	4 700	3 600	260	240
Greece	3 400	2 600	150	170
Belgium	1 000	2 000	260	590
Slovenia	2 300	1 500	130	110
Ireland	1 700	1 200	200	160
Luxembourg	<100	100	<10	20
Cyprus	<100	<100	<10	<10
Malta	<100	<100	<10	<10
Total EU 28	**352 500**	**364 800**	**31 940**	**34 550**

Source: EurObserv'ER 2018

Italy ends up in second place with an estimated 35 800 FTE and a turnover of € 2 550 million in 2017. This represents a 10% year on year increase in FTE. With companies such as the EPH group entering the biomass industry in Italy and acquiring smaller businesses[3], employment in the country is expected to continue to increase. Primary energy production of biomass increased from 7.2 Mtoe in 2016 to 7.7 Mtoe in 2017 while gross inland consumption increased from 8.4 Mtoe to 9.0 Mtoe within the same time period. This growth is also reflected in the gross electricity production from solid biomass which amounted to 4 193 TWh in 2017, a moderate annual growth of 1.6%. As part of its renewables strategy, Italy plans promote new investments through incentivising power generation and stimulating competition- and in the case of biomass, maintaining existing power generation from bioenergy sources without disrupting the agricultural sector chain[4].

France is in third place with 33 900 FTE in 2017 and a turnover of € 3 990 million. This is a slight decline of 4% and 2% respectively compared to 2016 levels. A slower pace in wood pellet output leading to a reliance on imports and a slump in residential heating needs could be potential underlying reasons. According to the Observation and Statistics Service, France's total domestic consumption of solid biomass (which includes its Overseas Territories) contracted slightly - sliding down from 11 Mtoe in 2016 to 10.8 Mtoe in 2017. It is postulated that the French biomass sector will pick up in the coming years as a consequence of the National Low Carbon Strategy (SNBC) and its Multiannual Energy Programme (PPE) with funding of € 1.6 billion for almost 4 000 projects totalling 2 million toe. ■

3. *https://www.eppowereurope.cz/en/tiskove-zpravy/eph-group-enters-biomass-business-italy/*
4. *https://www.mise.gov.it/images/stories/documenti/BROCHURE_ENG_SEN.PDF*

CONCLUSION

Similar as in the 2016 edition of *'The State of Renewable Energies in Europe'* the EurObserv'ER team has used a new employment modelling approach to estimate the number of FTEs initiated from renewable investments, operation and maintenance activities, production and trading of equipment and biomass feedstock. According to this approach, the number of renewable energy jobs in the EU in 2017 amounted to 1.45 million. This was, overall, comparable to the labour force in 2016 with an increase of just over 1%, corresponding to 18 500 jobs.

Technologies for which the 2017 estimates were lower than that of 2016 (which implies a contraction in the number of jobs) include: PV which decreased from 95 900 to 90 800 (-5.3%), heat pumps which decreased from 249 400 to 191 700 (-23.1%), biogas which decreased from 76 300 to 72 400 (-5.1%), hydropower which decreased from 75 900 to 70 700 (-6.9%) and solar thermal which decreased from 29 000 to 21 900 (-24.5%). On the other hand, several technologies saw an expansion in the number of FTEs created over the past year: wind power increased from 309 000 to 356 700 (+15.4%), solid biomass increased from 352 500 to 364 800 (+1.3%), biofuels rose from 205 100 to 230 400 (+12.3%), geothermal increased from 8 600 to 10 900 (+26.7%) and municipal solid waste saw job figures rise from 25 700 to 35 600 (+38.5%).

With a 2.7% growth, ***Germany*** remained the largest player in terms of renewable energy induced employment in 2017, with290 700 FTE. Jobs in the wind sector were especially abundant, totalling 140 800 FTE. Coming in second place was ***Spain*** with 168 800 jobs, an astounding year-on-year growth of 19.7%. This boost can be attributed to a rise of 58% in employment within the wind power sector (+ 13 700 FTE). Retaining the third spot from the previous year is ***France*** with 140 700 FTE, where the main labour force can be found in the heat pump sector (25.7% of all jobs in the renewable sector). Taking the last slot of the top four countries is the ***United Kingdom*** which showed positive growth leading to a total of 131 400 FTE at the end of the year (22.3% up from 2016). Most labour in the country can be found in the wind power sector which has seen continuous growth since 2015.

Turning to economic activity, the combined turnover for the 10 renewable energy sectors covered in the 28 EU member states amounted to 154.7 billion euro in 2017, 3.6% higher than 2016. This indicates positive investment activities as this rise occurs despite falling technology costs and political hesitation in many EU member states. The turnover for wind (€48.0 billion, equivalent to 31% of the total EU RES sector turnover), solid biomass (€34.6 billion, 22%) and heat pump (€22.7 billion, 15%) were the top 3 in terms among all the technologies.

Based on the turnover estimations by country, 15 out of 28-member states either increased or retained their industrial turnover. These 15 member states (Belgium, Cyprus, Czechia, Denmark, Finland, Germany, Greece, Hungary, Ireland, Malta, Portugal, Romania, Slovakia, Spain and the United Kingdom) together grew by 15.1 billion euro. And 13 countries showed a decline, cumulating to 9.7 billion euro: Austria, Bulgaria, Croatia, Estonia, France, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Slovenia and Sweden.

As mentioned in the methodology section at the start of the socio-economic chapter, the EurObserv'ER employment and turnover estimates are based on an evaluation of the economic activity of each renewable sector covered, which is then expressed into full-time equivalent (FTE) employment. The estimated FTE and turnover for each country-technology combination are therefore directly correlated to the changes in the amount of yearly installed capacity (MW) observed per country-technology combination. The model does not take into account the lead time required to build new capacity, nor does it include the ability of companies to withstand short periods of time with unfavourable market conditions. The estimated yearly FTE and revenues reported may therefore appear more volatile than observed by national statistics offices or renewables associations. ■

2016 EMPLOYMENT DISTRIBUTION BY SECTOR

	Country total	Biomass	Wind	Heat pumps	Biofuels	PV	Biogas	Hydro	Solar thermal	Waste	Geothermal
Germany	283 100	42 500	121 700	14 500	21 800	27 100	5 200	35 700	6 400	7 000	1 200
Italy	179 000	32 600	6 300	94 000	6 500	10 700	13 400	8 000	1 400	3 800	2 300
France	143 100	35 400	18 800	32 800	33 200	5 200	10 200	1 800	1 100	4 000	600
Spain	141 000	18 400	23 500	60 800	15 100	2 200	10 900	1 300	8 000	700	<100
United Kingdom	107 400	12 600	42 900	1 800	4 500	29 000	2 200	11 800	200	2 300	<100
Poland	81 800	26 100	11 400	2 200	34 800	1 500	1 300	3 100	1 100	<100	200
Sweden	47 900	18 700	4 900	10 400	7 600	300	4 800	<100	<100	900	<100
Romania	44 900	11 400	2 500	300	23 800	1 800	4 400	200	200	<100	200
Denmark	43 000	8 500	26 600	2 100	200	1 200	<100	300	3 200	500	300
Finland	39 200	25 400	3 500	4 500	2 900	400	1 200	400	<100	700	<100
Netherlands	37 600	3 900	21 500	3 600	400	4 700	<100	800	100	2 000	500
Hungary	35 200	12 000	800	500	15 700	2 000	<100	1 500	400	1 000	1 200
Czechia	30 500	11 400	900	1 800	8 000	1 700	1 700	4 300	400	200	<100
Latvia	27 400	21 800	<100	<100	3 100	<100	1 100	800	<100	<100	<100
Portugal	26 800	6 500	6 400	7 400	400	700	3 800	800	200	500	<100
Austria	24 000	8 600	1 700	1 900	2 900	1 300	4 800	500	2 000	200	<100
Bulgaria	23 200	9 600	600	3 900	3 000	800	2 900	800	1 300	<100	200
Croatia	20 500	15 000	900	<100	1 900	<100	1 600	600	100	<100	<100
Greece	18 300	3 400	3 700	1 400	4 500	1 100	1 700	800	1 500	<100	<100
Lithuania	18 300	4 700	1 600	400	9 200	300	800	800	<100	300	<100
Slovakia	15 500	8 700	<100	100	4 000	400	1 300	600	<100	<100	100
Estonia	14 600	10 000	1 600	2 100	200	200	<100	<100	<100	<100	<100
Belgium	9 500	1 000	2 300	1 500	900	2 400	400	400	200	300	<100
Ireland	7 300	1 700	4 200	400	<100	<100	200	300	100	<100	<100
Slovenia	4 800	2 300	<100	500	<100	300	900	200	200	<100	100
Luxembourg	1 500	<100	200	<100	<100	<100	500	<100	<100	<100	<100
Cyprus	1 000	<100	<100	<100	<100	<100	<100	<100	100	<100	<100
Malta	1 000	<100	<100	<100	<100	100	<100	<100	<100	<100	<100
Total EU 28	1 427 400	352 500	309 000	249 400	205 100	95 900	75 900	76 300	29 000	25 700	8 600

Source: EurObserv'ER 2018

2016 TURNOVER BY SECTOR (€M)

	Country total	Wind	Biomass	Heat pumps	Biofuels	PV	Hydro	Biogas	Solar thermal	Waste	Geothermal
Germany	35 500	16 060	5 110	1 920	2 300	3 400	650	4 120	760	1 030	150
Italy	21 420	950	2 540	12 280	630	1 400	1 760	880	170	500	310
France	17 850	2 790	4 090	4 630	3 160	710	1 460	220	150	550	90
Spain	12 750	2 820	770	5 800	900	220	1 080	90	980	80	<10
United Kingdom	10 580	4 490	1 090	170	370	2 810	240	1 120	10	270	<10
Sweden	8 740	1 010	4 090	2 110	330	60	940	<10	20	160	<10
Denmark	7 370	4 600	1 450	340	30	200	<10	50	530	110	50
Finland	6 300	520	4 320	700	300	80	190	50	<10	120	<10
Netherlands	4 740	2 680	480	450	70	560	<10	120	10	290	70
Austria	4 120	280	1 740	300	390	190	770	80	330	30	10
Poland	3 690	790	1 010	140	1 310	90	100	160	70	<10	10
Belgium	1 950	450	260	280	240	440	80	100	30	60	<10
Portugal	1 930	500	580	440	20	40	260	30	10	40	<10
Czech Republic	1 780	60	690	110	420	110	110	240	20	10	<10
Romania	1 610	150	330	10	750	90	240	<10	<10	<10	10
Hungary	1 460	50	350	20	750	90	<10	70	20	40	60
Greece	1 120	300	150	110	150	90	150	40	110	<10	<10
Latvia	1 000	<10	720	<10	130	<10	50	40	<10	<10	<10
Estonia	840	90	560	120	<10	10	<10	<10	<10	<10	<10
Slovakia	840	<10	340	<10	300	20	90	40	<10	<10	10
Bulgaria	780	30	270	130	110	30	120	30	40	<10	<10
Ireland	780	440	200	40	<10	<10	20	30	10	<10	<10
Lithuania	710	60	260	10	290	10	30	20	<10	<10	<10
Croatia	700	50	380	<10	100	<10	90	30	<10	<10	<10
Slovenia	310	<10	130	30	<10	20	60	20	<10	<10	<10
Luxembourg	180	30	<10	<10	<10	10	70	10	<10	<10	<10
Cyprus	100	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Malta	100	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Total EU 28	149 250	39 250	31 940	30 200	13 110	10 730	8 620	7 640	3 380	3 430	950

Source: EurObserv'ER 2018

2017 EMPLOYMENT DISTRIBUTION BY SECTOR

	Country total	Biomass	Wind	Biofuels	Heat pumps	PV	Biogas	Hydro	Solar thermal	Waste	Geothermal
Germany	290 700	44 900	140 800	15 500	9 300	29 300	35 000	4 600	4 500	6 300	500
Spain	168 800	20 800	37 200	26 600	56 600	5 500	1 600	11 200	8 100	1 100	<100
France	140 700	33 900	18 500	24 400	36 200	9 300	2 400	9 900	1 000	2 600	2 500
United Kingdom	131 400	15 000	69 900	10 100	1 700	12 900	8 400	2 300	200	10 800	<100
Italy	129 900	35 800	7 500	9 000	41 300	11 200	8 100	10 800	600	2 500	3 100
Poland	73 900	25 900	8 000	31 400	3 000	1 100	2 300	1 100	300	700	100
Romania	53 000	11 400	2 100	34 300	200	900	300	3 400	<100	100	200
Denmark	50 200	10 500	34 200	700	1 500	1 100	700	<100	200	600	600
Sweden	43 100	20 700	2 700	8 300	5 100	500	100	4 700	<100	800	<100
Finland	40 300	26 800	4 100	1600	4 700	700	600	1 200	<100	400	<100
Hungary	36 000	13 300	800	18 200	400	1 300	600	100	200	400	700
Portugal	33 100	8 000	3 100	400	13 800	1 500	700	4 200	500	500	400
Czechia	32 500	12 300	900	8 400	2 600	1 300	4 500	1 500	200	700	<100
Netherlands	28 700	4 800	5 800	2800	6 800	6 000	700	<100	100	1 500	100
Latvia	27 200	20 700	<100	4000	<100	<100	900	1 000	<100	<100	<100
Greece	25 200	2 600	3 100	11 500	1 200	1 300	1 300	2 000	2 000	100	<100
Austria	23 500	8 700	2 000	2000	1 300	1 600	400	4 600	1 200	1 600	<100
Bulgaria	22 700	8 700	500	7700	700	600	600	2 300	1 300	<100	200
Croatia	20 300	14 400	1 100	2000	<100	100	800	1 400	200	<100	100
Belgium	17 800	2 000	5 500	1500	1 400	3 000	500	400	100	3 200	200
Slovakia	15 900	9 000	<100	3800	200	200	500	1 200	100	100	700
Estonia	12 200	8 000	1 200	700	1 700	100	100	<100	<100	<100	<100
Lithuania	10 700	3 600	500	4 500	300	100	700	700	<100	100	100
Ireland	9 700	1 200	6 500	200	300	<100	200	300	100	700	<100
Slovenia	4 300	1 500	<100	500	900	100	100	800	100	<100	100
Cyprus	1 500	<100	200	100	<100	500	100	<100	100	<100	<100
Luxembourg	1 400	100	100	<100	<100	100	100	500	<100	100	<100
Malta	1 200	<100	<100	<100	<100	300	<100	<100	100	<100	<100
Total EU 28	1 445 900	364 800	356 700	230 400	191 700	90 800	72 400	70 700	21 900	35 600	10 900

Source: EurObserv'ER 2018

2017 TURNOVER BY SECTOR (€M)

	Country total	Wind	Biomass	Heat pumps	Biofuels	PV	Hydro	Biogas	Solar thermal	Waste	Geothermal
Germany	39 180	20 040	5 630	1 350	1 640	4 010	650	4 190	580	1 020	70
France	18 430	2 860	3 990	5 310	2 350	1 310	1 480	290	130	350	360
Spain	15 080	4 340	1 030	5 330	1 590	500	1 070	120	970	120	<10
Italy	14 400	1 120	2 550	5 440	780	1 450	1 420	840	70	320	410
United Kingdom	13 100	7 360	1 230	170	820	1 310	250	800	10	1 140	<10
Denmark	9 170	6 310	1 890	270	120	190	<10	120	30	130	100
Sweden	7 690	620	4 460	1 030	350	90	950	10	10	160	10
Finland	6 860	630	4 860	740	150	120	190	80	<10	70	<10
Austria	4 090	350	1 630	220	300	260	790	60	200	270	10
Belgium	3 820	1 100	590	270	420	570	80	130	30	590	40
Netherlands	3 790	830	550	870	440	730	<10	110	10	230	10
Poland	3 350	660	1 000	220	1 110	80	100	100	20	50	10
Portugal	2 380	320	670	860	20	90	290	30	30	40	30
Czechia	2 090	70	840	180	450	100	110	270	10	50	<10
Romania	1 790	160	320	10	960	60	240	10	<10	<10	10
Hungary	1 480	50	420	20	820	60	<10	30	10	20	40
Greece	1 320	230	170	100	370	90	140	70	130	10	<10
Ireland	1 070	700	160	40	20	10	30	20	10	70	<10
Latvia	1 050	<10	770	<10	130	<10	50	40	<10	<10	<10
Slovakia	900	<10	350	20	300	20	90	40	<10	<10	50
Bulgaria	880	30	280	40	280	30	120	30	50	<10	10
Estonia	790	80	490	120	40	<10	<10	<10	<10	<10	<10
Croatia	650	70	280	<10	110	<10	90	50	10	<10	10
Lithuania	530	30	240	10	150	<10	30	30	<10	<10	10
Slovenia	350	<10	110	60	60	10	60	10	<10	<10	10
Luxembourg	180	20	20	<10	<10	10	70	10	<10	10	<10
Cyprus	130	20	<10	<10	10	30	<10	10	10	<10	<10
Malta	110	<10	<10	<10	<10	20	<10	<10	<10	<10	<10
Total EU 28	154 660	48 040	34 550	22 730	13 810	11 190	8 360	7 520	2 410	4 750	1 300

Source: EurObserv'ER 2018

RES DEVELOPMENT IMPACT ON FOSSIL FUEL SECTORS

The deployment of renewable energy technologies has an impact on the economic activity in the fossil fuel based energy sector.

For the second time in the EurObserv'ER barometer project, the socio-economic chapter includes a dedicated indicator to take the effects of the growing shares of renewables on the European fossil fuel sector into account. In this year's edition, eighteen countries are evaluated (Austria, Belgium, Czechia, Germany, Spain, France, Italy, the Netherlands, Denmark, Finland, Greece, Ireland, Luxembourg, Poland, Portugal, Romania, Sweden and United Kingdom). The next edition of 'The State of Renewable Energy in Europe' will have a complete coverage of the European Union Member States.

1

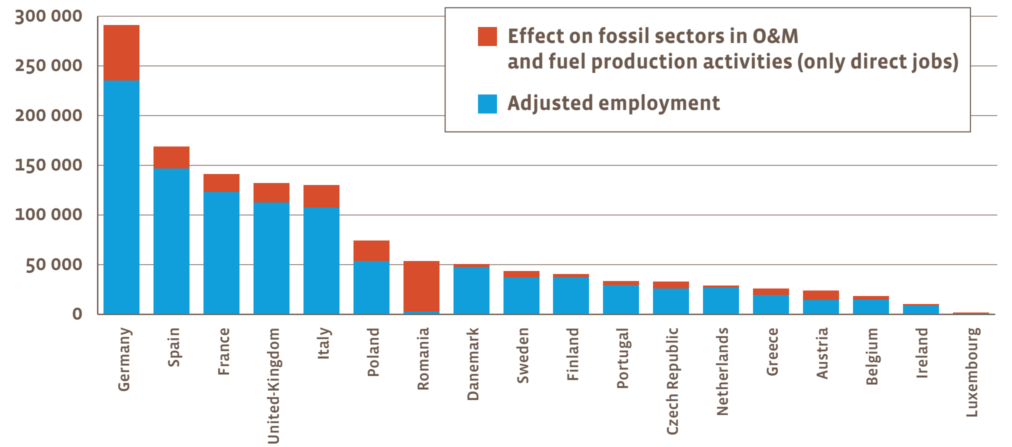
Details of RES development effect on fossil sectors for 18 European countries (figures for 2017)

	Employment (direct and indirect jobs)	Effect on fossil sectors in O&M and fuel production activities only direct jobs	Adjusted employment
Germany	290 700	56 072	234 628
Spain	168 800	22 651	146 149
France	140 700	18 297	122 403
United-Kingdom	131 400	19 159	112 241
Italy	129 900	23 056	106 844
Poland	73 900	21 024	52 876
Romania	53 000	50 648	2 352
Danemark	50 200	3 075	47 125
Sweden	43 100	6 450	36 650
Finland	40 300	3 476	36 824
Portugal	33 100	4 187	28 913
Czech Republic	32 500	6 998	25 502
Netherlands	28 700	2 497	26 203
Greece	25 200	6 181	19 019
Austria	23 500	9 410	14 090
Belgium	17 800	3 228	14 572
Ireland	9 700	1 190	8 510
Luxembourg	1 400	931	469
TOTAL	**1 293 900**	**258 530**	**1 035 370**

Source: EurObserv'ER 2018

1

Details of RES development effect on fossil sectors for 18 European countries (figures for 2017)



Source : EurObserv'ER 2018. Note: The effect of renewables on operation, maintenance and fuel production activities in fossil fuel sectors. The impact of renewables on investment-related employment and indirect employment is not considered.

The results presented here are for 2017 and evaluate the impact of renewables on the fossil fuel sector. The impact is estimated for the following six subsectors: power generation, mining, oil for power generation, refining, heat production and extraction and supply of crude oil and natural gas. The results are expressed in direct jobs only. Our approach only covers the effects on operation and maintenance (O&M) and fuel production activities (effects on O&M are assumed to be proportional to the reduced/avoided production). It must be noted that reduced construction activities of new conventional plants are not considered. The presented impact on the fossil fuel sector therefore does not give the full picture.

The graph shows that the impact on the fossil fuel sector varies significantly between Member States. The relative impact on the fossil sector, when compared to the total employment, is of a completely different nature in Luxembourg and Romania than it is in Denmark and the United Kingdom. The reason for this lies in the difference in composition of the fossil fuel sector and in the type of renewable technology that is deployed. Countries that have coal mining activities are more susceptible to the influence of renewables development than countries that import coal for power generation, as can be seen in, for example, the significant impact of renewables on the fossil fuel sector of Czechia, Germany, Romania and Spain.

The type of renewable technology deployed is also an important factor. Technologies that use feedstock (biogas, solid biomass, biofuels and MSW) generate a relatively high amount of jobs per MW. Therefore, development of employment in the production of feedstock for such renewable technologies results in a proportionally smaller impact on the fossil fuel sector than the development of e. g. wind industry. ■

1. *In our methodology, the employment affected by reduced use of natural gas is assumed to be negligible. It is not likely that installations for natural gas extraction, conversion and transports are taken out of operation due to the uptake of renewables on the short term. O&M staffing of the existing installations is not likely to be affected by reduced gas demand.*
2. *Note that solid biomass consists for a large part of fuel wood used by households, which is often not obtained via official retail channels. Solid biomass consumption therefore does not fully contribute to formal employment.*

INVESTMENT INDICATORS

In this chapter, EurObserv'ER presents indicators that shed light on the financing side of RES. In order to show a comprehensive picture, the investment indicators cover two broader aspects:

- The first group of indicators relates to investment in the application of RE technologies (e.g. building power plants).
- The second group of indicators shifts the focus towards the development and the production of the technologies themselves (e.g. producing solar modules).

First of all, investments in new built capacity for all RES sectors in all EU member states are covered under asset finance. Asset finance data is derived from the Bloomberg New Energy Finance (BNEF) data base as well as other data sources and covers utility-scale investments in renewable energy, i.e. investment in power plants. Furthermore, average investment expenditures per MW of capacity are compared to main EU trading partners In order to capture the involvement of the public sector in RES financing, information on national and EU-wide financing programmes for RES will be presented.

It should be mentioned that the data on asset finance and VC/PE investment presented in this edition cannot be compared to the data in the previous overview barometers. The reason is that the database evolves continuously. This means that, whenever information on investment deals in previous years is found, it is added to the database to make it as comprehensive as possible. Hence, the investment figures for 2016 presented in last year's edition and this edition naturally differ.

The second part starts to analyse investment in RE technology by providing venture capital and private equity (VC/PE) investment data as derived from BNEF and other sources for all RES for the EU as a whole in order to capture the dynamics of the EU market for new technology and project developing companies. Then, RES stock indices are constructed which cover the largest European firms for the major RES. This indicator captures the performance of RES technology companies, i.e. companies that develop / produce the RES components needed for RES plants to function. The data used for the construction of the indices is collected from the respective national stock exchanges as well as public databases. In addition, YieldCos, i.e. infrastructure assets, e.g. renewable energy plants, where the ownership is offered on public markets, will be included in this chapter.

Investment in Renewable Energy Capacity

In this section, the EurObserv'ER investment indicators focus on investment in RES capacity, i.e. investments in utility-size RES power plants (asset finance). Hence, an overview of investments in capacity across RES in the EU Member States is provided. Furthermore, average investments costs per MW of capacity are calculated for the EU and compared with main EU trading partners. Finally, information in public financing programmes for RES is presented.

Methodological note

Asset finance covers all investment into utility-scale renewable energy generation projects. It covers wind, solar PV, CSP, solid biomass, biogas, and waste-to-energy projects with a capacity of more than 1 MW and investments in biofuels with a capacity of more the one million litres per year. Furthermore, the underlying data is deal-based and for the investment indicators presented here, all completed deals in 2016 and 2017 were covered. This means that for all included projects the financial deal was agreed upon and finalised, so the financing is secured. Note that this does not give an indication when the capacity will be added. In some cases the construction starts immediately, while in several cases a financial deal is signed for a project, where construction starts several months (or sometimes years) later. Hence, the data of the associated capacity added shows the estimated capacity added by the asset finance deals closed in the respective year. This capacity might be added either already in the respective year or in the following years. In addition to investments in RES capacity in the Member States, an overview of investment expenditures per MW of RES capacity will be calculated for the EU and main trading partners in order to compare investment costs.

Asset finance is differentiated by three types: balance-sheet finance, non-recourse project finance, and bonds and other instruments. In the first case, the respective power plant is financed from the balance-sheet of typically a large energy company or a utility. In this case the utility might borrow money from a bank and is – as company – responsible to pay back the loan. Non-recourse project finance implies that someone provides equity to a single purpose company (a dedicated project company) and this project company asks for additional bank loans. Here, only the project company is responsible to pay back the loan and the project is largely separated from the balance sheet of the equity provider (sponsor). Finally, the third type of asset finance, new / alternative financing mechanisms are captured as bonds (that are issued to finance a project), guarantees, leasing, etc. These instruments play so far a very minor role in the EU, particularly in comparison to the US, where the market for bond finance for RES projects is further developed. Nevertheless, these instruments are captured to monitor their role in the EU.

WIND POWER

After the record year 2016, investments in wind capacity decreased notably in 2017, where they totalled almost € 24 billion. In 2016, wind investments amounted to almost € 38 billion, which are the highest investments since the introduction of the investment indicators. The 2017 investments, however, are still higher than those of 2014 and previous years. In line with the decline in investments, the number of wind projects decreased notably from 785 in 2016 to 533 in 2017. The capacity added associated with asset finance went down by 26% from 16.6 GW in 2016 to 12.2 GW in 2017. The weaker decrease in capacity compared to investment indicates a decline in investment costs in the wind power sector.

The way wind power projects were financed remained relatively similar in both years. The majority of wind investments were financed from firms' balance sheets: on-balance-sheet finance accounted for almost 71% in 2016 and 74% in 2017. A small reduction could be observed for project financing, which decreased from 28% of all wind investments in 2016 to 23% in 2017. The shares of the number of project financed investments in both years indicate that on average smaller wind power plants are financed through on-balance-sheet finance, while larger investments use project finance structures. Although project finance is associated with between 23% and 28% of financing volumes in 2017 and 2016, respectively, only 11.6% (2017) and 9.8% (2016) of all projects are covered by project financing. For other financing instruments, as e.g. bonds or guarantees, a small increase from a share of 1% in 2016 to 3.7% in 2017 can be observed. Overall, these instruments play a minor role in financing wind investments in the EU.

SHARE OF ONSHORE WIND INCREASES IN 2017

Comparing onshore and offshore wind investments shows that the slump in overall wind investments was mainly driven by a substantial drop in offshore investments. The latter have been the driver of high investments in previous years. Compared to the very high offshore investments of € 21.6 billion in 2016, investments in offshore wind dropped by almost 50% to € 11.3 billion in 2017. Thus, in 2017 wind offshore investments do not dominate overall wind investments anymore. In 2016, their share dropped from 56% in 2016 to 47% in 2017. As in previous years, wind offshore projects are, not surprisingly, by far larger than the average onshore project. The average size of an offshore wind project remained relative stable with € 1.66 billion in 2016 and € 1.61 billion in 2017. In contrast, the average project size of an onshore wind project in the EU was only € 21 million in 2016 and € 24 million in 2017. The relative role of on-balance-sheet and project financing is relatively similar in offshore and onshore wind in 2017, which is somewhat unexpected due to the high financing volumes in the offshore sector. In 2016, however, project finance is more important in the offshore sector compared to the onshore sector.

1

Overview of asset finance in the wind power sector (onshore + offshore) in the EU Member States in 2016 and 2017

	2016			2017		
	Asset Finance - New Built (in € m)	Number of Projects	Capacity (MW)	Asset Finance - New Built (in € m)	Number of Projects	Capacity (MW)
Germany	11 869.41	458	6 388.9	8 846.82	271	4 245.6
United Kingdom	15 573.39	83	4 216.3	5 077.29	23	1 945.9
Denmark	1 302.20	16	617.9	2 903.69	16	867.7
France	2 137.73	92	1 496.5	2 216.26	91	1 580.6
Sweden	994.02	20	747.8	1 648.12	15	1 355.1
Greece	176.48	4	133.4	805.19	18	523.1
Netherlands	86.76	6	62.1	512.48	7	364.2
Ireland	672.67	14	466.9	425.66	19	277.3
Italy	802.46	14	532.4	382.76	13	264.1
Belgium	2 616.85	27	916.6	331.49	27	241.4
Spain	85.70	8	63.1	227.47	11	164.5
Austria	391.89	12	244.4	212.79	7	166.7
Finland	621.13	18	388.2	142.56	9	103.9
Croatia	93.88	2	67.2	73.94	2	59
Czechia	0.00	0	0	35.67	1	26
Portugal	78.79	6	56.4	32.65	3	23.8
Estonia	166.22	1	102			
Poland	93.17	3	61.4			
Lithuania	10.48	1	7.5			
Total EU	**37 773.23**	**785**	**16 569.1**	**23 874.83**	**533**	**12 208.6**

Source: EurObserv'ER 2018

2

Share of different types of asset finance in the wind power sector (onshore + offshore) in the EU in 2016 and 2017

	2016		2017	
	Asset Finance - New Built	Number of Projects	Asset Finance - New Built	Number of Projects
Balance Sheet	70.84%	89.17%	73.64%	87.43%
Project Finance	28.02%	9.81%	22.63%	11.63%
Bond/Other	1.14%	1.02%	3.72%	0.94%
Total EU	100.0%	100.0%	100.0%	100.0%

Source: EurObserv'ER 2018

Capacity added associated with offshore investments fell from 5.2 GW in 2016 to 3.05 GW in 2017. This corresponds to a decline by 41%, which is less than the drop in investment and thus indicating that the investments cost also declined for offshore wind. In 2016, average expenditure per MW of offshore capacity was almost € 4.2 million compared to only € 3.7 million in 2017. In the case of onshore, investment costs are as expected substantially lower. They marginally declined from € 1.42 million in 2016 to € 1.38 million in 2017.

HIGHEST INVESTMENTS IN THE UK AND GERMANY DUE TO OFFSHORE

In 2017, Germany retook the lead in wind investments from the UK, while both countries remain the two biggest players in this sector. Both countries, however, experienced substantial drops in investment between the two years. In Germany, wind investments totalled € 8.8 billion in 2017 compared to € 11.9 billion in 2016. In the UK, the slump in wind investments was particularly dramatic. Investments dropped from very impressive € 15.6 billion in 2016 to around one third of this amount in 2017, namely € 5.1 billion. The high 2016 investments in the UK were almost entirely driven by five very large offshore investments totalling € 13.5 billion. In Germany, offshore also plays a very important role, but remains at a relatively stable level around € 4.5 billion in both years.

DENMARK TAKES THIRD PLACE

Denmark saw a particularly high upsurge in wind investments. Investments increased from already noteworthy € 1.3 billion in 2016 to impressive € 2.9 billion in 2017. With this increase Denmark is ranked third in the EU. The high investments in 2017 are mainly driven by the offshore sector, where Denmark saw investments of € 2.54 billion. Sweden saw a similarly drastic increase in wind investments, which increased from almost € 1 billion in 2016 to € 1.65 billion in 2017. As the number of projects declined in Sweden, this increase in investment was driven by substantially larger projects in 2017

In France, investments in the wind sector remained at a very high level. Asset finance increased from € 2.14 billion in 2016 to € 2.22 billion in 2017. The number of projects also remained stable in both years. This positive trend ensures that France is the fourth largest player with respect to wind investments in 2017.

Three other Member states experienced high and increasing investments in wind power plants. In Greece investments more than quadrupled from € 176 million in 2016 to almost € 805 million in 2017. An even higher increase in wind investments could be observed in the Netherlands, where asset finance amounted to € 512 million in 2017 compared to only € 87 million in the previous year. In contrast to Greece, this upsurge in investment was driven by large wind projects. Finally also Spain experienced a good year 2017, where wind investments totalled € 227 million. In 2016, only € 86 million were invested into wind capacity in Spain.

3

Overview of asset finance in the wind power sector offshore in the EU Member States in 2016 and 2017

	2016			2017		
	Asset Finance - New Built (in € m)	Number of Projects	Capacity (MW)	Asset Finance - New Built (in € m)	Number of Projects	Capacity (MW)
Germany	4 630.99	3	1231	4 432.32	4	1 061
United Kingdom	13 535.72	5	2 819.5	4 273.89	1	1 386
Denmark	1 045.50	2	434	2 542.98	1	604.8
France	0.00	0	0	5.05	1	1.2
Belgium	2 283.49	2	678.7			
Finland	108.16	1	40			
Total EU	21 603.85	13	5 203.2	11 254.23	7	3 053

Source: EurObserv'ER 2018

Finally, wind investments in Croatia remained relatively stable between the two years. In 2016, € 94 million were invested in Croatian wind capacity compared to € 74 million in the subsequent year. In Czechia, one wind project saw financial close in 2017 and amounted to € 36 million.

4

Share of different types of asset finance in the wind power sector offshore in the EU in 2016 and 2017

	2016		2017	
	Asset Finance - New Built	Number of Projects	Asset Finance - New Built	Number of Projects
Balance Sheet	65.72%	69.23%	79.83%	71.43%
Project Finance	34.28%	30.77%	20.17%	28.57%
Bond/Other	0.00%	0.00%	0.00%	0.00%
Total EU	100.0%	100.0%	100.0%	100.0%

Source: EurObserv'ER 2018

DECREASING INVESTMENTS IN SEVERAL MEMBER STATES

The most dramatic drop in investments could be observed in Belgium, where investment slumped from € 2.6 billion in 2016 to € 331 million in 2017. This decline, however, should not be over overrated as it is mainly due to two very large offshore wind investments in 2016. Thus, when only considering on-shore, the trend is relatively stable. In Finland, asset finance dropped significantly from € 621 million in 2016 to only € 143 million in 2017. In Ireland, Italy, Austria, and Portugal wind investments dropped less dramatically. Finally, Estonia, Poland, and Lithuania only saw wind investments in 2016. ■

PHOTOVOLTAIC

When analysing investments in solar PV, two points are particularly important to be kept in mind. First of all, asset financing only contains utility-scale investments. Hence, all small-scale investments as rooftop installations, which make up the largest share in PV installations in most of the EU countries, are not included in the asset finance data. As in the last editions, EurObserv'ER reports, in addition to utility-scale PV investments by Member State, overall EU investments in small-scale PV installations, i.e. PV installations with capacities below 1 MW.

PV INVESTMENTS STABILISE

After a continuous downward trend in solar PV investments in the last years, investments in utility-scale PV (>1 MW) totalled € 2.05 billion in 2017. This is a 7% decline relative to the 2016 investments of € 2.2 billion. The number of new investments fell at a

1

Overview of asset finance in the PV sector in the EU member states in 2016 and 2017 (PV Plants)

	2016			2017		
	Asset Finance - New Built (in € m)	Number of Projects	Capacity (MW)	Asset Finance - New Built (in € m)	Number of Projects	Capacity (MW)
France	478.69	52	430.0	614.36	75	585.4
United Kingdom	1 253.96	185	1 152.4	353.77	59	339.0
Germany	232.47	33	175.9	336.89	53	314.5
Netherlands	85.39	14	79.0	287.97	30	269.7
Portugal	0.00	0	0	206.27	1	221
Spain	5.02	1	4.6	83.68	8	77.4
Denmark	41.39	1	37.9	68.15	3	64.7
Poland	0.00	0	0	43.91	2	41.0
Italy	72.09	2	66.1	20.14	3	18.8
Hungary	0.00	0	0	14.35	6	13.4
Greece	4.79	1	4.4	10.29	3	9.6
Finland	0.00	0	0	3.86	1	3.6
Austria	0.00	0	0	3.43	1	3.2
Sweden	2.95	1	2.7	1.61	1	1.5
Cyprus	14.61	2	13.4			
Belgium	13.96	1	12.8			
Total EU	2 205.33	293	1 979.3	2 048.66	246	1 962.9

Source: EurObserv'ER 2018

higher rate, namely by 16% from 293 solar PV investments in 2016 to 246 in 2017. This indicates that the average project size increased between the two years. An average PV project in 2016 amounted to € 7.53 million compared to € 8.3 million in 2017. Similar to overall asset finance for PV power plants, the associated capacity added also dropped, however, with a lower magnitude, namely from 1.98 GW in 2016 to 1.96 GW in 2017. This indicates that the investment costs of PV dropped marginally between the two years. In 2016, investment expenditures per MW of PV capacity were on average € 1.11 million compared to € 1.04 million in 2017. This corresponds to a decrease in investment costs by 6%. This decline in costs, however, is wea-

2

Overview of asset finance in the PV sector in the EU in 2016 and 2017 (commercial and residential PV)

	2016		2017	
	Investment (in € m)	Capacity (MW)	Investment (in € m)	Capacity (in MW)
Total EU	3 949.30	5 584	3 702.53	5 978

Source: EurObserv'ER 2018

3

Share of different types of asset finance in the PV sector in the EU 2016 and 2017 (PV Plants)

	2016		2017	
	Asset Finance - New Built	Number of Projects	Asset Finance - New Built	Number of Projects
Balance Sheet	80.37%	83.96%	78.34%	80.49%
Project Finance	19.63%	16.04%	21.37%	19.11%
Bond/Other	0.00%	0.00%	0.29%	0.41%
Total EU	100.0%	100.0%	100.0%	100.0%

Source: EurObserv'ER 2018

ker than the considerable decline between 2015 and 2016 reported in the last edition.

With respect to the sources of finance for PV power plants, there is no substantial change observable. In both years, the majority of PV power plants were financed through on-balance-sheet financing. Between 2016 and 2017, the share of balance sheet financed PV investments decreased marginally from 80% in 2016 to 78% in 2017, while the share of non-recourse project financing rose from almost 17% to 21%. Bonds or other financing mechanisms were not used for PV investments in 2016 and only played a negligible role in 2017.

As in previous years, investments in small-scale PV superseded utility-scale PV investments. Between the two years, however, investments dropped marginally. While small-scale PV investments totalled almost € 4 billion in 2016, they amounted to € 3.7 billion in 2017. This corresponds to a decline by around 6%. In spite of this slight decrease in investment volumes, the associated capacity added actually increased between 2016 and 2017, namely from 5.6 GW to almost 6 GW, which indicates a considerable drop of the investment expenditures per MW, which dropped by 12%.

FRANCE WITH HIGHEST INVESTMENTS IN 2017, DECLINE IN UK INVESTMENTS

Since 2012, there has been a strong concentration of PV investments in the UK. In 2017, however, this picture seems to have changed: France has taken over the first rank in utility-scale PV investments in the EU. After already very high 2016 investments totalling € 479 million, asset finance even increased to € 614 million in 2017. The reversed situation can be observed for the UK. After the very high 2016 investments of € 1.25 billion, UK PV investments dropped to only € 354 million in 2017, such that the UK is ranked second in 2017.

After continuous reductions in most of the previous years, German investments show a positive trend again. PV investments in Germany grew from € 232 million in 2016 to € 337 million in 2017, which corresponds to an increase by 45%. Another Member State with a notable increase in investments is the Netherlands, where investments increased from only € 85 million in 2016 to € 289 million in 2017.

After having experienced high PV investments in the past, Italian PV investments are on a very low level and keep declining. In 2016, only € 72 million were invested into utility-scale PV, while 2017 investments decreased even further to only € 20 million. In the rest of the EU Member States, where investment were recorded, the numbers of projects and the investments volumes are rather low. Across most of these countries, there were increases in investments, as Poland or Denmark, while in some countries investments declined between the two years. ■

BIOGAS

In the biogas sector, the following four types of biogas utility-scale investments are tracked: (i) electricity generation (new) – new built biogas plants with 1 MWe or more that generate electricity, (ii) electricity generation (retrofit) – converted power plants such that they can (at least partly) use biogas (also includes refurbished biogas plants), (iii) heat – biogas power plants with a capacity of 30 MWth or more generating heat, and (iv) combined heat & power (CHP) – biogas power plants with a capacity of 1 MWe or more the generate electricity and heat. In addition to power plants for heating and/or electricity that use biogas, there are also plants that do not produce electricity, but rather produce biogas (biomethane plants), which is injected into the natural gas grid. The latter are by far the minority in the data. However, to allow for distinguishing between these two types of biogas investments, two tables are presented, one with asset finance for biogas power plants and one for facilities producing biogas.

INVESTMENTS IN BIOGAS POWER DECLINE

Asset finance for biogas – including biogas power plants as well as biogas production plants – remained marginally declined. In 2016, overall € 113 million were invested compared to € 85 million in 2017. The relative importance of biogas power plants and biogas production plants changed considerably between the two years. Investments in biogas power plants fell considerably between the two years. In 2016, € 113 million were invested in biogas power plants compared to only € 10 million in the subsequent year. The associated capacity added of these investments fell slightly weaker from 31.8 MW in 2015 to 4 MW. This indicates that the investment costs of biogas plants seemed to decline between the two years namely from € 3.55 million per MW to € 2.47 million per MW in 2017. This change in investment expenditures per MW of biogas capacity, however, should be interpreted with care due to the very few observations, in particular in 2017, where only two investments could be observed.

In contrast to the investments in biogas power plants, investments in biogas production plants were only observed in 2017. In that year, one relatively large investment of

1

Overview of asset finance in the biogas sector in the EU member states in 2016 and 2017 (biogas plants)

	2016			2017		
	Asset Finance - New Built (in € m)	Number of Projects	Capacity (MW)	Asset Finance - New Built (in € m)	Number of Projects	Capacity (MW)
United Kingdom	102.38	7	28.6	9.88	2	4
France	10.46	3	3.2			
Total EU	112.84	10	31.8	9.88	2	4.0

Source: EurObserv'ER 2018

2

Overview of asset finance in the biogas sector in the EU member states in 2016 and 2017 (biomethane)

	2016			2017		
	Asset Finance - New Built (in € m)	Number of Projects	Capacity (m³/hr)	Asset Finance - New Built (in € m)	Number of Projects	Capacity (m³/hr)
Denmark	0.00	0	0	75.03	1	3139.27
Total EU	0.00	0	0	75.03	1	3139.27

Source: EurObserv'ER 2018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€ 75 million was performed. The associated capacity of the biogas production plant is 3139 m³/hr. Thus, this investment is the main driver for the overall relatively marginal decline in overall biogas investments.

The way biogas power plants were financed changed between 2016 and 2017. In 2016, 73% of all investments were financed from balance sheets, while the remaining 27% used project finance. As only 10% of all plants used project finance, project financed investments were on average larger than those financed from balance sheets, which is the typical observation that can often be made across RES. In 2017, all biogas power plants as well as the biogas production plant were on-balance-sheet financed.

INVESTMENTS MAINLY IN DENMARK AND THE UK

Only the UK saw biogas investments in both years. In 2016, the UK dominated the investments in biogas power plants with € 102 million that went into 7 new plants with an aggregate capacity added of 28.6 MW. In 2017, only € 9.9 million were invested in the UK. Another Member State with investments in 2016 was France with three rather small investments totalling € 10.5 million with an associated capacity added of 3.2 MW. Finally, the € 75 million investment in a biogas production facility occurred in Denmark. ■

3

Share of different types of asset finance in the biogas sector in the EU in 2016 and 2017 (biogas plants)

	2016		2017	
	Asset Finance - New Built	Number of Projects	Asset Finance - New Built	Number of Projects
Balance Sheet	72.64%	90.00%	100.00%	100.00%
Project Finance	27.36%	10.00%	0.00%	0.00%
Bond/Other	0.00%	0.00%	0.00%	0.00%
Total EU	100.0%	100.0%	100.0%	100.0%

Source: EurObserv'ER 2018

Rémi Vilaggi / Terre d'info

RENEWABLE MUNICIPAL WASTE

Similar to the solid biomass data, the asset financing data on waste-to-energy data includes four types of utility-scale investments: (i) electricity generation (new) – new built plants with 1 MWe or more that generate electricity, (ii) heat – thermal plants with a capacity of 30 MWth or more generating heat, and (iii) combined heat & power (CHP) – power plants with a capacity of 1 MWe or more to generate electricity and heat. Another element to note is that waste to energy plants burn municipal waste, which is conventionally deemed to include a 50% share of waste from renewable origin. This part presents investments related to plants, not to the production of renewable waste used for energy production.

DROP IN WASTE INVESTMENTS

Overall EU investments in the waste-to-energy sector dropped significantly between the two years. In 2016, € 1.1 billion were invested in waste-to-energy plants compared to only € 164 million in 2017. The number of waste-to-energy projects reaching financial close dropped from 10 projects in 2016 to 2 projects in 2017. The average project size also declined from, on average, € 110 million to € 82 million.

Similarly, the capacity added associated with investments is notably larger in 2016 with 224 MW compared to 27 MW in 2017. Thus, the investment cost increased notably between the two years, namely from € 5 million per MW in 2016 to € 6 million in 2017, which, however, should be interpreted with care. A main driver of the relatively low costs in 2016 is that the largest plant in that year (70MW) is a retrofit of an existing power plant, which typically involves significantly less expenditures per MW compared to new built plants.

In 2016, the shares of on-balance-sheet (42%) and project financed (58%) investments are relatively balanced. In that year, the average size of project financed investments was significantly larger than those financed from balance sheets, which is the typical observation that can often be made across RES. In 2017 all waste projects used balance-sheet financing.

In the previous years, the UK typically dominated waste-to-energy investments. This is still true for 2016, where all investments were conducted in that country. In 2017, however, only a small investment of € 8 million was recorded in the UK. The by far largest investment of € 156 million was conducted in Lithuania. ■

1

Overview of asset finance in the waste sector in the EU member states in 2016 and 2017

	2016			2017		
	Asset Finance - New Built (in € m)	Number of Projects	Capacity (MW)	Asset Finance - New Built (in € m)	Number of Projects	Capacity (MW)
Lithuania	0.00	0	0	155.91	1	24
United Kingdom	1104.46	10	223.9	8.15	1	3.3
Total EU	1104.46	10	223.9	164.06	2	27.30

Source: EurObserv'ER 2018

2

Share of different types of asset finance in the waste sector in the EU in 2016 and 2017

	2016		2017	
	Asset Finance - New Built	Number of Projects	Asset Finance - New Built	Number of Projects
Balance Sheet	42.00%	70.00%	100.00%	100.00%
Project Finance	58.00%	30.00%	0.00%	0.00%
Bond/Other	0.00%	0.00%	0.00%	0.00%
Total EU	100.0%	100.0%	100.0%	100.0%

Source: EurObserv'ER 2018


EDF

GEOTHERMAL ENERGY

This technology uses geothermal energy for heating and/or electricity generation. Before discussing the asset financing for geothermal plants in the EU, the types of investments included in the underlying data have to be differentiated. The data includes four types of geothermal investments, namely: (i) conventional geothermal energy, (ii) district heating, (iii) combined heat and power (CHP), and (iv) enhanced geothermal systems. Geothermal energy has a strong regional focus in the EU. The largest user of geothermal energy by far is Italy, although other EU countries also use this energy source to a certain extent.

INCREASING GEOTHERMAL INVESTMENTS IN THE EU

In 2017, € 131 million were invested in geothermal capacity in the EU. This is an increase by 64% compared to the 2016 investments of € 80 million. Thus, in 2017, investments reached the relatively high level of 2015, which was substantially higher than in previous years, where often small or no investments in geothermal were observed in the EU. The number of new geothermal projects increased from 3 to 4, which indicates that the average project size increased between the two years, namely from € 26.5 million per geothermal plant in 2016 to € 32.7 million in 2017. The associated capacity increased at a slower pace from 46 MW to 66 MW. Thus, the average investment expenditures marginally increased from € 1.73 million per MW in 2016 to € 2 million per MW in 2017.

The way geothermal projects are financed changed notably between the two years. In 2016, more than 76% of investments used on-balance-sheet finance, while only 24% were project financed. The picture changed completely in 2017, where all geothermal plants used project finance. In both years, bonds and other financing instruments did not play any role in geothermal investments.

THE NETHERLANDS DOMINATE 2017 INVESTMENTS

The Netherlands dominate geothermal investments in 2017, where € 125 million were invested in 3 geothermal plants. Furthermore, the Netherlands are the only Member State with investments in both years. In 2016, however, asset finance was at a notably lower level with € 19 million. The only other country with geothermal investments in 2017 is Hungary with a rather small investment of € 5.4 million. The highest investments in 2016 were conducted in Germany, where € 53 million were invested into a 26 MW geothermal plant. In the same year, € 8 million were invested in Portugal into a 4 MW plant. ■

1

Overview of asset finance in the geothermal sector in the EU member states in 2016 and 2017

	2016			2017		
	Asset Finance - New Built (in € m)	Number of Projects	Capacity (MWth)	Asset Finance - New Built (in € m)	Number of Projects	Capacity (MW)
Netherlands	18.75	1	16	125.48	3	63
Hungary	0.00	0	0	5.38	1	2.7
Germany	52.73	1	26	0.00	0	0
Portugal	8.11	1	4	0.00	0	0
Total EU	79.59	3	46	130.86	4	66

Source: EurObserv'ER 2018

2

Share of different types of asset finance in the geothermal sector in the EU in 2016 and 2017

	2016		2017	
	Asset Finance - New Built (in € m)	Number of Projects	Asset Finance - New Built (in € m)	Number of Projects
Balance Sheet	76.44%	66.67%	0.00%	0.00%
Project Finance	23.56%	33.33%	100.00%	100.00%
Bond/Other	0.00%	0.00%	0.00%	0.00%
Total EU	100.0%	100.0%	100.0%	100.0%

Source: EurObserv'ER 2018

EDF

SOLID BIOMASS

Asset financing for solid biomass discussed here solely includes investment into solid biomass power plants. Hence, there are no investments in biomass production capacity in the data. The data contains four types of biomass utility-scale investments: (i) electricity generation (new) – new built biomass plants with 1 MWe or more that generate electricity, (ii) electricity generation (retrofit) – converted power plants such that they can (at least partly) use biomass (also includes refurbished biomass plants), (iii) heat – biomass power plants with a capacity of 30 MWth or more generating heat, and (iv) combined heat & power (CHP) – biomass power plants with a capacity of 1 MWe or more that generate electricity and heat.

SLUMP IN BIOMASS INVESTMENTS

2016 has been a very strong year with respect to asset finance for utility-scale biomass. EU-investments totalled more than € 5 billion. These investments are notably higher than in most of the previous years. In 2017, however, biomass investment slumped by almost 87% to only € 679 million. The capacity added fell at almost the identical rate. While the capacity added associated with 2016 investments totalled 1.7 GW, capacity added in 2017 only amounted to 208 MW. The number of biomass projects, however, only fell by 55% from 20 projects in 2016 to 9 projects in 2017. Thus, the very high investments in 2016 were mainly driven by, on average, very large investments. In fact, the average biomass project in 2017 was € 75 million compared to € 253 million in the previous year. Investment cost per MW marginally increased from € 3 million per MW in 2016 to € 3.3 million in 2017.


Erik Westberg

1

Overview of asset finance in the solid biomass sector in the EU Member States in 2016 and 2017

	2016			2017		
	Asset Finance - New Built (in € m)	Number of Projects	Capacity (MW)	Asset Finance - New Built (in € m)	Number of Projects	Capacity (MW)
Denmark	666.23	1	150.0	163.26	1	25.0
Italy	57.33	1	22.8	121.28	1	30.0
Portugal	0.00	0	0	104.82	1	30.0
Finland	145.09	1	170.0	91.21	1	30.7
United Kingdom	1 258.95	10	408.0	86.69	2	35.1
Spain	0.00	0	0	84.30	1	46.0
Croatia	0.00	0	0	24.80	1	5.0
Sweden	0.00	0	0	2.57	1	6.0
Netherlands	2 381.96	2	801.0			
Lithuania	338.11	1	87.6			
France	124.67	2	28.8			
Estonia	64.49	1	21.4			
Germany	21.00	1	6.4			
Total EU	5 057.84	20	1 696.0	678.93	9	207.8

Source: EurObserv'ER 2018

The way biomass power plants are financed did not change notably between the two years. In both years, the majority of biomass projects were on-balance-sheet financed with shares around 72% in both years. The remainder of all biomass plants used project finance. In both years, the size of project financed investments was on average significantly larger than those financed from balance sheets, which is the typical observation that can often be made across RES.

DIVERSE DEVELOPMENTS ACROSS THE EU

In 2016, by far the largest investments in biomass capacity could be observed in the UK and, in particular, the Netherlands. In the UK, € 1.26 billion were invested and in the Netherlands almost € 2.4 billion. In line with these large investment sums, the associated capacity additions in both countries were quite large, namely 801 MW in the Netherlands and 408 MW in the UK. A notable difference between the two countries is the low number of biomass projects in the Netherlands, namely two very large investments.

Overall, there are only few Member States that saw investments

in both years. Furthermore, almost all countries with investments in 2017, with the exception of the UK, saw only one biomass investment in that year, respectively. The largest investment of € 163 million was recorded in Denmark, followed by Italy with € 121 million and Portugal with € 105 million. While no biomass investments happened in Portugal in 2016, € 57 million were invested in Italy and even € 666 million in Denmark. The fourth country with investments in the two years, next to Denmark, Italy, and the UK, is Finland where € 145 million were invested in 2016 and € 91 million in 2017.

The remainder of the Member States experienced investments in only one of the two years. Spain, Croatia, and Sweden saw biomass investments only in 2017. In contrast, only in 2016 there were biomass investments in Lithuania, France, Estonia, and Germany. Among those, the very high investment of € 338 million in Lithuania is particularly noteworthy. ■

2

Share of different types of asset finance in the solid biomass sector in the EU in 2016 and 2017

	2016		2017	
	Asset Finance - New Built (in € m)	Number of Projects	Asset Finance - New Built (in € m)	Number of Projects
Balance Sheet	72.51%	75.00%	72.14%	77.78%
Project Finance	27.49%	25.00%	27.86%	22.22%
Bond/Other	0.00%	0.00%	0.00%	0.00%
Total EU	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Source: EurObserv'ER 2018

INTERNATIONAL COMPARISON OF INVESTMENT COSTS

In this section, RES investment costs in the EU and major EU trading partners are presented and compared. This comparison is based on investments in utility-size RES power plants. Investment costs are defined as the average investment expenditures per MW of capacity in the respective RES sector. These average investment expenditures per MW are calculated for the EU as well as for some major EU trading partners, namely Canada, China, India, Japan, Norway, Russia, Turkey and the United States. However, there are several cases, where some of these countries did not experience investments in capacity in certain RES sectors. Hence, the number of countries, where investments costs can be calculated and reported, differs across RES technologies and years.

WIND ONSHORE AND OFFSHORE INVESTMENT EXPENDITURES

Investments expenditures per MW of onshore wind capacity in the European Union dropped by more than 3% from € 1.42 million per MW in 2016 to € 1.38 million in 2017. The average investment costs of onshore wind in the analysed non-EU countries remained constant around € 1.41 million per MW in both years. Thus, while investment expenditures per MW of new onshore capacity were marginally higher in 2016 in the EU, they dropped below the average investment costs of its main trading partners. In some of the non-EU countries, e.g. in Canada and the United States, the investment costs of onshore wind dropped even stronger than in the EU, while in other countries, as India, investment costs marginally increased.

In contrast to onshore, only one of the analysed non-EU countries experienced offshore wind investments, namely China. Investment expenditures per MW of offshore remained relatively stable around € 2.5 million in both years. Overall, investment costs of offshore wind seem to be notably higher in the EU, where they, however, decreased from € 4.15 million to € 3.69 million.

1

Wind Onshore Investment Expeditures (in € m per MW)

	2016	2017
Canada	1.59	1.42
China	1.25	1.20
India	1.18	1.32
Japan	1.93	1.73
Norway	1.18	1.37
Russian Federation	1.40	1.57
Turkey	1.35	1.37
United States	1.43	1.34
European Union	1.42	1.38

Source: EurObserv'ER 2018

2

Wind Offshore Investment Expeditures (in € m per MW)

	2016	2017
China	2.49	2.52
European Union	4.15	3.69

Source: EurObserv'ER 2018

INVESTMENT EXPENDITURES FOR PV AND BIOMASS

In the EU solar PV sector, the investment costs of utility-scale plants dropped even stronger than for onshore wind, namely by more than 6%. Investment expenditures per MW of solar PV decreased from € 1.11 million per MW in 2016 to only € 1.04 million in 2017. The same trend could be observed for the majority of the analysed non-EU countries, where, on average, investment expenditures per MW of PV dropped from € 1.17 million to € 1.16 million.

Hence, in both years, investment costs for PV are below the average of the analysed non-EU economies and the EU investment cost advantage even increased in 2017.

In the EU biomass sector, the investment expenditures for one MW increased from € 2.98 million per MW in 2016 to € 3.27 million in 2017. These investment expenditures were higher than the average of the considered non-EU countries, which were € 2.42 million per MW in 2016 and € 2.12 million in 2017. The main driver of these low costs is China, where investment costs per MW of biomass capacity were significantly below € 2 million in both years.

Overall, the analysis shows a heterogeneous picture across RES technologies. In the two sectors with the highest investments in the EU, onshore wind and solar PV, investment costs per MW of capacity seem to be below the average of the considered non-EU countries. In addition to the lower absolute investment costs, these costs were still decreasing between 2016 and 2017 in the EU. For biomass and offshore wind, investment expenditures per MW seem to be higher in the EU. These results for biomass, however, have to be interpreted with care due to very few observations of biomass investments. ■

3

Solar PV Investment Expeditures (in € m per MW)

	2016	2017
Canada	1.09	1.11
China	1.16	1.08
India	0.90	0.94
Japan	1.63	1.53
Russian Federation	1.09	1.28
Turkey	1.09	1.07
United States	1.19	1.13
European Union	1.11	1.04

Source: EurObserv'ER 2018

4

Biomass Investment Expeditures (in € m per MW)

	2016	2017
China	1.60	1.39
Japan	3.14	2.49
United States	2.52	2.47
European Union	2.98	3.27

Source: EurObserv'ER 2018

DR

PUBLIC FINANCE PROGRAMMES FOR RES INVESTMENTS

To capture the involvement of the public sector in RES financing, EurObserv'ER gathered information on national and EU-wide financing or promotion programmes. In general, public finance institutions can play an important role in catalysing and mobilising investment in renewable energy. There are numerous instruments which are used by these institutions, which are typically either state-owned or mandated by their national government or the European Union. The instruments range from providing subsidies/grants or equity to classic concessional lending (loans with favourable conditions / soft loans) or guarantees. The dominant instrument in terms of financial volume is concessional lending. The loans provided by public finance institutions are typically aimed at projects that have commercial prospects, but would not have happened without the public bank's intervention.

In this section, an overview of public finance programmes for RES investments available in 2016 and/or 2017 is presented. This overview only contains programmes, where financial instruments, as debt / equity finance or guarantees, are offered. Grant and subsidy programmes are not covered in this section, as they are tracked, next to other RES policies, in the EU EurObserv'ER Policy Files. Hence, this overview is complementary to the country profiles on RES policies and regulations. As the overview concentrates on dedicated RES financing programmes or funds focussing on RES, it might omit public finance institutions that provide RES financing without having explicitly set up a programme or dedicated fund. An example is the Nordic Investment Bank (NIB) that also offers loans for RES investments to its member countries, namely Denmark, Finland, Iceland, Norway, Sweden, Estonia, Latvia, and Lithuania. The overview comprises both programmes and funds that only provide finance for RES investments as well as those, which have other focus areas next to renewables, such as energy efficiency investments. An example of the latter is the Polish Sustainable Energy Financing Facility (PolSEFF[2]), where investments in energy efficiency measures for equipment, systems and processes or residential and commercial buildings play an important role.

OVERVIEW OF INSTITUTIONS

There are a number of public finance institutions with dedicated financing programmes for RES in the EU. These include, but are not limited to, the two European public banks – the European Investment Bank (EIB) and the European Bank of Reconstruction and Development (EBRD) – as well as numerous regional and national public banks such as the KfW (Kreditanstalt für Wiederaufbau), or the Croatian Bank for Reconstruction and Development (HBOR). Furthermore, there are numerous funds, which provide financing for RES investments. These include EU-wide funds, such as the European Regional and Development Fund (ERDF) or the Cohesion Fund of the EIB, as well as national funds, as the Slovenian Environmental Public Fund (Eco-Fund) or the Lithuanian Environmental Investment Fund (LEIF). Finally, there are also dedicated financing facilities that provide lending for RES investments and typically also offer technical assistance to private banks. Examples are the Polish Sustainable Energy Financing Facility (PolSEFF) or the Slovak Energy Efficiency and Renewable Energy Finance Facility (SLOVSEFF III) of the EBRD.

FINANCING SCHEMES AND INSTRUMENTS

The presented public finance programmes differ with respect to financing instruments used, financing amounts, and types of final beneficiaries. Most of the programmes and funds offer concessional financing. In some cases, also loan guarantees are offered.

There are also substantial differences in the way financing is provided for RES investments of the final beneficiaries. In many cases, as the KfW Renewable Energies Programme, direct lending is available, i.e. the borrower directly receives a loan from the public finance institution. The loans might also be tight to certain conditions, e.g. that private banks also provide financing for the respective RES investment. In the KfW Programme Offshore Wind Energy, direct public loans are given in the framework of bank consortia, where private banks have to provide at least the same amount of debt financing. Alternatively, there are cases, where financing is provided indirectly, i.e. via a private partner institution. Such a structure is being used within EBRD's PolSEFF that offers loans to SMEs for investments in sustainable energy technologies. PolSEFF, however, is not lending directly to SMEs, but rather provides credit lines to private partner banks, which then on lend to the final beneficiaries.

PIXABAY

Finally, there are considerable differences in the financing volumes across programmes. The KfW Funding Initiative Energy Transition, e.g., focuses on large-scale RES investments with loans ranging from € 25 to € 100 million. In contrast, the Polish programme PROSUMER focuses on micro-installations, e.g. small RES electricity installations of up to 40 kWe. Overall, a wide variety of financing schemes, used instruments, and focused final borrowers can be observed in the EU.

It is possible that public involvement in financing RES projects in the EU will slow down in the next years, similar to other RES support mechanisms. One example is the Fondo Kyoto of Cassa Depositi e Prestiti in Italy, which was removed from the overview as no budget was assigned for 2017. The need of public finance might decline as different RES technologies mature over the years. However, RES investments will remain highly dependent on services provided by capital markets. As they are typically characterised by high up-front and low operation costs, the cost structure of RES projects is dominated by capital costs. ■

1

Public Finance Programmes for RES

Programme	Involved Institutions / Agencies	Country	Date effective	Targeted RES Sector	Short Discription RES Financing Scheme
EIB European Regional and Development Fund (ERDF)	European Investment Bank (EIB)	EU 28	2014	Multiple RES (and other non-RES focus areas)	Provision of loans. guarantees. and equity for RES projects in all EU Member States
EIB Cohesion Fund	European Investment Bank (EIB)	EU Member States with GNI per capita below 90% of EU average.	2014	Multiple RES (and other non-RES focus areas)	Financial support (guarantees. loans. (quasi-) equity participation and other risk-bearing mechanisms).
Loan Programme	Environmental Protection and Energy Fund (EPEEF)	Croatia	2003	Multiple RES	Loans. subsidies. financial assistance. and grants for RES (and environmental protection and waste management)
Loan Programme for Environmental Protection, Energy Efficiency and Renewable Energy	Croatian Bank for Reconstruction and Development (HBOR)	Croatia	1992	Multiple RES	Loans for RES investments
Loan guarantees for local initiatives for the construction of wind-energy plants	Energinet.dk	Denmark	2009	Onshore Wind	Provision of loan guarantees
Heat Fund	French Agency for Environment and Energy Management (ADEME)	France	2009	Solar thermal. biomass. geothermal. biogas. waste heat and district heating	Subsidies for large RES heating installations
Funding Initiative Energy Transition	Kreditanstalt für Wiederaufbau (KfW)	Germany	2012	Multiple RES	Loans for large scale RES investments
Programme Offshore Wind Energy	Kreditanstalt für Wiederaufbau (KfW)	Germany	2011	Offshore Wind	Direct loans of KfW in the framework of bank consortia for offshore wind
Renewable Energies Programme	Kreditanstalt für Wiederaufbau (KfW)	Germany	2009	Solar photovoltaic Solar thermal	Loans for RES (with different conditions based on RES technology)
Market Incentive Programme	Kreditanstalt für Wiederaufbau (KfW), Federal Ministry of Economic Affairs	Germany	1999	Biomass. geothermal, solar PV	Soft loans for larger/commercial RES installations
Environment Innovation Program	The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB); Kreditanstalt für Wiederaufbau (KfW)	Germany	1997	Multiple RES	Loans / interest rate subsidies for large scale RES plants with demonstration character
The Lithuanian Environmental Investment Fund (LEIF)	The Lithuanian Environmental Investment Fund (LEIF)	Lithuania	1996	Multiple RES	Soft loans for RES investments
Loans from the National Fund for Environmental Protection and Water Management	National Fund for Environmental Protection and Water Management (NFEPWM)	Poland	2015	Biomass. geothermal, solar PV	Loans for RES investments
BOCIAN - support for distributed renewable energy sources	National Fund for Environmental Protection and Water Management (NFEPWM)	Poland	2014	Multiple RES	Provision of soft loans for distributed RES
PROSUMER - programme supporting deployment of RES microinstallation	The National Fund for Environmental Protection and Water Management	Poland	2014	Multiple RES	Loans for micro-installations of RES. Beneficiaries: individuals. housing associations and communities. local governments.
Polish Sustainable Energy Financing Facility - 2nd Edition (PolSEFF)	European Bank for Reconstruction and Development (EBRD)	Poland	2011	Multiple RES	Provision of credit lines that are available through partner banks
Slovak Energy Efficiency and Renewable Energy Finance Facility (SLOVSEFF III)	European Bank for Reconstruction and Development (EBRD)	Slovakia	2014	Multiple RES	Loans for RES investments (and energy efficiency)
Slovenian Environmental Public Fund (Eco-Fund)	Slovenian Environmental Public Fund (Eco-Fund)	Slovenia	2000	Multiple RES	Soft loans for RES projects of SMEs and large-scale companies
Commercial Loans to Start-up Energy Companies	Swedish Energy Agency	Sweden	2006	Multiple RES	Loans for start-up RES-companies
Energy Saving Scotland Small Business Loans scheme	Energy Saving Trust	United Kingdom	1999	Multiple RES	Soft loans for SMEs for RES measures

Investment in Renewable Energy Technology

The EurObserv'ER investment indicators also focus on investments related to the development and production of RES technologies as well as the performance of RES firms and assets. Hence, information of venture capital and private equity investments is presented. Additionally, RES indices based on EU RES firms are constructed and the performance of YieldCos is tracked.

Methodological note

VENTURE CAPITAL & PRIVATE EQUITY

EurObserv'ER collects data investments of venture capital and private equity funds into renewable energy technology developing firms. Venture capital (VC) focuses on very young start-up companies typically with high risks and high potential returns. Venture capital can be provided to back an idea of an entrepreneur before the business has started. It may be used to finalize technology development or to develop initial business concepts before the start-up phase. Venture capital can be also used in the subsequent start-up phase to finance e.g. product development and initial marketing or the expansion of a business. Basically, venture capital funds finance risky start-ups with the aim to sell the shares with a profit. Private equity (PE) is a type of equity that is not traded on stock markets. Generally, PE aims at more mature companies than VC and can be divided into two types. PE expansion capital is financing companies that plan to expand or restructure their operations or enter new markets. While expansion capital is usually a minority investment, PE buy-outs are investments to buy a company. These investments are often accompanied by large amount of borrowed money due to the usually high acquisition costs.

Summing up, venture capital investments target renewable energy technology firms at the start-up phase, while private equity aims at relatively mature companies. While VC investments are typically small, private equity deals are usually larger. PE-buyouts are in general the by far largest deals since in such a deal a mature company is acquired. All these investments together shed a light on the activity of start-up und young renewable energy technology firms, while it is essential to distinguish between the typically large PE buy-outs and the other investments when analysing the VC/PE investments in the RES sectors. Hence, a breakdown of VC/PE investments by investment stage will be provided to show a more comprehensive picture. Overall, the trends in VC/PE investments have to be interpreted with care as the data coverage might not be perfect and due to the rather low amount of observations for VC/PE, potentially missing data might have a dilutive effect on the results.

PERFORMANCE OF RES TECHNOLOGY FIRMS AND ASSETS ON PUBLIC MARKETS

The RES indices are intended to capture the situation and dynamics on the EU market for equipment manufacturers and project developers. The methodological approach is to include EU RES firms that are listed on stock markets and where the firms' revenues were (almost) entirely generated by RES operations. Hence, there might be important large firms that are not included in the indices. The reason is that there are numerous (partly very large) companies that produce renewable energy technologies but are also active in other sectors (e.g. manufacturers producing wind turbines, but as well turbines for conventional power plants). These are not included since their stock prices might be largely influenced by their operations in other areas than RES. Furthermore, there is also a large group of small firms that are not listed on stock markets which hence are also not included here. For the sectoral indices, RES firms are allocated if they are only (or mainly) active in the respective sector. The final choice among the firms in each sector is done by the firm size measured in revenues. Hence, the indices contain the ten largest quoted RES firms in the EU in the respective sector and year.

The indices are constructed as Laspeyres-Indices. The aim of a Laspeyres-Index is to show the aggregated price changes, since the weighting is used based on the base values. Hence, firms are weighted by their revenues in the respective previous period. In 2016, e.g., the firms are weighted by their 2015 revenues whereas in 2017, the 2016 revenues are applied. So the weighting is adjusted every year in order to keep the structure appropriate. The reason for this approach – in contrast to weighting the firms according to their market capitalisation – is that this approach reflects less the short term stock market fluctuations but rather focuses on long-term developments as it is in this analysis that concentrates on the development of two years. The top ten firms for the respective RES Technology Indices are selected and, if necessary replaced, based on their revenues.

Furthermore, EurObserv'ER collects and analyses data on YieldCos. YieldCos are entities that own cash-generating infrastructure assets, e.g. renewable energy plants, where the ownership is offered on public markets. Hence, YieldCos are also listed on stock markets. As there are only very few YieldCos currently operational in the EU, the stock prices of these will be captured rather than constructing an index as in the case of RES firms.

VENTURE CAPITAL – PRIVATE EQUITY

Total venture capital (VC) and private equity (PE) investments in renewable energy companies decreased between 2016 and 2017 by around 18%. In 2017, total VC/PE investments in the EU amounted to € 1.6 billion compared to € 2 billion in 2016. Thus, the development of VC/PE investments in the RES sectors runs against the overall positive trend in VC/PE investments in the EU. According to the data of the European Private Equity and Venture Capital Association (EVCA), overall EU-wide VC/PE investments (covering all sectors) increased by around 29%.

BREAKDOWN OF VC/PE INVESTMENT STAGES

For this analysis, the overall VC/PE investments for all RES in the EU are disaggregated into four investment stages: (i) VC Early Stage, (ii) VC Late Stage, (iii) PE Expansion Capital, and (iv) PE Buy-outs. Early-stage venture capital is provided to early-stage / emerging young companies, e.g., for research and development in order to develop a product or business plan and make it marketable. Late-stage VC is typically used to finance initial production capacities or marketing activities. PE is typically used in later stages of a firm's life cycle. PE Expansion Capital is typically used by mature / established companies to expand their activities by, e.g., scaling-up production facilities. Finally, PE Buy-outs are investments to buy (a majority of) a RES company and often imply high investments compared to the other PE and particularly VC deals.

This disaggregated analysis shows that the decrease in overall VC/PE investments was mainly driven by a decline of PE investments that fell by 20%, namely from € 1.77 billion in 2016 to € 1.42 billion in 2017. As also observed in previous years, PE Buy-outs have the largest share in overall VC/PE investments. Their share totalled 82% in 2016 and marginally increased to almost 86% in 2017. A similar pattern can also be observed for overall VC/PE investments as reported by the EVCA, where the share of PE Buy-outs increased from 67% to more than 71% between the two years. PE Expansion Capital declined even more, namely from € 118 million in 2016 to only € 21 million in 2017.

VC investments only fell by 7% from € 231 million in 2016 to € 215 million in 2017. This decline was mainly driven by a reduction of early-stage VC from € 129 million to € 55 million. In contrast, late-stage VC increased notably from € 102 million to € 160 million. The most striking change, however, is the significant increase in the number of VC deals that almost doubled between the years. This indicates that, even though the overall volumes did not change a lot, there is an increasing innovative activity in the RES sectors, i.e. more young technology firms seek VC to launch or scale up a RES technology company in the EU.

SOLAR DOMINATES VC/PE INVESTMENTS

When taking a more detailed look at the respective renewable energy technologies, it should be pointed out that biogas, biomass, and waste-to-energy are not disaggregated. The main reason is that the data includes several companies that are either project developer active in at least two of these sectors or equipment developers/producers that provide technologies for two or more sectors.

In both years, VC/PE investments in the solar PV sector dominate all other RES sectors with respect to investment volumes. From 2016 to 2017, VC/PE investments into solar firms decreased from € 1.3 billion to € 1.06 billion, whereas its share in total VC/PE investments remained very stable around 65%. The number of VC/PE deals in this sector even slightly increased. The relatively high investments in the solar PV sector, however, are largely driven by very large PE Buy-outs in both years. Thus, the innovative activities in the solar PV sector relative to other RES should not be over-interpreted.

VC/PE investments in the wind sector dropped notably from € 663 million in 2016 to € 267 million in 2017. The number of deals fell by one third. This decline in investments can be largely explained by a decrease of PE Buy-outs, which were the main driver of the higher number in 2016. VC investments were relatively stable in the wind sector between 2016 and 2017.

The only other sectors that experienced VC/PE investments in both years are biogas, biomass, and waste. Furthermore, these are the only sectors that experienced a notable increase in VC/PE investments, which increased tenfold between both years. In 2016, VC/PE investment in biogas, biomass, and waste totalled almost € 36 million compared to € 348 million in 2017. The main driver of this increase, however, is one relatively large PE-Buyout deal totalling around € 300 million. Finally, the small hydro sector saw one rather small VC/PE investment of € 1.6 million in 2017. ■

1

Venture Capital and Private Equity Investment in Renewable Energy per Technology in the EU in 2016 and 2017

	2016		2017	
	Venture Capital / Private Equity (in € m)	Number of Projects	Venture Capital / Private Equity (in € m)	Number of Projects
Solar	1 307.86	18	1 057.70	19
Biogas, Biomass & Waste	32.13	4	308.09	12
Wind	663.25	9	266.95	6
Small Hydro	0.00	0	1.42	1
Total EU	2 003.24	31	1 634.15	38

Source: EurObserv'ER 2018

2

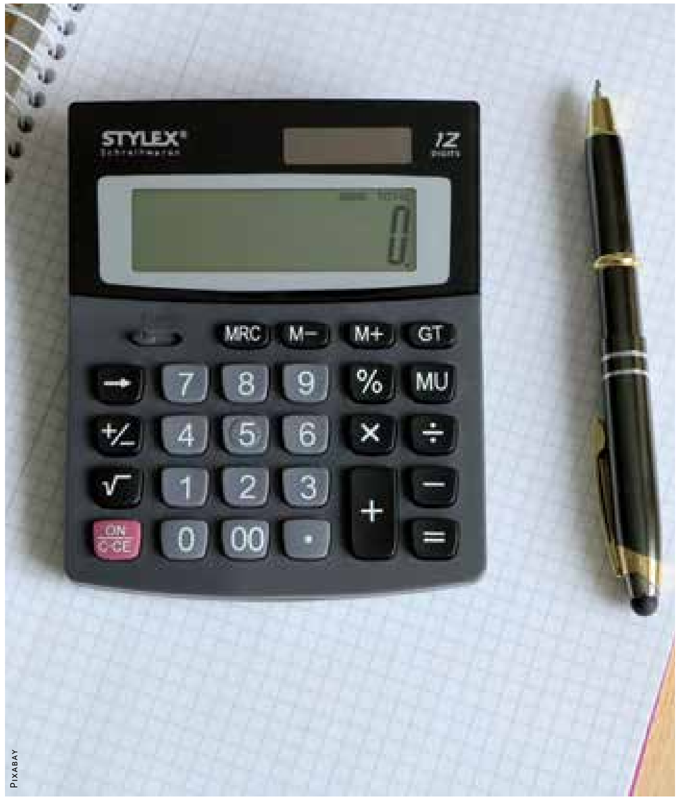
Venture Capital and Private Equity Investment in Renewable Energy per Investment Stage in the EU in 2016 and 2017

	2016		2017	
	Venture Capital / Private Equity (in € m)	Number of Projects	Venture Capital / Private Equity (in € m)	Number of Projects
VC Early Stage	128.69	8	54.70	16
VC Late Stage	102.49	7	160.44	12
PE Expansion Capital	118.48	7	21.45	2
PE Buy-out	1 653.57	9	1 397.57	8
Total EU	2 003.24	31	1 634.15	38

Source: EurObserv'ER 2018

PERFORMANCE OF RES TECHNOLOGY FIRMS AND RES ASSETS

In this section, EurObserv'ER presents indices based on RES company stocks to capture the performance of RES companies, i.e. companies that develop / produce the RES technology. The RES indices are an indicator of current and expected future performance of EU RES companies listed on stock markets. As in the last edition, four indices are presented, i.e. a Wind, a Solar, a composite Bio-Energy Index, and an aggregate RES Index. The first three indices consist of 10 firms that are (almost) entirely active in the respective RES sectors. The latter is an aggregate index based on all RES firms included in the other indices. The Bio-Energy Index includes firms that are active in the biofuels, biogas, biomass, and / or the waste sector. All these firms are included in one joint index as these firms are active on several of these sectors, which would make an allocation of firms to only one specific sector almost impossible.



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When analysing these indices it is essential to bear in mind that they only capture companies that are listed on stock exchanges. Entities that are owned by parent companies or limited liability companies (e.g. Enercon) are not listed on stock markets and hence not reflected. Furthermore, there are numerous companies that are not only active in RES. Examples are Abengoa, a Spanish company that is active in RES, but also in other fields as water treatment and conventional generation and hence does not satisfy the criteria of the RES indices. As in the last edition, the EURO STOXX 50 index is used to compare the performance of RES companies to the other sectors in the EU.

COMPOSITION OF RES INDICES

As in the last editions, some firms in the indices were replaced in this edition. As the indices cover all years since the based date and not just the last two years, as in older editions, the constellation of firms might change between years (all firms included in the indices are listed in detail in the footer of this section). A notable change compared to last edition is the removal of KTG Energie and BDI-BioEnergy International in the year 2017. These companies were replaced by EBIOSS Energy and Fluid. As these two new firms are based in Bulgaria and Poland, respectively, the variety of Member States is notably increased in this index. It is further noteworthy that the two by far largest companies with respect to revenues, Cropenergies and Verbio Bioenergie, are (mainly) active in the biofuels sector. More Member States are represented in the PV and the Wind Indices. The by far largest company in the Solar PV Index is SMA Solar Technology AG, while in the Wind Index, the dominant company is Vestas.

HETEROGENEOUS DEVELOPMENTS ACROSS RES SECTORS IN 2017

The trends of the Wind and the Bio-Energy Indices were relatively similar for the most of 2016. The steady growth continued until the end of the year in the case of the Bio-Energy Index. In contrast, the Wind Index experienced a very strong increase in the second quarter of 2016 that was followed by a substantial drop in the fourth quarter. At the end of 2016, the Wind Index was almost at the same level as at the beginning of the year. In contrast to these two indices, listed solar PV firms experienced a rather bad year 2016. Throughout the year, the Solar Index experienced a continuous decline and closes at almost the same level as it started in the beginning of 2015. In the subsequent year, however, the development of all three indices is notably more heterogeneous.

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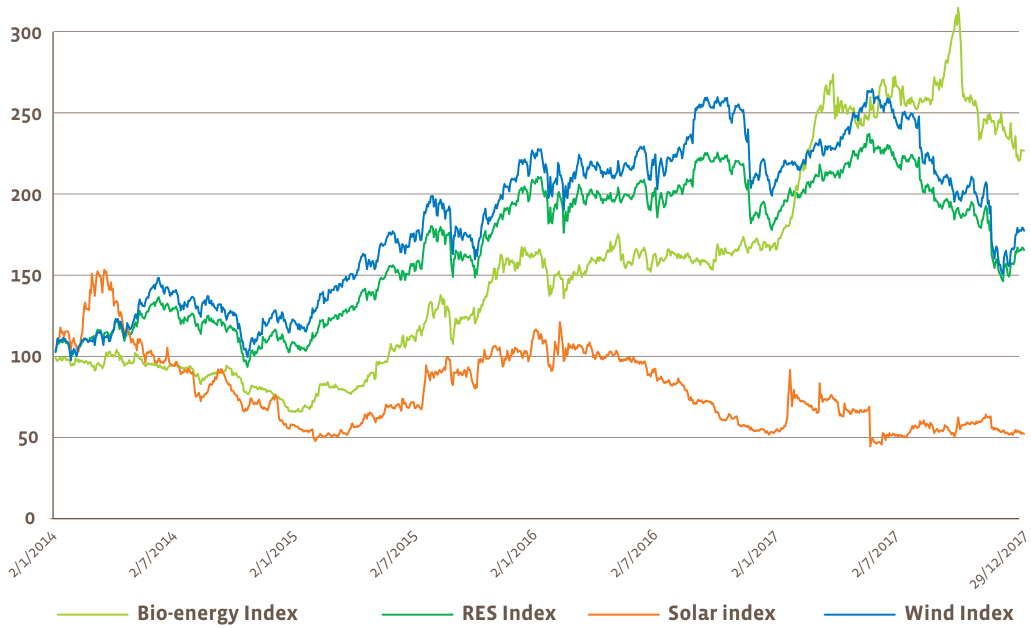
Evolution of the RES indices from 2014 to 2017



Overall, the Solar Index shows substantially different development compared to the other two RES indices in 2017, as it remains relatively stable on one level. At the end of the year it closes at almost the identical value as at the beginning of that year. Compared to previous years, however, the performance of listed PV firms is relatively low, as the index is with marginally above 50 points substantially below the 100 points mark at the beginning of 2014. The sharp decline in May 2017 is driven by Solarworld that filed for insolvency in that month, which led to a substantial decline on the share prices of this company.

The year 2017 can be divided into two main phases in the case of the Wind Index. The index experienced substantial growth up into the second quarter of that year. At its peak, the index reached almost 268 points. Afterwards, however, listed firms in the wind sector experienced a noticeable decline in their performance on stock markets. The drop of the index is particularly strong at the beginning of the third quarter in 2017. Although the Wind Index marginally grows at the end of the year, it closes at 179 points and thus substantially below its value at the beginning of 2017.

Bio-energy firms performed exceptionally well at the beginning of 2017. The Bio-Energy Index grows substantially from around 180 points at the start of 2017 to more than 270 points at the end of the first quarter. In the subsequent months, the index fluctuates slightly above the 250 points mark before it experiences another growth peak at the end of the third quarter and as a first index breaks through the 300 points mark. In spite of the decrease at the end of the year, Bio-Energy firms experienced a very good year 2017. Finally, it is noteworthy that this is the first year since 2014, where the Wind sector was not the best performing sector, but rather the bio energy sector.

The aggregate RES Index and the Wind Index differ in the level, but show very similar fluctuations. The reason is that the three RES Technology Indices are weighted by aggregate revenues in the respective sectors. As aggregate revenues are relatively high in the wind sector compared to the solar PV and bio-technology sectors – covering around 80%-85% of the aggregate revenues generated by all RES firms in the indices – the Wind Index dominates the aggregate RES Index.

2

Evolution of the Euro STOXX 50 index from 2014 to 2017

The level of the EURO STOXX 50 remains rather constant in 2016. In 2017, however, a positive trend can be observed, which indicates a rather good economic development in the EU. In 2016, the development across RES sectors is similar to all other sectors in the EU, while in 2017 the Bio-Energy sector even outperforms the overall good state of the economy in the EU, whereas the Solar Index, and, the Wind Index show a relatively weaker picture. Overall, however, one should be careful to draw conclusions for the overall situation of RES technology firms in the EU. As explained above, many important RES technology firms and developers are not listed on stock exchanges.

YIELDCOS

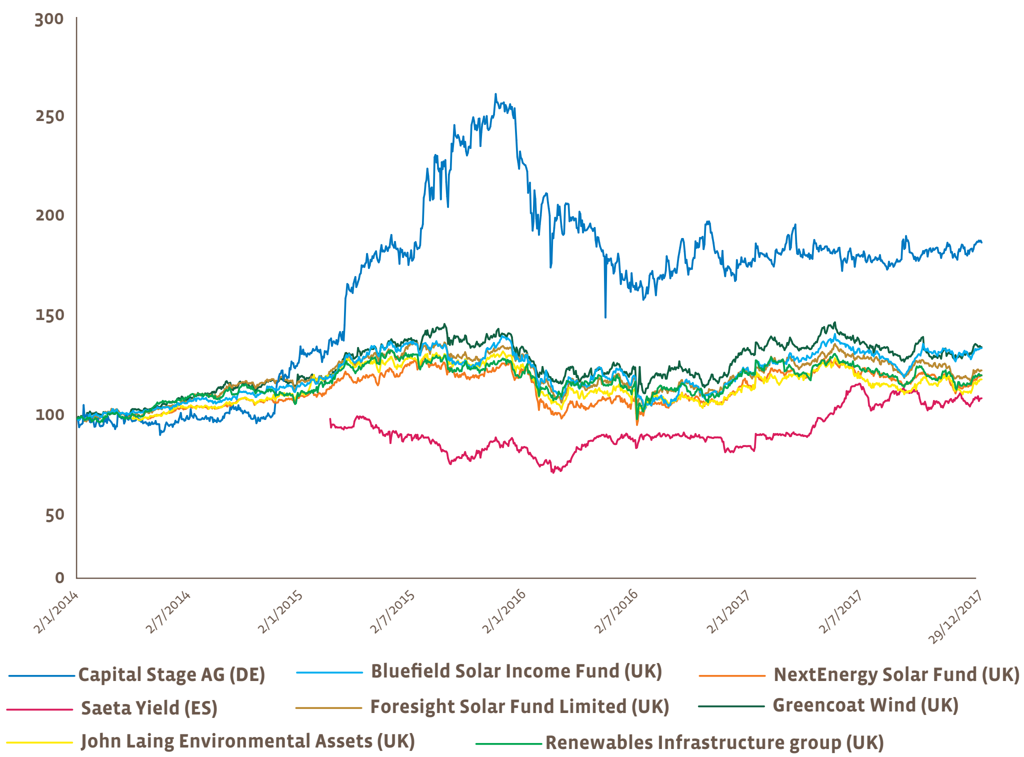
YieldCos are own cash-generating infrastructure assets offered on public markets. These assets are RES plants with typically long-term energy delivery contracts with customers. The YieldCo concept is based on risk profile splitting, where the de-risked operational projects are bundled in a separate company and equity stakes are sold on public markets, while the renewable energy projects in the development stage stays with the energy company. The rationale behind this spin-off is that YieldCos can raise capital at lower cost due to their low risk profile and predictable cash flows.

In the analysed period, only eight YieldCos were publicly traded in the EU and no additional YieldCos were observed in 2017. The stock prices of all UK based YieldCos develop quite similarly. In the last two years, there seems to be a positive trend from mid-2016 until the end of the first quarter of 2017. Afterwards, the prices marginally decline and stabilise at the end of the year. Overall, there are no substantial changes in the stock prices of UK YieldCos. The stock price of the German YieldCo substantially stabilised in the last two years. After large price changes, in particular in 2015, the price fluctuated without clear positive or negative throughput in 2017 and most of 2016. After a fairly stable year 2016, the Spanish YieldCo experienced a positive trend in 2017 and caught up with the UK YieldCos at the end of that year.

It remains to be seen whether the positive development EU YieldCos continues in the long run. On the one hand, they provide attractive yields to investors. On the other hand, many of the largest utilities are still reluctant to create YieldCos. Up to this point, it is striking that no new YieldCos entered the market. EurObserv'ER will continue to track the role of YieldCos for RES in the EU. ■

3

Evolution of European YieldCos from 2014 to 2017



Wind Index: *Vestas (DK), Siemens Gamesa (ES), Nordex (DE), EDP Renovaveis (PT), Falck Renewables (IT), Energiekontor (DE), PNE Wind (DE), ABO Wind (DE), Futuren (FR, 2014-2016), Enel Green Power (IT, 2014-2015), Good Energy (UK, 2016-2017), Arise (SE, 2017)*
Photovoltaic Index: *SMA Solar Technology (DE), Solarworld (DE), Ternienergia (IT), Centrotherm Photovoltaics (DE) , Enertronica (IT), PV Crystalox Solar (UK) , Solaria Energia (ES), Etrion (SE),7C Solarparken (DE, 2015-2017), E4U (CZ, 2015-2017), Auhua Clean Energy (UK, 2014), Solar-Fabrik (DE, 2014)*
Bio-Technologies Index: *Cropenergies (DE), Verbio Bioenergie (DE), Albioma (FR), Envitec Biogas (DE), 2G Energy (DE),Cogra (FR), Europlasma (FR), EBIOSS Energy (BG, 2017), Global Bioenergies (FR, 2017), Fluid (PL, 2017), KTG Energie (DE, 2014-2016), Active Energy (UK, 2014-2016), BDI-BioEnergy International (DE, 2014-2016)*

ON THE WHOLE

INVESTMENT IN RENEWABLE ENERGY CAPACITY

The indicators on investment in renewable energy projects capture asset finance for utility-scale renewable energy generation projects. Aggregating asset finance for all RES sectors shows that investment in energy generation capacity fell considerably between 2016 and 2017. After a record year 2016 with EU investments in RES capacity totalling € 46.3 billion, investments slumped to € 27 billion in 2017. In spite of this decline, the 2017 investment amount is still higher than investments in 2014, i.e. prior to the two impressive years 2015 and 2016.

As in previous years, and thus not surprisingly, the by far highest investments, could be observed in the wind sector. In 2016, wind investments, including both onshore and offshore wind, reached an absolute record high since the introduction of the investment indicators, namely almost € 38 billion. Around 57% of these investments went into offshore capacity. In 2017, overall investments in wind capacity decreased by more than one third to almost 24 billion. In that year offshore investments were still a main driver in investments, however, with a lower share of 47%.

ES Group

In contrast to the wind sector, asset finance for utility-scale solar PV capacity remained relatively stable between the two years after a continuous downward trend in previous years. Investments into PV power plants totalled € 2.2 billion in 2016 and dropped by 7% to 2.05 billion in 2017. Similar to these investments in utility-scale PV, investments in small scale PV installations also only dropped marginally, namely by 6% from € 4 billion in 2016 to € 3.7 billion in 2017. With respect to investments into capacity in the biomass sector, 2016 has been a very strong year. EU-investments totalled more than € 5 billion. These investments are notably higher than those in most of the previous years. In 2017, however, biomass investment slumped to € 679 million. In the geothermal sector, € 131 million were invested in capacity in the EU. This is an increase by 64% compared to the 2016 investments of € 80 million. Both years' investments were substantially higher than those in previous years, where often small or no investments in geothermal were observed in the EU.

As in the last editions, investment costs for utility-scale RES capacity in the EU were compared to selected trading partners of the EU, namely China, Canada, India, Japan, Norway, Russia, Turkey and the United States. The analysis of investment costs shows a heterogeneous picture across RES technologies in the EU. In two very large RES sectors in the EU, onshore wind and solar PV, investment costs per MW of capacity in the EU seem to be below the average of the considered non-EU countries. Investments expenditures per MW of onshore wind capacity in the European Union dropped by more than 3% from € 1.42 million per MW in 2016 to € 1.38 million in 2017. In the EU solar PV sector, the investment costs of utility-scale plants dropped even stronger, namely by more than 6% from € 1.11 million per MW in 2016 to only € 1.04 million in 2017. For biomass and offshore wind, investment expenditures per MW in the EU seem to be higher than in the analysed non-EU countries. The results for offshore wind and biomass, however, have to be interpreted with care due to rather few observations for these investments.

VENTURE CAPITAL & PRIVATE EQUITY

Total venture capital (VC) and private equity (PE) investments in renewable energy companies decreased between 2016 and 2017 by around 18%. In 2017, total VC/PE investments in the EU amounted to € 1.6 billion compared to € 2 billion in 2016. This decrease in overall VC/PE investments was mainly driven by a decline of PE investments that fell by 20%, namely from € 1.77 billion in 2016 to € 1.42 billion in 2017, while VC investments only fell by 7% from € 231 million to € 215 million. In both years, VC/PE investments in the solar PV sector dominated all other RES sectors with respect to investment volumes.

The development of VC/PE investments in the RES sectors runs against the overall positive trend in VC/PE investments in the EU. According to the data of the European Private Equity and Venture Capital Association (EVCA), overall EU-wide VC/PE investments (covering all sectors) increased by around 29%.

PERFORMANCE OF RES TECHNOLOGY FIRMS AND ASSETS ON PUBLIC MARKETS

In order to capture the performance of RES technology companies, i.e. companies that develop / produce the RES components needed for RES plants to function, EurObserv'ER constructed several indices based on RES company stocks. The three presented RES indices, the Wind Index, the Solar PV Index, and the Bio-Energy Index, comprise the ten largest quoted RES companies in the respective sectors. The latter includes firms that are active in the biofuels, biogas, biomass, and / or the waste sector.

The trends of the Wind and the Bio-Energy Indices were relatively similar and positive for the most of 2016. In contrast to these two indices, listed solar PV firms experienced a rather bad year 2016. Also in 2017, the Solar Index shows a substantially different development as it remains relatively stable on one level. The Wind Index grew substantially until the second quarter of 2017. Afterwards, however, listed firms in the wind sector experienced a noticeable decline in their performance on stock markets. Bio-energy firms performed exceptionally well in 2017. In spite of a decline in the end of the year, it is noteworthy that this is the first year since 2014, where the Bio-Energy Index performs best and not the Wind Index. As in the previous editions, a non-RES stock index, the EURO STOXX 50, is captured in order to assess how RES companies perform relative to the whole market. In 2016, the development across RES sectors is similar to all other sectors in the EU, while in 2017 the Bio-Energy sector even outperforms the overall good state of the economy in the EU, while the Solar Index and the Wind Index show a relatively weaker picture.

In order to track the performance of RES assets on public markets, EurObserv'ER tracked the development of YieldCos in the EU. YieldCos are own cash-generating infrastructure assets, e.g. renewable energy plants, where the ownership is offered on public markets. In the anaysed period, only eight YieldCos were publicly traded in the EU, which overall performed rather well. Up to this point, it is striking that no new YieldCos entered the market. EurObserv'ER will continue to track the role of YieldCos for RES in the EU. ■

RENEWABLE ENERGY COSTS, REFERENCE PRICES AND COMPETITIVENESS

In the previous release of 'The State of Renewable Energy in Europe' (Edition 2017) competition between renewable energy sources and energy from conventional sources has been illustrated for the years 2005, 2010 and 2016. This was done by comparing levelised costs of energy (LCoE) of renewables to reference prices. This section in the 2018 Edition brings two updates: firstly, input data for the LCoE calculation have been updated to be in line with the 2017 Edition of JRC's publication 'Cost development of low carbon energy technologies - Scenario-based cost trajectories to 2050' (2018). Secondly, instead of 2016 data currently 2017 data are presented. The approximate historic costs in this chapter (for 2005 and 2010) have not been updated compared to the previous edition.

The overarching question whether renewable technologies are competitive or not depends, among others, on the reference prices paid for energy. In some demand sectors in a number of EU Member States various renewables are already competitive, and in some not yet.

In this section, levelised costs of energy (LCoE) are estimated for various renewable energy technologies and their cost competitiveness is assessed by comparing the LCoE to reference prices. Complications are: firstly, there is not a 'single technology cost' (many factors determine the costs, notably locational and operational aspects, but also quality and financing characteristics); secondly the energy yield from various renewables differs widely across Europe; and finally, reference prices can vary significantly.

QUANTIFYING COSTS: PRESENTATION IN DATA-RANGES

Differences occur in the costs of energy from renewable sources among EU countries. These differences are driven by multiple factors. For example, heat from solar energy can be generated more cheaply in Southern Europe than in Northern Europe due to the higher average harvested thermal energy. Likewise, electricity from wind is usually cheaper in areas with high average wind resources. One also has to take into account where the wind farm is located, e.g. is it located onshore or offshore, in a remote mountainous area or close to the grid. These factors influence costs significantly. Consequently, even within a single country, renewable energy generation costs can vary considerably. Therefore, the costs are presented here in data-ranges, thereby considering country-specific yields, financing characteristics and biomass fuel costs.

METHODOLOGY

This chapter assesses renewable energy competitiveness by presenting aggregate results for the European Union. The estimated renewable energy production costs (expressed in euro per megawatt-hour, €/MWh) are presented in comparison to the energy price of the relevant conventional energy carriers.

The levelised cost of energy (LCoE) of renewable energy technologies refers to the cost estimate of renewable energy production. The LCoE enables reporting the cost information of different renewable energy technologies in all Member States in a comparable manner.

The renewable energy technology LCoE analysis requires a significant amount of data and assumptions, such as the capital expenditures, operational expenditures, fuel costs, economic life, annual energy production, auxiliary energy requirements, fuel conversion efficiency, project duration and the weighted average cost of capital (WACC). The estimated WACC rates are country and technology specific; for the current analysis WACC estimates for 2016 were used (see Edition 2017). All input parameters are defined as ranges. A Monte Carlo (MC) approach is then applied to perform the LCoE calculation (5000 MC draws per LCoE value), resulting in LCoE ranges. Whereas technology costs were taken from (JRC 2018), fuel price assumptions were borrowed from (Elbersen et al, 2016) and interpolated from modelled data. Due attention is paid to the monetary year of the cost data.

The conventional energy carrier costs are based on statistical sources (Eurostat, European Commission) and own calculations. For heating technologies the reference fuels (a Member State specific mix) are exposed to an assumed reference thermal energy conversion efficiency of 90% (capital and operational expenses are currently neglected in this approach).

TECHNOLOGIES CONSIDERED

The technologies addressed are: residential ambient heat from heat pumps (an average of ground source, air source and water source heat pumps), bioenergy (biofuels for transport, power derived from biogas and liquid biomass, heat and power from solid biomass), geothermal power, hydropower, ocean energy, solar PV (commercial and residential), solar thermal water heaters, concentrating solar power and wind energy (both onshore and offshore).

TECHNOLOGY DATA UPDATES

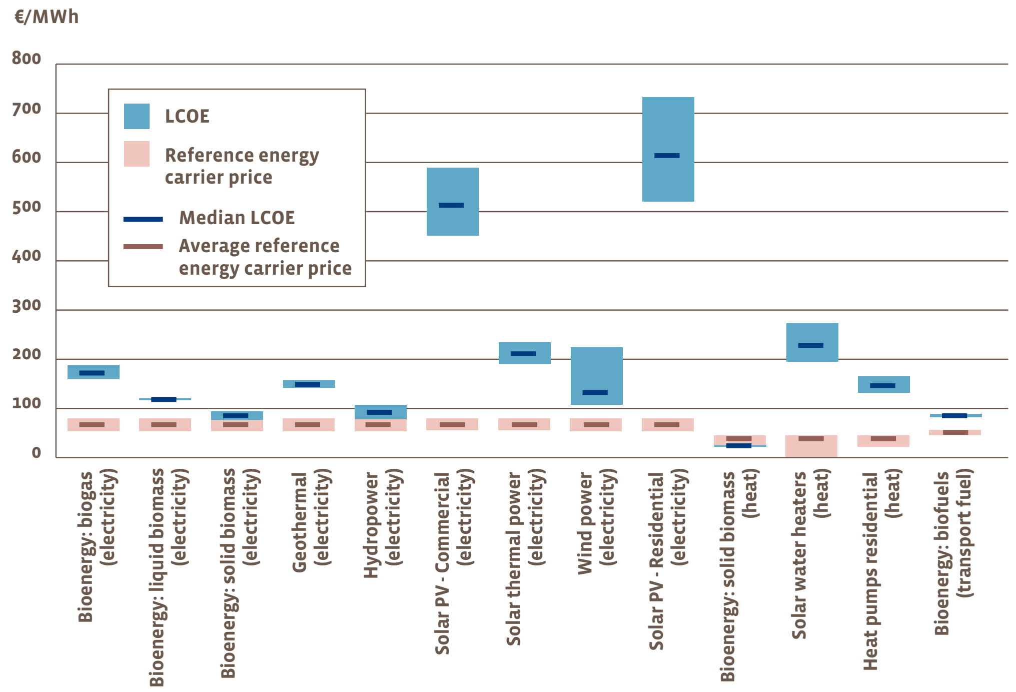
As mentioned above, for most of the technologies data updates were applied, based on work from JRC (2018). The data changes mostly refer to investment costs. For the following technologies these were adjusted downward: wind power, solar PV, hydropower, geothermal. Cost assumptions for heat pumps and solar thermal energy were not updated compared to the previous edition. The biomass-based technologies were unchanged compared to the 2017 edition of 'The State of Renewable Energies in Europe'. The publication JRC (2018) reports the underlying data assumptions.

COST-COMPETITIVENESS OF RENEWABLE ENERGY TECHNOLOGIES

As mentioned above, the cost-competitiveness of renewable energy technologies varies per technology per Member State and varies with differences in reference energy prices in Member States. Mature technologies such as hydropower and solid biomass can provide, in principle, low-cost power that is comparable to the reference electricity prices in some of the Member States. Likewise onshore wind and large scale commercial solar PV can be cost-competitive in countries with good wind resources or high insolation and relatively high electricity prices.

1

LCoE and reference energy carrier (€/MWh) EU ranges derived from Member State analysis for 2005



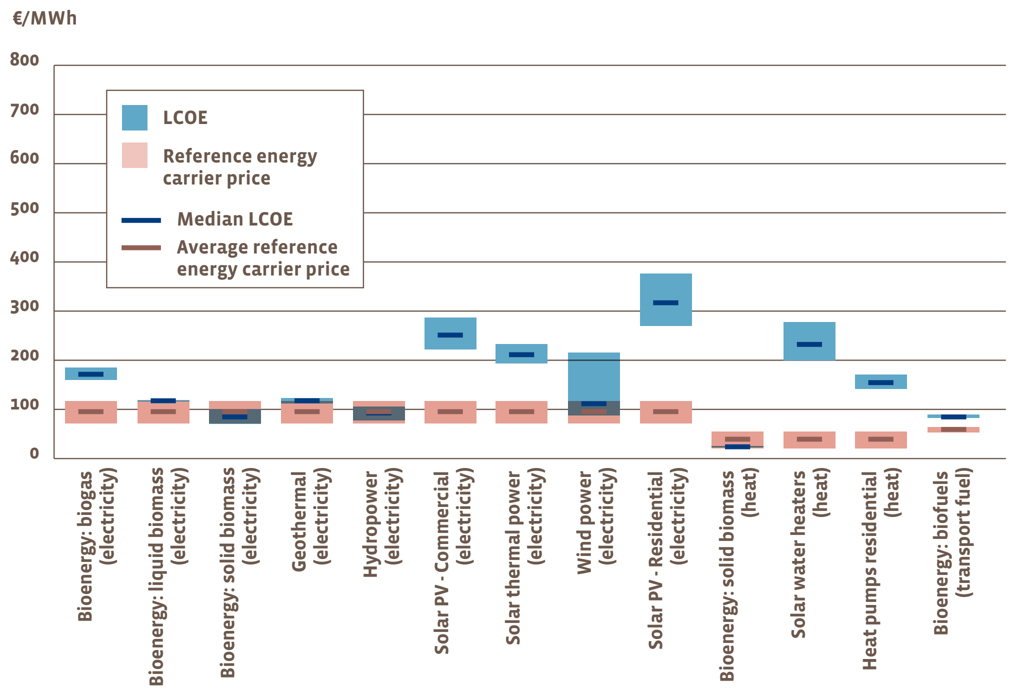
Source: EurObserv'ER 2018

LCOE RESULTS AND THE COST-COMPETITIVENESS

Because the LCoEs from renewable sources as well as reference energy carrier prices vary across Member States, the outcomes here are presented in data ranges, thus aggregating Member State differences into a single bandwidth. In order to display the costs and prices associated to the individual reference years, separate graphs are shown. Estimates for historic costs have been calculated using ECN data on cost development and are unchanged compared to their first release in the 2017 Edition of the EurObserv'ER report 'The state of renewable energies'. The reference energy prices have been presented in the graphs as well in order to be able to indicatively compare them with the calculated LCoE's. The (nominal) reference prices have been presented without taxes and levies, for large consumer types. Estimated electricity prices for 2005 data have been defined by Eurostat using a different method than for the years 2010 – 2016, therefore they cannot easily be compared. Electricity prices for industrial consumers are defined without taxes for medium size industrial consumers (annual consumption between 500 and 2000 MWh, source: Eurostat). Heat prices are all excluding taxes and levies and based on large consumers and have been calculated based on the country-specific average fuel mix and assumptions on the conversion efficiency (90% for fos-

2

LCoE and reference energy carrier (€/MWh) EU ranges derived from Member State analysis for 2010



Source: EurObserv'ER 2018

sil energy to heat, no investment or maintenance costs are considered). Where data were missing, average EU-data were used.

Renewable electricity

As a result of the data update, small LCoE reductions have taken place in the 2017 data set. Cost reductions are most pronounced for wind energy, where the upper range, constituted by offshore wind power, has come down. Generally, the calculated average ranges for LCoE do not change much, but for individual renewable projects cost reductions may be sharper than indicated here. The country variations among Member States are mostly a result of differences in assumed yield (for solar energy and wind power) and financing conditions. The graphs depicted here show aggregate values for the European Union as a whole.

For electricity from deep geothermal energy all countries have estimated LCoE values displayed, although no realisations might have occurred in the period under consideration, and economical potential might be non-existent. Both solar PV variants are assumed to have realised important cost reductions compared to 2005, making this technology more and more competitive. In the residential sector, PV is in multiple countries competitive compared to residential electricity prices. Wind energy investment costs are assumed to have decreased rapidly since 2005, both for onshore and offshore, resulting in lower LCoE levels. For offshore wind wide ranges in realisation costs can be observed, and the JRC (2018) study reports a cost reduction on both investment as well as O&M costs, and an increased operational lifetime.

Renewable heat

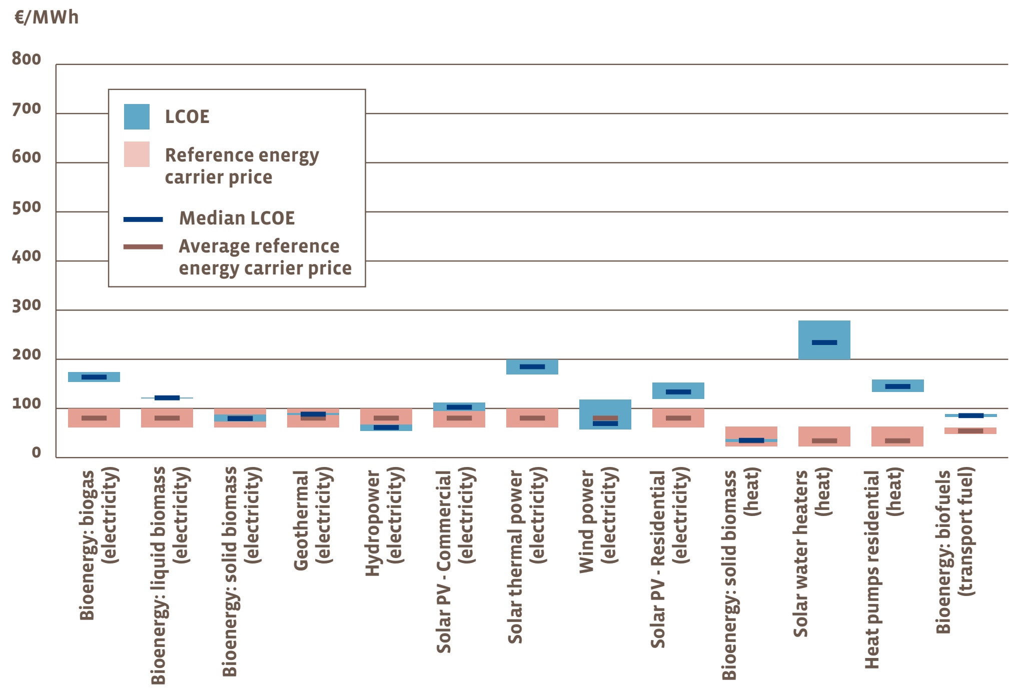
For the technologies producing heat, the LCoE for solid biomass is overlapping the reference heat range, indicating it is competitive in many countries. The LCoE range for solar water heaters and heat captured from ambient heat via heat pumps shows, according to the analysis, relatively high LCoE levels. Note that the LCoE's for these systems refer to small-scale equipment. Scaling up to collective systems, possibly in combination with district heating, may decrease the costs.

Renewable transport

LCoEs for biofuels for transport show quite a narrow range, above the reference transport fuel price levels. ■

3

LCoE and reference energy carrier (€/MWh) EU ranges derived from Member State analysis for 2017



Source: EurObserv'ER 2018

Note to the figure: Overview of the LCoE assessment on a European Union level; ranges derive from technology cost ranges and Member State differentiation. The graph also presents, based on large consumer tariffs, the ranges of reference electricity, reference heat and reference transport fuel prices, all excluding taxes and levies. The LCoE ranges represent median values, the ranges were defined based on the interval between 25% and 75% of all values resulting from the Monte Carlo analysis. Data refer to the years 2005, 2010 and 2017 (monetary values of LCoE are defined in EUR2015) while reference energy costs are in nominal values.

AVOIDED FOSSIL FUEL USE AND RESULTING AVOIDED COSTS

LESS CONVENTIONAL ENERGY CARRIERS, AVOIDED BY RENEWABLE ENERGY

Avoided fossil fuels represent conventional non-renewable energy carriers not consumed – both domestic and imported fuels – due to development and use of renewable energy. In this chapter, fossil fuels and non-renewable waste are collectively named fossil fuels. Avoided costs refer to the expenses that do not occur as a result of avoided fossil fuels. Thus, cumulative amounts of avoided fossil fuels multiplied by the corresponding fuel price levels observed in the various countries represent the avoided costs.

The amount of avoided fossil fuels have been analysed by the European Environment Agency and presented in the report *'Renewable energy in Europe 2018 - Recent growth and knock-on effects'*, (EEA 2018). The fossil fuel types assumed to be substituted are transport fuels (diesel and gasoline), fuels used for heating (gaseous fuels, petroleum products and non-renewable waste) and fuels used for the production of electricity (a mix of gaseous, solid and oil products). This section makes use of the EEA data.

The avoided fossil fuel costs are based on the country specific fuel prices derived from multiple sources (Eurostat, European Commission, BP). The figure 1 highlights the fuel price ranges observed in the 28 EU Member States for 2016 and 2017 for five energy carriers: coal, diesel, gasoline, natural gas and oil. These five fuels are assumed to reasonably cover the fuels reported in (EEA, 2018). Note that non-renewable waste has not been priced here (usually the tariff setting of waste is a local issue and not so much driven by a global market).

Looking at the individual energy carriers and their ratios, it can be seen that fossil fuel prices in 2017 are slightly higher than the prices in 2016. The ranking remains unchanged with coal being the least expensive fuel (expressed in euro per tonne oil equivalent, and excluding taxes and levies), next natural gas, followed by (heating) oil. Diesel and gasoline are the most expensive fuels.

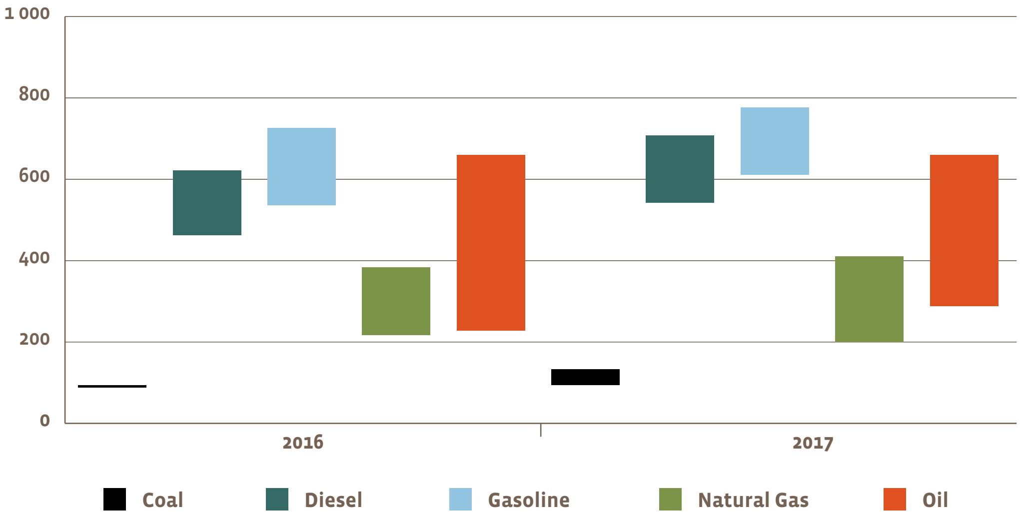
Methodological note

- *The focus of the analysis is on the national level, quantifying the avoided costs in the case where all fossil energy carriers are being purchased abroad. As a consequence, all fuel prices considered exclude taxes and levies.*
- *For countries producing their own fossil fuels the analysis is similar and no correction is made for the indigenous resources.*
- *The reference is a situation where no renewables at all are in place. Other studies often refer to the situation in the year 2005 to compare with, but that is not being done here; we also convert the renewables status of 2005 to avoided fossil energy carriers.*
- *The avoided costs through the substitution of natural gas by synthetic natural gas (SNG) is not quantified explicitly.*
- *Only the impact on fossil fuel displacement is being addressed: in the electricity mix nuclear energy is not considered.*
- *Pricing non-renewable waste is not straightforward; therefore this impact is not quantified in monetary terms.*
- *For liquid biofuels only the biofuels compliant with the Directive 28/EC/2009 are included.*
- *Data refer to values not normalised for hydropower and wind power.*
- *Energy data [Mtoe] may vary from totals mentioned elsewhere in this EurObserv'ER Barometer because a different base data set was used. The 2017 estimates are proxies, borrowed from EEA (2018).*

1

Fossil fuel prices ranges in the European Union (excluding taxes and levies)

M€/Mtep



Source: Eurostat, European Commission, BP 2018

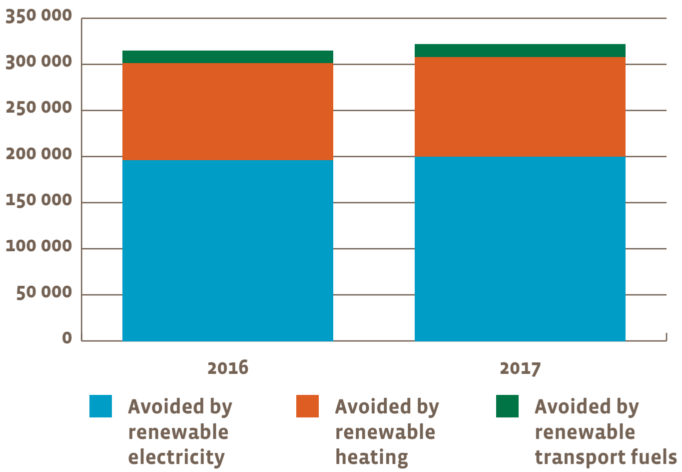
In 2016 and 2017 renewable energy substituted around 315 Mtoe and 322 Mtoe of fossil fuels respectively. These figures correspond to an avoided annual cost of € 84.6 billion for EU28 collectively in 2016, increasing to € 93.5 billion in 2017. The largest financial contributions derive from renewable electricity and renewable heat (at approximately equal contributions together representing about 90% of the avoided expenses).

AVOIDED FOSSIL FUEL USE & AVOIDED COSTS PER TECHNOLOGY

The use of renewable electricity contributed to 62% of the total

2

Avoided fossil fuels per sector (ktoe)



Source: EurObserv'ER 2018 based on EEA data

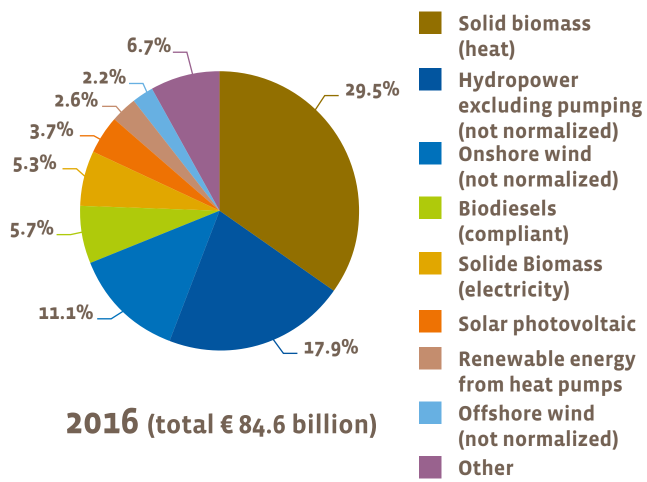
avoided fossil fuels (in terms of energy, the share is equal for 2016 and 2017). This is followed by renewables in the heating and cooling sector contributing to 33% (both years) of the total avoided fossil fuels and the remaining share was substituted through renewable transport fuels (4.3% in 2016 and 4.5% in 2017, only fuels compliant with Directive 2009/28/EC are included). In monetary terms, the avoided costs were € 42.8 billion in 2016 and € 47.2 billion in 2017 in the electricity sector. Second, renewable heat contributed to avoided costs reaching to € 34.5 billion in 2016. In 2017 this increased to € 37.3 billion. Third is renewable transport fuels which contributed to avoided costs of € 7.3 billion in 2016 and € 9.0 billion in 2017. For correctly interpreting these results it is important to take into account a number of methodological notes, see the text box in the beginning of this chapter.

While the penetration of renewable energy (expressed in avoided fossil fuels) expanded by approximately 2.3% from 2016 to 2017, the cumulative effect of the avoided fossil fuel expenses is, with a 10.5% increase (from 84.6 to € 93.5 billion) more pronounced. Reason for this is the increasing fossil fuel prices in 2017 compared to 2016.

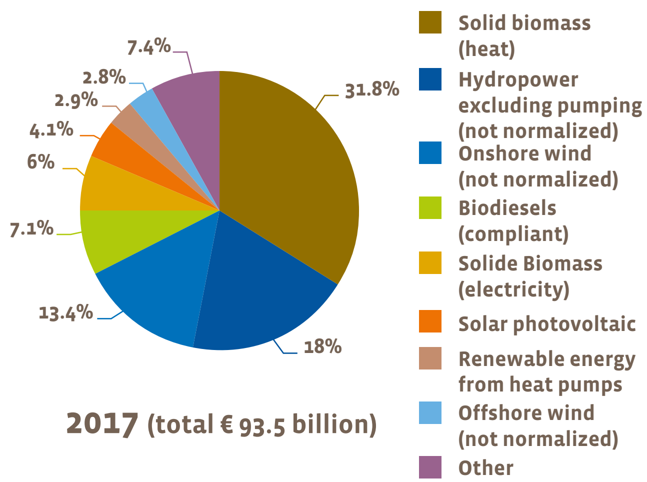
Among the RES technologies, solid biomass for heating purposes avoided the purchase of fossil fuels at an amount of € 31.8 billion in 2017 (€ 29.5 billion in 2016). Next, hydropower has been responsible

3

Avoided fossil fuel costs in EU 28 through renewables in 2016 and 2017



2016 (total € 84.6 billion)



2017 (total € 93.5 billion)

Source: EurObserv'ER (2018) based on EEA data

for € 18.0 billion in 2017 (€ 17.9 billion in 2016). Onshore wind is third in the row with € 13.4 billion in 2017 (€ 11.1 billion in 2016).

In a graphical manner, in a graphical manner, graph 3 shows how each technology contributes to the total avoided costs.

The largest share of avoided fossil fuels comes from natural gas (37% for both 2016 and 2017), followed by solid fuels (mainly coal, 35% for both 2016 and 2017). Next are oil products, with a contribution of 22% in both 2016 and 2017. The remaining fuels (transport fuels and non-renewable waste) cover the remaining share (together 5% in both years).

AVOIDED FOSSIL FUELS & EXPENSES PER MEMBER STATE

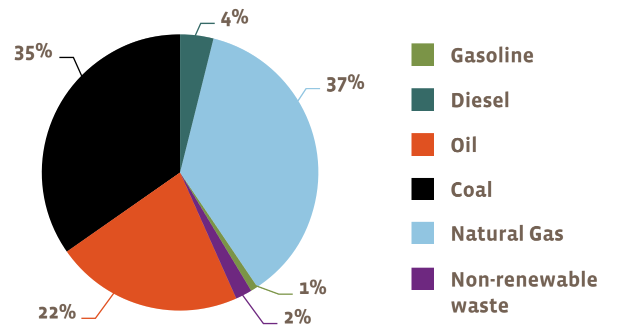
At Member State level, the avoided costs have been estimated as displayed in the table. Note that there is a strong correlation between the avoided amount and the size of a country.

As can be expected, the avoided cost follow the fuel price development: with fossil fuel prices higher in 2017 compared to 2016, almost all counties show a similar pattern.

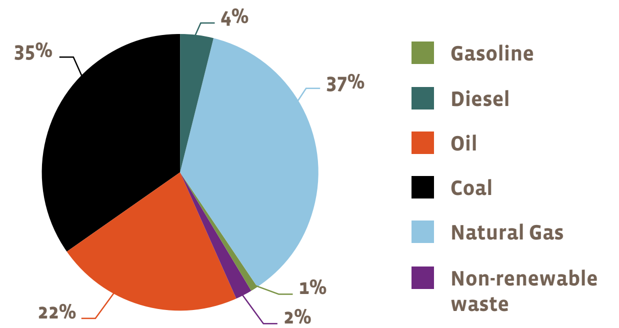
Four Member States show a decreasing trend in avoided fossil fuels expenses due to decreased renewable energy deployment in 2017 compared to 2016. These countries are France, Hungary,

4

EU substituted fossil fuels during 2016 and 2017



2016 (total 314.9 Mtoe)

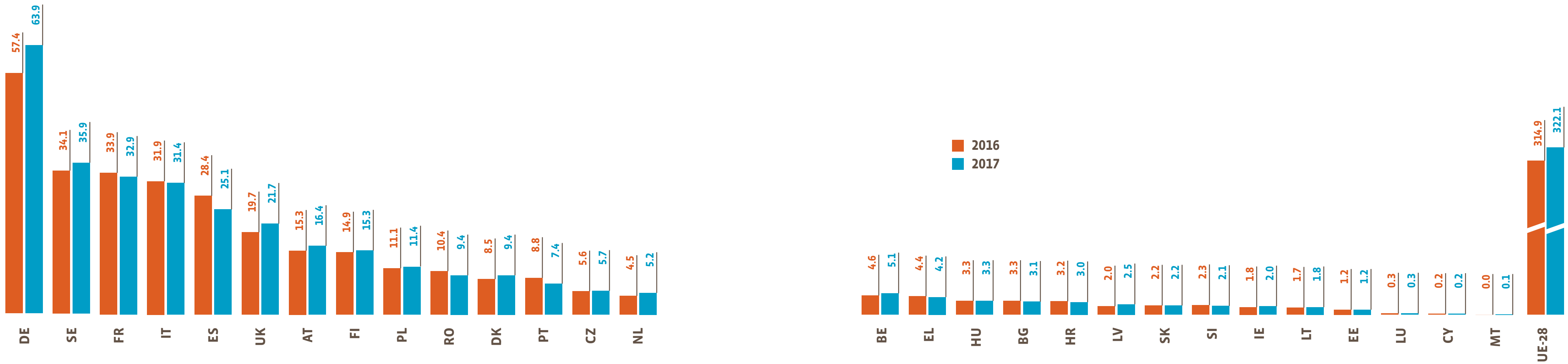


2017 (total 322.1 Mtoe)

Source: EurObserv'ER (2018) based on EEA data

5

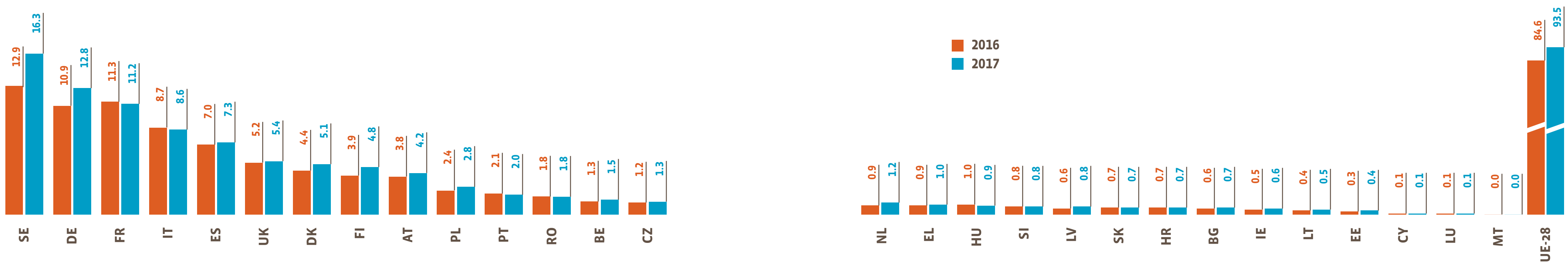
Avoided fossil fuels per country (Mtoe)



Source: EurObserv'ER (2018) based on EEA data. Note: For 2017 proxy data are used.

6

Avoided expenses per country (billion euro)



Source: EurObserv'ER (2018) based on EEA data. Note: For 2017 proxy data are used.

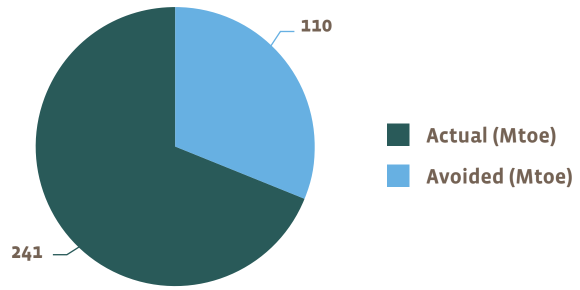
Italy and Portugal. All other countries had higher avoided fossil fuel expenses in 2017 compared to 2016, of which four even at lower amounts of avoided fossil fuels: Bulgaria, Greece, Spain and Romania. See also the methodological notes.

The data have been displayed graphically in the figures 5 and 6.

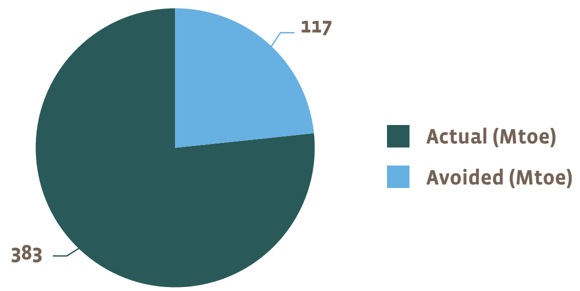
Next, figure 7 indicates how the amounts of estimated avoided fuel relate to the total EU-28 fuel use. The relevant parameter for comparing the avoided fuel use with is the primary energy consumption, which indicates the gross inland consumption excluding all non-energy use of energy carriers (e.g. natural gas used not for combustion but for producing chemicals). For the transport fuels a comparison is not possible because these are not primary fuels (but instead secondary fuels). Reference year depicted is 2016, because this period regards final data (and not estimates). ■

7

Contributions per fuel 2016 compared to total

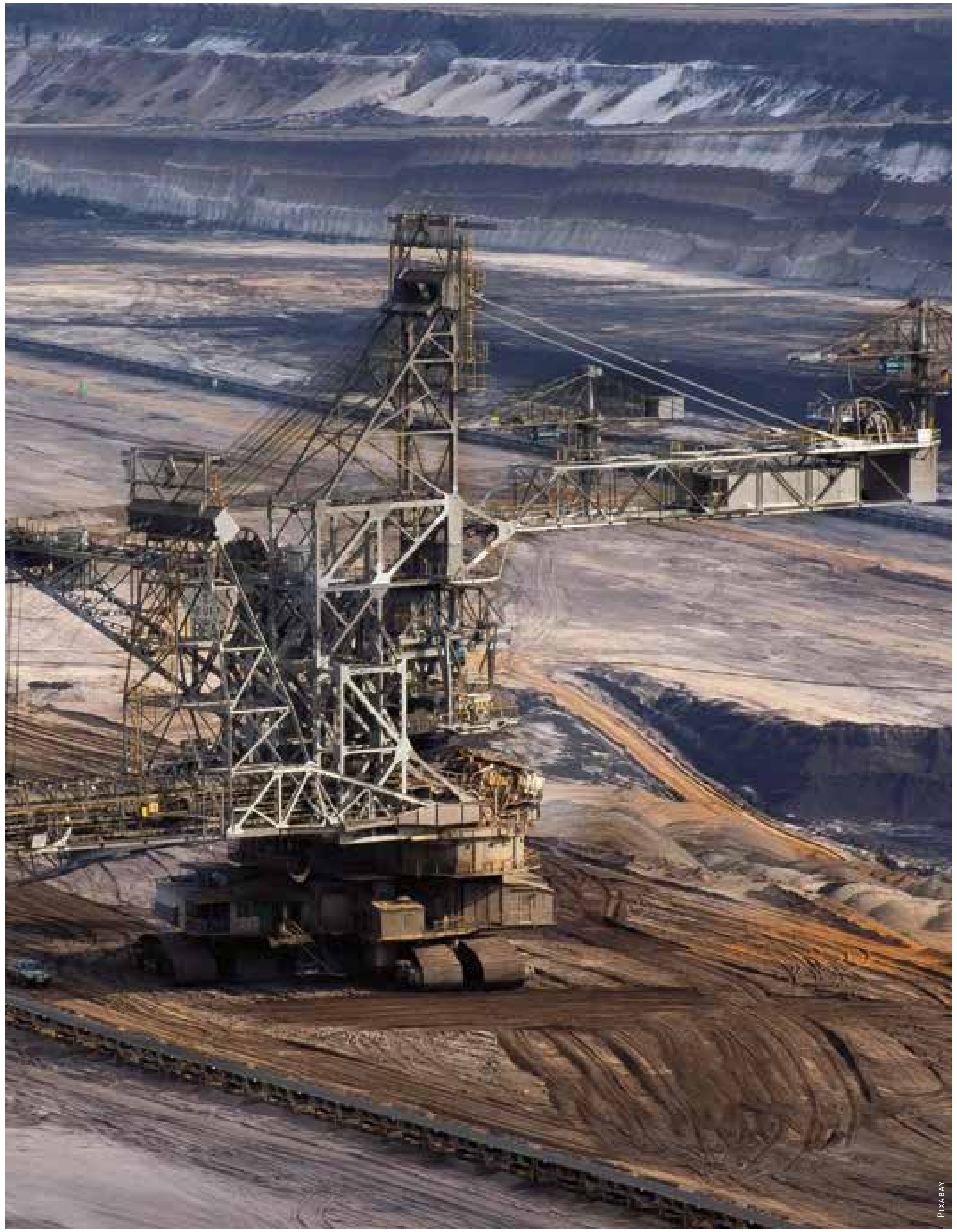


Gross inland coal consumption in 2016



Gross inland gas consumption in 2016

Source: Eurostat (2018) based on EEA data



INDICATORS ON INNOVATION AND COMPETITIVENESS

The Energy Union strives to provide a secure, sustainable, affordable energy supply by increasing renewable energy uses, energy efficiency, internal energy market integration and competitiveness. Wiser energy use, the European Commission states, is both a spur for new jobs and growth, and an investment in the future of Europe. Economic theory underpins this understanding. Expenditures for research and development are seen as investments into new or better processes, products or services that might create new markets or increase market shares and strengthen competitiveness of firms, sectors and nations. Regarding RET, R&D investments spur innovations in RET, which are often measured by the number or share of patent applications in the respective technology field. How well the R&D output translates into a strong market position, i.e. competitiveness in RET, is measured for example by the trade share in RET products. These three indicators are depicted in the following chapters: R&D expenditures (public & private) showing the efforts or investments of countries w.r.t. RET, patent applications reflecting the output of R&D efforts and finally trade shares in RET displaying how competitive a country is in RET products.

R&D Investments

In general, investments into R&D and innovation are commonly seen as the basis for technological changes and hence competitiveness. Therefore, they are an important factor for or driver of economic growth. From a macro-economic perspective, R&D investments can be viewed as a major indicator to measure innovative performance of economies or innovation systems. The indicator is able to display the position of a country in international competition with regard to innovation.

Methodological approach

Overall, R&D expenditures are financed by private and public resources, while R&D is performed by both, business (private), government and higher education sector (public). This differentiation into financing (grey area) and performing (white area) is depicted in Figure 1. In this section, we will analyze public and private R&D expenditures of a selected set of countries with regard to renewable energy technologies, i.e. research investments originating from the public sector (see light grey area in Figure 1) as well as from the business sector are taken into account (see dark grey area in Figure 1).

R&D investments from the public sector are supposed to spur innovation in the private sector. Although the specific returns to public-sector R&D investments are largely unknown, the basic idea is to create follow-up investments from the private sector and generate spill-over effects.

1

Sectors by financing and performing of R&D

	Total R&D spending		
Financing sectors	Business	Government	
Performing sectors	Business	Government	Higher education

For this report, the data on public and private R&D investment were provided by JRC SETIS. Its R&D data relies on IEA statistics , which collects and depicts national R&D investments. They address 20 of the EU Member States with varying regularity and granularity of technology detail. However, there is a 2-year time delay in reporting for most Member States, thus data is available for 2016, while only a few are available in 2017. For the data on private R&D, the time delay is even longer (2012 and 2013) as JRC's assessment is based on patent data. The methodology is described in more detail in the JRC Science for Policy Report "Monitoring R&D in Low Carbon Energy Technologies: Methodology for the R&I indicators in the State of the Energy Union Report, - 2016 Edition". Data gaps are supplemented by the Member States through the SET Plan Steering Group or through targeted data mining.
Besides providing absolute figures for R&D expenditures (Euro) of the given countries, the share of R&D expenditures on GDP (%) is calculated to get an impression of the relative size of a country's investments in RET technologies.

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1. IEA. International Energy Agency RD&D Online Data Service. Available from: http://www.iea.org/statistics/RDDonlinedataservice/
2. A. Fiorini, A. Georgakaki, F. Pasimeni, E. Tzimas, "Monitoring R&D in Low-Carbon Energy Technologies", EUR 28446 EN (2017). Available from: https://setis.ec.europa.eu/related-jrc-activities/jrc-setis-reports/monitoring-ri-low-carbon-energy-technologies

PUBLIC R&D INVESTMENTS

Public R&D investments are depicted by RE technologies.

PRIVATE R&D INVESTMENTS

Private R&D investments are depicted by RE technologies. Data are only available for the countries of the EU 28 in 2013 and 2014.

PUBLIC R&D INVESTMENTS

WIND ENERGY

		Public R&D Exp. (in € m)		Share of Public R&D Exp. by GDP	
		2016	2017	2016	2017
EU 28	Germany	49.6	75.0	0.0017%	0.0026%
	Denmark	22.7	20.6	0.0086%	0.0077%
	Spain	19.9	n.a.	0.0018%	n.a.
	Netherlands	13.9	n.a.	0.0021%	n.a.
	United Kingdom	9.3	6.9	0.0004%	0.0003%
	France	6.9	n.a.	0.0003%	n.a.
	Belgium	2.7	n.a.	0.0007%	n.a.
	Sweden	2.5	1.8	0.0006%	0.0004%
	Finland	2.0	n.a.	0.0010%	n.a.
	Austria	1.9	n.a.	0.0006%	n.a.
	Poland	0.2	n.a.	0.0000%	n.a.
	Czechia	0.1	n.a.	0.0001%	n.a.
	Total EU	131.7	104.2	0.0010%	0.0007%
Other Countries	Japan	190.1	154.3	0.0042%	0.0036%
	United States	66.5	108.7	0.0004%	0.0006%
	Korea	26.9	n.a.	0.0021%	n.a.
	Norway	17.2	12.6	0.0048%	0.0035%
	Canada	4.1	2.9	0.0003%	0.0002%
	Switzerland	2.5	2.5	0.0005%	0.0005%
	Australia	0.3	0.2	n.a.	n.a.
	Turkey	0.1	0.3	0.0000%	0.0000%
	New Zealand	0.0	0.0	n.a.	n.a.

Note: *a value of 0 indicates a share or expenditures below 0.0000% or below 500 000 Euros expenditures.* ***Source: JRC SETIS, Eurostat, WDI Database***

In wind energy, Japan scores first with regard to public R&D spending, followed by the U.S., which has increased its public spending between 2016 and 2017, and the EU 28 (although data for many countries is not available in 2017). Within the EU 28, it is once again Germany, Denmark as well as Spain (2016) and the Netherlands with the largest public R&D budget (2016). This can be explained by the fact that main players among the wind power manufacturers are located in these EU countries. In terms of GDP shares, the values are by far largest for Denmark, followed by Norway, Japan and Korea (2016). ■

PUBLIC R&D INVESTMENTS

SOLAR ENERGY

		Public R&D Exp. (in € m)		Share of Public R&D Exp. by GDP	
		2016	2017	2016	2017
EU 28	Germany	78.5	99.2	0.0027%	0.0034%
	France	62.7	n.a.	0.0029%	n.a.
	Netherlands	16.9	n.a.	0.0025%	n.a.
	United Kingdom	14.5	10.0	0.0007%	0.0005%
	Spain	14.0	n.a.	0.0013%	n.a.
	Austria	12.4	n.a.	0.0039%	n.a.
	Sweden	10.0	5.4	0.0024%	0.0012%
	Denmark	8.5	5.9	0.0032%	0.0022%
	Finland	6.4	n.a.	0.0033%	n.a.
	Belgium	4.9	n.a.	0.0012%	n.a.
	Slovakia	1.2	0.2	0.0016%	0.0002%
	Estonia	0.6	0.6	0.0034%	0.0033%
	Poland	0.6	n.a.	0.0001%	n.a.
	Czechia	0.4	n.a.	0.0002%	n.a.
	Total EU	231.4	121.2	0.0017%	0.0009%
Other Countries	United States	98.4	103.1	0.0006%	0.0006%
	Japan	54.6	48.1	0.0012%	0.0011%
	Korea	50.5	n.a.	0.0039%	n.a.
	Switzerland	48.1	48.1	0.0099%	0.0098%
	Australia	30.8	33.8	n.a.	n.a.
	Norway	14.6	17.5	0.0041%	0.0048%
	Canada	12.3	29.7	0.0009%	0.0020%
	Turkey	1.5	2.4	0.0002%	0.0003%
	New Zealand	0.0	0.1	n.a.	n.a.

Note: *a value of 0 indicates a share or expenditures below 0.0000% or below 500 000 Euros expenditures.* ***Source: JRC SETIS, Eurostat, WDI Database***

In the field of solar energy, the EU 28 is the largest player in terms of national R&D investment, although the data are not complete for 2017. The U.S, Korea (value from 2016) and Japan follow the EU 28. Table 1 displays a stagnation in national R&D investments in the US, while the figures decrease for Japan and the EU 28. Figures for China as well as some other countries are not available.

Within the EU 28, there are four countries with significant public R&D investments, namely Germany, France (value for 2016), and with a gap the Netherlands (value for 2016) and the UK. In 2016, Germany, the Netherlands, France and the UK are responsible for 75% of the R&D in-vestments of the EU 28 (2016). In Germany, public R&D expenditures have increased between 2016 and 2017, while the value for the UK has decreased. For France and the Netherlands, data for 2017 is not yet available.

When looking at the normalization of the R&D figures by GDP (share of Public R&I expenditures by GDP), the share of the EU 28 is low, especially compared to Korea (in 2016). However, as data are still incomplete in 2017 a general trend cannot yet be seen. In 2017, the EU 28 reveals slightly lower figures than Japan, but still higher figures than the United States. Within the EU, Austria, Estonia and Finland have the largest budget share for solar energy, followed by Denmark, France, Germany and the Netherlands. ■

PUBLIC R&D INVESTMENTS

HYDROENERGY

		Public R&D Exp. (in € m)		Share of Public R&D Exp. by GDP	
		2016	2017	2016	2017
EU 28	Finland	16.2	n.a.	0.0084%	n.a.
	Netherlands	3.7	n.a.	0.0005%	n.a.
	Denmark	3.3	0.0	0.0013%	0.0000%
	Germany	2.0	2.1	0.0001%	0.0001%
	Austria	2.0	n.a.	0.0006%	n.a.
	France	1.9	n.a.	0.0001%	n.a.
	Sweden	1.3	0.8	0.0003%	0.0002%
	Slovakia	0.4	0.0	0.0005%	0.0000%
	Czechia	0.2	n.a.	0.0001%	n.a.
	United Kingdom	0.2	0.0	0.0000%	0.0000%
	Belgium	0.1	n.a.	0.0000%	n.a.
	Poland	0.0	n.a.	0.0000%	n.a.
	Total EU	31.3	2.9	0.0002%	0.0000%
Other countries	United States	22.0	22.2	0.0001%	0.0001%
	Turkey	18.7	15.5	0.0022%	0.0017%
	Switzerland	13.9	13.9	0.0029%	0.0028%
	Korea	8.2	n.a.	0.0006%	n.a.
	Norway	8.1	10.1	0.0023%	0.0028%
	Canada	6.5	6.9	0.0005%	0.0005%
	New Zealand	0.0	0.0	n.a.	n.a.
	Australia	n.a.	0.1	n.a.	n.a.

Note:** a value of 0 indicates a share or expenditures below 0.0000% or below 500 000 Euros expenditures. **Source: JRC SETIS, Eurostat, WDI Database

Hydro energy is a small field with regard to public R&D investment when compared to solar energy. In this field, the U.S. has the largest public R&D investment among all countries (Table 3). It is followed by Turkey, Switzerland, Norway and Canada, which all have significant hydro-power resources. In the EU 28, Finland, and with a gap the Netherlands, Denmark and Germany show the largest values (2016) with € 16.2, 3.7 billion, € 3.3 billion and € 2.0 billion, respectively. The GDP shares show that the highest shares can be found in Finland (2016), Switzerland, Norway, Turkey and Denmark (2016). Within the EU 28, the GDP shares (2016) are highest in Finland and Denmark, followed by Austria and the Netherlands. ■

PUBLIC R&D INVESTMENTS

GEOTHERMAL ENERGY

		Public R&D Exp. (in € m)		Share of Public R&D Exp. by GDP	
		2016	2017	2016	2017
EU 28	Germany	12.5	16.5	0.0004%	0.0006%
	France	4.7	n.a.	0.0002%	n.a.
	Netherlands	3.1	n.a.	0.0005%	n.a.
	Denmark	2.3	0.0	0.0009%	0.0000%
	Spain	1.1	n.a.	0.0001%	n.a.
	Austria	0.8	n.a.	0.0002%	n.a.
	Slovakia	0.4	0.0	0.0005%	0.0000%
	Czechia	0.4	n.a.	0.0002%	n.a.
	Sweden	0.3	n.a.	0.0001%	n.a.
	Belgium	0.1	n.a.	0.0000%	n.a.
	Poland	0.1	n.a.	0.0000%	n.a.
	United Kingdom	0.0	0.0	0.0000%	0.0000%
	Total EU	25.8	16.5	0.0002%	0.0001%
Other Countries	United States	59.8	85.3	0.0004%	0.0005%
	Switzerland	18.4	18.4	0.0038%	0.0038%
	Japan	14.6	17.4	0.0003%	0.0004%
	Korea	4.3	n.a.	0.0003%	n.a.
	New Ezaland	3.9	0.9	n.a.	n.a.
	Norway	0.9	1.4	0.0002%	0.0004%
	Canada	0.7	1.7	0.0000%	0.0001%
	Australia	0.4	0.5	n.a.	n.a.
	Turkey	0.1	0.1	0.0000%	0.0000%

Note:** a value of 0 indicates a share or expenditures below 0.0000% or below 500 000 Euros expenditures. **Source: JRC SETIS, Eurostat, WDI Database

With regard to geothermal energy, the U.S. displays the largest public R&D investments of € 59.8 billion in 2016 and € 85.3 billion in 2017. It is followed by Japan with € 17.4 billion and the EU 28 with € 16.5 billion. Compared to solar energy, the R&D expenditures for geothermal energy are rather low. The GDP normalization shows that Switzerland has the largest share of public R&D investment on GDP followed by Denmark (value from 2016). In addi-tion, Germany, the U.S. and Japan show comparably large shares. ■

PUBLIC R&D INVESTMENTS

BIOFUELS

		Public R&D Exp. (in € m)		Share of Public R&D Exp. by GDP	
		2016	2017	2016	2017
EU 28	France	73.3	n.a.	0.0035%	n.a.
	Germany	37.2	32.7	0.0013%	0.0011%
	United Kingdom	33.6	0.1	0.0016%	0.0014%
	Netherlands	25.6	n.a.	0.0038%	n.a.
	Sweden	24.6	13.8	0.0058%	0.0032%
	Finland	13.1	n.a.	0.0068%	n.a.
	Austria	11.1	n.a.	0.0035%	n.a.
	Denmark	9.6	4.9	0.0037%	0.0018%
	Slovakia	7.2	0.1	0.0092%	0.0001%
	Belgium	6.7	n.a.	0.0017%	n.a.
	Spain	4.4	n.a.	0.0004%	n.a.
	Poland	2.8	n.a.	0.0006%	n.a.
	Czechia	2.0	n.a.	0.0012%	n.a.
	Estonia	0.4	n.a.	0.0020%	n.a.
	Total EU	251.6	80.4	0.0018%	0.0006%
Other Countries	United States	477.1	605.1	0.0028%	0.0035%
	Canada	54.2	41.5	0.0039%	0.0028%
	Japan	33.0	39.3	0.0007%	0.0009%
	Switzerland	18.7	18.7	0.0039%	0.0038%
	Korea	17.1	n.a.	0.0013%	n.a.
	Norway	13.2	17.2	0.0037%	0.0047%
	Australia	4.5	3.9	n.a.	n.a.
	Turkey	0.6	1.2	0.0001%	0.0001%
	New Zealand	0.0	0.6	n.a.	n.a.

Note: *a value of 0 indicates a share or expenditures below 0.0000% or below 500 000 Euros expenditures.* ***Source: JRC SETIS, Eurostat, WDI Database***

In terms of public R&D investment, biofuels is the largest field within renewables. This is mostly due to strong commitment of the U.S., with the largest investment of more than € 600 billion in 2017. Other countries in this analysis depict much lower public R&D investments, all below € 50 billion, except for the EU 28 as a whole. The U.S. is followed by the EU 28, Canada and Japan. Within the EU 28, the largest national R&D investments can be observed in France (2016), Germany, the UK and Sweden. With regard to the GDP shares, Finland (2016) shows the largest value, followed by Sweden, Canada, Switzerland and the Netherlands. Also Slovakia showed large shares in 2016. Albeit large absolute investments in biofuels, the U.S. display only mediocre shares, yet with an increasing tendency between 2016 and 2017. ■

PUBLIC R&D INVESTMENTS

OCEAN ENERGY

		Public R&D Exp. (in € m)		Share of Public R&D Exp. by GDP	
		2016	2017	2016	2017
EU 28	United Kingdom	16.4	17.7	0.0008%	0.0008%
	Sweden	4.4	2.4	0.0010%	0.0006%
	France	4.4	n.a.	0.0002%	n.a.
	Spain	0.7	n.a.	0.0001%	n.a.
	Belgium	0.3	n.a.	0.0001%	n.a.
	Netherlands	0.0	n.a.	0.0000%	n.a.
	Denmark	0.0	0.7	0.0000%	0.0002%
	Czechia	0.0	n.a.	0.0000%	n.a.
	Poland	0.0	n.a.	0.0000%	n.a.
	Total EU	26.1	20.7	0.0002%	0.0001%
Other countries	United States	40.2	49.5	0.0002%	0.0003%
	Japan	7.9	4.7	0.0002%	0.0001%
	Korea	5.6	n.a.	0.0004%	n.a.
	Norway	2.4	3.4	0.0007%	0.0009%
	Canada	1.4	2.2	0.0001%	0.0001%
	Australia	1.0	1.8	n.a.	n.a.
	New Zealand	0.3	0.0	n.a.	n.a.
	Turkey	0.0	0.0	0.0000%	0.0000%

Note: *a value of 0 indicates a share or expenditures below 0.0000% or below 500 000 Euros expenditures.* ***Source: JRC SETIS, Eurostat, WDI Database***

Ocean energy is a comparably small field when interpreted alongside public R&D investment. Here, the U.S. shows the largest values followed by the EU 28, although many data points are missing. In 2017, the EU 28 expenditures have decreased, while the U.S. expenditures have increased. The gap between the EU 28 and the U.S. thus has enlarged between 2016 and 2017. Besides the U.S., it rather seems that the investments of the EU in total and of other countries have decreased between 2016 and 2017 except for Norway and Canada. The GDP shares show the largest values for Norway, the UK and Sweden. ■

PUBLIC R&D INVESTMENTS

RENEWABLE ENERGY TECHNOLOGIES IN TOTAL

		Public R&D Exp. (in € m)		Share of Public R&D Exp. by GDP	
		2016	2017	2016	2017
EU 28	France	153.9	n.a.	0.0072%	n.a.
	United Kingdom	73.9	63.5	0.0035%	0.0030%
	Netherlands	63.2	n.a.	0.0093%	n.a.
	Denmark	46.5	32.0	0.0177%	0.0119%
	Sweden	43.0	n.a.	0.0102%	n.a.
	Belgium	14.8	n.a.	0.0038%	n.a.
	Poland	3.7	n.a.	0.0008%	n.a.
	Czechia	3.1	n.a.	0.0018%	n.a.
	Total EU	697.9	346.0	0.0050%	0.0024%
Other Countries	United States	763.9	973.8	0.0045%	0.0057%
	Korea	112.6	n.a.	0.0088%	n.a.
	Canada	79.0	84.9	0.0057%	0.0058%
	Norway	56.4	62.2	0.0158%	0.0171%
	Turkey	21.1	19.6	0.0025%	0.0022%
	New Zealand	4.2	1.6	n.a.	n.a.
	Australia	n.a.	40.2	n.a.	n.a.

Note: *a value of 0 indicates a share or expenditures below 0.0000% or below 500 000 Euros expenditures. Source: JRC SETIS, Eurostat, WDI Database ;*
Note: *the sum across technologies is only given, if data of all RET in one country are available, i.e. as soon as one RET is missing, the data are indicated as n.a.*

Finally, a look at the overall public R&D investment in all renewable energies technologies re-veals a strong position of the US in 2016, which could even be strengthened in 2017 while the EU 28 seems to lose ground. Yet, due to many missing values in the 2017 data, this table has to be interpreted with caution. The GDP shares display a very strong position of Norway, Korea and Canada, when compared to the EU 28 and the U.S. Within the EU, the largest shares can be found in Denmark, Sweden, the Nether-lands and France (2016). However, only a few coun-tries display data in 2017, which makes comparisons difficult. ■

PRIVATE R&D INVESTMENTS

WIND ENERGY

	Private R&D Exp. (in € m)		Share of Private R&D Exp. by GDP	
	2013	2014	2013	2014
EU 28				
Germany	505.2	544.9	0.0187%	0.0197%
Denmark	213.8	194.8	0.0858%	0.0769%
Spain	116.0	89.3	0.0114%	0.0086%
France	44.0	69.7	0.0021%	0.0034%
United Kingdom	59.0	52.7	0.0030%	0.0026%
Italy	41.8	33.6	0.0027%	0.0022%
Netherlands	47.6	31.9	0.0074%	0.0049%
Belgium	8.6	19.4	0.0023%	0.0051%
Sweden	58.3	18.6	0.0152%	0.0047%
Austria	14.5	8.1	0.0047%	0.0026%
Poland	14.1	7.9	0.0036%	0.0020%
Romania	6.8	7.5	0.0050%	0.0054%
Finland	3.7	5.5	0.0020%	0.0030%
Hungary	2.1	2.3	0.0021%	0.0022%
Slovenia	n.a.	2.3	n.a.	0.0063%
Slovakia	n.a.	2.3	n.a.	0.0031%
Greece	0.4	1.1	0.0002%	0.0006%
Luxembourg	4.7	1.1	0.0110%	0.0025%
Estonia	n.a.	0.8	n.a.	0.0044%
Lithuania	n.a.	0.8	n.a.	0.0023%
Ireland	6.1	n.a.	0.0035%	n.a.
Latvia	0.2	n.a.	0.0008%	n.a.
Total EU	1146.9	1094.6	0.0088%	0.0082%

Note: *a value of 0 indicates a share or expenditures below 0.0000% or below 500 000 Euros expenditures.* ***Source: JRC SETIS, Eurostat, WDI Database***

In wind energy, Germany scores first with regard to private R&D spending. With investments of about 544 billion Euros in 2014, it has increased its private R&D expenditures since 2013 and invests more than twice as much as Denmark, where the figures have decreased since 2013. Spain ranks third, however, with only about half of the budget of Denmark. In terms of GDP shares, the values are by far largest for Denmark, followed by Germany and Spain. In sum, this pattern is very similar to the public R&D investment in wind energy. This is also true for the other RET fields. ■

PRIVATE R&D INVESTMENTS

SOLAR ENERGY

	Private R&D Exp. (in € m)		Share of Private R&D Exp. by GDP	
	2013	2014	2013	2014
EU 28				
Germany	1031.4	808.0	0.0382%	0.0293%
France	232.1	205.5	0.0113%	0.0099%
United Kingdom	129.7	117.1	0.0067%	0.0058%
Netherlands	76.2	80.3	0.0119%	0.0123%
Austria	31.5	76.2	0.0103%	0.0246%
Italy	160.1	74.8	0.0104%	0.0048%
Spain	101.2	67.9	0.0099%	0.0066%
Sweden	22.7	34.0	0.0059%	0.0087%
Ireland	5.9	18.3	0.0033%	0.0095%
Finland	33.7	14.9	0.0180%	0.0080%
Belgium	40.5	14.8	0.0108%	0.0039%
Poland	31.0	13.1	0.0079%	0.0032%
Romania	1.3	7.0	0.0010%	0.0050%
Luxembourg	1.6	4.4	0.0038%	0.0097%
Czechia	5.4	3.5	0.0034%	0.0022%
Lithuania	n.a.	3.5	n.a.	0.0106%
Portugal	6.4	3.5	0.0038%	0.0021%
Denmark	17.6	2.2	0.0070%	0.0009%
Cyprus	n.a.	1.8	n.a.	0.0100%
Greece	4.8	n.a.	0.0026%	n.a.
Croatia	0.6	n.a.	0.0015%	n.a.
Hungary	3.2	n.a.	0.0032%	n.a.
Latvia	0.6	n.a.	0.0032%	n.a.
Total EU	1937.7	1550.7	0.0148%	0.0117%

Source: JRC SETIS, Eurostat, WDI Database

In the field of solar energy within the EU 28, Germany is the largest player in terms of national R&D investment. Although the figures have decreased between 2013 and 2014, they still are at a very high level compared to the other EU 28 countries. Germany is followed by France, where the private R&D expenditures for solar energy technologies also have decreased since 2013. The UK and the Netherlands score at ranks three and four within this comparison, followed by Austria and Italy.

When looking at the normalization of the R&D figures by GDP, Germany has the largest share though it has decreased in 2014 due to decreases in absolute figures (in terms of private R&D but also in terms of GDP). Germany is followed by Austria, where the share has increased due to the growth in absolute figures. The Netherlands score third, followed by Lithuania and Cyprus. In all these countries, the shares of public R&D in GDP are above 0.01% for solar energy technologies. Compared to public R&D spending in 2016/17, private R&D investments in solar energy are significantly higher in 2013/14. ■

PRIVATE R&D INVESTMENTS

HYDROPOWER

	Private R&D Exp. (in € m)		Share of Private R&D Exp. by GDP	
	2013	2014	2013	2014
EU 28				
France	37.2	32.4	0.0018%	0.0016%
Germany	31.3	25.3	0.0012%	0.0009%
United Kingdom	7.9	9.7	0.0004%	0.0005%
Austria	8.8	5.0	0.0029%	0.0016%
Spain	3.8	3.4	0.0004%	0.0003%
Poland	5.1	2.3	0.0013%	0.0006%
Slovenia	n.a.	2.3	n.a.	0.0063%
Finland	3.0	1.8	0.0016%	0.0010%
Czechia	0.7	1.7	0.0005%	0.0011%
Netherlands	5.3	1.1	0.0008%	0.0002%
Italy	26.1	0.8	0.0017%	0.0000%
Belgium	2.5	n.a.	0.0007%	n.a.
Denmark	1.3	n.a.	0.0005%	n.a.
Greece	0.8	n.a.	0.0005%	n.a.
Croatia	2.5	n.a.	0.0058%	n.a.
Ireland	1.3	n.a.	0.0008%	n.a.
Romania	3.4	n.a.	0.0025%	n.a.
Slovakia	5.1	n.a.	0.0071%	n.a.
Total EU	146.1	85.8	0.0011%	0.0006%

Source: JRC SETIS, Eurostat, WDI Database

Compared to solar energy, hydro energy is also a rather small field with regard to private R&D investment. But private R&D investments in 2013/14 are larger than public investments in 2016/17 (at least for the EU 28 countries). France has the largest private R&D investment among the countries in our comparison. It is followed by Germany, which also has significant private R&D investments in hydro power. These two countries are followed by the UK and Austria where private R&D expenditures exceeds 5 billion, although there has been a decrease between 2013 and 2014 in Austria. Italy also showed large expenditures in 2013, but they have massively decreased in 2014. For the year 2013, we can also see that Slovakia, Poland and the Netherlands displays significant private R&D spending. The GDP shares, however, show a different ranking: The highest shares can be found in Slovakia (2013) and Slovenia and Croatia (2013). Furthermore, Austria shows comparably high (but decreasing) shares. The countries that have shown large absolute values, i.e. France, Germany and the UK, score in the midfield. ■

PRIVATE R&D INVESTMENTS

GEOTHERMAL ENERGY

	Private R&D Exp. (in € m)		Share of Private R&D Exp. by GDP	
	2013	2014	2013	2014
EU 28				
Germany	40.5	33.2	0.0015%	0.0012%
Sweden	9.6	19.3	0.0025%	0.0049%
France	3.2	15.5	0.0002%	0.0007%
Italy	0.8	11.9	0.0001%	0.0008%
Netherlands	5.0	8.9	0.0008%	0.0014%
Austria	n.a.	6.0	n.a.	0.0019%
Denmark	n.a.	2.3	n.a.	0.0009%
Poland	7.7	1.5	0.0020%	0.0004%
Finland	n.a.	0.5	n.a.	0.0003%
Spain	4.8	n.a.	0.0005%	n.a.
United Kingdom	10.8	n.a.	0.0006%	n.a.
Total EU	82.4	99.2	0.0006%	0.0007%

Source: JRC SETIS, Eurostat, WDI Database

In geothermal energy, the private (as well as the public) R&D expenditures are much lower than within solar energy. Once again, Germany can be found to have the largest private R&D investments of € 33.2 billion in 2014, but the expenditures have decreased since 2013. It is followed by Sweden, France, Italy and the UK (2013) all with less than € 20 billion of private R&D expenditures, though especially Sweden, France and the UK have increased their ex-penditures, while in Poland a decrease can be observed between 2013 and 2014. The GDP normalization shows that Sweden has the largest share of private R&D investment on GDP (across all countries in our comparison), which has even grown quite significantly between 2013 and 2014. It is followed by Austria, the Netherlands and Germany all with similar shares. However, it has to be kept in mind that many data points are missing in the table, which might blur the ranking. ■

PRIVATE R&D INVESTMENTS

BIOFUELS

	Private R&D Exp. (in € m)		Share of Private R&D Exp. by GDP	
	2013	2014	2013	2014
EU 28				
Germany	127.0	159.1	0.0047%	0.0058%
Denmark	118.3	101.0	0.0474%	0.0399%
France	52.5	86.9	0.0026%	0.0042%
United Kingdom	34.7	40.1	0.0018%	0.0020%
Netherlands	54.4	36.2	0.0085%	0.0056%
Finland	26.2	35.0	0.0140%	0.0188%
Italy	33.5	29.7	0.0022%	0.0019%
Poland	34.6	12.3	0.0088%	0.0030%
Sweden	25.3	11.3	0.0066%	0.0029%
Czechia	10.0	9.7	0.0064%	0.0060%
Hungary	10.6	8.9	0.0105%	0.0085%
Slovakia	1.8	8.9	0.0025%	0.0121%
Luxembourg	4.4	8.8	0.0103%	0.0196%
Spain	36.0	8.7	0.0035%	0.0008%
Slovenia	n.a.	4.5	n.a.	0.0123%
Belgium	10.4	3.3	0.0028%	0.0009%
Austria	14.1	1.1	0.0046%	0.0004%
Estonia	2.6	n.a.	0.0157%	n.a.
Ireland	2.8	n.a.	0.0016%	n.a.
Portugal	1.4	n.a.	0.0008%	n.a.
Romania	8.8	n.a.	0.0066%	n.a.
Total EU	609.5	565.6	0.0047%	0.0043%

Source: JRC SETIS, Eurostat, WDI Database

In biofuels, which is the third largest field in terms of private R&D investments after solar energy and wind technologies, Germany clearly shows the largest investment with nearly € 159 billion in 2014. Denmark shows the second largest private R&D investment in this field, although it has decreased in 2013 while an increase could be observed in Germany. All other countries in this comparison have values below € 100 billion of private R&D investment. France scores third with € 87 billion, followed by the UK and the Netherlands with € 40 billion and € 36 billion, respectively. In sum, however, it can be found that the private R&D expenditures within biofuels have decreased between 2013 and 2014, which is reflected in decreasing figures for the EU 28 as a whole. With regard to the GDP shares, Denmark is leading in 2014, followed by Luxembourg, Finland, Slovenia and Slovakia. ■

PRIVATE R&D INVESTMENTS

OCEAN ENERGY

	Private R&D Exp. (in € m)		Share of Private R&D Exp. by GDP	
	2013	2014	2013	2014
EU 28				
Germany	35.4	46.3	0.0013%	0.0017%
United Kingdom	45.4	43.4	0.0023%	0.0022%
France	29.2	31.4	0.0014%	0.0015%
Finland	15.4	20.6	0.0082%	0.0110%
Sweden	20.8	19.6	0.0054%	0.0050%
Ireland	5.3	14.5	0.0030%	0.0075%
Spain	12.1	11.5	0.0012%	0.0011%
Italy	9.9	9.5	0.0006%	0.0006%
Denmark	2.7	3.3	0.0011%	0.0013%
Netherlands	15.9	3.2	0.0025%	0.0005%
Portugal	n.a.	2.4	n.a.	0.0014%
Slovenia	n.a.	2.4	n.a.	0.0067%
Austria	n.a.	1.3	n.a.	0.0004%
Luxembourg	n.a.	1.2	n.a.	0.0027%
Romania	n.a.	0.5	n.a.	0.0003%
Belgium	2.8	n.a.	0.0007%	n.a.
Greece	1.5	n.a.	0.0008%	n.a.
Total EU	196.6	211.0	0.0015%	0.0016%

Note: *a value of 0 indicates a share or expenditures below 0.0000% or below 500 000 Euros expenditures.* ***Source: JRC SETIS, Eurostat, WDI Database***

Ocean energy is also one of the comparably smaller field in terms of private R&D investment. Here, also Germany shows the largest values in 2014, closely followed by the UK and France. Finland and Sweden score at ranks four and five, respectively. However, also in this field many data points are missing. In 2014, the investments for ocean energy have increased for the EU 28 as a whole, although the UK shows declining figures. The growth can mostly be attributed to increasing investments in Germany as well as Finland and France. The largest GDP shares in comparison can be found for Finland and Ireland, followed by Slovenia, Sweden, Luxembourg and the UK. ■

PRIVATE R&D INVESTMENTS

RENEWABLE ENERGY TECHNOLOGIES IN TOTAL

	Private R&D Exp. (in € m)		Share of Private R&D Exp. by GDP	
	2013	2014	2013	2014
EU 28				
Germany	1770.8	1616.8	0.0656%	0.0586%
France	398.2	441.4	0.0194%	0.0213%
Netherlands	204.4	161.7	0.0319%	0.0248%
Italy	272.2	160.3	0.0177%	0.0104%
Austria	n.a.	97.5	n.a.	0.0315%
Finland	n.a.	78.3	n.a.	0.0420%
Spain	274.0	n.a.	0.0268%	n.a.
United Kingdom	287.5	n.a.	0.0148%	n.a.
Total EU	4119.1	3606.7	0.0316%	0.0271%

Note: *a value of 0 indicates a share or expenditures below 0.0000% or below 500 000 Euros expenditures ;* ***Note 2 :*** *the sum across technologies is only given, if data of all RET in one country are available, i.e. as soon as one RET is missing, the data are indicated as n.a.* ***Source: JRC SETIS, Eurostat, WDI Database***

A final look at the private R&D investment in all renewable energies technologies shows a strong position of Germany in 2013 and 2014. Although the German private R&D investments in RET technologies have decreased in 2014 it still is in the top position. Large private R&D in-vestments in RET can also be found in France, which scores second on this indicator. As for the other countries, for which data is available, the UK (2013) and Spain (2013) have similar investments levels, which also counts for the Netherlands and Italy. The GDP shares also display a quite strong position of Germany, although the decreasing trends in absolute investments are also reflected in the share. Yet, as for the public R&D investments, this table has to be inter-preted with caution due to many missing values in the data. ■

PUBLIC AND PRIVATE R&D CONCLUSIONS

Due to missing data, especially for China but also for other non-European countries with regard to private R&D expenditures, it is difficult to draw conclusions. China is currently the largest investor in RET installations (wind and solar power), followed by the US. Thus, it is expected to show also significant financial allocations for R&D. Furthermore, China is the main exporter in PV as well as in hydro power. Based on the assumption of strengthening competitiveness through innovation, China is supposed to allocate significant financial resources for R&D to these technologies as well.

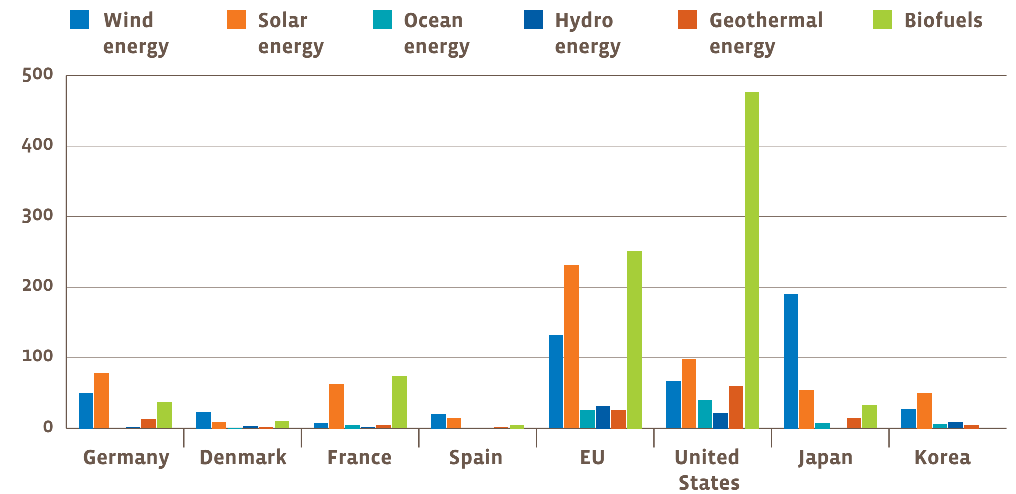
Nevertheless, it can be stated that many countries have specialized in certain technology fields within RET technologies. This can be found for public as well as for private R&D investments (see Figure 1 and Figure 2):

- So far, the EU 28 (2016/17) scores first in public solar energy R&D spending, above the U.S., Japan and Korea, while data for China is not available. Within Europe, especially Germany, France, the Netherlands and the UK have the largest public R&D investments. For private R&D investments, only data for the EU 28 countries are available (2013/2014). Here, it can be shown that Germany scores first in terms of national R&D investment, followed by France, the UK and the Netherlands.

- With regard to geothermal energy, the U.S. ranks first, although many countries have been found to be active here. When looking at the share of public R&D investments on GDP, especially Switzerland and Denmark stick out. The figures for private R&D expenditures show that Germany has the largest private R&D investments of € 33.3 billion in 2015 but the expenditures have decreased since 2013. Germany is followed by Sweden, France, Italy and the UK (2013).

1

Public R&D spending by technologies and selected countries in 2016, (in € m)



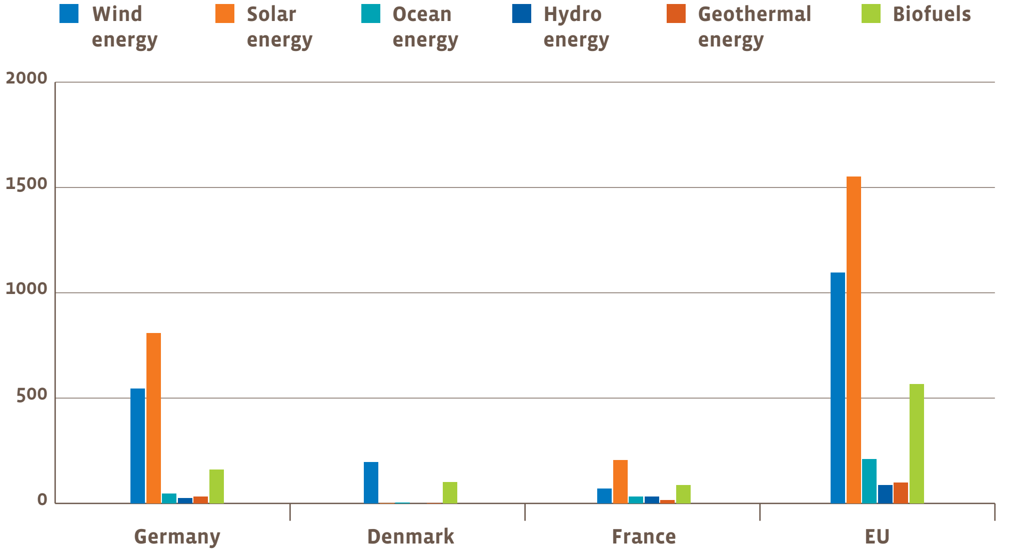
Source: JRC SETIS, Eurostat, WDI Database

- In hydro energy, which is a comparably small field with regard to public R&D investment, the EU ranks first (2016), followed by the U.S. which can be explained by its geo graphical position, i.e. large hydro power resources. It is followed by Turkey, Switzerland, Norway and Canada. Within the EU 28, Finland, the Netherlands, Denmark and Germany show the largest public investments. As for the private R&D investments, France shows the largest values among the countries in our comparison (EU 28 only). It is followed by Germany, the UK and Austria, who have significant private R&D investments in hydro power.

- Within biofuels, the U.S. clearly shows the largest investment with more than € 600 billion in 2017, which constitutes a rise in investment since 2016. The other countries in our comparison have much lower public R&D investments (all below € 50 billion, except for the EU 28 as a whole). As for the private investment, Germany scores first with nearly

2

Private R&D spending by technologies and selected countries in 2014, in mio Euro



Source: JRC SETIS, Eurostat, WDI Database

€ 159 billion in 2017. Denmark shows the second largest private R&D investment in this field. All other (EU 28) countries in our comparison have values below € 100 billion.

- In wind energy, Japan scores first with regard to public R&D spending in 2016, followed by the EU 28 and the U.S, while in 2017, the EU 28 ranks third (although data for many countries is not available here in 2017). With regard to private R&D spending, Germany scores first followed by Denmark, which scores second on this indicator. Spain ranks third, however, with only about half of the budget of Denmark.

- In ocean energy – also a rather small field in terms of public R&D – the U.S. shows the largest values followed by the EU 28. In 2017, the EU 28 expenditures have decreased (based on available data), while the U.S. expenditures have increased. This is also due to increasing public R&D investments of the U.S. Concerning private R&D investments, Germany shows the largest values in 2013 closely followed by the UK and France as well as Finland and Sweden.

- Regarding all renewables, Germany, France, the UK and also the Netherlands, Denmark and Spain should be mentioned. These are countries that have significant public R&D investment in nearly all RET fields.

- Overall, the data shows that private R&D financing by far exceeds public R&D financing. Thus, it supports the theoretical assessments, saying that public R&D spending can be seen as a driver for private R&D investments. ■

Patent Filings

The technological performance of countries or innovation systems in general is commonly measured by patent filings as well as patent grants, which can be viewed as the major output indicators for R&D processes. Countries with a high output of patents are assumed to have a strong technological competitiveness, which might be translated into an overall macroeconomic competitiveness. Patents can be analyzed from different angles and with different aims, and the methods and definitions applied for these analyses do differ. Here, we focus on a domestic, macro-economic perspective by providing information on the technological capabilities of economies within renewable energies technologies.

Methodological approach

The patent data for this report were provided by JRC SETIS. The data originate from the EPO Worldwide Patent Statistical Database (PATSTAT)[1]. A full dataset for a given year is completed with a 3.5 year delay. Thus, data used for the assessment of indicators have a 4-year delay. Estimates with a 2-year lag are provided at EU level only. The data specifically address advances in the area of low carbon energy and climate mitigation technologies (Y-code of the Cooperative Patent Classification (CPC)[2]). Datasets are processed by JRC SETIS to eliminate errors and inconsistencies. Patent statistics are based on the priority date, simple patent families[3] and fractional counts of submissions made both to national and international authorities to avoid multiple counting of patents. Within the count of patent families, filings at single offices, also known as "singletons" are included. This implies that the results regarding the global technological competitiveness could be biased towards countries with large domestic markets and specialties in their patent systems, e.g. China, Japan and Korea. Thus, these results might wrongly signal a strong international competitiveness.

For the analyses of patents in different renewable energy technologies, not only the number of filings but also a specialization indicator is provided. For this purpose, the Revealed Patent Advantage (RPA) is estimated, which builds on the works by Balassa (Balassa 1965), who has created this indicator to analyse international trade. Here the RPA indicates in which RET fields a country is strongly or weakly represented compared to the total patent applications in the field of energy technologies. Thus, the RPA for country i in field RET measures the share of RET patents of country i in all energy technologies compared to the RET world share of patents in all energy technologies. If a country i's share is larger than the world share, country i is said to be specialised in renewable energies within its energy field. The data were transformed, so values between 0 and 1 imply a below average interest or focus on this renewable technology, while values above 1 indicate a positive specialization, i.e. a strong focus on this RET compared to all energy technologies. It should be noted that the specialization indicator refers to energy technologies, and not to all technologies. This makes the indicator more sensitive to small changes in RET patent filings, i.e. it displays more ups and downs, and depicts small numbers in renewable patents as large specialisation effects if the patent portfolio in energy technologies is small, i.e. the country is small. To account for this size effect of the country or economy and to make patent data more comparable between countries, patent filings per GDP (in trillion €) are depicted as well.

The methodology is described in more detail in the JRC Science for Policy Report "Monitoring R&D in Low Carbon Energy Technologies: Methodology for the R&D indicators in the State of the Energy Union Report, - 2016 Edition".[4]

1. EPO. Worldwide Patent Statistical Database (PATSTAT), European Patent Office. Available from: https://www.epo.org/searching-for-patents/business/patstat.html#tab1

2. EPO and USPTO. Cooperative Patent Classification (CPC), European Patent Office & United States Trademark and Patent Office. Available from http://www.cooperativepatentclassification.org/index.html

3. Patents allow companies to protect their research and innovations efforts. Patents covering the domestic market only (single patent families), provide only a protection at the domestic level, while patents filed at the WIPO or the EPO provide a protection outside the domestic market (i.e. they are forwarded to other national offices), and hence signal an international competitiveness of the company.

4. A. Fiorini, A. Georgakaki, F. Pasimeni, E. Tzimas, "Monitoring R&D in Low-Carbon Energy Technologies", EUR 28446 EN (2017). Available from: https://setis.ec.europa.eu/related-jrc-activities/jrc-setis-reports/monitoring-ri-low-carbon-energy-technologies

WIND ENERGY

	Number of patent families		Patent specialization		Patents per € trillion GDP	
	2013	2014	2013	2014	2013	2014
EU 28						
Germany	268	258	2.2	2.3	99.2	93.6
Denmark	98	89	11.1	11.2	394.8	349.4
Spain	48	40	5.8	6.0	46.9	38.4
France	22	30	0.6	0.9	10.8	14.5
United Kingdom	28	23	1.5	1.4	14.3	11.7
Netherlands	23	14	1.9	1.3	36.3	22.3
Italy	21	10	2.1	1.4	13.6	6.6
Sweden	23	8	2.1	0.9	58.9	19.1
Belgium	5	7	1.4	2.7	12.3	19.7
Romania	5	7	4.1	7.2	34.7	52.7
Poland	11	7	2.0	1.5	28.4	16.1
Austria	6	3	1.0	0.4	20.9	10.2
Finland	2	3	0.3	0.4	12.0	13.4
Hungary	1	1	2.0	4.0	9.9	9.5
Slovenia	0	1	0.0	2.1	0.0	27.7
Slovakia	1	1	2.0	4.6	13.9	13.6
Estonia	0	1	0.0	5.1	0.0	38.5
Greece	0	1	0.8	7.0	1.1	2.7
Luxembourg	2	1	3.0	0.6	51.5	11.1
Lithuania	0	0	0.0	2.3	0.0	10.1
Bulgaria	0	0	0.0	0.0	0.0	0.0
Cyprus	0	0	0.0	0.0	0.0	0.0
Czechia	0	0	0.0	0.0	0.0	0.0
Croatia	0	0	0.0	0.0	0.0	0.0
Ireland	3	0	2.5	0.0	14.2	0.0
Latvia	2	0	2.5	0.0	77.9	0.0
Malta	0	0	0.0	0.0	0.0	0.0
Portugal	0	0	0.0	0.0	0.0	0.0
Total EU 28	**569**	**504**	**2.2**	**2.2**	**43.6**	**38.0**
Other Countries						
China	669	721	0.9	0.9	92.5	91.2
Korea	268	277	1.2	1.1	272.6	260.8
Japan	215	199	0.5	0.5	55.2	54.4
United States	222	156	1.0	0.9	17.7	11.9
Rest of the world	103	79	n.a.	n.a.	0.0	0.0

Continues overleaf

Note: *the value 0 signals that there is no patent application.* ***Note:*** *Single patent families (singletons) have been included.* ***Source:*** ***JRC SETIS, Eurostat, WDI Database.***

In contrast to hydro energy and biofuels, in wind energy the EU 28 as a group is at a similar patenting level as China. However, the EU 28 has slightly lost ground in 2014 while China has increased its patent activities in wind energy technologies. Korea scores third, followed by Germany, Japan, the United States and Denmark. This strong position of Europe is mostly borne out of the strong position of two European countries, namely Germany and Denmark, who together are responsible for nearly 69% of all European patents within wind energy.

Yet, also Spain, France, the UK, the Netherlands and Italy have filed a significant number of patents within this field in 2014.

In terms of patents per GDP in wind energy, Denmark is the leading country with the largest value in this comparison. It is followed by Korea, Germany, China and Japan. Romania, Estonia and Spain are above the EU 28 average but behind China.

With regard to the patent specialization, especially Denmark shows a large value, implying that wind energy can be seen as an important factor within its domestic energy technology portfolio. Large values can also be found for Romania, Greece, and Spain. Germany also shows an above average specialization (as is the EU 28 in general), yet it is not as strongly pronounced as in the case of Denmark and the other mentioned countries. This is due to the fact that Germany in general files a large number of patents in energy technologies so the effect of wind energy patents on its portfolio is not that pronounced. ■

SOLAR ENERGY

	Number of patent families		Patent specialization		Patents per € trillion GDP	
	2013	2014	2013	2014	2013	2014
EU 28						
Germany	359	268	0.8	0.8	132.8	97.2
France	124	104	0.9	1.0	60.0	50.0
United Kingdom	53	45	0.8	0.9	27.1	22.5
Spain	48	43	1.6	2.1	47.0	42.0
Netherlands	37	38	0.9	1.1	57.7	58.6
Austria	12	25	0.5	1.1	37.9	80.1
Italy	48	20	1.3	0.9	31.3	12.8
Poland	17	15	0.8	1.1	42.6	36.5
Belgium	22	12	1.9	1.4	60.1	32.4
Sweden	8	10	0.2	0.4	19.6	26.1
Romania	5	6	1.1	1.7	34.7	39.6
Ireland	4	5	1.1	1.7	21.6	27.8
Finland	13	5	0.6	0.3	70.6	26.9
Portugal	3	3	2.7	2.1	17.9	18.9
Denmark	7	2	0.2	0.1	26.6	9.6
Lithuania	0	2	0.0	4.4	0.0	60.5
Latvia	3	2	1.5	5.9	167.0	97.4
Czechia	2	2	0.4	0.6	10.6	9.3
Luxembourg	1	1	0.2	0.5	11.8	27.8
Slovakia	1	1	0.6	1.5	13.9	13.6
Cyprus	0	1	0.0	0.7	0.0	28.6
Bulgaria	0	0	0.0	0.0	0.0	0.0
Estonia	0	0	0.0	0.0	0.0	0.0
Greece	2	0	1.6	0.0	8.1	0.0
Croatia	0	0	0.7	0.0	4.6	0.0
Hungary	1	0	0.6	0.0	9.9	0.0
Malta	0	0	0.0	0.0	0.0	0.0
Slovenia	0	0	0.0	0.0	0.0	0.0
Total EU 28	767	610	0.8	0.9	58.8	45.9
Other Countries						
China	2 328	2 108	0.8	0.8	321.7	266.8
Japan	2 062	1 362	1.2	1.2	530.9	372.6
Korea	1 115	1 144	1.4	1.5	1 133.4	1 075.6
United States	575	455	0.7	0.8	45.7	34.6
Rest of the world	517	397	n.a.	n.a.	0.0	0.0

Continues overleaf

***Note:** the value 0 signals that there is no patent application. **Note:** Single patent families (singletons) have been included. **Source:** JRC SETIS, Eurostat, WDI Database.*

In the field of solar energy, China has the highest number of patents filed domestically or internationally and ranks third based on patents per GDP. Yet, it is rather closely followed by Japan, although Japan's patenting activity between 2013 and 2014 has decreased (as opposed to China). Korea scores third with regard to patent counting, with stagnating figures between 2013 and 2014. However, it by far ranks first when patents are related to GDP. The EU 28 as a total ranges behind Korea - with about half of the number of patent filings - and ahead of the US, although the figures have been decreasing for both countries in 2014. Within Europe, Germany has filed the largest number of patents, followed by France, the UK, Spain and the Netherlands. Together with Latvia, Germany also ranks first regarding patents per GDP within the EU, followed by Austria and Lithuania. These differences in patent filings between the countries partly reflect different domestic patenting preconditions or behaviour. For example, China has a large number of patent filings for the domestic market, while its number of patent applications for the international market is lower.

When taking a closer look at the specialization indices of the respective countries, it can be found that European countries are generally more specialized in solar energy compared to other energy technology fields than the remaining countries in the analysis. The countries with the largest specialization values are Latvia, Lithuania, Portugal, Spain, Ireland and Romania. However, it has to be kept in mind that these countries have comparably low numbers of filings in general. Thus, a small number of filings in PV and a low number in filings for other energy technologies could lead to a relative high specialisation value. Consequently, minor changes in their patenting activity in a given year can have large influence on the patent specializations. ■

HYDROENERGY

	Number of patent families		Patent specialization		Patents per € trillion GDP	
	2013	2014	2013	2014	2013	2014
EU 28						
Germany	15	15	0.7	0.6	5.6	5.4
France	14	13	2.0	1.8	6.9	6.1
United Kingdom	3	4	0.9	1.1	1.6	2.1
Poland	6	4	5.6	3.5	15.3	8.7
Spain	3	3	1.6	2.2	2.4	3.1
Austria	3	2	2.6	1.2	10.9	6.5
Romania	2	1	10.8	4.4	17.4	7.2
Slovenia	0	1	0.0	9.4	0.0	27.7
Finland	1	1	0.9	0.6	6.2	4.2
Czechia	0	1	1.4	3.5	1.8	4.1
Netherlands	2	1	1.0	0.2	3.4	0.8
Italy	8	0	4.4	0.2	5.4	0.2
Belgium	1	0	1.6	0.0	2.7	0.0
Bulgaria	0	0	0.0	0.0	0.0	0.0
Cyprus	0	0	0.0	0.0	0.0	0.0
Denmark	1	0	0.3	0.0	2.0	0.0
Estonia	0	0	0.0	0.0	0.0	0.0
Greece	0	0	6.8	0.0	1.8	0.0
Croatia	1	0	69.3	0.0	22.9	0.0
Hungary	0	0	0.0	0.0	0.0	0.0
Ireland	1	0	2.6	0.0	2.8	0.0
Lithuania	0	0	0.0	0.0	0.0	0.0
Luxembourg	0	0	0.0	0.0	0.0	0.0
Latvia	0	0	0.0	0.0	0.0	0.0
Malta	0	0	0.0	0.0	0.0	0.0
Portugal	0	0	0.0	0.0	0.0	0.0
Sweden	0	0	0.0	0.0	0.0	0.0
Slovakia	2	0	21.6	0.0	27.9	0.0
Total EU 28	64	45	1.3	0.9	4.9	3.4
Other Countries						
China	185	221	1.3	1.2	25.5	27.9
Japan	68	71	0.8	0.9	17.6	19.5
Korea	36	52	0.9	1.0	36.6	49.1
United States	10	7	0.2	0.2	0.8	0.5
Rest of the world	23	34	n.a.	n.a.	0.0	0.0

Note: *the value 0 signals that there is no patent application.* ***Note:*** *Single patent families (singletons) have been included.* ***Source:*** ***JRC SETIS, Eurostat, WDI Database.***

Continues overleaf

In hydro energy, the patenting figures are higher than in geothermal energy. Here, especially China displays the largest number of patents. Japan, Korea and the EU 28 follow up but at a lower level than China. Korea has managed a growth in filings between 2013 and 2014, while the figures for the EU 28 decreased. Within Europe, Germany is responsible for 33% of all patent filings within this field, while France is responsible for 28%. The UK, Poland, Spain, Austria, Romania, Slovenia, Finland, Czechia and the Netherlands also show a certain activity level.

In relation to its economic size, Korea and China reveal the highest patent filing figures per GDP, followed by Slovenia, Japan, Poland and Romania. However, it has to be stressed again that these patents also include single domestic patent applications, an interpretation regarding the international competitiveness is therefore difficult.

The RPA indicator shows a high specialization for Slovenia, Romania, Poland, the Czechia, Spain and France. However, except for France, this is based on a very low absolute number of filings. ■

Rolf Sturm

GEOTHERMAL ENERGY

	Number of patent families		Patent specialization		Patents per € trillion GDP	
	2013	2014	2013	2014	2013	2014
EU 28						
Germany	9	6	1.0	0.7	3.5	2.0
Sweden	2	3	2.5	5.2	5.2	8.3
France	1	3	0.2	1.1	0.3	1.3
Poland	4	2	8.5	6.9	9.2	5.6
Belgium	0	2	0.0	9.9	0.0	5.3
Italy	0	2	0.2	3.7	0.1	1.3
Netherlands	1	2	1.2	1.9	1.7	2.3
Austria	0	1	0.0	1.8	0.0	3.2
Denmark	0	0	0.0	0.7	0.0	1.5
Finland	0	0	0.0	0.4	0.0	0.9
Bulgaria	0	0	0.0	0.0	0.0	0.0
Cyprus	0	0	0.0	0.0	0.0	0.0
Czechia	0	0	0.0	0.0	0.0	0.0
Estonia	0	0	0.0	0.0	0.0	0.0
Greece	0	0	0.0	0.0	0.0	0.0
Spain	1	0	1.6	0.0	1.0	0.0
Croatia	0	0	0.0	0.0	0.0	0.0
Hungary	0	0	0.0	0.0	0.0	0.0
Ireland	0	0	0.0	0.0	0.0	0.0
Lithuania	0	0	0.0	0.0	0.0	0.0
Luxembourg	0	0	0.0	0.0	0.0	0.0
Latvia	0	0	0.0	0.0	0.0	0.0
Malta	0	0	0.0	0.0	0.0	0.0
Portugal	0	0	0.0	0.0	0.0	0.0
Romania	0	0	0.0	0.0	0.0	0.0
Slovenia	0	0	0.0	0.0	0.0	0.0
Slovakia	0	0	0.0	0.0	0.0	0.0
United Kingdom	2	0	1.6	0.0	1.2	0.0
Total EU 28	20	21	1.0	1.2	1.5	1.6

Continues overleaf

Other Countries						
China	29	40	0.5	0.7	4.0	5.1
Japan	56	40	1.6	1.5	14.4	10.9
Korea	27	23	1.7	1.3	27.6	22.0
United States	11	12	0.6	0.9	0.9	0.9
Rest of the world	11	6	n.a.	n.a.	0.0	0.0

Note: the value 0 signals that there is no patent application. ***Note:*** *Single patent families (singletons) have been included.* ***Source:*** ***JRC SETIS, Eurostat, WDI Database.***

In terms of the number of patent filings, geothermal energy is a far less significant field than solar energy. The filing figures are below 50 in 2014 for each of the countries in our comparison. The EU 28 countries in total filed 21 patents in geothermal energy in 2014, with 6 patents originating from Germany. The other European countries that have actively patented inventions in geothermal energy in 2014 are Sweden, France, Poland, Belgium, Italy, the Netherlands and Austria. The largest patenting countries in geothermal energy worldwide are Japan and China, each with 40 patents in 2014, followed by Korea and the EU 28. The U.S. has only filed 12 patents within this field in 2014. With respect to patents per GDP, Korea and Japan are leading, i.e. they show the highest level of patent filings. In the EU 28, Sweden, Poland, Belgium, Austria, the Netherlands and Germany rank top, yet at a far lower level than Japan or Korea.

As mentioned before, there is a size problem with the specialisation indicator if countries are small. For example, in Belgium, Poland, Sweden or Italy, the indicator shows a large value, but it is based on only minor changes in the patenting of renewables. This is because the countries' energy technology portfolio is small and small changes in renewables patent become a large weight. Overall, Japan and Korea show a relatively high specialization of their domestic markets with a rather large number of patents, while some EU countries reveal a much stronger specialisation, which is, however, as already mentioned, based on a lower number of patent filings overall. ■

BIOFUELS

	Number of patent families		Patent specialization		Patents per € trillion GDP	
	2013	2014	2013	2014	2013	2014
EU 28						
Germany	50	49	0.5	0.5	18.4	17.7
France	23	33	0.8	1.2	11.3	16.1
Denmark	20	16	2.9	2.4	78.3	61.8
Netherlands	21	12	2.3	1.3	32.5	18.2
Poland	17	11	4.0	2.9	44.0	26.6
United Kingdom	12	11	0.9	0.8	6.2	5.3
Finland	12	11	2.4	2.1	63.3	56.3
Spain	17	8	2.7	1.5	16.8	8.1
Italy	11	6	1.4	0.9	7.2	3.7
Romania	5	3	5.7	3.5	37.2	21.6
Belgium	4	3	1.8	1.3	11.7	7.8
Sweden	7	3	0.9	0.4	18.7	7.1
Czechia	3	3	3.3	3.5	18.0	15.5
Luxembourg	1	2	2.2	2.9	29.1	46.4
Hungary	3	2	8.0	9.5	29.7	19.0
Slovakia	1	2	1.3	11.1	7.0	27.2
Slovenia	0	1	0.0	2.5	0.0	27.7
Austria	4	1	0.8	0.1	13.0	2.2
Bulgaria	0	0	0.0	0.0	0.0	0.0
Cyprus	0	0	0.0	0.0	0.0	0.0
Estonia	0.75	0	18.5	0.0	44.5	0.0
Greece	0	0	0.0	0.0	0.0	0.0
Croatia	0	0	0.0	0.0	0.0	0.0
Ireland	2	0	2.3	0.0	10.2	0.0
Lithuania	0	0	0.0	0.0	0.0	0.0
Latvia	6	0	12.4	0.0	297.5	0.0
Malta	0	0	0.0	0.0	0.0	0.0
Portugal	1	0	2.5	0.0	3.6	0.0
Total EU 28	220	175	1.1	0.9	16.9	13.2
Other Countries						
China	685	874	1.2	1.3	94.7	110.6
Korea	134	193	0.8	0.9	136.3	181.9
United States	239	150	1.4	1.0	19.0	11.4
Japan	172	126	0.5	0.4	44.3	34.4
Rest of the world	120	105	n.a.	n.a.	0.0	0.0

Continues overleaf

Note: *the value 0 signals that there is no patent application.* ***Note:*** *Single patent families (singletons) have been included.* ***Source: JRC SETIS, Eurostat, WDI Database.***

In biofuels, it is again China that has filed the largest number of patents in 2014. With 874 patent families, China clearly has a dominant position in this respect and also has managed a growth in filings since 2013. Following China, Korea scores second with 193 patent families. The U.S. and the EU 28 have lost ground and rank after China and Korea due to the decrease in filings since 2013. The EU 28 has filed 175 simple patent families in 2014 and the U.S. has filed 150. However, biofuels still is the only technology field where the U.S. has a significant number of patent filings, also in relation to its size. Within Europe, the picture is a little more balanced than in the other technology fields, with many of the countries being active in patenting. Germany scores first within the intra-EU comparison, followed by France, Denmark, the Netherlands, Poland, the UK and Finland.

In relation to their respective GDP, Korea and China display a strong position in biofuels patent filings. They are followed by Denmark and Finland at a comparably lower level. With regard to the specialization (RPA), Slovakia, Hungary, Romania and the Czechia have the largest values. Yet, this relates to a very low number of filings in 2014. Still, many European countries show positive (above 1) values here, while the non-European countries - except for China with a value of 1.2 - are less specialized within this technology field. ■

Bioconstruct

OCEAN ENERGY

	Number of patent families		Patent specialization		Patents per € trillion GDP	
	2013	2014	2013	2014	2013	2014
EU 28						
Germany	17	24	0.6	0.8	6.3	8.7
United Kingdom	19	19	4.8	4.4	9.6	9.4
France	15	13	1.8	1.5	7.4	6.2
Finland	7	9	4.8	5.4	35.5	45.8
Spain	9	9	4.9	4.9	8.3	8.2
Sweden	8	8	3.7	3.6	21.8	20.3
Ireland	2	6	9.3	21.2	11.3	28.6
Italy	4	4	2.0	2.0	2.8	2.6
Poland	1	3	0.8	2.1	2.6	6.2
Denmark	1	1	0.6	0.7	4.7	5.5
Netherlands	7	1	2.9	0.5	11.5	2.0
Portugal	2	1	22.8	7.9	8.9	5.9
Slovenia	0	1	0.0	7.9	0.0	27.7
Austria	0	1	0.0	0.3	0.0	1.6
Luxembourg	0	1	0.0	2.3	0.0	11.1
Romania	0	0	0.0	0.7	0.0	1.4
Belgium	2	0	2.5	0.0	4.6	0.0
Bulgaria	0	0	0.0	0.0	0.0	0.0
Cyprus	0	0	0.0	0.0	0.0	0.0
Czechia	0	0	0.0	0.0	0.0	0.0
Estonia	0	0	0.0	0.0	0.0	0.0
Greece	1	0	12.0	0.0	3.6	0.0
Croatia	0	0	0.0	0.0	0.0	0.0
Hungary	0	0	0.0	0.0	0.0	0.0
Lithuania	0	0	0.0	0.0	0.0	0.0
Latvia	0	0	0.0	0.0	0.0	0.0
Malta	0	0	0.0	0.0	0.0	0.0
Slovakia	0	0	0.0	0.0	0.0	0.0
Total EU 28	94	99	1.7	1.7	7.2	7.4
Other Countries						
China	165	219	1.0	1.0	22.7	27.7
Korea	50	92	1.1	1.4	51.0	86.3
Japan	51	49	0.5	0.5	13.2	13.5
United States	33	23	0.7	0.5	2.6	1.7
Rest of the world	42	27	n.a.	n.a.	0.0	0.0

Continues overleaf

Note: *the value 0 signals that there is no patent application.* ***Note:*** *Single patent families (singletons) have been included.* ***Source:*** ***JRC SETIS, Eurostat, WDI Database.***

Ocean energy is also a comparably small field in terms of the number of patent families, but the general trends are also mirrored by these figures here, i.e. China scores first, followed by Europe, Korea, Japan and the U.S. Germany is the largest applicant within this technology field within Europe. The UK scores second, France third.

Korea is strong in patent filings per GDP. Due to their small size, Finland and Ireland range before Japan while countries with a high number of filings (China, Japan, United Kingdom or Germany) show a lower ranking due to their economic size.

The UK also shows a large specialization within this field but due to the size factor some smaller countries score higher. However, there are many countries in Europe where positive specializations with regard to ocean energy can be found. ■

Micheal Smith / Rutgers University / Institute of Marine and Coastal Sciences

RENEWABLE ENERGY TECHNOLOGIES IN TOTAL

	Number of patent families		Patents per € trillion GDP	
	2013	2014	2013	2014
EU 28				
Germany	718	620	265.8	224.6
France	199	195	96.8	94.1
Denmark	126	108	506.4	427.8
Spain	125	103	122.4	99.8
United Kingdom	117	102	59.8	51.0
Netherlands	92	68	143.0	104.1
Italy	93	42	60.5	27.2
Poland	56	40	142.1	99.6
Austria	25	32	82.7	103.8
Sweden	48	32	124.2	80.9
Finland	35	28	187.6	147.5
Belgium	34	25	91.4	65.2
Romania	17	17	123.9	122.5
Ireland	11	11	60.1	56.4
Czechia	5	5	30.4	28.9
Luxembourg	4	4	92.3	96.4
Portugal	5	4	30.4	24.8
Slovenia	0	4	0.0	110.7
Slovakia	5	4	62.8	54.3
Hungary	5	3	49.6	28.5
Lithuania	0	2	0.0	70.6
Latvia	11	2	542.4	97.4
Estonia	1	1	44.5	38.5
Cyprus	0	1	0.0	28.6
Greece	3	1	14.7	2.7
Bulgaria	0	0	0.0	0.0
Croatia	1	0	27.4	0.0
Malta	0	0	0.0	0.0
EU 28 Total	**1734**	**1453**	**132.9**	**109.4**
Other Countries				
China	4060	4182	561.0	529.3
Japan	2624	1847	675.6	505.2
Korea	1630	1783	1657.6	1675.8
United States	1090	802	86.7	61.1
Rest of the world	815	647	n.a.	n.a.

Continues overleaf

Note: *the value 0 signals that there is no patent application.* ***Note:*** *Single patent families (singletons) have been included.* ***Source: JRC SETIS, Eurostat, WDI Database.***

A final look at the patenting figures in all renewable energies technologies shows that China has filed the largest number of patents in 2014, followed by Japan, Korea, the EU 28 and the U.S.. Within the EU 28, a strong position of Germany can be observed, which has also been found at the input side, i.e. in terms of R&D investments. Comparably large numbers of patents in RET can also be found in France, Denmark, Spain, the UK and the Netherlands. In terms of patents per GDP, Korea has the top position, followed by China and Japan. The EU 28 is in the (upper) midfield as well as the U.S. Within Europe, Denmark, Germany and Finland reach the largest number of patents per GDP. ■

CONCLUSIONS

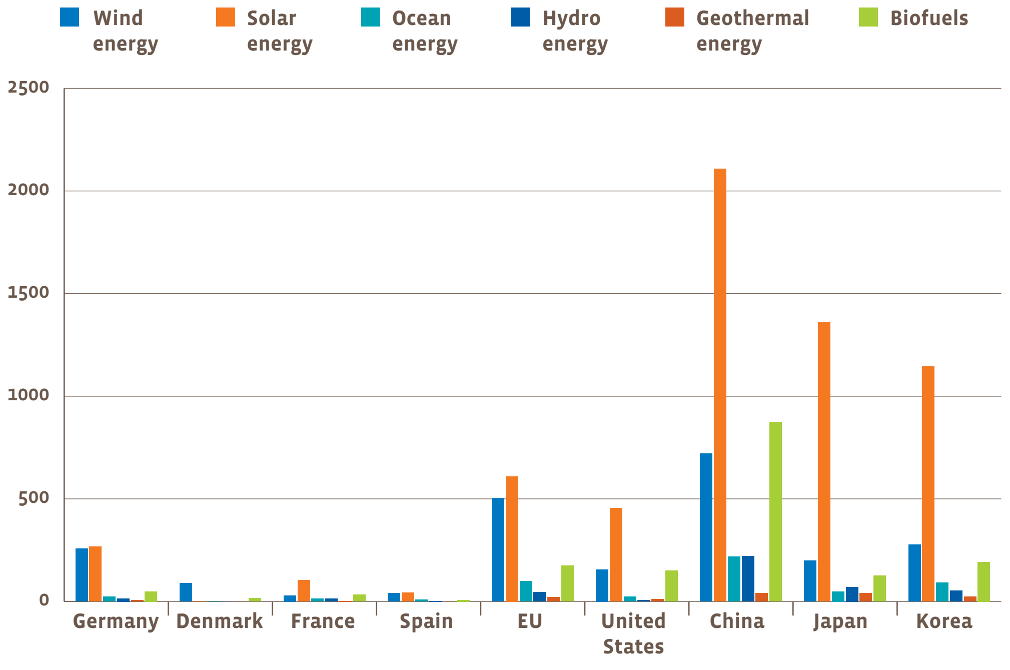
Across nearly all fields in renewable energies technologies, the Asian countries display the highest patenting activities in absolute and relative (GDP) numbers when including patent filings that refer only to the domestic market (singletons) (see Figure 3). It is mostly China that scores first in the number of patent families within the sample, although Korea often scores first when looking at patents per GDP. Europe takes a middle position between the Asian countries and the U.S.; but apart from wind technologies it is closer to the U.S. than to the Asian countries. Besides the technology field solar energy, the U.S. is not very active in patenting RET technologies. Relative to other countries, biofuels is the only field where the U.S. can score a rank among the top four in terms of patent counts. Within the EU 28, it is mostly Germany that files the largest number of patents. However, this is due to its size - in terms of patenting per GDP, Denmark ranks first in Europe.

Germany is also one of the few countries that show a certain activity level across all renewable energy technology fields, while most other countries are specialized in only one or two RET technologies. Denmark and Spain, for example, show remarkable filing figures in wind energy, while the UK is most patent active in ocean energy.

Regarding RE technologies, solar energy has the largest number of patent filings in the EU and worldwide, followed by wind energy. In contrast to the large R&D investments into biofuels, the patent statistics show relatively modest results for biofuels. Regarding ocean energy, in terms of patents and R&D spending it is less significant, despite its resource and technological development potentials. ■

3

Number of patent families by countries and RET, 2014



Note: *potentially biased due to the inclusion of single patent families (singletons).* ***Source: JRC SETIS, Eurostat, WDI Database.***

EnBW

International Trade

The analysis of trade and trade-flows has become an important topic in trade economics because it is understood that an increase in trade generally benefits all trading partners. According to the mainstream in international trade theories, the international trade of goods occurs because of comparative advantages. The different advantages in manufacturing goods between two countries lead to trade. However, empirical data revealed that not only factor endowment but also the technological capabilities of a country affect its export performance. Consequently, firms that develop new products or integrate superior technology, will dominate the export markets of these products. In sum, it can be stated that innovation is positively correlated with ex-post performance. This is why a closer look is taken at the export performance. It is considered as an important output indicator of innovative performance within renewable energies technologies.

Methodological approach

To depict trade, not only the absolute (export) advantage in terms of global export shares is analysed but also net exports, i.e. exports minus imports of a given country. It reveals whether there is a surplus generated by exporting goods and services. Moreover, a closer look is taken at the comparative advantage, which refers to the relative costs of one product in terms of a country vis-à-vis another country. While early economists believed that absolute advantage in a certain product category would be a necessary condition for trade, it has been shown that international trade is mutually beneficial under the weaker condition of comparative advantage (meaning that productivity of one good relative to another differs between countries). The analysis of trade-flows has thus become an important topic in trade economics where the most widely used indicator was the Revealed Comparative Advantage (RCA) developed by (Balassa 1965) because an increase in trade benefits all trading partners under very general conditions. Thus, the RCA is a very valuable indicator to analyse and describe specialisation in certain products or sectors. The share of a country i's RET exports is compared to the world's (sum of all other countries) RET export share. The RET shares itself show RET exports in relation to all exports. Therefore, the RCA for country i measures the share of e.g. wind power technology exports of country i compared to the world's share of wind power technology exports. If a country i's share is larger than the world share, country i is said to be specialised in this field. The tanhyp-log transformation does not change this general interpretation but it symmetrises this indicator by normalising it to an interval ranging from -100 to +100 in contrast to the RPA. Further, the RCA refers to all product groups traded, while the RPA indicator refers to energy technologies.
The RCA has to be interpreted in relation to the remaining portfolio of the country and the world share. For example, if countries only have a minimal (below average) share of renewable energies within their total trade portfolio, all values would be negative. In contrast, some countries e.g. DK, JP, CN and ES have in relation to all exported goods an above average share of RET in their export portfolio.
The analysis looks at renewable energies exports as a whole, but also at the disaggregated RET fields. These fields comprise photovoltaics (PV), wind energy and hydroelectricity and biofuels for the reporting year 2017. The export data were extracted from the UN Comtrade database. The fields were identified based on a selection of Harmonized System Codes (HS 2017).

1. The HS 2017 codes used for the demarcation are: Photovoltaics (85414090), wind energy (85023100) and hydroelectricity (84101100, 84101200, 84101300, 84109000). For biofu-els, the codes (22071000, 22072000) are based on the classification by JRC SETIS in A. Fiorini, A. Georgakaki, F. Pasimeni, E. Tzimas, "Monitoring R&I in Low-Carbon Energy Technologies", EUR 28446 EN (2017), doi: 10.2760/447418.

ALL RES

	Share of technology on global exports		Net exports (in € m)		Export specialisation (RCA)	
	2016	2017	2016	2017	2016	2017
EU 28						
Germany	7.74%	11.46%	1801	419	-10	-6
Denmark	4.55%	5.53%	2690	1704	97	95
Spain	1.90%	3.64%	971	939	5	30
United-Kingdom	0.64%	1.63%	-1255	-994	-89	-67
Italy	0.75%	1.30%	-175	-160	-88	-83
Belgium	0.82%	1.29%	139	70	-81	-77
Hungary	0.53%	1.03%	127	111	-22	8
Czechia	0.38%	0.63%	5	-15	-77	-70
Sweden	0.23%	0.48%	-186	-116	-88	-75
Poland	0.29%	0.45%	-149	-149	-90	-89
Portugal	0.20%	0.38%	7	12	-51	-31
Croatia	0.06%	0.29%	-28	3	-40	67
Slovenia	0.13%	0.22%	29	21	-29	-9
Slovakia	0.13%	0.22%	25	25	-87	-83
Luxemburg	0.08%	0.19%	1	6	-8	47
Bulgaria	0.06%	0.13%	0	1	-76	-58
Ireland	0.06%	0.13%	-66	-35	-99	-98
Estonia	0.04%	0.09%	11	8	-60	-39
Lithuania	0.04%	0.08%	-9	-7	-87	-82
Romania	0.05%	0.05%	-133	-138	-97	-98
Finland	0.02%	0.04%	-162	-107	-100	-99
Latvia	0.01%	0.03%	-28	-24	-93	-86
Greece	0.04%	0.02%	-223	-229	-90	-99
Cyprus	0.00%	0.00%	-5	-6	-100	-99
Austria	0.59%	n.a.	8	n.a.	-43	n.a.
France	1.53%	n.a.	196	n.a.	-62	n.a.
Malta	0.00%	n.a.	-9	n.a.	-100	n.a.
The Netherlands	2.23%	n.a.	-309	n.a.	-24	n.a.
Total EU-28 (incl. Intra-EU trade)	23.08%	29.32%	3273	1339	-36	-25

Continues overleaf

Other Countries						
United States	6.52%	13.27%	-6459	-3317	-34	3
Japan	5.67%	10.37%	-1270	-592	31	52
Canada	0.56%	0.94%	-777	-912	-90	-87
India	0.43%	0.69%	-2772	-2624	-88	-74
Norway	0.01%	0.50%	-77	-132	-100	-48
Switzerland	0.13%	0.27%	-270	-227	-99	-98
Russia	0.17%	0.24%	-120	-195	-98	-99
Turkey	0.03%	0.05%	-3395	-3446	-100	-100
New Zealand	0.01%	0.01%	-26	-30	-100	-100
Albania	0.00%	0.00%	-10	-5	-100	n.a.
China	25.48%	n.a.	7345	n.a.	56	n.a.
Rest of the world	37.92%	44.33%	4412	-1104	23	37

***Note:** the value 0 indicates that shares or net exports are smaller than 0.005% or 500 000 Euro.*
***Source:** EurObserv'ER 2018 based on data from UN - COMTRADE - exchange rate : OECD / MEI*

With regard to the export shares in all four selected renewable energies technologies, China has the largest values in 2016 with slightly above 25%. However, in 2017, we see an increase in export shares of the EU-28 from 23% to 29%, while decreasing shares of China could be observed in last year's report of this series. Among the single countries, the U.S., Germany, Japan, Denmark and the Netherlands (value from 2016) have the largest shares after China. It can be found that all of the observed countries have increased their RET exports in 2017, with the U.S. and Japan having the largest growth rates. This might be due to the declining shares of China that have been observed between 2015 and 2016. The countries with the smallest shares in comparison are Albania, Cyprus, New Zealand, Greece, Latvia, Finland, Turkey, Romania, Lithuania and Estonia.

The above mentioned trends, however, can be quantified when looking at the net exports, i.e. the exports of an economy minus its imports. This can be interpreted as a trade balance and aims at answering the question whether a country is exporting more than it is importing and vice versa. This indicator reveals that China has a very positive trade balance (value for 2016). The value is also highly positive for the EU-28, while it is negative for the U.S. Many European countries show positive trade balances, e.g. Denmark, Spain, Germany, Hungary, Belgium, Slovakia, Slovenia and Portugal. These countries are exporting more RET goods than they are importing. The countries with the most negative trade balances are Turkey, the U.S., India, the UK, Canada and Japan. Although Japan has positive export shares, it still imports more RET related goods than it exports – in monetary terms.

In a final step, the export specialization (RCA) was analyzed. With regard to this indicator, Denmark shows the largest values, i.e. goods related to RET technologies have a large weight in Denmark's export portfolio. Positive specialization values can also be found for China (2016), Croatia, Japan, Luxembourg, Spain, Hungary and the U.S. while all other countries (besides the "rest of the world" group) show a negative specialization with regard to goods related to RET technologies in 2017. ■

WIND ENERGY

	Share of technology on global exports		Net exports (in € m)		Export specialisation (RCA)	
	2016	2017	2016	2017	2016	2017
EU 28						
Denmark	41.80%	41.52%	2809	1800	100	100
Germany	29.32%	24.51%	1783	871	84	61
Spain	15.24%	23.64%	1007	970	97	97
Portugal	1.53%	2.36%	97	103	90	91
Estonia	0.33%	0.54%	22	24	89	89
Croatia	0.00%	0.38%	-22	-11	-100	79
Ireland	0.14%	0.38%	-18	9	-95	-81
Belgium	0.69%	0.35%	26	-3	-86	-98
Poland	0.06%	0.28%	-20	12	-100	-96
Greece	0.35%	0.13%	-195	-164	59	-62
United-Kingdom	0.08%	0.09%	-301	-625	-100	-100
Italy	0.04%	0.08%	-52	-20	-100	-100
Lithuania	0.02%	0.08%	-5	2	-97	-82
Romania	0.01%	0.03%	1	1	-100	-99
Czechia	0.03%	0.02%	2	1	-100	-100
Finland	0.00%	0.00%	-118	-71	-100	-100
Luxemburg	0.00%	0.00%	0	0	n.a.	-100
Latvia	0.00%	0.00%	0	0	n.a.	-100
Sweden	0.01%	0.00%	-65	-33	-100	-100
Hungary	0.00%	0.00%	0	0	-100	-100
Bulgaria	0.00%	0.00%	-1	0	-100	-100
Slovenia	0.00%	0.00%	0	0	n.a.	-100
Cyprus	0.00%	0.00%	0	0	-100	n.a.
Slovakia	0.00%	0.00%	0	0	n.a.	n.a.
Austria	0.00%	n.a.	-7	n.a.	-100	n.a.
France	0.45%	n.a.	-54	n.a.	-96	n.a.
Malta	0.00%	n.a.	-1	n.a.	-100	n.a.
The Netherlands	1.13%	n.a.	51	n.a.	-73	n.a.
Total EU-28 (incl. Intra-EU trade)	93.03%	91.49%	4727	4951	78	75
Other Countries						
Norway	0.00%	3.76%	-3	-46	-100	90
United States	0.22%	1.21%	-98	-134	-100	-98
India	0.11%	0.34%	1	11	-99	-93
Canada	0.14%	0.02%	-86	-247	-99	-100
Turkey	0.02%	0.01%	-797	-223	-100	-100
Russia	0.00%	0.01%	-16	-36	-100	-100
Japan	0.00%	0.01%	-67	-153	-100	-100
Switzerland	0.01%	0.01%	-11	0	-100	-100
New Zealand	0.02%	0.00%	-2	0	-98	-100
China	7.87%	n.a.	529	n.a.	-49	n.a.
Rest of the world	0.38%	0.23%	-2467	-1336	-100	-100

Continues overleaf

***Note:** the value 0 indicates that shares or net exports are smaller than 0.005% or 500 000 Euro.*
***Source:** EurObserv'ER 2018 based on data from UN - COMTRADE - exchange rate : OECD / MEI*

In wind power, it is clearly Denmark that has the largest export shares with 42%. It is followed by Germany, with export shares of nearly 25%. This implies that two thirds of worldwide exports in wind technologies originate from these two countries. When including Spain with a value of 24%, nearly 90% of all exported goods related to wind technologies come from these three EU-28 countries. In total, the EU-28 is responsible for a share of 94%. The Chinese export shares in 2016 are comparably small with 7.9% (2016). China is followed by Norway, Portugal and the United States.

This pattern can also be found in the trade balance. Here, the largest values can also be found for Denmark, Spain , Germany and China (2016), although the value for China is comparably smaller than for the other three countries.

With regard to the RCA, it can be observed that Denmark, Spain, Portugal, Norway, Estonia, Croatia and Germany are highly specialized in trade with wind technology related goods. China, on the other hand, has a negative export specialization in wind technology related goods in 2016; its focus seems to be more clearly on PV technologies. ■

PHOTOVOLTAIC

	Share of technology on global exports		Net exports (in € m)		Export specialisation (RCA)	
	2016	2017	2016	2017	2016	2017
EU 28						
Germany	5.22%	10.55%	273	-92	-46	-14
Italy	0.67%	1.33%	-118	-133	-90	-82
United-Kingdom	0.32%	0.80%	-810	-304	-97	-91
Czechia	0.29%	0.57%	-51	-48	-85	-75
Belgium	0.30%	0.52%	-100	-112	-97	-96
Croatia	0.07%	0.35%	-2	19	-24	75
Luxemburg	0.10%	0.28%	3	9	18	71
Poland	0.24%	0.25%	-89	-136	-93	-96
Spain	0.12%	0.20%	-56	-79	-99	-99
Slovenia	0.10%	0.16%	3	-4	-53	-40
Hungary	0.07%	0.15%	-143	-176	-98	-95
Denmark	0.05%	0.12%	-48	-11	-98	-96
Sweden	0.07%	0.10%	-38	-41	-99	-99
Ireland	0.04%	0.10%	-4	-2	-100	-99
Portugal	0.03%	0.07%	-66	-73	-98	-96
Lithuania	0.04%	0.07%	-1	-10	-87	-85
Slovakia	0.06%	0.07%	-17	-22	-97	-98
Finland	0.02%	0.06%	-41	-35	-99	-98
Romania	0.01%	0.04%	-97	-85	-100	-99
Estonia	0.00%	0.01%	-9	-15	-100	-98
Latvia	0.01%	0.01%	-6	-4	-97	-99
Greece	0.00%	0.01%	-10	-12	-100	-100
Bulgaria	0.00%	0.01%	-24	-30	-100	-100
Cyprus	0.00%	0.00%	-4	-6	-100	-99
Austria	0.30%	n.a.	-137	n.a.	-81	n.a.
France	0.71%	n.a.	-194	n.a.	-90	n.a.
Malta	0.00%	n.a.	-8	n.a.	-100	n.a.
The Netherlands	1.52%	n.a.	-212	n.a.	-56	n.a.
Total EU-28 (incl. Intra-EU trade)	10.39%	15.80%	-2004	-1400	-82	-70

Continues overleaf

Other Countries						
Japan	7.36%	15.01%	-817	-53	52	74
United States	4.35%	9.30%	-7813	-4758	-64	-32
Canada	0.54%	0.97%	-155	-163	-91	-86
India	0.24%	0.49%	-2740	-2559	-96	-86
Switzerland	0.12%	0.34%	-175	-132	-99	-96
Russia	0.04%	0.07%	-132	-168	-100	-100
Turkey	0.02%	0.03%	-2489	-3158	-100	-100
New Zealand	0.00%	0.00%	-20	-19	-100	-100
Norway	0.01%	0.00%	-17	-21	-100	-100
Albania	0.00%	0.00%	0	0	n.a.	n.a.
China	31.36%	n.a.	6852	n.a.	69	n.a.
Rest of the world	45.58%	58.00%	7305	833	40	58

Note: *the value 0 indicates that shares or net exports are smaller than 0.005% or 500 000 Euro.*
Source: EurObserv'ER 2018 based on data from UN - COMTRADE - exchange rate : OECD / MEI

Again, in photovoltaics, the top position of China can be confirmed. In 2016, more than 31% of worldwide exports in PV originate from China. The next largest countries in this respect are Japan (15%), Germany (10.5%) and the U.S. (9%) in 2017. In sum, the EU-28 countries reach a share of 15.8%. Since the values of Germany lies at 10.5%, Germany is responsible for two thirds of the worldwide exports of the EU-28 countries.

With regard to net exports in PV, positive values can only be found for China (2016), Croatia and Luxembourg. All other countries in this comparison are importing more PV technologies than they export. The most negative trade balance can be found for the U.S., followed by Turkey and India. These countries are thus highly dependent on imports from other countries with regard to PV technologies. These trends are also reflected in the RCA values. Croatia is the country that is most highly specialized in goods related to PV, followed by Japan, Luxemburg, China (2016) and Germany, although the specialization value is negative in the case of Germany. ■

BIOFUELS

	Share of technology on global exports		Net exports (in € m)		Export specialisation (RCA)	
	2016	2017	2016	2017	2016	2017
EU 28						
United-Kingdom	3.46%	6.25%	-153	-66	26	48
Hungary	4.50%	5.54%	267	286	96	94
Germany	3.71%	5.13%	-343	-395	-69	-70
Belgium	4.97%	5.12%	209	173	58	34
Sweden	1.66%	2.44%	-70	-40	55	57
Spain	0.95%	1.97%	-13	31	-57	-29
Poland	0.93%	1.41%	-42	-25	-30	-27
Slovakia	0.81%	1.01%	43	47	45	34
Italy	0.69%	0.83%	-85	-72	-90	-92
Czechia	0.69%	0.65%	14	-4	-39	-69
Bulgaria	0.49%	0.61%	22	26	79	71
Latvia	0.07%	0.14%	-7	-4	-9	29
Lithuania	0.06%	0.12%	-3	1	-75	-61
Ireland	0.10%	0.07%	-43	-42	-97	-99
Denmark	0.01%	0.05%	-70	-83	-100	-99
Romania	0.09%	0.04%	-48	-57	-90	-99
Portugal	0.03%	0.02%	-26	-19	-99	-100
Estonia	0.01%	0.02%	-2	-1	-94	-95
Slovenia	0.01%	0.01%	-4	-4	-100	-100
Croatia	0.01%	0.01%	-5	-7	-99	-100
Luxemburg	0.00%	0.00%	-1	-1	-100	-100
Greece	0.01%	0.00%	-17	-20	-100	-100
Cyprus	0.00%	0.00%	-1	-1	-100	-100
Finland	0.00%	0.00%	-1	0	n.a.	n.a.
Austria	1.58%	n.a.	60	n.a.	49	n.a.
France	7.88%	n.a.	402	n.a.	73	n.a.
Malta	0.00%	n.a.	-1	n.a.	-100	n.a.
The Netherlands	8.97%	n.a.	-153	n.a.	82	n.a.
Total EU-28 (incl. Intra-EU trade)	41.66%	31.46%	-71	-277	22	-18

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Other Countries						
United States	29.60%	39.00%	1439	1546	82	80
Canada	0.96%	1.41%	-485	-490	-74	-72
India	1.34%	1.10%	-87	-111	-22	-46
Russia	0.65%	0.90%	41	48	-77	-84
Switzerland	0.04%	0.02%	-63	-69	-100	-100
Japan	0.01%	0.02%	-387	-407	-100	-100
Turkey	0.01%	0.01%	-53	-57	-100	-100
New Zealand	0.00%	0.00%	-2	-2	-100	-100
Norway	0.00%	0.00%	-41	-38	-100	-100
Albania	0.00%	0.00%	-2	0	-99	n.a.
China	0.35%	n.a.	-346	n.a.	-100	n.a.
Rest of the world	25.38%	26.08%	98	-381	-17	-14

***Note:** the value 0 indicates that shares or net exports are smaller than 0.005% or 500 000 Euro.*
***Source:** EurObserv'ER 2018 based on data from UN - COMTRADE - exchange rate : OECD / MEI*

In biofuels (which comprises ethyl alcohols with a strength of 80 degrees or more as well as other spirits "denatured"), a different picture emerges. Here, the U.S. followed by the EU-28 score the top position. In 2017, more than 70% of worldwide exports in biofuels originate from these two regions. Yet, also here a decline since 2016 becomes obvious for the EU, while the U.S. enlarged its export activities within this field. The next largest countries in terms of trade shares are the Netherlands (2016 value), France (2016 value) the UK, Hungary and Germany. Regarding net exports in biofuels, the large positive value for the U.S. implies that the U.S. is exporting far more biofuel related technologies than they import. The next largest trade balance can be found for France (2016), Hungary and Belgium, while the most negative trade balance can be found for Canada, Japan, China (2016) and Germany. These countries are thus highly dependent on imports from other countries with regard to biofuels. These trends are also reflected in the RCA values. Hungary is the country that is most highly specialized in goods related to biofuels, followed by the Netherlands (2016), the USA, France (2016), Bulgaria and Sweden. ■

HYDROPOWER

	Share of technology on global exports		Net exports (in € m)		Export specialisation (RCA)	
	2016	2017	2016	2017	2016	2017
EU 28						
Italy	7.46%	13.69%	80	65	73	83
Germany	9.08%	9.95%	89	35	5	-19
Czechia	3.65%	7.24%	40	35	85	92
Slovenia	2.69%	6.44%	30	29	99	100
Spain	3.24%	4.54%	34	17	53	49
Belgium	0.39%	2.12%	4	12	-95	-48
United-Kingdom	1.34%	1.97%	9	1	-59	-56
Bulgaria	0.36%	1.42%	4	6	64	94
Romania	1.20%	0.88%	10	2	79	38
Portugal	0.52%	0.69%	2	1	36	27
Croatia	0.20%	0.43%	1	1	67	83
Poland	0.11%	0.26%	1	1	-98	-96
Sweden	0.22%	0.22%	-13	-2	-89	-94
Hungary	0.24%	0.17%	3	1	-76	-94
Estonia	0.00%	0.13%	0	1	-100	0
Slovakia	0.24%	0.09%	0	0	-61	-97
Finland	0.04%	0.09%	-3	-1	-98	-95
Denmark	0.03%	0.05%	-1	-2	-99	-99
Lithuania	0.02%	0.01%	0	0	-98	-99
Ireland	0.00%	0.01%	-1	-1	-100	-100
Greece	0.00%	0.00%	0	-34	-100	-100
Luxemburg	0.00%	0.00%	-1	-1	-100	-100
Latvia	0.00%	0.00%	-15	-16	-100	-100
Cyprus	0.00%	0.00%	0	0	n.a.	n.a.
Austria	9.06%	n.a.	91	n.a.	98	n.a.
France	5.52%	n.a.	41	n.a.	51	n.a.
Malta	0.00%	n.a.	0	n.a.	n.a.	n.a.
The Netherlands	0.35%	n.a.	4	n.a.	-97	n.a.
Total EU-28 (incl. Intra-EU trade)	45.99%	50.38%	410	149	31	28
Other Countries						
United States	4.68%	13.39%	13	29	-60	4
India	4.54%	7.53%	54	35	76	89
Japan	0.87%	5.65%	0	22	-92	-3
Russia	3.38%	2.78%	-13	-39	55	-8
Switzerland	1.43%	2.16%	-20	-25	-30	-15
Canada	1.46%	2.15%	-51	-11	-49	-46
Turkey	0.60%	1.46%	-56	-8	-39	10
Norway	0.41%	0.40%	-16	-26	-33	-64
New Zealand	0.06%	0.16%	-3	-8	-88	-60
Albania	0.00%	0.00%	-8	-5	n.a.	n.a.
China	24.40%	n.a.	311	n.a.	53	n.a.
Rest of the world	12.19%	13.95%	-524	-220	-72	-65

Note: the value 0 indicates that shares or net exports are smaller than 0.005% or 500 000 Euro.
Source: EurObserv'ER 2018 based on data from UN - COMTRADE - exchange rate : OECD / MEI

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In hydro-power the picture is more balanced than in the case of PV and wind energy. The largest export shares within the EU-28 can be observed for Italy (14%), Germany (10%), the Czechia (7%), Slovenia (6%) and Spain (5%). In sum, the EU-28 is responsible for half of the worldwide exports within the field. This share has increased since 2016, although the shares of Austria and France are missing where 9% and 5%, respectively, of export shares in hydroelectricity could be found in 2016.

As a single country, China shows a dominant position with a value of 24% (2016), although it is less pronounced than in PV. In addition, the U.S. and to a certain extent also India show comparably large values with 13% and 8% shares in global trade, respectively. The largest positive net export values within the EU-28 are displayed for Italy, Germany, the Czechia, Slovenia and Spain. Yet, the largest value globally can be found for China (2016). India as well as the U.S. also shows a positive trade balances.

The specialization values in hydroelectricity depict a quite positive picture for Europe, where eight EU-28 members have a positive RCA value (this increases to ten when taking the 2016 values of France and Austria into account). China also shows a positive value in 2016, but its specialization in PV is still higher. However, regarding the non-European countries it is India that is most specialized. ■

CONCLUSIONS

The analyses of export data in RET technologies have shown that China is in a strong position. The Chinese strength in RET exports mostly originates from its strengths in photovoltaics, but also in hydroenergy, while the share in wind technology is still low. Nevertheless, China still shows comparably large export shares and with its leading position in patenting, export shares in all RET are expected to rise. In biofuels, China's trade position is far behind the EU, but its research output is very strong in this technology field.

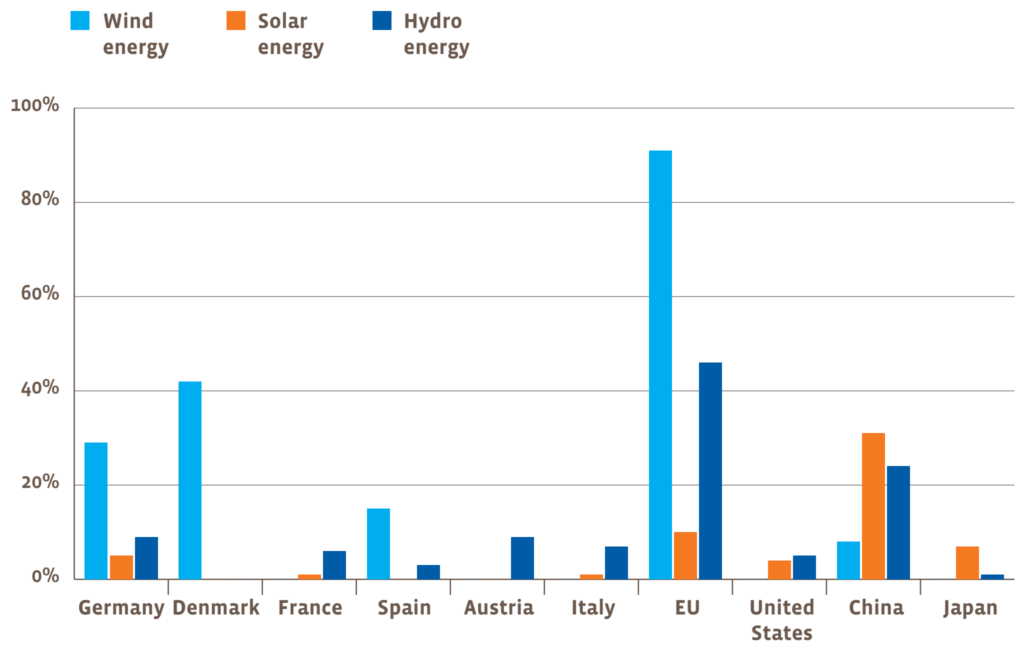
Still, some other countries are leading in wind energy and hydroelectricity. In wind energy, especially Denmark, but also Germany and Spain still display as strong competitiveness, dominating the worldwide export markets. These three countries in sum generate a worldwide export share of more than 90%, while China only plays a minor role. However, not only with respect to patenting activities but also with respect to trade shares China is catching up (at least when comparing the 2016 with the 2015 figures).

In hydroelectricity, the picture still is very balanced. Several European countries are active on worldwide export markets, while also China is responsible for comparably large shares. At a low level and pace, China is catching up in patent applications – at least in the domestic market – as well as in exports and might become a more competitive player in the future. However, the EU is once again gaining shares after a slight decline between 2015 and 2016 (see last year's report).

Overall, the EU displays a strong competitiveness in all RET fields, and has gained trade shares in 2017. The US is only strong in biofuels, and is enforcing its position there, while in other RET its contribution is far below that of the EU (see Figure 4). ■

4

Global export shares of selected countries, 2016, (in %)



Source: UN – COMTRADE

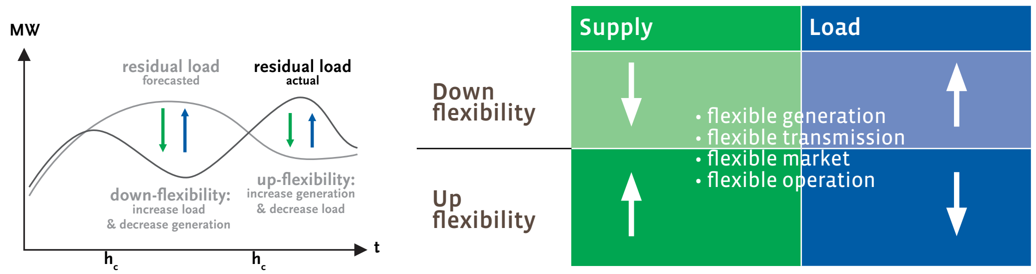
INDICATORS ON THE FLEXIBILITY OF THE ELECTRICITY SYSTEM

Balancing of electricity supply and load is nothing new as conventional resources may fail unexpectedly and demand cannot be perfectly forecasted. Increasing volatile renewable energy (vRE) production e.g. wind and solar power makes balancing of generation (and load) more difficult as more adjustments are needed to ensure system stability. For example, an unexpected decrease in load and simultaneously increasing wind power generation above the estimated value, requires additional flexibility adjustments. To mitigate deviations in load and power generation, several flexibility options are possible. Initially, when variable renewable energy from wind power and PV plants were low, small adjustments of generation by flexible generation capacities were sufficient. However, with increasing shares of wind or solar power this becomes more challenging. For example, in situations of a simultaneous increase in demand and decrease in wind power a steep positive ramp is needed.

The mechanisms work as follows: based on forecasts of load and vRE generation plants, the remaining generation capacity is scheduled at the day-ahead market. However, sudden changes in the supply-demand-balance, be it an unexpected decline or increase in vRE generation, or changes in load, challenge a system's flexibility. To adjust the system to changes in vRE supply and demand, different mechanisms are applicable. A mismatch could indeed be adjusted by increasing demand or decreasing generation (down-flexibility), or vice versa, by decreasing demand and increasing generation (up-flexibility). Also, unexpected changes within one country could

1

Flexibility needs of the power system



Source: EurObserv'ER 2018. Note: residual load is the difference between load and vRE electricity generation.

be compensated by cross-border transfers, and via short-term market or demand side adjustments. Thus, not only the supply side but also the demand side, the transmission infrastructure between countries and the markets sets the framework for flexibility in the power system. All these options become increasingly important for successfully integrating RE in the power system. To depict how flexible a system is, a set of indicators is applied that depict the use of flexible generation and transmission flexibility as well as the operational and market flexibility (see Figure 1)

Methodological note

In a first step, situations are identified in which high flexibility in the system is required. These situations are called critical hours (hc) and are defined as hours in which the difference between forecasted and actual load and vRE generation is the largest. Thus, critical hours are those hours in which either forecasted vRE generation is larger and forecasted load is smaller than actual (up-flexibility), or forecasted vRE generation is smaller and forecasted load is larger than actual (down-flexibility). In the first case, additional power is needed either through ramping-up of dispatchable power plants, power transmission via interconnectors, via short term power trading within intraday markets as well as adjustments of operational power reserves or load. The second case, called down-flexibility, entails curtailing especially of renewable power. The latter might reduce sustainability and cost efficiency of generation, but it is feasible in many situations. In the first case, ramping-up is limited by technical requirements which differ between type of fuel, plant and modernisation status. Thus, up-flexibility is of particular interest. In the following, up-flexibility within the power system is analyzed during the identified critical hours[1].

To depict the flexibility of a power system in critical hours four indicators are employed that cover generation, transmission, intraday market and operational balancing. A detailed description of the methodological approach can be found under: www.eurobserv-er.org

- *Generation flexibility: actual used generation in the critical hours is compared to the available flexible dispatchable power generation capacity of the respective countries. The available flexible capacity is defined as availability of capacities within 15 min, i.e. all capacities that could be made available for generation adjustments within 15 min are included (up-flexibility). Thus, it depicts the technically available flexibility of the system to adjust to a situation where generation and demand are in imbalance.*
- *Transmission flexibility: actual exports or imports in the critical hours are compared to the available transmission capacity. Ideally, available transmission capacity is a benchmarked transfer capacity at the borders. But due to data restrictions, the available transmission capacity is defined as the maximum import capacity of a country in the respective year.*
- *Market flexibility: actual intraday trade volumes in the critical hours are compared to the available maximum traded volume in the respective year. The indicator shows how far or close the intraday market in a critical situation is to the maximum traded volume, thus it shows how severe the situation is.*
- *Operational flexibility: actual used secondary and tertiary reserve volumes in the critical hours are compared to the maximum reserve in the respective year. It is employed as a proxy for the available/contracted reserve volume.*

1. Due to restriction in data availability, for 2017 no critical hours are defined for Malta therefore it is not further considered in this flexibility analysis. While for Austria, the Czechia, Croatia, Hungary, Luxembourg, the Netherlands, Poland and the United Kingdom critical hours are defined on the basis of incomplete data sets. In addition, data on actual generation, transmission, intraday and reserve market are limited from case to case for several EU countries. These limitations are indicated at the respective chapter or figure.

RESULTS

In the following, the results depicted in this overview illustrate those situations in which up-flexibility is needed, since it is constraining to guarantee energy supply. The shown blue bars visualize the relation of running flexible capacity during the critical hour to the estimated available flexible capacity, i.e. the percentage of used capacity within the identified critical hour. The closer the bar is to the 100% line (orange line) the lower the remaining range of flexibility in the system.

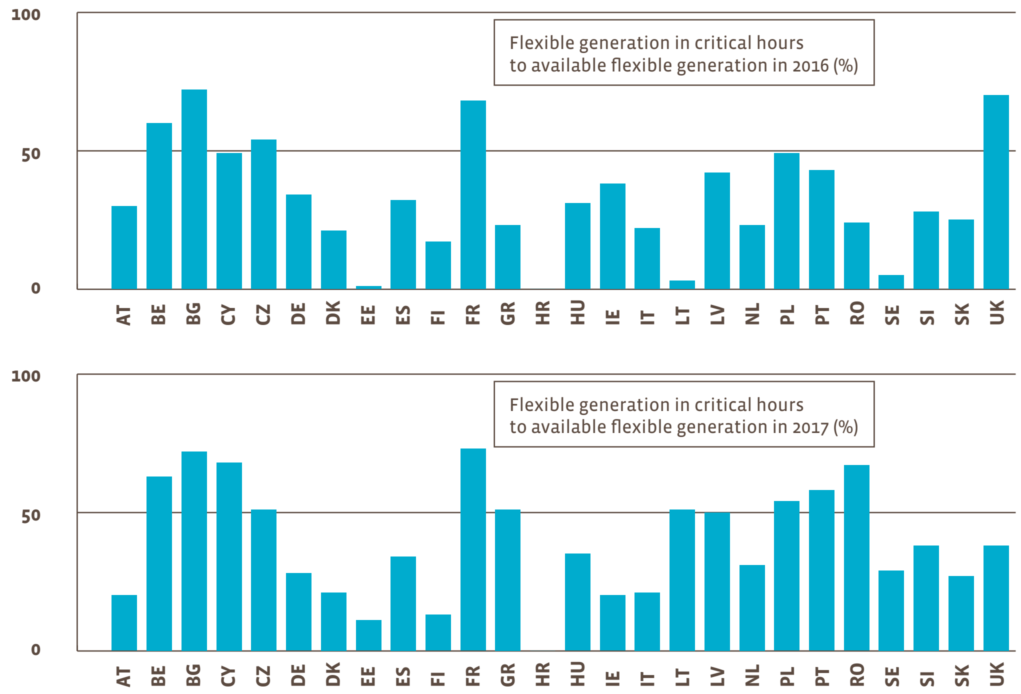
GENERATION FLEXIBILITY

To measure up-flexibility, we calculate the share of the used dispatchable generation capacity in critical hours to the estimated available total flexible generation. Thus, in each power system of the Member States, the available total flexible generation is estimated for all available generation technologies of the energy generation system. It is then weighted based on the ramp-up times and compared to the actual running flexible capacities in the critical hours of each country. The results are depicted in Figure 2.

Overall, all EU Member States have a sufficient range of flexibility in their generation. Even though the

2

Generation flexibility in critical hours in 2016 and 2017



***Source:** EurObserv'ER 2018 - own assessment based on ENTSO-E data downloaded 10/2018. Note: no data for HR, LU and MT. Incomplete Data for BG, EE, GR, HU, NL, PT, SE and UK.*

number of countries (11) using more than 50% of their flexible generation capacity rose in 2017 compared to 2016 (5), none of them got close to the critical threshold, i.e. the 100% line. Lithuania, Portugal and Romania used hydro pump technology in those hours which were complemented by gas power plants. But in some countries even during critical hours, the existing generation technologies dominate the structure of the generation mix: in France nuclear power, in Czechia lignite and nuclear power, and in Poland coal as well as lignite. Whereas Estonia, Latvia and Sweden show higher levels of used flexible capacities in 2017 than in 2016, Denmark, Finland and Italy remain below the 25%-level.

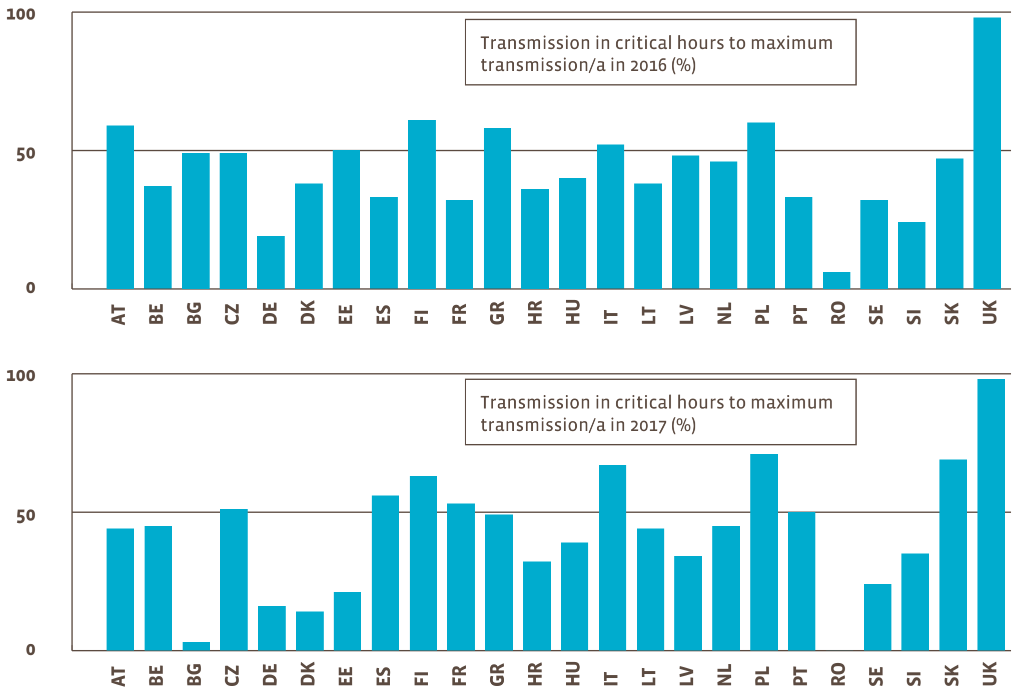
TRANSMISSION FLEXIBILITY

To illustrate the available flexibility through cross-border exchanges, the hourly import flows in critical hours are compared to the maximum hourly import flows within the respective year. Figure 3 shows the up-flexibility (imports) needed in critical hours during 2016 and 2017. The closer the bars approach the 100% line (orange line), the more available capacity of the interconnectors has been used in the critical hours, i.e. the more severe the situation was.

In 2016 and 2017, the flexibility of the power system with respect to

3

Transmission up-flexibility in critical hours in 2016 and 2017



Source: EurObserv'ER 2018 - own assessment based on ENTSO-E data downloaded 10/2018. Note: no data for CY, IE, LU and MT. Incomplete Data for HU, PL, RO, SK and UK.

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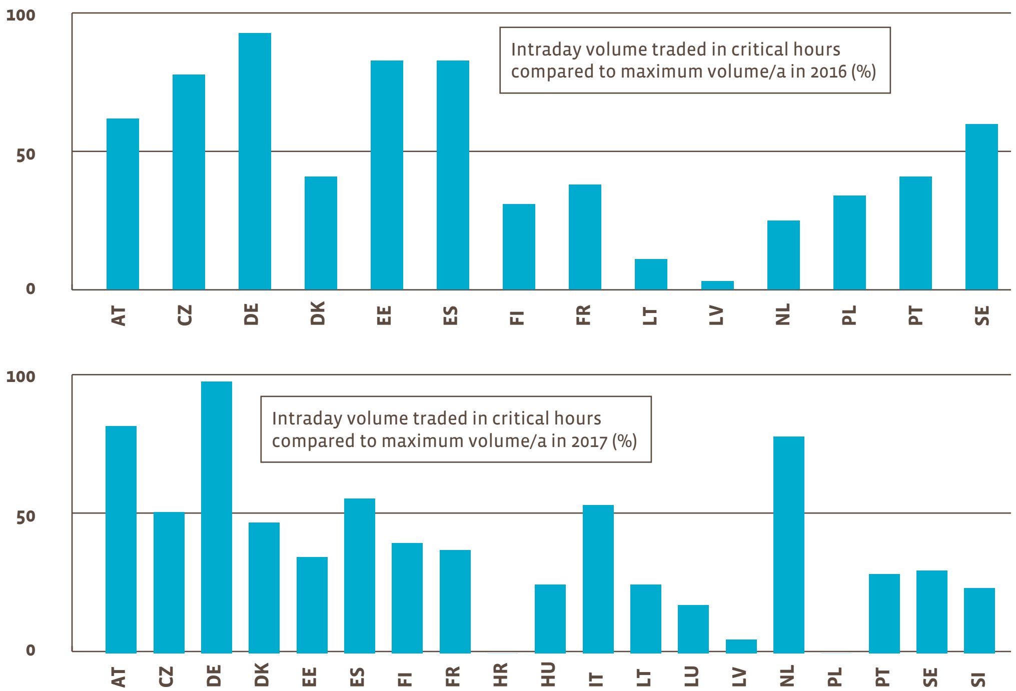
transmission has been broadly underemployed in the EU, except for United Kingdom where the import flows almost reached the maximum value in the critical hour – as in the year before. EU-wide, on average around 43% of the yearly maximum values were used for up-flexibility in extreme situations in both investigated years. Large countries such as Germany, France and Italy are in general characterized by high cross border flows. While Italy reaches two thirds and France increases to around half of its interconnector capacity share in 2017, Germany lowered its power imports during their critical hours down to 16% of their top value. Finland and Poland kept their relatively high transmission flexibility share in 2017 while this indicator declined for Denmark and Sweden. Bulgaria used low transfer capacity during the analyzed critical hours in 2017 but reached shares of almost 50% in 2016. Similar, Estonia is also less active in terms of transmission during their critical hours in 2017. Thus, many countries still have a large available potential for up-flexibility through cross-border transmission in their critical hours.

MARKET FLEXIBILITY

Market flexibility is based on the traded intraday volumes as depicted in Figure 4. The bars show the market volume within the critical hours compared to the maximum

4

Market flexibility in critical hours in 2016 and 2017



Source: EurObserv'ER 2018 - own assessment based on data of power exchanges downloaded 10/2018. Note: in 2017 no intraday market was available in BG, CY, GR, IE, MT and SK. No data for BE, RO and UK. In 2016 also no data for HR, HU, IT and SI. Incomplete Data for NL. AT, DE and LU have a common market, but different critical hours.

of hourly traded power volume within a year. The closer the blue bar to the orange line (100% line), the more the intraday market served as a mechanism for adjustments. Data is not available for all EU Member States.

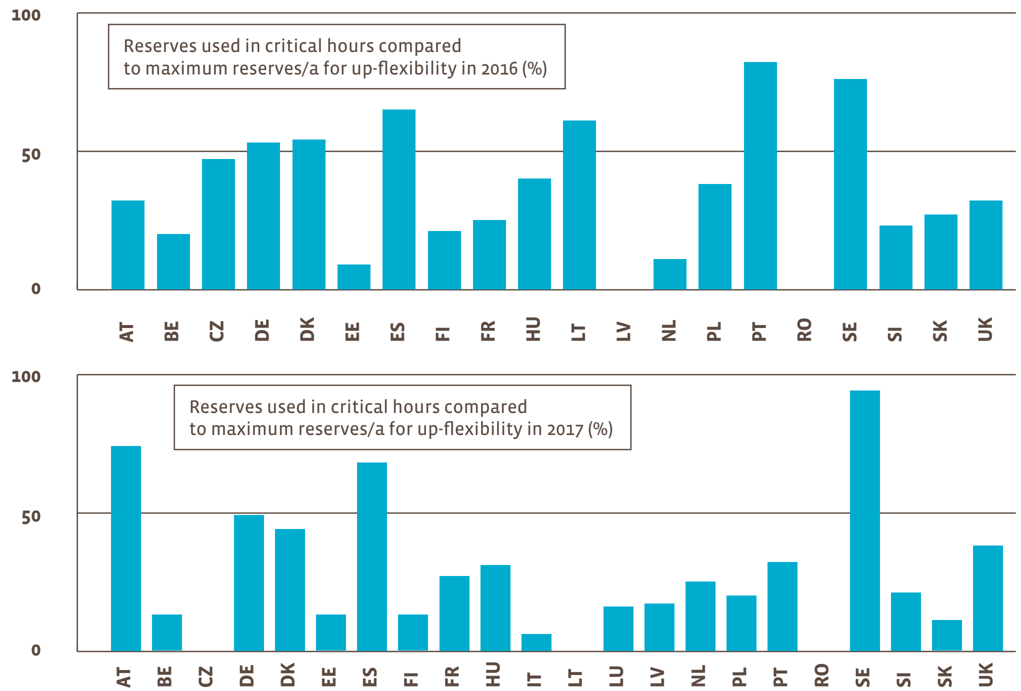
The depicted market flexibility indicators vary between 2017 and 2016. In 2017 the highest electricity trading volume in all considered intraday markets was reached within the common German, Austrian and Luxembourgish power exchange. During critical hours the greatest value of the indicator was obtained in Germany in both periods. In contrast the Czechia, Estonia, Spain and Sweden had high shares of used market flexibility in 2016 and low ones in 2017. While Denmark, Finland, France and Portugal remained with their share in the lower half of its intraday volume, Croatia and Poland have not used any intraday trading to compensate unexpected changes in load or vRE generation in 2017. This can be explained by the fact that Croatia just opened their intraday market in 2017. Poland's share in 2016 -one third of its market volume- was already low, and further decreased in 2017.

OPERATIONAL FLEXIBILITY

Operational flexibility is represented by the reserve market. Here the activated reserves of power wit-

5

Operationaly flexibility in critical hours in 2016 and 2017



Source: EurObserv'ER 2018 - own assessment based on ENTSO-E data downloaded 10/2018. Note: no data for BG, CY, GR, IE, HR, LU and MT. No data for IT in 2016. Trading conditions (e.g. time slots, contract volume, gate closure) vary among countries.

hin the critical hours are compared to the maximum hourly volume per annum. This ratio is considered as a proxy for the remaining available flexibility volume. The bars in Figure 5 depict the shares of actual activated reserves in the critical hours to the maximum available hourly volumes. The closer the bars to the orange line (100% line), the more the system relies on the operational flexibility potential in critical situations.

In general, the reserve market provides only a small share of the overall generation capacity as reserves, because the costs of holding reserve power are mostly higher than the average spot market electricity prices. Thus, there is a strong incentive to keep the use of reserves at minimum.

For 2016 and 2017, on average 40% and 32% of the maximum possible reserve power was used during critical hours, but it varies strongly among countries. For example, Italy used about 6% (2017) of the maximum operational reserves in the critical hours. However, it cannot be concluded that the contracted reserve volume could be cut down, because unexpected outages of conventional generation capacities or network problems (in addition to critical hours defined by this report) are still potential challenges to the power system, especially for countries with high loads such as Germany, France, Italy and Great Britain.

In 2017, Sweden reaches 94% of its balancing capacity and displays an increasing use of its reserve power. Portugal and Lithuania have lowered their balancing needs during critical hours significantly. Although Italy along with Germany display the highest reserve volumes, only less than half of their potentials were activated during the critical hours in 2017. For Romania, the same situation applies as in 2016, i.e. it does not use its reserves to increase generation. Similarly, Lithuania and Czechia also didn't use their up-flexibility potential of balancing power during their critical hours in 2017. ■

CONCLUSIONS

Overall, in critical hours all countries dispose of sufficient flexibility in their system. Countries with low or high vRE shares do not display a pattern regarding the use of flexibility mechanism, rather the use of those flexibility mechanisms depends on various country specific characteristics. Following the starting point of this chapter, stating that increasing vRE shares of wind and solar power make successful balancing of power supply and load more difficult, some final comparisons can be made.

Subsequently, the power system of those countries, in which the share of installed vRE capacities to total generation capacities is the highest, are of special interest of this analysis. Among them are Germany, Denmark and the United Kingdom, which display high vRE shares in decreasing order (see Figure 6). In contrast, countries with a low share of vRE such as Latvia, Hungary and Slovakia are supposed to display a small use of flexibility mechanisms.

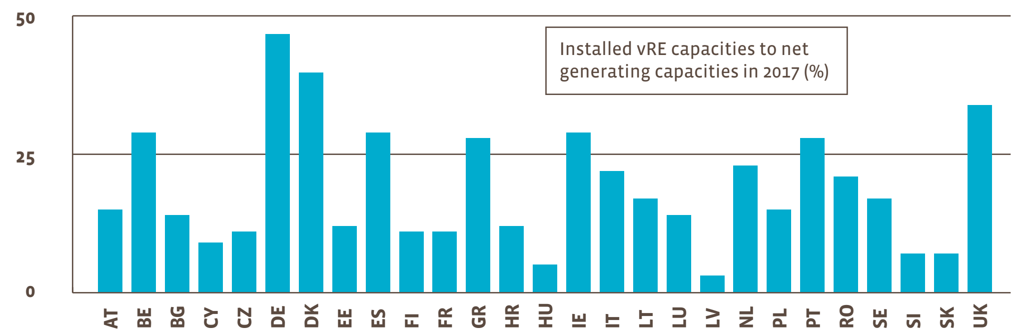
Figure 7 illustrates the pattern of flexibility options within the critical hours of countries with high and low shares of installed vRE capacity. Both groups use flexibility options during critical hours, but by differing degrees.

While in the United Kingdom, as a country with a high vRE share (34%), transmission flexibility is mainly used, Slovakia displays a similar pattern but at a lower level of use. Even though Denmark and Hungary are characterized by high and low vRE shares, respectively, both countries demonstrate rather low levels of up-flexibility usage with respect to all four indicators. Latvia compensates unexpected changes in load and supply by generation flexibility and intraday market flexibility and Germany relies on the intraday market as an outstanding mechanism to balance volatile RE generation. It has to be noted that in Slovakia no intraday market exists, and for the United Kingdom market data were not accessible.

For a further analysis, the flexibility option patterns of Germany, Spain, France and Italy in critical hours – as defined before - are

6

Share of volatile renewable energies (installed capacities) in 2017



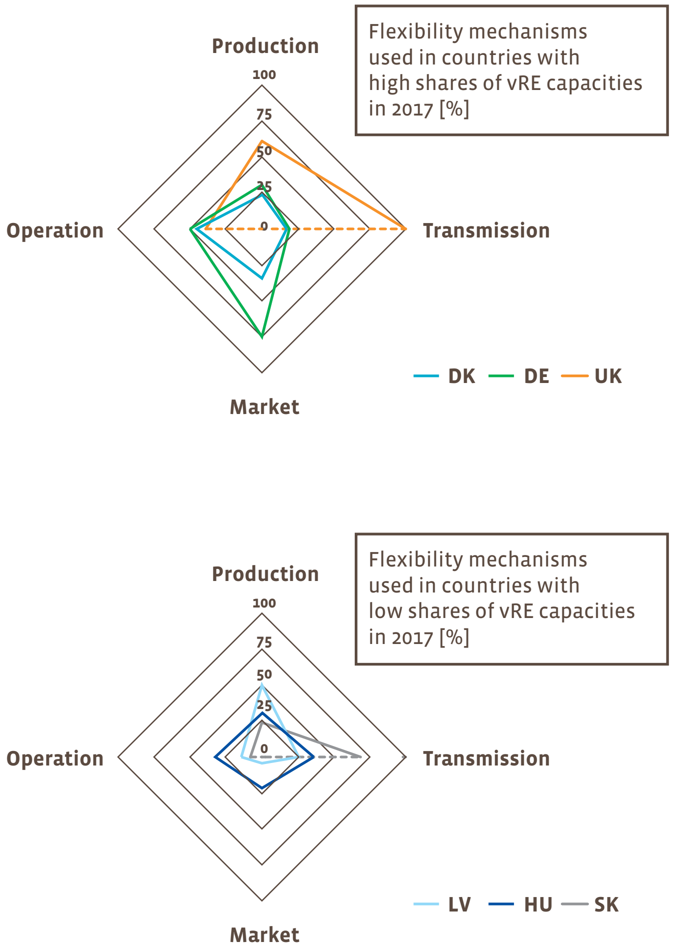
***Source:** EurObserv'ER 2018 - own assessment based on ENTSO-E data (download 10/2018).*

compared to the option patterns in hours of maximum load (see Figure 8). Given the logic of the indicators all countries strongly exploit their flexible generation capacities and market mechanism during peak load. Italy and France even reach the limit of their generation flexibility, and thus exploits much of its market flexibility as well. In contrast, the transmission option is less used. The operational option is similar to the critical hour, except for Italy, which used more of its reserves. However, any unexpected "normal" shortfall in generation in those countries could still be compensated by operational flexibility[2], or, if available, by imports of electricity. ■

2. *Operational flexibility covers the peak load by a factor of almost 0.2 (FR) and 0.05 (IT).*

7

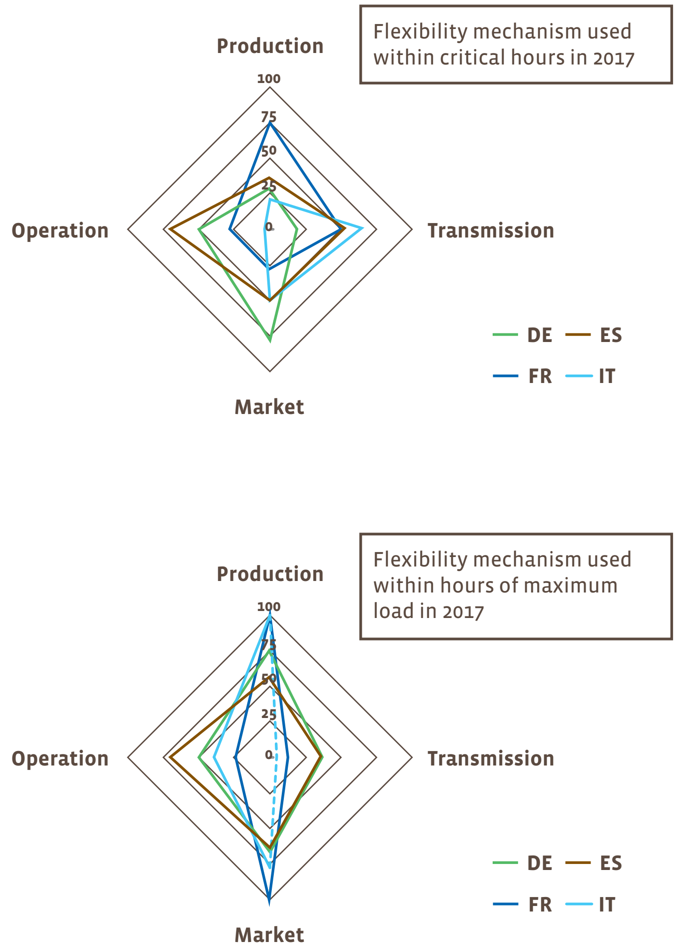
Pattern of flexibility mechanism in critical hours and in hours of maximum load



Source: EurObserv'ER 2018 - own assessment based on ENTSO-E data (download 10/2018) and data of power exchanges downloaded 10/2018. Note: no intraday data for UK and SK.

8

Pattern of flexibility mechanism in critical hours and in hours of maximum load



Source: EurObserv'ER 2018 - own assessment based on ENTSO-E and power stock exchange data (download 2017). Note: Incomplete data of transmission data for Italy during hours of maximum load.

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- BVES – German Energy Storage Association *(www.bves.de)*
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- EEG Aktuell *(www.eeg-aktuell.de)*
- EEX – European Energy Exchange *(www.eex.com)*
- Erneuerbare Energien *(www.erneuerbare-energien.de)*
- Fachverband Biogas – German Biogas Association *(www.biogas.org)*
- Fraunhofer-ISE – Institut for Solar Energy System *(www.ise.fraunhofer.de/)*

- Fraunhofer-IWES – Institute for Wind Energy and Energy System Technology *(www.iwes.fraunhofer.de/en.html)*
- FNR – Fachagentur Nachwachsende Rohstoffe – Agency for Sustainable Resources *(international.fnr.de/)*
- FVEE – Forschungsverbund Erneuerbare Energien – Renewable Energy Research Association *(www.fvee.de)*
- GTAI – Germany Trade and Invest *(www.gtai.de)*
- GtV – Bundesverband Geothermie *(www.geothermie.de)*
- GWS – Gesellschaft für Wirtschaftliche Strukturforschung *(www.gws-os.com/de)*
- KfW – Kreditanstalt für Wiederaufbau *(www.kfw.de)*
- RENAC – Renewables Academy AG *(www.renac.de)*
- UBA – Federal Environmental Agency (Umweltbundesamt) *(www.umweltbundesamt.de)*
- UFOP – Union for the Promotion of Oil and Protein plants e.V *(www.ufop.de)*
- VDB – German Biofuel Association *(www.biokraftstoffverband.de)*
- VDMA – German Engineering Federation *(www.vdma.org)*
- WI – Wuppertal Institute for Climate, Environment and Energy *(www.wupperinst.org)*
- ZSW – Centre for Solar Energy and Hydrogen Research Baden-Württemberg *(www.zsw-bw.de)*

GREECE

- CRES – Center for Renewable Energy Sources and Saving *(www.cres.gr)*
- DEDDIE – Hellenic Electricity Distribution Network Operator S.A. *(www.deddie.gr)*
- EBHE – Greek Solar Industry Association *(www.ebhe.gr)*
- HELAPCO – Hellenic Association of Photovoltaic Companies *(www.helapco.gr)*
- HELLABIOM – Greek Biomass Association c/o CRES *(www.cres.gr)*
- HWEA – Hellenic Wind Energy Association *(www.eletaen.gr)*
- Ministry of Environment, Energy and Climate Change *(www.ypeka.gr)*
- Small Hydropower Association Greece *(www.microhydropower.gr)*
- LAGIE – Operator of Electricity Market S.A. *(www.lagie.gr)*

HUNGARY

- Energiaklub – Climate Policy Institute *(www.energiaklub.hu/en)*
- Energy Centre – Energy Efficiency, Environment and Energy Information Agency *(www.energycentre.hu)*
- Ministry of National Development *(www.kormany.hu/en/ministry-of-national-development)*
- Hungarian Heat Pump Association *(www.hoszisz.hu)*
- Magyar Pellet Egyesület – Hungarian Pellets Association *(www.mapellet.hu)*
- MBE – Hungarian Biogas Association *(www.biogas.hu)*
- MGTE – Hungarian Geothermal Association *(www.mgte.hu/egyesulet)*
- Miskolci Egyetem – University of Miskolc Hungary *(www.uni-miskolc.hu)*
- MMESZ – Hungarian Association of Renewable Energy Sources *(https://hipa.hu/renewable)*
- Naplopó Kft. *(www.naplopo.hu)*
- SolarT System *(www.solart-system.hu)*

IRELAND

- Action Renewables *(www.actionrenewables.org)*
- EIRGRID *(www.eirgridgroup.com/)*
- IRBEA – Irish Bioenergy Association *(www.irbea.org)*
- Irish Hydro Power Association *(www.irishhydro.com)*
- ITI – InterTradeIreland *(www.intertradeireland.com)*
- IWEA – Irish Wind Energy Association *(www.iwea.com)*
- REIO – Renewable Energy Information Office *(www.seai.ie/Renewables/REIO)*
- SEAI – Sustainable Energy Authority of Ireland *(www.seai.ie)*

ITALY

- AIEL – Associazione Italiana Energie Agroforestali *(www.aiel.cia.it)*
- ANEV – Associazione Nazionale Energia del Vento *(www.anev.org)*
- FIPER – Associazione Produttori Energia da Fonti Rinnovabili *(www.fiper.it)*
- Assocostieri – Unione produttorri biocarburanti *(www.assocostieribiodiesel.com)*
- Assosolare – Associazione nazionale dell'industria solar fotovoltaica *(www.assosolare.org)*
- Assotermica *(www.anima.it/ass/assotermica)*
- CDP – Cassa depositi e prestiti *(www.cassaddpp.it)*
- COAER ANIMA – Associazione costruttori di apparecchiature ed impianti aeraulici *(www.coaer.it)*
- Consorzio italiano biogas – Italian Biogas Association *(www.consorziobiogas.it)*
- Energy & Strategy Group – Dipartimento diIngegneria gestionale, politecnico di Milano *(www.energystrategy.it)*
- ENEA – Italian National Agency for New Technologies *(www.enea.it)*
- Fiper – Italian Producer of Renewable Energy Federation *(www.fiper.it)*
- GIFI – Gruppo imprese fotovoltaiche italiane *(www.gifi-fv.it/cms)*
- GSE – Gestore servizi energetici *(www.gse.it)*
- ISSI – Instituto sviluppo sostenible Italia
- ITABIA – Italian Biomass Association *(www.itabia.it)*
- MSE – Ministry of Economic Development *(www.sviluppoeconomico.gov.it)*
- Ricerca sul sistema energetico *(www.rse-web.it)*
- Terna – Electricity Transmission Grid Operator *(www.terna.it)*
- UGI Unione geotermica italiana *(www.unionegeotermica.it)*

LATVIA

- CSB – Central Statistical Bureau of Latvia *(www.csb.gov.lv)*
- IPE – Institute of Physical Energetics *(www.innovation.lv/fei)*
- LATbioNRG – Latvian Biomass Association *(www.latbionrg.lv)*
- LBA – Latvijas Biogazes Asociacija *(www.latvijasbiogaze.lv)*
- LIIA – Investment and Development Agency of Latvia *(www.liaa.gov.lv)*
- Ministry of Economics *(www.em.gov.lv)*

LITHUANIA

- EA – State Enterprise Energy Agency *(www.ena.lt/en)*
- LAIEA – Lithuanian Renewable Resources Energy Association *(www.laiea.lt)*
- LBDA – Lietuvos Bioduju Asociacija *(www.lbda.lt)*
- LEEA – Lithuanian Electricity Association *(www.leea.lt)*
- LEI – Lithuanian Energy Institute *(www.lei.lt)*
- LHA – Lithuanian Hydropower Association *(www.hidro.lt)*
- Lietssa *(www.lietssa.lt)*
- LITBIOMA – Lithuanian Biomass Energy Association *(www.biokuras.lt)*
- LIGRID AB – Lithuanian Electricity Transmission System Operator *(www.litgrid.eu)*
- LS – Statistics Lithuania *(www.stat.gov.lt)*
- LWEA – Lithuanian Wind Energy Association *(www.lwea.lt)*

LUXEMBURG

- Enovos *(www.enovos.eu)*
- NSI Luxembourg – Service central de la statistique et des études économiques
- STATEC – Institut national de la statistique et des études économiques *(www.statec.public.lu)*

MALTA

- WSC – The Energy and Water Agency *(https://energywateragency.gov.mt)*
- MEEREA – Malta Energy Efficiency & Renewable Energies Association *(www.meerea.org)*
- MIEMA – Malta Intelligent Energy Management Agency *(www.miema.org)*
- Ministry for Energy and Health *(energy.gov.mt)*
- MRA – Malta Resources Authority *(www.mra.org.mt)*
- NSO – National Statistics Office *(www.nso.gov.mt)*
- University of Malta – Institute for Sustainable Energy *(www.um.edu.mt/iet)*

NETHERLANDS

- Netherlands Enterprise Agency (RVO) *(www.rvo.nl)*
- CBS – Statistics Netherlands *(www.cbs.nl)*
- CertiQ – Certification of Electricity *(www.certiq.nl)*
- ECN – Energy Research Centre of the Netherlands *(www.ecn.nl)*
- Holland Solar – Solar Energy Association *(www.hollandsolar.nl)*
- NWEA – Nederlandse Wind Energie Associatie *(www.nwea.nl)*
- Platform Bio-Energie – Stichting Platform Bio-Energie *(www.platformbioenergie.nl)*
- Stichting Duurzame Energie Koepel *(www.dekoepel.org)*
- Vereniging Afvalbedrijven – Dutch Waste Management Association *(www.verenigingafvalbedrijven.nl)*

- Bosch & Van Rijn *(www.windstats.nl)*
- Stichting Monitoring Zonnestroom *(www.zonnestroomnl.nl)*

POLAND

- CPV – Centre for Photovoltaicsat Warsaw University of Technology *(www.pv.pl)*
- Energy Regulatory Office *(www.ure.gov.pl)*
- Federation of Employers Renewable Energy Forum *(www.zpfeo.org.pl)*
- GUS – Central Statistical Office *(www.stat.gov.pl)*
- IEO EC BREC – Institute for Renewable Energy *(www.ieo.pl)*
- IMinistry of Energy, Renewable and Distributed Energy Department *(https://www.gov.pl/web/energia)*
- National Fund for Environmental Protection and Water Management *(www.nfosigw.gov.pl)*
- SPIUG – Polish heating organisation *(www.spiug.pl/)*
- PBA – Polish Biogas Association *(www.pba.org.pl)*
- PGA – Polish Geothermal Association *(www.pga.org.pl)*
- PIGEO – Polish Economic Chamber of Renewable Energy *(www.pigeo.org.pl)*
- POLBIOM – Polish Biomass Association *(www.polbiom.pl)*
- PORT PC – Polska Organizacja Rozwoju Technologii Pomp Ciepła *(www.portpc.pl)*
- POPiHN – Polish Oil Industry and Trade Organisation *(www.popihn.pl/)*
- PSG – Polish Geothermal Society *(www.energia-geotermalna.org.pl)*
- PSEW – Polish Wind Energy Association *(www.psew.pl)*
- TRMEW – Society for the Development of Small Hydropower *(www.trmew.pl)*
- THE – Polish Hydropower Association (PHA) *(www.tew.pl)*

PORTUGAL

- ADENE – Agência para a energia *(www.adene.pt)*
- APESF – Associação portuguesa de empresas de solar fotovoltaico *(www.apesf.pt)*
- Apisolar – Associação portuguesa da indústria solar *(www.apisolar.pt)*
- Apren – Associação de energies renováveis *(www.apren.pt)*
- CEBio – Association for the Promotion of Bioenergy *(www.cebio.net)*
- DGEG – Direcção geral de energia e geologia *(www.dgeg.pt)*
- EDP – Microprodução *(www.edp.pt)*
- SPES – Sociedade portuguesa de energia solar *(www.spes.pt)*

ROMANIA

- CNR-CME – World Energy Council Romanian National Committee *(www.cnr-cme.ro)*
- ECONET Romania *(www.econet-romania.com/)*
- ENERO – Centre for Promotion of Clean and Efficient Energy *(www.enero.ro)*
- ICEMENERG – Energy Research and Modernising Institute *(www.icemenerg.ro)*
- ICPE – Research Institute for Electrical Engineering *(www.icpe.ro)*
- INS – National Institute of Statistics *(www.insse.ro)*
- Romanian Wind Energy Association *(www.rwea.ro)*
- RPIA – Romanian Photovoltaic Industry Association *(rpia.ro)*
- University of Oradea *(www.uoradea.ro)*
- Transelectrica *(www.transelectrica.ro)*

SPAIN

- AEE – Spanish Wind Energy Association *(www.aeeolica.org)*
- AEBIG – Asociación española de biogás *(www.aebig.org)*
- AIGUASOL – Energy Consultant *(www.aiguasol.coop)*
- APPA – Asociación de productores de energías renovables *(www.appa.es)*
- ASIF – Asociación de la Industria Fotovoltaica *(www.asif.org)*
- ASIT – Asociación solar de la industria térmica *(www.asit-solar.com)*
- ANPIER – Asociación nacional de productores-inversores de energías renovables *(www.anpier.org)*
- AVEBIOM – Asociación española de valorización energética de la biomasa *(www.avebiom.org/es/)*
- CNMC – Comisión nacional de los mercados y la competencia *(www.cnmc.es)*
- FB – Fundación Biodiversidad *(www.fundacion-biodiversidad.es)*
- ICO – Instituto de crédito oficial *(www.ico.es)*
- IDAE – Institute for Diversification and Saving of Energy *(www.idae.es)*
- INE – Instituto nacional de estadística *(www.ine.es)*
- Ministry of Industry, Tourism and Trade *(www.minetad.gob.es)*
- OSE – Observatorio de la sostenibilidad en España *(www.forumambiental.org)*
- Protermosolar – Asociación española de la industria solar termoeléctrica *(www.protermosolar.com)*
- Red eléctrica de Espana *(www.ree.es)*

UNITED KINGDOM

- ADBA – Anaerobic Digestion and Biogas Association – Biogas Group (UK) *(www.adbiogas.co.uk)*
- BHA – British Hydropower Association *(www.british-hydro.org)*
- BSRIA – The Building Services Research and Information Association *(www.bsria.co.uk/)*
- BEIS – Department for Business, Energy & Industrial Strategy *(https://www.gov.uk/government/statistics/energy-trends-section-6-renewables)*
- DUKES – Digest of United Kingdom Energy Statistics *(www.gov.uk/government)*
- GSHPA – UK Ground Source Heat Pump Association *(www.gshp.org.uk)*
- HM Revenue & Customs *(www.hmrc.gov.uk)*
- National Non-Food Crops Centre *(www.nnfcc.co.uk)*
- MCS – Microgeneration Certification Scheme *(www.microgenerationcertification.org)*
- Renewable UK – Wind and Marine Energy Association *(www.renewableuk.com)*
- Renewable Energy Centre *(www.TheRenewableEnergyCentre.co.uk)*
- REA – Renewable Energy Association *(www.r-e-a.net)*
- RFA – Renewable Fuels Agency *(www.data.gov.uk/publisher/renewable-fuels-agency)*
- Ricardo AEA *(www.ricardo-aea.com)*
- Solar Trade Association *(www.solar-trade.org.uk)*
- UKERC – UK Energy Research Centre *(www.ukerc.ac.uk)*

SLOVAKIA

- ECB – Energy Centre Bratislava Slovakia *(www.ecb2.sk)*
- Ministry of Economy of the Slovak Republic *(www.economy.gov.sk)*
- SAPI – Slovakian PV Association *(www.sapi.sk)*
- Slovak Association for Cooling and Air Conditioning Technology *(www.szchkt.org)*
- SK-BIOM – Slovak Biomass Association *(www.4biomass.eu/en/partners/sk-biom)*
- SKREA – Slovak Renewable Energy Agency, n.o. *(www.skrea.sk)*
- SIEA – Slovak Energy and Innovation Agency *(www.siea.sk)*
- Statistical Office of the Slovak Republic *(portal.statistics.sk)*
- The State Material Reserves of Slovak Republic *(www.reserves.gov.sk/en)*
- Thermosolar Ziar ltd *(www.thermosolar.sk)*
- URSO – Regulatory Office for Network Industries *(www.urso.gov.sk)*

SLOVENIA

- SURS – Statistical Office of the Republic of Slovenia *(www.stat.si)*
- Eko sklad – Eco-Fund-Slovenian Environmental Public Fund *(www.ekosklad.si)*
- ARSO – Slovenian Environment Agency *(www.arso.gov.si/en/)*
- JSI/EEC – The Jozef Stefan Institute – Energy Efficiency Centre *(www.ijs.si/ijsw)*
- Tehnološka platforma za fotovoltaiko – Photovoltaic Technology Platform *(www.pv-platforma.si)*
- ZDMHE – Slovenian Small Hydropower Association *(www.zdmhe.si)*

SWEDEN

- Avfall Sverige – Swedish Waste Management *(www.avfallsverige.se)*
- Energimyndigheten – Swedish Energy Agency *(www.energimyndigheten.se)*
- SCB – Statistics Sweden *(www.scb.se)*
- SERO – Sveriges Energiföreningars Riks Organisation *(www.sero.se)*
- SPIA – Scandinavian Photovoltaic Industry Association *(www.solcell.nu)*
- Energigas Sverige *(www.energigas.se)*
- Uppsala University *(www.uu.se/en/)*

- Svensk Solenergi – Swedish Solar Energy Industry Association *(www.svensksolenergi.se)*
- Svensk Vattenkraft – Swedish Hydropower Association *(www.svenskvattenkraft.se)*
- Svensk Vindenergi – Swedish Wind Energy *(www.svenskvindenergi.org)*
- Swentec – Sveriges Miljöteknikråd *(www.swentec.se)*
- SVEBIO – Svenska Bioenergiföreningen / Swedish Bioenergy Association *(www.svebio.se)*
- SKVP – Svenska Kyl & Värmepumpföreningen *(skvp.se/)* (formely SVEP)

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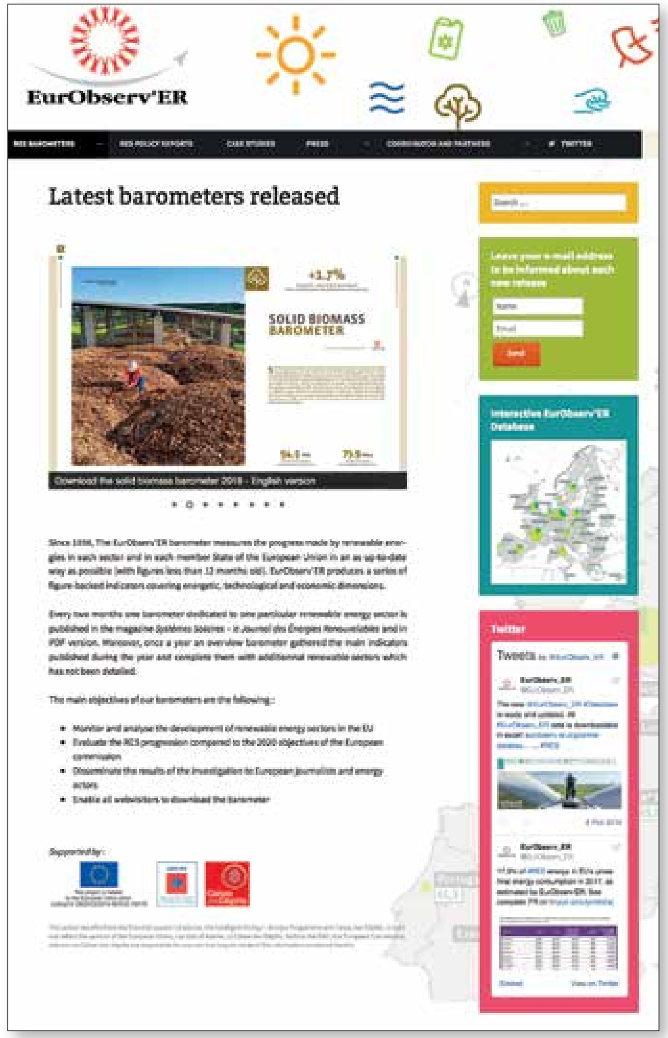

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Schedule for the 2019 EurObserv'ER barometers

Wind power	**>> February 2019**
Photovoltaic	**>> April 2019**
Solar thermal & CSP	**>> June 2019**
Biofuels	**>> September 2019**
Ocean energies	**>> November 2019**
Solid biomass	**>> December 2019**

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