# THE STATE OF RENEWABLE ENERGIES IN EUROPE

EDITION 2019

*19th EurObserv'ER Report*

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

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# A CHALLENGE

## *Vincent Jacques le Seigneur, president of Observ'ER*

***Every year for the last twenty years, Observ'ER with input from its partners has produced the European renewable energy barometer[1]. This freeze frame shows that the mean renewably-sourced share of energy has steadily risen (by 0.5% p.a.) and now gravitates around 18%, which is close to the Community target (20% in 2020).***

If we narrow our focus to renewable electricity, the results are also significant if not noteworthy, as we bear in mind that this transition has been achieved in less than twenty years. Almost a third of European electricity (32.1%) is now renewably sourced. The 8% growth spurt in 2018 over the 2017 level equates to a 78.3-TWh increase in production, or more than Belgium's total electricity output.

However, a snapshot at time T also reveals that the Member States' results are not all equal. The share of renewable electricity dominates the mix of five Member States – Austria (73.1%), Sweden (66.2%), Denmark (62.4%), Latvia (53.5%) and Portugal (52.2%). This contrasts with the under-10% share of four countries – Malta, Hungary, Luxembourg and Cyprus. Admittedly, some countries enjoy natural resources and/or climates that are more conducive than others to developing renewable energies. But they are not the only reasons, because there is no shortage of sunshine in the above two small Mediterranean countries, and it is hard to see what is missing from Hungary that its Central European neighbours have.

Another finding is that a country's wealth or GDP does not make the difference, as demonstrated by the countries that are furthest away from their 2020 objectives – the Netherlands, France, Ireland, the UK, Belgium and others. Rather, everything tends to prove that energy transition and the move away from fossil to renewable sources is first and foremost a question of ambitious, steadfast government policies.

What this barometer also shows, is that not all the sectors are in the same boat. The best in class, only in terms of growth, is hydropower. Even then, make no mistake... its score is only the result of better rainfall after years of drought. Besides, in Europe, almost all the potential is fully harnessed (excluding small hydropower) and the funding of major projects is increasingly problematic.

The same does not apply to wind energy whose positive performance reflects the efforts made by the front runners leading the pack, primarily the UK, Germany and France. Despite all the legal hearings and holdups, wind energy is the top renewable electricity generating sector in Europe. While the onshore segment marks time, the offshore installations are an excellent vector for growth with more powerful, less controversial installations that now offer a competitive, subsidy-free per kWh cost.

As for solar energy, it aspires to reach the top. Its output may well be three times less than wind energy, but the year's recorded growth of more than 8% demonstrates its strong drive. Given the continuous drop in module prices and the maintenance of incentive policies, this momentum will not run out of steam. As the best distributed renewable energy, photovoltaic also benefits from the appeal of self-consumption which is now encouraged as close as possible to the production site without suffering the opprobrium of public opinion like wind energy. "Decentralized" solar energy (photovoltaic panels on houses, factories or supermarkets, in contrast with major solar farms) will account for half of solar energy's expected growth.

Progress is much slower as regards renewable heat, which despite the relative stability of overall consumption, is struggling to get past the 20% mark (having risen from 19.5% in 2017 to 19.7% in 2018 of heating and cooling consumption). The explanation is to be found in the milder winters and improved building insulation, which reduces heating requirements. Yet renewable energies are used much more for space heating than for other heat uses (industrial processes, domestic hot water, etc.) whose needs do not change. Therefore, they are much more affected by this contraction than conventional energies, especially solid biomass (which accounts for more than ¾ of the renewable energy input to heating).

Although the 2020 target has not been achieved, the Member States have already decided to raise the renewable share target to 32% of the energy mix by 2030. While this target is no longer binding for the individual Member States, it is collectively binding and should be boosted by the new European Commission's first programme, the Green New Deal, voted by the European Parliament. The stakes are high, it is a matter of urgency, and the Member States are bound to be judged by their results. They only have ten years to get there. That is some challenge. ■

**1.** *All the results presented are 2018 consolidated data.*

# ENERGY INDICATORS

**EurObserv'ER has been gathering data on European Union renewable energy sources for twenty years to describe the state and development of the sectors in themed barometers. The first part of this opus is a summary of the barometers released in 2019 for the wind energy, solar photovoltaic, solar thermal, CSP, biofuel, ocean energies and solid biomass sectors. The summaries have provided the opportunity to consolidate all the energy indicators with the official (consolidated) 2017 and 2018 data.**

**Sectors for which no themed barometer was published in 2019 – namely hydropower, geothermal energy, heat pumps, biogas and renewable municipal waste – have also been analysed and monitored in detail using the latest official data for 2017 and 2018.**

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

### *Methodological note*

*The tables use the latest available figures for each sector. Given the publication date of this edition, the data published by EurObserv'ER has been comprehensively reconciled with that of the Eurostat online database that was updated on 30 January 2019 and the specific Renewable Energy Directive indicator data supplied by the Eurostat SHARES tool (SHort Assessment of Renewable Energy Sources), with the version updated on 28 January 2020. This reconciliation affects the indicators that cover electricity output, electrical capacity, final energy consumption and derived heat from heating or cogeneration plants.*

*As for the market indicators for segments that are not monitored by Eurostat, such as the market data for the various types of heat pumps (number of units sold) or the various types of solar thermal collectors (m² installed), the source of indicators used is that of EurObserv'ER. In the case of ocean energies and CSP, EurObserv'ER also publishes specific indicators including pilot projects and prototypes to point up their momentum and activity.*

*The energy indicators presented as being sourced from Eurostat are those defined in the methodological guide of the annual Renewable Questionnaire used by both Eurostat and the International Energy Agency that is available through the following link: https://ec.europa.eu/eurostat/web/energy/methodology/annual*

*Electrical capacity data thus refers to the net maximum capacity defined as the maximum active power that can be supplied, continuously, with all plants running, at the point of outlet to the network as of 31 December of the year and is expressed in MW.*

*As for the "heat" data, distinction is made between gross heat production (from the transformation sector) and final energy consumption in line with the Eurostat definitions. Gross heat production covers the total heat production in heating and cogeneration plants (combined heat and electricity production – CHP plants). It encompasses the heat used by the installation's auxiliary equipment that uses hot fluids (space heating, liquid fuel heating, etc.) and installation/network heat exchange losses, as well as the heat in chemical processes used as a form of primary energy. In self-producing units, only the part of the heat sold onwards to a third party is included, while the heat used by the firm for its own processes is excluded from the statistics.*

*Final energy consumption represents the sum of the energy consumption by end-users such as households, industry and agriculture. It is the energy delivered to the end-user for all energy uses. It implies that the energy used for transformation processes and used in own use of energy producing industries is excluded.*

*As for the gross electricity and heat production data, distinction is made between plants that only produce electricity or heat and combined heat and power plants. For French indicators, overseas departments are always included. The UK has been included in all graphs showing the 2020 projections of NREAPs.*

# WIND POWER

## EU WIND ENERGY CAPACITY RISES TO 179.1 GW IN 2018

In the wake of 2017, an exceptional record installation year, the European Union wind energy sector saw fewer connections in 2018. Eurostat reports that the EU added 10.5 GW of capacity compared to 14.1 GW in 2017 (i.e. a 26.7% drop). Net maximum wind energy electricity capacity – the maximum active capacity that can be continuously supplied – of the EU, **both onshore and offshore**, rose to 179.1 GW by 31 December 2018. This general trend is mainly attributed to the sharp year-on-year drop in newly-connected capacity in the European Union's three main markets, namely Germany (a 46.9% drop to 3 263 MW), the UK (a 36.8% drop to 2 186 MW) and France (a 27.5% drop to 1 401 MW).

However, not all the Member States followed suit, as the installation levels of a significant number of Western and Northern European countries clearly picked up, some displaying three-figure growth rates. This is true for Sweden (689 MW of additional capacity, 291.5% growth), Denmark (631 MW, 158.5% growth), and Spain (281 MW, 108.6% growth). Italy also put in a good performance with double-figure growth (494 MW, 40.0% growth).

Market weakness is an underlying trend in many countries whose wind energy activity is or has almost been at a standstill for several years. Roughly half the European Union Member States' wind turbine bases have not expanded. One reason for this is that some of them have already reached their European renewable energy targets for 2020 (or are very close to doing so).

## ADDITIONAL OFFSHORE CAPACITY OF ALMOST 3 GW

While across the EU the drop in new onshore wind energy connections was tangible, offshore wind energy provided a different picture. According to Eurostat, the EU's net maximum offshore wind energy electricity capacity stood at 18 731.9 MW in 2018, which

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## 1

*Wind power net capacity installed* in the European Union at the end of 2018 (MW)*

| | 2017 | *of which offshore* | 2018 | *of which offshore* |
|---|---|---|---|---|
| Germany | 55 580.0 | *5 406.0* | 58 843.0 | *6 396.0* |
| Spain | 23 124.5 | | 23 405.1 | |
| United Kingdom | 19 584.8 | *6 987.9* | 21 770.4 | *8 216.5* |
| France | 13 499.4 | | 14 900.1 | |
| Italy | 9 736.6 | | 10 230.2 | |
| Sweden | 6 611.0 | *203.0* | 7 300.0 | *203.0* |
| Denmark | 5 489.6 | *1 263.8* | 6 120.6 | *1 700.8* |
| Poland | 5 759.4 | | 5 766.1 | |
| Portugal | 5 124.1 | | 5 172.4 | |
| Netherlands | 4 202.0 | *957.0* | 4 393.0 | *957.0* |
| Ireland | 3 318.0 | | 3 676.1 | |
| Belgium | 2 796.5 | *877.2* | 3 260.7 | *1 185.9* |
| Austria | 2 886.7 | | 3 132.7 | |
| Romania | 3 029.8 | | 3 032.3 | |
| Greece | 2 624.0 | | 2 877.5 | |
| Finland | 2 044.0 | *72.7* | 2 041.0 | *72.7* |
| Bulgaria | 698.4 | | 698.9 | |
| Croatia | 576.1 | | 586.3 | |
| Lithuania | 518.0 | | 533.0 | |
| Hungary | 329.0 | | 329.0 | |
| Czechia | 308.2 | | 316.2 | |
| Estonia | 311.8 | | 310.0 | |
| Cyprus | 157.7 | | 157.7 | |
| Luxembourg | 119.7 | | 122.9 | |
| Latvia | 77.1 | | 78.2 | |
| Slovenia | 5.0 | | 5.2 | |
| Slovakia | 4.0 | | 3.0 | |
| Malta | 0.1 | | 0.1 | |
| **Total EU 28** | **168 515.3** | *15 767.6* | **179 061.7** | *18 731.9* |

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

is an additional 2 964.4 MW and similar to the sector's connection achievement of 2017 (3174.6 MW). Seven European Union countries (see table 1) operate the total offshore wind turbine base capacity, bearing in mind that Spanish and French pilot sites were not officially included in the 2018 statistics. Offshore wind energy thus accounted for 28.1% of the additional capacity connected in 2018, compared to 22.1% in 2017.

The UK and Germany again spearheaded offshore installation activity. According to data released by the BEIS (the Department for Business, Energy and Industrial Strategy) quoted by Eurostat, the UK added 1 228.7 MW of capacity in 2018 (1 694.5 MW in 2017), bringing the country's offshore wind power to 8 216.5 MW at the end of 2018. The fully-connected wind farms include the Walney 3 Extensions Phase 1 – West (66 MW) and Phase 2 – East (329 MW), Galloper (277.2 MW), Rampion (220.8 MW), Race Bank (50.4 MW), EOWDC (93.2 MW), as well as the partial connection of the Beatrice 2 Wind Farm (273 MW). Germany was the second most active country with 990 MW connected in 2018 (1275 MW in 2017), taking its offshore wind farm capacity to 6 396 MW. This additional capacity equates to the full or partial commissioning of the Borkum Riffgrund 2 (450 MW) and Merkur (396 MW) wind farms in the North Sea and Wikinger (350 MW) and Arkona (384 MW) wind farms in the Baltic Sea. Denmark came third with 437 MW connected in 2018 according to the Danish Energy Agency. In 2018, it had 1 700.8 MW of connected offshore capacity, primarily due to the commissioning of the Horns Rev 3 Wind Farm (407 MW). Belgium stood out by connecting the Rentel Wind Farm (309 MW), which made it the fourth EU country to pass the 1-GW offshore connected threshold with 1185.9 MW. It inched forwards overtaking the Netherlands (957 MW) which did not connect any extra offshore capacity.

### 377.4 TWH PRODUCED IN 2018

With an actual production of 377.4 TWh, wind power maintained in 2018 its status as the first renewable sector for the production of electricity, ahead of hydroelectricity (excluding pumping). Wind power thus represented 11.5% of total gross electricity production in the European Union in 2018 (11% in 2017).

2017 was a particularly windy and favorable year for wind energy. This was less the case in 2018, with a dozen countries (e.g. Sweden, Denmark, Poland, Romania, Austria), having recorded production declines. Wind power production, however, continues to increase across the European Union. According to Eurostat, it increased by 15.5 TWh compared to 2017 (+ 4.3%).

This can mainly be ascribed to offshore wind energy, whose output increased by 7.5 TWh to 58.6 TWh (14.7% more than in 2017). The offshore wind energy share of total EU wind power output increases every year (14.1% in 2017, 15.5% in 2018). The three countries that contributed most to this increase were the UK (a 7.3-TWh increase – a total of 56.9 TWh), Germany with an additional 4.3 TWh (a total of 110.0 TWh in 2018), and France (which added 4.0 TWh – a total of 28.6 TWh). The distinction of the UK's wind power output (21,8 TWh in 2018) is that almost half of it (46.9% in 2018) is based on its offshore installations.

## 2

*Electricity production from wind power in European Union in 2017 et 2018 (TWh)*

| | 2017 | *of which offshore* | 2018 | *of which offshore* |
|---|---|---|---|---|
| Germany | 105.693 | *17.675* | 109.951 | *19.467* |
| United Kingdom | 49.633 | *20.916* | 56.904 | *26.687* |
| Spain | 49.127 | | 50.896 | |
| France | 24.609 | | 28.599 | |
| Italy | 17.742 | | 17.716 | |
| Sweden | 17.609 | *0.670* | 16.623 | *0.550* |
| Denmark | 14.780 | *5.180* | 13.899 | *4.630* |
| Poland | 14.909 | | 12.799 | |
| Portugal | 12.248 | | 12.617 | |
| Netherlands | 10.569 | *3.700* | 10.564 | *3.630* |
| Ireland | 7.444 | | 8.640 | |
| Belgium | 6.514 | *2.870* | 7.465 | *3.411* |
| Romania | 7.407 | | 6.322 | |
| Greece | 5.537 | | 6.300 | |
| Austria | 6.572 | | 6.030 | |
| Finland | 4.795 | *0.102* | 5.839 | *0.238* |
| Croatia | 1.204 | | 1.335 | |
| Bulgaria | 1.504 | | 1.318 | |
| Lithuania | 1.364 | | 1.144 | |
| Estonia | 0.723 | | 0.636 | |
| Czechia | 0.591 | | 0.609 | |
| Hungary | 0.758 | | 0.607 | |
| Luxembourg | 0.235 | | 0.255 | |
| Cyprus | 0.211 | | 0.221 | |
| Latvia | 0.150 | | 0.122 | |
| Slovenia | 0.006 | | 0.006 | |
| Slovakia | 0.006 | | 0.006 | |
| Malta | 0.000 | | 0.000 | |
| **Total EU 28** | **361.939** | *51.112* | **377.423** | *58.613* |

*Source: Eurostat*



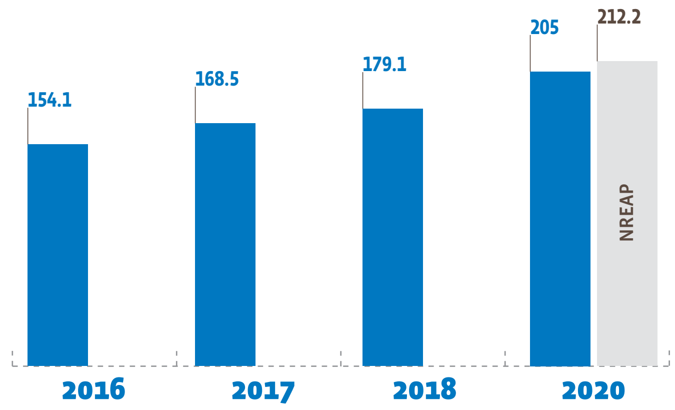


### INTEGRATION SPEED IS SUBJECT TO POLITICAL CHOICES

While renewable energies, such as onshore wind energy and fixed off-shore wind energy, have won the price competitiveness battle, the issue of integration speed in the EU's electricity mix hangs in the balance. Over the next decade, it will depend on the strength of the common commitment adopted in the new Renewable Energy Directive that aims for a 32% share of renewable energy in gross final energy consumption by 2030. A major milestone will be the publication by the Member States of the final version of their National Energy and Climate Plans at the start of 2020. They explain how they envisage their energy transitions nationally and collectively over the next decade to contribute to climate and energy targets. Countries have until 2023 to modify these plans, which will be submitted for approval by the European Commission, to accommodate the new climate ambitions if European legislation is revised by June 2021. While onshore wind energy will play an increasing role in decarbonising the European economy, offshore wind energy will be upscaled, primarily with the arrival on the market of turbines with more than 10 MW of capacity that offer annual load factors of about 60%. Fully harnessing offshore wind energy's potential in Europe for the benefit of all the EU countries is one of the priority areas of the European Green Deal presented on 11 December 2019 by the new European Commission, one of whose most ambitious challenges is to decarbonise the energy system by 2050. ■

## 3

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




*Source: EurObserv'ER*

# PHOTOVOLTAIC

## THE GLOBAL MARKET TOPS 100 GW IN 2018

New directions taken by the major global markets' policy decision makers flattened global market performance in 2018 after a run of robust growth between 2013 and 2017 (from 37.3 to 103.6 GW, revised figure). In 2018, according to the revised data provided by the IEA PVPS, at least 103.2 GW of new photovoltaic capacity was installed across the world, which is a similar installation level to that of the previous year. This new capacity raises global photovoltaic capacity to 512.3 GW. We remind you that in 1998, global photovoltaic capacity was plateauing at just over 0.2 GW (234 MW), so you can see how far the market has come in twenty years.

The 2018 global market is marked by the Chinese market's contraction over the year (from 53 068 to 44 260 MW), reflecting China's determination to keep its market's growth under control, give priority to connecting the first solar power plants to compete with coal and rein in electricity price rises. It is also characterized by the United States market's slight decline (from 10 845 MW to 10 680 MW) curbed by the introduction of customs duties on cell and module imports. This contrasts with the European Union market, which is clearly on an upturn and is going counter current to the global market. The global market should return to growth as early as 2019 and perform better in 2020.

## ACTIVITY PICKS UP IN THE EUROPEAN MARKET

The European Union's solar photovoltaic capacity picked up strongly in 2018, when according to Eurostat, the European Union added 7 985.2 MW of net capacity, compared to a 5 659.1 MW increase in 2017 (i.e., 41.1% growth). Europe's maximum net installed capacity is now 114 679.7 MW (table 1). This upturn signifies the completion of the transition phase to market mechanisms for large power plants. European calls for tender have also driven down module prices on the global market, partly due to lower Chinese demand, and the European Commission end-of-year removed its antidumping taxes on Chinese modules and cells that came into effect during the last quarter of 2018. The measure's full effect will be felt in 2019 and 2020.

All in all, the drop in module prices and regular calls for tender in the main European solar markets (Germany, Netherlands, France) have breathed new impetus into the sector. Solar photovoltaic also benefits from a strong self-consumption trend in the residential and collective sectors, enhanced by a new hike in electricity prices across Europe. The fact that the European market can stand on its own two feet again, through ground-based power plants and distributed solar power (residential and roof-mounted solar), will enable it to make much faster progress.

## 123 TWH PRODUCED IN THE EUROPEAN UNION

In 2018, sunshine conditions were generally poorer than in 2017 in Southern Europe, with lower load factors in Spain (from 1 803 to 1 654 hours) and Italy (from 1 239 to 1 127 hours). However, they were a little better in the Northern half


EAU DE PARIS

## 1

*Installed solar photovoltaic net capacity* in the European Union at the end of 2018 (MW)*

| | 2017 | 2018 |
|---|---|---|
| Germany | 42 291.0 | 45 179.0 |
| Italy | 19 682.3 | 20 107.6 |
| United Kingdom | 12 781.8 | 13 118.3 |
| France | 8 610.4 | 9 617.0 |
| Spain | 4 723.0 | 4 763.5 |
| Netherlands | 2 903.0 | 4 522.0 |
| Belgium | 3 616.2 | 3 986.5 |
| Greece | 2 605.5 | 2 651.6 |
| Czechia | 2 069.5 | 2 075.1 |
| Austria | 1 269.0 | 1 437.6 |
| Romania | 1 374.1 | 1 385.8 |
| Bulgaria | 1 035.6 | 1 032.7 |
| Denmark | 906.4 | 998.0 |
| Hungary | 344.0 | 726.0 |
| Portugal | 579.2 | 667.4 |
| Poland | 287.1 | 562.0 |
| Slovakia | 528.0 | 472.0 |
| Sweden | 244.0 | 428.0 |
| Slovenia | 246.8 | 221.3 |
| Finland | 82.0 | 140.0 |
| Malta | 112.3 | 131.3 |
| Luxembourg | 128.1 | 130.6 |
| Cyprus | 110.0 | 118.5 |
| Lithuania | 73.8 | 82.0 |
| Croatia | 60.0 | 67.7 |
| Estonia | 15.0 | 31.9 |
| Ireland | 15.7 | 24.2 |
| Latvia | 0.7 | 2.0 |
| **Total EU 28** | **106 694.5** | **114 679.7** |

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

of Europe with higher load factors witnessed in Germany (from 931 to 1 011 hours) and the UK (from 898 to 980 hours). According to Eurostat data released in January, solar photovoltaic electricity output in the European Union reached 123 TWh, which is 8.3% more than in 2017. Thus in 2018, solar photovoltaic accounted for 3.8% of the European Union's gross electricity output (3.4% in 2017). In some countries like Germany, Italy and Greece, the solar power share is already more than 7% (7.1% In Germany, 7.8% in Italy and 7.1% in Greece).

### ALMOST 3 GW ADDED IN GERMANY

The German solar photovoltaic market has continued its upswing, but much more clearly this time. According to Eurostat, it connected 2 888 MW of net additional capacity to the grid in 2018, compared to 1 614 MW in 2017, which equates to an improvement of 78,9%, and takes the German installed base to 45 179 MW at the end of the year. In addition to the scheduled tenders, the government launched a set of tenders for installations of capacities of ≥ 750 kW for an accumulated volume of 4 GW by 2021, to accelerate deployment of solar photovoltaic and approach its climate target. Having observed higher tender prices during 2019 compared to 2018, primarily because of the 10-MW limitation on solar farm capacity, the trend has reverted to lower prices. The tender due by 1 October, for a target volume of 153 MW, posts an average price of € 49 per MWh (compared to € 54.70 per MWh during the previous period). Like Spain, which enjoys much better sunshine conditions, the first unsubsidized solar farms



## 2

*Electricity production from solar photovoltaic in the European Union countries in 2017 and 2018 (in TWh)*

| | 2017 | 2018 |
|---|---|---|
| Germany | 39.401 | 45.784 |
| Italy | 24.378 | 22.654 |
| United Kingdom | 11.475 | 12.857 |
| France | 9.585 | 10.569 |
| Spain | 8.514 | 7.877 |
| Belgium | 3.307 | 3.902 |
| Greece | 3.991 | 3.791 |
| Netherlands | 2.208 | 3.693 |
| Czechia | 2.193 | 2.359 |
| Romania | 1.856 | 1.771 |
| Austria | 1.269 | 1.438 |
| Bulgaria | 1.403 | 1.343 |
| Portugal | 0.992 | 1.006 |
| Denmark | 0.751 | 0.953 |
| Hungary | 0.349 | 0.620 |
| Slovakia | 0.506 | 0.585 |
| Sweden | 0.230 | 0.407 |
| Poland | 0.165 | 0.300 |
| Slovenia | 0.284 | 0.255 |
| Cyprus | 0.172 | 0.199 |
| Malta | 0.162 | 0.190 |
| Luxembourg | 0.108 | 0.120 |
| Finland | 0.049 | 0.090 |
| Lithuania | 0.068 | 0.087 |
| Croatia | 0.079 | 0.075 |
| Estonia | 0.014 | 0.031 |
| Ireland | 0.011 | 0.017 |
| Latvia | 0.000 | 0.001 |
| **Total EU 28** | **113.521** | **122.972** |

***Source: Eurostat***

(not subjected to tender capacity constraints) are starting to emerge in Germany. The utility, EnbW, is getting ready to start construction of a >180 MW solar power plant at Weesow-Willmersdorf at the beginning of 2020 – the country's biggest –with no Feed-in Tariff, nor top-up remuneration. Another trend is that the self-consumption market for the smallest is increasingly linked to storage. According to the German Solar Association (BSW), the photovoltaic battery systems market was about 35 000 units in 2018 (20 000 in 2016, 31 000 in 2017). This figure means that a little less than one out of every two new installations is equipped with an electricity storage system (76 500 new installations in 2018).

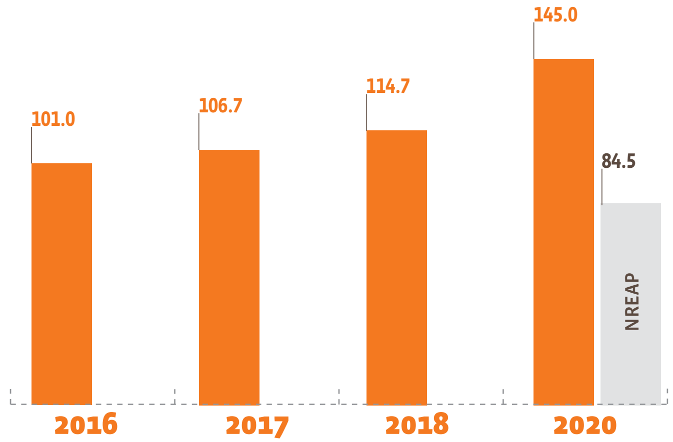
### CONNECTIONS OF MORE THAN ONE GW IN THE NETHERLANDS AND FRANCE

In 2018, the Netherlands' photovoltaic market was particularly buoyant. Eurostat reports that its net connected capacity increased by 1 619 MW, taking the country's total capacity by the end of the year to 4 522 MW. This sharp growth was primarily due to the connection of very high-capacity projects financed through the SDE+ programme, but it was also driven by a very active residential photovoltaic market. France is the third and latest EU country to have passed the one-GW connection threshold (adding 1 006.6 MW), which equates to about one hundred MW more than in 2017 (908.4 MW). The country's net maximum photovoltaic capacity stood at 9 617 MW at the end of 2018. On


a more general level, in February 2019 the French Energy Regulatory Commission (CRE) published its "Costs and profitability of large photovoltaic systems in metropolitan France" report which drew a lot of comment from the French specialist energy press. According to the CRE, a significant number of large photovoltaic projects offer similar if not lower production costs than the market prices seen in recent years. This situation is likely to enable the projects in question to develop without public support, as is the case in other European countries.

3

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




*Source: EurObserv'ER*

## PHOTOVOLTAIC EXPERIENCES RE-BIRTH IN THE EUROPEAN UNION

As Europe's 2020 deadlines approach, many countries will have to implement their solar PV projects faster if they are to fulfil their renewable energy obligations. The European Union will thus experience high demand in the next two years, the connected capacity is expected to double in 2019 (in excess of 16 GW). According to EurObserv'ER, which is revising its forecasts upwards again, this growth should be enough to achieve at least 145 GW by 2020 (graph 3). Furthermore, the prices guaranteed by tenders for large solar farms are increasingly below the average electricity prices observed on the market, which fully justifies the European Commission-backed market mechanism introduction policy. At the same time, new business models are also starting to emerge for very big power plants that no longer need subsidies such as direct contracts between producers and major consumers, with for instance projects for several GW already announced in Spain.

Another piece of good news is that the Renewable Energy Directive of 11 December 2018 created a framework that is highly conducive to solar self-consumption. The Directive requires Member States to set up a regulatory framework to enable all individuals to produce and use their own output, store and sell electricity, without having to bear disproportionate expenses. Member States are under obligation to incorporate the self-consumption provisions prior to 30 June 2021. Distributed solar, be it backed by a policy that encourages individual and collective self-consumption or intended for total resale, will remain an important aspect of solar power development. This new framework can now be translated politically by very ambitious national Climate-Energy Plan targets for 2030 and by the guarantee of seeing the share of solar power increase significantly over the next decade. ■

# SOLAR THERMAL

In a context where the consequences of climate warming are increasing all the time, solar thermal technology which harnesses the sun's radiation to convert it directly into heat, finally appears to have come out from the cold. According to EurObserv'ER, the European market, which has been on a downward trend since 2009, at last found its way back to growth in 2018 by increasing from just 2.08 million $m^2$ to 2.26 million $m^2$ (revised figures), equating to 8.6% year-on-year growth. This market data includes systems that use flat-glazed collectors, vacuum tube collectors and unglazed collectors… technologies intended for domestic hot water production, heating, and the production of heat and hot water for heating networks and industry.

## SOLAR THERMAL MARKET TRENDS ALL OVER THE PLACE

While market growth at the scale of the EU has turned positive again, development of the national markets is still piecemeal. The most positive development in 2018 comes from Poland, whose sector made a 179% leap to 310 000 $m^2$. The turnaround can be put down to implementation of the municipal tenders announced in 2017 and enacted on early in 2018. These local programmes, that benefit from European funds, were introduced to tackle the smog generated by the domestic coal-fired heating appliances that dominate the country's heating sector.

Another piece of good news is confirmation of the Greek market's growth that increased by 4% in 2018 to reach 328 500 $m^2$, having already grown by 16.2% between 2016 and 2017 (from 272 000 to 316 000 $m^2$). The EBHE (Greek Solar Industry Association) states that the additional installed surface outstrips decommissioned surface (i.e. 233 400 $m^2$ removed in 2018), which means that the solar thermal base in service is expanding. Just as in 2017, the EBHE ascribes this growth to a set of positive factors starting with falling system prices due to keen competition between the players, the rise of e-business, the arrival of major DIY retailers on this market and slight improvement in the Greek economy.

Spain's market growth was a little weaker (2%), but confirms the shift observed over 2016–2017 when market decline was limited to 5%. This return to growth can be ascribed to better new house start figures, as a direct consequence of Spain's thermal regulations (Technical Building Code – CTE) that specify solar thermal for all new build. This is contrasted by a few formerly expanding markets that are continuing to decline. This applies to the German market in particular. While it is still the European Union's leading market with 573 500 $m^2$ installed in 2018, it is fluctuating and posted a new drop of 11.8% in the 12-month period. The main reason for this decline is waning interest in combined solar systems (that supply both heating and hot water). The Italian market was unable to settle down and should again record an 8% drop in 2018 of about 179 400 $m^2$ (including thermosyphon systems). It also suffers from the internecine competition of photovoltaic. In France, the sector experienced overall growth in 2018 despite the fact that its individual solar water heater market had a hard time in mainland France, being "cannibalized" by competition from thermodynamic water heaters. The momentum comes from the French Overseas Territories that enjoy targeted incentives with substantial public funding.

Another market segment, the European solar heat and industrial solar heating networks market is gradually making new inroads with new projects completed in Denmark, Germany, Austria, Spain and France. In Europe, the latest Solar Heat Worldwide 2019 report published by the IEA SHC puts the collector surface connected in 2018 of solar heating networks at 83 760 $m^2$ (58.6 MWth). The report identifies 15 new solar thermal collector fields (> 500 $m^2$) connected to heating networks, six in Denmark (66 800 $m^2$ including two extensions to existing networks), six in Germany (9 380 $m^2$), two in Austria (3 010 $m^2$) and one in Turkey (4 575 $m^2$). The biggest heating network system has been installed in the Danish town of Aabybro with a collector surface of 26 195 $m^2$ (18.3 MWth).

## A EUROPEAN COLLECTOR BASE OF 53.5 MILLION $M^2$ AT THE END OF 2018

While official bodies do not specifically monitor market data to produce indicators, the total solar thermal base in service is monitored as part of the annual Renewable and Waste Questionnaire (used by both Eurostat and the International Energy Agency). This monitoring uses individual country decommissioning hypotheses, which explains some of the gaps between the installed base indicators published in January by Eurostat and the estimates made by EurObserv'ER or European solar thermal industry representatives from "Solar Heat Europe". Hence, Eurostat put the total European Union solar thermal collector base at 53.4 million $m^2$ at the end of 2018. If one adds an estimate of the total capacity (in $m^2$) of the three Baltic countries (not officially referenced), the surface area of the EU fleet approaches 53.5 million $m^3$, with an additional cumulative surface estimated of 1 323 615 $m^2$. The reason for difference with the market data is that older installations have been decommissioned. This decommissioning factor should intensify in the next few years as the growth of operations dating back to the first decade of the millennium, culminated in almost 4.6 million $m^2$ in 2008. According to official data, the German, Austrian and Swedish bases are already shrinking slightly (since 2017), as the decommissioned surface is greater than the newly-installed surface. This trend raises the issue of maintaining solar heat's input to the European Union's targets if the market fails to pick up significantly and sustain growth. Eurostat puts solar thermal heat's contribution at 2.5 Mtoe at the scale of the EU in 2018 (2.3 Mtoe in 2017), i.e. an increase of 6.8%.

## 6% OF THE EUROPEAN HEAT DEMAND IN 2030?

Even if the solar thermal market's late return to growth is consolidated in 2019 and 2020, it will not suffice to enable the European Union countries to reach their self-imposed targets for 2020 (6.45 Mtoe). EurObserv'ER reckons

## 1

*Annual installed surfaces in 2017 per type of collectors (in m²) and total installed capacity (in MWth)*

| | Glazed collectors | | Unglazed collectors | Total (m²) | Total capacity (MWth) |
|---|---|---|---|---|---|
| | Flat plate collectors | Vacuum collectors | | | |
| Germany | 573 000 | 57 000 | 20 000 | 650 000 | 455.0 |
| Greece | 312 840 | 3 160 | 0 | 316 000 | 221.2 |
| Spain | 190 666 | 7 187 | 3 652 | 201 505 | 141.1 |
| Italy | 171 600 | 23 400 | 0 | 195 000 | 136.5 |
| France | 117 076 | 0 | 5 500 | 122 576 | 85.8 |
| Poland | 107 200 | 3 900 | 0 | 111 100 | 77.8 |
| Austria | 99 770 | 1 060 | 630 | 101 460 | 71.0 |
| Portugal | 55 105 | 0 | 0 | 55 105 | 38.6 |
| Cyprus | 36 218 | 0 | 0 | 36 218 | 25.4 |
| Belgium | 30 200 | 5 200 | 0 | 35 400 | 24.8 |
| Denmark | 31 500 | 0 | 0 | 31 500 | 22.1 |
| Netherlands | 21 150 | 6 162 | 2 621 | 29 933 | 21.0 |
| United Kingdom | 25 500 | 2 500 | 0 | 28 000 | 19.6 |
| Bulgaria | 24 000 | 0 | 0 | 24 000 | 16.8 |
| Czechia | 16 500 | 7 500 | 0 | 24 000 | 16.8 |
| Slovakia | 24 000 | 0 | 0 | 24 000 | 16.8 |
| Croatia | 22 700 | 0 | 0 | 22 700 | 15.9 |
| Ireland | 11 254 | 9 049 | 0 | 20 303 | 14.2 |
| Hungary | 12 000 | 5 000 | 180 | 17 180 | 12.0 |
| Romania | 7 200 | 9 600 | 0 | 16 800 | 11.8 |
| Finland | 5 000 | 0 | 0 | 5 000 | 3.5 |
| Luxembourg | 3 600 | 0 | 0 | 3 600 | 2.5 |
| Sweden | 2 867 | 341 | 0 | 3 208 | 2.2 |
| Lithuania | 750 | 1 250 | 0 | 2 000 | 1.4 |
| Latvia | 1 350 | 250 | 0 | 1 600 | 1.1 |
| Slovenia | 1 300 | 250 | 0 | 1 550 | 1.1 |
| Estonia | 900 | 600 | 0 | 1 500 | 1.1 |
| Malta | 518 | 130 | 0 | 648 | 0.5 |
| Total EU 28 | 1 905 764 | 143 539 | 32 583 | 2 081 886 | 1 457.3 |

*Source: EurObserv'ER*

## 2

*Annual installed surfaces in 2018* per type of collectors (in m²) and total installed capacity (in MWth)*

| | Glazed collectors | | Unglazed collectors | Total (m²) | Total capacity (MWth) |
|---|---|---|---|---|---|
| | Flat plate collectors | Vacuum collectors | | | |
| Germany | 505 000 | 68 500 | 0 | 573 500 | 401.5 |
| Greece | 328 500 | 0 | 0 | 328 500 | 230.0 |
| Poland | 300 000 | 10 000 | 0 | 310 000 | 217.0 |
| Spain | 191 966 | 9 698 | 3 866 | 205 530 | 143.9 |
| Italy | 157 900 | 21 500 | 0 | 179 400 | 125.6 |
| France | 150 622 | 0 | 5 500 | 156 122 | 109.3 |
| Austria | 99 734 | 1 038 | 617 | 101 389 | 71.0 |
| Portugal | 56 000 | 1 000 | 0 | 57 000 | 39.9 |
| Denmark | 55 808 | 0 | 0 | 55 808 | 39.1 |
| Cyprus | 40 812 | 0 | 0 | 40 812 | 28.6 |
| United Kingdom | 35 000 | 2 128 | 0 | 37 128 | 26.0 |
| Netherlands | 28 089 | 5 409 | 2 621 | 36 119 | 25.3 |
| Belgium | 25 000 | 4 900 | 0 | 29 900 | 20.9 |
| Czechia | 16 500 | 7 500 | 0 | 24 000 | 16.8 |
| Bulgaria | 23 498 | 0 | 0 | 23 498 | 16.4 |
| Ireland | 22 191 | 0 | 0 | 22 191 | 15.5 |
| Hungary | 16 000 | 5 000 | 0 | 21 000 | 14.7 |
| Croatia | 18 850 | 592 | 0 | 19 442 | 13.6 |
| Romania | 7 200 | 9 600 | 0 | 16 800 | 11.8 |
| Finland | 5 000 | 1 000 | 0 | 6 000 | 4.2 |
| Slovakia | 5 000 | 0 | 0 | 5 000 | 3.5 |
| Luxembourg | 3 418 | 0 | 0 | 3 418 | 2.4 |
| Lithuania | 750 | 1 250 | 0 | 2 000 | 1.4 |
| Sweden | 1 755 | 167 | 0 | 1 922 | 1.3 |
| Latvia | 1 350 | 250 | 0 | 1 600 | 1.1 |
| Slovenia | 1 300 | 250 | 0 | 1 550 | 1.1 |
| Estonia | 900 | 600 | 0 | 1 500 | 1.1 |
| Malta | 486 | 122 | 0 | 608 | 0.4 |
| Total EU 28 | 2 098 629 | 150 504 | 12 604 | 2 261 737 | 1 583.2 |

** Estimate. Source: EurObserv'ER*

## 3

*Cumulated capacity of thermal solar collectors* installed in the European Union in 2017 and 2018*** *(in m² and in MWth)*

| | 2017 | | 2018 | |
|---|---|---|---|---|
| | m² | MWth | m² | MWth |
| Germany | 19 091 000 | 13 364 | 19 269 000 | 13 488 |
| Austria | 5 172 185 | 3 621 | 5 123 303 | 3 586 |
| Greece | 4 596 000 | 3 217 | 4 691 000 | 3 284 |
| Italy | 4 050 666 | 2 835 | 4 196 376 | 2 937 |
| Spain | 3 997 082 | 2 798 | 4 202 770 | 2 942 |
| France | 3 094 442 | 2 166 | 3 218 301 | 2 253 |
| Poland | 2 131 000 | 1 492 | 2 433 000 | 1 703 |
| Denmark | 1 774 747 | 1 242 | 1 830 555 | 1 281 |
| United Kingdom | 1 428 000 | 1 000 | 1 465 128 | 1 026 |
| Portugal | 1 231 105 | 862 | 1 288 104 | 902 |
| Cyprus | 1 043 860 | 731 | 1 064 662 | 745 |
| Belgium | 728 600 | 510 | 748 300 | 524 |
| Netherlands | 649 000 | 454 | 657 000 | 460 |
| Czechia* | 593 000 | 415 | 617 000 | 432 |
| Sweden | 472 000 | 330 | 466 000 | 326 |
| Bulgaria | 378 000 | 265 | 401 498 | 281 |
| Ireland | 311 216 | 218 | 333 407 | 233 |
| Hungary | 308 000 | 216 | 329 000 | 230 |
| Slovenia | 238 750 | 167 | 238 467 | 167 |
| Croatia | 226 700 | 159 | 246 100 | 172 |
| Slovakia | 201 000 | 141 | 206 000 | 144 |
| Romania | 189 000 | 132 | 189 000 | 132 |
| Malta | 72 250 | 51 | 72 860 | 51 |
| Luxembourg | 62 909 | 44 | 66 196 | 46 |
| Finland | 60 000 | 42 | 66 000 | 46 |
| Latvia | 24 520 | 17 | 26 120 | 18 |
| Lithuania | 20 150 | 14 | 22 150 | 16 |
| Estonia | 16 120 | 11 | 17 620 | 12 |
| **Total EU 28** | **52 161 302** | **36 513** | **53 484 917** | **37 439** |

** All technologies included unglazed collectors. ** Estimate.* ***Source: EUROSTAT, except Latvia, Estonia and Lithuania (EurObserv'ER estimations)***







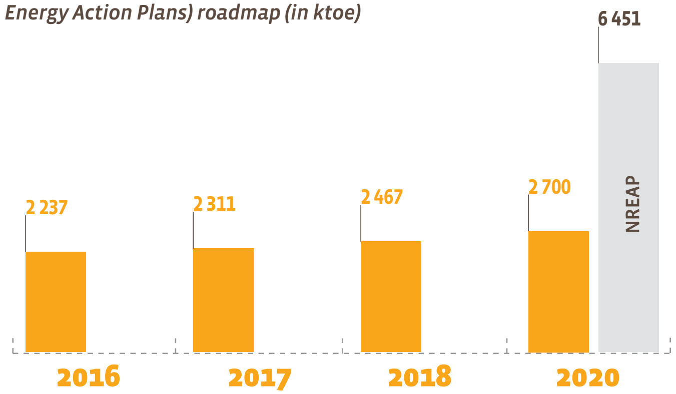
that solar thermal heat's input will only reach 2.7 Mtoe by this timeline (graph 4).

The main barrier to sector development is initial investment, because in the case of solar thermal, most of the energy bill over the installation's twenty-year service life is incurred at the time of purchase. Despite highly competitive energy production costs estimated by Solar Heat Europe at 2 euro cents per kWh for hot water production via thermosyphon system, and less than 3.5 euro cents per kWh for a heating network in Denmark, equipment investment remains an obstacle to market development. Another identified disincentive is changing a heating and hot water production system. The change is rarely programmed but tends to be carried out as an emergency when the existing system breaks down. When the problem is serious and a replacement is required, the fastest option entails opting for a similar solution, which makes it harder to introduce renewable energy solutions. Thus, sales efforts need to be made preventatively to help consumers plan for replacing their systems. One of the main challenges facing the sector is getting involved in modernising the existing boiler base.

Solar thermal's potential remains very high as shown by the "Renewable Energy Prospects for the European Union" report, published by Irena (the International Renewable Energy Agency) in conjunction with the European Commission in 2018. The report studied the most cost-effective renewable energy solution mixes likely to accelerate the rollout of renewable energies by 2030. The conclusions suggest that using solar thermal alongside solar photovoltaic in buildings and industry is one of the most relevant solutions to explore increasing the share of renewable energies sources, that at the same time would even exceed the current goal of 32% by 2030 to reach 34%. In a reference scenario where the renewable energy share only covers 24% of the total heat demand in 2030, solar thermal input would be 3%. In the most ambitious case, the REmap scenario, the renewable energy share would be 34% of heat demand and solar thermal input would be 6.2%. In that case, Irena projects that solar thermal energy in buildings and industry would probably reach 691 PJ (192 TWh) of energy output, which would require 269 MWth (384 million m²) of installed capacity. Of this total, solar thermal energy in buildings alone could generate 571 PJ (158 TWh), equating to 222 MWth (371 million m²) of installed capacity. ■

## 4

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

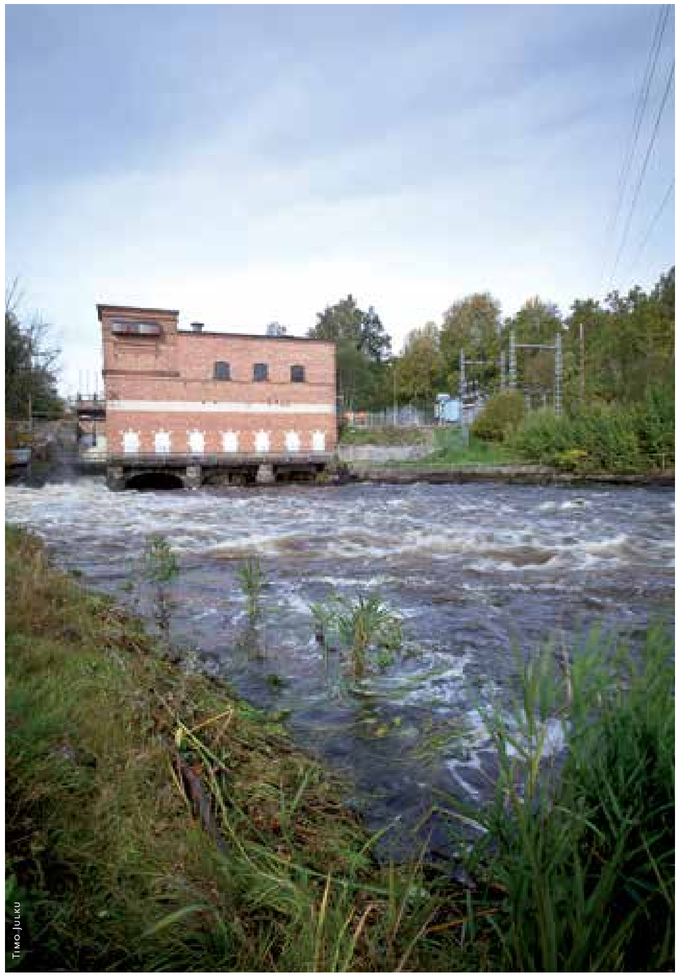



*Source: EurObserv'ER*

# HYDROPOWER

After slumping to a record low in 2017, hydroelectricity production from natural water flow, i.e., disregarding the electricity produced by pumping, recovered well across the European Union in 2018. According to Eurostat, it stood at 349.8 TWh compared to just above 300 TWh in 2017 (300.2 TWh, revised figure). Hydropower output picked up in Southern Europe in 2018 (Italy, Spain, Portugal, Greece) and France, which had recorded significant rainfall shortages the previous year.

As a result, French hydropower output (excluding pumping) bounced back (with 30.6% more than in 2017) to increase by 15.3 TWh and generate 65.3 TWh. In Spain and Portugal where year-to-year variations in output can be significant. Their respective outputs rose by 87.4% (adding 16 TWh for a total of 34.3 TWh) and 110.2% (adding 6.5 TWh, for a total of 12.4 TWh). Italy's output increased by 12.6 TWh (adding 34.8%) to generate 48.8 TWh and Greek output rose by 1.8 TWh (adding 44.9%) for a total of 5.7 TWh.










**1**

*Net capacity* of pure hydro plants, mixed plants and pure pumped plants in the European Union countries in 2017 and in 2018 (in MW)*

| | 2017 | | | | 2018 | | | |
|---|---|---|---|---|---|---|---|---|
| | Pure hydro power | Mixed hydro power | Pure pumped hydro power | Total | Pure hydro power | Mixed hydro power | Pure pumped hydro power | Total |
| France | 18 561 | 5 418 | 1 728 | 25 707 | 18 856 | 5 209 | 1 728 | 25 793 |
| Italy | 15 109 | 3 377 | 3 940 | 22 426 | 15 182 | 3 377 | 3 940 | 22 499 |
| Spain | 14 052 | 2 690 | 3 337 | 20 079 | 14 053 | 2 690 | 3 337 | 20 080 |
| Sweden | 16 403 | 99 | 0 | 16 502 | 16 332 | 99 | 0 | 16 431 |
| Austria | 8 506 | 5 644 | 0 | 14 150 | 8 591 | 5 925 | 0 | 14 516 |
| Germany | 4 449 | 1 178 | 5 493 | 11 120 | 4 456 | 1 129 | 5 355 | 10 940 |
| Portugal | 4 462 | 2 764 | 0 | 7 226 | 4 471 | 2 764 | 0 | 7 236 |
| Romania | 6 328 | 272 | 92 | 6 692 | 6 342 | 268 | 92 | 6 701 |
| United Kingdom | 1 873 | 300 | 2 600 | 4 773 | 1 878 | 300 | 2 600 | 4 778 |
| Greece | 2 693 | 699 | 0 | 3 392 | 2 710 | 699 | 0 | 3 409 |
| Bulgaria | 2 359 | 149 | 864 | 3 372 | 2 366 | 149 | 864 | 3 379 |
| Finland | 3 272 | 0 | 0 | 3 272 | 3 287 | 0 | 0 | 3 287 |
| Slovakia | 1 607 | 0 | 916 | 2 523 | 1 612 | 0 | 916 | 2 528 |
| Poland | 591 | 376 | 1 423 | 2 390 | 592 | 376 | 1 423 | 2 391 |
| Czechia | 1 093 | 0 | 1 172 | 2 265 | 1 093 | 0 | 1 172 | 2 264 |
| Croatia | 1 912 | 281 | 0 | 2 193 | 1 924 | 275 | 0 | 2 200 |
| Latvia | 1 564 | 0 | 0 | 1 564 | 1 565 | 0 | 0 | 1 565 |
| Belgium | 107 | 0 | 1 310 | 1 417 | 108 | 0 | 1 310 | 1 418 |
| Slovenia | 1 167 | 0 | 180 | 1 347 | 1 163 | 0 | 180 | 1 343 |
| Luxembourg | 35 | 0 | 1 296 | 1 331 | 34 | 0 | 1 296 | 1 330 |
| Lithuania | 117 | 0 | 760 | 877 | 117 | 0 | 760 | 877 |
| Ireland | 237 | 0 | 292 | 529 | 237 | 0 | 292 | 529 |
| Hungary | 57 | 0 | 0 | 57 | 57 | 0 | 0 | 57 |
| Netherlands | 37 | 0 | 0 | 37 | 37 | 0 | 0 | 37 |
| Denmark | 9 | 0 | 0 | 9 | 9 | 0 | 0 | 9 |
| Estonia | 7 | 0 | 0 | 7 | 7 | 0 | 0 | 7 |
| Malta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cyprus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total EU 28 | 106 605 | 23 248 | 25 403 | 155 256 | 107 079 | 23 260 | 25 264 | 155 603 |

**Net maximum electrical capacity. Source: Eurostat*

As often happens, the hydroelectricity output trend of Northern Europe's countries was the opposite of the Southern Member States. Output in Sweden, Finland, the Baltics (Estonia, Latvia and Lithuania), and the UK dropped in 2018. Low output levels were also recorded in Germany, Austria and most of Central Europe. The most severe declines in output were in Sweden (2.9 TWh, 4.5% less than in 2017), Germany (2.2 TWh, 10.8% less), Latvia (1.9 TWh, 44.5% less) and Finland (1.5 TWh, 10% less).

Note, that for the purposes of calculating the Member States' renewable energy targets, whose methodology is defined by the Renewable Energy Directive, hydroelectricity production is normalized over the last 15 years to mitigate the effect of variations in runoff. The SHARES statistics tool, used for calculating these targets, adopted 349.7 TWh as the normalized hydroelectricity output across the European Union in 2018... 0.6% more than in 2017 (347.4 TWh).

As for capacity, Eurostat now distinguishes three categories of hydropower plants: Pure hydro plants that only use direct inputs of natural water but have no pumped storage capacity to raise water upstream of the dam. Thus, all their output is qualified as renewable. Mixed hydro plants have natural water input using all or part of the equipment to pump water upstream of the dam. These plants can also generate electricity with the natural flow in addition to the pumped water. The only part of the output qualified as renewable is produced using natural flow.

**2**

*Hydraulic gross electricity production (without pumping) in the European Union (in TWh) in 2017 and 2018*

| | 2017 | 2018 |
|---|---|---|
| France | 50.001 | 65.285 |
| Sweden | 65.143 | 62.210 |
| Italy | 36.199 | 48.786 |
| Austria | 38.294 | 37.638 |
| Spain | 18.322 | 34.334 |
| Germany | 20.150 | 17.974 |
| Romania | 14.494 | 17.664 |
| Finland | 14.772 | 13.301 |
| Portugal | 5.897 | 12.393 |
| Croatia | 5.307 | 7.701 |
| Greece | 3.963 | 5.743 |
| United Kingdom | 5.902 | 5.490 |
| Bulgaria | 2.828 | 5.147 |
| Slovenia | 3.868 | 4.704 |
| Slovakia | 4.324 | 3.590 |
| Latvia | 4.381 | 2.432 |
| Poland | 2.560 | 1.970 |
| Czechia | 1.869 | 1.629 |
| Ireland | 0.692 | 0.694 |
| Lithuania | 0.602 | 0.431 |
| Belgium | 0.270 | 0.314 |
| Hungary | 0.220 | 0.222 |
| Luxembourg | 0.086 | 0.093 |
| Netherlands | 0.061 | 0.072 |
| Estonia | 0.026 | 0.015 |
| Denmark | 0.018 | 0.015 |
| Cyprus | 0.000 | 0.000 |
| Malta | 0.000 | 0.000 |
| Total EU 28 | 300.248 | 349.846 |

*Source: Eurostat*





Lastly, pumped hydroelectric energy storage plants (PHES) or pure pumped storage plants, are not linked to a water course and do not use natural water flow, thus the electricity they generate is not considered as renewable. A PHES comprises two reservoirs at different altitudes. They store the energy by pumping water from the lower reservoir to the upper reservoir when both electricity demand and the market price of electricity are low and restore it when both electricity demand and the price are high. Eurostat gauged the net maximum capacity of the European Union's pure hydro plants at 107 079 MW in 2018 (106 605 MW in 2017), compared to the net maximum capacity of mixed hydro plants at 23 260 MW in 2018 (23 248MW in 2016). If we only consider pure hydro plants, the five most richly endowed countries (2018 data) are France (18 856 MW), Sweden (16 332 MW), Italy (15 182 MW), Spain (14 053 MW) and Austria (8 591MW).

The European Union sector's growth potential hinges on small hydro plants or the modernisation of existing facilities. The potential of sites able to accommodate major power plants is almost depleted or else the sites pose overwhelmingly negative environmental barriers. In contrast, the potential of new small hydropower plants has been significantly affected by environmental legislation such as the EU Water Framework Directive and the setting up of the Natura 2000 network of protected sites, to protect the biodiversity of rivers and water courses. Nonetheless, hydropower plays an essential role in the electricity system. In addition to being a renewable energy, hydropower is competitive. It contributes to grid stability and provides daily, weekly and inter-seasonal energy storage means that are vital for rolling out the wind energy and solar power sectors. ■

André Laaks

# GEOTHERMAL ENERGY

Geothermal energy systems extract the heat contained in the subsoil and use it to heat buildings, cool them or produce electricity. Geothermal techniques and uses differ depending on the temperature of the soil or aquifers where water is drawn. When the temperature ranges from 30 to 150°C (from a depth of a few hundred metres to about 2 kilometres), geothermal heat can be used for collective urban heating (heating networks) or be directly drawn to heat individual homes, buildings or farming business activities. One or more very high capacity heat pumps (HPs) may be associated to increase the performance of a geothermal heating network, by increasing the temperature that can be harnessed by the network and making the most use of the available geothermal energy.

Electricity can also be produced using binary cycle technology when the aquifer temperature ranges from 90 to 150°C. In that case, the abstracted water, be it liquid or gaseous when it reaches the surface, transfers its heat to another working fluid that vaporizes at below 100 °C. The steam obtained in this way drives a turbine to produce electricity. These plants can operate in cogeneration mode and simultaneously produce electricity and heat to supply a network. Above 150 °C (up to 250 °C), water abstracted from depths of more than 1 500 metres reaches the surface as steam and can be directly used to drive electricity generating turbines. This is known as high-energy geothermal, that is found in volcanic and plate boundary regions. Heat pump systems that extract surface heat from the ground and surface aquifers are examined apart, and by convention are not included in the official geothermal energy production data.

**1**

*Capacity installed and net capacity* usable of geothermal electricity plants in the EU in 2017 and 2018 (in MWe)*

| | 2017 | | 2018 | |
|---|---|---|---|---|
| | Installed capacity | Net capacity | Installed capacity | Net capacity |
| Italy | 915.5 | 767.2 | 915.5 | 767.2 |
| Germany | 38.0 | 32.0 | 38.0 | 36.0 |
| Portugal | 34.3 | 29.1 | 34.3 | 29.1 |
| Croatia | 0.0 | 0.0 | 17.5 | 10.0 |
| France | 17.1 | 15.9 | 17.1 | 15.9 |
| Hungary | 3.4 | 3.0 | 3.4 | 3.0 |
| Austria | 0.9 | 0.9 | 0.9 | 0.9 |
| Romania | 0.05 | 0.05 | 0.05 | 0.05 |
| Total EU 28 | 1 009.2 | 848.2 | 1 026.7 | 862.2 |

** Net maximum electrical capacity.* ***Source: EurObserv'ER (Installed capacity), Eurostat (Net capacity)***

## HEAT PRODUCTION

Geothermal heat production has many applications. The main outlet is space heating for homes and commercial premises, but there are other outlets including farming (heating greenhouses, drying agricultural produce, etc.), pisciculture, swimming pool heating and cooling. The official statistical bodies still do not monitor the thermal capacity of the installations accurately or regularly, because of this plethora of uses.

At the European Geothermal Congress (EGC 2019) held in the Hague in the Netherlands in June 2019, country-by-country reports presented the state of Europe's geothermal sector. According to the Burkhard Sanner summary of the national reports that are not restricted to European Union countries, the capacity of direct geothermal energy uses for producing heat (or cooling) in the EU was about 4670.7 MWth in 2018, broken down as 1 795.1 MWth of district heating networks, 965.1 MWth of systems producing heat for agricultural purposes (including heating networks for heating greenhouses), 1001.9 MWth of systems for spas and 908.6 MWth for the direct heating of individual houses (i.e. without resorting to heat pumps) and other uses.

Nonetheless, the EGEC (European Geothermal Energy Council) in its annual market report ("Egec Geothermal Market Report") monitors the capacity of Europe's geothermal heating networks. The EGEC reports that 11 installations were commissioned or have been renovated in the European Union (8 new installations and 3 renovations) with combined new capacity of 144 MWth. This is new, not additional capacity, because the renovation operations replace existing installations. These renovation operations are bound to increase

1. http://europeangeothermalcongress.eu/wp-content/uploads/2019/07/CUR-00-Summary-Europe.pdf

Technopole Helioparc

## 2

*Gross electricity generation from geothermal energy in the European Union countries in 2017 and 2018 (in GWh)*

| | 2017 | 2018 |
|---|---|---|
| Italy | 6201.2 | 6105.4 |
| Portugal | 216.7 | 230.4 |
| Germany | 163.0 | 178.0 |
| France | 133.1 | 129.7 |
| Hungary | 1.0 | 12.0 |
| Croatia | 0.0 | 2.0 |
| Austria | 0.1 | 0.2 |
| Romania | 0.0 | 0.0 |
| Total EU 28 | 6715.0 | 6657.7 |

*Source: Eurostat*

as the existing geothermal facility "base" ages and is a major market for the sector. This wear also explains why some heating networks have lost performance.

In the European Union, four countries have increased the capacity of their geothermal heating networks. The Netherlands has commissioned 5 new installations for 66 MWth of capacity, France has commissioned a new heating network and renovated 3 others for 45 MWth of capacity, Germany has added a 24.5-MWth installation and Belgium another 8-MWth. The German installation work affects the heating network part of the Holzkirchen geothermal cogeneration plant. Thus, the EGEC puts European Union geothermal heating network capacity at 1 942 MWth, i.e. an increase of about 127 MWth.

Geothermal heat production data is regularly monitored by the national statistical bodies and Eurostat. The official data, that covers geothermal heat distributed by networks and the heat directly used by end-users, reports 867.6 ktoe of output in 2018 (276.8 ktoe of derived heat and 590.8 ktoe of final energy consumption), i.e. 4.1% growth over 2017.

### ELECTRICITY PRODUCTION

After Hungary and Romania's arrival in 2017, Croatia became the eighth EU country to have a geothermal electricity generating sector in 2018. The Velika 1 geothermal plant in the North-Eastern region, Velika Ciglena, was commissioned in December 2018 and has been operating at full capacity







## 3

*Capacity of geothermal district heating systems installed in the European Union in 2017 and 2018 (in MWth)*

| | 2017 | 2018 |
|---|---|---|
| France | 509 | 544 |
| Germany | 329 | 353 |
| Hungary | 254 | 254 |
| Netherlands | 142 | 208 |
| Italy | 160 | 153 |
| Romania | 88 | 88 |
| Austria | 86 | 86 |
| Poland | 75 | 75 |
| Sweden | 44 | 44 |
| Denmark | 33 | 33 |
| Belgium | 17 | 25 |
| Croatia | 20 | 20 |
| Slovakia | 17 | 17 |
| Lithuania | 14 | 14 |
| Greece | 13 | 13 |
| Czechia | 8 | 8 |
| Slovenia | 4 | 4 |
| United Kingdom | 2 | 2 |
| Spain | 1 | 1 |
| Total EU 28 | 1 816 | 1 942 |

*Source: EGEC Market Report 2019*

since March 2019. The nameplate capacity of this ORC plant, built by the Italian company Turboden, is 17.5 MW, which makes it Europe's highest capacity plant of its type in service. It required an investment of 43.7 million euros. An ORC (Organic Rankine Cycle), operates with an organic fluid that vaporize at low temperature which enables geothermal resources to be exploited at between 110 and 200°C. The Croatian Velika 1 plant's resource is at 170°C. The operator points out that the electricity purchasing contract signed with the Croatian energy utility (HROTE) is for 10 MW of installed capacity, which equates to the average consumption of 29 000 Croatian households.

It is the only European Union plant to have been connected during 2018, and thus takes EU geothermal electricity capacity to 1 027.6 MW. Eurostat puts net capacity, which is the maximum presumed exploitable, at 862.2 MW (14 MW growth). At slightly below 6.7 TWh, gross geothermal electricity output has changed very little (0.9% less than in 2017). The reason for this new drop is that the Italian plants were less available, and their output dropped by 1.5% to 6.1 TWh in 2018. Nonetheless Italy alone generates 91.7% of the EU's output is the main geothermal electricity producing country of the 28.

### NEW POLITICAL AMBITIONS ARE NEEDED

Geothermal energy continues to expand as it meets both electrical energy needs and heating and cooling needs. However geothermal energy's deployment over the past decade has remained far below its potential in Europe and well off the National Renewable Energy Action Plan targets.

Nevertheless. the EGEC has observed a clearly renewed interest in geothermal energy across Europe, in particular for heat/cooling production. This is emerging as a consolidated drive in the key markets (the Netherlands, France, Germany), and by the emergence of new markets or the revitalisation of stable markets such as Poland, Belgium, Croatia and Greece. The signals across Europe regarding geothermal electricity are mixed and regulatory uncertainty has to take the blame for the slowdown in developments.

European policies, especially in the new Renewable Energy Directive target with a national annual 1.3 points of a percentage target of the renewable share in heat and cooling, are positive. Yet the EGEC reckons that this important measure was not adhered to in the interim versions of the 2018

## 4

*Heat consumption* from geothermal energy in the countries of the European Union in 2017 and 2018 (in ktoe)*

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Total | Of which final energy consumption | Of which derived heat** | Total | Of which final energy consumption | Of which derived heat** |
| France | 170.1 | 40.2 | 130.0 | 187.3 | 40.2 | 147.2 |
| Italy | 149.8 | 130.8 | 18.9 | 149.1 | 128.1 | 21.0 |
| Hungary | 127.5 | 61.8 | 65.7 | 124.2 | 63.5 | 60.7 |
| Germany | 100.4 | 85.1 | 15.3 | 106.6 | 85.0 | 21.6 |
| Netherlands | 72.8 | 72.8 | 0.0 | 89.1 | 89.1 | 0.0 |
| Slovenia | 48.3 | 47.8 | 0.4 | 48.9 | 48.4 | 0.5 |
| Bulgaria | 34.6 | 34.6 | 0.0 | 34.6 | 34.6 | 0.0 |
| Romania | 32.5 | 26.2 | 6.3 | 31.3 | 25.5 | 5.9 |
| Austria | 26.7 | 12.6 | 14.1 | 25.6 | 11.9 | 13.7 |
| Poland | 22.6 | 22.6 | 0.0 | 23.7 | 23.7 | 0.0 |
| Spain | 18.8 | 18.8 | 0.0 | 18.8 | 18.8 | 0.0 |
| Greece | 8.8 | 8.8 | 0.0 | 8.9 | 8.9 | 0.0 |
| Croatia | 8.2 | 8.2 | 0.0 | 7.6 | 7.6 | 0.0 |
| Slovakia | 5.0 | 1.5 | 3.5 | 5.2 | 1.4 | 3.8 |
| Portugal | 1.6 | 1.6 | 0.0 | 1.7 | 1.7 | 0.0 |
| Cyprus | 1.6 | 1.6 | 0.0 | 1.6 | 1.6 | 0.0 |
| Denmark | 1.8 | 0.0 | 1.8 | 1.3 | 0.0 | 1.3 |
| Belgium | 1.2 | 0.0 | 1.2 | 1.3 | 0.0 | 1.3 |
| United Kingdom | 0.8 | 0.8 | 0.0 | 0.8 | 0.8 | 0.0 |
| Czechia | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Estonia | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Ireland | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Latvia | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Lithuania | 0.4 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 |
| Total EU 28 | 833.5 | 575.9 | 257.6 | 867.6 | 590.8 | 276.8 |

*** Gross heat production in the transformation sector. **Source: Eurostat***

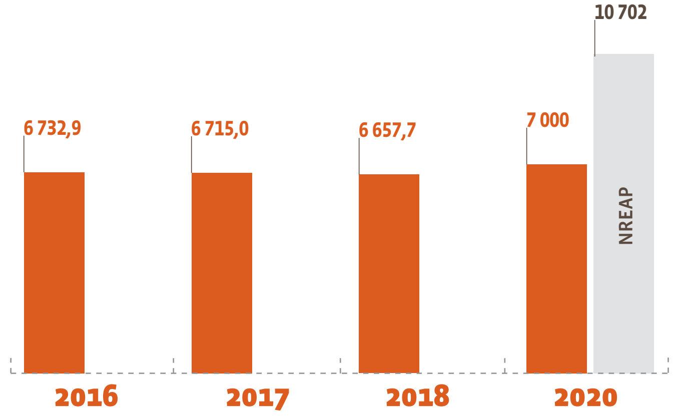
Climate and Energy Action Plans and this applies to most of the Member States.

Current market dynamics – leaving aside application of the 2018 Renewable Energy Directive – equate to an increase of almost 11 GWth for geothermal energy capacity in heating networks, and up to 3 GWe for geothermal electrical energy by 2030.

The European Commission's political resolve restated through the presentation of its Green Deal on 11 December, to make Europe the world's first climate-neutral continent by 2050, can only give the geothermal sector a boost. The sector view the Green Deal as an opening to fully exploit the potential of geothermal energy and support the technological development of its sectors. Using the lithium in the water extracted from geothermal boreholes (present in the form of lithium chloride) by the geothermal plants is one of the new technological options likely to enhance the profitability and deployment of new deep geothermal energy projects. The deep geothermal energy players highlight the "clean" quality of the lithium that could be recovered after refining with very low environmental impact, compared to the current production methods practised in Australia and Chile. European battery manufacturing would benefit strongly from this local lithium production. ■

## 5

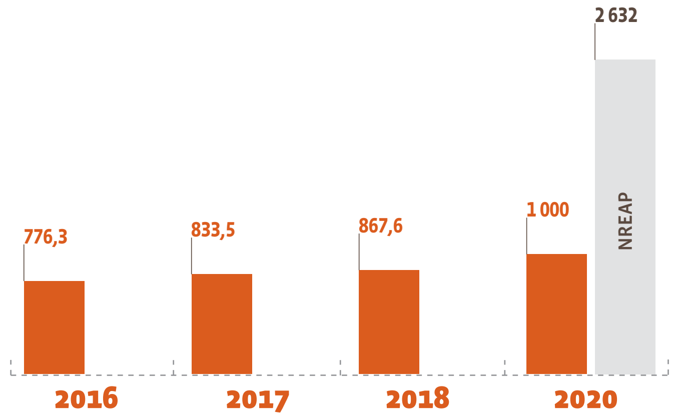
*Comparison of the current geothermal electricity generation trend against the NREAP (National Renewable Energy Action Plan) roadmap (in GWh)*




*Source: EurObserv'ER*

## 6

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




*Source: EurObserv'ER*

# HEAT PUMPS

Being able to distinguish the different heat pump (HP) system types is required to understand market trends. There are three main types of HP characterized by the element from which their energy is sourced. Air-source heat pumps (ASHPs) are those that extract thermal energy from the ambient air. Ground-source heat pumps (GSHPs) comprise those systems that extract thermal energy from the ground and hydrothermal HPs from water (groundwater). In the interests of simplicity and in view of their technical similarity, EurObserv'ER includes the hydrothermal HP family in its GSHP indicators.

In the case of GSHPs, the heat is diffused by a heating circuit – typically an underfloor or low- or high-temperature radiator heating system. They are described as water-borne HPs. ASHPs offer several different heat diffusion systems. Some ASHPs, like GSHPs, use water to diffuse the heat and are known as air-water HPs. Others use systems that blow hot air and are known as air-air HPs. Almost all of them operate in reverse mode and cooling tends to be their main application in warm countries. Reversible air-air HPs account for a major proportion of system sales in the European Union. Their unit capacity is generally much lower than that of water-borne HPs.

Now, these various types of HP do not produce the same amount of renewable energy. Their output depends on the auxiliary energy source used to run the compressor (electricity or natural gas), the thermal energy source used (ground, water, air), the application mode (heating or cooling), the period of use and the climate zone where the HPs are installed. In March 2013, the European Commission published a methodology guide that set out the guidelines for calculating the share of renewable energy produced by the various heat pump technologies, in line with article 5 of the 2009/28/EC Directive, to help Member States gauge the renewable energy output of their HP bases.

## 4 MILLION HPS SOLD IN THE EU IN 2018

The heat pump market, buoyed by both heating and cooling needs, continues to prosper, although it is still concentrated in just a few EU countries. According to EurObserv'ER, at least 4 million HPs were sold, all capacity ranges and technologies taken together, during 2018, which is a 10.5% increase on 2017 (3.6 million units sold). These figures are particularly representative of the residential and service sector markets (in capacities ranging from a few kW to more than 20 kW). The market for middle- and high-capacity HPs is much smaller (e.g.: fewer than a thousand industrial HPs were sold in the EU).

About a third of this total, or just under 1.3 million units, are primarily intended to cover heating needs, according to the specific count carried out by EHPA in its "European Heat Pump Market and Statistics Report 2019". The remaining two-thirds are applied to cooling needs in warm climate countries (i.e. Italy, Spain, Portugal, South of France). This ambivalence in use raises statistical comparison issues between the European Union markets as the needs and applications differ by climate zone.

Reversible air-air ASHPs still dominate European market sales, with 3.5 million systems sold in 2018 according to EurObserv'ER, or just over 300 000 (9.6%) more than in 2017. Note that the four major markets (Italy, Spain, France and Portugal) alone account for 87.8% of the newly-installed reversible air-air systems sold in Europe. The reasons for this concentration are the countries' sizes and their climates, with significant cooling needs during the summer. Italy remains the biggest reversible air-air HP market, with 1 507 000 units sold in 2018 compared to 1 403 000 in 2017 (7.4% growth) according to the Ministry of Economic Development. A particularly hot summer boosted sales on the Italian peninsula. The increase in summer comfort needs is also the main driver of the French, Spanish and Portuguese reversible air-air HP markets.

The water-borne ASHP market specifically addresses heating needs. Once again, sales have risen steadily since 2013 and have picked up speed since 2017. They actually increased by 21.5% between 2017 and 2018, equating to more than 366 200 units sold (in 20 EU countries), having risen the previous year by 18.5%. This new growth differs In that it took place both in the historic ASHP (air-water) markets in Scandinavia (19.4% growth in Sweden, 28.2% in Denmark), Finland (21.4%), France (14.5%) and Germany (10.2%) and also less mature markets such as Spain 134.1%), the Netherlands (35.8%), Poland (31.6%) and the UK (24.7%).

The GSHP (ground-to-water) HP market also specifically addresses heating needs to a lesser extent coming in with 87 126 units sold... a clear 4.9% upturn in 2018 after stabilizing its 2017 sales. The revised market figures for 2017 recorded 83 020 units sold, almost the same as in 2016 (0.1% more). This good performance can firstly be put down to the momentum of the leading European GSHP market, Sweden. According to the SKVP (Swedish Refrigeration & Heat Pump Association), 24 162 units were sold in 2018 (6.7% growth), while Germany, according to AGEEstat, chalked up 21 137 sales (4.6% growth). It should also be noted that the Dutch market expanded considerably (by 34.7%). Statistics Netherlands claims that 6 504 units were sold in 2018.

## 1

*Market of aerothermal heat pumps in 2017 and 2018* (number of units sold).*

| | 2017 | | | | 2018 | | | |
|---|---|---|---|---|---|---|---|---|
| | 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 | 1 440 500 | 1 403 000 | 37 500 | 0 | 1 550 000 | 1 507 000 | 43 000 | 0 |
| Spain | 912 378 | 901 406 | 10 972 | 0 | 942 569 | 916 879 | 25 690 | 0 |
| France | 501 403 | 419 703 | 81 700 | 0 | 591 700 | 498 120 | 93 580 | 0 |
| Portugal | 145 012 | 144 141 | 871 | 0 | 156 078 | 155 438 | 640 | 0 |
| Netherlands | 92 465 | 70 872 | 21 593 | 0 | 106 267 | 76 933 | 29 334 | 0 |
| Sweden | 78 355 | 52 000 | 9 035 | 17 320 | 80 672 | 52 000 | 10 788 | 17 884 |
| Germany | 69 494 | 0 | 55 994 | 13 500 | 76 720 | 0 | 61 720 | 15 000 |
| Belgium | 55 528 | 49 190 | 6 338 | 0 | 71 069 | 64 041 | 7 028 | 0 |
| Finland | 54 141 | 47 281 | 4 138 | 2 722 | 67 621 | 59 395 | 5 024 | 3 202 |
| Malta | 36 704 | 36 704 | 0 | 0 | 62 633 | 62 633 | 0 | 0 |
| Denmark | 41 793 | 35 504 | 6 125 | 164 | 47 508 | 39 488 | 7 855 | 165 |
| Slovakia | 2 554 | 306 | 2 248 | 0 | 34 944 | 31 149 | 3 773 | 22 |
| Czechia | 20 528 | 6 750 | 13 718 | 60 | 24 542 | 7 500 | 16 977 | 65 |
| United Kingdom | 19 260 | 0 | 18 935 | 325 | 23 615 | 0 | 23 615 | 0 |
| Poland | 16 370 | 8 280 | 8 080 | 10 | 19 905 | 9 265 | 10 630 | 10 |
| Austria | 13 865 | 0 | 13 689 | 176 | 15 157 | 0 | 14 862 | 295 |
| Estonia | 15 010 | 13 700 | 1 280 | 30 | 15 010 | 13 700 | 1 280 | 30 |
| Lithuania | 8 819 | 7 321 | 1 474 | 24 | 11 410 | 8 750 | 2 660 | 0 |
| Ireland | 4 457 | 0 | 4 398 | 59 | 4 457 | 0 | 4 398 | 59 |
| Slovenia | 3 200 | 0 | 3 200 | 0 | 3 200 | 0 | 3 200 | 0 |
| Hungary | 1 700 | 1 700 | 0 | 0 | 2 850 | 2 850 | 0 | 0 |
| Luxembourg | 88 | 0 | 88 | 0 | 206 | 0 | 206 | 0 |
| Total EU 28 | 3 533 624 | 3 197 858 | 301 376 | 34 390 | 3 908 133 | 3 505 141 | 366 260 | 36 732 |

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

## 2

*Market of geothermal (ground source) heat pumps* in 2017 et 2018** (number of units sold)*

| | 2017 | 2018 |
|---|---|---|
| Sweden | 22 641 | 24 162 |
| Germany | 20 217 | 21 137 |
| Finland | 7 986 | 7 995 |
| Netherlands | 4 830 | 6 504 |
| Poland | 5 660 | 5 831 |
| Austria | 5 230 | 5 408 |
| France | 3 100 | 3 080 |
| United Kingdom | 2 358 | 2 310 |
| Denmark | 2 143 | 2 310 |
| Belgium | 1 963 | 1 872 |
| Estonia | 1 750 | 1 750 |
| Czechia | 1 561 | 1 647 |
| Italy | 860 | 775 |
| Lithuania | 633 | 615 |
| Slovenia | 598 | 598 |
| Slovakia | 168 | 332 |
| Hungary | 800 | 300 |
| Ireland | 291 | 291 |
| Luxembourg | 84 | 89 |
| Spain | 95 | 73 |
| Portugal | 52 | 47 |
| Total EU 28 | 83 020 | 87 126 |

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



EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2019 EDITION

## 3

*Total number of heat pumps in operation in 2017 and 2018**

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Aerothermal heat pumps | Ground source heat pump | Total HP | Aerothermal heat pumps | Ground source heat pump | Total HP |
| Italy | 19 522 000 | 14 200 | 19 536 200 | 19 569 000 | 14 150 | 19 583 150 |
| France | 5 587 056 | 154 870 | 5 741 926 | 6 178 756 | 157 950 | 6 336 706 |
| Spain | 3 201 810 | 1 388 | 3 203 198 | 4 144 379 | 1 461 | 4 145 840 |
| Sweden | 1 130 341 | 525 678 | 1 656 019 | 1 204 328 | 537 878 | 1 742 206 |
| Germany | 613 605 | 358 228 | 971 833 | 684 439 | 376 902 | 1 061 341 |
| Finland | 683 621 | 110 981 | 794 602 | 751 242 | 118 976 | 870 218 |
| Portugal | 529 092 | 909 | 530 001 | 685 170 | 956 | 686 126 |
| Netherlands | 406 361 | 54 870 | 461 231 | 509 650 | 60 379 | 570 029 |
| Denmark | 290 254 | 61 204 | 351 458 | 332 520 | 65 149 | 397 669 |
| Malta | 0 | 323 429 | 323 429 | 0 | 344 212 | 344 212 |
| Belgium | 147 466 | 11 337 | 158 803 | 218 535 | 13 209 | 231 744 |
| Bulgaria | 214 971 | 4 272 | 219 243 | 214 971 | 4 272 | 219 243 |
| Austria | 92 869 | 103 185 | 196 054 | 108 026 | 106 819 | 214 845 |
| United Kingdom | 150 112 | 31 541 | 181 653 | 173 727 | 33 851 | 207 578 |
| Estonia | 131 727 | 14 125 | 145 852 | 146 737 | 15 875 | 162 612 |
| Czechia | 104 658 | 22 559 | 127 217 | 129 200 | 24 028 | 153 228 |
| Poland | 61 731 | 47 655 | 109 386 | 81 636 | 53 486 | 135 122 |
| Slovakia | 11 049 | 3 483 | 14 532 | 45 993 | 3 815 | 49 808 |
| Slovenia | 27 900 | 10 648 | 38 548 | 31 100 | 11 246 | 42 346 |
| Ireland | 17 941 | 4 115 | 22 056 | 22 398 | 4 406 | 26 804 |
| Hungary | 7 100 | 2 110 | 9 210 | 9 950 | 2 410 | 12 360 |
| Lithuania | 3 466 | 3 268 | 6 734 | 3 466 | 3 268 | 6 734 |
| Luxembourg | 1 422 | 634 | 2 056 | 1 628 | 742 | 2 370 |
| Total EU 28 | 32 936 551 | 1 864 689 | 34 801 240 | 35 246 850 | 1 955 440 | 37 202 290 |

*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***

## RENEWABLE ENERGY OUTPUT OF ALMOST 12 MTOE IN 2018

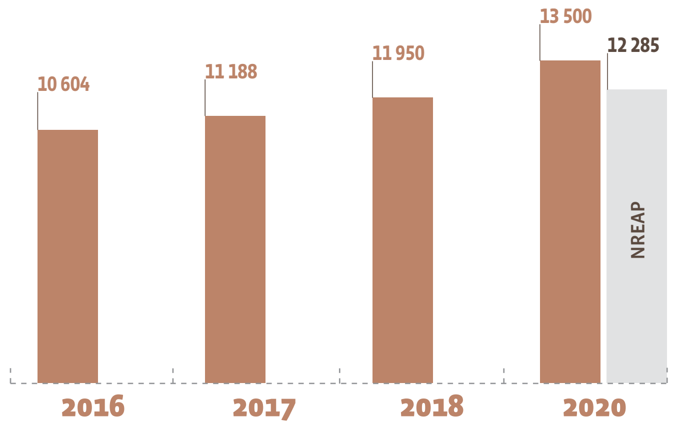
While the Eurostat SHARES monitoring tool, that is used to calculate progress on reaching renewable energy targets does not provide market indicators, it details the capacity of HP bases eligible for producing renewable energy. This data is used to identify the amount of renewable energy delivered by HPs by applying Renewable Energy Directive methodology and criteria. According to SHARES, this contribution was 11 950 ktoe in 2018, i.e. a 762.7-ktoe increase over 2017. Without this positive contribution, final renewable energy consumption for heating and cooling would have declined across the European Union. The latter taken together, has risen from 102.4 Mtoe in 2017 to 102.9Mtoe in 2018 (0.5 Mtoe growth). Thus, HP technologies across the European Union, contribute most to the increase in renewable heat and are the main renewable technologies capable of meeting cooling needs.

## A SOLID ENERGY TRANSITION VALUE

Since the implementation of the 2009 RES Directive, the HP sector has demonstrated that it can be relied on to make a significant contribution every year to the renewable energy targets of the countries using these technologies. According to the SHARES tool, in 2018 the share of renewable energy produced by heat pumps already represented 2.4% of total heat and cooling needs (11.9 Mtoe out of 522.8 Mtoe). This is half a percentage point higher than in 2015 (1.9%). In Portugal, this share exceeds 10% (10.4% in 2018), in Sweden it is almost 10% (9.8% in 2018), it is over 4% in France (4.3%) and Italy (4.7%). In the coming years, major trends will help boost this technology, with promising regulatory and political signals made for greater electrification of heating and cooling needs and gradual withdrawal from gas- and oil-fired heating solutions. For instance, the Netherlands published its roadmap for achieving carbon neutrality by 2050 in the middle of 2019 and cites pulling out totally from using gas in residential space heating among its measures. Heat pumps (electric and hybrid) will be one of the preferred ways of substituting natural gas. The sector's confidence is currently very high, projecting continuance of the current growth pace that will probably take the HP contribution to more than 13.6 Mtoe by 2020. Turning to technology, the progress made over the last decade has opened up new growth opportunities. «High-temperature» HPs are now capable of running efficiently when outdoor temperatures are negative. This progress has led to the proliferation of their use in a much higher number of buildings and enabled them to enter the renovation market head-on, which is the greatest challenge for the forthcoming decades. ■

## 4

*Actual trend of renewable energy* from heat pumps compared with the National renewable energy action plans NREAP (in ktoe)*




** Renewable energy production according to the criteria set by the Renewable Energy Directive. **Source : EurObserv'ER***

# 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 by three sub-sectors along the lines of the origin and treatment of the waste. They are methanization of non-hazardous waste storage facility biogas ("landfill gas"), wastewater treatment plant sludge ("sewage sludge gas"), and the methanization of non-hazardous waste or raw plant matter ("other biogases"). 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, which have been identified in Finland, Denmark, Spain, Italy and Belgium, produce hydrogen ($H_2$) and carbon monoxide (CO), which when combined can be transformed into synthetic biogas to substitute natural gas ($CH_4$).

## 16.8 MILLION TOE OF BIOGAS PRODUCED IN THE EUROPEAN UNION

In 2018, primary energy output from biogas (from anaerobic fermentation and thermal processes) across the European Union remained stable. According to Eurostat, it rose to 16 838.7 ktoe in 2018, from 16 786.3 ktoe in 2017.
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 this trend in certain major producer countries. Yet, biogas still enjoys good growth, for example in Denmark (26.5%, with output at 489 ktoe), Finland (9.1%, with output at 186.2 ktoe) and France (6.9%, with output at 877.4 ktoe). Denmark's output increased the most in 2018 (by 102.5 ktoe) primarily because of the build-up of biogas production from thermal processes.

In France, biogas continues to enjoy an incentive framework that has established a Feed-in Tariff of about € 95 per MWh for 15-year contracts for biomethane injected into the grid, in addition to an improved Feed-in Tariff for biogas electricity for small installations (<500 kW) and a tendering procedure for bigger installations.

As for the various biogas feedstock trends in 2018, they are similar to those of the previous year. Biogas output from the methanization of non-hazardous waste and raw plant matter ("other biogases") continues to increase but at a slower pace (0.8%,from 12 472.5 ktoe to 12574.5 ktoe), and now accounts for nearly three-quarters of all EU biogas output (74.3% in 2017, 74.7% in 2018). This increase outperforms landfill biogas whose output dropped again from 2 584.7 to 2 429.0 ktoe (its share dropping from 15.5 to 14.4%). The third source, wastewater sludge biogas output increased slightly in 2018 by 2.7% (from 1468.6 to 1508.8 ktoe) and saw its share increase from 8.7% to 9%. The most remarkable growth in output is that of thermal process biogas (25.3% between 2017 and 2018). Its production level has doubled

in two years (159.9 ktoe in 2016, 260.4 ktoe in 2017 and 326.4 ktoe in 2018) so doubling its share in total biogas output (1% in 2016, 1.6% in 2017 and 1.9% in 2018). In Finland, its prime mover, thermal biogas accounted for 63.6% of the country's biogas output in 2018 while it also accounts for more than one third of Denmark's biogas output (34.5% in 2018).

According to Eurostat, biogas electricity output contracted slightly (by 1.1%) between 2017 and 2018, from 61.7 to 60 TWh, essentially because of drops in output in Germany and the UK. As for the production of heat (from the processing sector), it reached 859.9 ktoe at the end of 2018 (704.9 ktoe at the end of 2017)… a 22.0 % hike.

Most of this improvement can be explained by a sharp increase in biogas heat output in Germany (71.1%, i.e. an increase of 152.6 ktoe between 2017 and 2018). Concerning final energy consumption directly used in industry and other sectors (notably agriculture),

## 1

*Primary energy production from biogas in the European Union in 2017 and 2018 (in ktoe)*

| | 2017 | | | | | 2018 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 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 | 132.0 | 459.6 | 7129.1 | 0.0 | 7720.7 | 123.2 | 492.6 | 7015.2 | 0.0 | 7631.1 |
| United Kingdom | 1276.7 | 361.3 | 1135.4 | 0.0 | 2773.4 | 1168.1 | 367.8 | 1273.4 | 0.0 | 2809.2 |
| Italy | 349.8 | 53.5 | 1488.0 | 6.4 | 1897.7 | 333.5 | 51.7 | 1500.0 | 6.8 | 1892.2 |
| France | 307.5 | 32.5 | 480.6 | 0.0 | 820.6 | 322.4 | 35.3 | 519.8 | 0.0 | 877.4 |
| Czechia | 23.1 | 43.1 | 541.4 | 0.0 | 607.7 | 21.3 | 44.0 | 538.5 | 0.0 | 603.8 |
| Denmark | 4.7 | 23.3 | 236.0 | 122.5 | 386.5 | 4.0 | 23.9 | 292.4 | 168.6 | 489.0 |
| Netherlands | 16.9 | 57.6 | 246.4 | 0.0 | 320.8 | 12.7 | 58.2 | 255.3 | 0.0 | 326.2 |
| Poland | 48.0 | 115.0 | 117.5 | 0.0 | 280.6 | 38.9 | 116.1 | 133.4 | 0.0 | 288.3 |
| Spain | 149.9 | 64.7 | 22.8 | 23.9 | 261.4 | 149.3 | 66.3 | 24.2 | 25.2 | 264.9 |
| Austria | 2.4 | 41.1 | 273.4 | 0.0 | 317.0 | 2.1 | 25.8 | 205.7 | 0.0 | 233.6 |
| Belgium | 20.0 | 25.7 | 174.1 | 5.3 | 225.1 | 18.9 | 25.3 | 176.4 | 7.4 | 228.0 |
| Finland | 20.9 | 16.1 | 31.4 | 102.3 | 170.7 | 18.0 | 17.5 | 32.3 | 118.4 | 186.2 |
| Sweden | 4.7 | 78.6 | 94.6 | 0.0 | 177.8 | 4.0 | 78.0 | 93.8 | 0.0 | 175.8 |
| Slovakia | 9.9 | 12.5 | 130.1 | 0.0 | 152.5 | 6.8 | 13.3 | 128.7 | 0.0 | 148.8 |
| Greece | 68.8 | 16.1 | 22.2 | 0.0 | 107.1 | 64.8 | 17.0 | 31.1 | 0.0 | 112.8 |
| Hungary | 15.1 | 29.0 | 54.9 | 0.0 | 98.9 | 12.7 | 28.5 | 50.8 | 0.0 | 92.0 |
| Latvia | 8.1 | 2.4 | 82.7 | 0.0 | 93.2 | 7.6 | 2.0 | 77.5 | 0.0 | 87.0 |
| Portugal | 73.5 | 3.0 | 8.6 | 0.0 | 85.1 | 67.8 | 5.9 | 8.8 | 0.0 | 82.5 |
| Croatia | 5.0 | 3.5 | 55.3 | 0.0 | 63.8 | 5.0 | 3.2 | 65.4 | 0.0 | 73.6 |
| Bulgaria | 0.0 | 2.8 | 44.0 | 0.0 | 46.8 | 0.0 | 8.8 | 44.9 | 0.0 | 53.6 |
| Ireland | 39.0 | 9.2 | 7.2 | 0.0 | 55.5 | 33.5 | 9.0 | 7.8 | 0.0 | 50.4 |
| Lithuania | 5.1 | 7.2 | 19.9 | 0.0 | 32.2 | 10.0 | 6.9 | 20.2 | 0.0 | 37.1 |
| Slovenia | 1.9 | 2.1 | 21.8 | 0.0 | 25.7 | 2.0 | 2.0 | 20.4 | 0.0 | 24.3 |
| Luxembourg | 0.0 | 1.8 | 18.9 | 0.0 | 20.7 | 0.0 | 1.6 | 20.2 | 0.0 | 21.9 |
| Romania | 0.0 | 0.0 | 18.0 | 0.0 | 18.0 | 0.0 | 0.0 | 20.7 | 0.0 | 20.7 |
| Estonia | 1.8 | 6.2 | 4.9 | 0.0 | 12.9 | 1.4 | 7.5 | 4.8 | 0.0 | 13.6 |
| Cyprus | 0.0 | 0.7 | 11.4 | 0.0 | 12.0 | 1.1 | 0.7 | 11.4 | 0.0 | 13.2 |
| Malta | 0.0 | 0.0 | 1.8 | 0.0 | 1.8 | 0.0 | 0.0 | 1.6 | 0.0 | 1.6 |
| Total EU 28 | 2 584.7 | 1 468.6 | 12 472.6 | 260.4 | 16 786.3 | 2 429.0 | 1 508.8 | 12 574.5 | 326.4 | 16 838.7 |

*Source: Eurostat*

it increased from 2 658.5 ktoe to 2 667.2 ktoe.

Biogas can also be purified to be transformed into biomethane. It can then either be injected into the network after purification and odorization and valued in the same way as can be natural gas, in the form of electricity and or heat, or either be used by natural gas vehicles (bioGNV).

The European Biomethane Observatory reports that at the end of 2018, the European sector had at least 621 biomethane plants (including 570 in the European Union, 39 in Switzerland and 12 in Norway). The annual combined biogas purification capacity of these plants stands at 567 000 $Nm^3$ per hour, or 22 TWh of biomethane. This number is relatively low compared to the 16 500 biogas plants of these countries that are primarily used to generate electricity. Germany has the highest number of biomethane plants – 216 at the end of 2018 – followed by the UK (88), France (76) and Sweden (70). France is currently most actively engaged in developing biomethane. According to the dashboards of the Sdes (Data and Statistical Studies Department), 76 plants were injecting biomethane into the gas grid at the end of 2017, for maximum production capacity of 1 218 GWh per annum. By 30 June 2019, the number of plants had risen to 91 with maximum production capacity of 1 425 GWh per annum. Sweden is a special case, because only 21% of its plants inject biomethane directly into the grid. There, most of the biomethane produced is used

## 2

*Gross electricity production from biogas in the European Union in 2017 and 2018 (in GWh)*

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Electricity only plants | CHP plants | Total | Electricity only plants | CHP plants | Total |
| Germany | 7 827.0 | 26 052.0 | 33 879.0 | 7 177.0 | 26 239.0 | 33 416.0 |
| Italy | 2 961.1 | 5 338.0 | 8 299.1 | 2 895.7 | 5 403.9 | 8 299.6 |
| United Kingdom | 5 251.1 | 784.6 | 6 035.7 | 4 907.8 | 793.1 | 5 700.9 |
| Czechia | 41.3 | 2 598.0 | 2 639.3 | 41.8 | 2 565.4 | 2 607.2 |
| France | 405.3 | 1 716.4 | 2 121.6 | 370.1 | 1 994.7 | 2 364.8 |
| Poland | 0.0 | 1 096.4 | 1 096.4 | 0.0 | 1 127.6 | 1 127.6 |
| Belgium | 72.3 | 866.0 | 938.3 | 70.5 | 874.2 | 944.7 |
| Spain | 742.0 | 199.0 | 941.0 | 740.0 | 183.0 | 923.0 |
| Netherlands | 29.7 | 893.6 | 923.3 | 23.3 | 863.6 | 886.9 |
| Austria | 601.2 | 69.2 | 670.3 | 562.1 | 66.2 | 628.3 |
| Denmark | 1.0 | 580.9 | 581.9 | 0.8 | 619.0 | 619.8 |
| Slovakia | 86.0 | 508.0 | 594.0 | 81.0 | 458.0 | 539.0 |
| Finland | 231.6 | 174.9 | 406.5 | 234.9 | 184.7 | 419.7 |
| Latvia | 0.0 | 405.4 | 405.4 | 0.0 | 374.1 | 374.1 |
| Croatia | 24.1 | 285.6 | 309.7 | 27.8 | 327.1 | 354.9 |
| Hungary | 102.0 | 246.0 | 348.0 | 111.0 | 220.0 | 331.0 |
| Greece | 51.0 | 249.2 | 300.2 | 53.6 | 248.5 | 302.1 |
| Portugal | 269.6 | 16.9 | 286.5 | 253.3 | 18.1 | 271.4 |
| Bulgaria | 93.0 | 122.8 | 215.8 | 85.0 | 127.2 | 212.3 |
| Ireland | 158.1 | 42.6 | 200.7 | 139.2 | 44.9 | 184.1 |
| Lithuania | 0.0 | 127.2 | 127.2 | 0.0 | 139.9 | 139.9 |
| Slovenia | 1.1 | 129.0 | 130.1 | 0.6 | 118.2 | 118.8 |
| Luxembourg | 0.0 | 72.5 | 72.5 | 0.0 | 75.5 | 75.5 |
| Romania | 38.1 | 28.6 | 66.7 | 40.0 | 30.2 | 70.2 |
| Cyprus | 0.0 | 51.8 | 51.8 | 0.0 | 56.9 | 56.9 |
| Estonia | 0.0 | 41.8 | 41.8 | 0.0 | 38.0 | 38.0 |
| Sweden | 0.0 | 11.0 | 11.0 | 0.0 | 10.0 | 10.0 |
| Malta | 0.0 | 9.7 | 9.7 | 0.0 | 9.0 | 9.0 |
| Total EU 28 | 18 986.5 | 42 717.1 | 61 703.6 | 17 815.7 | 43 209.9 | 61 025.6 |

*Source: Eurostat*

## 3

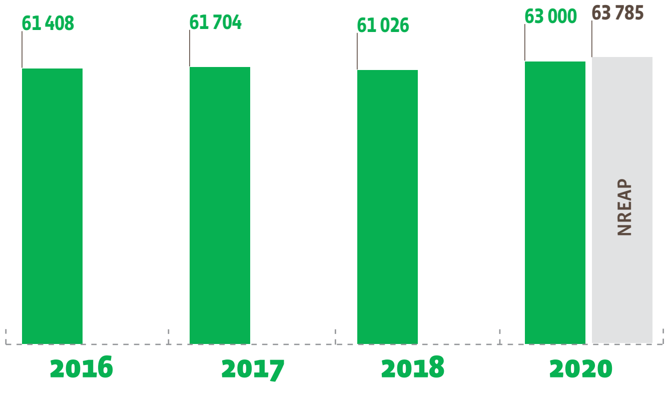
*Gross heat production from biogas in the European Union in 2017 and in 2018 (in ktoe) in the transformation sector**

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | heat only plants | CHP plants | Total | heat only plants | CHP plants | Total |
| Germany | 6.3 | 208.5 | 214.7 | 8.7 | 358.7 | 367.4 |
| Italy | 0.2 | 225.9 | 226.0 | 0.1 | 213.7 | 213.8 |
| France | 9.1 | 50.9 | 60.0 | 9.4 | 59.9 | 69.3 |
| Denmark | 2.5 | 46.2 | 48.7 | 1.9 | 46.0 | 47.9 |
| Poland | 0.3 | 21.0 | 21.3 | 0.4 | 21.7 | 22.0 |
| Latvia | 0.0 | 24.2 | 24.2 | 0.1 | 21.2 | 21.4 |
| Finland | 6.0 | 15.1 | 21.2 | 4.9 | 13.8 | 18.7 |
| Czechia | 0.0 | 17.2 | 17.2 | 0.0 | 17.5 | 17.5 |
| Slovakia | 0.1 | 13.0 | 13.1 | 0.1 | 14.1 | 14.2 |
| Croatia | 0.0 | 7.8 | 7.8 | 0.0 | 11.5 | 11.5 |
| Belgium | 0.0 | 8.9 | 8.9 | 0.0 | 9.1 | 9.1 |
| Netherlands | 0.0 | 6.4 | 6.4 | 0.0 | 8.4 | 8.4 |
| Sweden | 7.1 | 3.3 | 10.4 | 4.5 | 3.1 | 7.6 |
| Austria | 1.2 | 2.7 | 3.8 | 1.1 | 6.0 | 7.1 |
| Slovenia | 0.0 | 5.3 | 5.3 | 0.0 | 5.3 | 5.3 |
| Bulgaria | 0.0 | 3.3 | 3.3 | 0.0 | 4.1 | 4.1 |
| Romania | 1.6 | 3.3 | 4.9 | 2.2 | 1.9 | 4.0 |
| Lithuania | 0.0 | 2.0 | 2.0 | 0.0 | 2.8 | 2.8 |
| Hungary | 0.0 | 1.8 | 1.8 | 0.0 | 2.6 | 2.6 |
| Luxembourg | 0.0 | 2.0 | 2.0 | 0.0 | 2.4 | 2.4 |
| Estonia | 0.0 | 0.6 | 0.6 | 0.0 | 1.8 | 1.8 |
| Cyprus | 0.0 | 1.3 | 1.3 | 0.0 | 1.3 | 1.3 |
| Total EU 28 | 34.3 | 670.5 | 704.9 | 33.4 | 826.6 | 859.9 |

** Corresponds to "derived heat" (see Eurostat definition). **Source: Eurostat***

## 4

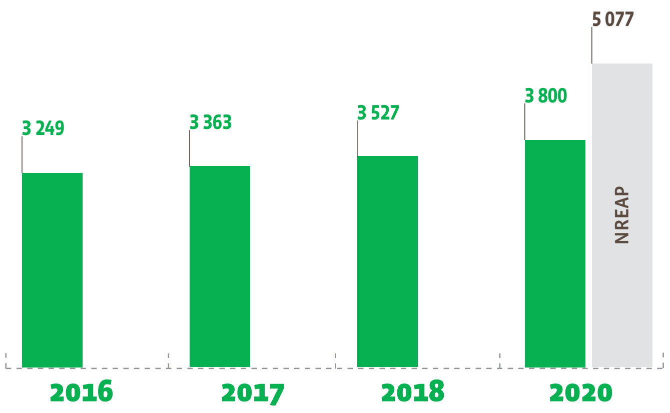
*Comparison of the current trend of electricity biogas generation against the NREAP (National Renewable Energy Action Plans) roadmap (in GWh)*




*Source: EurObserv'ER*

## 5

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




*Source: EurObserv'ER*

by the country's road transport. According to Statistics Sweden, 118.5 ktoe of biomethane was used directly in transport in 2018, compared to 111.1 ktoe in 2017.

## A NEW FRAMEWORK TO BE SET UP TO GREEN THE GRIDS

The new European regulations and the decision made by the main European biogas producer countries to reduce incentives and manage the use of food crops has had a strong impact on the biogas sector's growth. Its future development will be more closely based on energy recovery from fermentable waste than using energy crops, while thermal biogas will be another growth driver. The potential for growth will remain strong even if the upturn in production hinges on the introduction of a more encouraging regulatory framework, with more assertive political determination to substitute fossil gas. The European Commission has already analysed the biogas sector's potential in its publication "In-depth Analysis in Support of the Commission Communication COM (2018) 73". The analyses show that methanization biogas input could increase from 16 Mtoe in 2015 to 30 Mtoe by 2030 (including a small proportion of "thermal" biogas), and according to the scenarios examined could vary from 45 Mtoe (EE scenario) to 79 Mtoe (P2X scenario) by 2050. E-gas (biomethane produced by electrolysis) would add 91 Mtoe in 2050 according to one scenario, and between 40 and 50 Mtoe according to the other scenarios that have examined its widescale use. The EBA (European Biogas Association) points out that to achieve the carbon neutrality goal by 2050, the fossil aspect will have to be gradually taken out of the gas sector and the natural gas grid. Taxing gas sector's revenues should logically be contemplated as the main way forward to finance the green transition, along with the introduction of a European Union-wide carbon tax and the gradual removal of subsidies underpinning fossil fuels. The EBA also suggests that Europe's funding mechanisms, for example through the European Investment Bank, should focus on backing the development of biomethane projects and that special funds should be devoted to alternative technologies such as biomass gasification, power-to-methane and biomethane liquefaction to make them market competitive and upscalable. Focusing on the biomethane sector, the EBA recommends implementing a harmonized system of guarantees of origin across Europe to make virtual cross-border sales possible, giving priority access to the gas grid to renewable methane, encouraging the use of biomethane for maritime transport and in heavy industry and clarifying the role that biomethane can play in the new Renewable Energy Directive's indicative heat target (namely 1.3 of a percentage point increase of renewable energy in final heat consumption per annum, taking the 2020 situation as the reference point). The leaders of the various renewable gas sectors claim they are ready to help the European Commission meet its ambitions. They point up the advantages of the gas distribution grids in managing intermittent renewable electricity production. They highlight the gas distribution grids' technical simplicity and storage capacities, the advantages of a hybrid energy infrastructure, built on an upgraded construction of gas and electricity grids that according to them, would be the backbone of a decarbonized European energy system. ■

# BIOFUELS

## 16.7 MTOE OF BIOFUEL USED IN TRANSPORT IN 2018

After a long struggle, biofuel consumption started to pick up two years ago. In 2018 European Union biofuel consumption in transport made two-figure growth to reach 16.7 Mtoe in 2018 compared to 14.9 Mtoe in 2017 (12.2% growth) (revised figures) according to Eurostat's Shares tool (its 20 January 2020 version) used to calculate the renewable energy targets of each Member State. As only the consumption that complies with the environmental requirements of the European directive can be included in the national targets, it is very close, at 16.6 Mtoe in 2018 compared to 14.8 Mtoe in 2017 (12.5% growth). The proportion of biofuels certified as compatible is now 99.5% (99.3% in 2017). It should be noted that these quantities are calculated for each type of biofuel with the calorific values defined by Annexe 3 of the Renewable Energy Directive, which provides a common basis for comparison between countries.

The Shares tool does not directly distinguish the distribution of consumption between the three main biofuel families (biodiesel, bioethanol and biogas), so EurObserv'ER has based its estimates on its own surveys of the official bodies. Distribution between them, always expressed in energy content, is heavily dominated by the biodiesel sector that has an 81% share compared to 17.9% for the bioethanol and 1.1% for the biogas fuel sectors respectively. Pure vegetable oil consumption used as fuel in transport is no longer representative because of its marginal consumption.

As in 2017, most of the increase in biofuel consumption came from the biodiesel sector, be it classic fatty acid methyl esters (FAME) or synthetic (HVO) biodiesel obtained by hydrolysed vegetable oil or animal fats. According to EurObserv'ER, 13.5 Mtoe of biofuel consumption was exclusively dedicated to transport in 2018 in the EU of 28. This amounts to 13.4% growth over 2017, equating to 1.6 Mtoe of extra consumption which can mainly be attributed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to the higher incorporation rates in several countries. For instance, in Spain, the common rate for bioethanol and biodiesel (in energy content) rose from 5% in 2017 to 6% in 2018. In the UK, the rate expressed in incorporation volumes has risen from 4.75% since 2013 to 7.25% from 14 April 2018 onwards. The common incorporation rate calculated as energy content for Poland rose from 7.1 to 7.5%; in Italy, from 6.5 to 7% and in the Netherlands, from 7.75% to 8.5%.

Bioethanol consumption dedicated to transport, be it directly blended with petrol or first converted into ETBE (ether tert-butyl ether), has also been on the increase since 2017, but at a slower pace than biodiesel. In 2018, consumption increased by 7% to reach 3.0 Mtoe (0.2 Mtoe more than in 2017). This rise came after a long period when incorporated volumes stabilized as a result of changes to the legislation that penalized bioethanol, such as the suspension or overhaul of a number of incorpora-

## 1

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

| | Bioethanol | Biodiesel | Biogas fuel | Other biofuels* | Total consumption | % compliant** |
|---|---|---|---|---|---|---|
| France | 544.5 | 2 592.5 | 0.0 | 0.0 | 3 137.1 | 100.0% |
| Germany | 733.4 | 1 845.6 | 38.3 | 1.7 | 2 619.0 | 97.7% |
| Sweden | 94.7 | 1 169.9 | 111.1 | 0.0 | 1 375.7 | 100.0% |
| Spain | 138.0 | 1 231.5 | 0.0 | 0.0 | 1 369.5 | 100.0% |
| Italy | 33.1 | 1 028.7 | 0.1 | 0.0 | 1 061.9 | 99.8% |
| United Kingdom | 383.2 | 565.3 | 0.0 | 0.0 | 948.5 | 100.0% |
| Poland | 176.2 | 428.7 | 0.0 | 0.0 | 604.9 | 100.0% |
| Austria | 56.0 | 422.2 | 0.3 | 0.0 | 478.5 | 93.3% |
| Belgium | 86.7 | 378.5 | 0.0 | 0.0 | 465.1 | 100.0% |
| Finland | 80.7 | 309.3 | 2.6 | 0.0 | 392.7 | 99.2% |
| Czechia | 59.3 | 254.5 | 0.0 | 0.0 | 313.8 | 100.0% |
| Netherlands | 128.9 | 177.2 | 5.4 | 0.0 | 311.5 | 97.3% |
| Romania | 91.1 | 206.1 | 0.0 | 0.0 | 297.2 | 100.0% |
| Portugal | 2.9 | 239.2 | 0.0 | 0.0 | 242.1 | 100.0% |
| Denmark | 43.6 | 172.0 | 2.9 | 0.0 | 218.5 | 99.6% |
| Greece | 0.0 | 165.8 | 0.0 | 0.0 | 165.8 | 99.1% |
| Hungary | 46.4 | 117.6 | 0.0 | 0.0 | 164.0 | 100.0% |
| Bulgaria | 26.6 | 136.4 | 0.0 | 0.0 | 163.0 | 100.0% |
| Ireland | 24.5 | 136.1 | 0.0 | 0.0 | 160.6 | 100.0% |
| Slovakia | 19.6 | 126.7 | 0.0 | 0.0 | 146.2 | 100.0% |
| Luxembourg | 6.7 | 103.5 | 0.0 | 0.0 | 110.3 | 100.0% |
| Lithuania | 8.3 | 63.5 | 0.0 | 0.0 | 71.8 | 100.0% |
| Slovenia | 3.5 | 20.7 | 0.0 | 0.0 | 24.1 | 100.0% |
| Latvia | 7.9 | 1.4 | 0.0 | 0.0 | 9.3 | 100.0% |
| Cyprus | 0.0 | 8.6 | 0.0 | 0.0 | 8.6 | 100.0% |
| Malta | 0.0 | 7.3 | 0.0 | 0.0 | 7.3 | 100.0% |
| Croatia | 0.2 | 0.3 | 0.0 | 0.0 | 0.5 | 100.0% |
| Estonia | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0% |
| **Total EU 28** | **2 795.9** | **11 909.1** | **160.8** | **1.7** | **14 867.5** | **99.3%** |

** Pure used vegetable oil and unspecified biofuel. ** Compliant with Articles 17 and 18 of Directive 2009/28/EC. The breakdown between types of biofuel has been estimated by EurObserv'ER.* ***Source: Shares (Eurostat)***

## 2

*Biofuels consumption for transport in the European Union in 2018 (in toe)*

| | Bioethanol | Biodiesel | Biogas fuel | Other biofuels* | Total consumption | % compliant** |
|---|---|---|---|---|---|---|
| France | 582.8 | 2 559.3 | 0.0 | 0.0 | 3 142.0 | 100.0% |
| Germany | 748.0 | 1 937.7 | 33.4 | 1.0 | 2 720.1 | 98.8% |
| Spain | 153.8 | 1 584.6 | 0.0 | 0.0 | 1 738.4 | 100.0% |
| Sweden | 131.5 | 1 249.8 | 118.5 | 0.0 | 1 499.7 | 100.0% |
| United Kingdom | 387.2 | 923.1 | 14.1 | 0.0 | 1 324.3 | 98.9% |
| Italy | 32.6 | 1 217.1 | 0.4 | 0.0 | 1 250.1 | 100.0% |
| Poland | 172.8 | 739.6 | 0.0 | 0.0 | 912.4 | 100.0% |
| Netherlands | 169.7 | 332.9 | 7.2 | 0.0 | 509.8 | 99.5% |
| Austria | 57.6 | 413.9 | 0.4 | 0.0 | 471.8 | 97.6% |
| Belgium | 108.0 | 347.8 | 0.0 | 0.0 | 455.8 | 100.0% |
| Finland | 84.4 | 283.2 | 4.7 | 0.0 | 372.2 | 98.4% |
| Czechia | 61.3 | 247.4 | 0.0 | 0.0 | 308.7 | 100.0% |
| Romania | 90.4 | 206.6 | 0.0 | 0.0 | 297.1 | 100.0% |
| Portugal | 5.6 | 275.9 | 0.0 | 0.0 | 281.5 | 100.0% |
| Denmark | 42.9 | 170.5 | 5.2 | 0.0 | 218.7 | 99.7% |
| Hungary | 50.2 | 141.8 | 0.0 | 0.0 | 192.0 | 100.0% |
| Bulgaria | 28.6 | 132.3 | 0.0 | 0.0 | 160.9 | 88.8% |
| Greece | 0.0 | 158.8 | 0.0 | 0.0 | 158.8 | 99.1% |
| Ireland | 27.3 | 127.0 | 0.0 | 0.0 | 154.2 | 100.0% |
| Slovakia | 17.6 | 127.9 | 0.0 | 0.0 | 145.4 | 100.0% |
| Luxembourg | 10.0 | 109.5 | 0.0 | 0.0 | 119.6 | 99.9% |
| Lithuania | 8.0 | 69.8 | 0.0 | 0.0 | 77.8 | 100.0% |
| Slovenia | 6.7 | 65.3 | 0.0 | 0.0 | 72.0 | 100.0% |
| Latvia | 8.5 | 27.7 | 0.0 | 0.0 | 36.1 | 100.0% |
| Croatia | 0.4 | 26.6 | 0.0 | 0.0 | 27.0 | 100.0% |
| Estonia | 4.9 | 12.3 | 3.3 | 0.0 | 20.5 | 100.0% |
| Malta | 0.0 | 9.2 | 0.0 | 0.0 | 9.2 | 100.0% |
| Cyprus | 0.0 | 9.0 | 0.0 | 0.0 | 9.0 | 100.0% |
| **Total EU 28** | **2 990.5** | **13 506.4** | **187.2** | **1.1** | **16 685.2** | **99.5%** |

** Pure used vegetable oil and unspecified biofuel. ** Compliant with Articles 17 and 18 of Directive 2009/28/EC. The breakdown between types of biofuel has been estimated by EurObserv'ER.* ***Source: Shares (Eurostat)***

tion quotas (e.g. as in Spain which discontinued the incorporation quotas specific to bioethanol in 2016), by the advantages of double accounting that mainly favoured the consumption of biodiesel produced from spent oil and by low fossil fuel prices during that period. In countries such as Spain and the Netherlands, the reason for this bioethanol consumption recovery is the gradual increase in common incorporation quotas. In Belgium, it is more directly connected to the increase in bioethanol's specific mandate of incorporation that has risen from 4 to 8.5% since 1 January 2017 (and will stay at that level until 2020). In Germany, bioethanol consumption took advantage of lower incorporation of ETBE in petrol, which favours the incorporation of pure bioethanol. In France, the sector has continued to make the most of the increase in incorporation targets from 7 – 7.5%, effective since 2017 and the extension of the national network of service stations that have E10 and E85 pumps (see below). The main shortcoming is that British consumption of bioethanol plummeted in 2018 because of the very sharp increase in demand for biodiesel that benefitted from double accounting.

As for the consumption of biogas fuel intended for NGVs (vehicles running on compressed natural gas), it is now counted in nine countries, with considerable volumes in Sweden and Germany. Its consumption rose from 160.8 ktoe in 2017 to 187.2 ktoe in 2018. Sweden is the leading biogas fuel consumer. According to data released in March 2019 by Statistics Sweden, biogas fuel consumption (purified until it achieves a quality equivalent to that of natural gas) rose from 133 613 000 Nm3 (normalized m3) in 2017 (equating to 111.1 ktoe ) to 142 038 000 Nm3 in 2018 (equating to 118.5 ktoe ). At the end of 2018, the country had 185 public service stations that deliver biogas (ten more than in 2017), as well as some sixty non-public stations used by institutions, public transport and corporate vehicle fleets.

## THE FINAL SPRINT TO THE FINISHING LINE

The European development framework for biofuel and its use in the transport sector has been clearly redefined and has boosted EU biofuel consumption. In 2015, the 2015/1513 directive known as the ILUC Directive (Indirect Land Use Change) confirmed the 10% RES target in transport for 2020 with a 7% ceiling for biofuels in competition with food production and an indicative target of 0.5% in 2020 for advanced biofuels, specifying the list of raw materials authorized for their development. EU consumption of sustainably certified biofuels should thus surge in the next two years and be linked to the increase in national incorporation mandates and other specific obligations made of distributors (such as in Germany and Sweden, to reduce the greenhouse gas

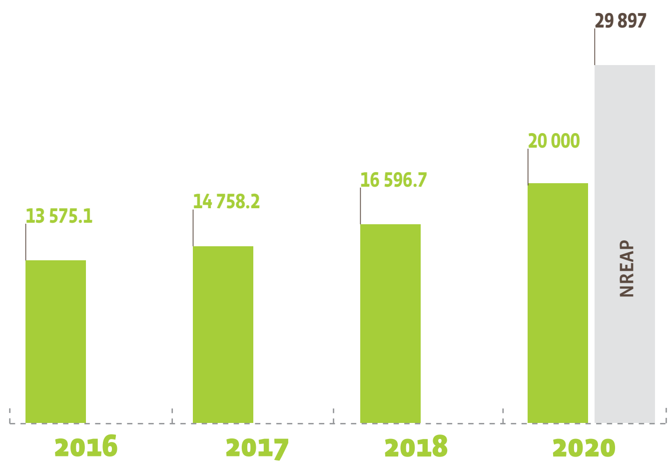






**3**

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




** Compliant with Articles 17 and 18 of Directive 2009/28/EC.* ***Source : EurObserv'ER***

emissions of road fuels). By way of examples, between 2018 and 2020, the energy content incorporation obligations of sustainable fuels will rise from 7 to 9% in Italy, 6 to 8.5% in Spain, 7.5 to 8.5% in Poland, 8 to 16.4% in the Netherlands, 5.75 to 8.75% in Austria, 15 to 20% in Finland and 7.5 to 10% in Portugal. Even if double accounting limits the volumes actually incorporated, the Member States will embark on a final sprint to achieve their 2020 targets. In some cases, biofuel imports will be a convenient adjustment variable used to achieve these targets, be it at the level of the transport sector or more generally. According to EurObserv'ER, at the end of 2020, the energy content consumption level of biofuels could exceed 20 Mtoe, and even be close to 21 Mtoe, including the UK.

The new European Renewable Energy Directive (RED II) has defined a new 14% renewable energy target in transports in 2030 (the threshold is described as the "minimum share" to achieve), by reformulating and adding new sustainability and GHG reduction criteria and by setting specific targets for biofuels produced from waste (oils or fats) or feedstocks not sourced from energy crops. To achieve the assigned 14% target, the RED II Directive allows for the share of biofuels (and biogas) used for transport and produced from specific raw materials to be considered at double their energy content in the energy assessment of the countries that will use them. This double accounting affects "advanced biofuels" (and biogas). The Directive defines these in Article 2, as being produced from the raw materials listed in Annexe IX – part A (algae, forestry waste and residue and from the timber sector, straw, manure, wastewater treatment sludge, raw glycerin, bagasse, etc.). It also affects biofuels (and biogas) produced with other feedstocks listed in part B of the same annexe, namely spent cooking oil and animal fats. However, biofuels produced from these materials are not considered as advanced and thus will not contribute to the specific targets of minimum shares allotted to advanced biofuels. RED II provides a specific target for each Member State of 0.2% in 2022, at least 1% in 2025 and at least 3.5% in 2030 to enable the industrial development of "advanced biofuels" to go ahead. Nonetheless, the Directive enables the Member States to depart from these limits if they can prove they have problems sourcing the feedstocks in question. RED II also sets a ceiling for biofuels produced from crops traditionally used in human and animal food (defined as "agrofuels"). Their share in 2030 will be subject to a double constraint: they will not be permitted to exceed a maximum share of 7% of the final energy consumption in the transport sector. Furthermore, their share may not exceed one percentage point above their reference level in 2020. RED II has also introduced a limit for the contribution of biofuels or biogas produced from spent oil or animal fats (annexe IX, part B) capped at 1.7% by 2030. Given the set framework, EurObserv'ER forecasts that biofuel consumption in transport could approach 30 Mtoe (including the UK). ■

# RENEWABLE MUNICIPAL WASTE

Eurostat reports that renewable municipal waste treatment with energy recovery by incineration (waste-to-energy) plants generated about 10 Mtoe of primary energy in 2018 (9 993,4 ktoe to be precise). This output is more or less stable with the previous year (0.4% more) which was 9 957 ktoe (revised figure). The consumption figure that allows for the balance of imports and stock variations is a little higher at 10.4 Mtoe, and so stable with 2017 (0.5% more).

These figures do not include all the recovered energy output of these plants but only an estimate of the biodegradable part of household refuse (carton, paper, kitchen waste, etc.). The energy recovered from non-renewable household refuse (plastic packaging, water bottles, etc.), resulted in comparable, slightly lower output. The trends differ more across the Member States. In 2018, only a minority of the countries saw their renewable municipal waste primary energy outputs rise. The UK recorded the most significant rise with an additional 152.3 ktoe , for a total of 1 052.8 ktoe (16.9% growth), ahead of Ireland whose renewable waste energy recovery made a 46-ktoe leap in primary energy output in 2018 (49.0% more than in 2017), taking its total to 140 ktoe . France came in third with 42.3 ktoe growth and total output of 1 326.7 ktoe (3.3% growth). Germany leads the EU for renewable household refuse energy recovery (3102.6 ktoe in 2018), however it recorded its biggest drop in output (114.6 ktoe , 3.6% less than in 2017) and so returned to exactly the same level as in 2016. Sweden, which is another country making major household refuse energy recovery efforts (724 ktoe) also posted a decline (55.1 ktoe , 7.1% less than in 2017). The drops in energy production from household refuse incineration should not necessarily be viewed as an environmental setback in those countries that are highly advanced in terms of prevention, composting and recycling and where no more dumping in landfills takes place. This applies to Germany where the composting and recycling rate is almost 70% – the highest of any EU country), and Sweden where this rate is close to 50%. The other European Union countries where landfilling is almost non-existent or very low are Denmark, Finland, the Netherlands, Belgium, Austria and Luxembourg. In these countries, drops in energy production may well be explained by less waste produced (prevention) or by increased recycling rates. In the UK, Ireland and France, the increases in primary energy output from municipal waste are more indicative of their willingness to move towards banning landfilling and complying with European regulations. There is still a yawning gap with the countries further to the east of the European Union that still dispose of a very high percentage of waste in landfills (roughly half to three quarters). In their case, the energy recovery from waste growth potential by incineration (and likewise for recycling) is still very high and will require major waste-to-energy plant construction efforts.

### COMING UP TO 500 WASTE-TO-ENERGY RECOVERY PLANTS IN THE EU

This sector has an advantage in that waste-to-energy plants tend to be located close to major urban centres that are both providers of waste but also major energy consumers. The proximity encourages optimum and local use of the energy, be it in the form of heat, electricity or more often than not both, through cogeneration. Heat can also be more easily exported to supply a district heating network or the process heat to an industrial site. According to the latest figures released by CEWEP, Europe had just under 500 urban waste energy recovery plants in 2017 (478 in the EU and 18 in Norway), that treat just under 100 million tonnes of renewable or non-renewable waste (96 million including 1.6 million tonnes in Norway).

In 2018, electricity remained the main energy recovery mode from incinerators. If we only include the renewable part of waste, the incineration plants generated 22.9 TWh by the end of 2018, i.e. 0.75 TWh or 3.4% more than in 2017. Cogeneration is the main recovery method in these plants. The share of cogeneration electricity thus increased by 54.6% in 2018.

**1**

*Primary energy production of renewable municipal waste in the European Union in 2017 and 2018 (in ktoe)*

| | 2017 | 2018 |
|---|---|---|
| Germany | 3 216.9 | 3 102.3 |
| France | 1 284.3 | 1 326.7 |
| United Kingdom | 900.5 | 1 052.8 |
| Italy | 853.2 | 846.6 |
| Netherlands | 764.3 | 746.6 |
| Sweden | 779.1 | 724.0 |
| Denmark | 467.8 | 440.9 |
| Belgium | 378.4 | 372.4 |
| Finland | 326.9 | 348.9 |
| Spain | 259.7 | 254.1 |
| Austria | 174.7 | 182.3 |
| Ireland | 94.0 | 140.0 |
| Portugal | 119.0 | 110.6 |
| Poland | 92.5 | 98.3 |
| Czechia | 92.0 | 87.6 |
| Hungary | 46.1 | 38.8 |
| Bulgaria | 29.6 | 36.3 |
| Estonia | 0.0 | 23.1 |
| Lithuania | 29.4 | 19.8 |
| Slovakia | 28.5 | 15.0 |
| Luxembourg | 14.1 | 14.0 |
| Latvia | 3.7 | 9.5 |
| Romania | 2.0 | 2.0 |
| Cyprus | 0.5 | 0.7 |
| EU 28 | 9 957.0 | 9 993.4 |

*Source: Eurostat*

However, sales of heat through networks slipped slightly (by 1.1%) to 2 874.3 ktoe (2 905.1 ktoe in 2017) although this is not an EU-wide reduction. It can mainly be ascribed to lower input to the district heating networks of the Netherlands (110.2 ktoe less) and Sweden (33.2 ktoe less). On analysis, lower demand for heat appears to have prompted these two countries to channel more energy into electricity production. The proportion of heat produced by cogeneration also increased and rose from 80.1% in 2017 to 80.7% in 2018.

The UK is currently one of the most active countries building new incineration plants. According to the Department for Business, Energy & Industrial Strategy (BEIS), energy output from renewable household waste increased in the UK by 16.9% between 2017 and 2018, which took it past the one million toe threshold in 2018 (1 052.8 ktoe ). Most of this energy was recovered as electricity, generating 5.2 TWh in 2018 (5.8% more than in 2017, whose revised output figure is 4.9 TWh). The reason for this growth spurt is that several new incineration plants with energy recovery were commissioned, as the UK has insufficient capacity to treat its own waste. The BEIS claims that the net electricity capacity of its incineration plants rose from 1 028 MW in 2016, to 1 131 MW in 2017 and to 1 179 MW in 2018. The electricity recovery capacity of its incinerators has more than doubled since 2012 (513 MW). One of the biggest sites to be commissioned in 2018 is the 27-MW Allerton Waste Recovery Park in North Yorkshire (Northern England). While the Republic of Ireland did not connect any new plants in 2018, the 60-MW Poolberg incineration plant in Dublin that was commissioned in 2017 is now running at full capacity, and so doubled its output between 2017 and 2018 (from 150.7 to 330.2 GWh).

If in the Netherlands electricity output from renewable waste also increased (by 14.1% compared to 2017) to 2 172 GWh in 2018, this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## 2

*Gross electricity production from renewable municipal waste in the European Union in 2017 and 2018 (in GWh)*

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Electricity-only plants | CHP plants | Total | Electricity-only plants | CHP plants | Total |
| Germany | 3 309.0 | 2 647.0 | 5 956.0 | 3 704.0 | 2 459.0 | 6 163.0 |
| United Kingdom | 2 010.4 | 1 436.4 | 3 446.8 | 2 110.0 | 1 527.7 | 3 637.6 |
| Italy | 1 160.1 | 1 223.6 | 2 383.6 | 1 139.3 | 1 231.7 | 2 370.9 |
| France | 1 180.5 | 1 024.6 | 2 205.1 | 1 189.5 | 1 014.2 | 2 203.7 |
| Netherlands | 0.0 | 1 903.7 | 1 903.7 | 0.0 | 2 172.2 | 2 172.2 |
| Sweden | 0.0 | 1 778.0 | 1 778.0 | 0.0 | 1 656.0 | 1 656.0 |
| Belgium | 488.5 | 498.3 | 986.8 | 471.8 | 495.8 | 967.6 |
| Denmark | 0.0 | 883.6 | 883.6 | 0.0 | 860.1 | 860.1 |
| Spain | 674.0 | 98.0 | 772.0 | 661.0 | 94.0 | 755.0 |
| Finland | 28.0 | 528.4 | 556.4 | 80.1 | 582.2 | 662.3 |
| Austria | 245.4 | 70.1 | 315.5 | 248.9 | 86.9 | 335.8 |
| Ireland | 150.7 | 0.0 | 150.7 | 330.2 | 0.0 | 330.2 |
| Portugal | 360.3 | 0.0 | 360.3 | 326.9 | 0.0 | 326.9 |
| Hungary | 83.0 | 77.0 | 160.0 | 83.0 | 79.0 | 162.0 |
| Czechia | 0.0 | 114.3 | 114.3 | 0.0 | 100.2 | 100.2 |
| Poland | 0.0 | 80.7 | 80.7 | 0.0 | 85.0 | 85.0 |
| Lithuania | 0.0 | 73.2 | 73.2 | 0.0 | 48.0 | 48.0 |
| Luxembourg | 46.9 | 0.0 | 46.9 | 46.8 | 0.0 | 46.8 |
| Estonia | 0.0 | 0.0 | 0.0 | 30.0 | 16.0 | 46.0 |
| Slovakia | 0.0 | 22.0 | 22.0 | 0.0 | 16.0 | 16.0 |
| EU 28 | 9 736.8 | 12 458.8 | 22 195.6 | 10 421.3 | 12 524.0 | 22 945.2 |

*Source: Eurostat*

achievement will not be repeated in 2019, because the AEB Amsterdam waste-to-energy plant ran into technical problems and had to shut down 4 of its 6 production lines early in July and did not reopen them until early November. This plant that usually treats more than 1.4 million tonnes of waste (including 250 000 tonnes imported from the UK in 2018) normally produces about 1 TWh of electricity and supplies heat to more than 35 000 households in Greater Amsterdam. As for its renewable heat output (heat sold), that dropped sharply in 2018 (39.8% less than in 2017, equating to a drop of 110.2 ktoe ) because of the lower demand for heating. Heat output is unlikely to make a strong recovery in 2019 as the autumn and the month of December 2019 were particularly mild.

### CHANGE OF FRAMEWORK

Over the past decade, the drive for renewable municipal waste energy recovery has been generally positive, so given the European Union's strong requirements, the low growth observed between 2018 and 2019 has not dampened the waste-to-energy industry's spirits. Since 2008, primary energy output

## 3

*Gross heat production from renewable municipal waste in the European Union in 2017 and in 2018 (in ktoe) in the transformation sector*

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Heat only plants | CHP plants | Total | Heat only plants | CHP plants | Total |
| Germany | 284.8 | 488.5 | 773.3 | 260.9 | 599.8 | 860.7 |
| Sweden | 56.4 | 528.0 | 584.4 | 51.8 | 499.4 | 551.2 |
| France | 149.8 | 280.2 | 430.0 | 159.8 | 287.5 | 447.4 |
| Denmark | 34.8 | 331.3 | 366.1 | 34.2 | 336.4 | 370.7 |
| Finland | 25.3 | 141.5 | 166.9 | 21.9 | 146.7 | 168.6 |
| Netherlands | 0.0 | 277.0 | 277.0 | 0.0 | 166.9 | 166.9 |
| Italy | 0.0 | 124.2 | 124.2 | 0.0 | 126.8 | 126.8 |
| Austria | 14.6 | 50.9 | 65.5 | 14.3 | 50.0 | 64.3 |
| Czechia | 0.0 | 40.6 | 40.6 | 0.0 | 40.2 | 40.2 |
| Belgium | 0.1 | 26.0 | 26.1 | 0.1 | 27.7 | 27.8 |
| Hungary | 0.0 | 10.9 | 10.9 | 0.0 | 12.3 | 12.3 |
| Poland | 0.1 | 10.8 | 10.9 | 0.1 | 11.3 | 11.4 |
| United Kingdom | 12.1 | 0.0 | 12.1 | 9.9 | 0.0 | 9.9 |
| Lithuania | 0.0 | 16.4 | 16.4 | 0.0 | 9.9 | 9.9 |
| Estonia | 0.0 | 0.0 | 0.0 | 0.0 | 4.9 | 4.9 |
| Slovakia | 0.8 | 0.0 | 0.8 | 1.4 | 0.0 | 1.4 |
| Romania | 0.011 | 0.000 | 0.011 | 0.010 | 0.000 | 0.010 |
| EU 28 | 578.8 | 2 326.3 | 2 905.1 | 554.5 | 2 319.8 | 2 874.3 |

*Source: Eurostat*

has risen from 7.2 to 10 Mtoe in 2018, encouraged by a policy that aims to increase landfill taxes and ban household refuse from landfills. CEWEP claims that 24 Member States have already introduced landfill taxes that range from 3 to more than 100 euros per tonne for Belgium. The remaining four states have not introduced landfill taxes, namely Germany (where a landfill ban is in effect), Cyprus, Malta and Croatia.

One reason for this optimism comes from Europe's revised waste legislation ("Circular Economy Package") which came into force in July 2018. It sets out clear waste reduction targets and an ambitious, credible long-term path for waste management and recycling. The revised proposal's key elements on waste are a binding landfill target to reduce landfilling to a maximum of 10% of household refuse by 2035 (note: the above-mentioned eight countries are already compliant); a common EU recycling target of 65% for municipal waste by 2035; a common EU recycling target of 70% for packaging waste by 2030. There are also specific packaging material recycling targets (paper and carton: 85%, ferrous metals: 80%, aluminium: 60%, glass: 75%, plastic: 55% and wood: 30%).

According to CEWEP, despite ambitious prevention and recycling efforts being made, this binding legislation will create significant thermal waste treatment needs in the next 15 years. On the assumption of a 65% recycling rate for municipal waste and a 68% rate for non-hazardous commercial and industrial waste, CEWEP puts the required waste treatment capacity at about 142 million tonnes by 2035, compared to the current 90 million tonnes of treatment capacity in waste-to-energy plants and 11 million tonnes of co-firing capacity in cement furnaces. Thus, according to CEWEP, about 40 million tonnes of waste remain without thermal treatment coverage in addition to the recycling and waste prevention targets to be achieved. If this target is met, CEWEP reckons that waste-to-energy plants could be capable of supplying electricity to about 18 million individuals and heat to 22 million individuals in the European Union. A simple rule of three calculation compared to the energy situation (making no allowance for energy efficiency increases) would lead to minimum output of about 7.7 TWh or power and heat sales of more than 4.2 Mtoe by 2035 according to EurObserv'ER.

New investments will be made essentially where the needs are greatest, namely in the countries with the highest landfill rates. The ambitious Green Deal which will mobilize European industries around the energy transition and circular economy themes should partly focus on the countries that are less advanced in these areas. In this context, the European Commission President undertook to roll out a "Just Transition Mechanism" on January 14, with 100 billion euros of funding between 2021 and 2027, destined to help the most fossil fuel-dependent regions switch to low-carbon economies. ■

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# SOLID BIOMASS

Solid biomass is an umbrella term for all solid organic components to be used as fuels. They include wood, timber industry by-products (wood chips, sawdust, etc.), wood pellets, black liquor from the paper industry, straw, bagasse, animal waste and other solid plant residues. The renewable portion of municipal waste is monitored separately by the statistics organizations and so is not included in the solid biomass indicator. Charcoal is usually included with solid biomass but is accounted for separately. By way of illustration, Eurostat quantified the European Union's final charcoal energy consumption at 404,9 ktoe in 2018 (376,1 ktoe in 2017). Energy recovery from solid biomass is mainly used to produce heat and electricity. While lignocellulosic biomass (cereal straw, forest waste, etc.) can also be converted into 2nd-generation liquid biofuel or gas, such as hydrogen or methane, these recovery methods are still marginal across the European Union.

## THE CLIMATE CONTEXT IS AFFECTING THE CONSUMPTION TREND

The European Union's solid biomass energy consumption trend is driven by its two main outlets – the supply of heat and the supply of electricity. The trend in heat supply, which is the main biomass energy recovery form, is particularly climate-sensitive during the heating season. According to the World Meteorological Organization (WMO), 2018 was the third hottest year ever recorded in Europe. France, Germany, the Czech Republic and Hungary had their hottest years on record since climate readings have been made. Thus, many European countries' heating requirements were lower than in 2017, which limited households' wood energy consumption and demand from heating networks running on solid biomass. Unfortunately, climate warming appears to be continuing. According to the WMO, 2019 was the second hottest year's ranking since the first records in 1850. It marks the end of a decade of exceptionally warm weather globally.

## BELOW THE 100-MTOE THRESHOLD

Eurostat reports that in 2018 solid biomass primary energy consumption did not pass the 100-Mtoe threshold. Across the European Union, overall consumption contracted slightly, by 0.1%, from 99.6 to 99.4 Mtoe (table 1), the Member States showing differences, as about half of them used less solid biomass, with sharper drops registered in Italy (502 ktoe), Germany (314 ktoe), Austria (265 ktoe), Hungary (227 ktoe) and Sweden (209 ktoe). The biggest increases in solid biomass consumption were registered in the UK (885 ktoe), Bulgaria (339 ktoe) and Finland (273 ktoe), driven by the increase in solid biomass electricity output (see below). The production of solid biomass-sourced primary energy, namely the solid biomass gleaned from European Union soil, also slipped, by 0.3% compared to 2017, to 94.4 Mtoe in 2018. The main reason for the difference, which is accounted for by nett imports plus or minus stock variations, is made up of wood pellet imports mainly from the USA, Canada and Russia.

The tables distinguish the two types of final energy use from solid biomass, namely electricity (table 2) and heat (for heating or industrial processes). Solid biomass heat produced by the transformation sector and distributed via heating networks (table 3) is differentiated from solid biomass heat directly used by end consumers (ex: in residential, agriculture or industry sectors) (table 4). According to EurObserv'ER, the latter declined across the EU (by 1.5% compared to 2017) reaching 67.9 Mtoe, primarily because of the decrease in household wood energy consumption in France, Italy and Sweden. This drop could have been even steeper had it not been for the clear increases in final energy consumption in the UK (326 ktoe ) and Finland (214 ktoe). The sale of biomass heat (gross heat production in the processing sector) held up better. At EU level, it remained stable at 10.4 Mtoe. Decreases in production in Finland (-112 ktoe), Germany (-46 ktoe), Sweden (-33 ktoe) and Austria (-30 ktoe) were offset by the commissioning

## 1

*Primary energy production and gross inland consumption of solid biomass* in the European Union in 2017 and 2018 (in Mtoe)*

| | 2017 | | 2018 | |
|---|---|---|---|---|
| | Production | Consumption | Production | Consumption |
| Germany | 11.916 | 12.382 | 11.702 | 12.069 |
| France | 10.350 | 10.386 | 10.225 | 10.324 |
| Sweden | 9.498 | 9.529 | 9.231 | 9.320 |
| Finland | 8.576 | 8.608 | 8.852 | 8.881 |
| Italy | 7.826 | 9.013 | 7.066 | 8.511 |
| United Kingdom | 4.024 | 6.421 | 4.473 | 7.306 |
| Poland | 6.211 | 6.341 | 6.147 | 6.347 |
| Spain | 5.479 | 5.479 | 5.441 | 5.441 |
| Austria | 4.833 | 4.873 | 4.601 | 4.608 |
| Romania | 3.564 | 3.639 | 3.443 | 3.463 |
| Denmark | 1.740 | 3.248 | 1.774 | 3.251 |
| Czechia | 2.997 | 2.962 | 3.070 | 2.981 |
| Portugal | 2.619 | 2.421 | 2.662 | 2.456 |
| Hungary | 2.363 | 2.378 | 2.132 | 2.151 |
| Belgium | 1.215 | 2.051 | 1.231 | 2.003 |
| Latvia | 2.040 | 1.428 | 2.447 | 1.494 |
| Bulgaria | 1.126 | 1.069 | 1.524 | 1.441 |
| Croatia | 1.543 | 1.241 | 1.496 | 1.259 |
| Lithuania | 1.306 | 1.263 | 1.249 | 1.248 |
| Netherlands | 1.364 | 1.194 | 1.338 | 1.196 |
| Estonia | 1.487 | 0.984 | 1.648 | 1.036 |
| Slovakia | 0.841 | 0.827 | 0.908 | 0.889 |
| Greece | 0.809 | 0.862 | 0.782 | 0.834 |
| Slovenia | 0.592 | 0.592 | 0.549 | 0.549 |
| Ireland | 0.246 | 0.275 | 0.247 | 0.270 |
| Luxembourg | 0.070 | 0.077 | 0.092 | 0.092 |
| Cyprus | 0.023 | 0.025 | 0.023 | 0.024 |
| Malta | 0.000 | 0.001 | 0.000 | 0.001 |
| Total EU 28 | 94.659 | 99.567 | 94.353 | 99.444 |

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

## 2

*Gross electricity production from solid biomass* in the European Union in 2017 and 2018 (in TWh)*

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Electricity-only plants | CHP plants | Total | Electricity-only plants | CHP plants | Total |
| United Kingdom | 20.542 | 0.000 | 20.542 | 23.532 | 0.000 | 23.532 |
| Finland | 0.918 | 9.973 | 10.890 | 1.429 | 10.392 | 11.821 |
| Germany | 4.598 | 6.046 | 10.644 | 5.363 | 5.464 | 10.827 |
| Sweden | 0.000 | 10.250 | 10.250 | 0.000 | 10.195 | 10.195 |
| Poland | 1.415 | 3.893 | 5.309 | 1.500 | 3.833 | 5.333 |
| Denmark | 0.000 | 4.797 | 4.797 | 0.000 | 4.418 | 4.418 |
| Spain | 3.458 | 0.907 | 4.365 | 3.289 | 0.932 | 4.221 |
| Italy | 2.198 | 2.033 | 4.232 | 2.168 | 2.024 | 4.191 |
| Austria | 0.931 | 3.004 | 3.935 | 0.985 | 2.981 | 3.966 |
| France | 0.190 | 3.249 | 3.439 | 0.566 | 3.201 | 3.767 |
| Belgium | 2.491 | 1.326 | 3.816 | 2.177 | 1.307 | 3.484 |
| Portugal | 0.799 | 1.775 | 2.573 | 0.841 | 1.717 | 2.558 |
| Czechia | 0.004 | 2.209 | 2.213 | 0.003 | 2.118 | 2.121 |
| Hungary | 0.955 | 0.691 | 1.646 | 1.103 | 0.696 | 1.799 |
| Netherlands | 1.094 | 0.678 | 1.772 | 0.424 | 1.072 | 1.496 |
| Bulgaria | 0.014 | 0.167 | 0.180 | 0.721 | 0.559 | 1.280 |
| Estonia | 0.140 | 0.856 | 0.996 | 0.271 | 0.952 | 1.223 |
| Slovakia | 0.000 | 1.080 | 1.080 | 0.000 | 1.070 | 1.070 |
| Latvia | 0.000 | 0.525 | 0.525 | 0.000 | 0.570 | 0.570 |
| Romania | 0.064 | 0.395 | 0.458 | 0.021 | 0.346 | 0.367 |
| Lithuania | 0.000 | 0.303 | 0.303 | 0.000 | 0.355 | 0.355 |
| Ireland | 0.366 | 0.016 | 0.381 | 0.317 | 0.013 | 0.330 |
| Croatia | 0.000 | 0.216 | 0.216 | 0.000 | 0.313 | 0.313 |
| Slovenia | 0.000 | 0.155 | 0.155 | 0.000 | 0.146 | 0.146 |
| Luxembourg | 0.000 | 0.052 | 0.052 | 0.000 | 0.095 | 0.095 |
| Greece | 0.010 | 0.000 | 0.010 | 0.012 | 0.000 | 0.012 |
| Total EU 28 | 40.185 | 54.596 | 94.781 | 44.722 | 54.767 | 99.489 |

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

of new cogeneration plants in Bulgaria (+95 ktoe), in the Netherlands (+60 ktoe) and in Poland (+41 ktoe). Total solid biomass heat consumption, decreased by almost 1 Mtoe to 78.8 Mtoe (by 1.3%), if these two elements – the heat sold by heating networks and directly used by households and industry – are added together.

The solid biomass electricity production trend is largely governed by certain member states' policies to pull out of coal by converting or adapting all or part of their power (or cogeneration) plants to use solid biomass fuels (pellets, woodchips, etc.). Across the EU, biomass electricity output increased by 5% over 2017 (by 4.7 TWh) with 99.5 TWh in 2018, which kept it below the 100-TWh threshold. Growth was essentially driven by the UK, Finland and Bulgaria.

## REGULATED DEPLOYMENT FOR SUSTAINABLE AND EFFICIENT USE OF BIOMASS

As solid biomass has the technical capacity substitute coal in producing heat and electricity, it has become the focus of many states' strategies for achieving the 2020 targets they set out to achieve as part of the 2009/28/CE Renewable Energies Directive. After that deadline, solid biomass will continue to play a major role in decarbonising the European Union's energy system, but stricter regulations will apply to its deployment. It will be subject to new rules following the recast Renewable Energies Directive (2018/2001) that defines the legal framework for renewable energies from 2021-2030 and in particular the rules set by article 29 on the sustainability requirements and GHG reduction criteria for liquid, solid and gaseous fuels. The sustainability criteria now cover all bioenergy uses (biofuel, electricity and heat). The Directive aims to minimise negative environmental risks such as deforestation, the loss of biodiversity and minimise the risks of negative impacts on forest carbon sinks. In the short and medium term, if we include the projects under development, there are good growth prospects for electricity production across the European Union with current growth at the same rate. In the Netherlands, several major biomass co-firing projects in existing coal-fired plants have taken up grants through the SDE + programme and should be producing 7 TWh of electricity per annum by 2020. The solid biomass electricity sector will also benefit from the conversion of Danish coal-fired power plants and the development of biomass cogeneration in Sweden. Acceleration is expected in 2019 and 2020 and according to EurObserv'ER, could increase solid biomass and municipal waste electricity output to 135 TWh in 2020 (graph 3).


As for solid biomass heat, it has to be said that current deployment has slowed down with readability blurred by milder winters. Yet, the situation should improve as the new RES Directive sets an indicative 1.3 of a percentage point target for annual increase in renewable energies use in final heat consumption, taking the situation in 2020 as the reference point. However, there is a limiting factor, because the Directive allows for the possibility of integrating recovery of up to 40% of waste heat and cold






### 3

*Gross heat production from solid biomass* in the European Union in 2017 and in 2018 (in Mtoe) in the transformation sector***

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Heat only plants | CHP plant | Total | Heat only plants | CHP plants | Total |
| Sweden | 0.709 | 1.808 | 2.518 | 0.685 | 1.799 | 2.484 |
| Finland | 0.711 | 0.995 | 1.706 | 0.691 | 0.903 | 1.594 |
| Denmark | 0.475 | 0.878 | 1.353 | 0.498 | 0.866 | 1.364 |
| France | 0.562 | 0.555 | 1.117 | 0.574 | 0.548 | 1.122 |
| Austria | 0.530 | 0.372 | 0.902 | 0.519 | 0.353 | 0.872 |
| Germany | 0.208 | 0.401 | 0.609 | 0.141 | 0.422 | 0.564 |
| Italy | 0.078 | 0.466 | 0.544 | 0.080 | 0.458 | 0.538 |
| Lithuania | 0.422 | 0.124 | 0.545 | 0.396 | 0.135 | 0.532 |
| Poland | 0.054 | 0.225 | 0.279 | 0.068 | 0.252 | 0.320 |
| Estonia | 0.165 | 0.132 | 0.296 | 0.127 | 0.189 | 0.316 |
| Latvia | 0.146 | 0.147 | 0.292 | 0.146 | 0.163 | 0.310 |
| Czechia | 0.032 | 0.139 | 0.171 | 0.033 | 0.129 | 0.162 |
| Netherlands | 0.024 | 0.077 | 0.101 | 0.030 | 0.131 | 0.161 |
| Slovakia | 0.049 | 0.083 | 0.133 | 0.042 | 0.080 | 0.122 |
| Bulgaria | 0.004 | 0.010 | 0.014 | 0.006 | 0.103 | 0.109 |
| Hungary | 0.048 | 0.064 | 0.112 | 0.040 | 0.058 | 0.098 |
| United Kingdom | 0.082 | 0.000 | 0.082 | 0.095 | 0.000 | 0.095 |
| Romania | 0.018 | 0.047 | 0.065 | 0.014 | 0.043 | 0.057 |
| Croatia | 0.000 | 0.036 | 0.036 | 0.000 | 0.056 | 0.056 |
| Luxembourg | 0.004 | 0.018 | 0.022 | 0.004 | 0.032 | 0.036 |
| Slovenia | 0.011 | 0.020 | 0.030 | 0.010 | 0.018 | 0.029 |
| Belgium | 0.000 | 0.007 | 0.007 | 0.000 | 0.006 | 0.006 |
| **Total EU 28** | **4.332** | **6.603** | **10.935** | **4.199** | **6.746** | **10.944** |

** Excluding charcoal. ** Corresponds to "Derived heat". **Source: Eurostat***

## 4

*Heat consumption from solid biomass* in the countries of the European Union in 2017 and 2018*

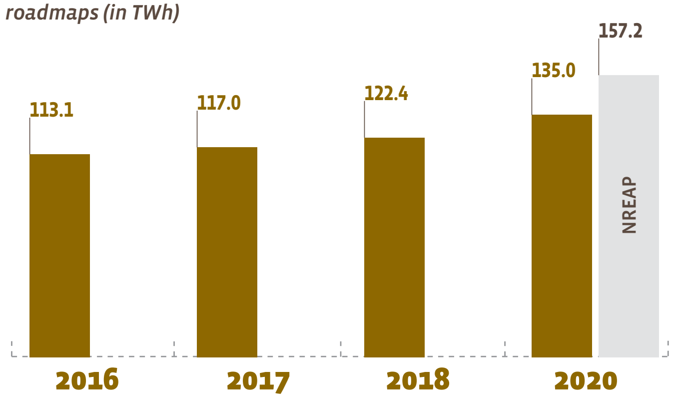
| | 2016 | of which final energy consumption | of which derived heat** | 2017 | of which final energy consumption | of which derived heat** |
|---|---|---|---|---|---|---|
| Germany | 9.791 | 9.182 | 0.609 | 9.439 | 8.876 | 0.564 |
| France | 9.362 | 8.245 | 1.117 | 9.261 | 8.139 | 1.122 |
| Sweden | 7.792 | 5.275 | 2.518 | 7.584 | 5.100 | 2.484 |
| Italy | 7.716 | 7.173 | 0.544 | 7.211 | 6.673 | 0.538 |
| Finland | 7.012 | 5.306 | 1.706 | 7.115 | 5.521 | 1.594 |
| Poland | 5.272 | 4.993 | 0.279 | 5.270 | 4.950 | 0.320 |
| Spain | 4.065 | 4.065 | 0.000 | 4.056 | 4.056 | 0.000 |
| Austria | 4.141 | 3.239 | 0.902 | 3.888 | 3.016 | 0.872 |
| Romania | 3.512 | 3.447 | 0.065 | 3.424 | 3.368 | 0.057 |
| United Kingdom | 2.795 | 2.712 | 0.082 | 3.133 | 3.038 | 0.095 |
| Denmark | 2.653 | 1.301 | 1.353 | 2.692 | 1.329 | 1.364 |
| Czechia | 2.446 | 2.275 | 0.171 | 2.486 | 2.324 | 0.162 |
| Portugal | 1.772 | 1.772 | 0.000 | 1.791 | 1.791 | 0.000 |
| Hungary | 1.935 | 1.823 | 0.112 | 1.678 | 1.580 | 0.098 |
| Latvia | 1.232 | 0.940 | 0.292 | 1.306 | 0.996 | 0.310 |
| Belgium | 1.270 | 1.263 | 0.007 | 1.286 | 1.280 | 0.006 |
| Bulgaria | 1.040 | 1.026 | 0.014 | 1.144 | 1.035 | 0.109 |
| Lithuania | 1.157 | 0.612 | 0.545 | 1.144 | 0.612 | 0.532 |
| Croatia | 1.160 | 1.124 | 0.036 | 1.131 | 1.075 | 0.056 |
| Greece | 0.857 | 0.857 | 0.000 | 0.827 | 0.827 | 0.000 |
| Netherlands | 0.750 | 0.649 | 0.101 | 0.816 | 0.655 | 0.161 |
| Estonia | 0.716 | 0.420 | 0.296 | 0.737 | 0.421 | 0.316 |
| Slovakia | 0.527 | 0.394 | 0.133 | 0.580 | 0.459 | 0.122 |
| Slovenia | 0.562 | 0.531 | 0.030 | 0.522 | 0.493 | 0.029 |
| Ireland | 0.197 | 0.197 | 0.000 | 0.201 | 0.201 | 0.000 |
| Luxembourg | 0.067 | 0.045 | 0.022 | 0.076 | 0.040 | 0.036 |
| Cyprus | 0.021 | 0.021 | 0.000 | 0.021 | 0.021 | 0.000 |
| Malta | 0.001 | 0.001 | 0.000 | 0.001 | 0.001 | 0.000 |
| Total EU 28 | 79.823 | 68.888 | 10.935 | 78.821 | 67.877 | 10.944 |

* *Excluding charcoal. ** Gross heat production in the transformation sector.* ***Source: Eurostat***



## 5

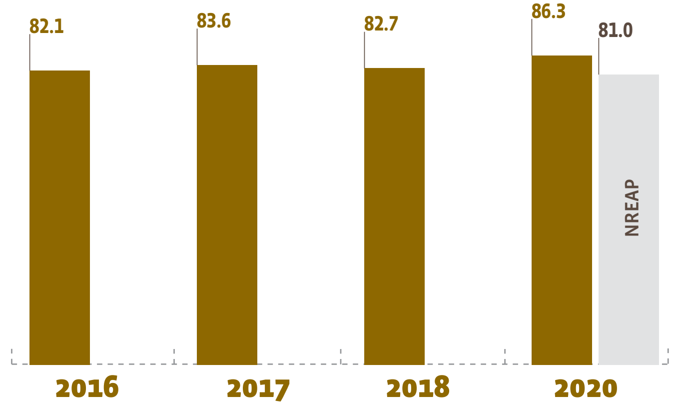
*Comparison of the current trend of electricty production from solid biomass against the NREAP (National Renewable Energy Action Plan) roadmaps (in TWh)*




*This data includes an estimate of renewable electricity from municipal waste incineration plants.* ***Source: EurObserv'ER 2019***

## 6

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




*This data includes an estimate of renewable heat from municipal waste incineration plants.* ***Source: EurObserv'ER 2019***

of the average annual increase in this target. Waste energy recovery is defined as a by-product in industrial, service installations or electricity production sites, which for want of access to an urban heating or cooling system, will not be used and will dissipate into the atmosphere or into water. Thus, the Member States have two levers available to them to meet this trajectory, energy efficiency via the deployment of heating networks or the development of renewable cooling or heat.

It we stick to the targets set in the National Renewable Energy Action Plans (NREAP) for solid biomass heat, the combined targets of the European Union countries taken together were exceeded back in 2016 (graph 4). Only a few countries that have opted for electricity recovery from biomass (the UK, the Netherlands and Ireland) appear unable to achieve them. This overall success, four years prior to the 2020 deadline, can be put down to poor sizing of the targets, and in particular the fact that the solid biomass sector includes renewable municipal waste-to-energy recovery. The future growth of biomass heat will depend on the implementation and strategic choices defined by the National Energy and Climate plans for 2030 which will have to factor in the annual increase target of 1.3% of a percentage point. ■

# CONCENTRATED SOLAR POWER

Concentrated solar power involves all the technologies that aim to transform the sun's rays into very high-temperature heat. They consist of tower plants, whose heliostats concentrate the radiation on a receiver at the top of a tower, plants that use Fresnel collectors – rows of flat mirrors that concentrate the radiation on a tube receiver, parabolic trough collectors – that concentrate the sun's rays onto a tube, and parabolic collectors, where a parabolic mirror reflects the sun's rays on a convergence point. The main application of these plants is to generate electricity, yet CSP can also be used for supplying heating networks, desalinating seawater or be integrated into industrial processes. One of the features of thermodynamic plant technology is that these plants can smooth their electricity output using a thermal storage buffer that can extend operating time by about ten hours. Storage is generally provided by means of molten salts heated in a tank to keep them at high temperature.

## 5 663 MW OF ELECTRICITY CAPACITY ACROSS THE WORLD

The countries that offer highly promising sunshine conditions, such as China, India, Australia, South Africa, the Gulf States and North Africa are engaged on most of the development work on CSP plants. The latest Protermosolar (Spanish Association for the promotion of the Solar Thermal Industry) database update puts the global capacity of these plants at 5 663 MW at the end of 2018 (4 704 MW at the end of 2017). During 2018, 11 new plants were commissioned across the globe, most of which have a storage system. These include the South African plants of Ilanga I (100 MW, 5 hours' storage) and Kathu Solar Park (100 MW, 4.5 hours' storage), both of the parabolic trough type. China has connected three new projects... the CGN Delingha plant (50 MW, 9 hours' storage) of the parabolic trough type and two tower plants... the Shouhang Dunhuang (100 MW, 11 hours' storage) and Supcon Delingha (50 MW, 6 hours' storage). India, which had installed no additional capacity since 2014, inaugurated the Dhursar Fresnel plant (100 MW, without storage) in 2018. In the Middle-East, Saudi Arabia connected the Waad Al Shamal ISCC parabolic trough plant (50 MW, without storage) and Kuwait the Shagaya parabolic trough plant 50 MW, 10 hours' storage). Finally, Morocco commissioned the Noor II and Noor III plants. The first is a 200-MW parabolic trough plant (7 hours' storage), the second, a 150-MW tower plant (7 hours' storage). According to the Protermosolar survey, the 11 provide almost 1 000 MW of additional capacity (959 MW to be precise) commissioned in 2018. This burst of construction should be followed by 2 166 MW currently in development across the globe, including 1 045 MW of new projects awaited in 2019 in China and the Middle-East.

A significant drop in production costs has spurred this positive momentum. According to the latest Irena "Renewable Power Generation Costs" report for 2018, the levelized cost (LCOE) of CSP projects has fallen to 18.6 ¢ per kWh (about 16.4 euro cents per kWh), which is 26% cheaper than in 2017 and 46% less than in 2010. Irena forecasts that








LCOE costs could shortly drop by a further 6–10 euro cents per kWh, encouraged by the implementation of tendering mechanisms.

## THE EUROPEAN MARKET IS IN SLEEP MODE

The European Union market is idle after the 2007-2014 wave of installations concentrated in Spain. Nothing moved in 2018 with capacity stuck at 2 314.3 MW, including pilot and demonstrator plants (see graph 4 and table 7). The net maximum capacity data published by Eurostat reports 2 306 MW (2 304 MW in Spain and 2 MW in Germany). The mathematical difference results from the fact that some countries do not officially include their demonstrators in their statistics. The bulk of this capacity is concentrated in Spain, whose officially recorded installed capacity is 2 304 MW (i.e. 99% of the EU's total capacity). Spain's sunshine conditions were weaker than in 2017, when it registered record output. According to Eurostat, Spanish output was 4 867 GWh, compared to 5 883 GWh in 2017 (5 579 GWh in 2016).

# 1

*Concentrated solar power plant in operation at the end of 2018*

| Projects | Technology | Capacity (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** | | **2314.3** | |

*Continues overleaf*

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

As for projects under development in the EU, the situation has hardly changed. The Ello plant in the Eastern Pyrenees, France, has been up and running since the end of October 2018 but will only be connected to the grid in 2019 and therefore will be included in next year's statistics. Four bigger projects (Solecaldo 41 MW at Aidone, Sicily; Reflex Solar Power 12.5 MW at Gela, Sicily; Lentini 55 MW in Sicily and the CSP San Quirico 10 MW hybrid solar project in Sardinia) are still likely to be completed by 2020-2021, but their investors are waiting for publication of the decree setting the remuneration terms of the future energy produced. So, the commercial commissioning date is still on hold. The only outstanding project in Cyprus – EOS – at Alassa, near the city of Limassol, initially scheduled for 2018 according to the Ministry of Energy and the developers, should be running by the end of 2021 at the latest. This tower plant project is a little different in that although it will be equipped with two 25-MW generators, it will effectively guarantee 25 MW of capacity only. The plant has been designed to run at this capacity twenty-four hours a day thanks to a storage system but can also run for twelve hours at 50 MW capacity. At the same time, CSP technology seeks new outlets for industrial applications and heating networks. Here it competes directly with flat glazed collector technology, in an as yet niche market, that should expand. As it happens, the new European RES directive targets renewable heat. Its strong renewable heat focus is expressed in its indicative annual renewable energy increase target of 1.3 of a percentage point in final heat consumption, taking the 2020 situation as the reference point.

## NEW AMBITIONS FOR 2030 TO BE CONFIRMED

European prospects for sector growth remain below the targets assigned by the Member States in their National Renewable Energy Action Plans (graph 5) for 2020. Every year, project delays make it clearer that revival of the European sector, if it is to take place, will not happen until the next decade. Its future is currently being debated in the Member States with the first indications from their National Energy and Climate Plans (NECPs). The Energy Union governance rules that came into effect on 24 December 2018 obliged EU countries to draw up NECPs to cover the period from 2021 to 2030 and submit a draft plan to the European Commission before 31 December 2018 followed by their final plans before 31 December 2019.

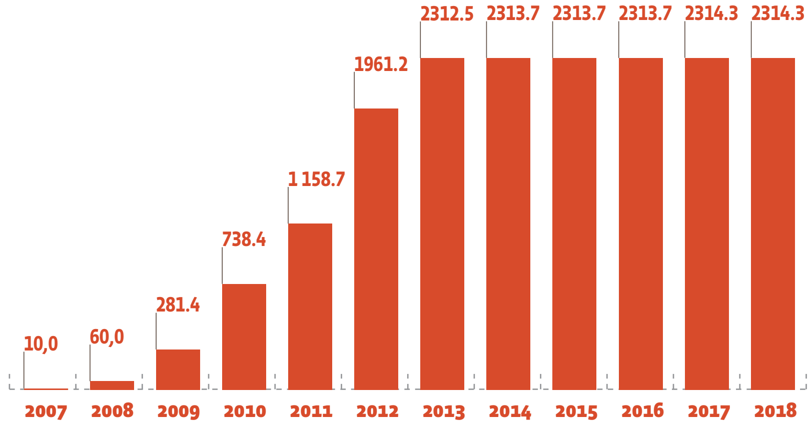






**2**

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




*Source: EurObserv'ER*

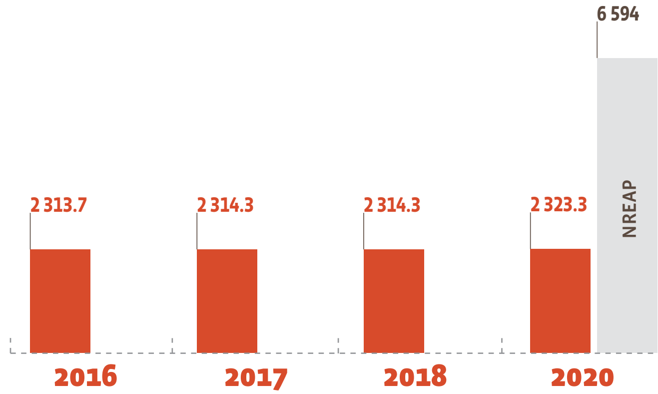
The first documents available on the European Commission website indicate that the future of the European CSP sector will be largely based in Spain. The Spanish NECP project has the merit of giving the sector a medium- and long-term timeframe. Its target scenario is for a 4 803 MW installed base in 2025 (for 13 953 TWh of output) and of 7 303 MW in 2030 (for 22 578 TWh of output), namely an additional 5 GW of capacity to the current situation (equating to 17.6 TWh of additional output). In that case, concentrated solar power would alone provide 6.7% of Spain's electricity output, which is similar to that of its nuclear sector (7.3%).

While the scale of Italy's NPEC project is smaller, it also shows that the country intends to bank on its CSP sector with 250 MW in 2025 and 850 MW in 2030. As for the other countries that present sunshine conditions compatible with CSP technologies, the Greek project is smaller with 70 MW (for 260 GWh of output). Cyprus has no other projects in the pipeline, and the same goes for Portugal.

At first glance, the European Union's CSP electricity capacity could contribute up to 8.3 GW by 2030. The technology has already demonstrated how reliable and robust it is and its capacity to contribute to balancing the grid. However, it must confirm its current cost-lowering trajectory if it is to achieve the proposed installation level. ■

**3**

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




*Source: EurObserv'ER*

# OCEAN ENERGY

The seas and oceans are a major energy resource that is harnessed in five ways – tidal energy (tidal range), current energy (tidal stream energy), wave energy (swell energy) and the energy drawn from the temperature (thermal) or salinity gradient (osmosis) difference between two bodies of water). Thanks to its kilometres of continental and outermost shores, Europe has significant and varied potential, which make it the sector leader. The ocean energy sector has been a beehive of activity over the past three years with a large number of prototypes being submerged off the British, Brittany, North Sea and Mediterranean coastlines. Tidal stream energy leads wave energy conversion and the other technologies in this ocean race.

## AT LEAST 263 MW IN SERVICE AT THE END OF 2018

Statistics on the very varied ocean energy sectors can be somewhat hit and miss. So far, the official statistics bodies have not monitored the on-grid prototypes, while the constant turnover (immersion, improvement and decommissioning phases) of the prototypes tested over relatively short time spans (in the region of 1–2 years) does nothing to clarify the active projects' details. The official count published at the beginning of 2020 by Eurostat attests to European Union connected renewable energy capacity (excluding pumped storage, for the specific case of the La Rance tidal range power plant) of 243.4 MW in 2018 (242.7 MW in 2017). Electricity output (excluding pumped storage) has slipped slightly from 525.9 to 489.2 GWh.

EurObserv'ER has chosen to publish another ocean energy capacity follow-up indicator that includes all the pre-commercial prototypes and demonstrators that were operating in 2018 (list of projects and source in table 2), which at 263.4 MW in 2018 is slightly different, including the 4.1 MW of projects that went on grid that year. As stated above, the capacity of active ocean sites does not represent all the machines that have been tested over the past decade. In its annual publication, Ocean Energy – Key Trends and Statistics 2018, published by the Ocean Energy Europe association monitored tidal stream and wave energy converter projects. It claims that 3.7 MW of projects using marine currents were submerged during 2018, which is more than double the amount in 2017. Furthermore, 26.8 MW of projects using tidal stream energy have been deployed since 2010, and of that total, 11.9 MW are currently operational, which means that 14.9 MW have been taken out of service since they completed their test programme. As for wave energy converter technology, 7 new projects for a combined capacity of 444.2 kW were identified in 2018. Since 2010, 11.3 MW of projects have been deployed, but only 2.9 MW were operating in 2018, which means that 8.4 MW were taken out of service on completion of their test programmes.

## PROJECTS ABOUND IN THE UK

The UK's "tidal stream" and "wave energy" sectors are particularly active, with the political and strategic resolve to get these two




SABELLA


EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2019 EDITION

## 1

*Ocean energy capacity installed in the European Union at the end of 2018 (MW)*

| | 2017 | | | | | 2018 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Wave | Tidal stream | Tidal range | Others | Total | Wave | Tidal stream | Tidal range | Others | Total |
| France* | 0.0 | 0.0 | 218.9 | 0.0 | 218.9 | 0.0 | 0.0 | 218.0 | 0.0 | 218.0 |
| United Kingdom** | 5.7 | 12.7 | 0.0 | 0.0 | 18.4 | 5.7 | 14.7 | 0.0 | 0.0 | 20.4 |
| Spain | 0.3 | 0.0 | 0.0 | 4.5 | 4.8 | 0.3 | 0.0 | 0.0 | 4.5 | 4.8 |
| Portugal*** | 0.4 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.4 |
| Total EU 28 | 6.4 | 12.7 | 218.9 | 4.5 | 242.5 | 6.4 | 14.7 | 218.0 | 4.5 | 243.6 |

** In France only the capacity of La Rance tidal power plant is taken into account in official statistics. The total power of this plant is 240 MW but includes a pumped storage device. Only renewable capacity part is taken into account in this table. ** In the UK, devices are not permanently deployed at test sites, therefore «operational project» does not means that the devices are in the water permanently. *** In Portugal. the Pico Wavec plant (0.4 MW) , located in the Azores was disconnected on 17th April 2018.*
***Source: Eurostat (technology breakdown by EurObserv'ER)***

## 2

*Electricity production from ocean energy in the European Union in 2017 et 2018 (GWh)*

| | 2017 | | | | | 2018 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Wave | Tidal stream | Tidal range | Others | Total | Wave | Tidal stream | Tidal range | Others | Total |
| France* | 0.0 | 0.0 | 521.7 | 0.0 | 521.7 | 0.0 | 0.0 | 479.9 | 0.0 | 479.9 |
| United Kingdom | 0.0 | 4.2 | 0.0 | 0.0 | 4.2 | 0.0 | 9.3 | 0.0 | 0.0 | 9.3 |
| Portugal | 0.006 | 0.0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.0 | 0.0 | 0.0 | 0.0 |
| Spain | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total EU 28 | 0.0 | 4.2 | 521.7 | 0.0 | 525.9 | 0.0 | 9.3 | 479.9 | 0.0 | 489.2 |

** The electricity production of La Rance tidal power plant, taking into account pumped storage, was 565 GWh in 2017 and 522 GWh in 2018.* ***Source: Eurostat (technology breakdown by EurObserv'ER)***

sectors' industries underway as fast as possible. The official BEIS count, taken up by Eurostat, identified 18 active projects in 2018 for 20.4 MW of combined capacity (2 MW up on 2017). The output of only three of these 18 projects, is monitored (i.e. a total of 9.3 GWh). The Ocean Energy Europe association's figures are slightly lower coming in at 13.3 MW of capacity at the end of 2018. The difference between the lists arises from Ocean Energy Europe's decision to remove certain projects that they consider have been permanently mothballed. The UK has the distinction of having the first and biggest commercial marine turbine array on the MeyGen project site in Pentland Firth, Scotland. The first phase of this project (MeyGen Phase A1) entailed installing 4 No. 1.5-MW turbines in October 2016. The BEIS reported its electricity output at 7.2 GWh in 2018. Since March 2017, the project has been accredited by OFGEM (Office of Gas and Electricity Markets) which manages the ROCs (Renewable obligation certificates) system and it was formally commissioned in April 2018 with plans to run for 25 years. The site is now in its second development phase (Phase 1B) to set up a hub to connect several turbines to a single power export cable and connect two new 2-MW marine turbines (Atlantis AR 2000), the highest nameplate capacities ever built, by 2020.

# 3

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

| Summary | Device Developper | Technology | Commissioning year | Location | Total capacity (kW) | Number of turbines |
|---|---|---|---|---|---|---|
| **France** | | | | | | |
| Estuary of the Rance* | EDF | Tidal Range | 1966 | Richardais-Saint Malo | 240.0 | 1 |
| EEL at Brest | EEL | Tidal Stream | 2017 | Port of Brest | 0.010 | 1 |
| Ouessant | Sabella | Tidal Stream | 2018 | Brittany - Fromveur | 1.0 | 1 |
| Test in La Rochelle | HACE | Wave energy | 2018 | Port of la Rochelle | 0.050 | 1 |
| Test in Seeneoh | DesignPro Renewables and Mitsubishi Electric | Tidal Stream | 2018 | Seeneoh | 0.025 | 1 |
| Test p66 | Guinard Energies | Tidal Stream | 2018 | Port of Brest | 0.004 | 1 |
| Total France | | | | | 241.089 | |
| **United Kingdom** | | | | | | |
| Open Hydro scale demonstration | Naval Energies | Tidal Stream | 2006 | EMEC, Scotland | 0.250 | 1 |
| Eco Wave Power - Gibraltar | Eco Wave Power | Wave energy | 2016 | Gibraltar | 0.100 | 1 |
| MeyGen phase 1A | Andritz | Tidal Stream | 2016 | Pentland Firth, Scotland | 4.500 | 3 |
| Scotrenewables Tidal Power Ltd | Orbital Marine Power | Tidal Stream | 2016 | EMEC, Scotland | 2.0 | 2 |
| MeyGen phase 1A | SIMEC Atlantis Energy | Tidal Stream | 2016 | Pentland Firth, Scotland | 1.500 | 1 |
| Shetland tidal array | Nova Innovation | Tidal Stream | 2016 | Bluemull Sound. Shetland, Scotland | 0.300 | 3 |
| Mingary Bay | Albatern | Wave energy | 2016 | Mingary Bay, Scotland | 0.045 | 1 |
| EMEC | Wello Oy | Wave energy | 2017 | EMEC, Scotland | 1.0 | 1 |
| Nautricity demonstration EMEC | Nautricity | Tidal Stream | 2017 | EMEC, Scotland | 0.500 | 1 |
| Sustainable Marine Energy Plat-I | Schottel Hydro | Tidal Stream | 2017 | Connell Sound, Scotland | 0.280 | 4 |
| InToTidal | Tocardo | Tidal Stream | 2017 | EMEC, Scotland | 0.250 | 1 |
| HiWave | CorPower Ocean | Wave energy | 2017 | EMEC, Scotland | 0.025 | 1 |
| Marine Power Systems | Marine Power Systems | Wave energy | 2017 | Ramsey Sound. Pembrokeshire, Wales | 0.010 | 1 |
| Magallanes Renovables EMEC demonstration | Magallanes Renovables | Tidal Stream | 2018 | EMEC, Scotland | 2.0 | 1 |
| Fish farm shetland | Aqua Power Technologies | Wave energy | 2018 | Shetland, Scotland | 0.005 | 1 |
| Holyhead Deep | Minesto | Tidal Stream | 2018 | Anglesey, Wales | 0.5 | 1 |
| Total United Kingdom*** | | | | | 13.265 | |

*Continues overleaf*

| Spain | | | | | | |
|---|---|---|---|---|---|---|
| Voith Hydro, Ente Vasco de la Energia (EVE) Project | Voith Hydro | Wave energy | 2011 | Pais Vasco | 0.296 | 16 |
| Planta de Huelva, OTEC (between ocean and Liquified natural gas) | Enagas | OTEC | 2013 | Huelva. Andalousia | 4.5 | 1 |
| Wedge | Wedge | Wave energy | 2014 | Plocan. Gran Canaria | 0.2 | 1 |
| Oceantec - oscilating water column prototype | Oceantec | Wave energy | 2016 | Biscay Marine Energy Platform | 0.030 | 1 |
| **Total Spain** | | | | | **5.026** | |
| **Netherlands** | | | | | | |
| IHC Merwede | IHC Merwede | Wave energy | 2009 | Western schelde | 0.030 | 1 |
| Afsluitdijk project (reverse electrodialysis techno) | Redstack | Gradient Salinity | 2014 | Afsluitdijk | 0.005 | 1 |
| Oosterscheldedam | Tocardo | Tidal Stream | 2015 | Oosterscheldedam | 1.250 | 5 |
| Tocardo Afsluitdijk | Tocardo | Tidal Stream | 2015 | Afsluitdijk | 0.3 | 3 |
| **Total Netherlands** | | | | | **1.585** | |
| **Sweden** | | | | | | |
| Seabased - Sotenas Phase 1A** | Seabased | Wave energy | 2016 | Sotenäs | 1.080 | 36 |
| **Total Sweden** | | | | | **1.080** | |
| **Portugal** | | | | | | |
| Wavec | n.a. | Wave energy | 1999 | Azores | 0.4 | 1 |
| **Total Portugal** | | | | | **0.4** | |
| **Italy** | | | | | | |
| Messina Strait | ADAG | Tidal Stream | 2000 | Strait of Messina | 0.050 | 1 |
| Wave for Energy | Wave for Energy | Wave energy | 2015 | n.a. | 0.2 | 1 |
| Port of Naples | University of Campania | Wave energy | 2015 | Port of Naples | 0.003 | 3 |
| Wavenergy | Wavenergy | Wave energy | 2016 | Civittavecchia | 0.020 | 1 |
| 40South Marina di Pisa | 40South energy | Wave energy | 2018 | Marina di Pisa | 0.050 | 1 |
| Adriatic | OPT | Wave energy | 2018 | Adriatic | 0.003 | 1 |
| **Total Italy** | | | | | **0.326** | |

*Continues overleaf*

| | | | | | | |
|---|---|---|---|---|---|---|
| **Denmark** | | | | | | |
| Wavepiston at DanWEC prototype project | Wavepiston | Wave energy | 2017 | Danish Wave Energy Centre. Hanstholm | 0.012 | 1 |
| Test in Denmark | Crestwing | Wave energy | 2018 | Port of Fredrikshaven | 0.3 | 1 |
| Wavepiston at DanWEC prototype project | Wavepiston | Wave energy | 2018 | Danish Wave Energy Centre. Hanstholm | 0.012 | 1 |
| Total Denmark | | | | | 0.324 | |
| **Belgium** | | | | | | |
| Demo antwerp | Water2Energy | Tidal Stream | 2018 | Port of Antwerp | 0.150 | 1 |
| Total Belgium | | | | | 0.150 | |
| **Greece** | | | | | | |
| Port of Heraklion | SINN Power | Wave energy | 2016 | Heraklion | 0.024 | 1 |
| Port of Heraklion | SINN Power | Wave energy | 2017 | Heraklion | 0.048 | 2 |
| Port of Heraklion | SINN Power | Wave energy | 2018 | Heraklion | 0.048 | 2 |
| Total Greece | | | | | 0.120 | |
| **Total EU28** | | | | | 263.365 | |

* The 240 MW La Rance Tidal range power station includes some pumped storage capacity. ** Because of the increased efficiency of the new generators, the 36 WECs of the Seabased Sotenas project suggest an installed capability up to 3 MW instead of 1 MW. *** There is a discrepancy between the BEIS official data on the total capacity of marine energy installed in the United Kingdom and those from the Ocean Energy Europe database, which has withdrawn some projects, considering that they are no longer operational. **Source: Ocean Energy Europe 2019 (for wave and tidal stream projects). EurObserv'ER 2019 (for tidal range projects, salinity gradient and ocean thermal energy projects)**

## BRITTANY TAKES ON THE TIDAL STREAM CHALLENGE FOR FRANCE

The official ocean energy capacity and production figures only refer to the La Rance tidal range power plant. Its capacity is 240 MW, but it includes a pumped storage device. The plant's renewable capacity excluding pumping varies very slightly from year to year. It was recorded at 218 MW in 2018 compared to 218.9 MW in 2017. The plant's electricity output dropped between 2017 and 2018. If we include output from pumping, it slipped from 565 GWh in 2017 to 522 GWh in 2018, and without the pumped output, from 522 GWh in 2017 to 480 GWh in 2018. The official data does not cover the pre-industrial Sabella D10 marine turbine demonstrator that was immersed in the Fromveur Passage off Ushant Island (Finistère). A second marine turbine, called "Hydroquest Ocean" developed by the Isère manufacturer Hydroquest and its partner Constructions Mécaniques de Normandie (CMN), was connected to the French national grid at the end of May 2019 and has been injecting electricity into the grid since the middle of June. This 1-MW marine turbine is 25 metres wide and 11 metres high and was submerged for a year on the test site of Brehat Island (Côtes d'Armor) developed by EDF.

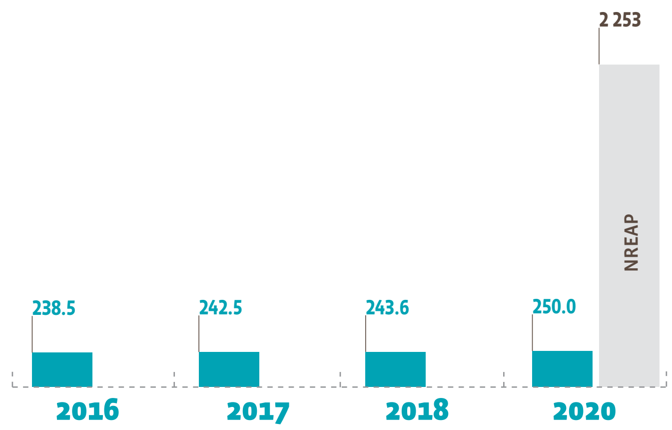
## ENTERING THE COMMERCIALISATION PHASE

If we exclude tidal range energy, which is technically very close to that of hydroelectricity dams, ocean energy technologies have not yet reached the commercial phase where machines will be mass-produced with the appropriate durability and reliability to operate over the long term. The most advanced sector in this respect is the tidal stream sector, which is gathering feedback on full-scale prototypes, namely "commercial" size turbines at the scale of one MW. During this phase, turbines are still evolving and perfectible and will be tested over a fairly short period, typically one or two years, to validate the technology choices. Ocean Energy Europe predicts that by 2020 tidal stream will enter a new project phase with more rugged machines that will pave the way for commercial operation with higher-capacity arrays. This stage will call for guaranteed remuneration systems to be set up, such as Feed-in Tariffs. ■




**3**

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




*Source: EurObserv'ER*

## SUBSTANTIAL SUPPORT FROM THE EUROPEAN COMMISSION

The issue of production costs is vital to safeguard the commercial development of ocean technologies. Developers have various support mechanisms to reduce costs, via regional funds, national and European programmes. The European Commission is particularly involved in developing ocean energies. Thus, the developers benefit from funding under the European Commission's Horizon 2020 research and innovation programme through dedicated projects (e.g.: the Ocean_2G and FloTEC projects) or via the NER 300 programme (e.g.: the STROMA project). They can also take up inter-regional project funding via the European Interreg programme. It aims to finance economic development or environmental management cooperation projects between European regions. A particularly ambitious Interreg project, the Tiger (Tidal Stream Industry Energiser) project, directly involving the marine turbine sector was announced on 16 October 2019. It is part of the Interreg France (Channel) England Programme to develop submerged turbines off the coasts to harness tidal stream energy. It thus aims to foster growth in the area of marine energy turbines by developing machines of capacities up to 8 MW. This programme will serve to demonstrate the economic profitability of marine turbine energy so that it can enter England's and France's energy mix, by using economies of scale through mass production. The project preamble states that the total theoretical tidal energy capacity in the Channel region is nearly 4 GW – enough to power up to three million homes. The project budget is 46.8 million euros, making it the biggest ever of the 75 Interreg programmes to be financed in the 2014-2020 programming period. Carolyn Reid, Programme Manager for the Interreg France (Channel) England Programme said: *"The long-term aim is to support the industry to reduce generating costs of tidal stream energy from the existing € 300 per MWh to € 150 per MWh by 2025 and increase uptake. There is an EU target to reach € 100 per MWh by 2030"*. The funding will particularly help the machine manufacturers (such as Hydroquest, Orbital Marine Power, CMN, Minesto AB, etc.), university research programmes, the EMEC centre and other French and British tidal stream players.

# 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 changes 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 approach*

*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.*

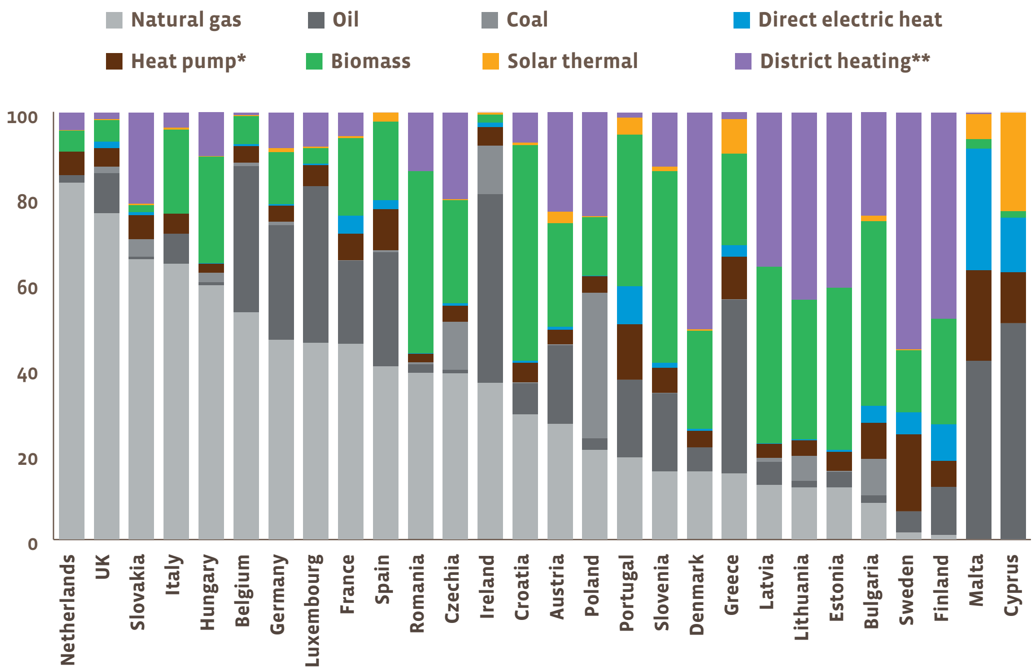
*In contrast to consumption shares of RES, market sales shares of RES depict the dynamics and development of RES at the edge. Market shares show the share of technologies sold in relation to the total of all sold heating units. They may vary from year to year in each country. As data on sales were not available for all technologies or countries, the number of system exchanges is assessed based on the average exchange rate of systems in 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 under link to methodological paper and for Eurostat's methodology on consumption shares see http://ec.europa.eu/eurostat/web/energy/data/shares. Because Eurostat data for 2018 are not published yet, the shares are shown for 2017 only.*

# RESULTS AND INTERPRETATION

*1*

*RES consumption shares in 2017*




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

## CONSUMPTION SHARES OF RES

Figure 1 presents the consumption shares of heating and cooling with renewable energies in 2017 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 2018 is expected to be similar to 2017.

In the Netherlands and the United Kingdom, and to a smaller extent in Italy, Slovakia, Hungary and Belgium, gas is still dominating the heating system. Oil boilers are mainly used in Cyprus, Ireland, Malta and Greece. In addition, in Luxembourg, Belgium, Germany, Spain, France, Austria, Slovenia and Portugal they still represent an important technology or source for heat. 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 relies on existing networks.







*2*

*District heating supply mix in 2017*

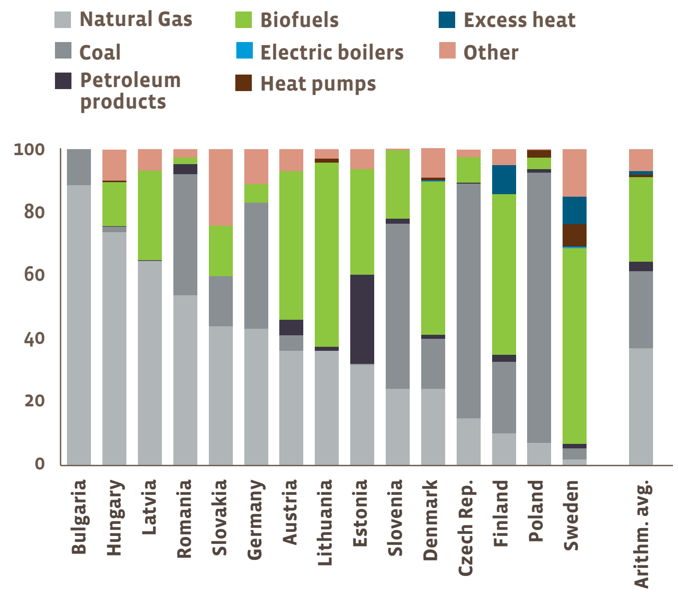
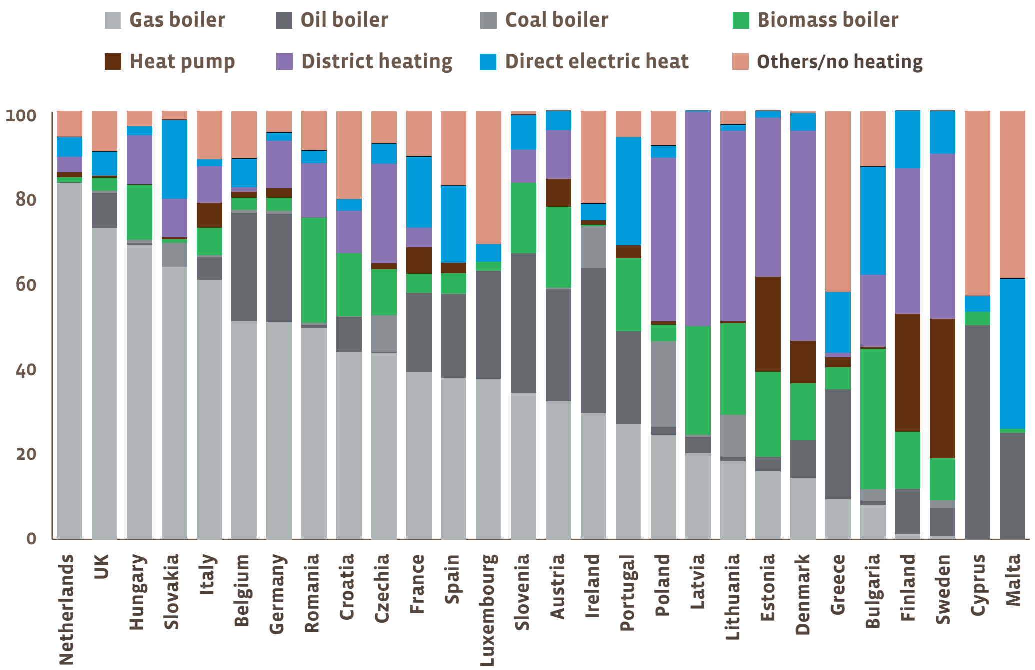



*Figure 2 depicts the existing supply mix in the countries where DH covers around 10% or more from the heating and hot water demand in 2017. On the basis of the arithmetic average, it can be concluded that the existing DH networks still rely on fossil fuels with natural gas and coal as a predominant source. Coal is mostly used in Poland, Czech Republic, Slovenia, Germany and Romania. Oil as energy carrier for DH consumption is almost phased out except for Estonia and presents an insignificant amount in the supply mix. Among renewable energies, biofuels such as biomass, biogas and renewable waste play a significant role with 27% (arithmetic average). The biofuels are a predominant DH heat source in the Scandinavian countries and Austria and have a substantial share in the Baltic countries and Slovenia. Excess heat and heat pumps are mostly used in Sweden.*

*Source: EurObserv'ER - Based on 2017 data for: SE, DE, AT, FI; 2015 data for: DK, LT, EE, LV, SI, PL, HU, CZ; 2014 data for: SK; 2013 data for: RO, BG*

RES dominate in Croatia (51%), Slovenia (46%) and Bulgaria (45%). 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 (41%) and Portugal (40%). Although 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 (21%), Cyprus (12%), Greece (10%) and Spain (10%). 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 (23%) 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, Cyprus, Portugal and Finland but also in Sweden, France, Bulgaria and Greece.

## 3
*RES market stock shares in 2017*



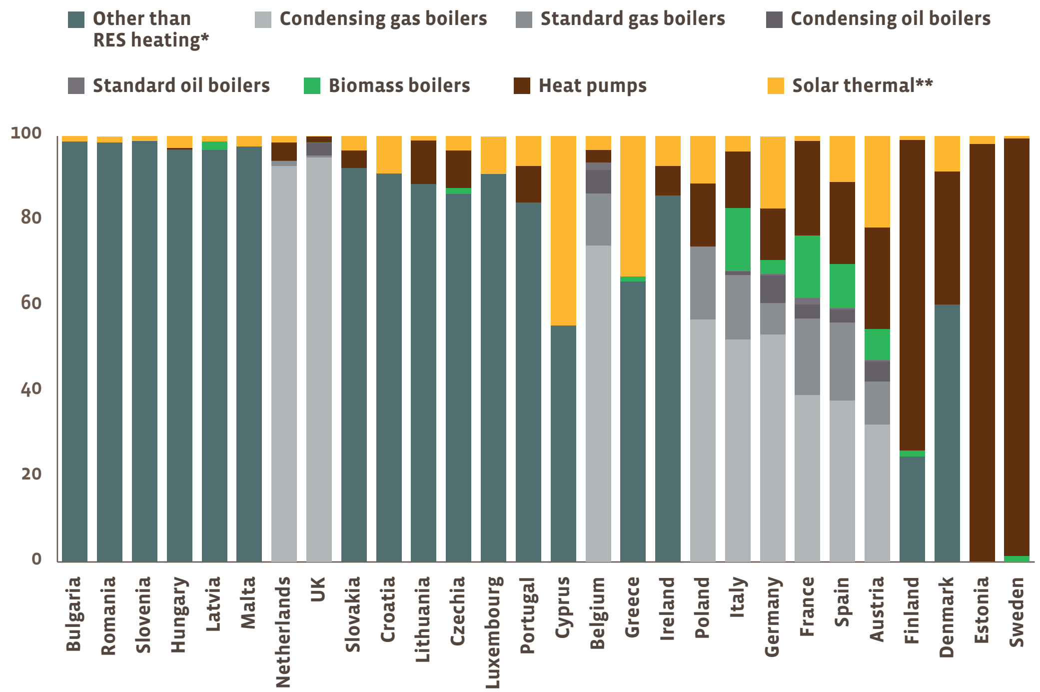

*Source: EurObserv'ER - own assessment based on diverse sources. Note: solar is not counted as an alone standing system as it is used mainly in combination with other systems*

### MARKET STOCK SHARES OF RES

Figure 3 depicts the technology shares in the building stock, i.e. technology shares for dwellings. In contrast to Figure 1 above, it shows the share of households with the respective heating technologies, and bundles further categories such as other or unknown heating system or no heating system. This share is very high for Cyprus, Greece, Malta and Luxemburg. It is also considerable high for Ireland, Croatia 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 of unknown heating 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 the power sector, electric heating gains in significance. In Malta, Portugal and Bulgaria 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.

## 4
*Sale shares of heating systems sold in the EU in 2018 as a percentage of total systems sold*



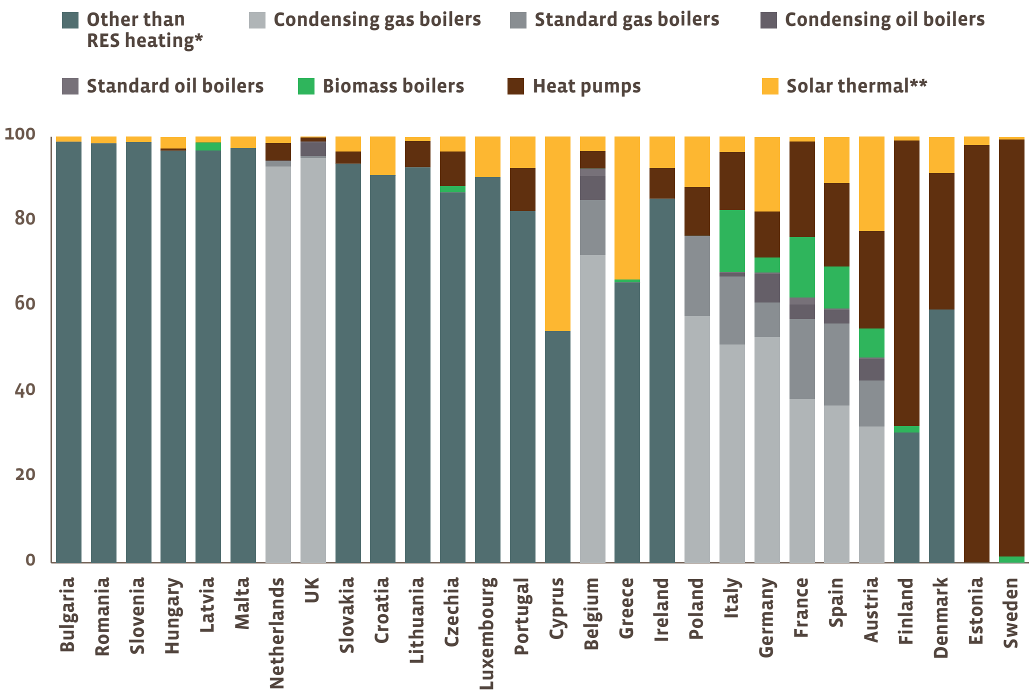

*Source: EurObserv'ER - own assessment based on diverse sources. * could comprise gas, oil and SEB_CHP, calculated for EU countries with missing data, based on average share of sales of AT, BE, FR, DE, IT, NL, PL, ES, UK; ** solar thermal system corresponds to 4 m² collector area*

### 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, Sweden, Finland, Denmark, Austria 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 base 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. In Austria, Germany, Poland and Spain it reveals a moderate development. Overall, in many EU countries, the dynamic of RES in the heating/cooling sector is low. Overall, the market sales share of 2017 and 2018 are very similar, which points to a very low dynamic in the RE heating technology market. In other words, sales

## 5

*Sale shares of heating systems sold in the EU in 2017 as a percentage of total systems sold*




*EurObserv'ER - Updated data as compared to 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*

of RES are not gaining momentum, and thus, RE in H&C are currently failing to contribute significantly to the GHG emission targets 2020 and 2030.

### CONCLUSIONS

Overall, natural gas boilers remains the most commonly used heating technology, 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 still 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, and thus counteracting the decarbonisation efforts in the H&C sector.

Albeit the relatively high dynamic of heat pumps in some of the countries (high sales shares), the consumption shares remain small, compared to fossil fuel based heating. Solar thermal power has quite some potentials but its dynamic as well as share in the stock is again 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 the countries with high shares of households supplied by a district heating network.






## 1

*Heating systems exchange rates as a percentage of households*

| Country | 2017 | 2018 |
|---|---|---|
| Austria | 2.27% | 2.35% |
| Belgium | 5.44% | 5.50% |
| France | 3.53% | 3.53% |
| Germany | 1.81% | 1.88% |
| Italy | 4.96% | 5.05% |
| Netherlands | 5.62% | 5.84% |
| Poland | 1.44% | 1.52% |
| Spain | 2.19% | 2.22% |
| Sweden | 2.34% | 2.49% |
| United Kingdom | 6.31% | 6.52% |
| Total EU | 3.57% | 3.66% |

*Source: own assessment based on diverse sources*

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 has played a significant role in some eastern European countries. In Romania, Bulgaria and Hungary the dynamics in RES-H is low albeit a relatively high RE share, because 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. Finally, the market sales share of RE technologies remain unchanged, showing a low dynamic in this market, albeit action is needed. ■

# TRAJECTORIES WELL UNDERWAY

***The Member States are well on their way along their energy trajectories with just two years to go before the main renewable energy deadline set by the 2009/28/EC Directive. It is becoming increasingly clear which countries will meet their binding commitments and which are lagging too far behind to meet their targets. The latter will be able to use transfer mechanisms to take advantage of the surplus renewable energy outputs of the countries that are furthest ahead and/or put on a last-minute spurt to minimize their shortfalls.***

***Before we produce our in-depth review of the achievement of the Member States' individual renewable energy targets deriving from the Renewable Energy Directive (electricity, heat and cooling, and gross final energy consumption), this concluding section attempts to make an initial assessment of the 2018 state of real renewable electricity production, namely the non-normalised output of hydropower and wind energy.***

## THE 1000-TWH RENEWABLE ELECTRICITY THRESHOLD HAS BEEN WELL AND TRULY OUTSTRIPPED

This is the best renewable energy headline 2018 has to offer. Real (non-normalised) gross renewable electricity output surged between 2017 and 2018. For the first time it sailed past the 1 000 TWh output threshold to reach 1 051.5 TWh in 2018, which represents 8.0% growth over 2017 (Graph 1).

This growth corresponds to an increase of 78.3 TWh in the amount of renewable electricity produced between 2017 and 2018. To make this figure more meaningful, the increase exceeds Belgium's total gross electricity output (74.6 TWh in 2018), and if we take 2016 as the reference year, the increase over two years is actually 97.6 TWh, which equates to the total combined electricity output of Greece (53.3 TWh), Denmark (30.4 TWh) and Croatia (13.6 TWh). Thus, the boost in renewable electricity output is a Europe-wide phenomenon.

Most of this growth can be ascribed to hydropower (excluding pumping) whose output rose from 300.2 TWh in 2017 to 349.8 TWh in 2018 (16.5% growth). Its share of total renewable electricity output increased from 30.9% in 2017 to 33.3% in 2018. Now if we include pumped output, hydropower output rose from 331.2 TWh in 2017 to 378.6 TWh in 2018 (14.3%). The underlying factor is the upturn in hydropower output in Southern Europe (Italy, Spain, Portugal, Greece) and France in 2018, which all suffered from record low rainfall in 2017. For instance, Spanish hydropower output almost doubled between 2017 and 2018 (by 87.4%), Portuguese output more than doubled (by 110.2%), Italian output increased by 34.8% and French output by 30.6%. As often happens, the Northern European countries' hydropower output trend contrasted with that of the countries further south, albeit with smaller variations. Output fell in Sweden, Finland, the Baltics (Estonia, Latvia, Lithuania), and the UK in 2018. It also fell in Germany, Austria and most of Central Europe. It must be said that "natural" variations in hydropower production can swing from one year to the next. The 2017 level was a far cry from those of 2014 (375.9 TWh) and 2010 (376.9 TWh) – both particularly rainy years across the European Union. In 2018, EU hydropower output can be described as average because it is very close to its normalised output over the last fifteen years (349.7 TWh in 2018).

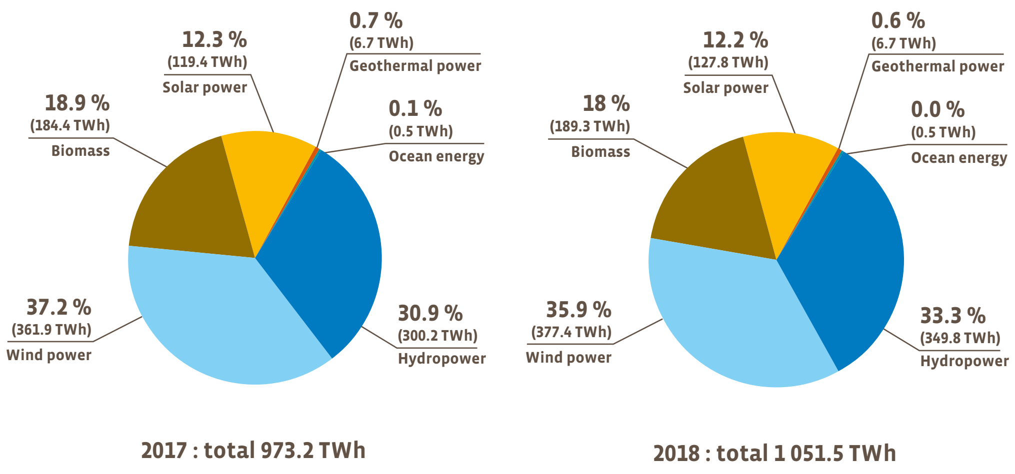
With real output at 377.4 TWh, wind energy retained its top ranking status for renewable electricity output in 2018. However, its share of total electricity production fell between 2017 and 2018 (from 37.2 to 35.9%), because of hydropower's upturn. Furthermore 2017 was a particularly windy year that was conducive to generating wind energy. This was not so in 2018, as a dozen countries (e.g.: Sweden, Denmark, Poland, Romania and Austria) registered falls in production. However, across the European Union wind power output continued to rise. According to Eurostat, it increased 15.5 TWh over its 2017 level (by 4.3%). Wind power output is slightly higher than its normalised output (over the last five years) of 376.2 TWh. Thus, it can also be considered as normal at European Union level. The three countries that provided the highest input to the increase in wind power output are the UK (adding 7.3 TWh, for a total of 56.9 TWh), Germany with an additional 4.3 TWh (i.e. a total of 110.0 TWh in 2018), and France (which added 4.0 TWh for a total of 28.6 TWh). Almost half of the UK's output (46.9% in 2018) has the distinction of being produced offshore. Wind energy was driven by the offshore segment, whose output increased by 7.5 TWh to reach 58.6 TWh in 2018 (14.7% more than in 2017). The offshore wind energy share of the EU's total wind energy output increases every year (by 14.1% in 2017 and 15.5% in 2018).

There was generally less suitable sunshine in 2018 than in 2017 in Southern Europe. Load factors fell in Spain (from 1 803 to 1 654 hours) and Italy (from 1 239 to 1 127 hours). This contrasted with the Northern half of Europe with load factors rising in Germany (from 931 to 1 011 hours) and the UK (from 898 to 980 hours). According to the data released in January by Eurostat, European Union solar photovoltaic electricity output reached 123 TWh, which equates to 8.3% growth over 2017 or 9.4 TWh of additional output. The lower sunshine level in Spain naturally hit concentrated solar plant output, which fell by 1.0 TWh to just below 4.9 TWh. Total solar output thus stood at 127.8 TWh (an increase of 8.4 TWh).

As for biomass energy taken as a whole (solid biomass, biogas, renewable municipal waste, liquid biomass), electricity output rose to 189.3 TWh in 2018, increasing by 2.6% over the previous year (adding 4.9 TWh). Most

**1**

*Share of each energy source in renewable electricity generation in the EU 28 (in %)*




***Note:** Figures for actual hydraulic and wind generation (no normalisation), pumped hydro are excluded. All electricity production from bioliquids (compliant and not compliant) is included (not compliant bioliquids electricity production represents 161,4 GWh in 2017 and 166 GWh in 2018). Renewable electricity from biogas injected into the grid is included (it represents 733,1 GWh in 2017 and 883,3 GWh in 2018).*
***Source : EurObserv'ER***

of the growth in biomass electricity production was provided by solid biomass, which increased 5.0% over 2017, to reach 99.5 TWh in 2018 (adding 4.7 TWh) and was mainly attributable to the rise in the net maximum electrical capacity of those countries that promote its use to substitute coal and through the development of biomass cogeneration. Biomass electricity also benefitted from an increase in the renewable electricity share from the incineration of household waste (0.7 TWh, for a total of 22.9 TWh). The input from biogas electricity, which has less political support than formerly, was negative. If in addition to the plants running exclusively on biogas, we allow for the biomethane (purified biogas) share injected into the grid used in gas-fired power stations, biogas electricity output fell by 0.5 TWh to 61.9 TWh. The remaining biomass sector to produce electricity, liquid biomass, slipped very slightly (by 0.1 TWh) to 4.9 TWh. Output from the geothermal and ocean energy electricity production sectors changed very little between 2017 and 2018, dipping by 57 GWh for geothermal (for a total of 6.7 TWh) and by 37 GWh for ocean energies (or a total of 489 GWh).

## *THE SPECIFIC TARGETS OF THE EUROPEAN DIRECTIVE*

### ALMOST ONE IN EVERY THREE TWH OF ELECTRICITY IN THE EU IS RENEWABLY SOURCED

The renewable electricity output monitoring indicator used to calculate the Renewable Energy Directive's target (2009/28/EC) is different, in that it includes normalised production for hydropower and wind energy (the normalisation formula is defined in Annex II of the directive), to erase the climatic variations, at least for rain and wind, and thus better reflects the efforts made by each Member State. Furthermore, it only includes the electricity produced by certified liquid biomass (see insert on Method and definitions).

The figure of 349.7 TWh was thus retained for normalised hydropower production in 2018 (347.4 TWh in 2017), and 376.2 TWh for wind energy (347.4 TWh in 2017). Following identical output in 2017, the trans-

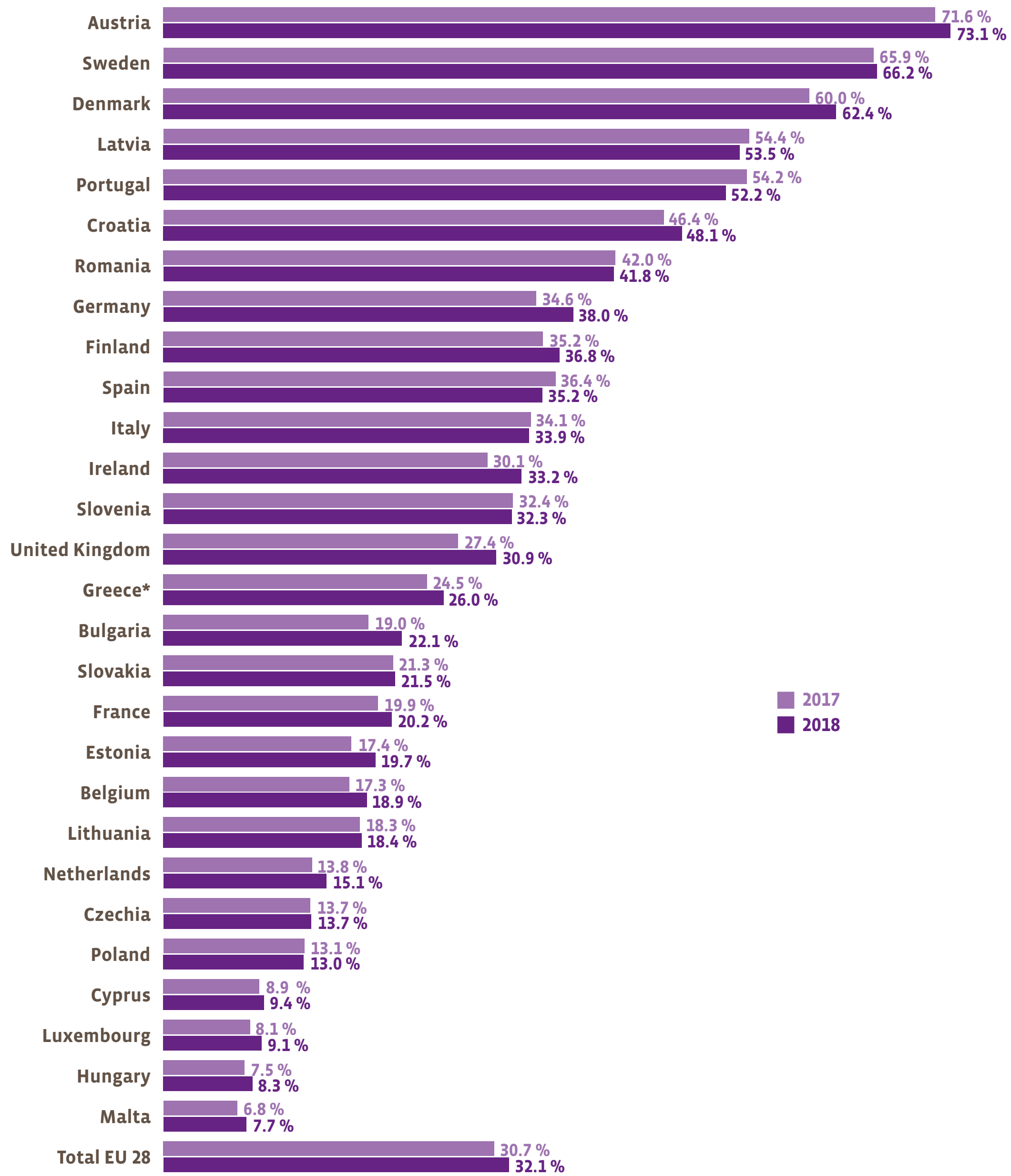






**2**

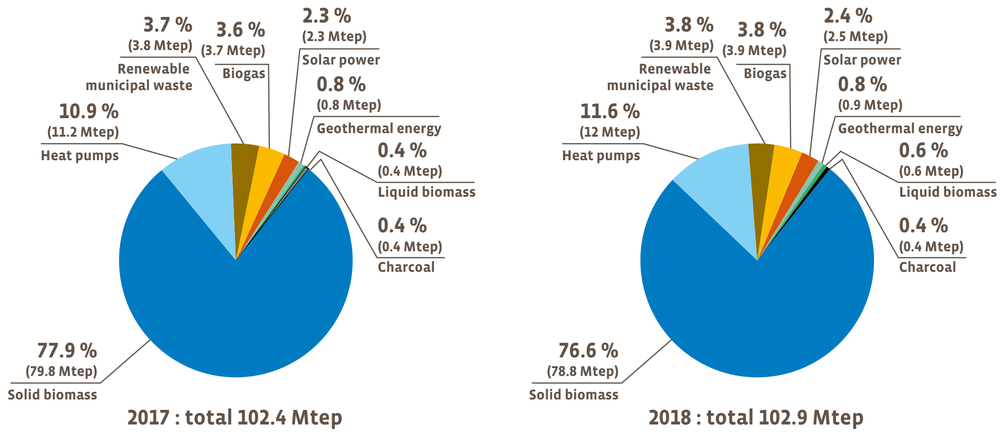
*Share of renewable energy in the electricity generation of EU countries in 2017 and 2018*




**** 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: Eurostat (updated 31 janvier 2020)***

## 3

*Share of each energy source in renewable heat and cooling consumption in the EU 28 (in %)*




***Note for calculation:** Renewable sources for heating and cooling correspond to the sum of final energy consumption of renewable fuels in Industry and Others Sectors, of production of derived heat from renewable fuels and heat pumps. Heating and cooling from biogas injected into the grid is included, only compliant liquid biomass is included. **Source : EurObserv'ER***

fer of power between hydro and wind power was made by taking normalised production indicators into account. It takes the renewable electricity output, admitted for calculating the European targets (the numerator), to 1 050.7 TWh in 2018 (compared to 1 005.7 TWh in 2017). The increase in "normalised" renewable electricity output is thus 44.3 TWh between 2017 and 2018, and 89.8 TWh between 2016 and 2018.

The total electricity output retained (the denominator) is almost stable. It slipped 0.1 TWh to 3 275.5 TWh in 2018, from 3 275.6 TWh in 2017, resulting in an increase in the renewable electricity share from 30.7% in 2017 to 32.1% in 2018 – a 1.4 of a percentage point (pp) gain (Graph 2). If we compare this with the share in the first reference year set for calculating targets, 2004 (14.2%), the "normalised" renewable electricity share has more than doubled (by 2.3).

It is clear that there has been a significant increase in the renewable electricity share over this reference period (between 2004 and 2018) in many European Union countries, with far-reaching changes to the electricity production mix. The renewable share of the Danish electricity production mix has risen from 23.8 to 62.4% (38.7 pp), that of Germany from 9.5 to 38% (28.6 pp), the UK from 2.5 to 30.9% (28.3 pp), Ireland from 6 to 33.2% (28.3 pp), Portugal from 27.4 to 52.2% (24.8 pp), Estonia from 0.5 to 19.7% (19.1 pp), Italy from 16.1 to 33.9% (17.8 pp). This contrasts with renewable electricity's fortunes in countries such as Slovenia rising from 29.3 to 32.3% (3.1 pp), Hungary from 2.2 to 8.3% (6.1 pp), Slovakia from 15.4 to 21.5% (6.1 pp), Luxembourg from 2.8 to 9.1% (6.4 pp) and France from 13.8 to 21.2% (7.4 pp).

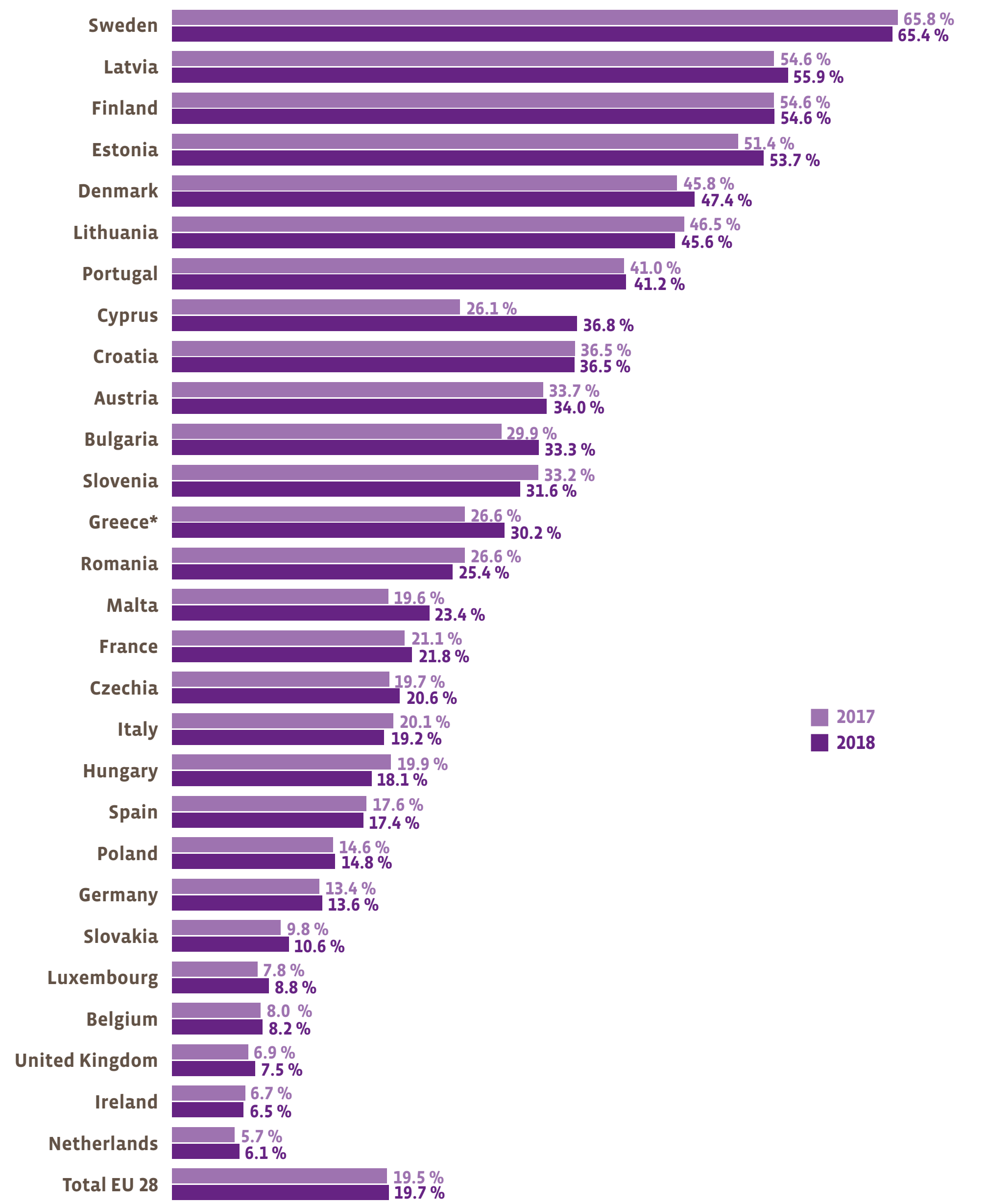
Graph 2 shows that the renewable electricity share of the Member States can vary considerably depending on renewable energy potential and the support policies they implement. Renewable production dominates in the top five countries: Austria (73.1% in 2018),





## 4

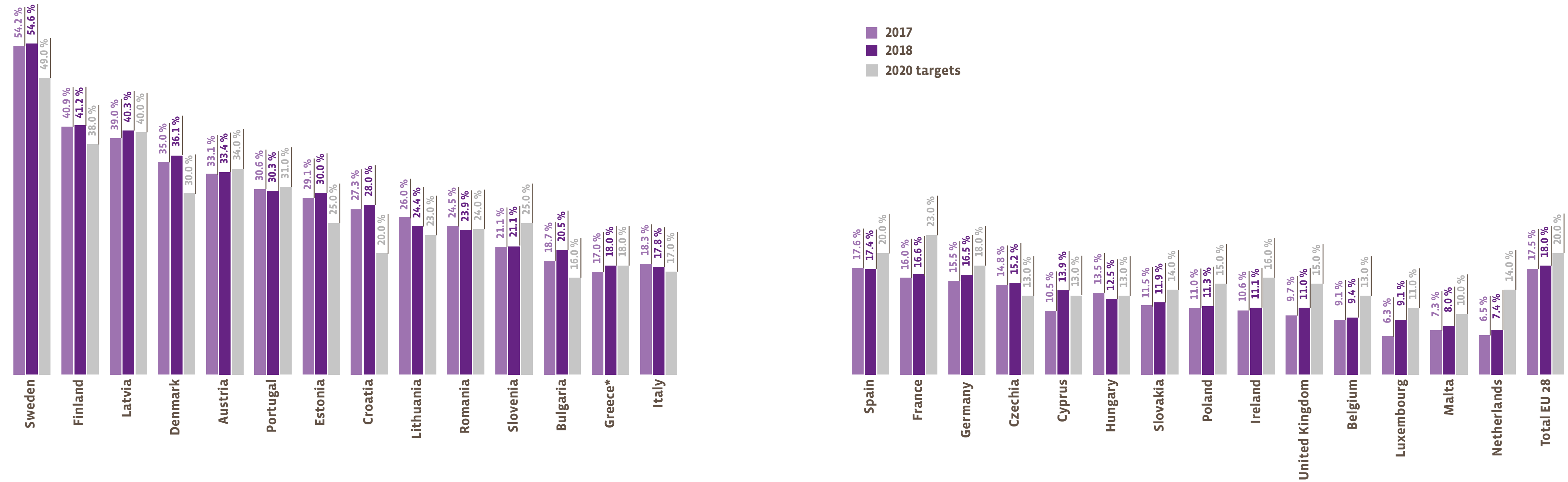
*Share of renewable energy in heating and cooling of EU countries in 2017 and 2018*




****estimated, provisional for Greece. Source: Eurostat (updated 31 janvier 2020)***

## 5

*Share of energy from renewable sources in gross final energy consumption in 2017 and 2018 and 2020 targets*




***Year 2018 (estimated, provisional for Greece). Source: Eurostat (updated 31 janvier 2020)***

Sweden (66.2%), Denmark (62.4%), Latvia (53.5%) and Portugal (52.2%%), while it is less than 10% in the four countries at the back of the pack – Malta, Hungary, Luxembourg and Cyprus.

### RENEWABLE HEAT IS STRUGGLING TO IMPROVE ITS FIGURES

According to the Eurostat data made available through its Shares (Short Assessment of Renewable Energy Sources) tool (updated on 28 January 2020), renewable heat (and cooling) consumption rose slightly from 102.4 to 102.9 Mtoe (by 0.5 Mtoe). This indicator includes both the energy directly used by end-users in industry and “other sectors” (e.g.: residential, commercial, agriculture, forestry, fishing and other non-specified sectors such as military), in addition to the heat produced by the processing sector (derived heat) and the renewable output yielded by heat pumps.

Global needs slipped by 2.3 Mtoe, from 525.1 to 522.8 Mtoe of consumption between 2017 and 2018. In the final analysis, Eurostat reckons that the renewable energy share of heat and cooling increased slightly from 19.5 to 19.7% between 2017 and 2018 (graph 4). This rise illustrates the renewable sector’s difficulty in replacing fossil energies. Although heating and cooling needs have remained relatively stable since 2016 (523 Mtoe in 2016, 525.1 Mtoe in 2017, 522.8 Mtoe in 2018), the renewable share has only increased by 0.6 points in three years, gaining 3 Mtoe.

If we go into more detail, final energy directly used in industry and the “other sectors” declined from 76.3 Mtoe in 2017 to 75.9 Mtoe in 2018 (by 0.4 Mtoe) while derived heat output (from the processing sector) increased slightly from 14.9 to 15.1 Mtoe (by 0.2 Mtoe), with heat pumps accounting for the highest input, rising from 11.2 to 12 Mtoe (adding 0.8 Mtoe).

According to EurObserv’ER, the reasons for the low increase in the renewable share are the implementation of policies that are too diluted to develop renewable heat, and also the reduction in space heating needs resulting from a succession of mild winters (the trend was confirmed by the extremely mild winter of 2019/2020 and the warmest month of January ever recorded in Europe in 2020). While mild winters reduce energy consumption needs for heating, irrespective of the fuel used (gas, oil, coal, wood, wood pellets), the impact on renewable heat is statistically higher. This observation is based on the fact that more renewable heat is used for space heating requirements (biomass heating networks and wood-fired heating stoves), than for other heat uses (heating for industrial processes, steel making, domestic hot water, cooking, etc.).

Energy efficiency policies with higher performance heating appliances and also efforts to insulate buildings have a further impact on the winter consumption trends of renewable, as well as other fuels.

There is much stronger momentum for renewable energy produced by heat pumps. In 2018 it accounted for the largest share of the rise in final renewable thermal energy. It benefits from the policy of countries that encourage the electrification of their heating requirements through legislation (France, Sweden, etc.) and the increase in summer cooling requirements (another consequence of climate warming) for the reversible heat pump cooling component.

The lesser use of solid biomass (excluding coal) is borne out by analysing the contribution of each renewable energy sector to final thermal energy consumption (graph 3). According to the calculations made by EurObserv’ER, it dropped by 1 Mtoe between 2017 and 2018 (from 79.8 to 78.8 Mtoe). This fall was offset by an increase in the contribution by heat pumps (of 0.8 Mtoe, for a total of 12 Mtoe in 2018), biogas (0.26 Mtoe, i.e. a total of 3.9 Mtoe), solar energy

**6**

*Share of energy from renewable sources in gross final energy consumption in 2017 and 2018 and indicative trajectory*

| Countries | 2017 | 2018 | *Indicative trajectory 2017-2018* |
|---|---|---|---|
| Sweden | 54.2% | 54.6% | 45.8% |
| Finland | 40.9% | 41.2% | 34.7% |
| Latvia | 39.0% | 40.3% | 37.4% |
| Denmark | 35.0% | 36.1% | 25.5% |
| Austria | 33.1% | 33.4% | 30.3% |
| Portugal | 30.6% | 30.3% | 27.3% |
| Estonia | 29.1% | 30.0% | 22.6% |
| Croatia | 27.3% | 28.0% | 17.4% |
| Lithuania | 26.0% | 24.4% | 20.2% |
| Romania | 24.5% | 23.9% | 21.8% |
| Slovenia | 21.1% | 21.1% | 21.9% |
| Bulgaria | 18.7% | 20.5% | 13.7% |
| Greece* | 17.0% | 18.0% | 14.1% |
| Italy | 18.3% | 17.8% | 12.9% |
| Spain | 17.6% | 17.4% | 16.0% |
| France | 16.0% | 16.6% | 18.6% |
| Germany | 15.5% | 16.5% | 13.7% |
| Czechia | 14.8% | 15.2% | 10.6% |
| Cyprus | 10.5% | 13.9% | 9.5% |
| Hungary | 13.5% | 12.5% | 10.0% |
| Slovakia | 11.5% | 11.9% | 11.4% |
| Poland | 11.0% | 11.3% | 12.3% |
| Ireland | 10.6% | 11.1% | 11.5% |
| United Kingdom | 9.7% | 11.0% | 10.2% |
| Belgium | 9.1% | 9.4% | 9.2% |
| Luxembourg | 6.3% | 9.1% | 7.5% |
| Malta | 7.3% | 8.0% | 6.5% |
| Netherlands | 6.5% | 7.4% | 9.9% |
| **Total EU 28** | **17.5%** | **18.0%** | **-** |

**Year 2018 (estimated, provisional for Greece). Source: Eurostat (updated 31 janvier 2020)*

(0.16 Mtoe, i.e. a total of 2.5 Mtoe), renewable municipal waste (0.10 Mtoe, i.e. a total of 3.9 Mtoe) and liquid biomass (0.15 Mtoe, i.e. a total of 0.6 Mtoe).

Between 2017 and 2018, the distribution between the various renewable heat sectors penalized solid biomass (which fell from 77.9 to 76.6%) in favour of heat pumps (which rose from 10.9 to 11.6%). The biogas share rose from 3.6 to 3.8%, that of renewable municipal waste from 3.7 to 3.8% and solar from 2.3 to 2.4%. The geothermal heat share stayed at 0.8%, that of liquid biomass rose from 0.4 to 0.6%, while charcoal remained at 0.4%.

If 2004 is taken as the reference year (10.4%), renewable energy's contribution towards heating and cooling has practically doubled (to 19.7% in 2018), but still only covers a fifth of overall needs.

From 2004 to 2018, the largest increases in the renewable heat share can be credited to Cyprus (27.5 pp), Denmark (26.8 pp), Malta (22.3 pp), Estonia (20.4 pp), Bulgaria (19.2 pp) and Sweden (18.7 pp). The countries with the lowest increases are Ireland (3.6 pp), the Netherlands (4 pp), Poland (4.6 pp) and Belgium (5.3 pp).

The renewable heat share of total heat consumption at Member State level is naturally higher in the forested countries, as biomass is far and away the main renewable heat source. It is or is almost the major player in Northern Europe (65.4% in Sweden, 54.6% in Finland, 47.4% in Denmark) and in the Baltics (55.9% in Latvia, 53.7% in Estonia and 45.6% in Lithuania). However, it is a very minor player in the Benelux (8.8% in Luxembourg, 8.2% in Belgium and 6.1% in the Netherlands), 7.5% in the UK and 6.5% in Ireland.

## MAIN TARGET – A SURGE IS EXPECTED IN 2019 AND 2020

Through its Shares tool, Eurostat has published its results for the renewably-sourced energy share that meets the 2009/28/EC directive criteria. The renewable energy share of gross final energy consumption was put at 18% in 2018, which is half of a percentage point more than in 2017. This increase was at the same pace as it observed between 2016 and 2017 (0.5 of a percentage point) (graph 5). The methods used for calculating the target are detailed in the insert.

From an accounting standpoint, the UK's departure from the European Union, that took effect on 1 February 2020, will make it easier to achieve the common target of a share of at least 20% by 2020, as the UK's current renewable energy share is much lower (11% in 2018) than that of the European Union. In the new European Union of 27 without the UK, the share is virtually at 18.9% in 2018 as it stands.

While the common 2020 target has lost some of its meaning in the absence of the UK, each EU Member State has its own binding target for 2020. These national targets were defined making allowance for the differences in the starting situations as well as the renewable energy potentials, ambitions and economic performance levels of the individual Member States. The large forested countries and/or those that have high hydropower potential are naturally at an advantage. This holds true for Sweden, whose renewably-sourced energy share at 54.6% in 2018 covers more than half its needs. Four other countries use renewable sources to produce a third or more of their final energy consumption – Finland (41.2%), Latvia (40.3%), Denmark (36.1%) and Austria (33.4%).

With two years to go before the deadline, the Member States' energy trajectories are well underway. It is becoming increasingly clear which countries will meet their binding commitments on renewable energy and which are lagging too far behind to meet their targets.

This new 2018 review shows that the vast majority of Member States are in line with their target, namely they have either already reached target, or they are in line with the indicative trajectory set by the Renewable Energy Directive (graph 6). Twelve countries have already exceeded their 2020 targets, sometimes very clearly as applies to Croatia (by 8 pp), Denmark (by 6.1 pp), Sweden (by 5.6 pp), Estonia (by 5 pp), Bulgaria (by 4.5 pp) and Finland (by 3.2 pp). Other countries ahead of target are the Czechia (by 2.2 pp) Lithuania (by 1.4 pp), Cyprus (by 0.9 pp), Italy (by 0.8 pp), Latvia (by 0.3 pp) and Greece (by 0.0 pp). Four others are very close to their 2020 targets, with less than one percentage point to make up – Romania (0.1 pp), Hungary (0.5 pp), Austria (0.6 pp) and Portugal (0.7 pp).

Now, some of these countries took their binding targets in their stride a few years ahead of schedule. Then, some contented themselves with just honouring their community commitments and slackened their renewable sector development efforts rather than pushing on to overshoot their targets. If we take 2014 as the reference year and compare it with the 2018 results, the renewable energy share has actually declined in Hungary (by 2.1 pp), Romania (by 1 pp), Slovenia (by 0.4 pp), Austria (by 0.2 pp) and Poland (by 0.2 pp). It is almost unchanged in the Czechia (with 0.07 pp more), Slovakia (0.2 pp more) and Croatia (0.2 pp more) and has increased very slightly in Italy (by 0.7 pp) and Portugal (by 0.8 pp).

In fact, just two years away from the deadline only a handful of countries (five in all) are out of line with the indicative 2017-2018 trajectory set by the Renewable Energy Directive, with considerable shortfalls in the case of the Netherlands (2.6 pp behind its trajectory) and France (2 pp behind). The three other foot-draggers are Poland (1 pp behind), Slovenia (0.7 pp behind) and Ireland (0.4 pp behind).

If we take the 2020 targets, the countries bringing up the rear are the Netherlands (6.6 pp), France (6.4 pp), Ireland (4.9 pp), the UK (4.0 pp), Slovenia (3.9 pp), Poland (3.7 pp) and Belgium (3.6 pp).

The latter can either put on a final spurt to minimize the shortfalls and/or use cooperation mechanisms to take up the surpluses in renewable energy output of the countries that are in advance. The final spurt is now underway. Many countries have planned to intensify their consumption of compliant biofuel in transport, for instance (which is possibly the easiest adjustment variable), very sharp increases in solar and wind energy capacities have also been announced in some countries (an exception for wind energy in Germany in 2019), as well as new coal-fired power station conversions to biomass fuel (primarily the Netherlands).

The cooperation mechanisms also offer the possibility of transferring quantities of renewable energies from one country to another. So, those with higher potentials are encouraged to exceed their targets. This mechanism was built into the 2009 European Directive, to enable European countries to cooperate closely to achieve common targets together. So far, only a few of them have contracted or announced their intention to resort to these transfer mechanisms. Realizing that it was behind schedule, Luxembourg was one of the first countries to plan to take up these mechanisms by signing a preliminary exchange agreement with Lithuania in October 2017, and a second with Estonia a month later. The agreements have been in force since 2018, Thus, Luxembourg has benefitted from a statistical transfer of 94.6 ktoe, half coming from Lithuania and the other half from Estonia. It should be noted that electricity exports/imports do not qualify as being renewable energy, unless a specific intergovernmental agreement has been signed, which as it stands only exists between Sweden and Norway. This difference explains the fact that Sweden has been transferring a small amount of its electricity to its neighbour since 2012. Although Norway is not part of the EU, it has adopted the 2009 Renewable Energy Directive (with a 2020 RES target share of 67.5%).

While 2020 will mark an important review point, new commitments have already been devised through the new Renewable Energy Directive 2018/2001 dated 11 December 2018. The Member States must collectively ensure that the energy share produced from renewable sources in the European Union's gross final energy consumption in 2030 is at least 32%. This target will be binding at European level, but will not be apply nationally, which leaves the Member States free to set their own national targets. Here again, common renewable energy projects will be encouraged in the case of electrical energy, heating or cooling production, to enable the countries with better natural or technical resources to share them with others, (including third countries in the case of electricity production). Wind, solar, hydro and even biomass energy produced at lower cost can thus benefit all Member States. This European strategy is part and parcel of the implementation of the Energy Union, the programme that aims to revive integration in the energy sector and ensure Europe's energy independence. Europe has the ambition to become the "world number one in renewable energy and the fight against climate change" and achieve carbon neutrality in 2050. ■

## *Methods and definitions (Graphs 2, 4 and 5)*

*Renewable energy sources cover solar thermal and photovoltaic energy, hydro (including tide, wave and hydrokinetics), wind, geothermal energy and all forms of biomass (including biological waste and liquid biofuels). The contribution of renewable energy from heat pumps is also covered for the Member States for which this information was reported. The renewable energy delivered to final consumers (industry, transport, households, services including public services, agriculture, forestry and fisheries) is the numerator of this indicator. The denominator, the gross final energy consumption of all energy sources, covers total energy delivered for energy purposes to final consumers as well as the transmission and distribution losses for electricity and heat. It should be noted that exports/imports of electricity are not considered as renewable energy. However, statistical transfers and other flexibility measures reported to Eurostat and complying with the requirements of Articles 6-11 of Directive 2009/28/EC on the promotion of the use of energy from renewable sources are also considered in the presented data. Currently only Sweden with Norway, Luxembourg with Estonia and Luxembourg with Lithuania are using these flexibility measures. The national shares of energy from renewable sources in gross final energy consumption are calculated according to specific calculation provisions of Directive 2009/28/EC on the promotion of the use of energy from renewable sources and Commission Decision 2013/114/EU establishing the guidelines for Member States on calculating renewable energy from heat pumps from different heat pump technologies. Electricity production from hydro power and wind power is accounted according to normalisation rules of Annex II of Directive 2009/28/EC. For data as of 2011, only biofuels and bioliquids declared by countries as compliant with criteria of sustainability as defined in Articles 17 and 18 of Directive 2009/28/EC are accounted towards the share of energy from renewable sources. Adjustments of energy consumption in aviation are applied for all countries according to Article 5(6).*

# SOCIO-ECONOMIC INDICATORS

**The following chapter sheds a light on the European renewable energy sectors in terms of socio-economic impacts, primarily industrial turnover and renewable energy employment. All 28 EU Member States are covered for 2017 and 2018.**

## *Methodological note*

*Since the 2017 Edition of 'The State of Renewable Energy in Europe', a formalised model developed by the Energy Research Centre of the Netherlands (ECN), currently TNO Energy Transition, has been used to assess employment and turnover in the EU 28.*

*The approach applied here is based on an evaluation of the economic activity of each renewable sector covered.* ***A consistent and mathematical approach is used to generate the employment levels and turnover effects, allowing for a comparison between the European Union Member States****. Distinct characteristics of each economic sector from the EU Member States are taken into account by using input-output tables to determine the renewable employment and turnover effects. The underlying databases stem from Eurostat, JRC and EurObserv'ER. The focus of this analysis is centred on money flows from four distinct activities in the renewable energy value chain:*

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

*Further important model features are briefly highlighted below:*

- *For employment indicators, the term 'job' is expressed in* ***full-time equivalents*** *(FTE). The sudden decline or increase in jobs presented in this study does not necessarily correspond with what is observed in scorings by national sector associations which may use different assessment methodologies.*
- *Employment data presented in each chapter refer to* ***gross employment****. Developments in non-renewable energy sectors or reduced expenditure in other sectors are not taken into account.*
- *Employment data includes both* ***direct and indirect employment****. Direct employment includes renewable equipment manufacturing, renewable plant construction, engineering and management, operation and maintenance, biomass supply and exploitation. Indirect employment refers to secondary activities, such as transport and other services.* ***Induced employment*** *is outside the scope of this analysis.*
- *Employment related to* ***energy efficiency*** *measures,* ***electric mobility*** *or* ***energy storage*** *remains outside the scope of this analysis.*
- *Socio-economic indicators for the* ***bioenergy*** *sectors (biofuels, biomass and biogas)* ***include the upstream activities*** *in the agricultural, farming and forestry sectors.*
- *Investments in renewables can only be traced by the model in the year of commissioning. Activities in project preparation, taking place in previous years, are all allocated to that year. For this reason, large projects with longer lead times (common for technologies such as hydropower, offshore wind power and geothermal energy) cause* ***more volatility in the employment and turnover estimates.***
- *Turnover figures are expressed in current* ***million euros (€M).***
- *The socio-economic indicators have been* ***rounded to 100 for employment*** *figures and to* ***10 million euro for turnover*** *data.*

*Since the 2017 edition of "The state of renewable energies in Europe", a new indicator was introduced: the employment effects on fossil fuel chains based on the energy replaced through increased renewables production. This indicator only takes into account direct jobs in fossil sectors, but not replaced investment or the indirect effects.*

*For more information regarding the methodology used in this chapter, interested readers should refer to the* ***methodology paper*** *that explains the new approach works in more detail. This paper can be downloaded from the EurObserv'ER project website.*

# WIND POWER

Both the onshore and offshore wind sectors were assessed in terms of their socio-economic impact. Wind energy remains an important renewable backbone in the European Union. In their April 2019 financing and investment report, WindEurope - the European Wind Industry Association - claimed that €65 billion. were invested in the wind industry in Europe in 2018. This included investments in new assets, refinancing transactions, mergers and acquisition at both the project and corporate levels, public market transactions and private equity raised. According to WindEurope, investments for 16.7 GW of new wind capacity alone accounted for €27 billion., which is quite in line with the EurObserv'ER estimates.

However, the picture is no longer a completely rosy one. After some years of steady growth, turnover decreased by nearly €4.2 billion to €43.9 billion within this time period. The job head count is down from 356 700 to 325 300 job positions in 2018. A loss of over 31 400 jobs is one of the highest drops so far ever witnessed in the EurObserv'ER socioeconomic account. A continued growth in the offshore wind sector could not compensate the losses in the onshore industry.

The main reason for this regression is found in the historically largest wind sector - Germany. ***Germany*** witnessed another unprecedented decline in 2018. EurObserv'ER estimates a shrunk workforce of 34 600 in the on- and offshore sector. Not only could the domestic record installation level of 5.6 GW in 2016 not be maintained, a downward spiral seems to have set in. There are many reasons for this trend. The switch from fixed feed in tariffs to tenders fuelled investor reluctance. Growing public resistance and stricter regulations concerning the minimum distance between wind turbines and villages has created the perfect storm for reduced new investments. And it is not only statistics. Adwen shut down in 2017, Powerblades in 2018, SiemensGamesa and Enercon reduced their staff, and

*Employment and turnover*

| | Employment (direct and indirect jobs) | | Turnover (in € m) | |
|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 |
| Germany | 140 800 | 106 200 | 20 040 | 15 340 |
| United Kingdom | 69 900 | 82 800 | 7 360 | 8 750 |
| Denmark | 34 200 | 35 400 | 6 310 | 6 420 |
| Spain | 37 200 | 32 300 | 4 340 | 3 770 |
| France | 18 500 | 15 700 | 2 860 | 2 480 |
| Italy | 7 500 | 8 100 | 1 120 | 1 190 |
| Belgium | 5 500 | 7 400 | 1 100 | 1 480 |
| Netherlands | 5 800 | 6 800 | 830 | 960 |
| Greece | 3 100 | 5 100 | 230 | 350 |
| Sweden | 2 700 | 4 600 | 620 | 980 |
| Ireland | 6 500 | 4 500 | 700 | 510 |
| Poland | 8 000 | 3 000 | 660 | 280 |
| Portugal | 3 100 | 2 600 | 320 | 280 |
| Austria | 2 000 | 2 500 | 350 | 430 |
| Romania | 2 100 | 2 200 | 160 | 170 |
| Czechia | 900 | 1 300 | 70 | 100 |
| Croatia | 1 100 | 1 100 | 70 | 70 |
| Hungary | 800 | 900 | 50 | 60 |
| Finland | 4 100 | 700 | 630 | 130 |
| Bulgaria | 500 | 500 | 30 | 30 |
| Lithuania | 500 | 500 | 30 | 30 |
| Estonia | 1 200 | 400 | 80 | 30 |
| Latvia | < 100 | 200 | < 10 | 10 |
| Cyprus | 200 | 100 | 20 | 10 |
| Luxembourg | 100 | 100 | 20 | 10 |
| Malta | < 100 | < 100 | < 10 | < 10 |
| Slovenia | < 100 | < 100 | < 10 | < 10 |
| Slovakia | < 100 | < 100 | < 10 | < 10 |
| **Total EU 28** | **356 700** | **325 300** | **48 040** | **43 900** |

*Source: EurObserv'ER*



Senvion went insolvent in 2019, and shut its turbine blade manufacturing with likely effects on the European wind job count table, although these effects cannot be captured in the EurObserv'ER employment modelling approach. Additionally, ***France*** saw some losses with a slight industry turnover decline to €2.5 billion.

On the positive side, the ***United Kingdom*** clearly is on second spot in our EU wind industry account. Estimated turnover grew by €1.4 billion to €8.8 billion and the corresponding employment rose by 12 900 job places to 82 800 in 2018. ***Denmark's*** slight growth (now estimated as 35 400 jobs and sector volume of €6.4 billion in 2018) gave it a slight lead over ***Spain*** (an estimated €3.8 billion turnover and 32 400 full time employees), from which it snapped the fourth position. Countries such as ***Sweden*** (€1 billion and 4 600 jobs), ***the Netherlands*** (€1 billion and 6 800 wind employees), ***Belgium*** (€1.5 billion and 7 400 jobs) and ***Italy*** (€1.2 billion and 8 100 workers) stood out and prevented an even more disastrous year.

The outlook is somewhat inconclusive. If we look at the market development in Germany in 2019 (where market growth came to a virtual standstill) we should expect even further declines. However, wind energy is a very mature and competitive renewable energy technology and we can quite confidently assume that wind energy might be the main renewable beneficiary of an intensified global commitment to fight climate change. The New Green Deal of the new EU Commission might further stimulate market development in the EU Member States, as well as advance export activities of the European wind industry. ■

# PHOTOVOLTAIC

In contrast to last year's assessment, the installation activity in the European PV markets picked up momentum again in 2018. Newly-connected solar capacity in the European Union rose by 33.7% over 2017 to 7.6 GW of newly added on-grid capacity, according to the data collected by EurObserv'ER. Although the annually installed volumes in Germany, the UK, France and Italy do not reach previous multi-gigawatt record levels, a turnaround and more organic growth can be observed in consolidated PV markets. Overall EurObserv'ER estimates the socioeconomic impacts of photovoltaic system installation and operation at €14.5 billion in 2018 (against €11.2 billion in 2017) and employment at 117 600 persons – a clearly visible uptake compared to 90 800 job places in 2017. The clear growth in PV could thus compensate parts of the socioeconomic decline in the wind power sector.

With 41 900 jobs (up from 29 300 in 2017) EurObserv'ER ranks ***Germany*** again on top of the PV job table. This figure seems plausible and is quite in line with estimations from the market observer EUPD research that puts PV jobs in 2017 at 26 400 direct full-time equivalents (FTE)). Sector turnover increased to nearly €5.7 billion in 2018.

EurObserv'ER monitors a quite remarkable PV and related socioeconomic growth in ***the Netherlands*** for 2018. Having emerged as the second largest PV market in 2018 (with 1.4 GWp of new installed capacity), this positive trend is also reflected in a €1.7 billion. sector turnover – a doubling compared to 2017 – and 14 300 jobs. This growth was fuelled by a very active residential PV market, along with connection of very high-capacity projects funded under the SDE+ programme.

Although not often on the radar, ***Italy*** has re-emerged on the PV map. With surpassing the 20 GW mark of installed capacity, the country reaps the socioeconomic benefits of 11 400 full time employees and PV volume amounting to €1.5 billion. The Mediterranean country

*Employment and turnover*

| | Employment (direct and indirect jobs) | | Turnover (in € m) | |
|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 |
| Germany | 29 300 | 41 900 | 4 010 | 5 680 |
| France | 9 300 | 15 000 | 1 310 | 2 120 |
| Netherlands | 6 000 | 14 300 | 730 | 1 710 |
| Italy | 11 200 | 11 400 | 1 450 | 1 480 |
| United Kingdom | 12 900 | 8 600 | 1 310 | 890 |
| Hungary | 1 300 | 4 500 | 60 | 210 |
| Poland | 1 100 | 3 100 | 80 | 230 |
| Spain | 5 500 | 2 200 | 500 | 220 |
| Austria | 1 600 | 1 900 | 260 | 310 |
| Czechia | 1 300 | 1 900 | 100 | 140 |
| Greece | 1 300 | 1 800 | 90 | 120 |
| Belgium | 3 000 | 1 700 | 570 | 320 |
| Denmark | 1 100 | 1 600 | 190 | 290 |
| Portugal | 1 500 | 1 600 | 90 | 100 |
| Finland | 700 | 1 200 | 120 | 200 |
| Romania | 900 | 1 100 | 60 | 70 |
| Sweden | 500 | 1 100 | 90 | 210 |
| Bulgaria | 600 | 600 | 30 | 30 |
| Estonia | 100 | 500 | <10 | 30 |
| Croatia | 100 | 400 | <10 | 20 |
| Cyprus | 500 | 200 | 30 | 10 |
| Ireland | <100 | 200 | 10 | 20 |
| Malta | 300 | 200 | 20 | 20 |
| Slovakia | 200 | 200 | 20 | 10 |
| Lithuania | 100 | 100 | <10 | <10 |
| Luxembourg | 100 | 100 | 10 | 10 |
| Latvia | <100 | <100 | <10 | <10 |
| Slovenia | 100 | 100 | 10 | 10 |
| Total EU 28 | 90 800 | 117 600 | 11 190 | 14 480 |

*Source: EurObserv'ER*





confirmed its slow but continuous PV recovery trend already observed over the past years.

Positive growth trends could be observed for 2018 in ***Hungary*** and ***Poland***, which in 2018 for the first time became really visible on the socioeconomic PV map of Europe. The market growth of over 400 MW installed in ***Hungary*** in 2018 is represented in a similar socioeconomic leapfrog of €150 million, with a turnover almost four times as high as in 2017 (€60 million), and 4 500 jobs representing 3 200 new employment positions. In ***Poland***, employment nearly tripled to 3 100 job places and sector turnover also clearly grew to a remarkable €230 million (compared to €80 million in 2017), underpinning hopes that renewables might play a more vital role in the so far coal dominated electricity mix of the country.

***France*** is the second largest PV job market with 15 000 FTEs and nearly €2.1 billion in industry turnover. Employment and market growth is France is primarily due to the installation activities of new and larger PV plants. For example the largest European floating PV system was set up in France and other multi megawatt projects also rank at the higher end of the scale.

The outlook for PV in Europe is a more prosperous one than for wind energy. The European Industry body Solar Power Europe (SPE) forecast a substantial growth, rising from the current global level of 500 GW to 1 044 GW in a low scenario, and up to 1 610 GW in an ambitious high scenario by 2023. There are different variables that will determine on which end of these scenarios the world and the European Union as major PV region will be. The current trend witnessed in several European countries of more and more projects being developed without feed-in tariffs or other public aid, points into a rather promising direction. The socioeconomic recovery in recent years has also demonstrated that the EU PV sector is not willing to take a back seat in future RE development in the European Union. ■

# SOLAR THERMAL

In their trends and market statistics report for the year 2017, the European solar thermal industry body published an estimated EU sector turnover of €1.7 billion and 17 400 jobs. This corresponds well with the assumptions of the EurObservER modelling that arrived at €2.4 billion and 21 900 jobs for 2017. Following the 2019 solar thermal and CSP barometer, the solar thermal heating sector grew by 8.4% in 2018. Correspondingly, EurObserv'ER quantifies the EU sector at a slightly grown sector turnover of €2.8 billion. in 2018. Employment levels are assessed at 25 300 jobs, slightly up from 21 900 in 2017.

***Spain*** once more defended its title of the largest European player, in the solar thermal sector with the number of FTE totalling 8 200 and revenues reaching €980 million, a slight increase from 2017 levels. In Spain it is not only the continuous installation activity of solar thermal collectors for hot water provision but also the operation and maintenance (O&M) services in the CSP sector that positively affect employment. Spain is home to the largest CSP power plant fleet in the EU. The most notable jump in jobs could however be observed in ***Poland*** where the market expanded by a factor of 2.5 and increased from 111 100 to about 310 000 m² according to SPIUG (the Association of Manufacturers and Importers of Heating Appliances). Municipal tenders announced in 2017 and in place since the start of 2018, backed by European funds can be seen as driver for this positive growth trend. We rate the Polish solar thermal sector at 2 200 job places and a financial turnover volume of €160 million. The solar thermal sector in ***Greece*** continued to grow by another 4% in 2018, yielding a turnover of €120 million and 1 800 persons employed. ***Austria*** ranks on a similar level. With a well-established and diverse solar thermal industry, we observed a continued growth in industry turnover to €310 million and 1 800 employees. The country is traditionally a strong and well-developed solar thermal market with many domestic players and the technology is widely used throughout the country.

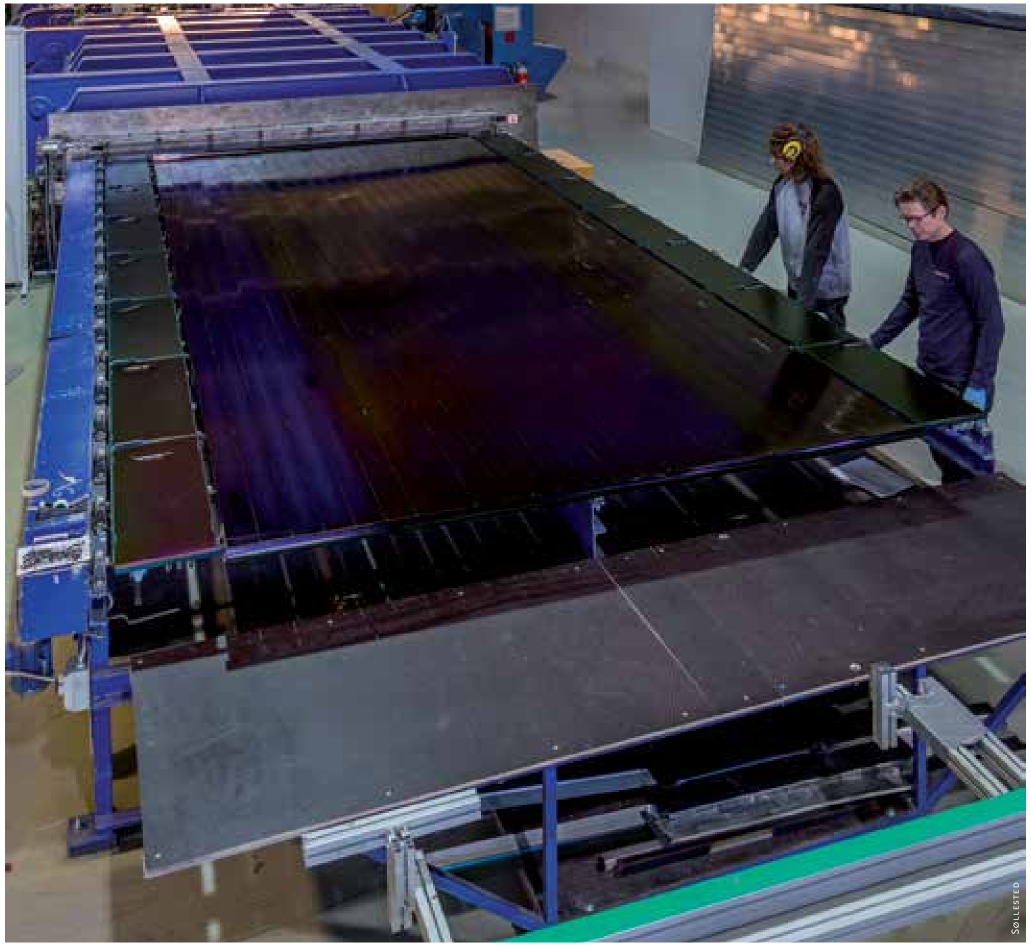
*Employment and turnover*

| | Employment (direct and indirect jobs) | | Turnover (in € m ) | |
|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 |
| Spain | 8 100 | 8 200 | 970 | 980 |
| Germany | 4 500 | 3 700 | 580 | 470 |
| Poland | 300 | 2 200 | 20 | 160 |
| Austria | 1 200 | 1 800 | 200 | 310 |
| Greece | 2 000 | 1 800 | 130 | 120 |
| France | 1 000 | 1 800 | 130 | 250 |
| Bulgaria | 1 300 | 1 300 | 50 | 50 |
| Italy | 600 | 1 100 | 70 | 130 |
| Denmark | 200 | 500 | 30 | 80 |
| Portugal | 500 | 500 | 30 | 30 |
| Cyprus | 100 | 300 | 10 | 20 |
| Czechia | 200 | 200 | 10 | 10 |
| Croatia | 200 | 200 | 10 | 10 |
| Hungary | 200 | 200 | 10 | 10 |
| United Kingdom | 200 | 200 | 10 | 20 |
| Belgium | 100 | 100 | 30 | 20 |
| Estonia | <100 | <100 | <10 | <10 |
| Finland | <100 | <100 | <10 | <10 |
| Ireland | 100 | 100 | 10 | 10 |
| Lithuania | <100 | <100 | <10 | <10 |
| Luxembourg | <100 | <100 | <10 | <10 |
| Latvia | <100 | <100 | <10 | <10 |
| Malta | 100 | <100 | <10 | <10 |
| Netherlands | 100 | 100 | 10 | 10 |
| Romania | <100 | 100 | <10 | 10 |
| Sweden | <100 | <100 | 10 | 10 |
| Slovenia | 100 | <100 | <10 | <10 |
| Slovakia | 100 | 100 | <10 | 10 |
| **Total EU 28** | **21 900** | **25 300** | **2 410** | **2 790** |

*Source: EurObserv'ER*

The concentrated solar power (CSP) market segment stagnated over the last years with little new installation activity in EU Member States. Employment in CSP sector should thus primarily stem from technology providers and EU based manufacturers of components. The actual installation currently takes place outside the European union. Further positive news can be reported from ***Italy*** (1 100 jobs and €130 million), Denmark, or ***Bulgaria*** (1 300 jobs resulting from a sector turnover of €50 million). Despite remaining the largest solar thermal market in terms of overall installed capacity (13.489 MWth or one third of the European total), ***Germany*** also in the solar thermal segment saw declines of a scale that is rather worrying. 3 700 persons employed and a sector worth €470 million is all that remains from an industry that used provide jobs for up to 14 000 people some years ago according to time series data provided by BMWi the energy and economics ministry.

Solar thermal remains a small renewable technology, however with a very high, and so far unrealised potential. Studies by IRENA suggest that alongside with PV in building solar thermal can make substantial contributions to meet 2030 targets. The EU Green Deal or national ambitions to replace old oil heating systems (Germany) might revitalize the European market over the coming years. ■





EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2019 EDITION

# HYDROPOWER

The 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. The model used captures the employment effect of hydro power installations of all sizes, including pumped hydro and run-of river plants. The model is quite sensitive to sudden increases in capacity, which lead to peaks in employment because employment related to preparation activities are also allocated to the year of commissioning (see methodological note). The effect is especially noticeable for technologies like hydropower with large projects only being finalised sporadically. This is the case for Austria (that witnessed new capacity additions of 366 MW between 2017 and 2018) as well as Italy (+73 MW). We consider the appearance of the observed peaks for hydropower a consequence of the modelling approach. The overall employment level jumped by 31 400 FTE to 102 100 hydro power jobs in the EU 28, increasing most due to the capacity additions in Austria and Italy. And a similar rise is observed for the turnover part that is estimated at €12.3 billion.

The highest hydro power turnover can be observed in the Member States with large hydro power capacities: **France** (25.7 GW), **Italy** (22.4 GW), and **Spain** (20 GW). **Italy** has a large hydro power plant fleet and ranks among the top 3 positions with €2.3 billion in turnover and 17 300 jobs. The importance of hydropower in Italy should not be downplayed. In 2018, 60% of the electricity derived from renewable sources was from hydropower and the total installed capacity stood at 22 499 MW in 2018.

In part due to the large increase in capacity and the modelling specifications outlined above, **Austria's** work force has a substantially grown to 17 300 jobs and possesses the highest turnover monitored with over €2.9 billion. **Spain** ranks third in employment with 12 300 jobs in 2018, followed by **France** (10 500 FTE and over €1.5 billion). The growth for France's hydro industry is expected continue as the country charges ahead to meet its 2020 target of increasing hydropower capacity to 30 000 MW.

It should be noted that the hydropower sector is quite directly affected by changing weather patterns due to global warming as varied precipitation levels are directly leading to higher or lower hydro electricity production. Hot and dry regions in the EU may be negatively affected. However, hydro power remains a solid and proven renewable energy technology providing a stable power supply in many Member States and thus contributes to the EU 2020 and 2030 target achievement. Fortunately, it also generates an increasing number of jobs and economic value for many Member States. ■





*Employment and turnover*

| | Employment (direct and indirect jobs) | | Turnover (in € m) | |
|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 |
| Austria | 4 600 | 17 300 | 790 | 2 850 |
| Italy | 10 800 | 17 300 | 1 420 | 2 250 |
| Spain | 11 200 | 12 300 | 1 070 | 1 180 |
| France | 9 900 | 10 500 | 1 480 | 1 550 |
| Portugal | 4 200 | 7 700 | 290 | 530 |
| Germany | 4 600 | 7 600 | 650 | 1 060 |
| Sweden | 4 700 | 4 300 | 950 | 860 |
| Latvia | 1 000 | 3 300 | 50 | 170 |
| Romania | 3 400 | 3 300 | 240 | 220 |
| United Kingdom | 2 300 | 2 500 | 250 | 270 |
| Greece | 2 000 | 2 400 | 140 | 170 |
| Bulgaria | 2 300 | 2 300 | 120 | 120 |
| Croatia | 1 400 | 2 100 | 90 | 130 |
| Slovenia | 800 | 2 000 | 60 | 150 |
| Czechia | 1 500 | 1 300 | 110 | 90 |
| Finland | 1 200 | 1 300 | 190 | 210 |
| Slovakia | 1 200 | 1 200 | 90 | 100 |
| Poland | 1 100 | 1 000 | 100 | 80 |
| Lithuania | 700 | 600 | 30 | 30 |
| Luxembourg | 500 | 500 | 70 | 70 |
| Belgium | 400 | 400 | 80 | 70 |
| Ireland | 300 | 300 | 30 | 30 |
| Cyprus | <100 | <100 | <10 | <10 |
| Denmark | <100 | <100 | <10 | <10 |
| Estonia | <100 | <100 | <10 | <10 |
| Hungary | 100 | 100 | <10 | 10 |
| Malta | <100 | <100 | <10 | <10 |
| Netherlands | <100 | <100 | <10 | <10 |
| **Total EU 28** | **70 700** | **102 100** | **8 360** | **12 250** |

*Source: EurObserv'ER*

# GEOTHERMAL ENERGY

The European district heating market as a whole has seen a 3% annual growth rate in the last five years. In the EU, there are currently about 200 geothermal district heating plants in operation. It comes as no surprise that just like in previous years, the (deep) geothermal energy represents the smallest sector of renewable energy in the EU – both in terms of turnover and induced employment Geothermal electricity production in the EU amounted to only 0.2 % of the total electricity consumption of the EU, according to Eurostat. According to the modelling results, overall EU sector turnover diminished slightly from €1.3 billion to €1 billion. and employment down to 9 500 in 2018 (from a previous level of 10 900 jobs. The sector also shows the least dynamics of all renewable energy technologies.

***Italy*** remains the single most dominant player that is home to the largest geothermal power plant fleet. 2 200 jobs are estimated to be working in the Italian geothermal installations (directly or indirectly), creating an economic value of €300 million. Italy also dominates geothermal power production with 6.2 TWh out of an EU total of 6.7 TWh, which speaks a clear language.


SMW

The total installed geothermal electricity capacity in Europe is largely stable. Capacity additions are rather observed in the district heating system side than on electricity generation in the European Union Member States. ***Hungary*** is another major user of deep geothermal heat application. With 336 MWth of geothermal heating capacity it is the second largest user. EurObserv'ER estimates a sector turnover of €40 million and 700 jobs for the year 2018.

***France*** is also clearly visible on the geothermal map, having increased its geothermal power plant capacity over recent years. The benefit is an industry worth €140 million and 900 jobs involved. In 2018, ***Croatia*** became a new geothermal energy user with a new 17.5 MWe plant installed.

***The Netherlands*** with a €100 million sector turnover and 800 job places are worth mentioning. Geothermal heat fits especially well to the horticulture sector, from which the clearly visible growth in socioeconomic indicators mainly originates. ■






Pôle Avenia

*Employment and turnover*

| | Employment (direct and indirect jobs) | | Turnover (in € m ) | |
|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 |
| Italy | 3 100 | 2 200 | 410 | 300 |
| Romania | 200 | 1 100 | 10 | 70 |
| France | 2 500 | 900 | 360 | 140 |
| Netherlands | 100 | 800 | 10 | 100 |
| Hungary | 700 | 700 | 40 | 40 |
| Austria | < 100 | 400 | 10 | 60 |
| Portugal | 400 | 400 | 30 | 30 |
| Slovakia | 700 | 400 | 50 | 30 |
| Germany | 500 | 300 | 70 | 40 |
| Slovenia | 100 | 300 | 10 | 20 |
| Bulgaria | 200 | 200 | 10 | 10 |
| Poland | 100 | 200 | 10 | 20 |
| Belgium | 200 | < 100 | 40 | < 10 |
| Cyprus | < 100 | < 100 | < 10 | < 10 |
| Czechia | < 100 | < 100 | < 10 | < 10 |
| Denmark | 600 | < 100 | 100 | 10 |
| Estonia | < 100 | < 100 | < 10 | < 10 |
| Greece | < 100 | < 100 | < 10 | < 10 |
| Spain | < 100 | < 100 | < 10 | < 10 |
| Finland | < 100 | < 100 | < 10 | < 10 |
| Croatia | 100 | 100 | 10 | 10 |
| Ireland | < 100 | < 100 | < 10 | < 10 |
| Lithuania | 100 | < 100 | 10 | < 10 |
| Luxembourg | < 100 | < 100 | < 10 | < 10 |
| Latvia | < 100 | < 100 | < 10 | < 10 |
| Malta | < 100 | < 100 | < 10 | < 10 |
| Sweden | < 100 | < 100 | 10 | 10 |
| United Kingdom | < 100 | < 100 | < 10 | < 10 |
| **Total EU 28** | **10 900** | **9 500** | **1 300** | **1 020** |

*Source: EurObserv'ER*

# HEAT PUMPS

The heat pump sector in the European Union saw a clear growth both in terms of industry turnover and EU wide employment. The modelling resulted in an estimated overall turnover of €26.8 billion (up nearly €4.1 billion) and a heat pump employment level of 224 500 workers. The European Heat Pump Association (EHPA) stated that 11.8 million heat pumps were operational in the EU in 2018. The association's statistic tool assumes around 68 000 jobs in the heat pump sector although different assumptions are made compared to the EurObserv'ER modelling. 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, an approach that is in line with the EU RES Directive.

A large part of the heat pumps sold and installed in Europe are also still manufactured and "Made in the EU". Only the compressors are largely imported from China. Thus, the heat pump value chain and creation are positive examples of how renewables contribute not only to lower emissions and reduced dependence on imported fossil fuels (see chapter on avoided fossil fuel use), but also how they promote economic prosperity in Member States. The modelling results indicate a growing domestic demand and domestic manufacturing industry which are reflected in increasing levels of local employment and turnover.

According to our estimates, Spain is a net importer of heat pumps and heat pump parts in 2018 (and also in 2017). But indigenous production increased in 2018, which means the estimated import requirement decreased compared to 2017. We estimate the Spanish industry was able to satisfy more of the local demand in 2018. Therefore the employment model estimates more of the heat pump equipment-related turnover remains in Spain, with increased employment in the heat pump sector as a result. This explains why **Spain** not only remains clear top runner in the socioeconomic list, but also shows

*Employment and turnover*

| | Employment (direct and indirect jobs) | | Turnover (in € m ) | |
|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 |
| Spain | 56 600 | 68 700 | 5 330 | 6 510 |
| France | 36 200 | 41 200 | 5 310 | 6 000 |
| Italy | 41 300 | 37 600 | 5 440 | 4 950 |
| Germany | 9 300 | 15 700 | 1 350 | 2 230 |
| Portugal | 13 800 | 13 900 | 860 | 880 |
| Netherlands | 6 800 | 8 000 | 870 | 1 010 |
| Sweden | 5 100 | 7 800 | 1 030 | 1 620 |
| Finland | 4 700 | 5 500 | 740 | 870 |
| Czechia | 2 600 | 5 300 | 180 | 370 |
| Belgium | 1 400 | 2 900 | 270 | 560 |
| Denmark | 1 500 | 2 700 | 270 | 470 |
| Poland | 3 000 | 2 600 | 220 | 200 |
| Slovakia | 200 | 2 400 | 20 | 180 |
| United Kingdom | 1 700 | 2 100 | 170 | 210 |
| Estonia | 1 700 | 1 800 | 120 | 120 |
| Austria | 1 300 | 1 700 | 220 | 290 |
| Greece | 1 200 | 1 500 | 100 | 130 |
| Hungary | 400 | 800 | 20 | 40 |
| Bulgaria | 700 | 600 | 40 | 30 |
| Ireland | 300 | 400 | 40 | 40 |
| Slovenia | 900 | 400 | 60 | 30 |
| Romania | 200 | 300 | 10 | 20 |
| Cyprus | <100 | <100 | <10 | <10 |
| Croatia | <100 | <100 | <10 | <10 |
| Lithuania | 300 | <100 | 10 | <10 |
| Luxembourg | <100 | <100 | <10 | <10 |
| Latvia | <100 | <100 | <10 | <10 |
| Malta | <100 | <100 | <10 | <10 |
| **Total EU 28** | **191 700** | **224 500** | **22 730** | **26 820** |

*Source: EurObserv'ER*

a substantial growth – now with a €6.5 billion industrial turnover and 68 700 jobs – an addition of over 12 100 new jobs compared to the previous year. ***France*** is in the follow up position. The French heat pump industry has a turnover volume of €6 billion and 41 200 workers, a clear continuation of the growth observed the year before. Increasing consumer awareness on the benefits of heat pumps motivated more houseowners and builders of new homes to switch to heat pumps as heating technology. The €5 billion in turnover and 37 600 jobs in ***Italy*** confirm that this technology is widely used and gaining relevance in the Mediterranean country.

Heat pumps are also popular in the Scandinavian EU member countries ***Sweden*** (€1.6 billion and 7 800 jobs) and ***Finland*** (€870 million in industry turnover). Germany is increasingly using heat pumps and experienced some growth in this sector. Being home to numerous manufacturers, it still ranks in the middle with a sector turnover of €2.2 billion and 15 700 jobs. Other positive socioeconomic impacts can be reported in ***Portugal*** – 13 900 jobs and €880 million turnover and ***the Netherlands*** (8 000 jobs and over €1 billion in industrial value). The push for modernization and renovation of existing heating infrastructures throughout EU Member States coupled with rising demand for space heating across polar climate regions, will drive the business growth of heat pumps over the coming years. A 2019 market report projected continued growth in the European heat pumps sector with the air source heat pump (ASHP) sector alone predicted to surpass the USD 7billion mark by 2024. ■

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# BIOGAS

Following a rapid rise in the first decade of the century, the momentum of biogas development was not sustained over the ten following years in EU Member States. In 2018, primary energy output from biogas in the European Union slightly rose to 16 839 ktoe (0,3% more than in 2017). Primary energy output growth has steadily declined ever since it peaked in 2011 (with a year-on-year rise of 21.9%). The main reason for this stagnation is the growing apprehension of many EU states towards the use of food crops (such as maize) as energy crops. In real terms, stronger regulations on energy crops were, for example, limiting the capacities allocated to biogas tenders, as well as much less attractive biogas electricity remuneration conditions. Consequently, investments in the biogas market decreased and had a strong impact on the biogas sector's growth. Accordingly, the models used to assess this sector's development pointed towards slightly lower socioeconomic indicators. The number of jobs in the biogas sector marginally contracted to 68 800 in 2018 - 3 600 full time jobs less than in 2017. In addition, the sector produced a turnover of €7 billion-a slight decline from €7.5 billion recorded in the previous year.

In 2017, this drop was largely due to the two weak biogas markets in the UK and ***Germany***. Primary energy production from biogas dropped to 7.631 ktoe between 2017 and 2018 in the largest major producing country Germany, resulting in a lower employment level of 30 800 persons -compared to 35 000 in 2017. Sector turnover remained at €3.6 billion. Despite this drop, the country remains the biogas leader in the EU 28. In July 2019, the German Biogas Association counted 9 523 biogas plants with a total installed electrical capacity of 5 229 MW, able to provide electricity for 9.5 million average households. Turnover also declined in the ***United Kingdom*** to €580 million alongside a reduced workforce now standing at approximately 6 100 persons in the anaerobic digestion section in the United Kingdom, which makes it the EU's second largest biogas job market. However, 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). ***France*** had introduced a more lucrative remuneration system which is starting to pay off also in socioeconomic terms with €550 million in turnover created by 4 200 biogas-related staff. ***Italy's*** biogas industry enjoyed continued stability with the number of employed individuals growing to 8 400 FTE with a turnover of €880 million.

EurObservER assumes that the 2030 target of 30 Mtoe from methanization of biogas is still within reach. Another - although somewhat slowed down - trend is the installation of biomethane units that inject biogas directly into local gas grids. The European Biogas Association counted over 500 biomethane plants in Europe (beginning 2018). Meanwhile over 200 biomethane plants are operational in Germany, 85 in the United Kingdom and over 60 in Sweden. ■





*Employment and turnover*

| | Employment (direct and indirect jobs) | | Turnover (in € m) | |
|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 |
| Germany | 35 000 | 30 800 | 4 190 | 3 640 |
| Italy | 8 100 | 8 400 | 840 | 880 |
| United Kingdom | 8 400 | 6 100 | 800 | 580 |
| France | 2 400 | 4 200 | 290 | 550 |
| Czechia | 4 500 | 4 100 | 270 | 240 |
| Poland | 2 300 | 2 700 | 100 | 130 |
| Croatia | 800 | 2 200 | 50 | 110 |
| Spain | 1 600 | 1 200 | 120 | 90 |
| Slovakia | 500 | 1 100 | 40 | 80 |
| Bulgaria | 600 | 1 000 | 30 | 40 |
| Greece | 1 300 | 800 | 70 | 30 |
| Latvia | 900 | 800 | 40 | 30 |
| Hungary | 600 | 700 | 30 | 30 |
| Netherlands | 700 | 700 | 110 | 100 |
| Portugal | 700 | 700 | 30 | 30 |
| Denmark | 700 | 600 | 120 | 110 |
| Finland | 600 | 500 | 80 | 70 |
| Austria | 400 | 400 | 60 | 70 |
| Belgium | 500 | 400 | 130 | 100 |
| Lithuania | 700 | 300 | 30 | 10 |
| Romania | 300 | 300 | 10 | 10 |
| Ireland | 200 | 200 | 20 | 20 |
| Cyprus | 100 | 100 | 10 | 10 |
| Estonia | 100 | 100 | <10 | <10 |
| Luxembourg | 100 | 100 | 10 | 10 |
| Malta | <100 | 100 | <10 | <10 |
| Sweden | 100 | 100 | 10 | 10 |
| Slovenia | 100 | 100 | 10 | 10 |
| **Total EU 28** | **72 400** | **68 800** | **7 520** | **7 010** |

*Source: EurObserv'ER*

# BIOFUELS

The European biofuels sector (EurObserv'ER subsumes biodiesel, bioethanol and biogas for transport in the biofuels technologies) saw some continued growth. Overall biofuel consumption rose by 10.1% between 2017 and 2018 to 16 959 ktoe (+ 1 551 ktoe). The increase in biofuel consumption is primarily due to an increase in quotas (legal obligations) or incorporation targets (linked to tax incentive) for some countries. The European bioethanol industrial sector continued its recovery in 2018 although substantial production capacities are still idle. Three countries share more than 50% of the bioethanol production for the entire European Union: The United Kingdom, France and Germany. As in 2018, most of the increase in biofuel consumption came from the biodiesel sector. Along with that, biofuels consolidated their role as major source of beneficial socioeconomic development in the EU renewable energy sector. According to EurObserv'ER calculations, the entire ***European Union*** biofuel induced industry turnover remained stable at around €14.4 billion, whereas the employment level increased from 230 400 to 248 200 jobs in 2018. This turns biofuels into the third largest renewable energy job creator in the EU, following wind energy and solid biomass.

The methodology used to evaluate the biomass industry covers biomass supply activities, i.e. supply in the agricultural sector. Also, this year, it should be noted that the leading countries in terms of employment are not necessarily the largest biofuel consumers such as France and Germany, but more notably EU Member States with large agricultural land area such as Romania, Hungary, Lithuania or Poland. And indeed, ***Poland*** (41 200 persons employed with a turnover of €1.5 billion) and ***Romania*** (40 000 jobs and €1.1 billion) and clearly lead the biofuels job head count in the EU in 2018.

In turn, large parts of biofuel value creation occur on the production side of the value chain, which explains that economic turnover are highest in Member States with huge biofuel plants (for example ***France*** with €2.8 billion). In 2018, France was also the number one consumer of biofuel in Europe. Accordingly, it is the third largest markets in terms of biofuel jobs with 29 100 jobs. It combines a vital agricultural basis with substantial biofuel production capacities. Similarly, ***Spain*** is a major biofuel hub. The economic volume of the biofuel industry is estimated at around €1.4 billion, albeit the employment level decreased to a still considerable 23 200 persons. ***Germany*** also had to accept some decline in biofuel induced turnover and employment (€1.54 billion, down from €1.64 billion in 2017) and correspondingly also saw lower job figures with 14 500 persons employed in 2018. This tendency corresponds well to national statistical accounts as released by the Ministry for Economic Affairs and Energy (BMWi). Our modelling exercise also found some significant job growth in ***Latvia***, now with 4 900 jobs and a stable workforce of 18 000 jobs and €810 million in ***Hungary***.

Some Member States decided to increase their biofuel incorporation rates in order to contribute





GICON

to their national 2020 emission reduction targets. This was the case for the ***Netherlands***, that witnessed significant growth in biofuel consumption although not yet directly in socio-economic terms (€380 million and 2 400 jobs). Similarly, in the ***UK***, the new RTFO (Renewable Transport Fuel Obligation) legislation came into force in 2018, aiming at rapidly increasing the use of sustainable biofuels. The biodiesel consumption jumped by 51.8% from 590.9 ktoe in 2017 to 897.1 ktoe in 2018. So far, there is no immediately visible socioeconomic impact. Turnover stays around €700 million and employment is slightly down to 8 600 people.

According to EurObserv'ER, at the end of 2020, the biofuel consumption level in terms of energy content could exceed 20 Mtoe and even reach 21 Mtoe – currently standing at 17 Mtoe. This, in turn, might stabilise the important socioeconomic role of the biofuel industry in the European Union's total employment and turnover accounts. ■

*Employment and turnover*

| | Employment (direct and indirect jobs) | | Turnover (in € m ) | |
|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 |
| Poland | 31 400 | 41 200 | 1 110 | 1 480 |
| Romania | 34 300 | 40 000 | 960 | 1 130 |
| France | 24 400 | 29 100 | 2 350 | 2 810 |
| Spain | 26 600 | 23 200 | 1 590 | 1 390 |
| Hungary | 18 200 | 18 000 | 820 | 810 |
| Germany | 15 500 | 14 500 | 1 640 | 1 540 |
| Greece | 11 500 | 10 900 | 370 | 360 |
| Sweden | 8 300 | 10 900 | 350 | 490 |
| United Kingdom | 10 100 | 8 600 | 820 | 700 |
| Italy | 9 000 | 8 500 | 780 | 740 |
| Czechia | 8 400 | 8 000 | 450 | 430 |
| Bulgaria | 7 700 | 7 500 | 280 | 270 |
| Lithuania | 4 500 | 6 100 | 150 | 200 |
| Latvia | 4 000 | 4 900 | 130 | 160 |
| Slovakia | 3 800 | 4 000 | 300 | 310 |
| Finland | 1 600 | 2 600 | 150 | 240 |
| Croatia | 2 000 | 2 500 | 110 | 130 |
| Netherlands | 2 800 | 2 400 | 440 | 380 |
| Austria | 2 000 | 2 100 | 300 | 320 |
| Belgium | 1 500 | 1 100 | 420 | 290 |
| Denmark | 700 | 700 | 120 | 120 |
| Estonia | 700 | 500 | 40 | 30 |
| Portugal | 400 | 300 | 20 | 20 |
| Ireland | 200 | 200 | 20 | 10 |
| Cyprus | 100 | 100 | 10 | 10 |
| Luxembourg | <100 | <100 | <10 | <10 |
| Malta | <100 | <100 | <10 | <10 |
| Slovenia | 500 | 100 | 60 | 10 |
| **Total EU 28** | **230 400** | **248 200** | **13 810** | **14 400** |

*Source: EurObserv'ER*





Jean-Claude Moschetti/AlgoSolis/CNRS Photothèque

# RENEWABLE MUNICIPAL WASTE

By definition, municipal waste is considered 50% renewable matter as household waste contains a substantial biodegradable part. Energy production from waste is largely based on the incineration in Waste-to-Energy (WtE) plants. This sector is relatively hard to quantify and remains one of the smaller RE sectors in the European Union. EurObserv'ER estimates the RMW sector is worth €4.4 billion in 2018. With 31 000 direct and indirect full-time equivalent jobs, a reduction by 5 600 jobs compared to 2017 can be observed.

Unfortunately, the biannual country reports on employment and industry trends in the European waste industry published by CEWEP (Confederation of European Waste-to-Energy Plants) was discontinued. EurObserv'ER estimates that roughly two thirds of the estimated turnover and employment are based on investment in new capacity (CAPEX) and around one third of turnover and jobs can be attributed to the operation and maintenance of Waste-to-Energy plants.

According to the EurObserv'ER modelling, ***Germany*** is the largest MSW member state in terms of socioeconomic impacts, with €1.2 billion. turnover and 7 600 jobs in the sector. This seems plausible, as the country also features the largest primary energy production from renewable municipal waste in 2018 (3 102 ktoe).

The ***United Kingdom*** ranks next with an estimated workforce of 4 400 workers and an industry turnover of €520 million in 2018, a decrease compared to 2017, in which more new RMW plant commissioning was modelled. ***Sweden***, with €660 million turnover and 3 400 jobs, has emerged as a major energy from waste energy supplier, with the largest growth of turnover and employment here. ***Italy*** (2 400 jobs) and ***France*** (2 100 full time jobs) are following next.

CEWEP (2019) believes that the 2020 renewable energy directive targets for energy from waste are well on their way to being met and could realistically reach 67 TWh by 2020, with 25 TWh of electricity generation and 42 TWh (3.6 Mtoe) of heat production. The ongoing commissioning of new incineration plants in the UK, coupled with improvements in the energy efficiency of existing plants, should also result in a stable sector development and corresponding employment in the renewable waste sector. ■







*Employment and turnover*

| | Employment (direct and indirect jobs) | | Turnover (in € m) | |
|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 |
| Germany | 6 300 | 7 600 | 1 020 | 1 180 |
| United Kingdom | 10 800 | 4 400 | 1 140 | 520 |
| Netherlands | 1 500 | 3 400 | 230 | 470 |
| Sweden | 800 | 3 400 | 160 | 660 |
| Italy | 2 500 | 2 400 | 320 | 310 |
| France | 2 600 | 2 100 | 350 | 280 |
| Ireland | 700 | 1 600 | 70 | 170 |
| Finland | 400 | 1 200 | 70 | 200 |
| Belgium | 3 200 | 600 | 590 | 100 |
| Denmark | 600 | 600 | 130 | 120 |
| Spain | 1 100 | 600 | 120 | 70 |
| Estonia | <100 | 500 | <10 | 30 |
| Portugal | 500 | 500 | 40 | 40 |
| Hungary | 400 | 400 | 20 | 20 |
| Austria | 1 600 | 200 | 270 | 50 |
| Czechia | 700 | 200 | 50 | 20 |
| Poland | 700 | 200 | 50 | 10 |
| Bulgaria | <100 | 100 | <10 | <10 |
| Cyprus | <100 | 100 | <10 | <10 |
| Greece | 100 | 100 | 10 | <10 |
| Croatia | 100 | 100 | <10 | <10 |
| Lithuania | 100 | 100 | <10 | <10 |
| Luxembourg | 100 | <100 | 10 | <10 |
| Latvia | <100 | <100 | <10 | <10 |
| Malta | <100 | <100 | <10 | <10 |
| Romania | 100 | <100 | <10 | <10 |
| Slovenia | <100 | <100 | <10 | <10 |
| Slovakia | 100 | <100 | <10 | <10 |
| **Total EU 28** | **35 600** | **31 000** | **4 750** | **4 360** |

*Source: EurObserv'ER*

# SOLID BIOMASS

Solid biomass remains the most important renewable energy source in terms of energy production and renewable employment in the EU 28. The reason for this is that unlike the other RE giant, wind power, biomass also makes a substantial contribution towards renewable heat generation. Plus: an important part of the employment activities originates from biomass fuel supply. The solid biomass sector comprises of different technologies that cover various end-user sectors: energy (biomass CHP, co-firing), industry (boilers), and households (pellet boilers and stoves). Solid biomass is not only used in the form of wood chips and briquettes, but also includes many other forms such as wood waste, pellets, sawdust, straw, bagasse, animal waste as well as black liquors from the papermaking industry. The energy recovery of this matter is basically channelled into producing heat. The demand for heat declined in the European Union, due to a milder winter in 2018, while there was a rise in electricity production. All in all, the sector's primary energy consumption was stable (0.2% lower than in 2017), and is just below the 100 Mtoe threshold (99.4 Mtoe).


With 360 600 persons employed in the corresponding value chains, solid biomass is the largest renewable energy source in 2018, ahead of wind power. In terms of turnover, biomass is a big player too - with €31.8 billion - ranked second just behind wind power. The EurObservER analysis also covers the forestry and agricultural components of the biomass value chain. Thus, the EU Member States with large forest areas are also the ones that have the best opportunity for this renewable energy use.

The Scandinavian countries ***Sweden*** and ***Finland*** should be mentioned here. Finland has the highest solid biomass turnover (€4.4 billion) and with 23 700 jobs is also home to one of the largest biomass work forces. The Nordic country has, in terms of turnover, just surpassed ***Germany*** (€4.3 billion) that lost almost 10 000 jobs and is down to 35 400 biomass-related jobs. The different ratios between employment and turnover are caused by how different types of activity are modelled. The national statistics of AGEE-Stat arrive at a somewhat higher figure on investment and economic impacts from operation and maintenance, but those figures include the biogas sector, which is covered separately in the EurObserv'ER accounts. ***Sweden*** ranks next in terms of turnover (€4.1 billion), but with 18 900 jobs remains behind ***France*** with 31 100 jobs and €3.7 billion. The dip in employment in the biomass sector in ***Italy*** - down to 24 400 jobs - is mostly caused by a decrease in biomass feedstock production, estimated by EurObservER based on the latest Eurostat statistics on the production and trade of agricultural and forestry products.

The conversion of coal-fired power plants with larger shares of biomass continued and had some notable effects in the Eastern European Member States ***Poland*** (28 900), ***Bulgaria*** (25 600) and ***Latvia*** (24 400 persons employed). The surprisingly high figure for Bulgaria can be explained by the conversion of more old coal energy plants into solid biomass plants. The ***United Kingdom*** (€1.4 billion and 16 500 jobs) is another major user and benefits economically primarily due to the increased processing and use of wood in the CHP and power plants sector.

From 2021 onwards, solid biomass use for energy will be subject to strict EU sustainability criteria. While the positive socioeconomic impacts of solid biomass in the EU 28 are enormous compared to more fluctuating sectors such as PV, wind or biofuels, the market dynamics are less strongly pronounced in this sector. ■

*Employment and turnover*

| | Employment (direct and indirect jobs) | | Turnover (in € m ) | |
|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 |
| Germany | 44 900 | 35 400 | 5 630 | 4 330 |
| France | 33 900 | 31 100 | 3 990 | 3 650 |
| Poland | 25 900 | 29 600 | 1 000 | 1 210 |
| Bulgaria | 8 700 | 27 000 | 280 | 990 |
| Italy | 35 800 | 24 400 | 2 550 | 1 750 |
| Latvia | 20 700 | 24 400 | 770 | 900 |
| Finland | 26 800 | 23 700 | 4 860 | 4 390 |
| Sweden | 20 700 | 18 900 | 4 460 | 4 080 |
| Spain | 20 800 | 18 300 | 1 030 | 800 |
| Czechia | 12 300 | 16 700 | 840 | 1 120 |
| Croatia | 14 400 | 16 700 | 280 | 410 |
| United Kingdom | 15 000 | 16 500 | 1 230 | 1 390 |
| Estonia | 8 000 | 12 200 | 490 | 740 |
| Hungary | 13 300 | 11 800 | 420 | 400 |
| Slovakia | 9 000 | 11 300 | 350 | 430 |
| Austria | 8 700 | 10 100 | 1 630 | 1 840 |
| Portugal | 8 000 | 7 100 | 670 | 610 |
| Romania | 11 400 | 6 800 | 320 | 210 |
| Denmark | 10 500 | 5 300 | 1 890 | 1 020 |
| Netherlands | 4 800 | 3 300 | 550 | 380 |
| Lithuania | 3 600 | 2 700 | 240 | 200 |
| Greece | 2 600 | 2 400 | 170 | 160 |
| Slovenia | 1 500 | 1 800 | 110 | 140 |
| Belgium | 2 000 | 1 500 | 590 | 500 |
| Ireland | 1 200 | 1 100 | 160 | 140 |
| Cyprus | <100 | 300 | <10 | 20 |
| Luxembourg | 100 | 100 | 20 | 10 |
| Malta | <100 | <100 | <10 | <10 |
| Total EU 28 | 364 800 | 360 600 | 34 550 | 31 830 |

*Source: EurObserv'ER*





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# CONCLUSION

The EurObserv'ER team uses an employment modelling approach to estimate the employment derived from renewable investments, operation and maintenance activities as well as the production and trading of equipment and biomass feedstock. The EurObserv'ER employment and turnover estimates are based on an evaluation of the economic activity of each renewable sector covered, which is then converted to full-time equivalent (FTE).

Summing up the socioeconomic indicator chapter we arrive at the following findings and development trends:

### EMPLOYMENT

- Overall, around 1.51 million persons are directly or indirectly employed in the European Union renewable energy sector. This represents a gross growth of 67 000 jobs (+4.6%) between 2017 and 2018.
- 20 out of 28 Member States either increased or maintained their number of renewable energy jobs
- The top 5 countries in terms of employment are: Germany (263 700 jobs, 17% of all EU renewable employment), Spain (167 100 jobs, 11%), France (151 600 jobs, 10%), the UK (131 900 jobs, 9%), and Italy (121 400 jobs, 8%).
- The largest growth in employment were found in Bulgaria (+18 400 new jobs, equal to +81%), Austria (+14 900, equal to +62%), and Poland (+11 900 jobs, equal to +16%). The greatest losses were observed in Germany (-27 000 jobs, equal to -9%), Italy (-8 500, -7%) and Finland (-3 400 jobs, equal to -7%).
- Solid biomass (360 600 jobs, 24% of the total EU) retained its title as the largest sector in terms of renewable energy induced employment, ahead of wind power (325 300 jobs, 22%), and biofuels (248 200 jobs, 16%). The most significant upward jump in employment per technology was in the heat pumps sector with an additional 33 000 jobs (+17%), followed by PV that saw an addition of 26 700 new jobs (+29%). The biofuel sector also grew by 17 800 FTE (+8%).

### TURNOVER

- In total the renewable energy related industry turnover in EU 28 Member States in 2018 amounted to around €158.9 billion, representing a gross growth of around €4.2 billion against 2017 (+2.7%).
- 18 out of 28 EU Member States either increased or maintained their industrial turnover created by renewable energy sources.
- The top 5 Member States in terms of turnover are Germany (€35.5 billion), France (€19.8 billion), Spain (€15.0 billion), Italy (€14.0 billion) and the United Kingdom with €13.3 billion.
- The largest growth in turnover according to the EurObserv'ER modelling was observed in Austria (+€2.4 billion), France (+€1.4 billion), and the Netherlands (+€1.3 billion). The largest dips in turnover also occurred in Germany (-€3.7 billion), Finland (-€530 million), and Denmark (-€520 million).
- The largest renewable energy technologies in terms of industry sector turnover were wind power with €43.9 billion, followed by solid biomass (€31.8 billion), and heat pumps (€26.8 billion).

The so-called "Green Deal" announced by the new EU Commission shall put the EU on track to further reduce emissions. It raises hopes for a continued upward development of renewable energy sources in the EU over the coming decade and along with that, even more positive socioeconomic indicators. ■

# 2017 EMPLOYMENT DISTRIBUTION BY SECTOR

| | Country total | Biomass | Wind | Biofuels | Heat pumps | PV | Biogas | Hydro | waste | Solar thermal | Geothermal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Germany | 290 700 | 44 900 | 140 800 | 15 500 | 9 300 | 29 300 | 35 000 | 4 600 | 6 300 | 4 500 | 500 |
| Spain | 168 800 | 20 800 | 37 200 | 26 600 | 56 600 | 5 500 | 1 600 | 11 200 | 1 100 | 8 100 | < 100 |
| France | 140 700 | 33 900 | 18 500 | 24 400 | 36 200 | 9 300 | 2 400 | 9 900 | 2 600 | 1 000 | 2 500 |
| United Kingdom | 131 400 | 15 000 | 69 900 | 10 100 | 1 700 | 12 900 | 8 400 | 2 300 | 10 800 | 200 | < 100 |
| Italy | 129 900 | 35 800 | 7 500 | 9 000 | 41 300 | 11 200 | 8 100 | 10 800 | 2 500 | 600 | 3 100 |
| Poland | 73 900 | 25 900 | 8 000 | 31 400 | 3 000 | 1 100 | 2 300 | 1 100 | 700 | 300 | 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 | 600 | 200 | 600 |
| Sweden | 43 100 | 20 700 | 2 700 | 8 300 | 5 100 | 500 | 100 | 4 700 | 800 | < 100 | < 100 |
| Finland | 40 300 | 26 800 | 4 100 | 1 600 | 4 700 | 700 | 600 | 1 200 | 400 | < 100 | < 100 |
| Hungary | 36 000 | 13 300 | 800 | 18 200 | 400 | 1 300 | 600 | < 100 | 400 | 200 | 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 | 700 | 200 | < 100 |
| Netherlands | 28 700 | 4 800 | 5 800 | 2 800 | 6 800 | 6 000 | 700 | < 100 | 1 500 | 100 | 100 |
| Latvia | 27 200 | 20 700 | < 100 | 4 000 | < 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 | 100 | 2 000 | < 100 |
| Austria | 23 500 | 8 700 | 2 000 | 2 000 | 1 300 | 1 600 | 400 | 4 200 | 1 600 | 1 200 | < 100 |
| Bulgaria | 22 700 | 8 700 | 500 | 7 700 | 700 | 600 | 600 | 2 300 | < 100 | 1 300 | 200 |
| Croatia | 20 300 | 14 400 | 1 100 | 2 000 | < 100 | 100 | 800 | 1 400 | < 100 | 200 | 100 |
| Belgium | 17 800 | 2 000 | 5 500 | 1 500 | 1 400 | 3 000 | 500 | 400 | 3 200 | 100 | 200 |
| Slovakia | 15 900 | 9 000 | < 100 | 3 800 | 200 | 200 | 500 | 1 200 | 100 | 100 | 700 |
| Estonia | 12 200 | 8 000 | 1 200 | 700 | 1 700 | 100 | 100 | < 100 | <100 | < 100 | < 100 |
| Lithuanie | 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 | 700 | 100 | < 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 | 35 600 | 21 900 | 10 900 |

*Source: EurObserv'ER*

## 2017 TURNOVER BY SECTOR (€M)

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

*Source: EurObserv'ER*

# 2018 EMPLOYMENT DISTRIBUTION BY SECTOR

| | Country total | Biomass | Wind | Biofuels | Heat pumps | PV | Hydro | Biogas | Waste | Solar thermal | Geothermal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Germany | 263 700 | 35 400 | 106 200 | 14 500 | 15 700 | 41 900 | 7 600 | 30 800 | 7 600 | 3 700 | 300 |
| Spain | 167 100 | 18 300 | 32 300 | 23 200 | 68 700 | 2 200 | 12 300 | 1 200 | 600 | 8 200 | <100 |
| France | 151 600 | 31 100 | 15 700 | 29 100 | 41 200 | 15 000 | 10 500 | 4 200 | 2 100 | 1 800 | 900 |
| United Kingdom | 131 900 | 16 500 | 82 800 | 8 600 | 2 100 | 8 600 | 2 500 | 6 100 | 4 400 | 200 | <100 |
| Italy | 121 400 | 24 400 | 8 100 | 8 500 | 37 600 | 11 400 | 17 300 | 8 400 | 2 400 | 1 100 | 2 200 |
| Poland | 85 800 | 29 600 | 3 000 | 41 200 | 2 600 | 3 100 | 1 000 | 2 700 | 200 | 2 200 | 200 |
| Romania | 55 300 | 6 800 | 2 200 | 40 000 | 300 | 1 100 | 3 300 | 300 | <100 | 100 | 1 100 |
| Sweden | 51 300 | 18 900 | 4 600 | 10 900 | 7 800 | 1 100 | 4 300 | 100 | 3 400 | <100 | <100 |
| Denmark | 47 600 | 5 300 | 35 400 | 700 | 2 700 | 1 600 | <100 | 600 | 600 | 500 | <100 |
| Bulgaria | 41 100 | 27 000 | 500 | 7 500 | 600 | 600 | 2 300 | 1 000 | <100 | 1 300 | 200 |
| Netherlands | 39 900 | 3 300 | 6 800 | 2 400 | 8 000 | 14 300 | <100 | 700 | 3 400 | 100 | 800 |
| Czechia | 39 100 | 16 700 | 1 300 | 8 000 | 5 300 | 1 900 | 1 300 | 4 100 | 200 | 200 | <100 |
| Austria | 38 400 | 10 100 | 2 500 | 2 100 | 1 700 | 1 900 | 17 300 | 400 | 200 | 1 800 | 400 |
| Hungary | 38 100 | 11 800 | 900 | 18 000 | 800 | 4 500 | 100 | 700 | 400 | 200 | 700 |
| Finland | 36 900 | 23 700 | 700 | 2 600 | 5 500 | 1 200 | 1 300 | 500 | 1 200 | <100 | <100 |
| Portugal | 35 300 | 7 100 | 2 600 | 300 | 13 900 | 1 600 | 7 700 | 700 | 500 | 500 | 400 |
| Latvia | 34 100 | 24 400 | 200 | 4 900 | <100 | <100 | 3 300 | 800 | <100 | <100 | <100 |
| Greece | 26 900 | 2 400 | 5 100 | 10 900 | 1 500 | 1 800 | 2 400 | 800 | <100 | 1 800 | <100 |
| Croatia | 25 500 | 16 700 | 1 100 | 2 500 | <100 | 400 | 2 100 | 2 200 | <100 | 200 | 100 |
| Slovakia | 20 900 | 11 300 | <100 | 4 000 | 2 400 | 200 | 1 200 | 1 100 | <100 | 100 | 400 |
| Estonia | 16 300 | 12 200 | 400 | 500 | 1 800 | 500 | <100 | 100 | 500 | <100 | <100 |
| Belgium | 16 200 | 1 500 | 7 400 | 1 100 | 2 900 | 1 700 | 400 | 400 | 600 | 100 | <100 |
| Lithuanie | 10 700 | 2 700 | 500 | 6 100 | <100 | 100 | 600 | 300 | 100 | <100 | <100 |
| Ireland | 8 700 | 1 100 | 4 500 | 200 | 400 | 200 | 300 | 200 | 1 600 | 100 | <100 |
| Slovenia | 5 100 | 1 800 | <100 | 100 | 400 | 100 | 2 000 | 100 | <100 | <100 | 300 |
| Cyprus | 1 500 | 300 | 100 | 100 | <100 | 200 | <100 | 100 | <100 | 300 | <100 |
| Luxembourg | 1 400 | 100 | 100 | <100 | <100 | 100 | 500 | 100 | <100 | <100 | <100 |
| Malta | 1 100 | <100 | <100 | <100 | <100 | 200 | <100 | 100 | <100 | <100 | <100 |
| **Total EU 28** | **1 512 900** | **360 600** | **325 300** | **248 200** | **224 500** | **117 600** | **102 100** | **68 800** | **31 000** | **25 300** | **9 500** |

*Source: EurObserv'ER*

## 2018 TURNOVER BY SECTOR (€M)

| | Country total | Wind | Biomass | Heat pumps | PV | Biofuels | Hydro | Biogas | Waste | Solar thermal | Geothermal |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Germany | 35 510 | 15 340 | 4 330 | 2 230 | 5 680 | 1 540 | 1 060 | 3 640 | 1 180 | 470 | 40 |
| France | 19 830 | 2 480 | 3 650 | 6 000 | 2 120 | 2 810 | 1 550 | 550 | 280 | 250 | 140 |
| Spain | 15 020 | 3 770 | 800 | 6 510 | 220 | 1 390 | 1 180 | 90 | 70 | 980 | <10 |
| Italy | 13 980 | 1 190 | 1 750 | 4 950 | 1 480 | 740 | 2 250 | 880 | 310 | 130 | 300 |
| United Kingdom | 13 340 | 8 750 | 1 390 | 210 | 890 | 700 | 270 | 580 | 520 | 20 | <10 |
| Sweden | 8 930 | 980 | 4 080 | 1 620 | 210 | 490 | 860 | 10 | 660 | 10 | 10 |
| Denmark | 8 650 | 6 420 | 1 020 | 470 | 290 | 120 | <10 | 110 | 120 | 80 | 10 |
| Austria | 6 530 | 430 | 1 840 | 290 | 310 | 320 | 2 850 | 70 | 50 | 310 | 60 |
| Finland | 6 330 | 130 | 4 390 | 870 | 200 | 240 | 210 | 70 | 200 | <10 | <10 |
| Netherlands | 5 130 | 960 | 380 | 1 010 | 1 710 | 380 | <10 | 100 | 470 | 10 | 100 |
| Poland | 3 800 | 280 | 1 210 | 200 | 230 | 1 480 | 80 | 130 | 10 | 160 | 20 |
| Belgium | 3 450 | 1 480 | 500 | 560 | 320 | 290 | 70 | 100 | 100 | 20 | <10 |
| Portugal | 2 550 | 280 | 610 | 880 | 100 | 20 | 530 | 30 | 40 | 30 | 30 |
| Czechia | 2 530 | 100 | 1 120 | 370 | 140 | 430 | 90 | 240 | 20 | 10 | <10 |
| Romania | 1 920 | 170 | 210 | 20 | 70 | 1 130 | 220 | 10 | <10 | 10 | 70 |
| Hungary | 1 630 | 60 | 400 | 40 | 210 | 810 | 10 | 30 | 20 | 10 | 40 |
| Bulgaria | 1 580 | 30 | 990 | 30 | 30 | 270 | 120 | 40 | <10 | 50 | 10 |
| Greece | 1 460 | 350 | 160 | 130 | 120 | 360 | 170 | 30 | <10 | 120 | <10 |
| Latvia | 1 320 | 10 | 900 | <10 | <10 | 160 | 170 | 30 | <10 | <10 | <10 |
| Slovakia | 1 170 | <10 | 430 | 180 | 10 | 310 | 100 | 80 | <10 | 10 | 30 |
| Estonia | 1 020 | 30 | 740 | 120 | 30 | 30 | <10 | <10 | 30 | <10 | <10 |
| Ireland | 960 | 510 | 140 | 40 | 20 | 10 | 30 | 20 | 170 | 10 | <10 |
| Croatia | 910 | 70 | 410 | <10 | 20 | 130 | 130 | 110 | <10 | 10 | 10 |
| Lithuania | 520 | 30 | 200 | <10 | <10 | 200 | 30 | 10 | <10 | <10 | <10 |
| Slovenia | 400 | <10 | 140 | 30 | 10 | 10 | 150 | 10 | <10 | <10 | 20 |
| Luxembourg | 160 | 10 | 10 | <10 | 10 | <10 | 70 | 10 | <10 | <10 | <10 |
| Cyprus | 120 | 10 | 20 | <10 | 10 | 10 | <10 | 10 | <10 | 20 | <10 |
| Malta | 110 | <10 | <10 | <10 | 20 | <10 | <10 | 10 | <10 | <10 | <10 |
| Total EU 28 | 158 860 | 43 900 | 31 830 | 26 820 | 14 480 | 14 400 | 12 250 | 7 010 | 4 360 | 2 790 | 1 020 |

*Source: EurObserv'ER*

# RENEWABLE ENERGY DEVELOPMENT AND ITS INFLUENCE ON FOSSIL FUEL SECTORS

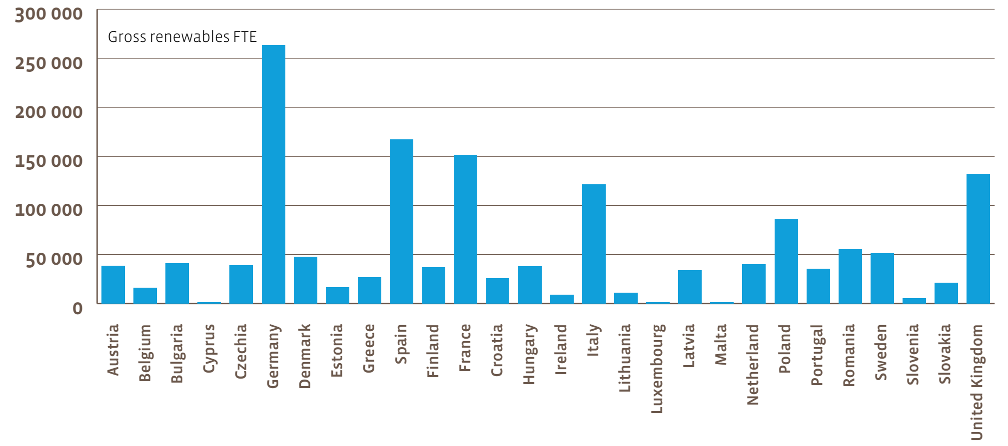
The deployment of renewable energy technologies can have an impact on the economic activity in other sectors and on the fossil fuel based energy sector. In this section EurObserv'ER indicatively estimates this substitution effect, assessing how much employment would be required in the fossil fuel sector if renewable generation would not have displaced fossil based energy. The displacement is formulated in terms of substituted final energy demand. We stress that this is only a partial coverage of more complex real-world interaction between renewable and fossil fuel sectors.

This 2019 edition of 'The State of Renewable Energy in Europe' covers the indicator for equivalent replaced fossil employment for all Member States of the European Union, for the year 2018. The effect 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 evaluation has been conducted in terms of direct jobs. 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 displaced production). It must be noted that reduced construction activities of new conventional plants are not considered, but at the same time that opposite effects are not considered: effects that influence the fossil sectors through other mechanisms (for example the impact of gas increase on the coal sector). Establishing a full reference picture is outside the scope of this analysis, so the presented indicator for equivalent replaced fossil employment does not give the full spectrum of effects. The figures show that the effects in the fossil fuel sector vary significantly between Member States. The relative impact on the fossil sector, when compared to the gross renewable employment, is for example of a completely different nature in Hungary than it is in Romania. 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 sensitive to the influence of renewables development than countries that import coal for power generation. This has been described in the JRC-report 'EU coal regions: opportunities and challenges ahead'. In our methodology, the employment affected by reduced use of natural gas in natural gas extraction, gas conversion and gas transport is assumed to be close to zero, while in the power sector there is an effect.

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 , for example, the wind industry. ■

**1**

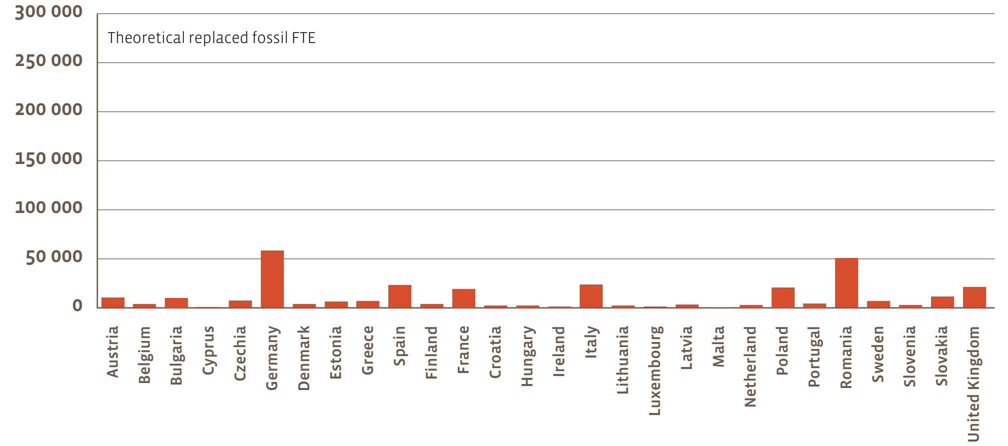
*Gross renewable employment as reported in the previous sections (data for 2018)*




*Source : EurObserv'ER*

**2**

*Indicator for equivalent replaced fossil employment, looking at operation, maintenance and fuel production activities only (data for 2018)*




*Source : EurObserv'ER*

# 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 2017 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, geothermal, 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 2017 and 2018 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 notable decrease of wind investments in the previous year, investments in new wind capacity marginally increased in 2018. Total investments in wind capacity went up from € 23.3 billion in 2017 by 4.5% to € 24.3 billion in 2018. The associated capacity added increased even stronger, namely by 11.2% from 13.1 GW to almost 14.6 GW. This indicates that investment costs in the wind sector declined between both years. This in analysed in more detail for onshore and offshore wind investments below. In contrast to the investment volume, the number of projects declined from 654 wind power plants in 2017 to only 405 in 2018.

The way of financing changed considerably between the two years. In 2017, balance sheet financing dominated in the wind sector: 73% of all investments were financed this way, while 23% of investments used non-recourse project finance structures and 4% other financing instruments as bonds. In 2018, the importance of project finance increased notably. More than half, namely more than 57% of all wind investments in the EU used project finance. The share of on balance sheet financed wind investments feel to 35%. The share of other financing instruments increased from 4% to almost 8%. Hence, these instruments still play a minor role in the wind sector, but they seem to get more relevant. The shares of the number of projects financed investments between the two 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 57% and 23% of financing volumes in 2018 and 2017, respectively, only 15.8% (2018) and 9.5% (2017) of all projects are covered by project financing.

### OFFSHORE DRIVES THE INCREASE IN WIND INVESTMENTS

The increase in total wind investments was mainly driven by offshore wind. In fact, onshore wind investments remained at the almost identical level with €14.7 billion in 2017 and €14.2 billion in 2018. In contrast, investments in offshore wind plants increased by 17% from €8.67 billion in 2017 to €10.1 billion in 2018. In contrast to previous years, however, offshore investments were not the dominant share in overall wind investments. The share of offshore was almost 42% in 2018 and 37% 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, however, dropped from €1.44 billion in 2017 to €922 million in 2018. In contrast, the average project size of onshore wind projects in the EU increased between the two years from €23 million to €36 million.

The associated capacity added of offshore wind investments increased notably stronger that the investment volumes, namely from 2.5 GW in 2017 to almost 4 GW in 2018. This indicates a strong reduction in investment costs of offshore wind plants. In 2017, average expenditure per MW of offshore capacity was €3.5 million compared to only €2.5 million in 2018. In the case of onshore, investment costs are as expected substantially lower. They marginally declined from €1.37 million in 2017 to €1.34 million in 2018.





**1**

*Overview of asset finance in the wind power sector (onshore + offshore) in the EU Member States in 2017 and 2018*

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Asset Finance - New Built (€ m) | Number of Projects | Capacity (MW) | Asset Finance - New Built (€ m) | Number of Projects | Capacity (MW) |
| United Kingdom | 5 045.87 | 23 | 1 908.3 | 5817.75 | 19 | 2163.6 |
| Sweden | 1 652.24 | 15 | 1 358.3 | 3416.57 | 26 | 2748.3 |
| Spain | 299.94 | 12 | 231.8 | 2584.73 | 36 | 2 078.16 |
| France | 2 573.39 | 107 | 1 847.65 | 2490.81 | 102 | 1774 |
| Belgium | 330.80 | 28 | 241.1 | 2168.54 | 29 | 914.7 |
| Netherlands | 518.52 | 9 | 368.55 | 1895.79 | 17 | 1063.6 |
| Germany | 9 949.77 | 353 | 5 087.56 | 1663.42 | 99 | 1 116.85 |
| Denmark | 559.48 | 25 | 426.5 | 1314.41 | 3 | 643.1 |
| Italy | 360.72 | 15 | 253.1 | 819.03 | 16 | 588.5 |
| Greece | 897.82 | 23 | 588.25 | 541.53 | 24 | 390.3 |
| Ireland | 557.48 | 18 | 369.1 | 529.06 | 10 | 288.9 |
| Finland | 142.62 | 9 | 103.95 | 332.32 | 9 | 282.5 |
| Portugal | 57.35 | 6 | 41.8 | 264.24 | 5 | 141.7 |
| Austria | 212.79 | 7 | 170 | 233.59 | 7 | 153.9 |
| Croatia | 134.57 | 3 | 107.9 | 172.33 | 1 | 156 |
| Poland | 0.00 | 0 | 0 | 125.18 | 1 | 88 |
| Luxembourg | 0.00 | 0 | 0 | 4.27 | 1 | 3 |
| Czechia | 35.67 | 1 | 26 | 0 | 0 | 0 |
| **Total EU 28** | **23 329.03** | **654** | **13 129.86** | **24 373.57** | **405** | **14 595.11** |

*Source: EurObserv'ER*

## 2

*Share of different types of asset finance in the wind power sector (onshore + offshore) in the EU in 2017 and 2018*

| | 2017 | | 2018 | |
|---|---|---|---|---|
| | Asset Finance - New Built (%) | Number of Projects | Asset Finance - New Built (%) | Number of Projects |
| Balance Sheet | 72.97% | 89.91% | 35.13% | 81.98% |
| Project Finance | 23.24% | 9.48% | 57.32% | 15.80% |
| Bond/Other | 3.79% | 0.61% | 7.56% | 2.22% |
| Total EU | 100.0% | 100.0% | 100.0% | 100.0% |

*Source: EurObserv'ER*

### UK KEEPS POLE POSITION, INVESTMENTS DROP IN GERMANY

The United Kingdom is the largest player in the wind sector in terms of new investments in both years. In 2018, investments totalled €5.8 billion which is an increase compared to the already high investments of €5 billion in 2017. This means that more than 20% of all EU wind investments, namely 22% in 2017 and 24% in 2018, were located in the UK. In both years, UK wind investments are almost entirely driven by very large offshore investments. After being among the top two Member States with respect to wind investments in most previous years, investments dropped notably in Germany. In 2018, investments totalled €1.66 billion in Germany, which are the 7th highest investments in that year in the EU. This relatively low number, however, should be interpreted bearing in mind the particularly high investments in 2017, where Germany saw the by far highest wind investments in the EU totalling almost €10 billion. Hence, this is not necessarily an indication of a downturn, but 2018 could rather be an exception after a year with very high investments.

### SWEDEN AND SPAIN IN THE TOP THREE, HIGH INVESTMENTS IN FRANCE.

After already very impressive developments in 2017, wind investments in Sweden increased even further to €3.4 billion in 2018. This means that Sweden more than doubled investments between the to years and thus is ranked second in 2018. An even stronger growth could be observed in Spain. After a few years of rather low wind investments, they amounted to almost €2.6 billion in 2018. This is a different league compared to the investments of €300 million in 2017. As a result, Spain is ranked third in 2018. In both Member States, investments targeted (almost) entirely the onshore wind sector, which renders those investment volumes even more impressive.

In France, investments in the wind sector remained at a very high level. Asset finance totalled from €2.57 billion in 2017 and €2.49 billion in 2018. The number of projects also remained stable in both years. This constant trend of high investment levels ensures that France is the fourth largest player with respect to wind investments in 2018.

### FURTHER SUCCESS STORIES IN SMALLER MEMBER STATES

Three Member States that also experienced very high increases in wind investments are Belgium, the Netherlands, and Denmark. All three have one thing in common: their large investments in 2018 are largely due to large offshore investments. In 2018, almost €2.2 billion were invested into wind capacity in Belgium, while investments in the Netherlands and Denmark totalled €1.9 billion and €1.3 billion, respectively. 2017 investments in those countries were notably lower, ranging from €331 million to €560 million. In addition to these three Member States, also Italy showed a very positive trend with investments more than doubling from €362 million in 2017 to €819 million in 2018. The number of wind projects remained almost the same indicating that this increase in investments is drive by larger project sizes.





## 3

*Overview of asset finance in the wind power sector offshore in the EU Member States in 2017 and 2018*

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Asset Finance - New Built (€ m) | Number of Projects | Capacity (MW) | Asset Finance - New Built (€ m) | Number of Projects | Capacity (MW) |
| United Kingdom | 4 273.89 | 1 | 1386 | 5 373.26 | 4 | 1 905.2 |
| Belgium | 0 | 0 | 0 | 1 876.26 | 2 | 705.5 |
| Netherlands | 0 | 0 | 0 | 1 409.05 | 1 | 731.5 |
| Denmark | 0 | 0 | 0 | 1 259.93 | 1 | 604.8 |
| Portugal | 0 | 0 | 0 | 121.87 | 1 | 25.2 |
| Germany | 4 389.96 | 4 | 1069.4 | 98.58 | 1 | 16.8 |
| Sweden | 0 | 0 | 0 | 10.16 | 1 | 3 |
| France | 5.05 | 1 | 1.2 | 0 | 0 | 0 |
| Total EU | 8 668.89 | 6 | 2 456.6 | 10 149.11 | 11 | 3992 |

*Source: EurObserv'ER*

## 4

*Share of different types of asset finance in the wind power sector offshore in the EU in 2017 and 2018*

| | 2017 | | 2018 | |
|---|---|---|---|---|
| | Asset Finance - New Built (%) | Number of Projects | Asset Finance - New Built (%) | Number of Projects |
| Balance Sheet | 74.30% | 66.67% | 9.94% | 27.27% |
| Project Finance | 25.70% | 33.33% | 83.89% | 63.64% |
| Bond/Other | 0.00% | 0.00% | 6.17% | 9.09% |
| Total EU | 100.0% | 100.0% | 100.0% | 100.0% |

*Source: EurObserv'ER*

Further success stories are Finland and Portugal. In Finland, asset finance in the wind sector more than doubled to €332 million in 2018. Portuguese investments amounted to €264 million compared to only €57 million in the previous years. Finally investments remained relatively stable in Ireland, Austria, and Croatia. The highest 2018 investments of those three Member States were recorded in Ireland with €529 million. In Austria, €234 million were invested into new wind capacity followed by Croatia with €172 million. After very high volumes of almost €900 million in 2017, Greece experienced a reduction in wind investment in 2018, where they totalled €542 million. ■

# PHOTOVOLTAIC

When analysing investments 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 DOUBLED IN 2018

After a continuous downward trend in solar PV investments in the last years and a stabilisation of investments in 2017, a large increase in investments could be observed in 2018. Investments in utility-scale PV (>1 MW) doubled from €2.35 billion in 2017 to €4.76 billion in 2018. The number of PV projects, however, decreased from 286 projects in 2017 to 254 in 2018. This indicates that the average project size increased considerably between the two years. An average PV project in 2017 amounted to €8.22 million compared to €18.76 million in 2018.

Similar to overall asset finance for PV power plants, the associated capacity added increased even stronger between the two years, namely from 2.22 GW in 2017 to almost 6 GW in 2018. This indicates that the investment costs of PV dropped considerably between the two years. In 2017, investment expenditures per MW of PV capacity were on average €1.06 million compared to only €0.8 million in 2017. Considering the observation that the average project size increased notably, this might indicate that larger PV plants are more cost efficient with respect to the investment costs.

**1**

*Overview of asset finance in the PV sector in the EU Member States in 2017 and 2018 (PV Plants)*

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Asset Finance - New Built (€ m) | Number of Projects | Capacity (MW) | Asset Finance - New Built (€ m) | Number of Projects | Capacity (MW) |
| Spain | 77.46 | 7 | 71.6 | 2 636.75 | 42 | 3 464.4 |
| Netherlands | 287.67 | 30 | 269.75 | 462.78 | 30 | 576.4 |
| France | 846.92 | 103 | 785.37 | 422.08 | 56 | 473.8 |
| Hungary | 14.35 | 6 | 13.4 | 373.83 | 25 | 371.5 |
| Italy | 20.14 | 3 | 18.8 | 209.23 | 15 | 265.7 |
| Germany | 360.99 | 59 | 337.01 | 148.83 | 45 | 189 |
| Poland | 43.91 | 2 | 41 | 129.37 | 7 | 174.3 |
| Denmark | 68.15 | 3 | 64.7 | 113.40 | 3 | 144 |
| Portugal | 206.27 | 1 | 218.8 | 90.13 | 4 | 107.1 |
| Belgium | 0.00 | 0 | 0 | 85.21 | 5 | 108.2 |
| United Kingdom | 375.71 | 62 | 350 | 64.81 | 16 | 82.3 |
| Greece | 11.15 | 4 | 11.2 | 11.02 | 2 | 14 |
| Ireland | 15.21 | 1 | 14.2 | 7.27 | 1 | 5 |
| Sweden | 1.61 | 1 | 1.5 | 5.50 | 2 | 6.99 |
| Estonia | 0.00 | 0 | 0 | 3.62 | 1 | 4.6 |
| Finland | 18.00 | 3 | 16.8 | 0 | 0 | 0 |
| Austria | 3.43 | 1 | 3.2 | 0 | 0 | 0 |
| Total EU | 2 350.97 | 286 | 2 217.33 | 4 763.83 | 254 | 5 987.29 |

*Source: EurObserv'ER*

## 2

*Overview of asset finance in the PV sector in the EU in 2017 and 2018 (commercial and residential PV)*

| | 2017 | | 2018 | |
|---|---|---|---|---|
| | Investment (€ m) | Capacity (MW) | Investment (€ m) | Capacity (MW) |
| Total EU | 4 071.88 | 3 289 | 6 181.20 | 5 599 |

*Source: EurObserv'ER*





## 3

*Share of different types of asset finance in the PV sector in the EU in 2017 and 2018 (PV Plants)*

| | 2017 | | 2018 | |
|---|---|---|---|---|
| | Asset Finance - New Built (%) | Number of Projects | Asset Finance - New Built (%) | Number of Projects |
| Balance Sheet | 78.66% | 80.77% | 57.13% | 66.93% |
| Project Finance | 21.09% | 18.88% | 42.87% | 33.07% |
| Bond/Other | 0.25% | 0.35% | 0.00% | 0.00% |
| Total EU | 100.0% | 100.0% | 100.0% | 100.0% |

*Source: EurObserv'ER*

With respect to the sources of finance for PV power plants, project finance gained importance. In both years, however, the majority of PV power plants were financed through on-balance-sheet financing. Between 2017 and 2018, the share of balance sheet financed PV investments decreased notably from 79% in 2017 to 57% in 2018, while the share of non-recourse project financing rose from almost 21% to 43%. Bonds or other financing mechanisms were almost negligible. Less than 1% of all investments in 2017 used such instruments and none in 2018.

In contrast to previous years, investments in small-scale PV do not superseed utility-scale PV investments in 2018. The main reason is the very high increase in the latter, but also small-scale PV investments increased notably between the two years While small-scale PV investments totalled almost €4.1 billion in 2017, they amounted to €6.2 billion in 2018. This corresponds to an increase by around 52%. The associated capacity added grew even stronger between 2017 and 2018, namely from 3.3 GW to almost 5.6 GW, which indicates a considerable drop of the investment expenditures per MW, which dropped by 11%.

### PV INVESTMENTS BY MEMBER STATES CHANGE NOTABLY BETWEEN 2017 AND 2018

The distribution of EU PV investments across Member States changed considerably between the last two years. The by far largest investments in utility-size PV in 2018 could be observed in Spain where an impressive amount of €2.6 billion were invested. This amount is not comparable to the only €77 million in the previous year. This means that more than 55% of all EU PV investments were located in Spain 2018. Previous big players with rather large reductions in investments are France, Germany, and the UK. In France, PV investments dropped from €847 million in 2017 to €422 million in 2018, such that France is ranked third in 2018. German PV investments more than halved to €149 million in 2018. In the UK only €65 million were invested in 2018 compared to €376 million in the previous year. Furthermore, Portugal experienced a drop in investments from €206 million to €90 million.

However, most of the other Member States show rather positive trends. After a large increase in PV investments from €288 million to €463 million, the Netherlands are ranked second with respect to PV investments in the EU. Two other Member States experiencing a very high upsurge are Hungary and Italy. In 2018, PV investments in Hungary totalled €374 million and those in Italy €209 million.

In Poland, investments into PV power plants more than tripled to almost €130 million in 2018. Denmark experienced a slightly lower upsurge in investment volumes, namely from €68 million in 2017 to €113 million in 2018. While there were no newly financed PV power plants recorded in Belgium in 2017, investments in 2018 amounted to €85 million. Finally, four Member States saw small PV investments in 2018, namely Greece, Ireland, Sweden, and Estonia. ■

# BIOGAS

## 1

*Overview of asset finance in the biogas sector in the EU Member States in 2017 and 2018 (biogas plants)*

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Asset Finance - New Built (€ m) | Number of Projects | Capacity (MW) | Asset Finance - New Built (€ m) | Number of Projects | Capacity (MW) |
| Netherlands | 0.00 | 0 | 0 | 3.84 | 1 | 5 |
| United Kingdom | 4.94 | 1 | 2 | 0 | 0 | 0 |
| Total EU | 4.94 | 1 | 2 | 3.84 | 1 | 5.0 |

*Source: EurObserv'ER*





## 2

*Overview of asset finance in the biogas sector in the EU Member States in 2017 and 2018 (biomethane)*

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Asset Finance - New Built (€ m) | Number of Projects | Capacity ($m^3$/hr) | Asset Finance - New Built (€ m) | Number of Projects | Capacity ($m^3$/hr) |
| France | 0.00 | 0 | 0 | 4.57 | 1 | 200 |
| Denmark | 75.03 | 1 | 3 139.27 | 0 | 0 | 0 |
| Total EU | 75.03 | 1 | 3 139.27 | 4.57 | 1 | 200 |

*Source: EurObserv'ER*

In the biogas sector, the following four types of biogas utility-scale investments are tracked: (i) electricity generation (new) – new built biogas plants with 1MWe 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 30MWth or more generating heat, and (iv) combined heat & power (CHP) – biogas power plants with a capacity of 1MWe 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.

### LOW INVESTMENTS IN BIOGAS IN 2018

Asset finance for biogas – including biogas power plants as well as biogas production plants – slumped drastically. In 2017, €80 million were invested in total compared to only €8.4 million in 2018. The relatively high investments in 2017 are driven by investments in biogas production. In that year, one relatively large investment of €75 million was performed in Denmark. The associated capacity of the biogas production plant is 3139 m3/hr. In 2018, there is also one investment in biogas production in France, however, in a notably smaller facility with a capacity of 200 m3/hr and an investment volume of €4.6 million.

Investments in biogas power plants remained relatively stable in the two years. In 2017, €4.9 million were invested in one biogas power plant in the United Kingdom compared to €4.5 million in the Netherlands in the subsequent year. The associated capacity added of these investments, however, increased from 2 MW in 2017 to 4 MW in 2018. This indicates that the investment costs of biogas plants seemed to decline between the two years. This change in investment expenditures per MW of biogas capacity, however, should not be interpreted as a trend as there were only two investments observed in 2017 and 2018.

The way biogas power plants were financed changed between 2017 and 2018. The 2017 investment was financed from balance sheets, while for the 2018 power plant project finance was used. In both years, the biogas production plants were on-balance-sheet financed. ■

# 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 1MWe or more that generate electricity, (ii) heat – thermal plants with a capacity of 30MWth or more generating heat, and (iii) combined heat & power (CHP) –power plants with a capacity of 1MWe 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.

**1**

*Overview of asset finance in the waste sector in the EU Member States in 2017 and 2018*

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Asset Finance - New Built (€ m) | Number of Projects | Capacity (MW) | Asset Finance - New Built (€ m) | Number of Projects | Capacity (MW) |
| United Kingdom | 8.15 | 1 | 3.3 | 481.45 | 5 | 83 |
| Finland | 0.00 | 0 | 0 | 387.43 | 1 | 164 |
| Spain | 96.95 | 1 | 46 | 134.07 | 1 | 50 |
| France | 25.78 | 1 | 22 | 96.86 | 1 | 41 |
| Lithuania | 155.91 | 1 | 24 | 0 | 0 | 0 |
| Total EU | 286.78 | 4 | 95.3 | 1 099.81 | 8 | 338.0 |

*Source: EurObserv'ER*





## INCREASE IN WASTE INVESTMENTS

Overall EU investments in the waste-to-energy sector increased significantly between 2017 and 2018. In 2018, almost €1.1 billion were invested in waste-to-energy plants compared to only €287 million in the previous year. Hence, investments in 2018 are on the same level as they were in 2016. The number of waste-to-energy projects reaching financial close doubled from 4 projects in 2017 to 8 projects in 2018. Consequently, the average project size increased notably between the two years from €71 million to €137 million.

The capacity added associated with investments increased at a similar pace as investment volumes. Capacity added totals 338 MW in 2018 compared to only 95 MW in 2017. Consequently, the investment expenditures per MW of capacity increased marginally from €3 million in 2017 and €3.25 million in 2018. This change of investment cost, however, should be interpreted with care due to the low number of observations, in particular in 2017.

The way waste-to-energy projects were financed remaining almost identical. In both years, roughly two thirds of all investments used balance sheet financing, while the remain third used project finance. For both years, the size of project financed investments was on average larger than those financed from balance sheets, which is the typical observation that can often be made across RES.

**2**

*Share of different types of asset finance in the waste sector in the EU in 2017 and 2018*

| | 2017 | | 2018 | |
|---|---|---|---|---|
| | Asset Finance - New Built (%) | Number of Projects | Asset Finance - New Built (%) | Number of Projects |
| Balance Sheet | 66.20% | 75.00% | 67.67% | 75.00% |
| Project Finance | 33.80% | 25.00% | 32.33% | 25.00% |
| Bond/Other | 0.00% | 0.00% | 0.00% | 0.00% |
| Total EU | 100.0% | 100.0% | 100.0% | 100.0% |

*Source: EurObserv'ER*

## UK TAKES POLE POSITION BACK

In many years prior to 2017, the UK dominated waste-to-energy investments. After a year of very low investments of €8 million in 2017, the UK experienced again very high investments in 2018. In total, €481 million were invested in five waste-to-energy plants, which makes the UK not only ranked first in that year but also the only Member State with more than one investment in a year. Finland is ranked second in 2018 with a large investment of €387 million.

Spain and France are, next to the UK, the only Member States that experienced investments in both years. In Spain, investments increased from €97 million in 2017 to €134 million in 2018. Similarly, also French waste-to-energy investments increased between both years, namely from €26 million to €97 million. Finally, Lithuania only saw investments in new waste-to-energy capacity in 2017. The investment volume of €156 million, however, was the highest across the EU in that year. ■

# GEOTHERMAL ENERGY


**1**

*Overview of asset finance in the geothermal sector in the EU Member States in 2017 and 2018*

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Asset Finance - New Built (€ m) | Number of Projects | Capacity (MWth) | Asset Finance - New Built (€ m) | Number of Projects | Capacity (MW) |
| Germany | 0.00 | 0 | 0 | 174.90 | 2 | 53.4 |
| United Kingdom | 0.00 | 0 | 0 | 46.38 | 1 | 10 |
| Croatia | 0.00 | 0 | 0 | 37.99 | 1 | 16.5 |
| Netherlands | 127.76 | 3 | 63 | 37.92 | 1 | 32 |
| Hungary | 5.48 | 1 | 2.7 | 0 | 0 | 0 |
| Total EU | 133.24 | 4 | 65.7 | 297.19 | 5 | 112 |

*Source: EurObserv'ER*

**2**

*Share of different types of asset finance in the geothermal sector in the EU in 2017 and 2018*

| | 2017 | | 2018 | |
|---|---|---|---|---|
| | Asset Finance - New Built (€ m) | Number of Projects | Asset Finance - New Built (€ m) | Number of Projects |
| Balance Sheet | 0.00% | 0.00% | 71.63% | 60.00% |
| Project Finance | 100.00% | 100.00% | 28.37% | 40.00% |
| Bond/Other | 0.00% | 0.00% | 0.00% | 0.00% |
| Total EU | 100.0% | 100.0% | 100.0% | 100.0% |

*Source: EurObserv'ER*

This technology uses geothermal energy to 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, (i) district heating, (iii) combined heat and power (CHP), and (iv) enhanced geothermal systems. Geothermal energy has a strong regional focus in the EU. By far the largest user of geothermal energy is Italy, although other EU countries also use this energy source to a certain extent.

## INCREASING GEOTHERMAL INVESTMENTS IN THE EU

For a second time in a row, investments in geothermal capacity increased in the EU. In 2017, €133 million were invested in geothermal capacity. Investments more than doubled to €297 million in 2018. The number of new geothermal projects increased at a slower pace, namely from 4 to 5. This indicates that the average project size increased between the two years, namely from €33.3 million per geothermal plant in 2017 to €59.4 million in 2018. The associated capacity added grew slower than the investment volumes from 66 MW to 112 MW. Thus, the average investment expenditures marginally increased from €2.02 million per MW in 2017 to €2.65 million per MW in 2018. This change of investment cost, however, should be interpreted with care due to the low number of observations.

The way geothermal projects are financed changed notably between both years. In 2017, all geothermal plants used project finance. The picture changed completely in 2018, where only 28% were project financed and 72% of investments used on-balance-sheet finance. In both years, bonds and other financing instruments did not play any role in geothermal investments.

## HIGH INVESTMENTS IN THE NETHERLANDS AND GERMANY

The highest investments in 2018 occurred in Germany, where two geothermal plants with a volume of €175 million were financed. Next to Germany, three other Member States saw geothermal investments in that year, namely the UK, Croatia, and the Netherlands. The latter two had almost identical investments of almost €38 million, whereas €46 million were invested in the UK. The Netherlands are the only Member States that also saw investments in 2017, where it dominated geothermal investments. In total €128 million were invested in 3 geothermal plants. The only other country with geothermal investments in 2017 is Hungary with a rather small investment of €5.5 million. ■

# 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 1MWe 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 30MWth or more generating heat, and (iv) combined heat & power (CHP) – biomass power plants with a capacity of 1MWe or more that generate electricity and heat.

## INCREASING BIOMASS INVESTMENTS

After a large slump of investments in 2017 compared to the previous year, investments into biomass power plants increased again in 2018. In 2018 biomass investments totalled €902 million, which corresponds to an increase by 41% compared to the €638 million in 2017. The capacity added associated with these investments increased at a notably higher rate. While the associated capacity added in 2017 totalled 204 MW, capacity added in 2018 amounted to 702 MW. The main reason for this large increase is the retrofit of a very large coal power plant in the UK. In such cases, the investment expenditures per MW are typically notably lower than for newly built biomass power plants. This is also the main reason for the larger project sizes in 2018 with on average €180 million compared to €71 million per biomass plant in 2017. In particular when comparing investments costs, it is advisable to exclude retrofit plants. For new built biomass power plants, investment expenditures drop notably from €3.12 million in 2017 to €2.41 million in 2018, which corresponds to a cost decline by 23%.







**1**

*Overview of asset finance in the solid biomass sector in the EU Member States in 2017 and 2018*

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Asset Finance - New Built (€ m) | Number of Projects | Capacity (MW) | Asset Finance - New Built (€ m) | Number of Projects | Capacity (MW) |
| United Kingdom | 86.69 | 2 | 35.1 | 775.24 | 3 | 649.5 |
| Spain | 0.00 | 0 | 0 | 64.01 | 1 | 46 |
| Finland | 91.21 | 1 | 30.7 | 62.98 | 1 | 6.7 |
| Denmark | 163.26 | 1 | 25 | 0 | 0 | 0 |
| Italy | 121.28 | 1 | 30 | 0 | 0 | 0 |
| Portugal | 104.82 | 1 | 30 | 0 | 0 | 0 |
| France | 43.44 | 1 | 42.5 | 0 | 0 | 0 |
| Croatia | 24.80 | 1 | 5 | 0 | 0 | 0 |
| Sweden | 2.57 | 1 | 6 | 0 | 0 | 0 |
| Total EU | 638.06 | 9 | 204.3 | 902.23 | 5 | 702.20 |

*Source: EurObserv'ER*

The way biomass power plants are financed did not change drastically between 2017 and 2018. In both years, almost all biomass projects were on-balance-sheet financed with shares of 84% in 2017 and even 93% in 2018. The remainder of all biomass plants used project finance. In 2017, the size of project financed investments was on average larger than those financed from balance sheets, which is the typical observation that can often be made across RES. In both years, no biomass plants were financed using other instruments as bonds.

## DIVERSE DEVELOPMENTS ACROSS THE EU

Overall, the picture is quite diverse when comparing 2017 and 2018, as there are only two Member States with investments in both years, Finland and the UK. In 2018, the by far largest investments in biomass capacity could be observed in the UK. In total €775 million were invested in that year. These investments are a dramatic increase compared to the previous year, where €87 million were invested. The associated capacity of these investments is

## 2

*Share of different types of asset finance in the solid biomass sector in the EU in 2017 and 2018*

| | 2017 | | 2018 | |
|---|---|---|---|---|
| | Asset Finance - New Built (€ m) | Number of Projects | Asset Finance - New Built (€ m) | Number of Projects |
| Balance Sheet | 83.57% | 88.89% | 92.91% | 80.00% |
| Project Finance | 16.43% | 11.11% | 7.09% | 20.00% |
| Bond/Other | 0.00% | 0.00% | 0.00% | 0.00% |
| Total EU | 100.0% | 100.0% | 100.0% | 100.0% |

*Source: EurObserv'ER*

particularly large with 650 MW, as it includes the large retrofit plant. Next to the UK, Spain and Finland are the only other Member States where biomass power plants reached financial close in 2018. In both countries, one investment was recorded, respectively, with investment volumes of €64 million in Spain and €63 million in Finland. In contrast to Spain, Finland also saw one biomass investment of €91 million in 2017.

In addition to the UK and Finland, there are six additional Member States with one investment in 2017, respectively. The largest investment in 2017 could be observed in Denmark amounting to €163 million. Italy and Portugal were ranked second and third with investments of €121 million and €105 million, respectively. Finally, France, Croatia, and Sweden experienced relatively smaller biomass investments in 2017. ■

# 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.

Alpha Ventus





### WIND ONSHORE AND OFFSHORE INVESTMENT EXPENDITURES

Investments expenditures per MW of onshore wind capacity in the EU dropped by more than 2% from €1.37 million in 2017 to €1.34 million in 2018. In the analysed non-EU countries, however, the average investment costs dropped even stronger, namely by, on average, almost 11%. In 2017, investment expenditures per MW of onshore capacity were notably lower in the EU compared to its main trading partners, where, on average, €1.47 million spend per MW. In 2018, these costs dropped to €1.31 million, i.e. slightly below the costs in the EU. There is also quite a heterogeneous picture across the non-EU countries. Some countries, as Japan, have notably higher investment costs for onshore, while in China investment expenditures per MW are lower than in the EU. The United States have very similar costs to the EU.

With respect to offshore, investment expenditures per MW dropped in China, which is the only analysed non-EU country with more than one investment in both years, from €2.57 million to €2.44 million. In the EU, investment costs of offshore wind seem to be

**1**

*Wind Onshore Investment Expenditures (€ m per MW)*

| | 2017 | 2018 |
|---|---|---|
| Canada | 1.79 | 1.16 |
| China | 1.20 | 1.22 |
| India | 1.33 | 1.39 |
| Japan | 1.78 | 1.48 |
| Norway | 1.37 | 1.30 |
| Russian Federation | 1.57 | 1.42 |
| Turkey | 1.37 | 1.19 |
| United States | 1.34 | 1.33 |
| European Union | 1.37 | 1.34 |

*Source: EurObserv'ER*

**2**

*Wind Offshore Investment Expenditures (€ m per MW)*

| | 2017 | 2018 |
|---|---|---|
| China | 2.57 | 2.44 |
| Japan | n.a. | 3.39 |
| Norway | n.a. | 4.88 |
| European Union | 3.53 | 2.54 |

*Source: EurObserv'ER*

notably higher in 2017. In 2018, however, costs dropped to €2.54 million, which is only marginally above the costs in China.

### INVESTMENT EXPENDITURES FOR PV AND BIOMASS

In the EU solar PV sector, the investment costs of utility-scale plants dropped by almost 25%. Investment expenditures per MW of solar PV decreased from €1.06 million per MW in 2017 to only €0.80 million in 2018. 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 €0.94 million. In both years, investment costs for PV in the EU are below the average of the analysed non-EU economies and the EU investment cost advantage even increased in 2018. When looking at individual countries, India seems to have particularly low investments costs for PV.

In the EU biomass sector, the investment expenditures for one MW decreased from €3.12 million per MW in 2017 to €2.41 million in 2018. In 2017, the EU investment expenditures were higher than the average of the considered non-EU countries, which were €2.13 million per MW in that year. The main driver of the low costs in 2017 is China, where investment costs per MW of biomass capacity were significantly below €2 million. In contrast to the EU, however, costs increased in the analysed trading partners such that they were at almost the same level as in the EU in 2018, namely at €2.4 million per MW.

Overall, the analysis shows that 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, at least in 2018. For biomass, investment expenditures per MW seem to have been higher in the EU in 2017, but on a similar level to the analysed non-EU countries in 2018. Across all analysed sectors, investment expenditures decreased between 2017 and 2018 in the EU. ■

**3**

*Solar PV Investment Expenditures (€ m per MW)*

| | 2017 | 2018 |
|---|---|---|
| Canada | 1.11 | 0.81 |
| China | 1.08 | 0.85 |
| India | 0.93 | 0.74 |
| Japan | 1.48 | 1.02 |
| Russian Federation | 1.39 | 1.04 |
| Turkey | 1.07 | 1.25 |
| United States | 1.13 | 0.83 |
| European Union | 1.06 | 0.80 |

*Source: EurObserv'ER*

**4**

*Biomass Investment Expenditures (€ m per MW)*

| | 2017 | 2018 |
|---|---|---|
| China | 1.39 | n.a. |
| Japan | 2.54 | 2.45 |
| Turkey | n.a. | 2.36 |
| United States | 2.47 | n.a. |
| European Union | 3.12 | 2.41 |

*Source: EurObserv'ER*

SWM - Thomas Einberger

# 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 2017 and/or 2018 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 Slovak Energy Efficiency and Renewable Energy Finance Facility (SLOVSEFF III), where investments in residential and, in particular, industrial energy efficiency are also core focus areas of the facility.

## 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 National Fund for Environmental Protection and Water Management (NFEPWM). 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[1]) 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. An example is the Danish programme under the Promotion of Renewable Energy Act, where Energienet.dk can offer loan guarantees for wind turbine owners associations or other local initiative groups for wind-energy plants.

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 SLOVSEFF III that offers loans to SMEs for investments in renewable energy and residential and industrial energy efficiency. SLOVSEFF III, 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 Renewable Energies Programme, e.g., provides loans up to €50 million. In contrast, the Polish programme PROSUMER focuses on micro-installations, e.g. small RES electricity installations of up to 40kWe. Overall, a wide variety of financing schemes, used instruments, and focused final borrowers can be observed in the EU. Next to such programmes addressing investment in RES capacity, there are also instruments dedicated to financing RES innovation, as the loans to start-up energy companies offered by the Swedish Energy Agency.

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. 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. PolSEFF - Polish Sustainable Energy Financing Facility*

# 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 |
| Renewable Energy Programme – Storage | Kreditanstalt für Wiederaufbau (KfW) | Germany | 2013 | Small photovoltaic battery storage systems | Low-interest loans |
| 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, | Direct loans of KfW in the framework of bank consortia for offshore wind |
| Climate Change Special Programme | Environmental Project Management Agency | Lithuania | 2010 | Multiple RES (and other climate related activities) | Loans and subsidies |
| 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 | National Fund for Environmental Protection and Water Management (NFEPWM) | 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 (PolSEFF²) | 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 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 that VC deals. 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 2017, e.g., the firms are weighted by their 2016 revenues whereas in 2018, the 2017 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

Between 2017 and 2018, total venture capital (VC) and private equity (PE) investments in renewable energy companies increased by 49%. In 2018, total VC/PE investments in the EU amounted to € 2.4 billion compared to € 1.6 billion in 2017. Thus, the development of VC/PE investments in the RES sectors surpasses the overall positive trend in VC/PE investments in the EU. According to the data of Invest Europe, overall EU-wide VC/PE investments (covering all sectors) increased by around 7%.

## 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 disaggregation shows that the largest volumes are associated with PE Buy-outs and corporate spin-offs. This is not RES specific, but can be observed across all other sectors as well. The share of PE Buy-outs in total VC/PE investments for RES is almost identical in both years with 86% in 2017 and 87% in 2018. A similar pattern can also be observed for overall VC/PE investments as reported by Invest Europe, where the share of PE Buy-outs is 71% in 2017 and 73% in 2018. The large increase of overall RES VC/PE investments was mainly driven by a substantial increase in PE Buy-out volumes, which increased from €1.4 billion in 2017 to almost €2.1 billion in 2018. PE Expansion Capital investment increased even stronger between both years, namely from only €21 million in 2017 to €321 million in 2018. Overall, this indicates that notably more young RES firms in the EU survived the difficult early stages of a venture and reached a stage, where they are trying to fully enter the market.

In contrast to the high increases in PE investments, VC investments fell notably between the two years. In 2018 only €11 million were invested compared to €188 million in the previous year. Similarly, the number of VC deals dropped form 23 in 2017 to only 3 in 2018. The reduction in investments is particularly dramatic for late stage VC, where investments dropped from €141 million to only €0.25 million in 2018. Early stage VC investments totalled €10 million in 2018 compared to €47 million in 2017.

## HIGHEST VC/PE INVESTMENTS IN SOLAR PV

When taking a more detailed look at the respective RES 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.

The highest VC/PE investments in both years can be observed in the solar PV sector. In 2017, VC/PE investments amounted to already very high €1.03 billion. In the subsequent year, however, they even increased further to €1.59 billion. The relatively high investments in the solar PV sector are largely driven by very large PE Buy-outs, in particular in 2018, where 9 out of 11 deals are PE buy-outs. This fits to the observation that the number of deals actually decreased between the two years in spite of the large increase in investment volumes.

After a decline in VC/PE investments in the wind sector between 2016 and 2017, investments increased again in 2018. Investments more than doubled from €277 million in 2017 to €554 million in 2018. This increase in investments is driven by PE Buy-outs as well as PE Expansion Capital. As for Solar PV, VC investments in the wind sector declined in the wind sector.

The only other sectors that experienced VC/PE investments in both years are biogas, biomass, and waste. In contrast to wind and solar PV, VC/PE investments decreased in those sectors from €309 million in 2017 to €203 million in 2018. Hence, biogas, biomass, and waste lost the second rank in VC/PE to solar PV in 2018. In 2018, there was one PE Buy-out deal in the geothermal sector amounting to almost €52 million. Finally, only in 2017 VC/PE investment for small hydro was recorded, namely an early-stage VC investment of €1.42 million. ■

**1**

*Venture Capital and Private Equity Investment in Renewable Energy per Technology in the EU in 2017 and 2018*

| | 2017 | | 2018 | |
|---|---|---|---|---|
| | Venture Capital / Private Equity (€ m) | Number of Projects | Venture Capital / Private Equity (€ m) | Number of Projects |
| Biogas. Biomass & Waste | 308.09 | 12 | 203.45 | 6 |
| Geothermal | 0.00 | 0 | 52.29 | 1 |
| Solar | 1 031.01 | 14 | 1 588.84 | 11 |
| Wind | 266.95 | 6 | 554.45 | 6 |
| Small Hydro | 1.42 | 1 | 0.00 | 0 |
| Total EU 28 | 1 607.46 | 33 | 2 399.03 | 24 |

*Source: EurObserv'ER*

**2**

*Venture Capital and Private Equity Investment in Renewable Energy per Investment Stage in the EU in 2017 and 2018*

| | 2017 | | 2018 | |
|---|---|---|---|---|
| | Venture Capital / Private Equity (€ m) | Number of Projects | Venture Capital / Private Equity (€ m) | Number of Projects |
| VC Early Stage | 47.44 | 15 | 10.43 | 2 |
| VC Late Stage | 141.01 | 8 | 0.25 | 1 |
| PE Expansion Capital | 21.45 | 2 | 320.85 | 5 |
| PE Buy-out | 1 397.57 | 8 | 2 067.49 | 16 |
| Total EU 28 | 1 607.46 | 33 | 2 399.03 | 24 |

*Source: EurObserv'ER*

# 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 former 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 of the active on several of these sectors, which would make an allocation of firms to only one specific sector almost impossible.

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

Some firms in the indices were replaced in this edition, as the indices always contain the ten largest firms in a sector with respect to revenues. As the indices cover all years since the base date, the constellation of firms changes between years. All firms included in the indices in specific years are listed in detail in the footer of this section. A notable change compared to last edition is the removal of Solarworld AG in the year 2018, which was the second largest company in the Solar Index before that year. As a replacement, Photon Energy N.V. was added to the index. In the Wind Index, Arise AB was replaced by Futuren SA due to their revenues in 2017. The composition of the Bio-Energy Index did not change in 2018. The by far largest company in the Solar Index is SMA Solar Technology AG, in particular after the Solarworld dropped out, while the Wind Index is rather dominated by Vestas and Siemens Gamesa.

## MOST RES SECTORS RELATIVELY STABLE IN 2018

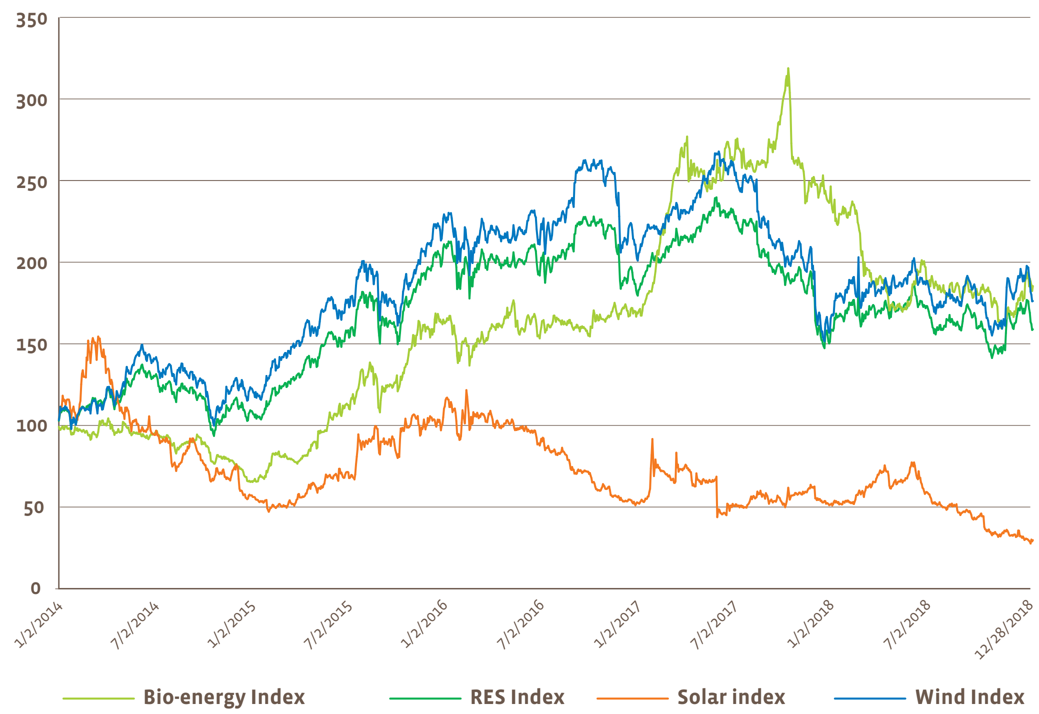
Listed Wind, Solar, and Bio-Energy firms performed quite differentially in 2017 and, in particular, 2018. In contrast to the other two indices, the Solar Index remains relatively stable on one level in 2017. At the end of the year it closes at almost the identical value as at the beginning of that year, namely at a level of around 50 points. 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. In 2018, Solarworld was replaced in the Solar Index as indicated above. In the second half of 2018, the overall performance of EU solar firms on stock markets further declined and the Solar Index closes at 30 points at the end of 2018, i.e. the lowest value since the beginning of 2014.

The Wind Index experienced high growth followed by an even stronger decline in 2017. Up into the second quarter of that year the index grew to almost 268 points. Afterwards, however, listed firms in the wind sector experienced a noticeable decline in their performance on stock markets, in particular at the beginning of the third quarter in 2017. The Wind Index closes at below its value at the beginning of that year at 179 points. In 2018, the Wind Index shows substantially different development compared to the other two RES indices, as it closes at almost the identical value as at the beginning of that year. Within 2018, however, there are some fluctuations, in particular at the beginning of the third quarter of that year.




**1**

*Evolution of the RES indices from 2014 to 2018*




Bio-Energy firms experienced a very good year 2017. In particular in the beginning of that year, the Bio-Energy Index grew substantially from around 180 points at the start of 2017 to more than 270 points at the end of the first quarter. At the end of the year, the index closed substantially above its starting value of the year at almost 230 points. In 2018, however, the trend in the sector reversed. In particular in the first quarter of 2018, the Bio-Energy Index dropped significantly to, at times, values below 170 points. Throughout the rest of the year, however, the development stabilised and the index ended at 185 points, which is, however, still notably below its 2018 starting point.

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 more than 85% of the aggregate revenues generated by all RES firms in the indices – the Wind Index dominates the aggregate RES Index.

The overall economic development in the EU, captured by the EURO STOXX 50, experienced a rather negative trend in 2018 after a positive trend in 2017. In 2017, the Bio-Energy sector outperforms the overall good state of the economy in the EU, while the Solar Index, and in particular, the Wind Index show a relatively weaker picture. In 2018, the developments of the Solar and the Bio-Energy Indices are similar to the rest of the economy. 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

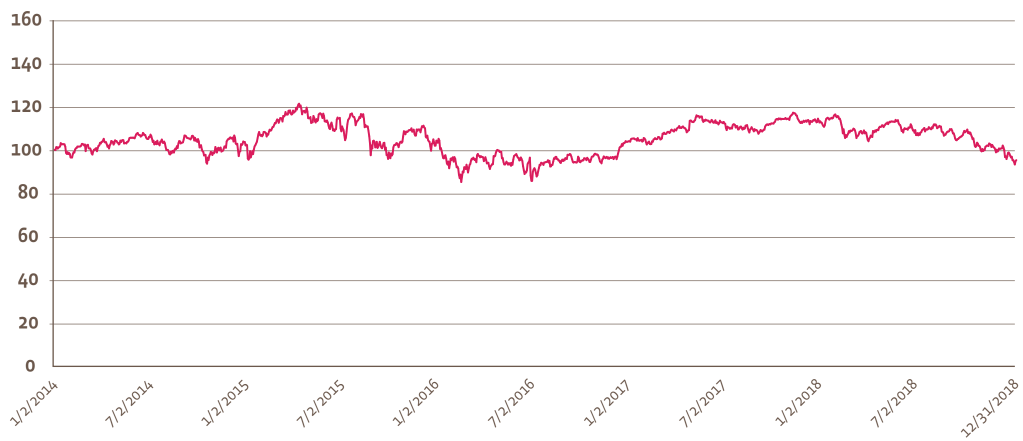
YieldCos are own cash-generating infrastructure assets offered on public markets. These assets are RES plants with typically long-term energy delivery contracts with customers. The YieldCo concept is based on risk profile splitting, where the derisked operational projects are bundled in a separate company 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 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 2018. In fact, the number of listed YieldCos goes down in 2018 due to a takeover of Saeta Yield by TerraForm Power. As in 2017, the stock prices of all UK based YieldCos develop quite similarly in 2018 and remain at a relatively stable level throughout the year. In contrast, the German YieldCo experienced a rather negative year 2018. After an increase in its stock price at the end of 2017, it dropped to 158 points at the end of 2018, which is, however, still notably above all other EU YieldCos.

Given the relatively stable number of YieldCos, it seems rather unlikely that the development of the EU YieldCo market will take up speed soon. YieldCos can provide attractive yields to investors. Due to reductions in overall support mechanisms as feed-in tariffs, however, these yields are likely to go down. This might be an explanation why many of the largest utilities are still reluctant to create YieldCos. ■

**2**

*Evolution of the Euro STOXX 50 index from 2014 to 2018*

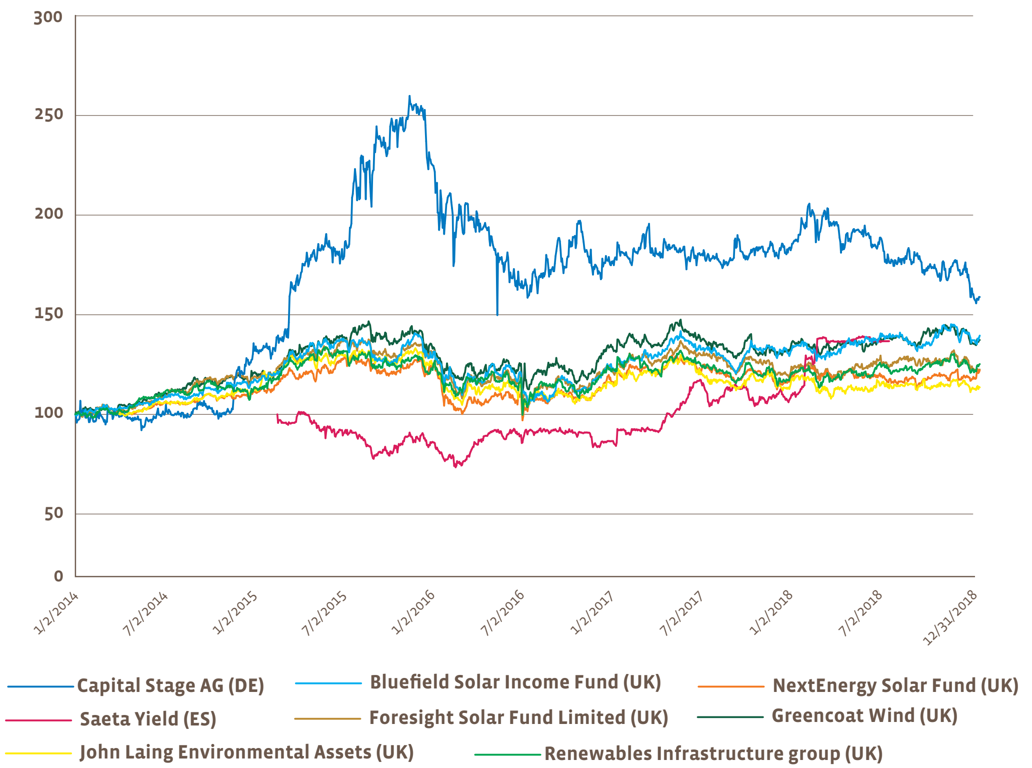







**3**

*Evolution of EU YieldCos from 2014 to 2018*




***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, 2018), Enel Green Power (IT, 2014-2015), Good Energy (UK, 2016-2018), Arise (SE, 2017)*

***Photovoltaic Index:*** *SMA Solar Technology (DE), Solarworld (DE, 2014-2017), Ternienergia (IT), Centrotherm Photovoltaics (DE), Enertronica (IT), PV Crystalox Solar (UK), Solaria Energia (ES), Etrion (SE),7C Solarparken (DE, 2015-2018), E4U (CZ, 2015-2018), Auhua Clean Energy (UK, 2014), Solar-Fabrik (DE, 2014), Photon Energy (NL, 2018)*

***Bio-Technologies Index:*** *Cropenergies (DE), Verbio Bioenergie (DE), Albioma (FR), Envitec Biogas (DE), 2G Energy (DE),Cogra (FR), Europlasma (FR), EBIOSS Energy (BG, 2017-2018), Global Bioenergies (FR, 2017-2018), Fluid (PL, 2017-2018), KTG Energie (DE, 2104-2016), Active Energy (UK, 2104-2016), BDI-BioEnergy International (DE, 2104-2016)*

# 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 increased notably between 2017 and 2018. Investments totalled almost €27 billion in 2017 compared to €31.5 billion in 2018.

Not surprisingly, the by far highest investments could be observed in the wind sector as in previous years. Total investments in wind capacity went up by 4.5% from €23.3 billion in 2017 to €24.3 billion in 2018. The increase in total wind investments was mainly driven by offshore wind, where investments increased by 17% from €8.67 billion to €10.1 billion. Thus, the share of offshore was almost 42% in 2018 and 37% in 2017.

After a continuous downward trend in solar PV investments in the last years and a stabilisation of investments in 2017, a large increase in investments could be observed in 2018. Investments in utility-scale PV (>1 MW) doubled from €2.35 billion in 2017 to €4.76 billion in 2018. The by far largest investments in utility-size PV in 2018 could be observed in Spain. Similar to investments in utility-scale PV, small-scale PV investments also increased from almost €4.1 billion in 2017 to €6.2 billion in 2018.

After a large slump of investments in 2017 compared to the previous year, investments into biomass power plants increased again in 2018. In 2018 biomass investments totalled €902 million, which corresponds to an increase by 41% compared to the €638 million in 2017.

For a second time in a row, investments in geothermal capacity increased in the EU, namely from €133 million in 2017 to almost €300 million in 2018.

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. Overall, the analysis shows that 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, at least in 2018. Investments expenditures per MW of onshore wind capacity in the EU dropped by more than 2% from €1.37 million in 2017 to €1.34 million in 2018. In the EU solar PV sector, the investment costs dropped by almost 25% from €1.06 million per MW to only €0.80 million. For biomass, investment expenditures per MW seem to have been higher in the EU in 2017, but on a similar level to the analysed non-EU countries in 2018.

Pixabay

## VENTURE CAPITAL & PRIVATE EQUITY

Between 2017 and 2018, total venture capital (VC) and private equity (PE) investments in renewable energy companies increased by 49%. In 2018, total VC/PE investments in the EU amounted to €2.4 billion compared to €1.6 billion in 2017. The development of VC/PE investments in the RES sectors surpasses the overall positive trend in VC/PE investments in the EU. According to the data of Invest Europe, overall EU-wide VC/PE investments (covering all sectors) increased by around 7%.

The overall increase in VC/PE investments was driven by high increases in PE investments, while VC investments declined notably between the two years. When taking a more detailed look at the respective RES technologies, the highest VC/PE investments in both years can be observed in the solar PV sector, namely €1.03 billion in 2017 and even €1.59 billion in 2018. The second largest sector is wind, where, after a decline in VC/PE investments between 2016 and 2017, investments increased again in 2018 to €554 million.

## PERFORMANCE OF RES TECHNOLOGY FIRMS AND ASSETS ON PUBLIC MARKETS

In order to capture the performance of RES companies, i.e. companies that develop / produce the RES technology, EurObserv'ER presents indices based on RES company stocks. 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, a Wind, a Solar, and a composite Bio-Energy Index are constructed consisting of 10 firms that are (almost) entirely active in the respective RES sectors. Listed Wind, Solar, and Bio-Energy firms performed quite differentially in 2017 and, in particular, 2018. In 2017, the Solar Index remains relatively stable on one level. In the second half of 2018, the overall performance of EU solar firms on stock markets declined and the Solar Index closes at the lowest value since the beginning of 2014. 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 2018, however, the trend in the sector reversed. After a significant drop in the first quarter of 2018, the Bio-Energy Index stabilised, but still closed notably below its 2018 starting point. 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 2017, the Bio-Energy sector outperforms the overall good state of the economy in the EU, while the Solar Index, and in particular, the Wind Index show a relatively weaker picture. In 2018, the developments of the Solar and the Bio-Energy Indices are similar to the rest of the economy, while the listed wind firms seem to perform better.

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. Given the relatively stable number of YieldCos, it seems rather unlikely that the development of the EU YieldCo market will take up speed soon. ■

# RENEWABLE ENERGY COSTS, REFERENCE PRICES AND COMPETITIVENESS

**In the previous releases of 'The State of Renewable Energy in Europe', competition between renewable energy sources and energy from conventional sources has been illustrated for the years 2005, 2010 and 2017. In this edition we add 2018 LCoE estimates to the series. The approximate historic costs in this chapter (for 2005 and 2010) have not been updated compared to the previous edition, except for heat from solar thermal water heaters.**
**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. There are a few uncertainties though: 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 (wind, geothermal, solar PV an solar thermal) 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 averagely 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 average 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. The assumed price increase for the conventional energy carriers, relative to the previous edition, is +3% (for conventional electricity), +7% (for conventional heat) and +10% for transport fuels (all without taxes and levies).

## 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, solar PV (commercial and residential), solar thermal water heaters, concentrating solar power and wind energy (both onshore and offshore).

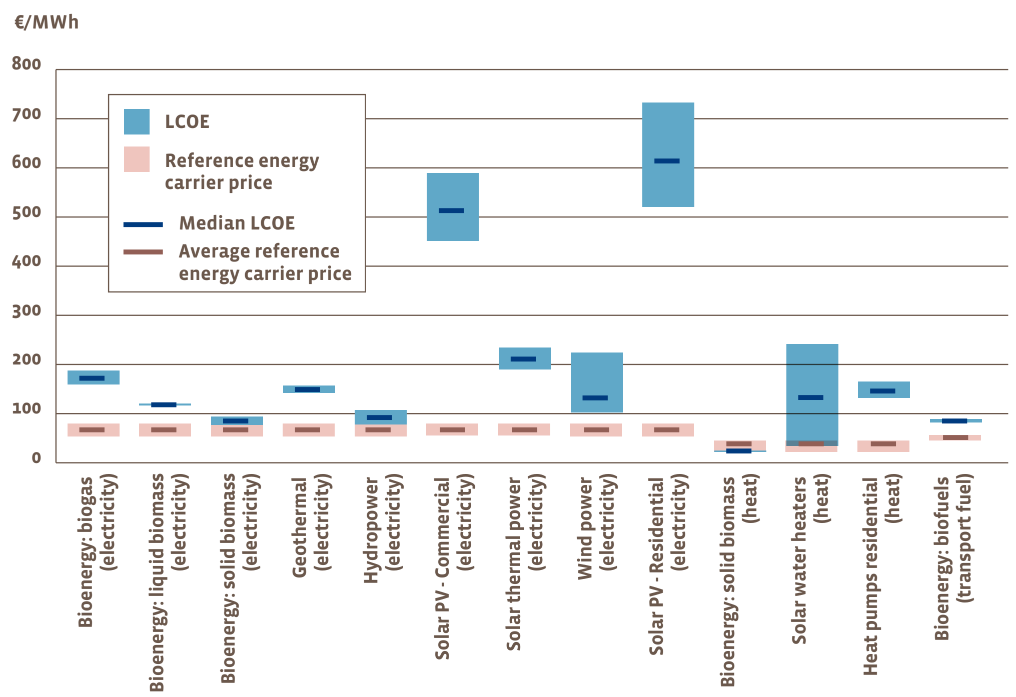
## TECHNOLOGY DATA UPDATES

This 2019 Edition of the 'The State of Renewable Energies in Europe' includes a major update for the levelized cost of energy for solar thermal water heaters. The technology is characterised by differences in system layouts for regions with high solar irradiation versus regions with worse conditions, typically systems in southern Europe versus central and northern Europe, and consequently in the resulting cost range. In previous editions of the Barometers the data range was inaccurately assessed in a post-processing step, reason for which the prices that were displayed were higher than our calculations showed. The original data have been crosschecked and were found to be in line with estimates as reported in the 'Strategic Research Priorities for Solar Thermal Technology' by the European Technology Platform on Renewable Heating and Cooling (2012). The corrected data have now been entered as a range covering all system variants, ranging from systems for hot sanitary water (thermosiphon systems and forced circulation systems) to combi systems for space and water heating, industrial heat and solar thermal in district heating). These costs have been used for all target years (2005, 2010 and 2018). For multiple other technologies, cost decreases are reported: wind power, solar PV, geothermal power. Cost assumptions for heat pumps



**1**

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




*Source: EurObserv'ER 2019*

and hydropower were not updated compared the previous edition. The biomass-based technologies were unchanged compared to the 2018 edition of 'The State of Renewable Energies in Europe'.

## COST-COMPETITIVENESS OF RENEWABLE ENERGY TECHNOLOGIES

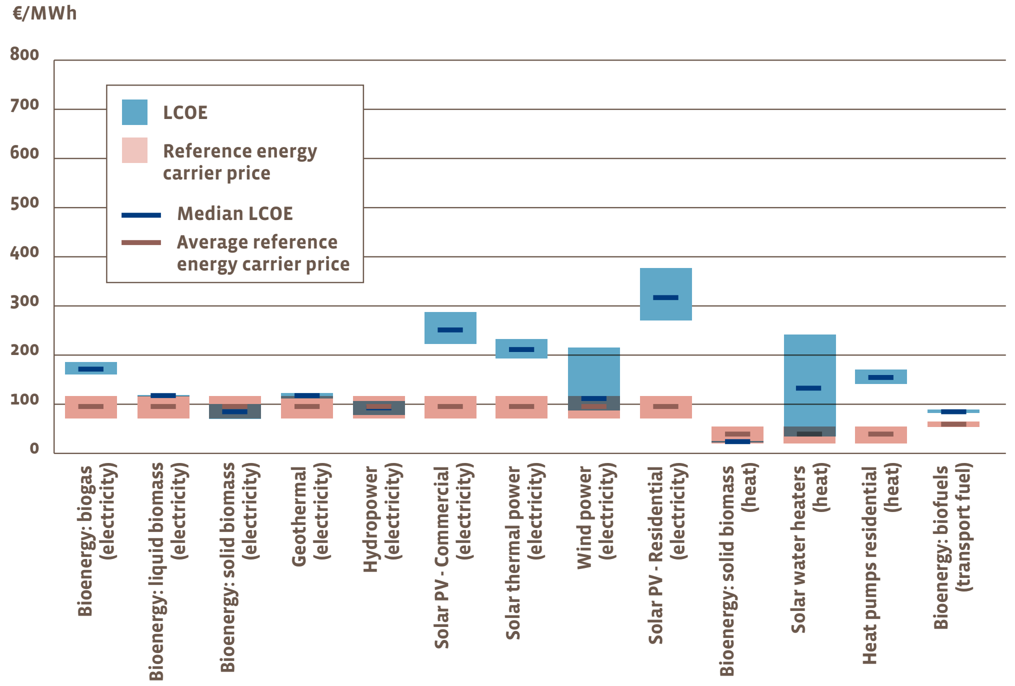
Cost-competitiveness of renewable energy technologies varies per technology per Member State and changes because of differences in reference energy prices in Member States. Mature technologies such as hydropower and solid biomass can provide, in principle, low-cost power that is comparable to the reference 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. Also solar thermal energy is competitive in countries with high energy costs or a generous solar yield.

## 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, except solar thermal water heaters, 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.

## 2

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




***Source: EurObserv'ER 2019***

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 – 2018, 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 fossil energy to heat, no investment or maintenance costs are considered). Where data were missing, average EU-data were used. The 2008 reference price ranges are based on the price ranges for 2017, adapted for the observed average EU price development according to Eurostat and the European Commission's Oil Bulletin: +3% for electricity, + 7 for natural gas and +10% for transport fuel (all excluding taxes and levies).

### Renewable electricity

Whereas especially the costs of electricity from wind power and solar PV have strongly come down compared to the 2005 estimates, the difference from the 2018 price ranges compared to 2017 is estimated to be moderate. Note that for individual renewable projects cost reductions may be sharper (or less) 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.

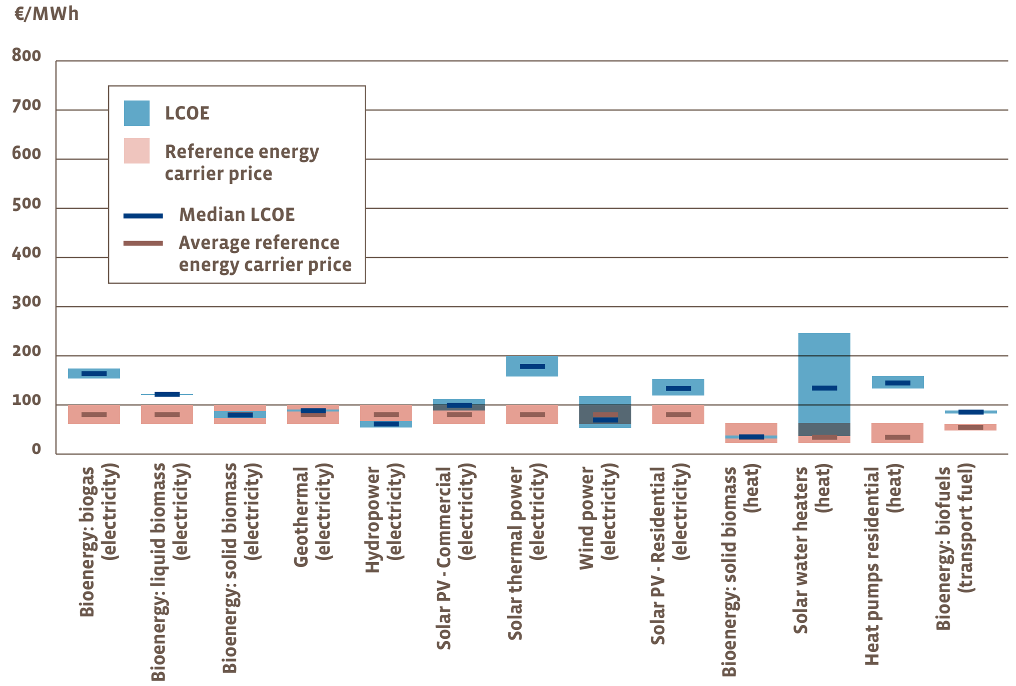
Both solar PV variants are assumed to have realised important cost reductions compared to 2005, making this technology more and more competitive. In the residential





## 3

*LCoE and reference energy carrier (€/MWh) EU ranges derived from Member State analysis for 2018*




***Source: EurObserv'ER 2019***

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.

### 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 same is true for solar water heaters, but not in all countries of the European Union. According to the analysis, heat captured from ambient heat via heat pumps (through small-scale equipment) shows relatively high LCoE levels. 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. ■

*Note to the figure: Overview of the LCoE assessment on a European Union level; ranges derived 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 2018 (monetary values of LCoE are defined in EUR2015) while reference energy prices 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. These are estimated as follows: 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 2019 - Recent growth and knock-on effects*', (EEA 2019). 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 as input for the analysis.**

**The avoided fossil fuel costs are based on the country specific fuel prices derived from multiple sources (Eurostat, European Commission). The figure 1 highlights the fuel price ranges observed in the 28 EU Member States for 2017 and 2018 for five energy carriers: coal, diesel, gasoline, natural gas and oil. Prices for coal and natural gas refer to wholesale prices. From transport and heating fuels wholesale prices aren't available, therefore end-user prices are applied as a proxy. These five fuels are assumed to reasonably cover the fuels reported in (EEA, 2019). 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 2018 are higher than the prices in 2017. Coal and natural gas are relatively low as these refer to wholesale prices, whereas the other energy carrier prices were derived from end-user prices. Observed fuel prices for diesel, gasoline and fuel oil differ widely across member states and along the year.**



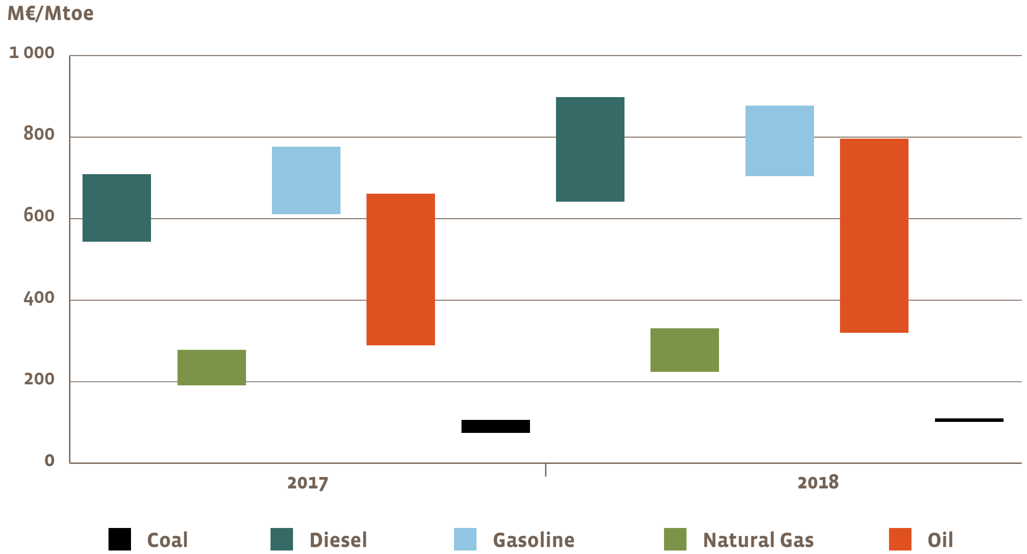


### *Methodological note*

- *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. Moreover, we do not differentiate caloric values of the fuels to their origin or quality.*
- *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 normalised values 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 2018 estimates are proxies, borrowed from EEA (2019).*

**1**

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

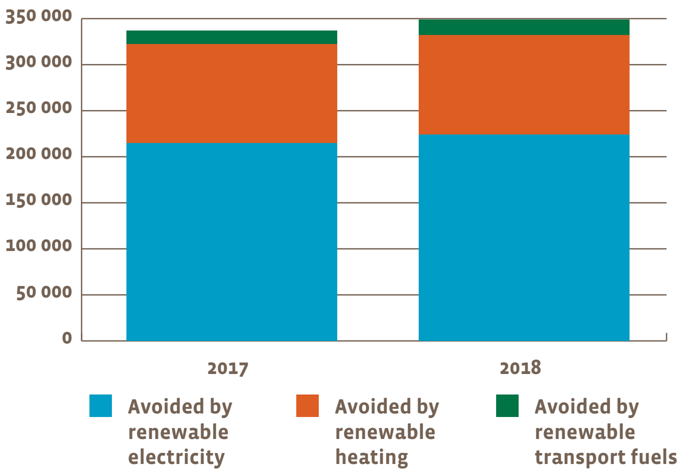



*Source: Eurostat, European Commission (2020)*

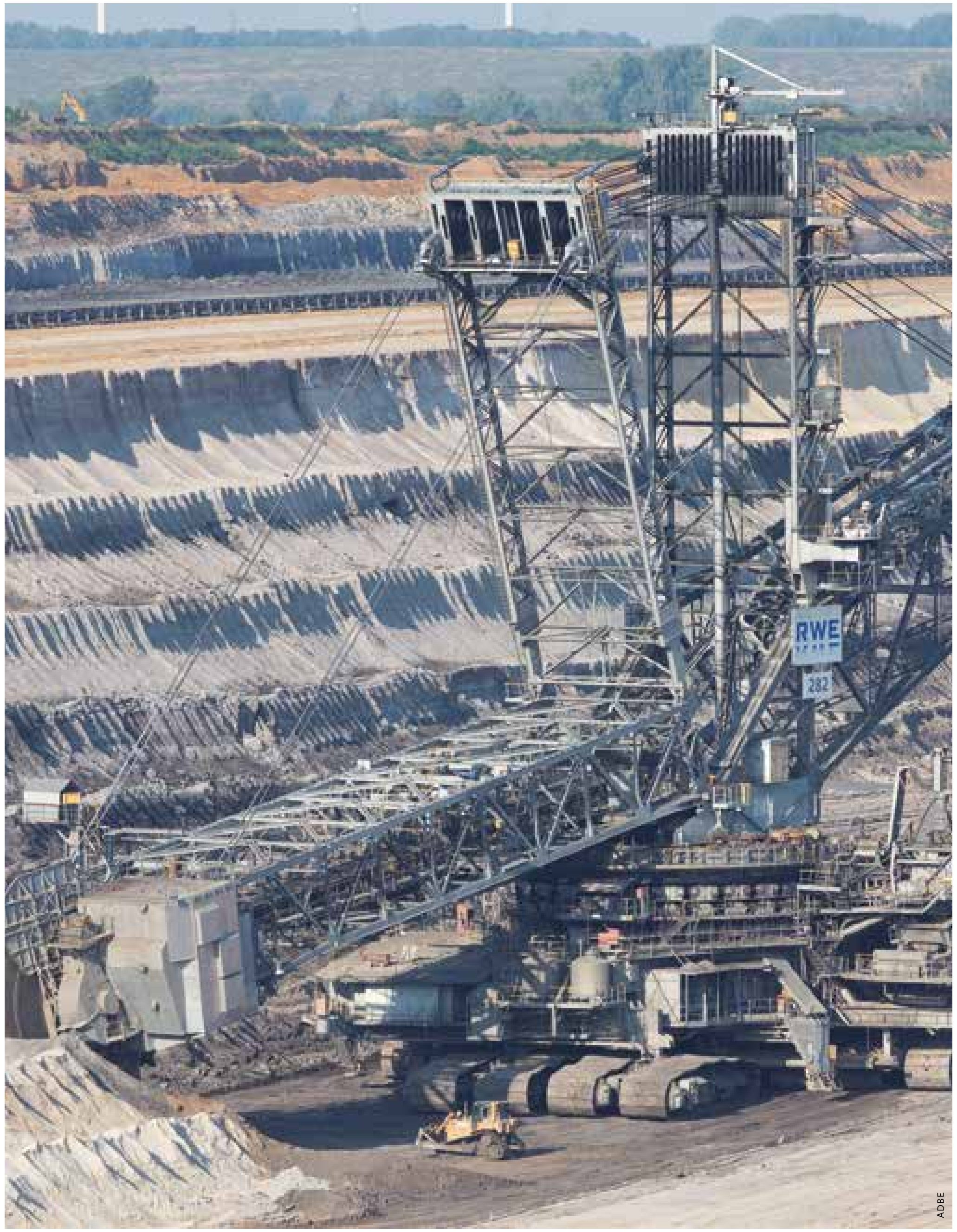
In 2017 and 2018 renewable energy substituted around 329.9 Mtoe and 351.3 Mtoe of fossil fuels respectively. These figures correspond to an avoided annual cost of EUR 89.0 billion for EU28 collectively in 2017, increasing to EUR 110.4 billion in 2018. The largest financial contributions derive from renewable electricity and renewable heat (representing about 90% of the avoided expenses).

**2**

*Avoided fossil fuels per sector (ktoe)*




*Source: EurObserv'ER based on EEA data*

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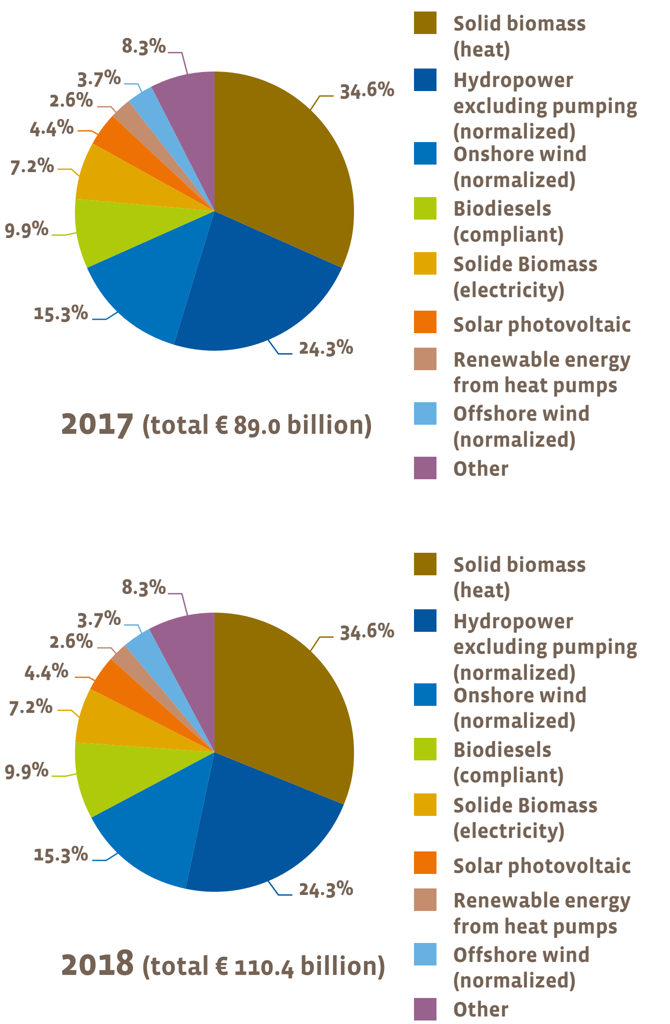
## AVOIDED FOSSIL FUEL USE & AVOIDED COSTS PER TECHNOLOGY

The use of renewable electricity contributed to 52% of the total avoided fossil fuels (in terms of energy; the share is equal for 2017 and 2018). This is followed by renewables in the heating and cooling sector contributing to more than 35% (both years) of the total avoided fossil fuels and the remaining share was substituted through renewable transport fuels (around 11% in both years, only fuels compliant with Directive 2009/28/EC are included). In monetary terms, the avoided costs were EUR 47.0 billion in 2017 and EUR 57.8 billion in 2018 in the electricity sector. Second, renewable heat contributed to avoided costs reaching to EUR 32.8 billion in 2017. In 2018 this increased to EUR 40.0 billion. Third is renewable transport fuels which contributed to avoided costs of EUR 9.2 billion in 2017 and EUR 12.4 billion in 2018. 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 6.5% from 2017 to 2018, the cumulative effect of the avoided fossil fuel expenses is, with a 24% increase (from EUR 89.0 billion to EUR 110.4 billion) more pronounced. Reason for this is the increasing fossil fuel prices in 2018 compared to 2017.

**3**

*Avoided expenses in fossil fuels in EU 28 through renewables in 2017 and 2018*




*Source: EurObserv'ER based on EEA data*

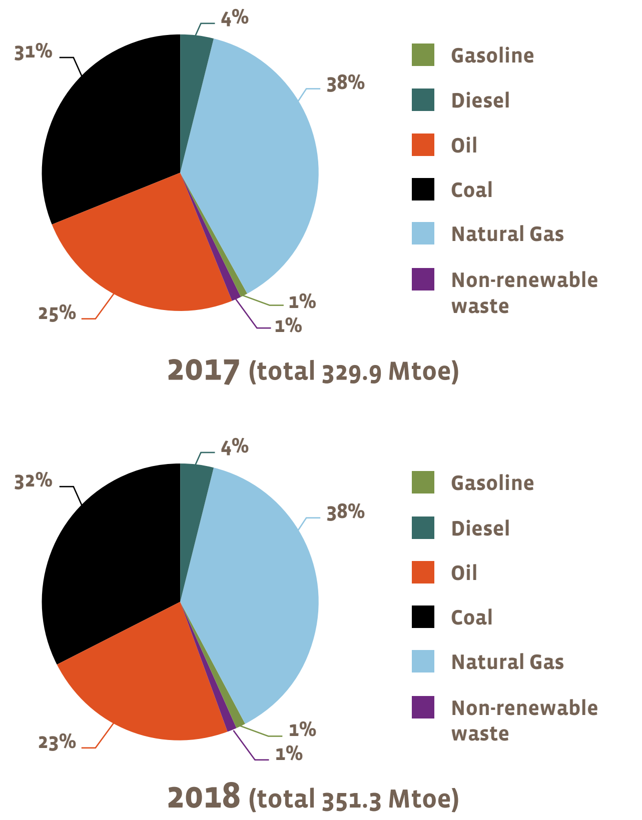
Among the RES technologies, solid biomass for heating purposes avoided the purchase of fossil fuels at an amount of EUR 34.6 billion in 2018 (EUR 28.4 billion in 2017). Next, hydropower has been responsible for EUR 24.3 billion in 2018 (EUR 20.4 billion in 2017, both for normalised production). Onshore wind is third in the row with EUR 15.3 billion in 2018 (EUR 12.1 billion in 2017, both for normalised production).

In a graphical manner, the graph and the pie charts below show how each technology contributes to the total avoided costs.

The largest share of avoided fossil fuels comes from natural gas (38% for both 2017 and 2018), followed by solid fuels (mainly coal, 31% for 2017 and 32% for 2018). Next are oil products, with a contribution of 25% in 2017 and 23% in 2018. The remaining fuels (transport fuels and non-renewable waste) cover the remaining share (around 5% in both years).

**4**

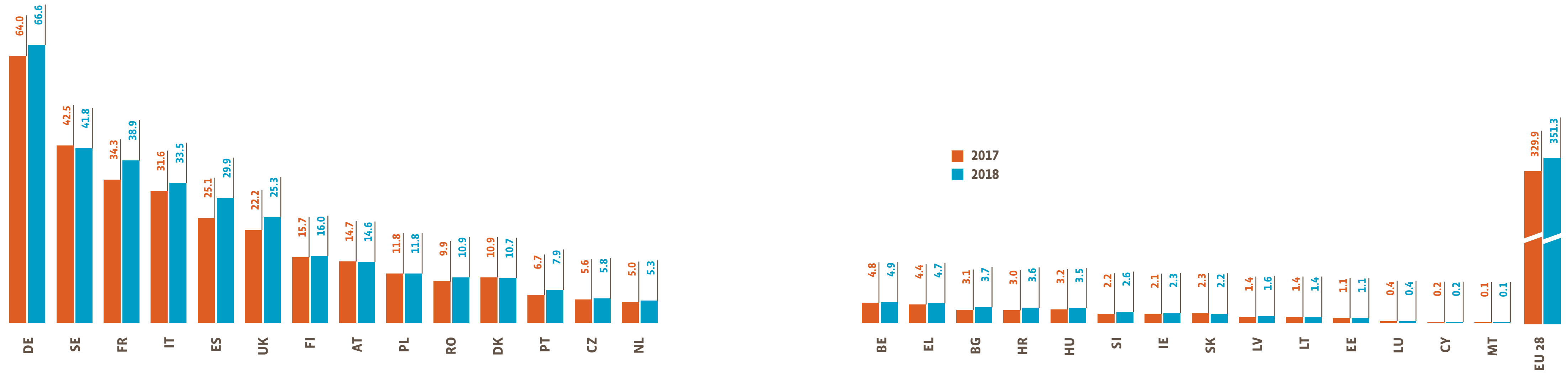
*EU substituted fossil fuels during 2017 and 2018*




*Source: EurObserv'ER based on EEA data*

## 5

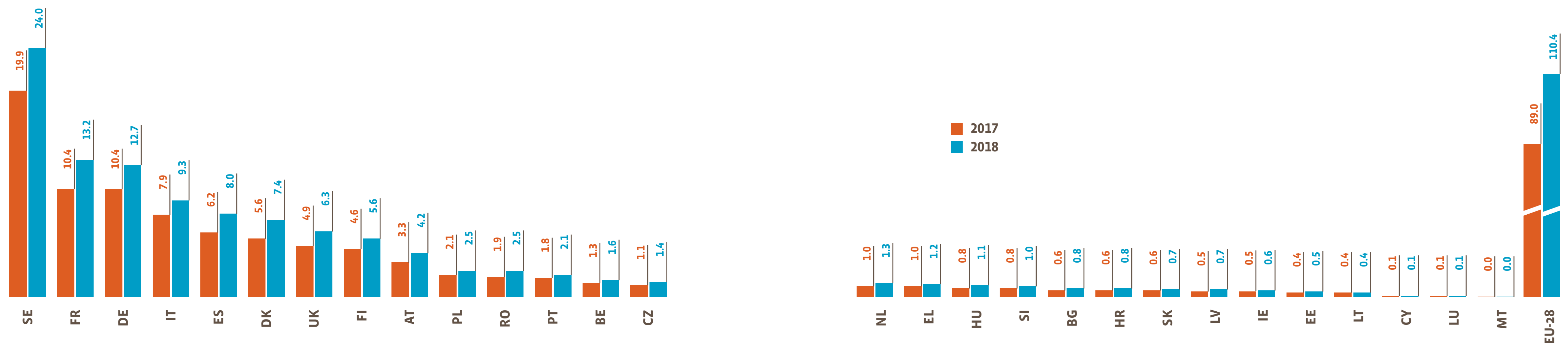
*Avoided fossil fuels per country [Mtoe]*




*Source: EurObserv'ER (2019) based on EEA data. Note: For 2018 proxy data are used.*

## 6

*Avoided expenses in fossil fuels per country [billion euro]*




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

## AVOIDED FOSSIL FUELS & EXPENSES PER MEMBER STATE

At Member State level, the amount of avoided fossil fuels and the avoided costs have been estimated as displayed in Figure 5. Note that there is a strong correlation between the avoided amount and the size of a country.

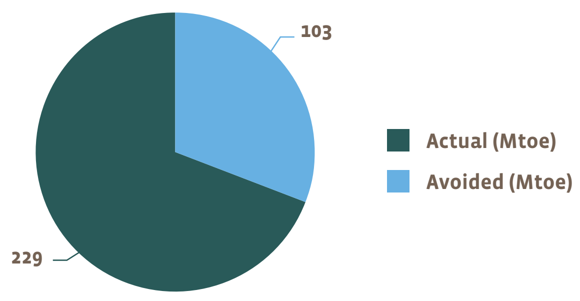
As can be expected, the avoided cost follow the fuel price development: with fossil fuel prices higher in 2018 compared to 2017, all counties show a similar pattern.

An interesting outcome is the estimate for Sweden, where renewables in absolute terms displace fewer fossil fuels in 2018 compared to 2017, at a higher cumulative amount of avoided expenses. The reason in this special case is that growth of biogenic transport fuels displaces expensive fuels, such as diesel and gasoline.

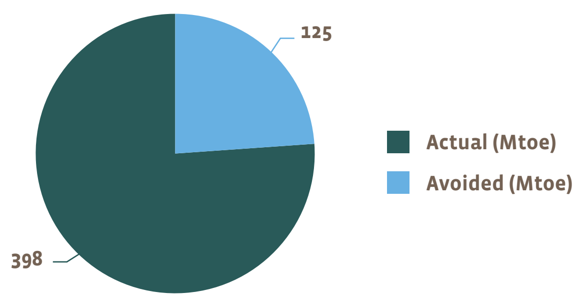
Next, the figures at the right indicate how the amounts of estimated avoided fuel relate to the total EU 28 fuel use. The relevant parameter for comparing the avoided fuel use with is the primary energy consumption, which indicates the gross inland consumption excluding all non-energy use of energy carriers (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 2017, because this period regards final data (and not estimates). ■

**7**

*Contributions per fuel 2017 compared to total*




Gross inland coal consumption in 2017

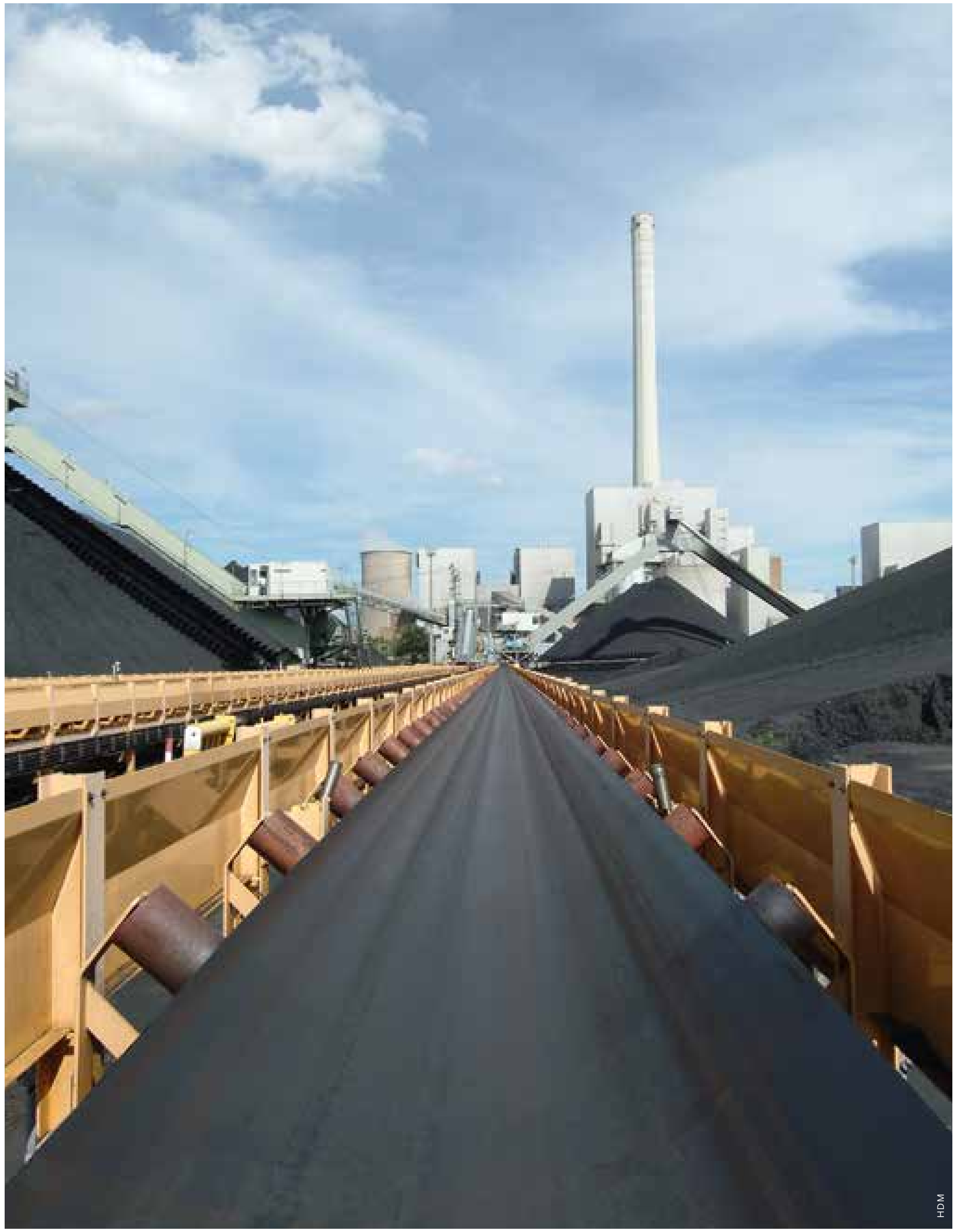



Gross inland gas consumption in 2018

*Source: Eurostat 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. A wiser energy use is both, a spur for new jobs and growth as well as an investment in the future of Europe as stated by the European Commission. This understanding is also underpinned by economic theory, which sees expenditures for research and development as investments into new or better processes, products or services that might create new markets or in-crease market shares and strengthen competitiveness of firms, sectors and nations.

Regarding RET, R&D investments spur RET innovations, 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, on the other hand can be 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 invest-ments 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.



EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2019 EDITION

# R&D Investments

*Investments into R&D and innovation are commonly seen as the basis for technological changes and hence competitiveness. Consequently, 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, which 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 per-formed by both, business (private), government and higher education sector (public). This differentiation into financing (grey area) and performing (white area) is depicted in grey 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. 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[1], 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 availa-ble for 2017, while only a few are available in 2018. For the data on private R&D, the time delay is even longer (2014 and 2015) as JRC's assessment is based on patent data. The methodolo-gy 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".[2] 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.*

**1**

*Sectors by financing and performing of R&D*

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

*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 2014 and 2015.*

PUBLIC R&D INVESTMENTS

# WIND ENERGY

| | | Public R&D Exp. (in € m) | | Share of Public R&D Exp. by GDP | |
|---|---|---|---|---|---|
| | | 2017 | 2018 | 2017 | 2018 |
| EU 28 | Germany | 75.1 | 59.7 | 0.0026% | 0.0020% |
| | UK | 30.0 | 35.7 | 0.0014% | 0.0017% |
| | Denmark | 18.1 | 32.0 | 0.0066% | 0.0116% |
| | Finland | 17.6 | n.a. | 0.0089% | n.a. |
| | Netherlands | 15.8 | 37.0 | 0.0023% | 0.0052% |
| | Spain | 9.1 | n.a. | 0.0008% | n.a. |
| | France | 6.2 | 6.6 | 0.0003% | 0.0003% |
| | Belgium | 6.2 | n.a. | 0.0016% | n.a. |
| | Poland | 3.4 | 1.7 | 0.0007% | 0.0004% |
| | Italy | 1.7 | 1.8 | 0.0001% | 0.0001% |
| | Sweden | 1.6 | 2.2 | 0.0004% | 0.0005% |
| | Austria | 0.3 | 0.5 | 0.0001% | 0.0002% |
| | Romania | 0.2 | n.a. | 0.0001% | n.a. |
| | Ireland | 0.1 | 0.4 | 0.0000% | 0.0001% |
| | Malta | 0.0 | n.a. | 0.0000% | n.a. |
| | Slovakia | n.a. | 0.0 | n.a. | 0.0000% |
| | EU 28 Total | 185.5 | 177.6 | 0.0013% | 0.0012% |
| Other Countries | Japan | 149.7 | 204.0 | 0.0035% | 0.0048% |
| | United States | 76.2 | 77.9 | 0.0004% | 0.0004% |
| | Korea | 22.5 | 27.5 | 0.0017% | 0.0020% |
| | Norway | 11.9 | 6.1 | 0.0033% | 0.0016% |
| | Canada | 3.5 | 2.7 | 0.0002% | 0.0002% |
| | Switzerland | 2.6 | 2.6 | 0.0005% | 0.0005% |
| | Australia | 0.3 | 0.2 | n.a. | n.a. |
| | Turkey | 0.2 | 0.4 | 0.0000% | n.a. |
| | New Zealand | 0.0 | n.a. | n.a. | n.a. |

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

In wind energy, Japan scores first with regard to public R&D spending, followed by the EU 28 and the U.S., though the U.S. is at a comparably lower level. Japan has increased its public R&D spending compared to 2018, while the value has slightly decreased in the EU 28 and stayed rather constant in the U.S.. Within the EU 28, it is Germany, the Netherlands, the UK and Denmark that have the largest public R&D budget. 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 Finland (2017), the Netherlands, Japan, Germany and Korea. ■







PUBLIC R&D INVESTMENTS

# SOLAR ENERGY

| | | Public R&D Exp. (in € m) | | Share of Public R&D Exp. by GDP | |
|---|---|---|---|---|---|
| | | 2017 | 2018 | 2017 | 2018 |
| EU 28 | Germany | 99.3 | 92.7 | 0.0034% | 0.0031% |
| | France | 56.2 | 54.7 | 0.0026% | 0.0025% |
| | Italy | 23.9 | 25.3 | 0.0015% | 0.0016% |
| | Netherlands | 17.8 | 20.5 | 0.0026% | 0.0029% |
| | UK | 23.6 | 19.5 | 0.0011% | 0.0009% |
| | Austria | 8.4 | 9.3 | 0.0026% | 0.0028% |
| | Poland | 5.6 | 5.0 | 0.0012% | 0.0010% |
| | Sweden | 5.0 | 4.9 | 0.0012% | 0.0011% |
| | Denmark | 5.1 | 1.7 | 0.0019% | 0.0006% |
| | Ireland | 0.3 | 0.5 | 0.0001% | 0.0002% |
| | Slovakia | 0.2 | 0.1 | 0.0002% | 0.0002% |
| | Belgium | 2.1 | n.a. | 0.0005% | n.a. |
| | Estonia | 0.6 | n.a. | 0.0033% | n.a. |
| | Spain | 7.8 | n.a. | 0.0007% | n.a. |
| | Finland | 4.7 | n.a. | 0.0024% | n.a. |
| | Malta | 0.0 | n.a. | 0.0005% | n.a. |
| | Romania | 1.7 | n.a. | 0.0010% | n.a. |
| | EU 28 Total | 262.6 | 234.1 | 0.0018% | 0.0016% |
| Other Countries | United States | 175.9 | 204.7 | 0.0010% | 0.0012% |
| | Korea | 48.7 | 49.8 | 0.0036% | 0.0036% |
| | Japan | 46.7 | 49.0 | 0.0011% | 0.0012% |
| | Switzerland | 46.9 | 46.9 | 0.0095% | 0.0092% |
| | Australia | 29.0 | 26.8 | n.a. | n.a. |
| | Canada | 25.6 | 21.8 | 0.0018% | 0.0015% |
| | Norway | 16.3 | 8.8 | 0.0045% | 0.0024% |
| | Turkey | 1.8 | 1.9 | 0.0002% | n.a. |
| | New Zealand | 0.1 | n.a. | n.a. | n.a. |

***Note** : a value of 0 indicates a share or expenditures below 0.0000% or below 500 000 Euro 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. The U.S, Korea and Japan follow the EU 28. The table displays an increase in national R&D investments in the U.S., while the figures slightly decrease for the EU 28. The figures for Korea as well as Japan remain at a similar level. Figures for China as well as some other countries are not available.

Within the EU 28, there are five countries with significant public R&D investments, namely Germany, France, Italy, the Netherlands and the UK. In 2018, Germany, the Netherlands, France, Italy and the UK are responsible for more than 90% of the R&D investments of the EU 28. In Germany, France and the UK public R&D expenditures have slightly decreased between 2017 and 2018, while the values for Italy and the Netherlands have increased.

When looking at the normalization of the R&D figures by GDP, the share of the EU 28 is low, especially compared to Korea, but still above the U.S. and Japan. Within the EU, Germany, the Netherlands, Austria, have the largest budget share for solar energy, followed by France and Italy. ■

**PUBLIC R&D INVESTMENTS**

# HYDROENERGY

| | | Public R&D Exp. (in € m) | | Share of Public R&D Exp. by GDP | |
|---|---|---|---|---|---|
| | | 2017 | 2018 | 2017 | 2018 |
| EU 28 | UK | 3.7 | 3.7 | 0.0002% | 0.0002% |
| | Austria | 1.6 | 2.0 | 0.0005% | 0.0006% |
| | France | 1.9 | 1.8 | 0.0001% | 0.0001% |
| | Germany | 2.2 | 1.4 | 0.0001% | 0.0000% |
| | Sweden | 0.7 | 0.9 | 0.0002% | 0.0002% |
| | Poland | 0.1 | 0.1 | 0.0000% | 0.0000% |
| | Denmark | 0.0 | 0.0 | 0.0000% | 0.0000% |
| | Italy | 0.0 | 0.0 | 0.0000% | 0.0000% |
| | Slovakia | 0.0 | 0.0 | 0.0000% | 0.0000% |
| | Spain | 3.0 | n.a. | 0.0003% | n.a. |
| | Finland | 0.1 | n.a. | 0.0001% | n.a. |
| | Malta | 0.0 | n.a. | 0.0000% | n.a. |
| | Netherlands | 0.0 | n.a. | 0.0000% | n.a. |
| | Romania | 0.2 | n.a. | 0.0001% | n.a. |
| | EU 28 Total | 13.6 | 9.8 | 0.0001% | 0.0001% |
| Other Countries | United States | 71.2 | 89.0 | 0.0004% | 0.0005% |
| | Turkey | 11.2 | 17.9 | 0.0012% | n.a. |
| | Switzerland | 13.3 | 13.3 | 0.0027% | 0.0026% |
| | Canada | 11.1 | 11.0 | 0.0008% | 0.0008% |
| | Norway | 8.9 | 9.4 | 0.0024% | 0.0025% |
| | Korea | 6.2 | 4.6 | 0.0005% | 0.0003% |
| | Japan | n.a. | 1.1 | n.a. | 0.0000% |
| | New Zealand | 0.0 | n.a. | n.a. | n.a. |

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

Hydro energy is also 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 in our comparison. It is followed by Turkey, Switzerland, Canada and Norway, which all have significant hydro-power resources. The EU 28 as a whole scores in between Canada and Norway in terms of public R&D spending. Wihtin the EU 28, the UK, Austria, France and Germany show the largest values. The GDP shares show that the highest shares can be found in Switzerland, Norway, Canada, the U.S. and Korea. Within the EU 28, the GDP shares are highest in Austria, Sweden, the UK and France. ■





**PUBLIC R&D INVESTMENTS**

# GEOTHERMAL ENERGY

| | | Public R&D Exp. (in € m) | | Share of Public R&D Exp. by GDP | |
|---|---|---|---|---|---|
| | | 2017 | 2018 | 2017 | 2018 |
| EU 28 | Netherlands | 3.9 | 21.7 | 0.0006% | 0.0030% |
| | Germany | 16.5 | 15.4 | 0.0006% | 0.0005% |
| | France | 3.2 | 7.2 | 0.0001% | 0.0003% |
| | Italy | 5.4 | 5.7 | 0.0003% | 0.0003% |
| | Denmark | 1.3 | 1.8 | 0.0005% | 0.0007% |
| | Austria | 0.8 | 1.5 | 0.0002% | 0.0005% |
| | Slovakia | 0.0 | 0.5 | 0.0000% | 0.0006% |
| | UK | 0.7 | 0.4 | 0.0000% | 0.0000% |
| | Poland | 0.3 | 0.3 | 0.0001% | 0.0001% |
| | Ireland | 0.2 | 0.2 | 0.0001% | 0.0001% |
| | Belgium | 2.8 | n.a. | 0.0007% | n.a. |
| | Spain | 0.5 | n.a. | 0.0000% | n.a. |
| | Malta | 0.0 | n.a. | 0.0000% | n.a. |
| | Romania | 0.0 | n.a. | 0.0000% | n.a. |
| | EU 28 Total | 35.5 | 54.6 | 0.0002% | 0.0004% |
| Other Countries | United States | 58.9 | 68.5 | 0.0003% | 0.0004% |
| | Japan | 16.9 | 22.0 | 0.0004% | 0.0005% |
| | Switzerland | 17.5 | 17.5 | 0.0035% | 0.0034% |
| | Korea | 2.5 | 4.0 | 0.0002% | 0.0003% |
| | Canada | 2.2 | 3.0 | 0.0001% | 0.0002% |
| | Norway | 1.2 | 1.6 | 0.0003% | 0.0004% |
| | Australia | 0.4 | 0.3 | n.a. | n.a. |
| | Turkey | 0.1 | 0.1 | 0.0000% | n.a. |
| | New Zealand | 0.9 | n.a. | n.a. | n.a. |

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

With regard to geothermal energy, the U.S. has the largest public R&D investments of 58.9 million Euros in 2017 and 68.5 million Euros in 2018. It is followed by the EU 28, where 54.6 billion Euros were spent in 2018 and Japan, which spent 22.0 million Euros on geothermal energy in 2018. In all three countries, the amount of public R&D spending has grown since 2017. This is also true for the Netherlands, which has strongly increased its public R&D spending in the field. Compared to solar energy, however, the R&D expenditures are rather low. The GDP normalization shows that Switzerland has the largest share of public R&D investment on GDP followed by the Netherlands and Denmark. In addition, Slovakia, Japan, Austria, Norway and the U.S. show comparably large shares. ■

## PUBLIC R&D INVESTMENTS

# BIOFUELS

| | | Public R&D Exp. (in € m) | | Share of Public R&D Exp. by GDP | |
|---|---|---|---|---|---|
| | | 2017 | 2018 | 2017 | 2018 |
| EU 28 | France | 52.8 | 48.9 | 0.0024% | 0.0022% |
| | Germany | 32.7 | 28.5 | 0.0011% | 0.0010% |
| | Netherlands | 22.5 | 16.7 | 0.0032% | 0.0023% |
| | Sweden | 13.0 | 14.2 | 0.0030% | 0.0032% |
| | UK | 31.5 | 11.0 | 0.0015% | 0.0005% |
| | Poland | 11.8 | 10.7 | 0.0026% | 0.0022% |
| | Italy | 9.5 | 10.1 | 0.0006% | 0.0006% |
| | Austria | 9.0 | 7.8 | 0.0028% | 0.0023% |
| | Denmark | 3.6 | 7.0 | 0.0013% | 0.0025% |
| | Ireland | 2.0 | 2.3 | 0.0008% | 0.0008% |
| | Slovakia | 0.1 | 0.2 | 0.0001% | 0.0003% |
| | Belgium | 4.9 | n.a. | 0.0012% | n.a. |
| | Spain | 3.0 | n.a. | 0.0003% | n.a. |
| | Finland | 12.5 | n.a. | 0.0063% | n.a. |
| | Malta | 0.0 | n.a. | 0.0000% | n.a. |
| | Romania | 0.4 | n.a. | 0.0003% | n.a. |
| | EU 28 Total | 209.3 | 157.4 | 0.0015% | 0.0011% |
| Other Countries | United States | 188.1 | 199.6 | 0.0011% | 0.0011% |
| | Japan | 38.1 | 58.5 | 0.0009% | 0.0014% |
| | Canada | 33.4 | 31.3 | 0.0023% | 0.0022% |
| | Norway | 13.8 | 23.1 | 0.0038% | 0.0062% |
| | Switzerland | 22.9 | 22.9 | 0.0046% | 0.0045% |
| | Korea | 17.2 | 17.6 | 0.0013% | 0.0013% |
| | Astralia | 3.5 | 4.2 | n.a. | n.a. |
| | Turkey | 0.9 | 0.4 | 0.0001% | n.a. |
| | New Zealand | 0.5 | n.a. | n.a. | n.a. |

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

In terms of public R&D investment, biofuels is the second largest field within renewables. This is mostly due to strong commitment of the U.S., with the largest investment of nearly 200 million Euros as well as the EU 28 with nearly 160 million Euros in 2018. Other countries in this analysis depict much lower public R&D investments, all below 50 million Euros, except for Japan, which scores third in terms of absolute public R&D spending in biofuels. Within the EU 28, France, Germany, the Netherlands and Sweden show that largest national R&D investments. In addition, Canada, Norway and Switzerland score in the top ranks regarding public R&D spending in 2018. With regard to the GDP shares, Norway shows the largest value, followed by Switzerland, Sweden, Denmark and the Netherlands. Also Finland showed large shares in 2017, but the value for 2018 is not available. Albeit large absolute investments in biofuels, the U.S. display only mediocre shares, which are stable between 2017 and 2018. ■







## PUBLIC R&D INVESTMENTS

# OCEAN ENERGY

| | | Public R&D Exp. (in € m) | | Share of Public R&D Exp. by GDP | |
|---|---|---|---|---|---|
| | | 2017 | 2018 | 2017 | 2018 |
| EU 28 | UK | 5.2 | 14.2 | 0.0002% | 0.0007% |
| | France | 6.9 | 8.9 | 0.0003% | 0.0004% |
| | Ireland | 6.7 | 5.3 | 0.0026% | 0.0019% |
| | Sweden | 2.2 | 2.8 | 0.0005% | 0.0006% |
| | Netherlands | 0.7 | 0.1 | 0.0001% | 0.0000% |
| | Germany | n.a. | 0.0 | n.a. | 0.0000% |
| | Denmark | 0.3 | 0.0 | 0.0001% | 0.0000% |
| | Italy | 0.0 | 0.0 | 0.0000% | 0.0000% |
| | Slovakia | n.a. | 0.0 | n.a. | 0.0000% |
| | Spain | 0.2 | n.a. | 0.0000% | n.a. |
| | Malta | 0.0 | n.a. | 0.0000% | n.a. |
| | Romania | 0.1 | n.a. | 0.0000% | n.a. |
| | EU 28 Total | 22.2 | 31.2 | 0.0002% | 0.0002% |
| Other Countries | Japan | 4.6 | 13.7 | 0.0001% | 0.0003% |
| | Australia | 0.9 | 3.4 | n.a. | n.a. |
| | Korea | 3.1 | 2.4 | 0.0002% | 0.0002% |
| | Canada | 2.2 | 1.7 | 0.0002% | 0.0001% |
| | Norway | 3.4 | 0.2 | 0.0009% | 0.0001% |
| | Turkey | 0.0 | 0.0 | 0.0000% | n.a. |
| | United States | 0.0 | 0.0 | 0.0000% | 0.0000% |
| | New Zealand | 0.0 | n.a. | n.a. | n.a. |

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

Ocean energy is a comparably small field when interpreted alongside public R&D investment. Here, the EU 28 as a whole shows the largest values, followed by the UK, Japan, France and Ireland. However, here, as well in the other fields, many data points are missing. In 2018, the EU 28 expenditures have increased, which is also true for the UK, Japan and France. The GDP shares show are largest for values for Ireland, the UK, Sweden, France, Japan and the EU 28 in total. ■

PUBLIC R&D INVESTMENTS

# RENEWABLE ENERGY TECHNOLOGIES IN TOTAL

| | | Public R&D Exp. (in € m) | | Share of Public R&D Exp. by GDP | |
|---|---|---|---|---|---|
| | | 2017 | 2018 | 2017 | 2018 |
| EU 28 | Germany | n.a. | 197.7 | n.a. | 0.0066% |
| | France | 127.2 | 128.0 | 0.0059% | 0.0058% |
| | UK | 94.7 | 84.5 | 0.0045% | 0.0039% |
| | Italy | 40.5 | 42.8 | 0.0025% | 0.0026% |
| | Denmark | 28.3 | 42.5 | 0.0104% | 0.0154% |
| | Slovakia | n.a. | 0.8 | n.a. | 0.0010% |
| | Spain | 23.6 | n.a. | 0.0021% | n.a. |
| | Malta | 0.0 | n.a. | 0.0005% | n.a. |
| | Netherlands | 60.8 | n.a. | 0.0087% | n.a. |
| | Romania | 2.5 | n.a. | 0.0015% | n.a. |
| | EU 28 Total | 728.6 | 664.7 | 0.0051% | 0.0046% |
| Other Countries | United States | 570.2 | 639.7 | 0.0033% | 0.0037% |
| | Japan | n.a. | 348.3 | n.a. | 0.0083% |
| | Korea | 100.3 | 105.8 | 0.0074% | 0.0077% |
| | Canada | 78.1 | 71.5 | 0.0053% | 0.0049% |
| | Norway | 55.5 | 49.2 | 0.0152% | 0.0133% |
| | Australia | n.a. | 35.1 | n.a. | n.a. |
| | Turkey | 14.1 | 20.8 | 0.0016% | n.a. |
| | New Zealand | 1.5 | n.a. | n.a. | n.a. |

*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 closer look at the public R&D investment in all renewable energies technologies reveals that the EU 28 has the largest amount of public R&D spending in renewable energies technologies, closely followed by the U.S., which has increased its amount of spending between 2017 and 2018, while the value has slightly decreased in the EU 28. Japan follows up the EU 28 at the third rank, while Germany, France and Korea score at ranks four, five and six. Yet, due to many missing values in the data, this table has to be interpreted with caution. The GDP shares display a very strong position of Denmark, and Norway and the Netherlands (2017), followed by Japan, Korea and Germany. The EU 28 scores in the midfield ahead of the U.S.. Within the EU 28, the largest shares can be found in Denmark, the Netherlands, Germany, France and the UK. However, only a few countries display data in 2018, which makes comparisons difficult. ■


SIMEC Atlantis Energy

PRIVATE R&D INVESTMENTS

# WIND ENERGY

| EU 28 | | Private R&D Exp. (in € m) | | Share of Private R&D Exp. by GDP | |
|---|---|---|---|---|---|
| | | 2014 | 2015 | 2014 | 2015 |
| | Germany | 566.7 | 466.3 | 0.0205% | 0.0166% |
| | Denmark | 195.6 | 227.8 | 0.0772% | 0.0879% |
| | Spain | 98.0 | 86.5 | 0.0095% | 0.0081% |
| | France | 69.7 | 52.0 | 0.0034% | 0.0025% |
| | UK | 55.9 | 49.3 | 0.0028% | 0.0024% |
| | Netherlands | 38.8 | 35.8 | 0.0060% | 0.0054% |
| | Sweden | 19.1 | 17.9 | 0.0049% | 0.0044% |
| | Poland | 5.7 | 17.2 | 0.0014% | 0.0041% |
| | Italy | 35.6 | 15.8 | 0.0023% | 0.0010% |
| | Finland | 5.8 | 8.4 | 0.0031% | 0.0045% |
| | Belgium | 18.3 | 8.1 | 0.0049% | 0.0021% |
| | Ireland | n.a. | 7.3 | n.a. | 0.0032% |
| | Austria | 8.3 | 5.6 | 0.0027% | 0.0018% |
| | Romania | 7.3 | 3.9 | 0.0052% | 0.0027% |
| | Slovakia | 2.3 | 3.9 | 0.0031% | 0.0051% |
| | Czechia | n.a. | 1.9 | n.a. | 0.0011% |
| | Latvia | 2 | 1.3 | 0 | 0.0059% |
| | Portugal | n.a. | 0.2 | n.a. | 0.0001% |
| | Estonia | 1.5 | n.a. | 0.0088% | n.a. |
| | Greece | 0.4 | n.a. | 0.0002% | n.a. |
| | Hungary | 2.3 | n.a. | 0.0022% | n.a. |
| | Lithuania | 0.6 | n.a. | 0.0017% | n.a. |
| | Luxembourg | 1.1 | n.a. | 0.0026% | n.a. |
| | Slovenia | 2.3 | n.a. | 0.0063% | n.a. |
| | EU 28 Total | 1137.6 | 1009.0 | 0.0086% | 0.0074% |

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

In wind energy, Germany scores first with regard to private R&D spending. With investments of about 466 million Euros in 2015, however, its private R&D expenditures since 2014 have de-creased. Still, Germany and invests more than twice as much investment as Denmark, where the figures have increased since 2014. Spain ranks third, however, with less than half of the budget of Denmark, followed by France and the UK. 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

| EU 28 | | Private R&D Exp. (in € m) | | Share of Private R&D Exp. by GDP | |
|---|---|---|---|---|---|
| | | 2014 | 2015 | 2014 | 2015 |
| | Germany | 1088.0 | 1210.6 | 0.0394% | 0.0431% |
| | UK | 88.7 | 138.1 | 0.0044% | 0.0067% |
| | France | 191.4 | 137.6 | 0.0092% | 0.0066% |
| | Spain | 102.9 | 83.4 | 0.0099% | 0.0078% |
| | Austria | 93.4 | 69.2 | 0.0303% | 0.0222% |
| | Netherlands | 81.7 | 59.3 | 0.0126% | 0.0089% |
| | Italy | 84.5 | 58.4 | 0.0055% | 0.0038% |
| | Poland | 32.7 | 53.5 | 0.0081% | 0.0127% |
| | Finland | 15.4 | 38.9 | 0.0083% | 0.0207% |
| | Belgium | 16.2 | 22.3 | 0.0043% | 0.0058% |
| | Ireland | 25.6 | 19.9 | 0.0138% | 0.0086% |
| | Romania | 8.7 | 14.0 | 0.0062% | 0.0097% |
| | Denmark | 3.1 | 13.6 | 0.0012% | 0.0052% |
| | Portugal | 5.8 | 12.9 | 0.0034% | 0.0075% |
| | Sweden | 45.8 | 11.8 | 0.0117% | 0.0029% |
| | Czechia | 15.3 | 11.2 | 0.0094% | 0.0066% |
| | Luxembourg | 5.4 | 4.2 | 0.0123% | 0.0091% |
| | Bulgaria | n.a. | 2.8 | n.a. | 0.0068% |
| | Hungary | 4.4 | 3 | 0.0041% | 0 |
| | Slovenia | n.a. | 0.9 | n.a. | 0.0025% |
| | Latvia | n.a. | 0.8 | n.a. | 0.0038% |
| | Cyprus | 2.2 | n.a. | 0.0125% | n.a. |
| | Estonia | 4 | n.a. | 0 | n.a. |
| | Lithuania | 5.4 | n.a. | 0.0165% | n.a. |
| | Slovakia | 4.4 | n.a. | 0.0059% | n.a. |
| | EU 28 Total | 1925.5 | 1966.4 | 0.0145% | 0.0145% |

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

In the field of solar energy within the EU 28, Germany is the largest player in terms of private R&D investment and the figures have even increased between 2014 and 2015. Germany is at a very high level compared to the other EU 28 countries. It is followed by the UK, where the private R&D expenditures for solar energy technologies also have increased since 2014, while France scores at the third rank due to a decrease in the amount of private R&D expenditures between 2014 and 2015. Spain, Austria and the Netherlands score at ranks four, five and six within this comparison, followed by Italy and Poland.

When looking at the normalization of the R&D figures by GDP, Germany has the largest share which has also increased in 2015. Germany is followed by Austria, where the share, however, has decreased due to the decline in absolute figures. Finland scores third, followed by Poland and Romania. Compared to public R&D spending in 2017/18, private R&D investments in solar energy are significantly higher in 2014/15. ■

PRIVATE R&D INVESTMENTS

# HYDRO ENERGY

| | | Private R&D Exp. (in € m) | | Share of Private R&D Exp. by GDP | |
|---|---|---|---|---|---|
| | | 2014 | 2015 | 2014 | 2015 |
| EU 28 | Germany | 30.1 | 46.2 | 0.0011% | 0.0016% |
| | France | 30.5 | 23.0 | 0.0015% | 0.0011% |
| | Poland | 2.3 | 18.8 | 0.0006% | 0.0045% |
| | Italy | 0.8 | 15.4 | 0.0001% | 0.0010% |
| | Finland | 1.7 | 7.5 | 0.0009% | 0.0040% |
| | UK | 8.9 | 6.3 | 0.0004% | 0.0003% |
| | Austria | 7.4 | 5.8 | 0.0024% | 0.0018% |
| | Sweden | n.a. | 4.9 | n.a. | 0.0012% |
| | Belgium | n.a. | 2.9 | n.a. | 0.0007% |
| | Netherlands | 1.2 | 2.9 | 0.0002% | 0.0004% |
| | Czechia | 1.8 | 1.9 | 0.0011% | 0.0011% |
| | Ireland | n.a. | 1.5 | n.a. | 0.0006% |
| | Denmark | n.a. | 1.0 | n.a. | 0.0004% |
| | Spain | 8.1 | 0.5 | 0.0008% | 0.0000% |
| | Romania | 0.4 | n.a. | 0.0003% | n.a. |
| | Slovenia | 2.3 | n.a. | 0.0064% | n.a. |
| | Slovakia | 2.3 | n.a. | 0.0032% | n.a. |
| | EU 28 Total | 97.8 | 138.4 | 0.0007% | 0.0010% |

***Note** : a value of 0 indicates a share or expenditures below 0.0000% or below 500 000 Euro expenditures. **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 2014/15 are larger than public investments in 2017/18 (at least for the EU 28 countries). Germany has the largest private R&D investment among the countries in our comparison. It is followed by France, which also has significant pri-vate R&D investments in hydro power. These two countries are followed by Poland and Italy, which highly increased their private R&D expenditures in this field in 2015. Finland, UK and Austria score at ranks five, six and seven. In these countries, the private R&D expenditures exceed 5 million, although there has been a decrease between 2014 and 2015 in the UK and in Austria. The GDP shares, however, show a slightly different ranking: The highest shares can be found in Slovenia (2014), Poland, Finland and Slovakia (2014). Furthermore, Austria shows comparably high (but decreasing) shares, while Germany, which in 2015 scores directly after Austria, has increased its shares. The countries that have shown large absolute values, i.e. France and Germany, score in the midfield in terms of GDP shares. ■





PRIVATE R&D INVESTMENTS

# GEOTHERMAL ENERGY

| | | Private R&D Exp. (in € m) | | Share of Private R&D Exp. by GDP | |
|---|---|---|---|---|---|
| | | 2014 | 2015 | 2014 | 2015 |
| EU 28 | Germany | 48.9 | 24.9 | 0.0018% | 0.0009% |
| | Austria | 3.1 | 7.7 | 0.0010% | 0.0025% |
| | UK | n.a. | 5.8 | n.a. | 0.0003% |
| | Finland | 0.4 | 3.8 | 0.0002% | 0.0020% |
| | Netherlands | 9.3 | 3.8 | 0.0014% | 0.0006% |
| | Italy | 6.2 | 3.1 | 0.0004% | 0.0002% |
| | Sweden | 17.6 | 2.0 | 0.0045% | 0.0005% |
| | Slovakia | n.a. | 1.6 | n.a. | 0.0021% |
| | Denmark | 2.2 | n.a. | 0.0009% | n.a. |
| | Poland | 2.1 | n.a. | 0.0005% | n.a. |
| | EU 28 Total | 89.6 | 52.7 | 0.0007% | 0.0004% |

***Note** : a value of 0 indicates a share or expenditures below 0.0000% or below 500 000 Euro expenditures. **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 24.9 million Euros in 2015, but the expenditures have decreased since 2014. It is followed by Austria, the UK and Finland all with less than 10 million Euros of private R&D ex-penditures, though especially Austria, but also Finland have increased their expenditures, while especially in Sweden a strong decrease between 2014 and 2015 can be observed. The GDP normalization shows that Austria has the largest share of private R&D investment on GDP (across all countries in our comparison), which also has increased between 2014 and 2015. It is followed by Slovakia, Finland, Germany and the Netherlands. 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 | |
|---|---|---|---|---|---|
| | | 2014 | 2015 | 2014 | 2015 |
| EU 28 | Denmark | 217.1 | 210.1 | 0.0857% | 0.0810% |
| | Germany | 212.3 | 164.8 | 0.0077% | 0.0059% |
| | France | 90.2 | 90.5 | 0.0043% | 0.0043% |
| | Netherlands | 50.7 | 74.1 | 0.0078% | 0.0112% |
| | UK | 50.0 | 56.1 | 0.0025% | 0.0027% |
| | Italy | 40.8 | 55.8 | 0.0026% | 0.0036% |
| | Spain | 15.9 | 37.2 | 0.0015% | 0.0035% |
| | Poland | 14.9 | 36.2 | 0.0037% | 0.0086% |
| | Finland | 41.2 | 34.4 | 0.0221% | 0.0183% |
| | Sweden | 15.9 | 17.4 | 0.0040% | 0.0042% |
| | Austria | 3.9 | 12.4 | 0.0013% | 0.0040% |
| | Czechia | 13.1 | 9.9 | 0.0081% | 0.0058% |
| | Ireland | n.a. | 8.5 | n.a. | 0.0037% |
| | Slovakia | 24.2 | 6.0 | 0.0328% | 0.0078% |
| | Luxembourg | 11.3 | 6.0 | 0.0256% | 0.0129% |
| | Hungary | 12.5 | 5.1 | 0.0119% | 0.0047% |
| | Latvia | n.a. | 3.0 | n.a. | 0.0141% |
| | Belgium | 4.5 | n.a. | 0.0012% | n.a. |
| | EU 28 Total | 818.6 | 827.4 | 0.0062% | 0.0061% |

***Note** : a value of 0 indicates a share or expenditures below 0.0000% or below 500 000 Euro expenditures. **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, Denmark shows the largest investment with 210 million Euros in 2015. Since Germany has decreased its private R&D investment in this field between 2014 and 2015 it now scores second after Denmark, which has increased its investment in 2015. All other countries in this comparison have values below 100 million Euros of private R&D investment. France scores third with about 90 million Euros, followed the Netherlands with 74 million Euros and the UK with 56 million Euros, respectively. In sum, it can be found that the private R&D expenditures within biofuels have slightly increased between 2014 and 2015, which is reflected in rising figures for the EU 28 as a whole. With regard to the GDP shares, Denmark is leading in 2015, followed by Finland, Latvia, Luxembourg, the Netherlands and Poland. ■

### PRIVATE R&D INVESTMENTS

# OCEAN ENERGY

| | | Private R&D Exp. (in € m) | | Share of Private R&D Exp. by GDP | |
|---|---|---|---|---|---|
| | | 2014 | 2015 | 2014 | 2015 |
| EU 28 | UK | 44.7 | 53.6 | 0.0022% | 0.0026% |
| | Sweden | 19.6 | 33.6 | 0.0050% | 0.0082% |
| | Germany | 49.7 | 29.1 | 0.0018% | 0.0010% |
| | France | 21.7 | 16.2 | 0.0010% | 0.0008% |
| | Finland | 21.6 | 11.1 | 0.0116% | 0.0059% |
| | Netherlands | 3.3 | 9.9 | 0.0005% | 0.0015% |
| | Ireland | 16.4 | 7.3 | 0.0088% | 0.0031% |
| | Romania | n.a. | 5.6 | n.a. | 0.0038% |
| | Italy | 9.2 | 5.1 | 0.0006% | 0.0003% |
| | Poland | n.a. | 4.9 | n.a. | 0.0012% |
| | Spain | 14.7 | 3.2 | 0.0014% | 0.0003% |
| | Bulgaria | n.a. | 1.4 | n.a. | 0.0034% |
| | Czechia | n.a. | 0.9 | n.a. | 0.0005% |
| | Belgium | n.a. | 0.6 | n.a. | 0.0001% |
| | Austria | 1.3 | n.a. | 0.0004% | n.a. |
| | Denmark | 3.4 | n.a. | 0.0013% | n.a. |
| | Luxembourg | 1.2 | n.a. | 0.0028% | n.a. |
| | Portugal | 2.5 | n.a. | 0.0015% | n.a. |
| | EU 28 Total | 209.3 | 182.3 | 0.0016% | 0.0013% |

***Note** : a value of 0 indicates a share or expenditures below 0.0000% or below 500 000 Euro 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, the UK shows the largest values in 2015, followed by Sweden, Germany and France. Finland and the Netherlands score at ranks five and six, respectively. However, also in this field many data points are missing. In 2015, the investments for ocean energy have decreased for the EU 28 as a whole, which can mostly be attributed to declines in Germany, France and Finland. The largest GDP shares in comparison can be found for Sweden, Finland and Romania, followed by Bulgaria, Ireland, the UK and the Netherlands. ■

### PRIVATE R&D INVESTMENTS

# RENEWABLE ENERGY TECHNOLOGIES IN TOTAL

| | Private R&D Exp. (in € m) | | Share of Private R&D Exp. by GDP | |
|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 |
| **EU 28** | | | | |
| Germany | 1995.6 | 1941.9 | 0.0723% | 0.0692% |
| UK | n.a. | 309.1 | n.a. | 0.0151% |
| Netherlands | 185.0 | 185.7 | 0.0284% | 0.0280% |
| Italy | 177.1 | 153.5 | 0.0115% | 0.0099% |
| Finland | 86.1 | 104.1 | 0.0461% | 0.0555% |
| Sweden | n.a. | 87.6 | n.a. | 0.0213% |
| Austria | 117.6 | n.a. | 0.0381% | n.a. |
| Total EU | 4278.5 | 4176.3 | 0.0322% | 0.0307% |

*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.*
*Source: JRC SETIS, Eurostat, WDI Database*

A final look at the private R&D investment in all renewable energy technologies shows a strong position of Germany in 2014 and 2015. The German private R&D investments in RET technologies have remained rather stable in 2015 and Germany keeps its top position. Large private R&D investments in RET can also be found in the UK, which scores second on this indicator. As for the other countries, for which data is available, the Netherlands and Italy have similar investment levels. The GDP shares also display a quite strong position of Germany but also Finland shows rather high shares. Yet, as for the public R&D investments, this table has to be interpreted with caution due to many missing values in the data. ■





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# 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 U.S.. 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:

- So far, the EU 28 (2017/18) scores first in public solar energy R&D spending, above the U.S, Korea and Japan, while data for China is not available. Within Europe, especially Germany, France, Italy, 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 (2014/2015). Here, it can be shown that Germany scores first in terms of private R&D investment, followed by the UK, France, Spain, Austria and Italy.
- 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, the Netherlands and Denmark stick out. The figures for private R&D expenditures show that Germany has the largest private R&D investments of 24.9 million Euros in 2015 but the expenditures have decreased since 2014. Germany is followed by Austria, the UK and Finland.
- In hydro energy, which is a comparably small field with regard to public R&D investment, the U.S. ranks first, which can be explained by its geographical position, i.e. large hydro power resources. It is followed by Turkey, Switzerland, Canada and Norway. Within the EU 28, the UK, Austria, France and Germany show the largest public investments. As for the private R&D investments, Germany shows the largest values among the countries in our comparison (EU 28 only). It is followed by France. Poland and Italy have highly increased their private R&D expenditures in this field in 2015 and thus score third and fourth in hydro power in the EU 28.
- Within biofuels, the U.S. shows the largest investment in 2018, followed by the EU 28. The other countries in our comparison have lower public R&D investments (all below 50 million Euros, except for Japan). As for the private investment, Denmark scores first with 210 million Euros in 2015. Germany has decreased its private R&D investment in this field but still shows the second largest private R&D investment. All other (EU 28) countries in our comparison have values below 100 million.
- In wind energy, Japan scores first with regard to public R&D spending, followed by the EU 28 and the U.S. (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, followed by France and the UK.
- In ocean energy – also a rather small field in terms of public R&D – the EU 28 shows the largest values followed by Japan. In 2018, the EU 28 expenditures have increased compared to 2017. Concerning private R&D investments, the UK shows the largest values in 2015 followed by Sweden, the UK and France.
- Regarding all renewables, Germany, France, the UK and also the Netherlands and Denmark and Spain should be mentioned. These are countries that have significant public R&D investment in nearly all RET fields.
- Overall, this analysis 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 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 patent output 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. 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]*

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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 | |
|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| **EU 28** | | | | | | |
| Germany | 272.9 | 235.2 | 2.3 | 2.1 | 98.9 | 83.8 |
| Denmark | 91.1 | 152.4 | 12.7 | 19.8 | 359.6 | 588.0 |
| Spain | 42.3 | 32.9 | 5.5 | 5.2 | 40.9 | 30.7 |
| France | 32.9 | 27.9 | 0.8 | 0.7 | 15.9 | 13.3 |
| United Kingdom | 25.1 | 27.0 | 1.4 | 1.4 | 12.5 | 13.1 |
| Netherlands | 18.8 | 21.6 | 1.8 | 1.9 | 28.9 | 32.6 |
| Poland | 8.7 | 11.8 | 1.4 | 1.6 | 21.4 | 28.2 |
| Sweden | 7.5 | 9.4 | 0.7 | 1.0 | 19.1 | 22.8 |
| Italy | 9.9 | 8.1 | 1.3 | 0.9 | 6.4 | 5.2 |
| Ireland | 0 | 3.8 | 0 | 2.6 | 0 | 16.2 |
| Belgium | 8.0 | 3.3 | 2.3 | 0.9 | 21.1 | 8.5 |
| Finland | 2.5 | 3.3 | 0.4 | 0.7 | 13.4 | 17.3 |
| Romania | 7.2 | 3.0 | 6.5 | 2.5 | 51.3 | 20.7 |
| Austria | 3.0 | 2.9 | 0.4 | 0.4 | 9.9 | 9.2 |
| Latvia | 1 | 2.6 | 6 | 8.6 | 49 | 125.0 |
| Slovakia | 1.0 | 2.1 | 1.8 | 2.9 | 13.6 | 27.4 |
| Czechia | 0 | 1.0 | 0 | 0.6 | 0 | 5.9 |
| Lithuania | 0.3 | 1.0 | 1.4 | 8.5 | 7.6 | 29.6 |
| Luxembourg | 0.5 | 0.5 | 0.4 | 0.5 | 11.3 | 10.8 |
| Malta | 0 | 0.2 | 0 | 1.5 | 0 | 23.1 |
| Portugal | 0 | 0.2 | 0 | 0.2 | 0 | 1.0 |
| Cyprus | 0 | 0 | 0 | 1 | 0 | 8 |
| Hungary | 1.0 | 0.1 | 2.4 | 0.5 | 9.5 | 1.1 |
| Bulgaria | 0 | 0 | 0 | 0 | 0 | 0 |
| Estonia | 0.7 | 0 | 2.2 | 0 | 38.5 | 0 |
| Greece | 0.3 | 0 | 3.0 | 0 | 1.8 | 0 |
| Croatia | 0 | 0 | 0 | 0 | 0 | 0 |
| Slovenia | 1.0 | 0 | 2.4 | 0 | 27.7 | 0 |
| EU 28 Total | 535.6 | 550.3 | 2.1 | 2.2 | 40.3 | 40.5 |
| **Other Countries** | | | | | | |
| China | 1 094.1 | 1 497.8 | 1.0 | 1.0 | 139.1 | 150.8 |
| Korea | 296.5 | 190.0 | 1.0 | 0.7 | 278.8 | 152.4 |
| Japan | 186.3 | 189.6 | 0.5 | 0.5 | 51.0 | 47.9 |
| United States | 159.6 | 165.9 | 0.8 | 0.8 | 12.1 | 10.1 |
| Rest of the world | 109.5 | 101.4 | 0.0 | 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 wind energy, it is China that has the largest number of patent filings in our comparison. The EU 28 as a group only has a third of the filing figures of China, although the number of filings from the EU 28 has slightly grown since 2014. China, however, also has increased its patent activities in wind energy technologies. Germany scores third, followed by Korea, 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 more than 70% of all European patents within wind energy. Yet, also Spain, France, the UK, the Netherlands and Poland have filed a significant number of patents within this field in 2015.

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, China, Latvia, Germany and Japan. 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 Latvia, Lithuania 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 | |
|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| **EU 28** | | | | | | |
| Germany | 281.7 | 230.2 | 0.8 | 0.7 | 102.1 | 82.0 |
| France | 103.6 | 97.2 | 0.8 | 0.9 | 49.9 | 46.3 |
| Spain | 48.6 | 35.7 | 2.0 | 2.0 | 47.0 | 33.3 |
| United Kingdom | 33.2 | 34.8 | 0.6 | 0.6 | 16.6 | 17.0 |
| Poland | 22.8 | 19.3 | 1.2 | 0.9 | 56.3 | 45.9 |
| Netherlands | 40.7 | 17.7 | 1.2 | 0.6 | 62.6 | 26.7 |
| Austria | 25.3 | 17.2 | 1.1 | 0.9 | 81.9 | 55.1 |
| Italy | 20.5 | 17.0 | 0.9 | 0.7 | 13.3 | 10.9 |
| Belgium | 11.9 | 12.4 | 1.1 | 1.2 | 31.5 | 32.2 |
| Finland | 4.5 | 9.9 | 0.2 | 0.7 | 24.2 | 53.0 |
| Romania | 5.5 | 7.5 | 1.6 | 2.2 | 39.3 | 51.7 |
| Ireland | 6.2 | 3.5 | 1.9 | 0.9 | 33.6 | 15.3 |
| Czechia | 5.0 | 3.5 | 0.9 | 0.7 | 30.9 | 20.5 |
| Denmark | 2.8 | 3.4 | 0.1 | 0.2 | 11.0 | 13.2 |
| Portugal | 3.6 | 3.1 | 1.9 | 1.3 | 21.2 | 17.9 |
| Slovakia | 5.3 | 2.7 | 3.0 | 1.3 | 71.3 | 34.8 |
| Sweden | 11.1 | 2.3 | 0.3 | 0.1 | 28.2 | 5.7 |
| Latvia | 2.0 | 2.1 | 4.1 | 2.5 | 97.4 | 101.3 |
| Lithuania | 2.3 | 1.5 | 4.0 | 4.5 | 68.0 | 44.5 |
| Luxembourg | 1.9 | 1.2 | 0.5 | 0.4 | 43.6 | 25.3 |
| Hungary | 1.0 | 1.0 | 0.8 | 1.4 | 9.5 | 9.2 |
| Slovenia | 0 | 0.8 | 0 | 2.3 | 0 | 22.5 |
| Greece | 0 | 0.6 | 0 | 0.5 | 0 | 3.3 |
| Bulgaria | 0 | 0.5 | 0 | 1.0 | 0 | 12.1 |
| Cyprus | 0.5 | 0 | 0.6 | 0 | 28.6 | 0 |
| Estonia | 1.0 | 0 | 1.1 | 0 | 57.7 | 0 |
| Croatia | 0 | 0 | 0 | 0 | 0 | 0 |
| Malta | 0 | 0 | 0 | 0 | 0 | 0 |
| **EU 28 Total** | **640.9** | **525.3** | **0.8** | **0.7** | **48.3** | **38.7** |
| **Other Countries** | | | | | | |
| China | 3 293.6 | 4 218.1 | 0.9 | 1.0 | 418.6 | 424.8 |
| Japan | 1 355.1 | 1 106.9 | 1.2 | 1.1 | 370.7 | 279.8 |
| Korea | 1 215.9 | 910.6 | 1.3 | 1.2 | 1 143.1 | 730.5 |
| United States | 490.3 | 472.4 | 0.7 | 0.8 | 37.1 | 28.8 |
| Rest of the world | 505.1 | 427.9 | 0.0 | 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 the field of solar energy, China has the highest number of patents filed domestically or internationally and ranks second based on patents per GDP. China is followed by Japan, although Japan's patenting activity between 2014 and 2015 has decreased, while China has increased its patenting between the two years. Korea ranks third regarding patent counts, however, also with a decrease between 2014 and 2015. Yet, it ranks first when patents are related to GDP. The EU 28 (as a total) ranges behind Korea - with about two thirds of the number of Korea's patent filings - ahead of the U.S., although the figures have been decreasing for both in 2015. Within Europe, Germany has filed the largest number of patents, followed by France, Spain, the UK, Poland and the Netherlands. Together with Latvia, Germany also ranks first regarding patents per GDP within the EU, followed by Austria, Finland and Romania. 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 (except for Korea). The countries with the largest specialization values are Lithuania, Latvia, Slovenia, Romania, Spain, Hungary and Slovakia. 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 a large influence on the patent specializations. ■

# HYDROENERGY

| | Number of patent families | | Patent specialization | | Patents per € trillion GDP | |
|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| **EU 28** | | | | | | |
| Germany | 16.0 | 17.7 | 0.4 | 0.5 | 5.8 | 6.3 |
| France | 12.8 | 9.1 | 0.9 | 0.8 | 6.2 | 4.3 |
| Poland | 5.0 | 9.0 | 2.5 | 4.0 | 12.4 | 21.4 |
| Italy | 0.3 | 4.5 | 0.1 | 1.7 | 0.2 | 2.9 |
| Romania | 1.2 | 3.5 | 3.2 | 9.6 | 8.3 | 24.1 |
| Finland | 0.8 | 2.6 | 0.4 | 1.8 | 4.1 | 13.9 |
| Netherlands | 0.8 | 2.3 | 0.2 | 0.7 | 1.2 | 3.5 |
| United Kingdom | 3.8 | 2.2 | 0.6 | 0.4 | 1.9 | 1.1 |
| Slovakia | 2.0 | 2.1 | 11.2 | 9.1 | 27.2 | 26.7 |
| Austria | 3.0 | 2.0 | 1.2 | 0.9 | 9.7 | 6.4 |
| Sweden | 0 | 1.7 | 0 | 0.6 | 0 | 4.1 |
| Belgium | 0 | 1.0 | 0 | 0.9 | 0 | 2.6 |
| Czechia | 1.7 | 0.7 | 3.0 | 1.2 | 10.3 | 3.9 |
| Ireland | 0 | 0.5 | 0 | 1.1 | 0 | 2.2 |
| Denmark | 0 | 0.3 | 0 | 0.1 | 0 | 1.3 |
| Spain | 5.2 | 0.2 | 2.1 | 0.1 | 5.0 | 0.2 |
| Hungary | 0 | 0.1 | 0 | 1.6 | 0 | 1.1 |
| Malta | 0 | 0.1 | 0 | 2.4 | 0 | 11.5 |
| Bulgaria | 0 | 0 | 0 | 0 | 0 | 0 |
| Cyprus | 0 | 0 | 0 | 0 | 0 | 0 |
| Estonia | 0 | 0 | 0 | 0 | 0 | 0 |
| Greece | 0 | 0 | 0 | 0 | 0 | 0 |
| Croatia | 0 | 0 | 0 | 0 | 0 | 0 |
| Lithuania | 0 | 0 | 0 | 0 | 0 | 0 |
| Luxembourg | 0 | 0 | 0 | 0 | 0 | 0 |
| Latvia | 0 | 0 | 0 | 0 | 0 | 0 |
| Portugal | 0 | 0 | 0 | 0 | 0 | 0 |
| Slovenia | 1.0 | 0 | 7.4 | 0 | 27.7 | 0 |
| EU 28 Total | 53.5 | 59.6 | 0.6 | 0.8 | 4.0 | 4.4 |
| **Other Countries** | | | | | | |
| China | 556.2 | 619.1 | 1.5 | 1.3 | 70.7 | 62.3 |
| Japan | 58.9 | 69.4 | 0.5 | 0.6 | 16.1 | 17.5 |
| Korea | 60.9 | 41.0 | 0.6 | 0.5 | 57.2 | 32.9 |
| United States | 7.0 | 6.3 | 0.1 | 0.1 | 0.5 | 0.4 |
| Rest of the world | 43.4 | 35.7 | 0.0 | 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 hydro energy, the patenting figures are lower than in wind or solar energy. Here again, it is espe-cially China that displays a large number of patents. Japan, the EU 28 and Korea follow up but at a lower level than China. China, the EU 28 and Japan have managed a growth in filings between 2014 and 2015, while the figures for Korea decreased. Within Europe, Germany is responsible for 30% of all patent filings within this field, while France is responsible for 15%. Poland, Italy, Romania, Finland, the Netherlands, the UK, Slovakia, Austria, Sweden and Belgium also have filed more than one patent in the field in 2015.


In relation to its economic size, China and Korea reveal the highest patent filing figures per GDP, followed by Slovakia, Romania, Poland and Japan. 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 Romania, Slovakia and Poland. However, this is based on a very low absolute number of filings. ■

# GEOTHERMAL ENERGY

| | Number of patent families | | Patent specialization | | Patents per € trillion GDP | |
|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| **EU 28** | | | | | | |
| Germany | 8.2 | 6.6 | 1.0 | 1.0 | 3.0 | 2.4 |
| Poland | 2.3 | 4.0 | 5.5 | 8.9 | 5.8 | 9.5 |
| France | 1.6 | 3.0 | 0.5 | 1.2 | 0.8 | 1.4 |
| Austria | 0.5 | 1.9 | 0.9 | 4.4 | 1.6 | 5.9 |
| United Kingdom | 0 | 1.5 | 0 | 1.3 | 0 | 0.7 |
| Finland | 0.1 | 1.0 | 0.3 | 3.5 | 0.6 | 5.3 |
| Netherlands | 1.5 | 1.0 | 2.0 | 1.5 | 2.3 | 1.5 |
| Slovakia | 0 | 0.8 | 0 | 18.5 | 0 | 10.9 |
| Italy | 1.0 | 0.8 | 1.9 | 1.5 | 0.6 | 0.5 |
| Sweden | 2.8 | 0.5 | 3.9 | 0.9 | 7.2 | 1.2 |
| Belgium | 1.5 | 0 | 6.0 | 0 | 4.0 | 0 |
| Bulgaria | 0 | 0 | 0 | 0 | 0 | 0 |
| Cyprus | 0 | 0 | 0 | 0 | 0 | 0 |
| Czechia | 0 | 0 | 0 | 0 | 0 | 0 |
| Denmark | 0.4 | 0 | 0.8 | 0 | 1.6 | 0 |
| Estonia | 0 | 0 | 0 | 0 | 0 | 0 |
| Greece | 0 | 0 | 0 | 0 | 0 | 0 |
| Spain | 0 | 0 | 0 | 0 | 0 | 0 |
| Croatia | 0 | 0 | 0 | 0 | 0 | 0 |
| Hungary | 0 | 0 | 0 | 0 | 0 | 0 |
| Ireland | 0 | 0 | 0 | 0 | 0 | 0 |
| Lithuania | 0 | 0 | 0 | 0 | 0 | 0 |
| Luxembourg | 0 | 0 | 0 | 0 | 0 | 0 |
| Latvia | 0 | 0 | 0 | 0 | 0 | 0 |
| Malta | 0 | 0 | 0 | 0 | 0 | 0 |
| Portugal | 0 | 0 | 0 | 0 | 0 | 0 |
| Romania | 0 | 0 | 0 | 0 | 0 | 0 |
| Slovenia | 0 | 0 | 0 | 0 | 0 | 0 |
| EU 28 Total | 19.9 | 21.1 | 1.1 | 1.4 | 1.5 | 1.6 |
| **Other Countries** | | | | | | |
| China | 59.5 | 58.3 | 0.7 | 0.6 | 7.6 | 5.9 |
| Korea | 29.2 | 42.6 | 1.4 | 2.6 | 27.4 | 34.2 |
| Japan | 41.4 | 32.7 | 1.6 | 1.5 | 11.3 | 8.3 |
| United States | 13.3 | 6.4 | 0.9 | 0.5 | 1.0 | 0.4 |
| Rest of the world | 5.4 | 3.9 | 0.0 | 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 terms of the number of patent filings, geothermal energy is a far less significant field than solar and wind energy. The filing figures are below 50 in 2015 for each of the countries in our comparison (except for China). The EU 28 countries in total filed 21 patents in geothermal energy in 2015, with 7 patents originating from Germany. The other European countries that have actively patented inventions in geothermal energy in 2015 are Poland, France, Austria, the UK, Finland, the Netherlands, Slovakia, Italy and Sweden. The largest patenting countries in geothermal energy worldwide are China (58 patents in 2015), Korea (43 patents in 2015) and Japan (33 patents in 2015). The U.S. has only filed 6 patents within this field in 2015. With respect to patents per GDP, Korea, Slovakia, Poland, Japan and Austria are leading, i.e. they show the highest level of patent filings per capita.

As mentioned before, there is a size problem with the specialisation indicator if countries are small. For example, in Slovakia, Poland, Austria or Finland 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, especially Korea, but also Japan 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 | |
|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| **EU 28** | | | | | | |
| Germany | 52.1 | 47.7 | 0.6 | 0.6 | 18.9 | 17.0 |
| France | 37.3 | 37.5 | 1.2 | 1.4 | 18.0 | 17.9 |
| Netherlands | 14.3 | 18.1 | 1.8 | 2.3 | 22.0 | 27.3 |
| Denmark | 23.3 | 14.6 | 4.2 | 2.7 | 91.9 | 56.4 |
| Spain | 9.0 | 14.2 | 1.5 | 3.2 | 8.7 | 13.2 |
| Poland | 12.6 | 12.8 | 2.7 | 2.5 | 31.1 | 30.4 |
| United Kingdom | 10.2 | 11.9 | 0.7 | 0.9 | 5.1 | 5.8 |
| Italy | 7.1 | 9.4 | 1.2 | 1.5 | 4.6 | 6.0 |
| Finland | 10.8 | 7.7 | 2.3 | 2.3 | 57.7 | 40.9 |
| Austria | 1.1 | 4.4 | 0.2 | 0.9 | 3.7 | 14.2 |
| Slovakia | 4.0 | 3.0 | 9.6 | 5.8 | 54.3 | 39.1 |
| Sweden | 3.1 | 2.9 | 0.4 | 0.4 | 7.9 | 7.1 |
| Ireland | 0 | 2.6 | 0 | 2.6 | 0 | 11.2 |
| Czechia | 4.0 | 2.0 | 3.1 | 1.6 | 24.7 | 11.7 |
| Romania | 4.0 | 1.3 | 4.8 | 1.6 | 28.6 | 9.2 |
| Belgium | 2.9 | 1.0 | 1.1 | 0.4 | 7.8 | 2.6 |
| Luxembourg | 2.1 | 1.0 | 2.3 | 1.6 | 46.8 | 21.7 |
| Hungary | 2.1 | 0.9 | 6.6 | 4.7 | 19.7 | 7.9 |
| Latvia | 0 | 0.5 | 0 | 2.3 | 0 | 23.6 |
| Bulgaria | 0 | 0 | 0 | 0 | 0 | 0 |
| Cyprus | 0 | 0 | 0 | 0 | 0 | 0 |
| Estonia | 0 | 0 | 0 | 0 | 0 | 0 |
| Greece | 0 | 0 | 0 | 0 | 0 | 0 |
| Croatia | 0 | 0 | 0 | 0 | 0 | 0 |
| Lithuania | 0 | 0 | 0 | 0 | 0 | 0 |
| Malta | 0 | 0 | 0 | 0 | 0 | 0 |
| Portugal | 0 | 0 | 0 | 0 | 0 | 0 |
| Slovenia | 0 | 0 | 0 | 0 | 0 | 0 |
| **EU 28 Total** | 199.9 | 193.5 | 1.0 | 1.1 | 15.1 | 14.2 |
| **Other Countries** | | | | | | |
| China | 1 000.8 | 1 204.6 | 1.1 | 1.1 | 127.2 | 121.3 |
| Korea | 216.5 | 152.7 | 1.0 | 0.8 | 203.6 | 122.5 |
| United States | 158.2 | 137.3 | 1.0 | 0.9 | 12.0 | 8.4 |
| Japan | 128.5 | 98.0 | 0.5 | 0.4 | 35.1 | 24.8 |
| Rest of the world | 117.8 | 108.5 | 0.0 | 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 biofuels, it is again China that has filed the largest number of patents in 2015. With 1205 patent families, China clearly has a dominant position in this respect and also has managed a growth in filings since 2014. Following China, the EU 28 scores second with 194 patent families, though the number has slightly decreased after 2014. Korea scores third after the EU 28 and has also lost ground due to the decrease in filings since 2014. For the U.S. and Japan, the filing figures in biofuels have also decreased and Japan has filed less than 100 single patent families in 2015. 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, the Netherlands, Denmark, Spain, Poland and the UK.

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, Spain and Denmark have the largest values. Yet, this relates to a very low number of filings in 2015, especially in the case of Slovakia and Hungary. Still, many European countries show positive (above 1) values here, while the non-European countries - except for China with a value of 1.1 - are less specialized within this technology field. ■

# OCEAN ENERGY

| | Number of patent families | | Patent specialization | | Patents per € trillion GDP | |
|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| **EU 28** | | | | | | |
| United Kingdom | 19.1 | 19.6 | 3.8 | 5.8 | 9.5 | 9.6 |
| Germany | 25.0 | 13.1 | 0.8 | 0.6 | 9.1 | 4.7 |
| Sweden | 7.7 | 12.5 | 2.8 | 7.3 | 19.6 | 30.5 |
| France | 16.2 | 11.6 | 1.4 | 1.7 | 7.8 | 5.5 |
| Netherlands | 1.3 | 4.9 | 0.5 | 2.4 | 2.0 | 7.4 |
| Finland | 8.6 | 4.0 | 5.4 | 4.7 | 46.3 | 21.3 |
| Poland | 2.5 | 3.0 | 1.6 | 2.3 | 6.2 | 7.1 |
| Ireland | 5.8 | 2.5 | 21.0 | 9.7 | 31.4 | 10.8 |
| Spain | 9.6 | 2.5 | 4.7 | 2.2 | 9.3 | 2.3 |
| Italy | 3.7 | 2.1 | 1.8 | 1.3 | 2.4 | 1.3 |
| Romania | 0 | 2.0 | 0 | 9.4 | 0 | 13.8 |
| Bulgaria | 0 | 0.7 | 0 | 20.7 | 0 | 16.2 |
| Czechia | 0 | 0.3 | 0 | 1.0 | 0 | 2.0 |
| Belgium | 0 | 0.2 | 0 | 0.3 | 0 | 0.5 |
| Greece | 0 | 0.2 | 0 | 2.8 | 0 | 1.1 |
| Malta | 0 | 0.1 | 0 | 4.0 | 0 | 11.5 |
| Cyprus | 0 | 0 | 0 | 3 | 0 | 4 |
| Slovakia | 0 | 0 | 0 | 0 | 0 | 1 |
| Austria | 0.5 | 0 | 0.3 | 0 | 1.6 | 0 |
| Denmark | 1.4 | 0 | 0.7 | 0 | 5.5 | 0 |
| Estonia | 0 | 0 | 0 | 0 | 0 | 0 |
| Croatia | 0 | 0 | 0 | 45 | 0 | 0 |
| Hungary | 0 | 0 | 0 | 0 | 0 | 0 |
| Lithuania | 0 | 0 | 0 | 0 | 0 | 0 |
| Luxembourg | 0.5 | 0 | 1.6 | 0 | 11.3 | 0 |
| Latvia | 0 | 0 | 0 | 0 | 0 | 0 |
| Portugal | 2.0 | 0 | 12.7 | 0 | 11.8 | 0 |
| Slovenia | 1.0 | 0 | 9.1 | 0 | 27.7 | 0 |
| **EU 28 Total** | **105.0** | **79.5** | **1.5** | **1.8** | **7.9** | **5.8** |
| **Other Countries** | | | | | | |
| China | 336.8 | 262.7 | 1.1 | 1.0 | 42.8 | 26.5 |
| Korea | 96.6 | 56.8 | 1.2 | 1.2 | 90.8 | 45.6 |
| Rest of the world | 35.6 | 36.5 | 0.0 | 0.0 | 0 | 0 |
| Japan | 40.1 | 25.1 | 0.4 | 0.4 | 11.0 | 6.3 |
| United States | 23.6 | 23.5 | 0.4 | 0.6 | 1.8 | 1.4 |

*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. The UK is the largest applicant within this technology field within Europe, followed by Germany, Sweden and France.

Korea is strong in patent filings per GDP. Due to its size, Sweden ranks ahead of China. These two countries are followed by Finland, Bulgaria and Romania, though their absolute filing figures are comparably small.

Sweden and 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. ■

# RENEWABLE ENERGY TECHNOLOGIES IN TOTAL

| | Number of patent families | | Patents per € trillion GDP | |
|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 |
| **EU 28** | | | | |
| Germany | 656 | 551 | 237.7 | 196.1 |
| France | 204 | 186 | 98.4 | 88.7 |
| Denmark | 119 | 171 | 469.6 | 658.9 |
| United Kingdom | 91 | 97 | 45.6 | 47.3 |
| Spain | 115 | 85 | 110.9 | 79.6 |
| Netherlands | 77 | 66 | 119.0 | 99.1 |
| Poland | 54 | 60 | 133.1 | 142.5 |
| Italy | 42 | 42 | 27.5 | 26.9 |
| Sweden | 32 | 29 | 82.0 | 71.6 |
| Finland | 27 | 28 | 146.3 | 151.7 |
| Austria | 33 | 28 | 108.4 | 90.8 |
| Belgium | 24 | 18 | 64.3 | 46.4 |
| Romania | 18 | 17 | 127.6 | 119.4 |
| Ireland | 12 | 13 | 65.0 | 55.5 |
| Slovakia | 12 | 11 | 166.3 | 139.4 |
| Czechia | 11 | 8 | 66.0 | 44.0 |
| Latvia | 3 | 5 | 146.1 | 249.9 |
| Portugal | 6 | 3 | 33.0 | 18.9 |
| Luxembourg | 5 | 3 | 112.9 | 57.8 |
| Lithuania | 3 | 3 | 75.6 | 74.1 |
| Hungary | 4 | 2 | 38.7 | 19.4 |
| Bulgaria | 0 | 1 | 0.0 | 28.3 |
| Slovenia | 3 | 1 | 83.0 | 22.5 |
| Greece | 0 | 1 | 1.8 | 4.4 |
| Malta | 0 | 0 | 0.0 | 46.2 |
| Cyprus | 1 | 0 | 28.6 | 12.0 |
| Estonia | 2 | 0 | 96.2 | 0.0 |
| Croatia | 0 | 0 | 0.0 | 0.0 |
| EU 28 Total | 1 555 | 1 429 | 117.1 | 105.2 |
| **Other Countries** | | | n.a. | n.a. |
| China | 6 341 | 7 861 | 806.0 | 791.6 |
| Japan | 1 810 | 1 522 | 495.2 | 384.6 |
| Korea | 1 916 | 1 394 | 1 800.9 | 1 118.0 |
| United States | 852 | 812 | 64.5 | 49.4 |
| Rest of the world | 817 | 714 | 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 energy technologies shows that China has filed the largest number of patents in 2015, followed by Japan, the EU 28, Korea 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, the UK, Spain and the Netherlands. In terms of patents per GDP, Korea has the top position, followed by China, Denmark and Japan. The EU 28 is in the (upper) midfield while the U.S. is located in the lower midfield. Within Europe, Denmark, Latvia, 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). It is mostly China who scores first in the number of patent families within the sample, although Korea often scores among first when looking at patents per GDP, which is also the case for China, but to a lesser extent. Europe takes a middle position between the Asian countries and the U.S. Besides the technology field biofuels, the U.S. is not very active in patenting RET technologies relative to other countries. It 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 (compared to the other countries in the field).

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, i.e. it is the third largest field behind solar energy and wind energy. Regarding ocean energy, in terms of patents and R&D spending it is less significant, albeit its resource and technological development potentials. ■

# International Trade

*Analysing international 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. The mainstream in international trade theories predict that the international trade of goods occurs because of comparative advantages, i.e. different advantages in manufacturing goods between two countries essentially lead to trade between these two countries. Empirical data, however, has shown that not only factor endowment but also the technological capabilities of a country affect its export performance. Firms that develop new products or integrate superior technology will thus dominate the export markets of these products (e.g. Dosi and Soete 1983, 1991; Krugman 1979; Posner 1961; Vernon 1966, 1979). In sum, it can be stated that innovation is positively correlated with export 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*

*In order to depict trade, the absolute (export) advantage in terms of global export shares as well as net exports, i.e. exports minus imports of a given country, are analysed. Net exports reveal 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 a product in terms of a country vis-à-vis another country. Early economists believed that absolute advantage in a certain product category would be a necessary condition for trade. Yet, 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 analy-sis of trade-flows has thus become an important topic in trade economics. The most widely used indicator is 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.*

$$RCA_{ij} = 100 \cdot \text{tanhyp}\left( \log \frac{E_{ij} / \sum_{k=1}^{j} E_{ik}}{\sum_{k=1}^{i} E_{kj} / \sum_{k=1}^{i} \sum_{l=1}^{j} E_{kl}} \right)$$

*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 ener-gies 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 years 2017 and 2018. The export data were extracted from the UN Comtrade database. The fields were identified based on a selection of Harmonized System Codes (HS 2012).*

1. *The HS 2012 codes used for the demarcation are: Photovoltaics (854140), wind energy (850231) and hydroelectricity (841011, 841012, 841013, 841090). For biofuels, the codes (220710, 220720) are based on the classification by JRC SETIS in Pasimeni F., EU energy technology trade: Import and export, EUR 28652 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-69670-1, doi:10.2760/607980, JRC107048.*

# ALL RES

| | Share of technology on global exports | | Net exports (in € m) | | Export specialisation (RCA) | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| **EU 28** | | | | | | |
| Germany | 6.70% | 11.72% | 524 | 278 | -24 | 13 |
| The Netherlands | 3.10% | 4.54% | 29 | -426 | 4 | 16 |
| Denmark | 3.19% | 4.15% | 1710 | 1389 | 93 | 94 |
| Spain | 2.10% | 2.94% | 939 | 460 | 11 | 29 |
| France | 1.57% | 2.93% | 24 | 215 | -59 | -24 |
| Belgium | 0.75% | 1.17% | 70 | -160 | -84 | -75 |
| United Kingdom | 0.95% | 1.14% | -994 | -645 | -77 | -78 |
| Hungary | 0.59% | 1.02% | 111 | 45 | -12 | 22 |
| Austria | 0.63% | 0.87% | -17 | -53 | -38 | -28 |
| Czechia | 0.36% | 0.53% | -15 | -36 | -80 | -72 |
| Portugal | 0.21% | 0.50% | 9 | 53 | -51 | 2 |
| Sweden | 0.28% | 0.47% | -121 | -233 | -83 | -69 |
| Poland | 0.26% | 0.32% | -149 | -225 | -93 | -93 |
| Luxemburg | 0.11% | 0.24% | 6 | 3 | 29 | 70 |
| Slovenia | 0.15% | 0.23% | 30 | 29 | -23 | -3 |
| Slovakia | 0.12% | 0.21% | 25 | 14 | -88 | -79 |
| Bulgaria | 0.08% | 0.12% | 1 | -4 | -72 | -53 |
| Croatia | 0.17% | 0.12% | 3 | 3 | 54 | 3 |
| Ireland | 0.07% | 0.07% | -35 | -37 | -98 | -99 |
| Lithuania | 0.05% | 0.06% | -8 | -22 | -87 | -85 |
| Estonia | 0.05% | 0.03% | 8 | -24 | -55 | -87 |
| Finland | 0.02% | 0.03% | -107 | -41 | -99 | -99 |
| Greece | 0.01% | 0.03% | -229 | -311 | -99 | -97 |
| Romania | 0.03% | 0.03% | -138 | -162 | -99 | -99 |
| Latvia | 0.02% | 0.02% | -24 | -16 | -91 | -91 |
| Cyprus | 0.00% | 0.00% | -7 | -25 | -100 | -100 |
| Malta | n.a. | 0.00% | n.a. | -6 | n.a. | -100 |
| **EU-28 total (incl. Intra-EU trade)** | 22.32% | 34.59% | 1478 | -213 | -39 | -18 |
| **Other Countries** | | | | | | |
| USA | 7.56% | 12.53% | -3353 | -983 | -19 | 13 |
| Japan | 5.98% | 9.25% | -592 | -228 | 36 | 57 |
| India | 0.50% | 0.69% | -3983 | -2399 | -85 | -81 |
| Canada | 0.54% | 0.66% | -916 | -823 | -91 | -91 |
| Switzerland | 0.16% | 0.32% | -227 | -170 | -98 | -95 |
| Russia | 0.14% | 0.21% | -195 | -248 | -99 | -99 |
| Turkey | 0.03% | 0.07% | -3446 | -652 | -100 | -99 |
| Serbia | 0.03% | 0.04% | -1 | -97 | -87 | -86 |
| Norway | 0.29% | 0.03% | -132 | -372 | -62 | -100 |
| New Zealand | 0.00% | 0.01% | -30 | -29 | -100 | -100 |
| Albania | 0.00% | 0.00% | -5 | -4 | n.a. | n.a. |
| Montenegro | 0.00% | 0.00% | -1 | -42 | -100 | -100 |
| China | 26.11% | n.a. | 6862 | 0 | 58 | n.a. |
| Liechtenstein | n.a. | n.a. | 0 | 0 | n.a. | n.a. |
| Rest of the World | 36.38% | 41.64% | 1900 | -3904 | 20 | 31 |

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

*Continues overleaf*

When taking a look at the export shares in all four selected renewable energies technologies, it can be observed China has the largest values in 2017 with 26%. For the EU-28, we see an in-crease in export shares from 22% in 2017 to nearly 35% in 2018. However, the trade values 2018 are not yet available for China, and this is why the EU-28 scores first - above the 2017 values of China. The U.S., Germany, Japan, the Netherlands and Denmark display the largest shares after China. The countries with the smallest shares in comparison are Albania, Monte-negro, Malta, Cyprus, New Zealand, Latvia, Finland, Romania and Estonia. In sum, however, nearly all of the observed countries have increased their RET exports in 2018. Germany, the U.S. and Japan have the largest growth rates in export shares.

The net exports, i.e. the exports of an economy minus its imports, allow us to provide a little more detail on the above described trends. Net exports 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. China has a very positive trade balance (value for 2017), i.e. the largest balance among the countries in comparison. China is followed by Denmark, Spain, Germany, France, Portugal, Hungary, Slovenia, Slovakia, Luxemburg, Croatia and Liechtenstein. Since these countries are all exporting more RET goods than they are importing, i.e. their trade balance is positive. All other countries in this comparison have negative trade balances. This is also true for the EU-28, where the trade balance has decreased since 2017. The countries with the most negative trade balances are India, the U.S., Canada, Turkey and the UK. Japan also still has a negative trade balance, but it has improved its position between 2017 and 2018.

In a final step, we take a closer look at the export specialization (RCA). Here, Denmark scores ahead of the remaining countries, i.e. goods related to RET technologies have a large weight in Denmark's export portfolio. Positive specialization values can also be found for Luxembourg, China (2017), Japan, Spain, Hungary, the Netherlands, Germany, the U.S., Croatia and Portugal while all other countries (besides the "rest of the world" group) show a negative specialization regarding the export of goods related to RET technologies in 2018. ■

# WIND ENERGY

| | Share of technology on global exports | | Net exports (in € m) | | Export specialisation (RCA) | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| **EU 28** | | | | | | |
| Germany | 23.23% | 39.61% | 923 | 1051 | 76 | 87 |
| Denmark | 37.55% | 33.38% | 1801 | 1480 | 100 | 100 |
| Spain | 21.38% | 19.66% | 970 | 791 | 98 | 98 |
| Portugal | 2.09% | 3.63% | 101 | 160 | 94 | 96 |
| The Netherlands | 1.72% | 0.83% | 74 | -25 | -50 | -91 |
| Sweden | 0.00% | 0.33% | -33 | -107 | -100 | -83 |
| Greece | 0.12% | 0.20% | -164 | -270 | -45 | -25 |
| Estonia | 0.49% | 0.17% | 24 | 5 | 93 | 37 |
| Belgium | 0.32% | 0.15% | -3 | -148 | -97 | -100 |
| Ireland | 0.34% | 0.14% | 9 | 4 | -70 | -97 |
| Poland | 0.25% | 0.08% | 12 | 3 | -93 | -100 |
| Lithuania | 0.07% | 0.07% | 2 | 3 | -72 | -80 |
| France | 0.02% | 0.03% | -132 | -112 | -100 | -100 |
| Czechia | 0.02% | 0.03% | 1 | -1 | -100 | -100 |
| United Kingdom | 0.08% | 0.03% | -626 | -381 | -100 | -100 |
| Italy | 0.07% | 0.02% | -20 | -41 | -100 | -100 |
| Finland | 0.00% | 0.01% | -71 | -1 | -100 | -100 |
| Latvia | 0.00% | 0.00% | 0 | 0 | -100 | -99 |
| Austria | 0.03% | 0.00% | -35 | -40 | -100 | -100 |
| Romania | 0.03% | 0.00% | 1 | -1 | -99 | -100 |
| Bulgaria | 0.00% | 0.00% | 0 | 0 | -100 | -100 |
| Slovakia | 0.00% | 0.00% | 0 | 0 | n.a. | -100 |
| Hungary | 0.00% | 0.00% | 0 | 0 | -100 | -100 |
| Luxemburg | 0.00% | 0.00% | 0 | 0 | -100 | -100 |
| Croatia | 0.35% | 0.00% | -11 | 0 | 86 | n.a. |
| Cyprus | 0.00% | 0.00% | 0 | 0 | n.a. | n.a. |
| Malta | n.a. | 0.00% | 0 | 0 | n.a. | n.a. |
| Slovenia | 0.00% | 0.00% | 0 | 0 | -100 | n.a. |
| EU-28 total (incl. Intra-EU trade) | 88.16% | 98.37% | 2823 | 2372 | 74 | 70 |

*Continues overleaf*

| | | | | | | |
|---|---|---|---|---|---|---|
| **Other Countries** | | | | | | |
| India | 0.33% | 0.61% | 8 | 23 | -93 | -85 |
| Japan | 0.01% | 0.28% | -153 | -88 | -100 | -99 |
| USA | 0.36% | 0.27% | -170 | -153 | -100 | -100 |
| Turkey | 0.01% | 0.01% | -223 | -211 | -100 | -100 |
| Canada | 0.02% | 0.01% | -253 | -133 | -100 | -100 |
| New Zealand | 0.00% | 0.00% | 0 | 0 | -100 | -100 |
| Russia | 0.01% | 0.00% | -36 | -9 | -100 | -100 |
| Switzerland | 0.01% | 0.00% | 0 | 0 | -100 | -100 |
| Norway | 3.40% | 0.00% | -46 | -296 | 94 | -100 |
| Montenegro | n.a. | 0.00% | 0 | -41 | n.a. | n.a. |
| Serbia | 0.00% | 0.00% | 0 | -69 | n.a. | n.a. |
| Albania | n.a. | n.a. | 0 | 0 | n.a. | n.a. |
| China | 7.47% | n.a. | 316 | 0 | -52 | n.a. |
| Liechtenstein | n.a. | n.a. | 0 | 0 | n.a. | n.a. |
| Rest of the world | 0.23% | 0.43% | -1474 | -2400 | -100 | -100 |

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

In wind power, Germany (40%) and Denmark (33%) are the major players in terms of export shares. They are followed by Spain, which also shows large export shares in wind energy of nearly 20%. Consequently, more than 90% of worldwide exports in wind technologies originate from these three countries. In total, the EU-28 is responsible for a share of 98%. The Chinese export shares are comparably small with 7.5% (only the value for 2017 is available). Similar patterns can also be observed for the trade balance. Here, the largest values can be found for Denmark, followed by Germany, Spain and China (2017), although the value for China is comparably smaller than for the other three countries.

In terms of export specialization (RCA), Denmark, Spain, Portugal, Germany, Croatia (2017) and Estonia are the most highly specialized in trade with wind technology related goods. China, on the other hand, has a negative export specialization in wind technology related goods (2017). China thus seems to focus much more clearly on PV technologies. ■



EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2019 EDITION

# PHOTOVOLTAICS

| | Share of technology on global exports | | Net exports (in € m) | | Export specialisation (RCA) | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| **EU 28** | | | | | | |
| Germany | 5.40% | 9.23% | -35 | -328 | -43 | -11 |
| The Netherlands | 2.09% | 3.81% | -158 | -514 | -34 | -1 |
| France | 0.78% | 1.95% | -219 | -80 | -88 | -58 |
| Italy | 0.68% | 1.14% | -138 | -209 | -90 | -82 |
| United Kingdom | 0.41% | 0.66% | -304 | -154 | -95 | -92 |
| Czechia | 0.29% | 0.59% | -48 | -44 | -86 | -68 |
| Austria | 0.34% | 0.47% | -138 | -151 | -78 | -72 |
| Belgium | 0.26% | 0.46% | -112 | -164 | -98 | -96 |
| Luxemburg | 0.14% | 0.36% | 9 | 6 | 50 | 86 |
| Hungary | 0.07% | 0.19% | -176 | -261 | -98 | -89 |
| Croatia | 0.18% | 0.16% | 19 | 8 | 56 | 34 |
| Slovenia | 0.09% | 0.16% | -4 | -8 | -64 | -40 |
| Spain | 0.10% | 0.16% | -79 | -386 | -99 | -99 |
| Sweden | 0.05% | 0.16% | -41 | -48 | -99 | -96 |
| Poland | 0.13% | 0.15% | -136 | -190 | -98 | -99 |
| Denmark | 0.06% | 0.14% | -9 | -11 | -98 | -92 |
| Slovakia | 0.03% | 0.10% | -22 | -25 | -99 | -95 |
| Ireland | 0.05% | 0.08% | -2 | -9 | -99 | -99 |
| Lithuania | 0.04% | 0.06% | -10 | -18 | -92 | -87 |
| Portugal | 0.03% | 0.06% | -73 | -89 | -98 | -97 |
| Finland | 0.03% | 0.04% | -35 | -40 | -99 | -99 |
| Romania | 0.02% | 0.02% | -85 | -103 | -100 | -100 |
| Estonia | 0.01% | 0.01% | -15 | -27 | -99 | -98 |
| Greece | 0.00% | 0.01% | -12 | -18 | -100 | -100 |
| Bulgaria | 0.00% | 0.00% | -31 | -32 | -100 | -100 |
| Cyprus | 0.00% | 0.00% | -7 | -8 | -99 | -100 |
| Latvia | 0.00% | 0.00% | -4 | -3 | -100 | -100 |
| Malta | n.a. | 0.00% | 0 | -5 | n.a. | -100 |
| EU-28 total (incl. Intra-EU trade) | 11.29% | 20.19% | -1865 | -2911 | -80 | -62 |

*Continues overleaf*

| | | | | | | |
|---|---|---|---|---|---|---|
| **Other Countries** | | | | | | |
| Japan | 7.66% | 13.82% | -53 | 239 | 55 | 78 |
| USA | 4.75% | 8.98% | -4745 | -2570 | -57 | -20 |
| Canada | 0.49% | 0.65% | -163 | -212 | -92 | -91 |
| Switzerland | 0.17% | 0.43% | -132 | -75 | -98 | -92 |
| India | 0.27% | 0.40% | -3905 | -2316 | -95 | -93 |
| Russia | 0.03% | 0.10% | -168 | -235 | -100 | -100 |
| Turkey | 0.01% | 0.07% | -3158 | -388 | -100 | -99 |
| Serbia | 0.03% | 0.04% | 8 | 4 | -81 | -79 |
| Norway | 0.00% | 0.01% | -21 | -24 | -100 | -100 |
| Albania | 0.00% | 0.00% | 0 | -2 | n.a. | n.a. |
| Montenegro | 0.00% | 0.00% | 0 | -1 | -100 | -100 |
| New Zealand | 0.00% | 0.00% | -19 | -21 | -100 | -100 |
| China | 32.23% | n.a. | 6240 | 0 | 71 | n.a. |
| Liechtenstein | n.a. | n.a. | 0 | 0 | n.a. | n.a. |
| Rest of the world | 43.08% | 55.35% | 4316 | -1182 | 35 | 54 |

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

On top of this general view on RET, we will take a closer look at the export shares by RET sub-fields. In photovoltaics (PV) (Table 23) again, the top position of China can be confirmed. In 2017, more than 32% of worldwide exports in PV originate from China, followed by Japan (8%), Germany (6%) and the U.S. (5%) in 2018. The EU-28 reach a share of 11% in 2017 and 20% in 2018 (China is still missing in 2018). For Japan, Germany and the U.S. also a growth in shares between 2017 and 2018 can be found, For the «rest of the world» category, share is also very high (55% in 2018). Regarding net exports in PV, positive values can only be found for China (2017), Japan, Croatia, Luxembourg and Serbia. All other countries in this comparison have a negative trade balance, i.e. they are importing more PV technologies than they export. The most negative one can be found for the EU-28, followed by the U.S. and India, implying that these countries are highly dependent on imports from other countries in PV technologies. These trends are also reflected in the RCA values. Luxembourg is most highly specialized in goods related to PV (though absolute values are very small), followed by Japan, China (2017) and Croatia. ■

# BIOFUELS

| | Share of technology on global exports | | Net exports (in € m) | | Export specialisation (RCA) | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| **EU 28** | | | | | | |
| The Netherlands | 10.60% | 9.74% | 110 | 112 | 85 | 73 |
| France | 7.10% | 7.66% | 353 | 377 | 68 | 61 |
| Hungary | 4.24% | 4.47% | 286 | 300 | 95 | 94 |
| Belgium | 3.93% | 4.25% | 173 | 145 | 41 | 31 |
| Germany | 3.90% | 3.51% | -398 | -454 | -66 | -79 |
| United Kingdom | 4.83% | 3.37% | -65 | -117 | 55 | 5 |
| Spain | 1.51% | 2.00% | 31 | 41 | -22 | -8 |
| Sweden | 1.87% | 1.62% | -45 | -74 | 62 | 37 |
| Poland | 1.08% | 1.08% | -25 | -39 | -19 | -44 |
| Austria | 1.28% | 1.06% | 63 | 41 | 29 | -10 |
| Slovakia | 0.78% | 0.72% | 47 | 38 | 41 | 15 |
| Bulgaria | 0.47% | 0.54% | 26 | 26 | 73 | 72 |
| Italy | 0.64% | 0.54% | -72 | -85 | -91 | -96 |
| Czechia | 0.50% | 0.19% | -3 | -23 | -65 | -96 |
| Latvia | 0.11% | 0.10% | -4 | -5 | 34 | 2 |
| Lithuania | 0.09% | 0.07% | 1 | -7 | -55 | -81 |
| Denmark | 0.07% | 0.04% | -80 | -78 | -98 | -99 |
| Portugal | 0.02% | 0.03% | -19 | -18 | -100 | -99 |
| Romania | 0.03% | 0.01% | -57 | -59 | -99 | -100 |
| Estonia | 0.02% | 0.01% | -1 | -2 | -95 | -98 |
| Ireland | 0.06% | 0.01% | -42 | -30 | -99 | -100 |
| Slovenia | 0.01% | 0.01% | -4 | -4 | -100 | -100 |
| Croatia | 0.00% | 0.00% | -7 | -8 | -100 | -100 |
| Greece | 0.00% | 0.00% | -20 | -20 | -100 | -100 |
| Luxemburg | 0.00% | 0.00% | -1 | -2 | -100 | -100 |
| Cyprus | 0.00% | 0.00% | 0 | -17 | -100 | -100 |
| Finland | 0.00% | 0.00% | 0 | 0 | n.a. | n.a. |
| Malta | n.a. | 0.00% | 0 | -1 | n.a. | n.a. |
| EU-28 total (incl. Intra-EU trade) | 43.12% | 41.04% | 244 | 38 | 24 | -1 |
| **Other Countries** | | | | | | |
| USA | 30.20% | 32.77% | 1573 | 1747 | 83 | 80 |
| India | 1.23% | 1.06% | -136 | -149 | -34 | -60 |
| Canada | 1.08% | 0.96% | -490 | -452 | -68 | -81 |
| Russia | 0.69% | 0.63% | 48 | 43 | -81 | -92 |
| Japan | 0.01% | 0.02% | -407 | -382 | -100 | -100 |
| Switzerland | 0.02% | 0.02% | -69 | -62 | -100 | -100 |
| Turkey | 0.01% | 0.01% | -57 | -53 | -100 | -100 |
| Serbia | 0.00% | 0.00% | -4 | -4 | -100 | -100 |
| New Zealand | 0.00% | 0.00% | -2 | -2 | -100 | -100 |
| Albania | 0.00% | 0.00% | 0 | 0 | n.a. | n.a. |
| Montenegro | 0.00% | 0.00% | 0 | 0 | n.a. | n.a. |
| Norway | 0.00% | 0.00% | -38 | -36 | -100 | n.a. |
| China | 0.83% | n.a. | 48 | 0 | -99 | n.a. |
| Liechtenstein | n.a. | n.a. | 0 | 0 | n.a. | n.a. |
| Rest of the world | 22.82% | 23.49% | -556 | -149 | -26 | -25 |

*Continues overleaf*

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

In biofuels (i.e. ethyl alcohols with a strength of 80 degrees or more as well as other denatured spirits), we see a different picture. In this field the EU-28 and the U.S. score the top positions when looking at the shares on global exports. More than 70% of worldwide exports in biofuels originate from these two regions (2017 as well as 2018). Yet, we see a slight decline for the EU-28 since 2017, while the U.S. enlarged its export activities within this field. The largest EU countries in terms of trade shares are the Netherlands, France, Hungary, Belgium, Germany and the UK. When looking at net exports, 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 net export values can be observed for France, Hungary and Belgium. The most negative trade balance becomes visible for Germany, Canada, Japan and India, implying that these countries are highly dependent on imports from other countries with regard to biofuels. Once again, these trends can be confirmed when looking at the RCA values. Hungary is the country that is most highly specialised in goods related to biofuels, followed by the U.S., the Netherlands, Bulgaria, France and Sweden. ■

# HYDROELECTRICITY

| | Share of technology on global exports | | Net exports (in € m) | | Export specialisation (RCA) | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| **EU 28** | | | | | | |
| Austria | 11.77% | 18.12% | 93 | 97 | 99 | 99 |
| Italy | 7.70% | 11.19% | 64 | 62 | 74 | 81 |
| France | 4.30% | 6.78% | 23 | 30 | 32 | 53 |
| Slovenia | 4.52% | 6.59% | 38 | 41 | 100 | 100 |
| Germany | 5.53% | 5.65% | 35 | 8 | -41 | -54 |
| Czechia | 4.08% | 5.47% | 35 | 32 | 87 | 89 |
| Spain | 2.55% | 2.77% | 17 | 14 | 29 | 24 |
| United Kingdom | 1.11% | 2.10% | 1 | 7 | -69 | -40 |
| Belgium | 1.19% | 0.89% | 12 | 6 | -64 | -84 |
| Hungary | 0.09% | 0.73% | 1 | 5 | -96 | -10 |
| Bulgaria | 0.81% | 0.64% | 6 | 3 | 90 | 79 |
| Romania | 0.49% | 0.54% | 2 | 0 | 17 | 2 |
| Portugal | 0.37% | 0.48% | 0 | -1 | 2 | -1 |
| Croatia | 0.24% | 0.47% | 1 | 2 | 74 | 89 |
| Sweden | 0.12% | 0.25% | -2 | -3 | -96 | -90 |
| Finland | 0.05% | 0.19% | -1 | 0 | -97 | -74 |
| Poland | 0.15% | 0.16% | 1 | 1 | -97 | -98 |
| The Netherlands | 0.29% | 0.14% | 3 | 1 | -98 | -100 |
| Denmark | 0.02% | 0.07% | -2 | -2 | -100 | -98 |
| Lithuania | 0.01% | 0.06% | 0 | 0 | -100 | -87 |
| Luxemburg | 0.00% | 0.02% | -1 | -1 | -100 | -92 |
| Latvia | 0.00% | 0.00% | -16 | -8 | -100 | -100 |
| Greece | 0.00% | 0.00% | -34 | -4 | -100 | -100 |
| Ireland | 0.00% | 0.00% | -1 | -1 | -100 | -100 |
| Slovakia | 0.05% | 0.00% | 0 | 0 | -98 | -100 |
| Malta | n.a. | 0.00% | 0 | 0 | n.a. | -100 |
| Cyprus | 0.00% | 0.00% | 0 | 0 | n.a. | n.a. |
| Estonia | 0.07% | 0.00% | 1 | 0 | -23 | n.a. |
| EU-28 total (incl. Intra-EU trade) | 45.53% | 63.32% | 275 | 288 | 29 | 40 |
| **Other Countries** | | | | | | |
| India | 5.84% | 7.31% | 50 | 44 | 84 | 84 |
| USA | 3.68% | 6.12% | -11 | -7 | -72 | -53 |
| Japan | 3.17% | 2.11% | 22 | 4 | -26 | -68 |
| Canada | 1.20% | 2.05% | -11 | -25 | -62 | -35 |
| Switzerland | 1.21% | 1.58% | -25 | -33 | -36 | -25 |
| Norway | 0.22% | 1.37% | -26 | -17 | -76 | 48 |
| Russia | 1.56% | 1.24% | -39 | -48 | -30 | -71 |
| Turkey | 0.82% | 1.18% | -8 | 1 | -12 | 7 |
| Serbia | 0.09% | 0.30% | -5 | -28 | -9 | 70 |
| New Zealand | 0.09% | 0.12% | -8 | -7 | -73 | -64 |
| Montenegro | 0.00% | 0.00% | -1 | 0 | n.a. | -100 |
| Albania | 0.00% | 0.00% | -5 | -2 | n.a. | n.a. |
| China | 26.01% | n.a. | 258 | 0 | 58 | n.a. |
| Liechtenstein | n.a. | n.a. | 0 | 0 | n.a. | n.a. |
| Rest of the world | 10.65% | 13.60% | -385 | -173 | -77 | -66 |

*Continues overleaf*

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

In hydro-power, we can see a more balanced picture than in the case of PV and wind energy. Within the EU-28, the largest export shares can be found for Austria (18%), Italy (11%), France (7%), Slovenia (7%) and Germany (6%). In sum, the EU-28 is responsible for more than 60% of the worldwide exports within hydro-power with rising shares In addition, we can even observe increases in the shares between 2017 and 2018.

As a single country, China shows a comparably large value of 26% (2017). China is followed by India and the U.S., which both show comparably small values for their size (7% and 6%, respectively). The largest positive net export values within the EU-28 are displayed for Austria, Italy, Slovenia, the Czech Republic, France, Spain and Germany. Yet, the largest value globally can be found for China (2017), followed by India. The US display a negative trade balance.

The specialization values in hydroelectricity show a rather positive picture for Europe, with ten EU-28 members having a positive RCA value. China also shows a positive value in 2017, but its specialization in PV is still higher than it is in hydroelectricity. India, however, shows the largest specialization in hydroelectricity among the non-European countries. ■


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# CONCLUSIONS

The export data in RET technologies provide evidence of the strong position of China in the last years, which China has even expanded in some fields. The Chinese strength in RET exports mostly originates from its strengths in photovoltaics, which is rather easy to assemble (for example compared to wind turbines). China has started building up PV cell and module manufacturing from scratch employing up-to-date automatization technologies. This makes China's production very competitive. In addition to PV, comparably large export shares for China can also be found in hydro power.

However, the picture becomes more diverse when looking at the other RET subfields, especially wind energy and also hydroelectricity. In wind energy, especially Germany and Denmark, but also Spain can be seen as strong competitive countries, dominating the worldwide export markets. These three countries in sum generate a worldwide export share of 98%, while China plays still a minor role. However, China is catching up with respect to trade shares (at least when comparing the 2017 with the 2016 and 2015 figures).

In hydroelectricity, the picture is very balanced. Several European countries are active on worldwide export markets, while also China is responsible for comparably large shares. However, the EU displays once more increasing shares in 2018 after increases between 2017 and 2016 (see last year's report).

Overall, the EU displays a strong competitiveness in all RET fields, and seems at least keeping its shares at a high level in 2018. The U.S. is mainly strong in biofuels, and is enforcing its position there, while in other RET its contribution is far below that of the EU. ■



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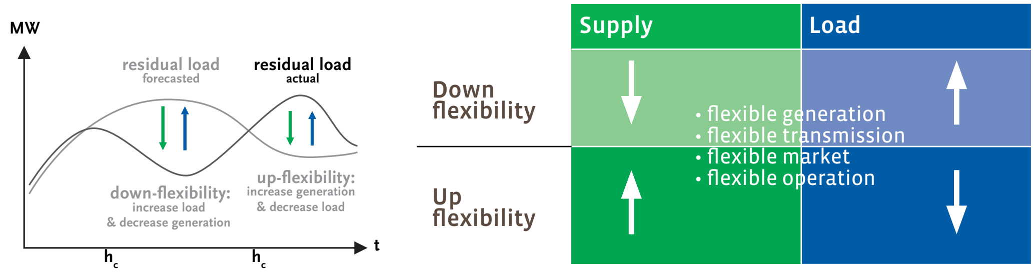
# INDICATORS ON THE FLEXIBILITY OF THE ELECTRICITY SYSTEM

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 be compensated by cross-border transfers,

**1**

*Flexibility needs of the power system*




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

**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.**

### 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.*

*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 Czech Republic, 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.

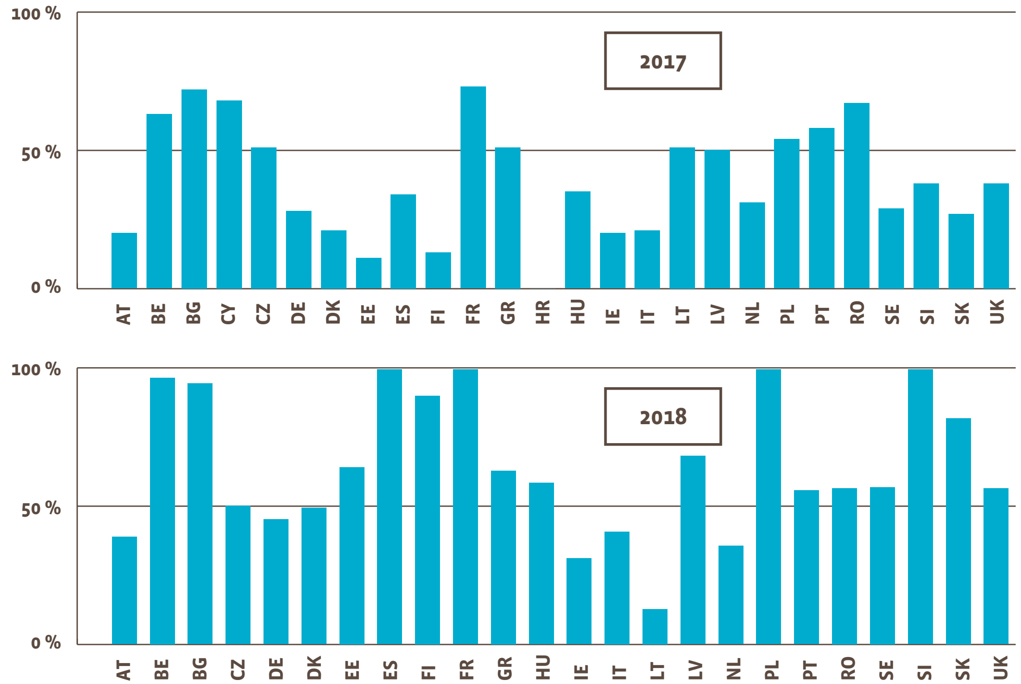
## GENERATION FLEXIBILITY

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.

Comparing the generation flexibility indicators of 2017 with those of 2018 a higher share of power

**2**

*Flexible generation in critical hours to available flexible generation (%) in 2017 and 2018*




*Source: EurObserv'ER - own assessment based on ENTSO-E data downloaded 10/2019. Note: no data available for CY, HR, LU and MT. Updates on generation capacity with data of net generation capacity in 2017 and installed generation capacity in 2018, due to incomplete data for installed generation capacity in 2018 and no data availability of net generation capacity in 2018.*

generation capacity has been used in critical hours. In 2017 the mean of the generation flexibility indicators was at 41% while in 2018 this ratio rose to 65%. Seven of the investigated EU MS, in particular Belgium, Bulgaria, Spain, Finland, France, Poland and Slovenia even used (almost) their total estimated generation flexibility potential during critical hours. Only Lithuania used less generation flexibility between 2017 and 2018, all the other EU MS increased their shares. In total, only eight countries remained at or below 50% of their generation flexibility potential in 2018. This puts emphasis on the fact, that out of all four flexibility indicators the generation flexibility has in average the highest relevance during critical hours.

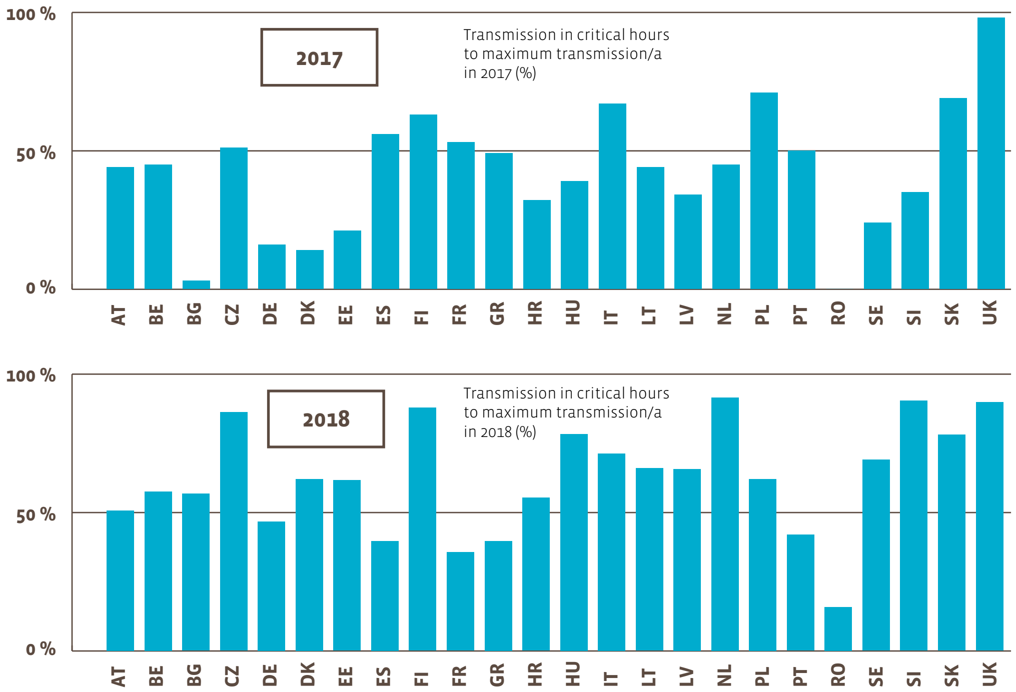
### TRANSMISSION FLEXIBILITY

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 2017 and 2018. 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.

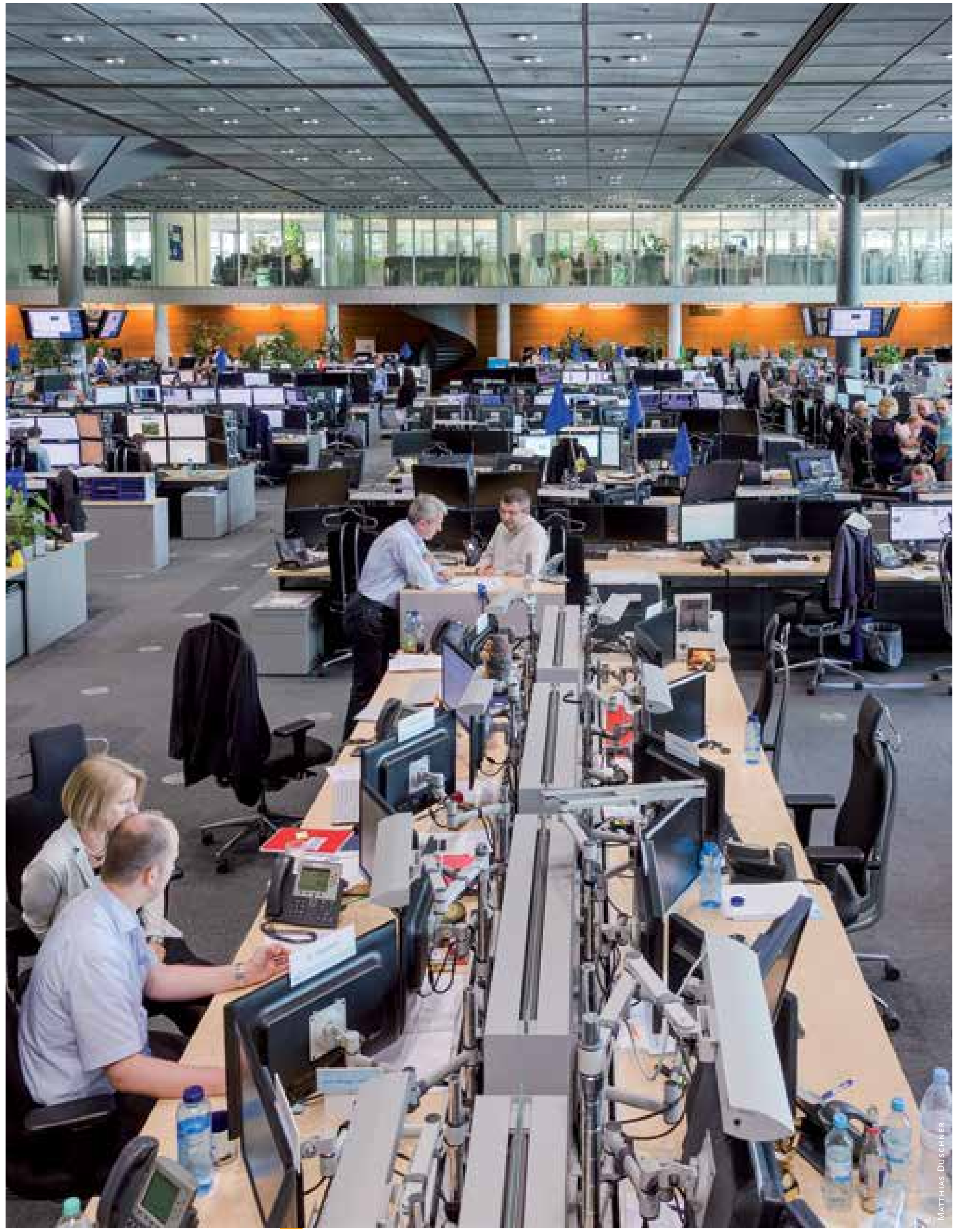
In 2018, the utilized transmission flexibility between neighboring EU MS depicts with 62% in average during critical hours a broadly

## 3

*Transmission up-flexibility in critical hours*



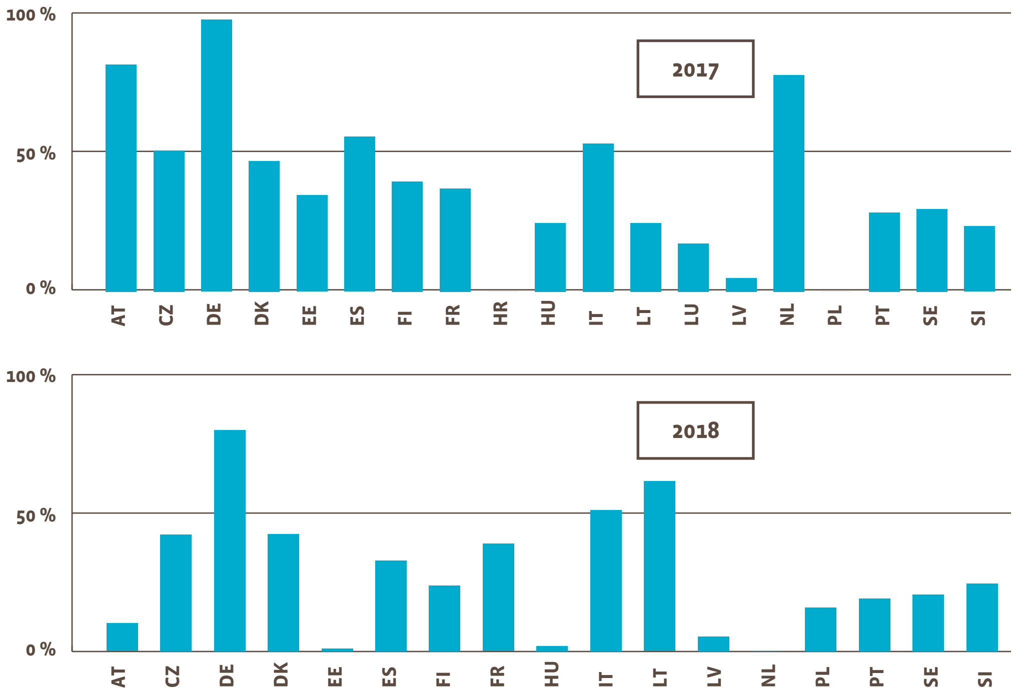

*Source: EurObserv'ER - own assessment based on ENTSO-E data downloaded 10/2019. Note: no data for CY, IE, LU and MT. In 2017 also no data for IE and LU.*



higher result compared to 2017 (41%). The Netherlands (91%), Slovenia (90%) and the United Kingdom (89%) depict the highest ratios, which states that these countries used around 90% of their power flows in times when power was scarce. In total 18 of the 25 investigated countries depict transmission flexibility indicators of 50% or higher. Especially in contrast to the measured values of 2017 one can conclude that during times of high forecast deviations the cross border power flows between neighboring countries in the EU increased in 2018. Though Romania with a ratio of just 16%, appears to remain far below its transmission potential during highest critical hours. Thus, with France (35%), Ireland (38%) and Spain (39%) following Romania, a significant difference between the utilized transmission flexibility in Romania and the rest of the EU MS is observed. Nevertheless, with regards to the results of 2017 (RO = 0%), it appears that in 2018 Romania starts relying more on power delivery from its neighbouring countries. Other countries like Bulgaria (56%), Germany (46%), Denmark (62%), Estonia (61%) and Sweden (69%) depict transmission ratios of around half or even higher of their potential while in 2017 their indicators remained in the lower quarter. Another EU MS that depict a significant growth is Slovenia, which almost tripled its ratio from 35% in 2017 to 90% in 2018.

**4**

*Intraday volume traded in critical hours compared to maximum volume/a*




*Source: EurObserv'ER - own assessment based on data of power exchanges downloaded 10/2019. Note: no intraday exchange in BG, CY, GR, IE, MT and SK. No data for RO. In 2017 also no data for BE and UK. In 2018 also no data for HR and LU. Data for BE, NL and UK in 2018 only from Nordpool. For DE and SI, the intraday auction data were also included.*





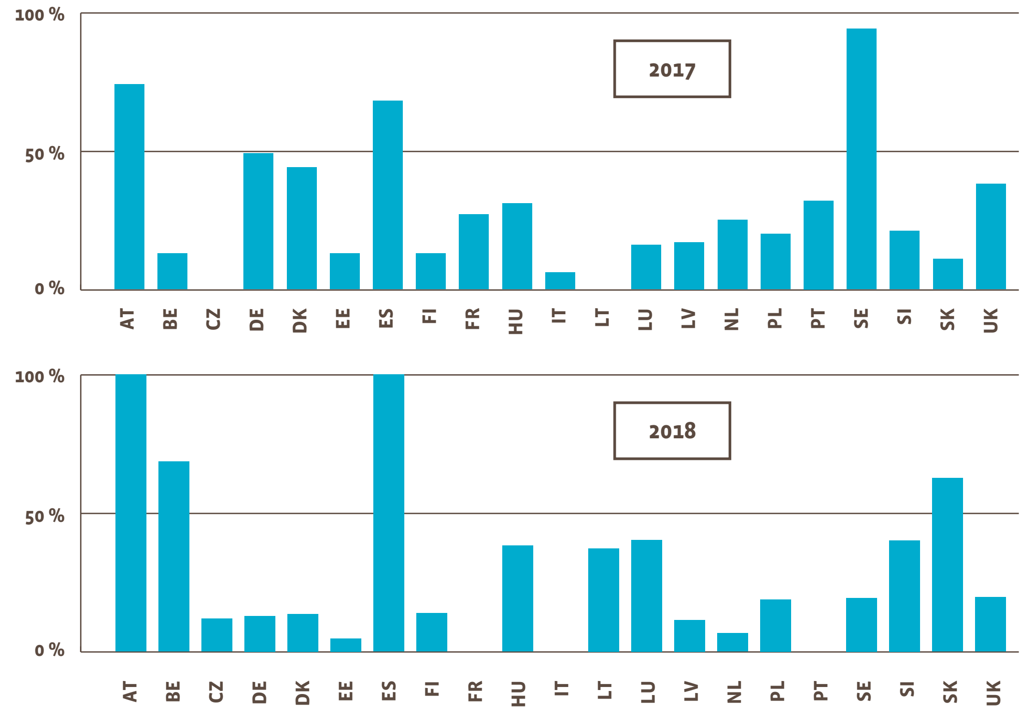
**MARKET FLEXIBILITY**

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 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.

More than half of the investigated countries in terms of market flexibility show similar patterns of their indicators in 2017 and 2018, in particular Czech Republic (42%) Germany (80%), Denmark (43%), Spain (33%), Finland (24%), Italy (51%), Latvia (5%) Portugal (19%) Sweden (21%) and Slovenia (25%), while the other countries depict different results. Austria (10%), Estonia (1%), Hungary (2%), and the Netherlands (0%)* decreased their intraday activity during critical hours while France (39%) and Poland (16%) increased their market flexibility indicator. Overall is the average share of all countries for this flexibility category with 26% the lowest mean of all indicators. Germany depicts in 2018 as well as in 2017 the highest market flexibility indicator among all investigated EU MS.

**5**

*Reserves used in critical hours compared to maximum reserves/a for up-flexibility*




*Source: EurObserv'ER - own assessment based on ENTSO-E data downloaded 10/2019. Note: no data for BG, CY, GR, IE, HR and MT. No data for RO in 2018. Trading conditions (e.g. time slots, contract volume, gate closure) vary among countries.*

## OPERATIONAL FLEXIBILITY

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

In 2018 two countries, Austria and Spain depict a 100% ratio of their operational flexibility indicators. These countries are followed by Belgium (69%) and Slovakia (63%). No activity of activated positive reserve capacity was observed in France, Italy and Portugal.in 2018. While France and Italy kept its remote operational flexibility share from 2017, Portugal depicts a different behavior in 2018. Also Germany (14%) Denmark (14%) Estonia (5%), Latvia (11%), Netherlands (7%) and the United Kingdom (20%) decreased their operational flexibility indicator compared to 2017. While Austria and Spain and Slovakia (63%) increased their shares, Hungary (38%) and Poland (19%) remained with similar patterns than the year before. ■






# CONCLUSIONS

Overall, the flexibility indicators depict in average higher values in 2018 compared to 2017. The mean share of all flexibility indicators in all EU countries rose from 34% to 46% within one year. 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.

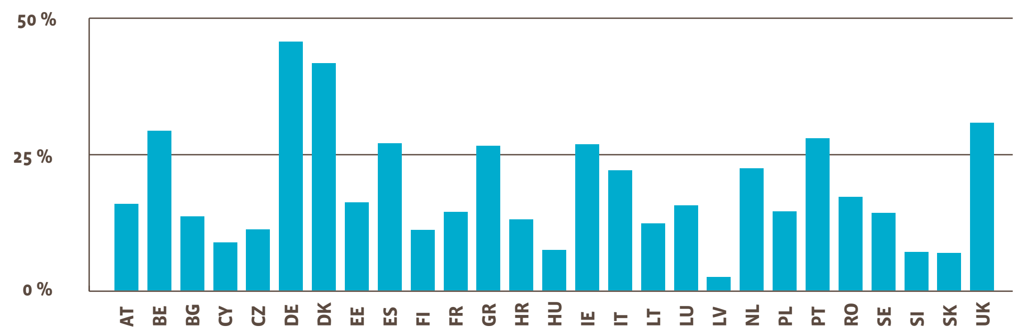
Subsequently, the power system of those countries, in which the share of installed vRE capacities to total generation capacities is the highest, are of special interest of this analysis. Among the investigated EU MS Germany (46%) and Denmark (42%) followed by the United Kingdom (31%) display the highest vRE shares in 2018 (see Figure 6). The lowest shares of vRE are depicted in Latvia (2%), Slovakia (7%), Slovenia (7%) and Hungary (7%).

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

While the countries with the highest vRE shares, Germany and Denmark, both reduced their operational flexibility during critical hours in 2018 compared to 2017, their market flexibility indicator rose. This observation illustrates a market shift from the regulated reserve market to the intraday market in order to allocate ramp-up power in times of forecast deviations. Though, Spain, with the fifth highest share of vRE, depicts the opposite behaviour in its critical hours with decreasing market flexibility and increasing operational and generation flexibility. Due to data accessibility the market flexibility indicators for UK and BE were only calculated with data from one of two market exchanges, which does not allow a final interpretation of the market behaviour of UK and BE during critical

**6**

*Share of volatile renewable energies (installed capacities) in 2018*




*Source: EurObserv'ER - own assessment based on ENTSO-E data downloaded 10/2019. Since the data of Net Generation Capacity is not anymore available for 2018 and the data of the Installed Capacity per Production Type is not consistent, the share of volatile renewable energies is assessed based on the data of Installed Capacity for 2018, adjusted by data of the Net Generation Capacity in 2017. Note: no data available for MT in 2018.*

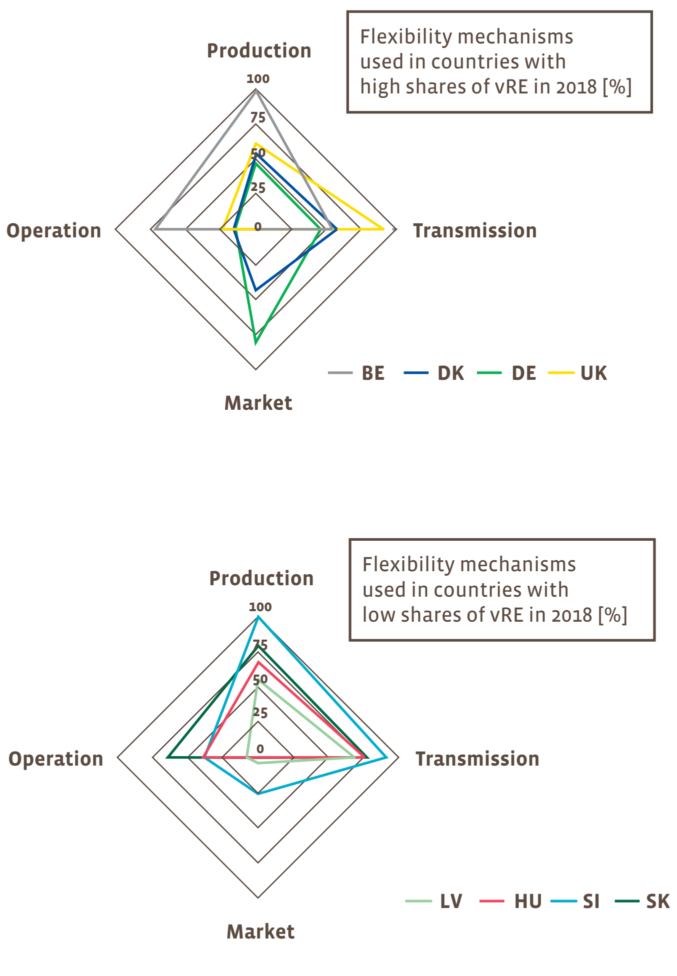
hours. Nevertheless, the indicators depict, that the UK relies the most on transmission flexibility in times of high forecast deviations and BE the most on generation flexibility.

The selected countries with low vRE shares have all small market flexibility indicators and intensive utilization of generation and transmission flexibility mechanisms in common. With regards to the market mechanisms, it has to be noticed, that Slovakia does not provide an intraday market exchange. While Latvia depicts rather small operational flexibility mechanisms during its critical hours, Slovenia (40%) and Slovakia (63%) illustrate higher shares of the latter mechanism.

In 2018, not only the overall average of the flexibility indicators was higher than in 2017 but also the number of countries with a flexibility indicator above 80% has increased. In Figure 8, the upper half shows the countries which depicts two or more indicators above 80% while the lower half illustrates the top three countries with the highest overall average (values of flexibility indicators). Regarding the upper half of Figure 8, depicting countries with two or more extensive flexibility indicators, Spain and Slovenia utilized all 100% and Finland 90% of their generation flexibility during their critical hours. Though, the other flexibility indicator which reached shares above 80% is differently partitioned. As for Spain the operational flexibility mechanism is utilized completely, Finland and

## 7

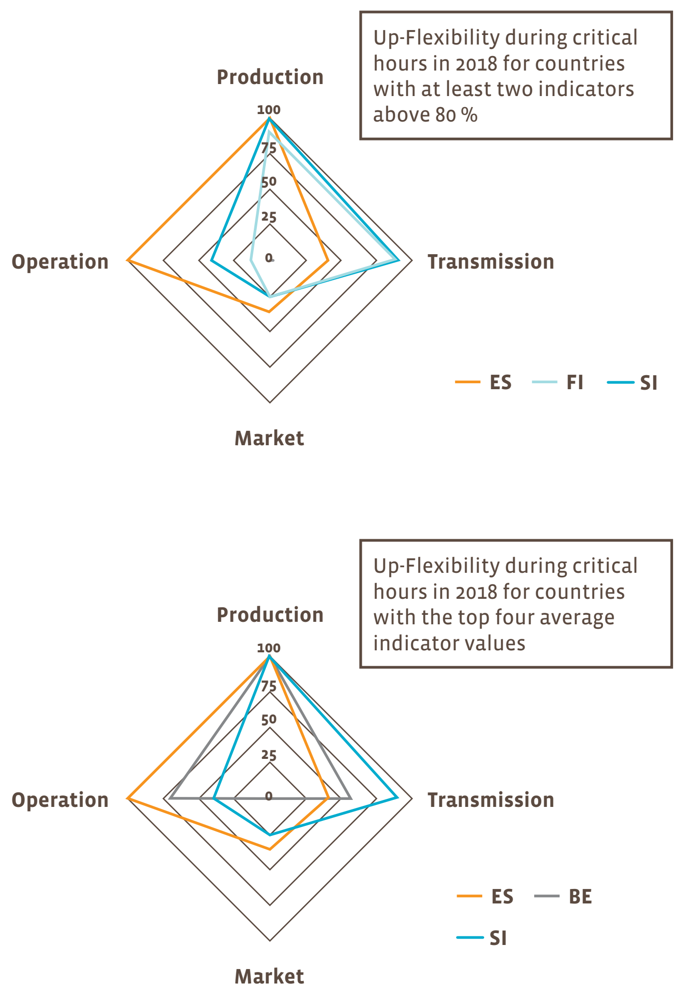
*Pattern of flexibility mechanisms for countries with high and low shares of vRE capacity*




***Source: EurObserv'ER - own assessment based on ENTSO-E data downloaded 10/2019 and data of power exchanges downloaded 10/2019.***
*Note: No intraday market in SK, incomplete intraday market data for BE and UK..*

## 8

*Pattern of flexibility mechanisms for countries with high flexibility indicators*




***Source: EurObserv'ER - own assessment based on ENTSO-E and power stock exchange data downloaded 10/2019.***
*Note: Incomplete intraday market data for BE..*

Slovenia are depending on transmission flexibility during their critical hours.

The lower part of Figure 8, depicts a similar observation as the one above, with the market flexibility as the least preferred mechanism to tackle forecast deviations. However, this might be explained by the rather heterogeneous developed state of the national intraday power exchanges. This means, that in some countries the intraday market is already well established, while in other countries it is still at its very early stages. ■

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- EEG (Energy Economics Group) / Vienna University of Technology *(www.eeg.tuwien.ac.at)*
- IG Windkraft – Austrian Wind Energy Association *(www.igwindkraft.at)*
- Kleinwasserkraft Österreich – Small Hydro Association Austria *(www.kleinwasserkraft.at)*
- Lebensministerium – Federal Ministry of Agriculture, Forestry, Environment and Water Management *(www.lebensministerium.at)*
- Nachhaltig Wirtschaften *(www.nachhaltigwirtschaften.at)*
- Österreichischer Biomasse-Verband – Austrian Biomass Association *(www.biomasseverband.at)*
- OeMAG – Energy Market Services *(www.oekb.at/en/energy-market/oemag/)*
- ProPellets Austria – Pellets Association Austria *(www.propellets.at)*
- PV Austria – Photovoltaic Austria Federal Association *(www.pvaustria.at)*
- Statistik Austria – Bundesanstalt Statistik Österreich *(www.statistik.at)*
- Umweltbundesamt – Environment Agency Austria *(www.umweltbundesamt.at)*
- Vienna University of Technology *(www.tuwien.ac.at)*




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**BELGIUM**

- ATTB – Belgium Thermal Technics Association *(www.attb.be/index-fr.asp)*
- APERe – Renewable Energies Association *(www.apere.org)*
- BioWanze – CropEnergies *(www.biowanze.be)*
- Cluster TWEED – Technologie wallonne énergie environnement et développement durable *(www.clusters.wallonie.be/tweed)*
- CWaPE – Walloon Energy Commission *(www.cwape.be)*
- ICEDD – Institute for Consultancy and Studies in Sustainable Development *(www.icedd.be)*
- SPF Economy – Energy Department – Energy Observatory *(www.economie.fgov.be)*
- ODE – Sustainable Energie Organisation Vlaanderen *(www.ode.be)*
- Valbiom – Biomass Valuation ASBL *(www.valbiom.be)*
- VEA – Flemish Energy Agency *(www.energiesparen.be)*
- VWEA – Flemish Wind Energy Association *(www.vwea.be)*
- Walloon Energie Portal *(www.energie.wallonie.be)*

**BULGARIA**

- ABEA – Association of Bulgarian Energy Agencies *(www.abea-bg.org)*
- APEE Association of Producers of Ecological Energy *(www.apee.bg/en)*
- CL SENES BAS – Central Laboratory of Solar Energy and New Energy Sources *(www.senes.bas.bg)*
- EBRD – Renewable Development Initiative *(www.ebrd.com)*
- Invest Bulgaria Agency *(www.investbg.government.bg)*
- NSI – National Statistical Institute *(www.nsi.bg)*
- SEC – Sofia Energy Centre *(www.sec.bg)*
- SEDA – Sustainable Energy Development Agency *(www.seea.government.bg)*

**CYPRUS**

- Cyprus Institute of Energy *(www.cyi.ac.cy)*
- MCIT – Ministry of Commerce, Industry and Tourism *(www.mcit.gov.cy)*
- CERA – Cyprus Energy Regulatory Authority *(www.cera.org.cy)*

**CROATIA**

- Croatian Bureau of Statistics *(www.dzs.hr/default_e.htm)*
- University of Zagreb *(www.fer.unizg.hr/en)*
- HEP – Distribution System Operator *(www.hep.hr)*
- HROTE – Croatian Energy Market Operator *(www.hrote.hr)*
- Croatian Ministry of Economy *(www.mingo.hr/en)*

**CZECHIA**

- MPO – Ministry of Industry and Trade – RES Statistics *(www.mpo.cz)*
- ERU – Energy Regulatory Office *(www.eru.cz)*
- CzBA – Czech Biogas Association *(www.czba.cz)*
- CZ Biom – Czech Biomass Association *(www.biom.cz)*
- Czech Wind Energy Association *(www.csve.cz/en)*

**DENMARK**

- DANBIO – Danish Biomass Association *(www.biogasbranchen.dk)*
- Danish Wind Industry Association *(https://en.winddenmark.dk)*
- Energinet.dk – TSO *(www.energinet.dk)*
- ENS – Danish Energy Agency *(www.ens.dk)*
- PlanEnergi *(www.planenergi.dk)*

**ESTONIA**

- EBU – Estonian Biomass Association *(www.eby.ee)*
- Espel – MTÜ Eesti Soojuspumba Liit *(www.soojuspumbaliit.ee)*
- EWPA – Estonian Wind Power Association *(www.tuuleenergia.ee/en)*
- Ministry of Finance *(www.fin.ee)*
- Ministry of Economics *(www.mkm.ee)*
- MTÜ – Estonian Biogas Association
- STAT EE – Statistics Estonia *(www.stat.ee)*
- TTU – Tallinn University of Technology *(www.ttu.ee)*

**FINLAND**

- Finbio – Bio-Energy Association of Finland *(www.bioenergia.fi)*
- Finnish Board of Customs *(www.tulli.fi/en)*
- Finnish Biogas Association *(biokaasuyhdistys.net)*
- Finnish Energy – Energiateollisuus *(energia.fi/)*
- Metla – Finnish Forest Research Institute *(www.metla.fi)*
- Statistics Finland *(www.stat.fi)*
- SULPU – Finnish Heat Pump Association *(www.sulpu.fi)*
- Suomen tuulivoimayhdistys – Finnish Wind Power Association *(www.tuulivoimayhdistys.fi)*
- TEKES – Finnish Funding Agency for Technology and Innovation *(www.tekes.fi/en)*
- Teknologiateollisuus – Federation of Finnish Technology Industries *(www.teknologiateollisuus.fi)*
- University of Eastern Finland *(www.uef.fi)*
- VTT – Technical Research Centre of Finland *(www.vtt.fi)*

**FRANCE**

- ADEME – Environment and Energy Efficiency Agency *(www.ademe.fr)*
- AFPAC – French Heat Pump Association *(www.afpac.org)*
- AFPG – Geothermal French Association *(www.afpg.asso.fr)*
- CDC – Caisse des Dépôts *(www.caissedesdepots.fr)*
- Club Biogaz ATEE – French Biogas Association *(www.biogaz.atee.fr)*
- DGEC – Energy and Climat Department *(https://www.ecologique-solidaire.gouv.fr)*
- Enerplan – Solar Energy organisation *(www.enerplan.asso.fr)*
- FEE – French Wind Energy Association *(www.fee.asso.fr)*
- France Énergies Marines *(www.france-energies-marines.org)*
- In Numeri – Consultancy in Economics and Statistics *(www.in-numeri.fr)*
- Observ'ER – French Renewable Energy Observatory *(www.energies-renouvelables.org)*
- OFATE – Office franco-allemand pour la transition énergétique *(enr-ee.com/fr/qui-sommes-nous.html)*
- SVDU – National Union of Treatment and Recovery of Urban and Assimilated Waste *(www.incineration.org)*
- SER – French Renewable Energy Organisation *(www.enr.fr)*
- SDES – Observation and Statistics Office – Ministry of Ecology *(www.statistiques.developpement-durable.gouv.fr)*
- UNICLIMA – Syndicat des industries thermiques, aérauliques et frigorifiques *(www.uniclima.fr/)*

**GERMANY**

- AA – Federal Foreign Office *(energiewende.diplo.de/home/)*
- AEE – Agentur für Erneuerbare Energien – Renewable Energy Agency *(www.unendlich-viel-energie.de)*
- AGEB – Arbeitsgemeinschaft Energiebilanzen *(www.ag-energiebilanzen.de)*
- AGEE-Stat – Working Group on Renewable Energy Statistics *(www.erneuerbare-energien.de)*
- AGORA Energiewende – Energy Transition Think Tank *(www.agora-energiewende.de)*
- BAFA – Federal Office of Economics and Export Control *(www.bafa.de)*

- BBE – Bundesverband Bioenergie *(www.bioenergie.de)*
- BBK – German Biogenous and Regenerative Fuels Association *(www.biokraftstoffe.org)*
- B.KWK – German Combined Heat and Power Association *(www.bkwk.de)*
- BEE – Bundesverband Erneuerbare Energie – German Renewable Energy Association *(www.bee-ev.de)*
- BDEW – Bundesverband der Energie und Wasserwirtschaft e.V *(www.bdew.de)*
- BDW – Federation of German Hydroelectric Power Plants *(www.wasserkraft-deutschland.de)*
- BMUB – Federal Ministry for the Environment, Nature Conservation and Nuclear Safety *(www.bmub.bund.de/en/)*
- BMWi – Federal Ministry for Economics Affairs and Energy *(www.bmwi.de/Navigation/EN/Home/home.html)*
- BWE – Bundesverband Windenergie – German Wind Energy Association *(www.wind-energie.de)*
- BSW-Solar – Bundesverband Solarwirtschaft – PV and Solarthermal Industry Association *(www.solarwirtschaft.de)*
- BWP – Bundesverband Wärmepumpe – German Heat Pump Association *(www.waermepumpe.de)*
- Bundesnetzagentur – Federal Network Agency *(www.bundesnetzagentur.de)*
- Bundesverband Wasserkraft – German Small Hydro Federation *(www.wasserkraft-deutschland.de)*
- BVES – German Energy Storage Association *(www.bves.de)*
- CLEW – Clean Energy Wire *(www.cleanenergywire.org)*
- Dena – German Energy Agency *(www.dena.de)*
- DGS – EnergyMap Deutsche Gesellschaft für Solarenergie *(www.energymap.info)*
- DBFZ – German Biomass Research Centre *(www.dbfz.de)*
- Deutsche WindGuard GmbH *(www.windguard.de)*
- 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 – German Environment Agency *(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)*

**LUXEMBOURG**
- 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)*
- Le portail des statistiques (STATEC) *(https://statistiques.public.lu/fr/index.html)*

**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)*
- 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 for the Ecological Transition *(https://energia.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/collections/renewables-statistics)*
- DUKES – Digest of United Kingdom Energy Statistics *(https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes)*
- 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)*



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**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 *(https://slovak.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/)*

## REFERENCES FOR SOCIO-ECONOMIC INDICATORS


- WindEurope 2019: Financing and investment trends. The European wind industry in 2018, published April 2019, *https://windeurope.org/about-wind/reports/financing-and-investment-trends-2018.*
- SPE 2019: Global Market Outlook for Solar Power 2019 -2023, Solar Power Europe (SPE), *https://www.solarpowereurope.org/eu-market-outlook-for-solar-power-2019-2023.*
- Solar Heat Europe 2019: Solar Heat Markets in Europe, Trends and Market Statistics 2017, Summary (November 2018), *http://solarheateurope.eu/publications/market-statistics/solar-heat-markets-in-europe/.*
- EGEC 2019: EGEC Geothermal Market Report 2018– Key findings, European Geothermal Energy Council, *https://www.egec.org/wp-content/uploads/2019/05/KeyFindings_MR-18.pdf, June 2019.*
- IEA 2019: IEA Geothermal, 2018 Annual Report, International Energy Agency, *http://iea-gia.org/publications-2/annual-reports/, November 2019.*
- Graphical Research 2018: Europe Air Source Heat Pump Market Size, Industry Analysis Report, Country Outlook, Growth Potential, Competitive Market Share & Forecast, 2018 – 2024, *https://www.graphicalresearch.com/industry-insights/1025/europe-air-source-heat-pump-market, August 2018.*
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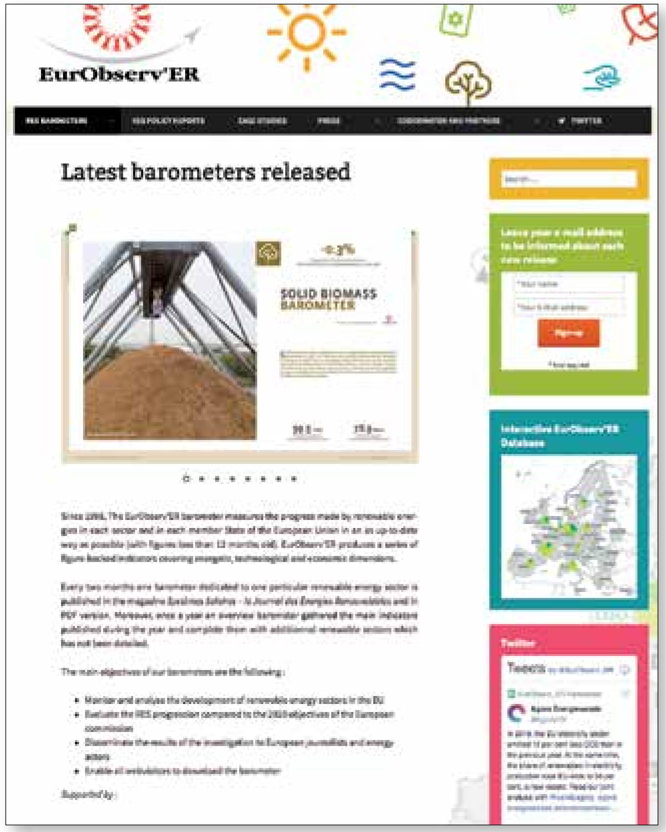

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### *Schedule for the 2020 EurObserv'ER barometers*

| | |
|---|---|
| **Wind power** | **›› March 2020** |
| **Photovoltaic** | **›› April 2020** |
| **Solar thermal** | **›› June 2020** |
| **Biofuels** | **›› September 2020** |
| **Heat pumps** | **›› November 2020** |
| **Solid biomass** | **›› December 2020** |

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