THE STATE OF RENEWABLE ENERGIES IN EUROPE

EDITION 2021

20th EurObserv'ER Report

This barometer was prepared by the EurObserv'ER consortium, which groups together Observ'ER (FR), TNO (NL),Renewables Academy (RENAC) AG (DE), Fraunhofer ISI (DE), VITO (Flemish Institute for Technological Research) (BE) and Statistics Netherlands (NL).

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EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2021 EDITION

TWENTY

Vincent Jacques le Seigneur, président of Observ'ER

Twenty, as in twentieth edition. The EurObserv'ER barometer produced on behalf of the European Commission, year after year, that assesses the progress made by the Member States to ensure the development of renewable energies, is coming of age. Twenty as in 2020 – a milestone year – a deadline that the European Council set itself in December 2008, during the French presidency, as part of an "energy-climate" legislative package, that was passed unanimously despite the fact that some thought that this voting system would condemn it to failure. Lastly, twenty as a simple percentage but an ambitious target to reach in the three dimensions of energy transition: the renewable share of the energy mix, the growth of energy efficiency and the effort to reduce greenhouses gases, the famous 3 x 20 policy.

The irrefutable result is there for all to see – renewable energies accounted for 22.1% of gross final energy consumption in 2020. That is the main conclusion of this new barometer produced by a consortium of European players led by Observ'ER. It is a success that confirms the position of those who had the temerity to silence the perennial doubters of this European gamble. It is thanks to the binding target for each country, the team game, the rivalry between Member States, the encouraging medium-term prospects for investors and companies alike, that this wild wager was won.

This new EurObserv'ER barometer gauges the progress made by renewable energies, sector by sector, country by country. Their share has more than doubled between 2004 and 2020. This performance can be credited to slightly higher renewable energy consumption in the transport sector driven by the 10% renewable energy target, the renewable share of total energy consumption for heating and cooling (23.1% in 2020), but above all by the surge in renewable electricity production. In fact, 38% of the European Union's total gross electricity output in 2020 was generated from renewable sources with variable inputs. While wind energy and hydropower account for the bulk of renewable electricity production, the photovoltaic sector is the fastest growing. This diversity of renewable electricity sources is a boon because their abundance means that corrections can make up for their variability. Wind energy is strongest in the winter months and in the early morning, whereas solar prevails in the middle of the day and the summer months and, lastly, hydropower can be controlled to delay turbine production until the end of the day when electricity needs are at their highest.

The current target of the new Renewable Energy Directive is to raise the renewable energy share to 32% by 2030, which will take the renewable share of the electricity mix to 57%. This is considered to be too low given the climate emergency. The European Commission has devised a new "Fit for 55"[1] legislative package, to raise the new renewable energy target to 40%. The challenge may seem far-fetched as it entails increasing the renewable energy share again to just over double its current level within a decade. However, the situation is urgent, and we have strengths: public opinion is behind us, decision makers, many of whom have had their aggiornamento in this area and a fully mature European industry with highly competitive technologies.

The undeniable success of 2020 was just a staging point in the European Union's strategy to be the first continent to achieve climate neutrality by 2050. It is already a source of hope for Old Europe to demonstrate its capacity to act and change the world, in this area, and perhaps others in the future. ■

1. *A set of twelve legislative proposals published by the European Commission on 14 July 2021 that aims at reducing GHG emissions by at least 55% in 2030 compared to their 1990 level.*

ENERGY INDICATORS

EurObserv'ER has been compiling data on the European Union's renewable energy sources for over twenty years, to chronicle the state and dynamics of the sectors in thematic barometers. The first part of this opus condenses the barometers released in 2021 for the solar thermal, CSP, heat pump, renewable energy in transport and solid biomass sectors. All the energy indicators have been consolidated in these summaries using the official Eurostat data published for 2019 and 2020. Analysis and detailed statistical monitoring incorporating the latest official data have also been conducted on the remaining sectors that were not subject to dedicated barometers last year, namely: wind energy, solar photovoltaic, hydropower, geothermal energy, ocean energy, biogas and renewable municipal waste. Thus, this document offers a comprehensive overview of the energy dimension of every industrially-developed renewable sector in the European Union.

Methodological note

The tables reproduce the most recent figures available for each sector. Bearing in mind the publication date of this edition, most of the energy indicators released in this work originate from the Eurostat database updated on 25 January 2022 (Complete energy balances), and from those specific to the Renewable Energy Directive indicators provided by the 1 February 2022 update of the Eurostat SHARES tool (Short Assessment of Renewable Energy Sources). This data alignment takes in the indicators for primary energy production, domestic energy consumption, net maximum electrical capacity, electricity production from power-only plants or cogeneration plants, gross heat production from heat-only plants or cogeneration plants, final energy consumption (industry, transport and other sectors), biofuel consumption in transport and the total solar thermal collector area in service.

However, whenever there are no parallel indicators published by Eurostat, such as market data for the various categories of heat pump (number of units sold) or solar thermal collector area (in installed square metres), the indicators used are solely those of EurObserv'ER. We also present specific indicators for pilot projects and prototypes in the ocean energy and CSP sectors, to enhance our appraisal of the sectors' momentum and activity.

The energy indicators drawn from Eurostat sources are those defined in the joint "Annual Renewable Questionnaire" methodology used by Eurostat and the International Energy Agency available through the following link: https://ec.europa.eu/eurostat/fr/web/energy/methodology/annual.

Accordingly, electrical capacity data refers to the notion of net maximum capacity defined as the maximum active capacity that can be supplied, continuously, by all the installations in service at their exit point, recording the net maximum capacity on 31 December of the year in question, expressed in MW.
As for the energy used for heating and cooling, gross heat production (from the processing sector) is distinguished from final energy consumption, in line with Eurostat definitions. Gross heat production corresponds to the total heat produced by heating plants and CHP plants (combined heat and power production). It includes the heat used by any auxiliary equipment in the installation that operates with hot fluids (space heating, liquid fuel heating, etc.) and heat exchange losses between the facility and the grid, in addition to chemical process heat used as a primary form of energy. In the case of auto-producing facilities, the heat used by the undertaking for its own processes is excluded from the data, only the part of the heat sold to third parties is included.

Final energy consumption represents all the energy for all uses delivered to end users such as households, industry and agriculture and thus excludes the energy used for processing processes and energy-producing industries' own use.
As for the gross electricity and heat production data, a distinction is made between the plants that only generate either electricity or heat and cogeneration plants that combine the production of both energy types.
The Overseas Departments are included in the indicators for France. The United Kingdom, that officially left the European Union on 1 February 2020, no longer features in the European Union energy indicators.

WIND ENERGY

THE EU'S NET WIND ENERGY CAPACITY BASE RISES TO 177 GW DURING 2020

According to Eurostat's calculations for the European Union, net installed wind energy capacity (defined as the net maximum capacity that can be injected into the grid), increased by 9.8 GW (9 822.1 MW) between 2019 and 2020, to a new figure of 177 GW (176 984.2 MW). This extra capacity, which makes allowance for the capacities decommissioned over the year, is a little less than the 10 GW (9 995.4 MW) added in 2019. The view is that had it not been for the COVID-19 pandemic that disrupted supply chains and delayed the commissioning of new wind farms, this growth would have been higher.

Eurostat reports that precisely 25% of the EU-27's new capacity installed over the 12-month period was offshore, thus 75% corresponds to land-based installations. This offshore proportion is higher than it was in 2019, when it amounted to 15.3% of net additional capacity. The Eurostat total installed wind energy capacity data for the EU-27, signals an 8.2% share for offshore wind energy in 2020 (7.2% in 2019), with net capacity of 14.5 GW (14 497.1 MW).

In 2020, the Netherlands pulled out all the stops to install new capacity, which resulted in 2 134.6 MW of net additional capacity, and was largely achieved by connecting new offshore wind farms. Germany came second with 1 446 MW of new capacity (2 021 MW in 2019) which is its smallest annual addition since 2010. Sweden, where the installation of several hundreds of MW had to be postponed during 2021, came third with 1 295 MW of new capacity in 2020 (1 381 MW in 2019). Spain could not match its 2019 effort (when it added 2 185 MW) and finished fourth with 1 229.1 GW. Similarly, France failed to equal its 2019 performance of 1 556.7 MW by only just managing to install one gigawatt of net capacity (1027.1 MW).

2.5 GW OF ADDITIONAL OFFSHORE WIND TURBINES JUST OUT OF REACH IN 2020

Eurostat reckons that the European Union was close to adding 2.5 GW (2 452.8 MW) of net offshore wind energy capacity in 2020, taking the EU's maximum net offshore wind energy capacity spread over seven countries, to 14.5 GW (14 497.1 MW) in 2020. In actual fact this figure is a little higher because Ireland's official wind energy capacity statistics do not single out the capacity of its offshore Arklow Bank Wind Park (25 MW) commissioned in 2004. Likewise, the official statistics omit the 5-MW Elisa prototype commissioned in 2019 off the coast of Gran Canaria (Canary Islands, Spain) and the 2-MW floating wind energy prototype commissioned in 2018 off the coast of Croisic (Brittany, France) (2 MW).

The four players driving the offshore wind energy segment are Germany with net capacity of 7 774 MW at the end of 2020, followed by the Netherlands (2 459.5 MW) just ahead of Belgium (2 261.8 MW) and Denmark (1 700.8 MW).

The Netherlands led the pack in 2020 by hooking up the Borssele I & II (752-MW) and Borssele V (19-MW) Wind Farms. The Borssele III & IV Wind Farms

VATTENFALL

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Wind power capacity installed in the European Union at the end of 2020 (MW)*

	2 019	*Of which Offshore*	2 020	*Of which Offshore*
Germany	60 742.0	*7 555.0*	62 188.0	*7 774.0*
Spain	25 590.1		26 819.2	
France	16 456.9		17 484.0	
Italy	10 679.5		10 870.6	
Sweden	8 681.0	*203.0*	9 976.0	*203.0*
Netherlands	4 484.2	*957.0*	6 618.8	*2 459.5*
Poland	5 837.8		6 298.3	
Denmark	6 102.9	*1 700.8*	6 259.5	*1 700.8*
Portugal	5 222.7		5 122.3	*25.0*
Belgium	3 863.4	*1 555.5*	4 680.9	*2 261.8*
Ireland	4 126.5		4 306.7	
Greece	3 589.0		4 119.3	
Austria	3 224.1		3 226.0	
Romania	3 037.5		3 012.5	
Finland	2 284.0	*73.0*	2 586.0	*73.0*
Croatia	646.3		801.3	
Bulgaria	703.1		702.8	
Lithuania	534.0		540.0	
Czechia	339.4		339.4	
Hungary	323.0		321.0	
Estonia	316.0		317.0	
Cyprus	157.7		157.7	
Luxembourg	135.8		152.7	
Latvia	77.9		77.9	
Slovenia	3.3		3.3	
Slovakia	4.0		3.0	
Malta	0.1		0.1	
Total EU-27	167 162.2	*12 044.3*	176 984.2	*14 497.1*

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

were partially connected in 2020 (with 732 MW). Belgium added 706 MW when it hooked up its Northwester (218-MW) and Sea-Made (487-MW) wind farms. The latter is now its biggest offshore wind farm. Continuing our survey of the North Sea, Germany added 219 MW of capacity through the EnBW Albatros and Trianel Borkum 2 wind farms. The EnBW Albatros Wind Farm (112-MW) is the most remote (105 km) of its offshore wind farms. In 2020, Portugal added two new Vestas V164-8.4 M turbines to its Windfloat Atlantic floating Wind Farm to make three (combined capacity of 25 MW). This wind farm's total capacity was also officially accounted for in 2020 despite the fact that its first floating wind turbine was installed in December 2019.

Two other wind farms were under construction in 2020 – the Danish Kriegers Flak Wind Farm (605-MW) which will comprise 72 x SG 8.4-167 DD turbines and the near-shore Dutch Fryslân Wind Farm (389-MW) with 89 x SWT-DD-130 4.4-MW turbines. The EU's most powerful offshore wind turbines put into service in 2020 were the Vestas V164-9.5-MW turbines installed on the Borssele III & IV, Borssele V and Northwester 2 sites. The wind turbines currently operating are Siemens Gamesa SG 8.0-167 DD in the Borssele Wind Farm and Siemens Gamesa SG 8.4-167 DD in the SeaMade Wind Farm. The German offshore wind farms use the Siemens Gamesa SWT-7.0-154 turbines in the EnBW Albatros Wind Farm and the Senvion 6.2M152 turbines in the Trianel Borkum 2 Wind Park.

THE EU-27 GENERATED NIGH ON 400 TWH OF WIND ENERGY IN 2020

Wind energy dominated the EU-27 renewable electricity production sectors with actual output of 397.4 TWh (Eurostat data), ahead of hydroelectricity (with or without pumping). This figure amounted to an annual 8.2% increase in wind energy electricity output over the 367.2 TWh in 2019. Thus, wind energy accounted for 14.3% of the European Union's gross total electricity output measured at 2 781.4 TWh (12.7% share in 2019). Wind energy's share was over 50% in Denmark's electricity mix (56.8%) and reached 35.8% in Ireland, 29.2% in Lithuania, 23.2% in Portugal, 23.1% in Germany and 21.4% in Spain. In 2020, 16 of the 27 countries' wind energy sectors provided more than 10% of the national electricity output.

Between 2019 and 2020, Sweden (with a 7.7-TWh rise, or a total of 27.5 TWh), Germany with an extra 6.2 TWh (or a total of 132.1 TWh), France (a 5.0-TWh rise, or a total of 39.8 TWh), the Netherlands (a 3.8-TWh rise, or a total of 15.3 TWh) and Belgium (a 3-TWh rise, or a total of 12.8 TWh) recorded the highest increases in wind energy electricity output. The connection of new offshore wind farms by the Netherlands and Belgium installed over the past two years brought about the strong rises in wind energy electricity output (33.3% for the former and 30.1% for the latter). The Swedish (38.7%) and Finnish (31.8%) output surges can be put down to the connection of onshore wind farms and better winds than in 2019.

Now, offshore wind energy electricity output as a proportion of total EU-27 wind energy electricity output rose, to reach 47.3 TWh in 2020 (40.2 TWh in 2019), namely a 11.9% share in 2020 (10.9% in 2019). This share exceeded 50% in Belgium (54.6% of wind energy electricity is offshore), 40.4% in Denmark, 35.7% in the Netherlands and 20.7% in Germany.

EVEN MORE WIND ENERGY AWAITED IN 2030

The EU's European Climate Law sets a binding target of achieving climate neutrality by 2050 in the context of the Green Deal for Europe. It has raised its climate aim for the 2030 timeline as an interim step to climate neutrality by committing to an emissions reduction of at least 55%. Work on revising Europe's climate, energy and transport legislation is now underway to take on board the terms of the "Fit for 55" package and align the current texts with the ambitions set for 2030 and 2050. This package includes a proposal to amend the Renewable Energies Directive and raises the existing EU overall renewable energy share goal for 2030 from "at least 32%" to "at least 40%".

It is accepted that the majority of this goal will be achieved by wind energy, which is now the leading renewable electricity production sector. In its *Wind energy and economic recovery in Europe* publication (October 2020), WindEurope estimated wind energy's contribution to the national energy climate action plan (NECP) at 339.7 GW by 2030 for the EU-27 (397 GW of wind energy including 111 GW offshore for the EU and the United Kingdom), which will just suffice to achieve

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Electricity production from wind power in the European Union in 2019 et 2020 (TWh)

	2019	*Of which Offshore*	2020	*Of which Offshore*
Germany	125.894	*24.744*	132.102	*27.306*
Spain	55.647		56.444	
France	34.787		39.792	
Sweden	19.847	*0.606*	27.526	*0.633*
Italy	20.202		18.762	
Denmark	16.150	*6.198*	16.330	*6.603*
Poland	15.107		15.800	
Netherlands	11.508	*3.573*	15.339	*5.484*
Belgium	9.750	*4.794*	12.764	*6.974*
Portugal	13.667		12.299	*0.051*
Ireland	10.019		11.549	
Greece	7.266		9.310	
Finland	6.025	*0.271*	7.938	*0.293*
Romania	6.773		6.945	
Austria	7.450		6.792	
Croatia	1.467		1.721	
Lithuania	1.499		1.552	
Bulgaria	1.317		1.477	
Estonia	0.687		0.844	
Czechia	0.700		0.699	
Hungary	0.729		0.655	
Luxembourg	0.281		0.351	
Cyprus	0.239		0.240	
Latvia	0.154		0.177	
Slovenia	0.006		0.006	
Slovakia	0.006		0.004	
Malta	0.000		0.000	
Total EU-27	367.178	*40.185*	397.418	*47.344*

Source: Eurostat

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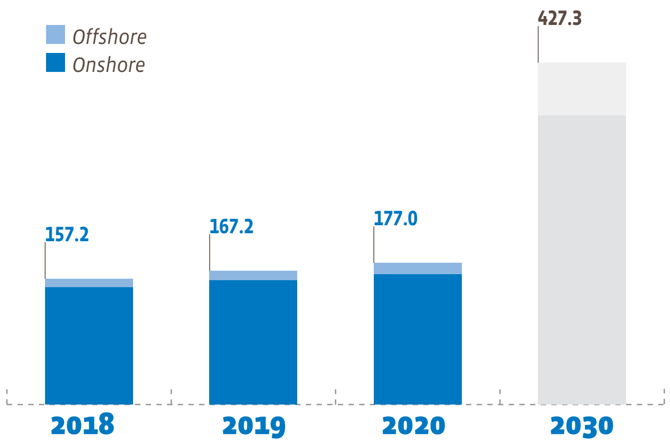
EurObserv'ER projection of the evolution of wind power net capacity in the EU-27 (in GW)



Source: EurObserv'ER 2019

the 32% renewable energy target in final energy, but will fall far short of achieving a 55% GHG reduction by 2030 founded on a renewable energy target closer to 40%. Wind-Europe warned that current NECP planned policies simply cannot supply these volumes of wind energy, because the rules for permitting projects have not been simplified and the lack of visibility surrounding tenders. Wind-Europe's Realistic Expectations Scenario indicated a mean of 15 GW per annum in the EU-27 for the next five years in its February 2021 publication, Wind energy Europe, whereas 18 GW is needed to adhere to the target trajectory of 32%. Rapid readjustment entailing a faster installation pace during the second half of this decade will be needed to raise the renewable energy targets to 40%. So, the success of the National Energy Climate Plan (NECP) revisions planned for 2023 will hinge on the wind energy targets. The European Commission published its own scenarios for implementing the European Green Deal in July 2021. Its MIX policy scenario suggests that the EU-27 net installed wind energy capacity figure needs to be 427.4 GW in 2030, including 361 GW of onshore and 63.4 GW of offshore wind energy. Projected electricity output would be 1 078.6 TWh (830.9 TWh onshore and 247.7 TWh offshore). The 2030 production level would be just over half (52.6%) of the total renewable electricity production contribution and 34.2% of all EU electricity produced.

The European Commission aims to raise the renewable electricity share to 75% by 2050, with 57% of energy consumption being supplied directly by electricity and an additional 18% from renewable hydrogen and its derivatives. The electricity demand needs to more than double from 3 000 to 6 800 TWh to achieve this. Given that the European Union aims for a wind energy share of about 50% by the 2050 timeline, the EU-27 should, according to WindEurope, increase its capacity to 1 000 GW of onshore and 300 GW of offshore wind energy by 2050. The upshot is that Europe will have to double its current annual wind farm construction pace, with no other option than to simplify the authorization rules and procedures for new wind farms if this is to be achieved. ■

PHOTOVOLTAIC

GLOBAL CAPACITY ROSE BY 145.2 GWp IN 2020

Globally, new photovoltaic capacity installations took off again in 2020 despite the raging COVID-19 pandemic. The IEA PVPS "TRENDS 2021" report identifies 145.2 GWp of newly-installed solar photovoltaic capacity (peak power), namely 31.2% growth on the 2019 installation figure (110.7 GWp). This additional capacity takes global photovoltaic capacity to 773.2 GWp. Looking back to 2000, overall photovoltaic capacity levelled off at just under 0.6 GWp (i.e., 570 MWp with 199 MWp installed that year). So, we can appreciate how far the world has come in twenty years. If this pace is sustained, the one peak terawatt of installed capacity threshold should be crossed in 2022.

The global market heavyweights are China whose annual installed capacity rose from 30.3 to 48.2 GWp in the year to 2020, the United States (which rose from 13.3 to 19.7 GWp) and Japan (which rose from 7 to 8.7 GWp). Now, the nominal DC capacity expressed in Wp used by the IEA-PVPS and the output capacity delivered to the grid as AC cannot be directly compared, because of conversion losses and regulations that limit photovoltaic facilities' output capacity onto the grid. Eurostat's indicators, which are quoted in this publication, represent the maximum net electrical capacity likely to be used as DC and thus are a little lower.

THE EUROPEAN MARKET HAS HELD UP WELL

The European Union of 27 also entered the new decade on a high note. While for a time, the market was upset by the pandemic's first wave, it made a strong comeback during the second half-year. Eurostat reports that the European Union added 18 224.8 MW of net capacity in 2020, compared to its 16 146.9 MW increase in 2019, registering a growth of 12.9%. The net additional capacity installed over the course of 2020 was actually the second highest ever posted for solar energy in the EU, after 2011, when an additional 22 253.8 MW of net capacity was installed. At the end of 2020, the EU's photovoltaic base stood at 136 136.6 MW, which is a 15.5% year-on-year increase. Preliminary estimates for 2021, suggest that the solar photovoltaic installation pace across the EU picked up speed and that the 2011 installation record should be broken.

While Spain led the field in 2019, Germany reclaimed its position as the European Union's largest solar photovoltaic energy market in 2020. Eurostat reports that its net installed capacity increased by 4 807 MW between 2019 and 2020 (compared to 3 756 MW between 2018 and 2019). The reason for Germany's success is its thriving self-consumption market, aided by a relatively high price electricity price for households and an attractive purchase premium mechanism for medium- and large-scale commercial systems (40–750 kW). The German market also relies on a proven tendering system for < 10 MW systems. Seven tenders were published over the 12 months, for a total of 1 300 MW. The lowest bid price was 3.55 euro cents per kWh, while the highest was 7.49 euro cents per kWh, for a maximum admissible price of 7.5 euro cents per kWh. During 2021, there were only three calls for tender for a total of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Installed solar photovoltaic capacity in the European Union at the end of 2020 (MW)*

	2019	2020
Germany	48 912.0	53 719.0
Italy	20 865.3	21 650.0
France	10 803.9	12 022.2
Netherlands	7 226.0	10 949.7
Spain	8 839.3	10 285.5
Belgium	4 636.6	5 574.8
Poland	1 539.3	3 955.0
Greece	2 833.8	3 287.7
Hungary	1 400.0	2 131.0
Czechia	2 086.4	2 122.7
Austria	1 702.1	2 042.9
Romania	1 397.7	1 382.5
Denmark	1 080.0	1 304.3
Sweden	714.0	1 107.0
Portugal	901.4	1 100.3
Bulgaria	1 048.0	1 097.4
Slovakia	590.0	535.0
Slovenia	277.9	369.8
Finland	222.0	318.0
Cyprus	151.3	229.1
Estonia	120.6	207.7
Malta	155.2	187.9
Luxembourg	159.7	186.6
Lithuania	103.0	164.0
Croatia	84.8	108.5
Ireland	58.3	92.8
Latvia	3.3	5.1
Total EU-27	117 911.7	136 136.6

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

1 637 MW, which were all largely over-subscribed The lowest bid price was 4.57 euro cents per kWh, the highest was 6.1 euro cents per kWh, for a maximum admissible price of 7.5 euro cents per kWh. The German market's size can also be attributed to the commissioning of major projects that do not require any state funding such as the country's biggest power plant, the 187-MWp Weesow-Willmersdorf photovoltaic solar park owned by the EnBW energy group. This solar farm, which is located in Brandenburg, 30 kilometres from Berlin, was formally inaugurated in November 2021, a year after it started injecting into grid while construction was still underway. The solar park should supply about 180 million kWh of electricity per annum, which equates to the annual consumption of 50 000 households. Unsubsidized solar park projects are becoming increasingly widespread in Europe. The European RE-Source platform reports that electricity purchasing agreements were entered into with operators of renewable facilities in Europe for a volume in excess of three gigawatts (GW) between January and November, and 53% of these electricity supply agreements were for solar energy. Because of its advantageous sunlight conditions, Spain is at the front line of this trend.

The Netherlands' 2020 solar photovoltaic energy activity level was the second highest in the European Union. It added 3 723.7 MW of additional net capacity (2 618 MW in 2019). The country's leading market segment is that of commercial roofs (50% of all installations) followed by the residential market

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Electricity production from solar photovoltaic in the European Union in 2019 and 2020 (in TWh)*

	2019	2020
Germany	44.383	48.641
Italy	23.689	24.942
Spain	9.420	15.675
France	12.227	13.398
Netherlands	5.401	8.765
Belgium	4.252	5.105
Greece	4.429	4.447
Hungary	1.497	2.459
Czechia	2.312	2.287
Austria	1.702	2.043
Poland	0.711	1.958
Romania	1.778	1.733
Portugal	1.342	1.716
Bulgaria	1.442	1.481
Denmark	0.963	1.181
Sweden	0.679	1.051
Slovakia	0.589	0.663
Slovenia	0.303	0.368
Cyprus	0.218	0.296
Malta	0.195	0.237
Finland	0.147	0.218
Luxembourg	0.130	0.161
Lithuania	0.091	0.129
Estonia	0.074	0.123
Croatia	0.083	0.096
Ireland	0.040	0.064
Latvia	0.003	0.005
Total EU-27	118.100	139.240

** Estimations.* ***Source: Eurostat***

(30%) and ground based solar parks (20%). Construction of large solar photovoltaic parks in excess of 100 MW has started. In September 2020, a 110-MW solar park was completed at Vlagtwedde, in Groningen province to the north. Construction has commenced on a larger, 147-MW solar park in Flevoland province. An increasing number of floating solar projects were also completed in 2020. Solar energy's two main drivers in the Netherlands are net invoicing for the residential and small business segments, while the commercial markets and major power plants rely on the SDE+ tendering system where solar energy faces competition from the other renewable sources.

Spain's installation pace plunged in 2020 and dragged it down to third place in the EU rankings. Only 1 446.2 MW of net additional capacity was installed in 2020 compared to 4 075.6 MW in 2019. The reason for its strong 2019 performance is that ground-based solar parks resulting from two tenders in 2017 went on stream, but in 2020 no such new parks were hooked up to the grid. The Spanish major power plant market relied solely on Power Purchase Agreement (PPA) projects, as there were no subsidies for long-term electricity supply contracts between two parties. SolarPower Europe reports that more than 100 GW of solar capacity is currently being developed under PPA agreements, which makes Spain the world's biggest market for unsubsidized projects. However, grid extension constraints bridle the Spanish market.

Spain's low solar power production cost is key to the size

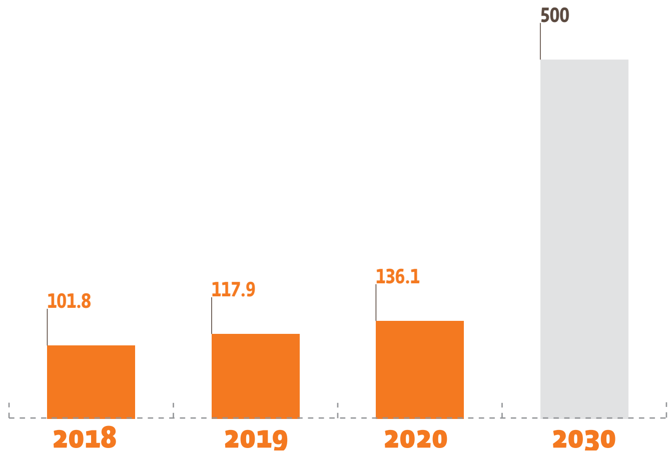
of this PPA market and makes the rollout of industrial green hydrogen production projects feasible. One of the most symbolic projects, Hydeal Ambition, brings together some forty European energy players. It aims to sell hydrogen at a market price of € 1.5 per kg of H_2 delivered on the basis of a solar power cost of < € 15 per MWh. The Hydeal project, with 95 GW of installed solar capacity and 67 GW of electrolysers, aims to supply 3.6 million tonnes of green hydrogen per annum by the 2030 timeline to the energy, industry and mobility sectors through gas transport and storage infrastructures.

139.2 TWH GENERATED IN THE EUROPEAN UNION

Exceptional sunlight conditions in 2020 played into solar energy's hands. Not only was 2020 the hottest year in Europe, because of the mildest winter and autumn ever recorded, but the number of sunshine hours on the European continent was the highest since satellite surveys began in 1983. This sunshine record combined with the increase in production capacities are the factors behind the high rise in solar power output. Eurostat reports that the European Union generated 139.2 TWh of solar power in 2020, equating to an 17.9% year-on-year rise. This sharp rise in the context of the COVID pandemic, which reduced demand for electricity in the EU, enabled solar energy to make a record contribution to the European Union's electricity mix. Accordingly, solar photovoltaic accounted for exactly 5% of the European Union's gross electricity production in 2020, compared to the previous year's 4.1% share. This share was as high as 11.1% in Malta (0.2 TWh of solar power produced in 2020), 9.2% in Greece (4.4 TWh in 2020), 8.9% in Italy (24.9 TWh in 2020) and 8.5% in Germany (48.6 TWh in 2020).

3

EurObserv'ER projection of the evolution of net photovoltaic capacity installed in the EU-27 (in GW)



Source: EurObserv'ER 2019

NEW AMBITIONS TO MATCH THE CHALLENGES

As a result of the European Union's new climate ambition to reduce GHG emissions by at least 55% by 2030 compared to its 1990 level, the Member States' solar photovoltaic facility installation targets will shoot up and so revision of the National Energy Climate Plans (NCEP) will be crucial to adjust the solar energy targets. According to SolarPower Europe's calculations, the Member States' current NCEP targets for solar energy are to add 335 GWp of capacity by 2030, but it is convinced that these targets will be outstripped much faster than expected. The Medium Scenario presented in its EU Market Outlook for Solar Power 2021-2025 predicts that 328 GW of installed solar capacity could be reached as early as 2025, and 672 GWp in 2030. The European Commission's MIX scenario modelling for implementing the European Green Deal, puts net installed solar energy capacity at 383 GW in 2030 (which according to SolarPower Europe equates to nominal DC capacity of 479 GWp). This capacity, which includes modest input from CSP, would be capable of producing 435.6 TWh in 2030, i.e., a 21.2% share of the renewable electricity output and 13.8% of the European Union's total electricity output. The European Commission's scenario is far below SolarPower Europe's medium scenario. Nevertheless, the association feels that this installation volume will not suffice to limit climate warming to 1.5 °C and that the target should be raised to a total of 870 GWp in 2030, optimally combined with a target of at least 45% (instead of 40% proposed by the European Commission) of renewable energy in gross final energy consumption in 2030 in the updated Renewable Energy Directive. ■

SOLAR THERMAL

From a physics standpoint, solar thermal is the ultimate way of transferring heat to water in a GHG emission- and pollutant-free manner. Nonetheless, the sector struggles to increase its hot water and heating production sector market share. In 2020, and after two years of appearing to re-establish itself, its installed area across the European Union took another tumble. EurObserv'ER has found that the installed area of the EU-27 contracted by about 14.7% compared to 2019, or by just under 2 million m². This market data includes all 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 HAS A BAD YEAR

Many of the national markets – and this applies to Austria, Italy, Spain and Belgium – followed previous years' trends and posted disappointing installation results for solar thermal installations. While it was certainly behind the first half-year's slump in certain national markets, such as the Greek market, which should pick up in 2021 and the Spanish market which slipped lightly in 2020, the health crisis cannot be held entirely responsible for the sector's woes. A number of poor results came as no surprise, such as the Danish solar heating network market's nosedive and the sharp contraction of the Polish market in response to the end of its municipal tendering incentive system. The French market, which has been fighting an uphill battle in the collective residential segment and saw less business in 2020 in the large installation segment, managed to hold up its head thanks to real momentum in the French overseas departments and regions. The redeeming news for 2020 is that the German market picked up, spurred by the government's reasserted strategy to decarbonize heating and hot water production in buildings.

DIFFERENT TRENDS BY MARKET SEGMENT

The solar thermal market has many segments, primarily geared to the residential hot water production segment (domestic and collective) which generates the majority of sales and collector installations, be they forced circulation systems (that use a small electric pump to take the fluid to the hot-water tank which is separated from the collectors) or thermosiphon systems where the collector is placed below the hot-water tank. Greece and Cyprus have decades-old, mature solar thermal thermosiphon system markets. This type of system, which is very cheap and suited to the Mediterranean climate of these sun-drenched countries, faces less competition from the other renewably-sourced domestic hot water production systems. Thermo-siphon system markets are usually quite robust and include a major replacement market for decommissioned systems, but there are exceptional years, and 2020 is one of them.

The forced circulation solar water heating system market, be it for individual, multi-family solar hot-water heaters or combined solar systems (that produce hot water and heat) has been under pressure for over a decade. Despite their excellent

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1

Annual installed surfaces in 2019 per collector type (in m²) and capacity equivalent (in MWth)

	Glazed collectors		Unglazed collectors	Total (m²)	Equivalent capacity (MWth)
	Flat plate collectors	Vacuum collectors			
Germany	441 000	70 000		511 000	357.7
Greece	361 350			361 350	252.9
Poland	282 160	5 030		287 190	201.0
Spain	193 650	7 600	2 900	204 150	142.9
Denmark	194 310			194 310	136.0
Italy	133 282	13 943		147 225	103.1
France*	124 117			124 117	86.9
Austria	90 040	310	460	90 810	63.6
Cyprus	69 945			69 945	49.0
Portugal	59 850			59 850	41.9
Netherlands	38 964	9 906	2 621	51 491	36.0
Belgium	23 500	4 300		27 800	19.5
Croatia+	26 100			26 100	18.3
Bulgaria+	23 980			23 980	16.8
Czechia	16 000	7 000		23 000	16.1
Latvia	21 672			21 672	15.2
Hungary+	21 000			21 000	14.7
Romania+	14 560			14 560	10.2
Slovakia+	13 000			13 000	9.1
Ireland	7 143			7 143	5.0
Finland+	7 000			7 000	4.9
Luxembourg+	3 011			3 011	2.1
Lithuania++	2 000			2 000	1.4
Sweden	1 084	76	522	1 682	1.2
Slovenia+	1 473			1 473	1.0
Estonia+	1 425			1 425	1.0
Malta	521	130		651	0.5
Total EU-27	**2 172 137**	**118 295**	**6 503**	**2 296 935**	**1 607.9**

*+ EurObserv'ER estimate based on Eurostat database or ESTIF last market survey. ++ EurObserv'ER estimate based on the market trend of recent years. * including 80 202 m² in the Overseas Departments.* ***Source: EurObserv'ER***

2

Annual installed surfaces in 2020 per collector type (in m²) and capacity equivalent (in MWth)*

	Glazed collectors		Unglazed collectors	Total (m²)	Equivalent capacity (MWth)
	Flat plate collectors	Vacuum collectors			
Germany	544 000	99 000		643 000	450.1
Greece	304 500			304 500	213.2
Spain	177 168	10 496	2 986	190 650	133.5
Poland	159 370	1 830		161 200	112.8
France**	120 812			120 812	84.6
Italy	97 765	11 561		109 326	76.5
Cyprus	76 784			76 784	53.7
Austria	72 210	1 400	1 730	75 340	52.7
Portugal	49 874			49 874	34.9
Hungary+	42 000			42 000	29.4
Netherlands	20 640	9 487	2 621	32 748	22.9
Czechia	15 000	7 000		22 000	15.4
Bulgaria+	20 060			20 060	14.0
Belgium	15 300	2 900		18 200	12.7
Denmark	17 613			17 613	12.3
Croatia+	15 800			15 800	11.1
Romania+	14 560			14 560	10.2
Slovakia+	13 000			13 000	9.1
Ireland	11 114			11 114	7.8
Finland+	7 000			7 000	4.9
Luxembourg+	4 469			4 469	3.1
Lithuania++	2 000			2 000	1.4
Latvia++	1 600			1 600	1.1
Sweden	1 000		500	1 500	1.1
Slovenia++	1 473			1 473	1.0
Estonia++	1 425			1 425	1.0
Malta	681			681	0.5
Total EU-27	**1 807 218**	**143 674**	**7 837**	**1 958 729**	**1 371.1**

*+ EurObserv'ER estimate based on Eurostat database. ++ EurObserv'ER estimate based on the market trend of recent years. * Estimate.** Including 91 352 m² in the Overseas Departments.* ***Source: EurObserv'ER***

3

Cumulated capacity of thermal solar collectors installed in the European Union in 2019 and 2020***
(in m² and in MWth)

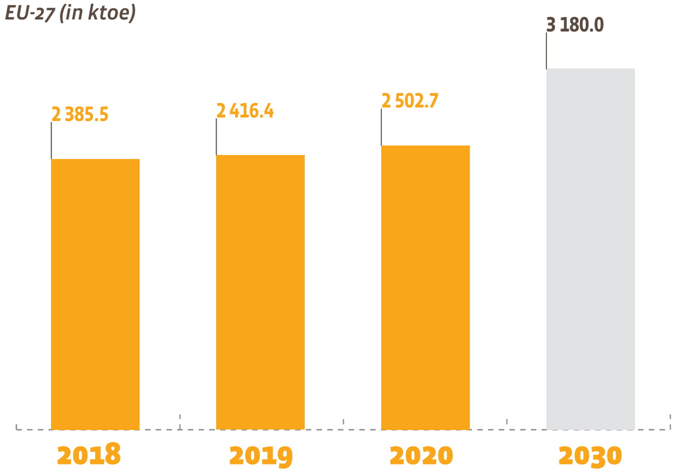
	2019		2020	
	m²	MWth	m²	MWth
Germany	19 326 000	13 528.2	19 455 000	13 618.5
Greece	4 867 500	3 407.3	4 991 000	3 493.7
Austria	5 050 403	3 535.3	4 922 944	3 446.1
Italy	4 343 765	3 040.6	4 457 525	3 120.3
Spain	4 067 774	2 847.4	4 235 816	2 965.1
France	3 302 191	2 311.5	3 397 731	2 378.4
Poland	2 696 000	1 887.2	3 006 690	2 104.7
Denmark	1 915 122	1 340.6	2 051 096	1 435.8
Portugal	1 347 955	943.6	1 406 955	984.9
Cyprus	1 084 111	758.9	1 102 430	771.7
Belgium	724 200	506.9	740 300	518.2
Netherlands	672 000	470.4	669 000	468.3
Czechia	555 000	388.5	577 000	403.9
Sweden	459 000	321.3	451 000	315.7
Bulgaria	425 478	297.8	445 538	311.9
Hungary	350 000	245.0	392 000	274.4
Ireland	336 951	235.9	347 062	242.9
Croatia	272 200	190.5	288 000	201.6
Slovakia	219 000	153.3	232 000	162.4
Slovenia	224 318	157.0	222 914	156.0
Romania	218 910	153.2	218 910	153.2
Finland	73 000	51.1	80 000	56.0
Luxembourg	69 889	48.9	74 358	52.1
Malta	73 485	51.4	74 166	51.9
Latvia	21 672	15.2	21 700	15.2
Total EU-27	**52 695 924**	**36 887.1**	**53 861 135**	**37 702.8**

** All technologies included unglazed collectors. ** Estimates. Note 1: Lithuania and Estonia do not officially monitor their solar thermal collector surface. Note 2: Variations in the officially recorded total solar thermal collector surfaces from one year to the next can be much higher than the market data collected by EurObserv'ER due to the delay in taking into account the data and statistical consolidations. This is notably the case of Poland and Denmark.* ***Source: Eurostat, except Slovakia 2019 data.***

energy efficiency performance and zero GHG emissions (apart from the small amount of electricity used by the pump), these systems are much more expensive to purchase than other 100% fossil fuel or 100% electrical solutions, primarily because of their lengthy installation times that involve climbing on the roof. Consequently, these appliances still rely on nationally implemented incentive policies. They also face fierce competition from other environmentally-friendly or low-emission heating systems, such as heat pumps, thermodynamic hot-water heaters and self-consumption photovoltaic systems, whose surplus energy is increasingly used for domestic hot water production.

4

EurObserv'ER projection of solar thermal heat consumption in the EU-27 (in ktoe)*



**Final energy consumption and gross heat production in the transformation sector .*
Source: EurObserv'ER

The SDH-solar district heating market is a distinct segment with specific operators and collector technologies that use much bigger collector areas (up to about fifteen m² per collector).This market segment accounted for about 10% of the European Union's installed solar thermal collector area in 2019. The solar district heating market share shrank (by 2–3%) in 2020 because of the downswing in activity in Denmark, the main player in this segment. The Danish consultancy planEnergi published its figures for the country showing that only 4 solar thermal collector fields were connected to a heating network in 2020, namely, Værum-Ørum (8 968 m² equating to 6.3 MWth), while the remaining three were extensions: Fras (2 722 m² equating to 1.9 MWth), Snedsted (1 865 m² equating to 1.3 MWth) and Flauenskjold (1 058 m² equating to 0.7 MWth), giving a total of 14 613 m² (equating to 10.1 MWth). This is much lower than the Denmark's 2019 figure, when it connected about fifteen collector fields including five extensions for a total area of 191 319 m².

With the hindsight of feedback on Danish solar heating networks, this market segment is finding its feet across Europe, driven by Germany. According to the Solar Heat Worldwide 2021 edition report, 10 new solar heating networks went on stream in 2020, in addition to the four Danish systems mentioned above, seven were constructed in Germany (for a total of 31 200 m²), two in Austria (6 571 m²) and one in Switzerland (784 m²). The biggest network is that of the German city of Ludwingsburg which has a 14 800-m² collector field.

Another niche market segment has emerged from the sidelines, that of solar thermal systems for industrial processes. It harbours ambitions for enterprising projects in areas as diverse as the food-processing industry, paper-making to heating greenhouses. The Nibbixwood plant in the Netherlands commissioned in April 2020 by brothers Jeroen and Marco Mol for their floral hot houses, is the biggest project to date. It comprises a 15 000-m² solar collector field (equating to 10.5 MWth) that heats 4 hectares in all. The installation's maximum annual yield is estimated at 8 100 MWh, instead of burning 875 000 m3 of natural gas every year. More recently, Kyotherm, an investment company specializing in third-party financing of renewable heat production projects, commissioned the Issoudun industrial solar plant, the biggest solar heating system in France. The plant has a 13 243-m² (10.6 MWth) collector field, which will supply heat to a malt house operated by Malteries Franco-suisses.

A 53.9 MILLION-M² SOLAR THERMAL BASE IN THE EU-27

While the official bodies do not ascribe a specific monitoring indicator to the market data, the total solar thermal collector area in service is monitored through the Annual Renewable and Waste Questionnaire (a joint questionnaire used by Eurostat and the International Energy Agency).

Sometimes this official monitoring is at variance with the market indicators that EurObserv'ER has collected, which can be explained by the time taken to include them and statistical consolidations. This clearly holds true for Poland and Denmark whose markets plummeted in 2020 despite the fact that their solar thermal installation areas officially enjoyed substantial expansion, deriving from the previous year's good performance.

According to Eurostat, the total European Union solar thermal base amounted to just under 53.9 million m² at the end of (52.7 million m² in 2019). The next few years will witness an increase in decommissioning because installation levels were particularly high in the 2000s, which peaked at about 4.6 million m² in 2008. According to official data, the collector bases of Austria, Sweden and the Netherlands are contracting because the volumes being decommissioned are outstripping those of new installations. Unless market recovery is significant and sustained, this trend will gradually raise the issue of whether solar heat's contribution towards the European Union's targets can be maintained. According to Eurostat, the solar thermal heat contribution across the EU-27 was 2.5 Mtoe in 2020 (2.4 Mtoe in 2019), which is a 3.6% increase.

RENEWABLE HEAT IS IN LINE FOR A BREAK

On 14 July 2021, the European Commission revealed the outlines of the Green Deal for Europe, the major political mission it set itself at the beginning of its mandate. One of the most important priorities of this policy will address the renovation of housing and buildings for more environmentally-friendly, energy-efficient lifestyles, which protect against extreme temperatures and combat energy precarity. The means made available match the challenges. The new European Social Climate Fund, which targets the EU citizens most exposed to energy precarity will contribute to reducing costs so that transition is fair and that nobody is left out. It will provide a 72.2 billion euro package over 7 years to finance building renovations and access to zero-emission and low-emission mobility. In addition to housing, public buildings must also be renovated, to use more renewable energies and be more energy-efficient. The Commission proposes to oblige the Member States to renovate at least 3% of the total floor area of all public buildings every year, set a reference value (indicative goal) of 49% of renewable energies in buildings by 2030, and oblige them to increase the use of renewable energies in heating and cooling by 1.1 of a percentage point per annum by 2030.

The funding level is likely to lead to great opportunities for the solar thermal sector, in Europe's Eastern and South-Eastern countries, particularly where solar thermal heat is suitable and often the cheapest option for replacing a fossil energy-fired heating appliance or to "green" the predominantly coal-fired heating networks of Eastern Europe.

The implications of this major European political mission are vital for all the European actors who have been involved in the renewable heat arena for many years, especially as it is clearly directed towards the development of an industry, jobs and technologies "Made in Europe". ■

HYDROPOWER

According to Eurostat, EU-27 hydroelectricity production, or actual hydropower output from natural water flow, i.e., disregarding the electricity produced by pumping, stood at 346.2 TWh in 2020, which is an 8.1% increase on the previous year's mediocre level (320.3 TWh).

Hydropower output increased in Northern Europe, in Sweden and Finland, and also in France, Spain, Portugal and Italy. Among the major European hydropower producer countries, Finland recorded the sharpest year-on-year growth (27.9%) that equates to a 3.5-TWh increase and total output of 15.9 TWh. In electricity output terms, the highest year-on-year surge was that of Sweden (7 TWh), which equates to 10.7% growth. In 2020, Sweden was the leading European Union hydropower producer country with 72.4 TWh of output excluding pumping. The only EU country likely to

1

Hydraulic capacity of pure hydro plants, mixed plants and pure pumped plants in the European Union countries in 2019 and in 2020 (in MW)*

	2019				2020			
	Pure hydro power	Mixed hydro power	Pure pumped hydro power	Total	Pure hydro power	Mixed hydro power	Pure pumped hydro power	Total
France	18 647	5 494	1 728	25 869	18 835	5 150	1 728	25 712
Italy	15 297	3 304	3 940	22 541	15 443	3 312	3 940	22 695
Spain	13 701	3 082	3 331	20 114	13 704	3 082	3 331	20 117
Sweden	16 363	99	0	16 462	16 307	99	0	16 406
Austria	8 924	5 673	0	14 597	8 933	5 671	0	14 605
Germany	4 249	1 129	5 355	10 733	4 304	1 134	5 354	10 792
Portugal	4 498	2 764	0	7 262	4 476	2 764	0	7 241
Romania	6 316	278	92	6 686	6 282	279	92	6 652
Greece	2 713	699	0	3 412	2 718	699	0	3 417
Bulgaria	2 365	149	864	3 378	2 363	149	864	3 376
Finland	3 157	0	0	3 157	3 164	0	0	3 164
Slovakia	1 611	0	916	2 527	1 613	0	916	2 529
Poland	598	376	1 423	2 397	601	376	1 423	2 400
Czechia	1 094	0	1 172	2 265	1 094	0	1 172	2 265
Croatia	1 924	275	0	2 200	1 924	275	0	2 200
Latvia	1 587	0	0	1 587	1 586	0	0	1 586
Belgium	104	0	1 310	1 414	106	0	1 310	1 416
Slovenia	1 171	0	180	1 351	1 172	0	180	1 352
Luxembourg	34	0	1 296	1 330	35	0	1 296	1 331
Lithuania	117	0	760	877	117	0	760	877
Ireland	237	0	292	529	237	0	292	529
Hungary	58	0	0	58	58	0	0	58
Netherlands	37	0	0	37	37	0	0	37
Estonia	6	0	0	6	8	0	0	8
Denmark	7	0	0	7	7	0	0	7
Total EU-27	104 815	23 323	22 658	150 796	105 124	22 990	22 657	150 771

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

rob it of its first place is France (this occurred during the last decade in 2018, 2014 and 2013). Actual French hydropower output also rose sharply in 2020 (by 9%, or 5.1 TWh) with total output gauged at 62.1 TWh.

Italy's hydropower sector enjoyed moderate growth with a total of 47.6 TWh (2.7%, or 1.2 TWh), and so it kept its third place in the European Union 2020 producer rankings. Hydropower production in Spain and Portugal is subject to huge swings either way from one year to the next. Growth in 2020 was measured at 37% for Portugal (3.3 TWh, for a total of 12.1 TWh) and 23.8% for Spain (5.9 TWh, for a total of 30.5 TWh).

We find a mixed bag of production variations if we turn our attention eastwards. Between 2019 and 2020, we record lower outputs in Germany (7.1%, 1.4 TWh), Greece (16.4%, 0.7 TWh), Bulgaria (3.7%, 0.1 TWh) and Romania (1.3%, 0.2 TWh) and higher outputs in Poland (8.2%, 1.2 TWh), Austria (2.9%, 1.2 TWh) and Czechia (6.8%, 0.1 TWh). The output levels are generally lower than those seen in recent years.

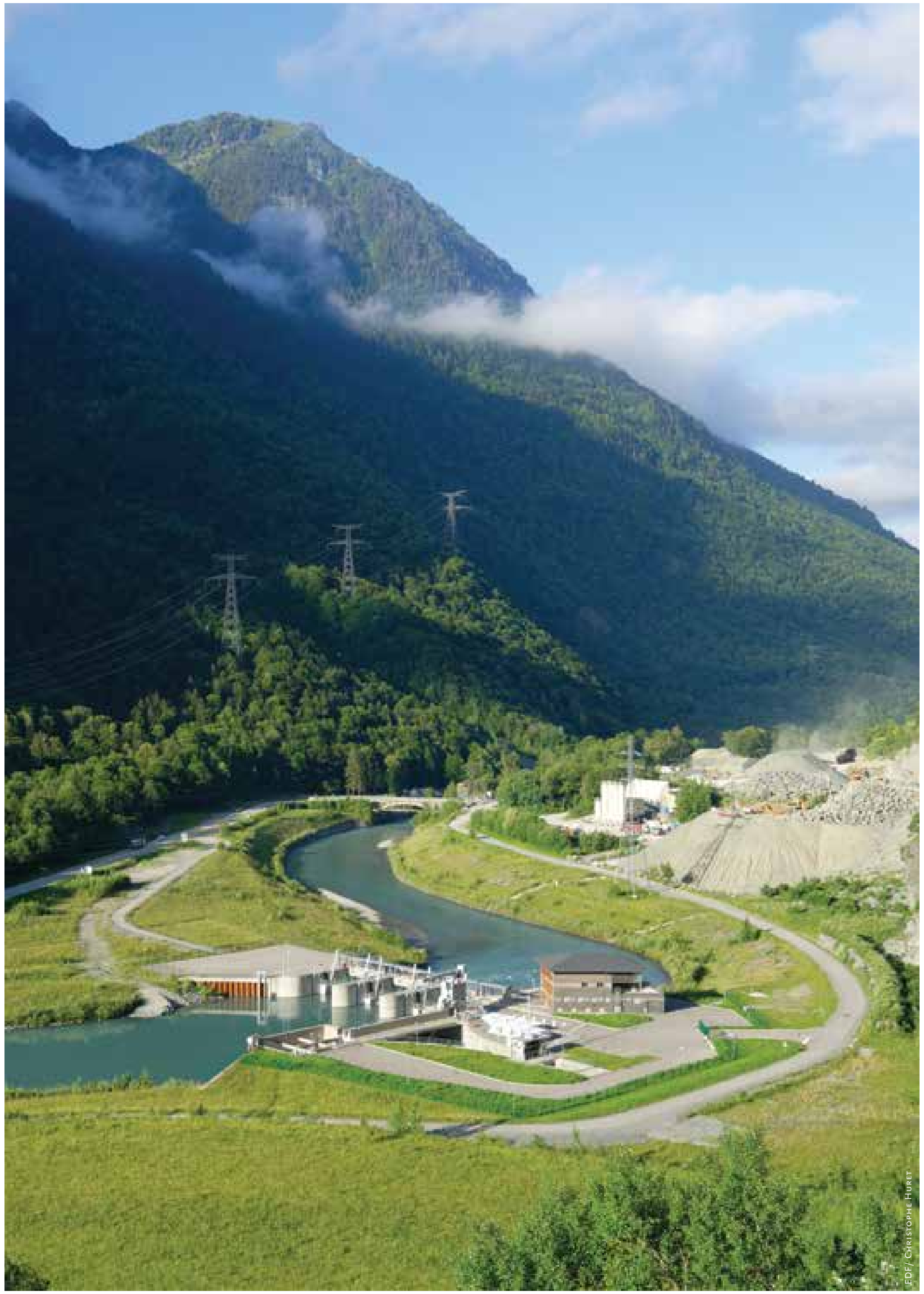
Note, that for the purposes of calculating the Member States' renewable energy targets, whose methodology is defined by the Renewable Energy Directive, hydroelectricity production is normalized over the last 15 years to mitigate the effect of variations in runoff. The SHARES statistics tool, used for calculating these targets, adopted 345.1 TWh as the normalized hydroelectricity output across the European Union in 2020… 0.6% more than in 2019 (343.2 TWh). Thus, the normalized hydropower output figure for 2020 across the European

2

Hydraulic gross electricity production (pumping excluded) in the European Union in 2019 and 2020 (in TWh)

	2019	2020
Sweden	65.371	72.389
France	56.914	62.062
Italy	46.319	47.552
Austria	40.826	41.998
Spain	24.646	30.507
Germany	19.731	18.322
Finland	12.421	15.883
Romania	15.581	15.381
Portugal	8.818	12.083
Croatia	5.826	5.662
Slovenia	4.479	4.934
Slovakia	4.356	4.517
Greece	4.000	3.343
Bulgaria	2.929	2.820
Latvia	2.108	2.603
Czechia	2.008	2.144
Poland	1.958	2.118
Ireland	0.887	0.933
Lithuania	0.345	0.301
Belgium	0.302	0.267
Hungary	0.219	0.244
Luxembourg	0.107	0.092
Netherlands	0.074	0.046
Estonia	0.019	0.030
Denmark	0.017	0.017
Total EU-27	320.261	346.248

Source: Eurostat



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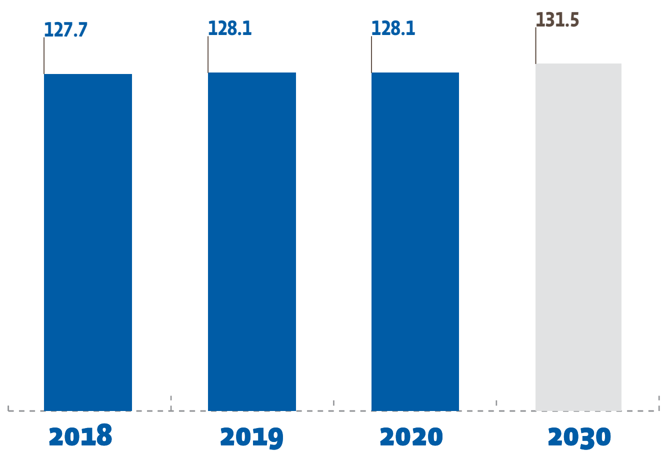
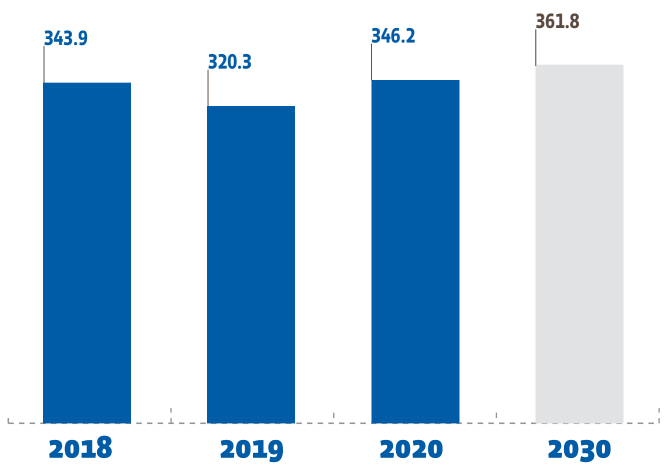
EurObserv'ER projection of the net hydraulic capacity (pure pumping excluded) in the EU-27 (in GW)



Source: EurObserv'ER

4

EurObserv'ER projection of hydroelectricity production (without pumped storage) in the EU-27 (in TWh)



Source: EurObserv'ER

Union, was similar to actual hydropower output.
As for capacity, Eurostat 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. 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 net maximum capacity of the EU-27 pure hydro plants at 105 124 MW in 2020 (104 815 MW in 2019), compared to the net maximum capacity of mixed hydro plants at 22 990 MW in 2020 (23 323 MW in 2019).
The five most well-equipped countries with pure hydro plants, (2020 data) are France (18 835 MW), Sweden (16 307 MW), Italy (15 443 MW), Spain (13 704 MW) and Austria (8 933 MW).

OUTPUT IS EXPECTED TO RISE TO ABOUT 362 TWH IN 2030

The European Union hydropower sector's growth potential is to a large extent contingent on the modernization of its existing installations and a handful of new projects. One of the newest facilities is the EDF Romanche Gavet hydro power plant on the course of the Romanche river, at Livet-et-Gavet, in the Isère, France. The design capacity of this run-of-the-river plant is 97 MW. It consists of an upstream dam at Livet, a gallery and a hydropower plant both built underground at Gavet. The 60-year operating lease was delivered on 31 December 2010 and the power plant was officially commissioned on 9 October 2020. It replaces six small historical power plants with 82 MW GWh of combined capacity producing 405 GWh of electricity. The new facility will provide a 40% increase in output while the installation of a fish ladder on the Livet dam infrastructure will ensure that fish farming in the Romanche River can continue. Some bigger projects in the European Union are nearing completion, such as the Tâmega Hydropower complex in Portugal (1 158 MW), on the Tâmega River, a tributary of the Douro River near Oporto in Northern Portugal. It comprises three dams and three power plants (Gouvães, Daivões and Alto Tâmega). A 118-MW hydro power plant works in conjunction with the Daivões Dam, while a 160-MW power plant will work in tandem with the Alto Tâmega Dam that is still under construction. The Daivões Dam is also the lower pool of the Gouvães (880-MW) pumped storage plant. This plant built in an underground cavern dug into the mountain is linked to the top reservoir 650 metres above it. The plant is reversible, which means that it can pump the water from the Daivões reservoir into the top reservoir, Gouvães, during excess electricity production periods and release it to the turbines during consumption peaks. The Gouvães and Daivões power plants went on stream in 2021 and early in 2022 and the Alto Tâmega plant is scheduled to start up in 2024. This will be a hybrid facility given that two wind farms with 300 MW of combined capacity will be built near the site and be linked to the pumping station. The hydropower complex is designed to generate 1 766 GWh with enough storage capacity to cover the daily consumption of 2 million Portuguese households. This project, led by Iberdrola at a cost of over € 1.5 billion, has benefitted from a € 650 million European Investment Bank (EIB) loan.
The European Commission's MIX scenario provides for 131 477 MW of net installed hydropower capacity (excluding pure pumping) in 2030 for the EU-27 including 89 535 MW from mountain lakes and 41 942 MW from run-of-the-river power plants. The resulting renewable electricity output should be 361.8 TWh in 2030 (190.3 TWh from lakes and 171.5 TWh from run-of-the-river power plants). Therefore, this simulation assumes that 3 363 MW of net additional capacity (excluding pure pumping) will be added in the decade up to 2030. ■

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 2019 and 2020 (in MWe)*

	2019		2020	
	Capacity installed	Net capacity	Capacity installed	Net capacity
Italy	915.5	767.2	915.5	771.8
Germany	47.0	40.0	47.0	40.0
Portugal	34.0	29.1	34.0	29.1
Croatia	16.5	10.0	16.5	10.0
France	17.1	16.2	17.1	16.2
Hungary	3.0	3.0	3.0	3.0
Austria	1.3	0.9	1.3	0.9
Romania	0.05	0.05	0.05	0.05
Total EU-27	**1 034.4**	**866.4**	**1 034.4**	**871.0**

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

2

Gross electricity generation from geothermal energy in the European Union countries in 2019 and 2020 (in GWh)

	2019	2020
Italy	6 074.9	6 026.1
Portugal	215.4	217.2
Germany	197.0	231.0
France*	128.5	133.2
Hungary	18.0	16.0
Croatia	91.9	93.7
Austria	0.2	0.1
Romania	0.0	0.0
Total EU-27	6 725.8	6 717.3

Source: Eurostat

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.

The EGEC (European Geothermal Energy Council) monitors the capacity of Europe's geothermal heating networks. It reports that there were 254 heating networks with 2 185.6 MW of combined capacity operating in the European Union in 2020. Only one new project, Pozo Barrero, went on stream in 2020 at Mieres, Spain (2 MWth), operated by Husona. This geothermal heating network project plays an integral part in the restructuring of the Asturias coal-producing region. The EGEC acknowledges the heavy blow dealt by the COVID pandemic to European Union geothermal project development activity and the installation of associated heating networks.

Eurostat regularly monitors geothermal heat production data. In the EU-27, heat from the processing sector, which is generally sold on to heating networks, is put at 314.5 ktoe in 2020 (309.2 ktoe in 2019). Final consumers directly used an estimated 556 ktoe of heat in 2020 (583.7 ktoe in 2019). When added together, we arrive at a total of 870.5 ktoe of geothermal heat used in 2020 (892.9 ktoe in 2019).

ELECTRICITY PRODUCTION

Across the European Union no developments of note exemplified by the commissioning of new geothermal plants, occurred in 2020. The standstill finally ended at the start of 2021. Germany, which had last commissioned a geothermal plant on the Holzkirchen site (3.4-MW) in July 2019, started up the Garching plant in Bavaria in January 2021. This plant has design capacities of 4.7 MWe for electricity and 6.9 MWth for heat production.

The only new project currently under construction in Italy is the 20-MWe Monterotondo 2 plant. Surface exploration was successfully completed in 2018 and preliminary drilling has been underway since August 2019, yet no commissioning date has been announced. There are no particular developments in the pipeline in Portugal, apart from the increase in the capacity of the Ribeira Grande plant from 28.7 to 30 MWe. Croatia, on the other hand, has new projects in the offing. In September 2020, MB Holding signed an agreement with the local project design company, Ekonerg, to design its forthcoming 19.9-MW geothermal plant. The Organic Rankine Cycle (ORC) power plant will be constructed at Legrad, near the town of Koprivnica, in Northern Croatia, and will generate approximately 165 GWh of electricity per annum. The Croatian ↘

3

Capacity of geothermal district heating systems installed in the European Union in 2019 and 2020 (in MWth)

	2019	2020
France	657.9	657.9
Germany	344.0	344.0
Netherlands	297.7	297.7
Hungary	256.4	256.4
Italy	170.6	172.6
Austria	105.2	105.2
Romania	88.0	88.0
Poland	61.9	61.9
Sweden	44.0	44.0
Denmark	33.2	33.2
Belgium	25.0	25.0
Croatia	22.1	22.1
Slovakia	17.5	17.5
Greece	17.0	17.0
Lithuania	13.6	13.6
Slovenia	12.7	12.7
Czechia	8.0	8.0
Spain	7.6	7.6
Cyprus	1.3	1.3
Finland	0.0	0.0
Ireland	0.0	0.0
Total EU-27	2183.6	2185.6

Source: EGEC

4

Heat consumption from geothermal energy in the countries of the European Union in 2019 and 2020 (in ktoe)***

	2019			2020		
	Total	*of which final energy consumption*	*Of which derived heat***	Total	*of which final energy consumption*	*Of which derived heat***
France	195.0	*40.2*	*154.8*	201.4	*40.2*	*161.2*
Netherlands	132.9	*132.9*	*0.0*	147.7	*147.7*	*0.0*
Italy	151.6	*130.8*	*20.8*	140.6	*119.7*	*20.8*
Hungary	136.0	*67.6*	*68.4*	128.5	*62.3*	*66.2*
Germany	122.3	*81.0*	*41.4*	122.4	*81.5*	*40.9*
Bulgaria	35.1	*35.1*	*0.0*	35.7	*35.7*	*0.0*
Poland	25.1	*25.1*	*0.0*	25.6	*25.6*	*0.0*
Austria	22.6	*11.4*	*11.2*	24.1	*11.8*	*12.3*
Romania	30.8	*25.0*	*5.8*	11.9	*5.8*	*6.1*
Slovenia	14.4	*13.9*	*0.5*	10.9	*10.5*	*0.5*
Croatia	7.2	*7.2*	*0.0*	7.2	*7.2*	*0.0*
Greece	10.3	*10.3*	*0.0*	5.6	*5.6*	*0.0*
Slovakia	5.6	*1.4*	*4.2*	5.0	*0.7*	*4.3*
Belgium	1.3	*0.0*	*1.3*	1.6	*0.0*	*1.6*
Portugal	1.7	*1.7*	*0.0*	1.3	*1.3*	*0.0*
Denmark	0.8	*0.0*	*0.8*	0.5	*0.0*	*0.5*
Spain	0.2	*0.2*	*0.0*	0.2	*0.2*	*0.0*
Total EU-27	**892.9**	**583.7**	**309.2**	**870.5**	**556.0**	**314.5**

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

geothermal power production sector is relatively young. Since 2018, the country's first geothermal power plant Velika 1 on the Bjelovar site has been running with a 16.5 MW turbine delivering 10 MW of net capacity and design output of 76 GWh. The plant was officially commissioned in November 2019.

No new geothermal capacity went on stream in 2020, so according to EurObserv'ER, installed European Union capacity remained at 1 034.4 MW. Eurostat puts net capacity, which is the maximum capacity presumed to be exploitable, at 871 MW in 2020 (i.e., 4.6 MW more than in 2019).

Eurostat claims that gross EU geothermal electricity output was stable between 2019 and 2020 at 6.7 TWh (slipping by 0.1%). Italian output, which provides almost 90% of total EU electricity production, dipped but was offset by a rise in German geothermal electricity output.

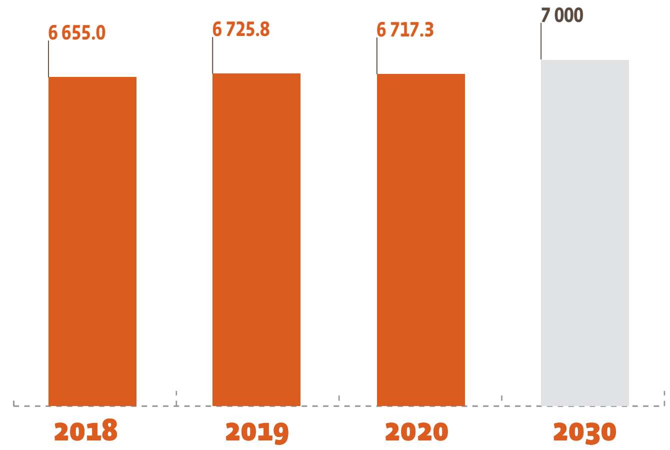
A SHARP UPSWING EXPECTED WITHIN A FEW YEARS

For European Union geothermal energy, 2020 was unmemorable, be it in terms of commissioning new heating networks or power plants. EGEC heaps responsibility for the temporary glitch in new geothermal power plant commissioning on the COVID-19 pandemic compounded by the lack of support and regulatory framework to assist the sector. Yet, projects do exist, and the situation should change in the next few decades, provided that the right conditions are achieved to consolidate the sector on new markets and continue expanding in its established markets.

The turndown in the heating network activity in 2020 which can be viewed as a direct result of the pandemic, is not material to the activity observed in the last few years in particular in the Netherlands, France and Germany. In its 2020 Geothermal Market Report, the EGEC expects a sharp upswing within a few years, primarily given the new policy that emphasizes heating and cooling in the European Green Deal. The association observes a Europe-wide trend to roll out renewable heating and cooling infrastructures initiated by local authorities. In Western Europe, the focus is on developing new systems to encourage the move away from gas networks. In Eastern Europe, where obsolete urban heating and cooling networks are widespread, the focus is on modernizing infrastructures and taking market shares from natural gas. According to the EGEC, new legislative provisions of the "Fit for 55% package", strengthening targets for renewable heating and cooling, and implementing various mechanisms to get the economy back on the right track after COVID-19 will be decisive for the future of the geothermal sector. ■

5

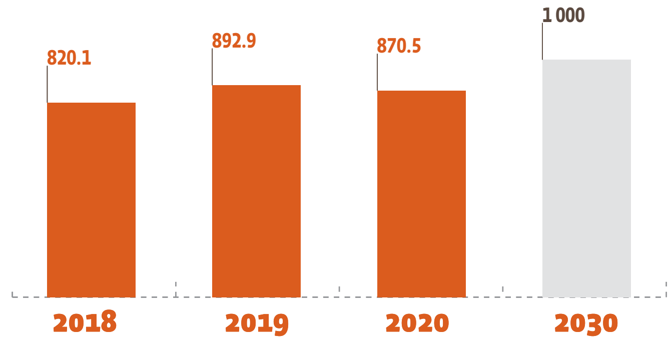
EurObserv'ER projection of geothermal electricity production in the EU-27 (in GWh)



Source: EurObserv'ER

6

EurObserv'ER projection of geothermal heat consumption in the EU-27 (in ktoe)*



**Final energy consumption and gross heat production in the transformation sector.*
Source: EurObserv'ER

HEAT PUMPS

The public authorities view heat pump technology as one of the keys to achieving carbon neutrality by 2050. Europe' heat pump industry claims to be ready to rise to the challenge. The European Union-wide HP market data for 2020 confirms that this technology is consolidating its foothold in the heating segment.
The reversible air-to-air heat pump segment is driven by cooling requirements in the southern countries and by heating requirements in the cold climate countries, making its market trends distinct. Lacklustre performances by Italy's and Spain's reversible air-to-air HP segments held back its growth across Europe in 2020.

INSULATION AND HEAT PUMPS… THE WINNING COMBINATION

The European Commission's strategy for integrating energy systems plans for 40% of all residential and 65% of all commercial buildings to be heated by electricity by 2030. Electrically-fuelled heat pumps should logically play a crucial role in decarbonating heating and cooling over the decade. As a result of more binding thermal regulations in new housing, HP systems are already the most popular form of heating in many European countries. This particularly applies to France and the northern European countries. Sweden has been the trailblazer in this trend. Its electricity mix is almost all low carbon (renewables and nuclear energy), while heating oil and gas in particular have been all but eliminated from the home heating segment. The Commission's strategy also intends to make heat pumps the technology of choice in renovation. To achieve this, the number and quality of renovated buildings where heat pumps operate offering optimum thermal comfort with affordable energy bills will have to increase. As it stands, roughly 35% of the EU's buildings are over 50 years old and nearly 75% of all building stock is energy-inefficient. At the same time, only 0.4–1.2% of the building stock (with country variations) is renovated in any year.
The HP manufacturers' catalogues now include high-temperature heat pumps capable of raising the heating circuit feedwater temperature to 65 °C (as opposed to 45 °C for so-called low-temperature HPs). These HPs are designed to work in conjunction with high-temperature radiators and are appropriate for installation when renovating dwellings with mediocre insulation, to replace a gas- or oil-fired boiler. Another alternative for the renovation market is to install a hybrid HP combining an air-to-water HP with a condensing boiler.

AIR-SOURCE HPS DOMINATE THE MARKET

The heat pump market for heat or cooling production expanded in 2020. According to EurObserv'ER, over 4.3 million HPs were sold over the year in the EU-27, all power ranges and technologies taken together, posting a 3.4% year-on-year rise (4.2 million units sold in 2019, revised figure). These data cover the residential and tertiary markets in particular (with power ranges starting at a few kW to several tens of kW). The medium- and high-capacity HP market is much smaller.
The majority of HP sales in the European market are for air-to-air ASHPs. According to EurObserv'ER, over 3.6 million units were sold in

2020, which is a similar volume to 2019 (sales increased by 1.3% between 2019 and 2020). However, this trend is chiefly representative of countries with significant summer cooling needs. Italy, Spain, Portugal and France together account for 80.8% of Europe's newly-installed air-to-air systems.
The water-borne ASHP market specifically caters for heating needs. Despite a year marked by the COVID-19 pandemic, sales in this market segment bounced back to rise by 15.2%. A total of 578 876 units were sold (counted in 21 countries), i.e., 76 288 more systems sold than in 2019. This market segment's growth was exceptionally high in Poland where sales doubled (108%) between 2019 and 2020. Growth was also strong in Denmark (50.6%), Germany (44.0%), Belgium (35.6%) and Sweden (34.0%). At least 10 countries recorded double-digit growth rates in this market segment.
On a smaller scale, the geothermal HP market (also water-borne) specifically caters for heating needs and also grew across the European Union. Market growth was 9.1% over its 2019 level, with 100 838 units sold. However, local market trends are highly variable.
Most of the positive growth

can be ascribed to the exponential rise of the Dutch market (which gained 64.6% over its 2019 level). Its installation approach is now similar to those of the German and Swedish markets. Double-digit growth between 2019 and 2020 was also registered in the main GSHP markets – Belgium (23.0%), and Germany (16.8%). The latter offers generous subsidies for powerful renewable energy heating appliances. This contrasts with Sweden's and Finland's GSHP markets which contracted year-on-year by 6.3% and 3.8% respectively in the face of competition from air-to-water HPs.

A EUROPEAN HP BASE OF ALMOST 42 MILLION UNITS

Estimating the number of HPs in service is a tricky task as the exercise depends on the decommissioning assumptions factored in by each country and the availability of statistics supplied by the Member States or HP industry associations. EurObserv'ER puts the combined total of installed HPs in the European Union at about 41.9 million units (40.1 million ASHPs and 1.8 million GSHPs). This figure is not restricted to HPs used for heating, but also includes cooling and heating applications, in that

1

Market of aerothermal heat pumps in 2019 and 2020 in the European Union (number of units sold)*

	2019				2020			
	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	1 614 016	1 563 659	50 356	0	1 574 000	1 526 000	48 000	0
France	904 653	728 433	176 220	0	987 626	812 404	175 222	0
Spain	446 926	395 173	51 753	0	400 373	351 275	49 098	0
Netherlands	154 255	120 761	33 494	0	230 309	187 870	42 439	0
Portugal	234 557	234 065	492	0	222 837	222 389	448	0
Germany	83 270	0	66 770	16 500	121 770	0	96 170	25 600
Sweden	97 380	70 000	10 994	16 386	103 667	70 000	14 727	18 940
Belgium	103 058	94 380	8 678	0	98 487	86 723	11 764	0
Finland	89 217	79 033	6 345	3 839	93 649	82 188	7 892	3 569
Malta	71 933	71 933	0	0	70 236	70 236	0	0
Denmark	57 998	48 853	8 945	200	62 571	48 893	13 474	204
Poland	31 314	11 018	20 286	10	54 125	11 924	42 201	0
Slovakia	48 593	45 640	2 916	37	42 274	38 626	3 648	0
Greece	29 878	27 586	2 292	0	40 224	37 138	3 086	0
Czechia	29 130	7 500	21 563	67	30 182	7 500	22 615	67
Slovenia	29 929	23 429	6 500	0	25 446	18 946	6 500	0
Austria	18 192	228	17 964	0	20 434	237	20 197	0
Lithuania	21 626	13 091	8 535	0	19 940	12 450	7 490	0
Estonia	15 010	13 700	1 280	30	14 980	13 700	1 280	0
Ireland	14 397	6 892	7 045	460	14 397	6 892	7 045	460
Hungary	2 850	2 850	0	0	5 820	400	5 420	0
Luxembourg	160	0	160	0	160	0	160	0
Total EU-27	4 098 342	3 558 224	502 588	37 529	4 233 507	3 605 791	578 876	48 840

*Note: Data from Italian, French, Spanish, Portuguese and Maltese aerothernnal heat pump market are not directly comparable to others, because they include a high number of reversible heat pumps whose principal function is cooling. Only heat pumps that meet the efficiency criteria (seasonal performance factor) defined by Directive 2009/28 / EC are taken into account. Market data for Romania, Bulgaria, Latvia, Croatia and Cyprus was not available at the time of our study. *Estimation.* ***Source: EurObserv'ER***

2

Market of geothermal (ground source) heat pumps in 2019 et 2020** in the European Union (number of units sold)*

	2019	2020
Sweden	25 343	23 757
Germany	19 000	22 200
Netherlands	11 755	19 349
Finland	8 988	8 644
Poland	6 710	5 622
Austria	4 690	4 581
Belgium	2 595	3 193
France	3 475	3 005
Denmark	2 251	2 308
Estonia	1 750	1 750
Czechia	1 417	1 440
Italy	753	1 242
Greece	1 008	1 000
Slovenia	930	924
Lithuania	702	580
Hungary	335	347
Ireland	316	316
Spain	199	236
Slovakia	149	216
Luxembourg	64	64
Portugal	28	64
Total EU-27	92 458	100 838

** Hydrothermal heat pumps included. ** Estimation. Note: Market data for Romania, Bulgaria, Latvia, Cyprus, Croatia and Malta was not available at the time of our study.* ***Source: EurObserv'ER***

3

*Total number of heat pumps in operation in 2019 and 2020 in the European Union **

	2019			2020		
	Aerothermal HP	Geothermal HP	Total	Aerothermal HP	Geothermal HP	Total
Italy	18 222 141	14 903	18 237 044	17 949 738	16 145	17 965 883
France	7 457 091	205 195	7 662 286	8 444 717	208 200	8 652 917
Spain	4 157 961	3 256	4 161 217	4 558 334	3 492	4 561 826
Sweden	1 349 857	551 776	1 901 633	1 441 828	561 033	2 002 861
Portugal	1 870 935	909	1 871 844	1 937 887	909	1 938 796
Germany	762 336	392 784	1 155 120	878 829	411 198	1 290 027
Finland	836 620	127 964	964 584	930 269	136 608	1 066 877
Netherlands	661 480	70 708	732 188	889 944	87 912	977 856
Denmark	380 995	68 997	449 992	445 455	72 453	517 908
Malta	425 237	0	425 237	485 289	0	485 289
Belgium	321 593	15 804	337 397	420 080	18 997	439 077
Greece	314 434	6 536	320 970	354 658	7 536	362 194
Slovenia	237 826	12 730	250 556	251 044	13 654	264 698
Austria	126 246	109 669	235 915	146 394	112 379	258 773
Poland	112 950	60 196	173 146	167 075	65 818	232 893
Bulgaria	214 971	4 272	219 243	214 971	4 272	219 243
Czechia	150 440	26 316	176 756	180 622	27 756	208 378
Estonia	161 747	17 625	179 372	176 727	19 375	196 102
Slovakia	94 586	3 964	98 550	136 860	4 180	141 040
Lithuania	43 551	4 160	47 711	63 491	4 749	68 240
Ireland	36 436	4 722	41 158	50 833	5 038	55 871
Hungary	12 800	2 745	15 545	18 620	3 092	21 712
Luxembourg	1 759	806	2 565	1 919	870	2 789
Total EU-27	37 953 992	1 706 037	39 660 029	40 145 584	1 785 666	41 931 250

*Note: Data from Italian, French, Spanish, Portuguese and Maltese aerothernnal heat pump market are not directly comparable to others, because they include a high number of reversible heat pumps whose principal function is cooling. Only heat pumps that meet the efficiency criteria (seasonal performance factor) defined by Directive 2009/28 / EC are taken into account. Market data for Romania, Bulgaria, Latvia, Croatia and Cyprus was not available at the time of our study. *Estimation.* ***Source: EurObserv'ER***

the system performance coefficients meet the criteria set out in the Renewable Energy Directive. HPs that do not meet the criteria are excluded. Incidentally, EHPA, in its 2021 *European Heat Pump Market and Statistics* report, puts the total European HP base in service primarily for heating purposes at about 14.86 million in 2020 (aggregate sales from 1997 to 2020). This estimate implies that about two-thirds of the HP base primarily meets cooling needs.

THE TIME HAS COME TO DECIDE

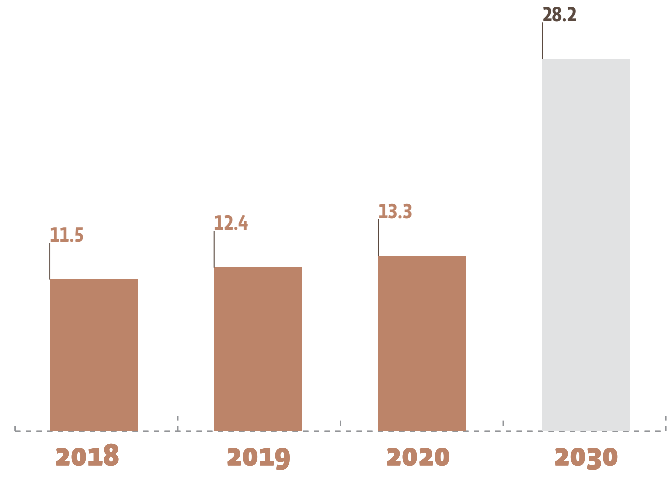
Heat pumps are not only identified as a key technology for decarbonating the building sector, but their technologies contribute a great deal to increasing renewable energy production. According to the Eurostat Shares tool, the total contribution made by heat pumps in the EU-27 was 13 316 ktoe in 2020, a 922.9-ktoe increase on its 2019 level. This sector has made the biggest contribution to increasing renewable heat (and cooling) in the EU-27. In 2020, it amounted to 12.7% of all renewable heat and cooling (11.9% in 2019).

As for the current decade, everything is in place to accelerate the contribution made by HPs to achieve our climate goals. A much more aggressive building energy renovation policy is required to fuel this acceleration.

The European Commission's "Fit for 55" package, published on 14 July 2021, is clearly a step in this direction. It comprises a string of legal texts that should reduce CO_2 emissions by 55% from their 1990 level, which is crucial to achieving carbon neutrality. The building sector which uses 40% of the energy consumed in the EU, and which generates about 36% of its energy-related CO_2 emissions is kernel to the Commission's legislative proposals. The proposed revision to the Renewable Energy Directive provides measures for accelerating heating and cooling systems' transition to renewable energies in the context of renovations. Thus, the Commission plans to set a reference value of 49% of renewable energies in buildings by 2030, which could be provided by the electrification of heating and cooling needs with heat pumps alongside direct use of renewable heat (biomass heating, geothermal and solar thermal energy partially via heating networks). The Commission also proposes to oblige its Member States to increase renewable energy use in heating and cooling by 1.1 of a percentage point by 2030. Apart from housing, public buildings must also be renovated to use more renewable energies and be more energy-efficient. Accordingly, the Commission plans to set the Member States an annual binding renovation target of at least 3% of the total floor area of all public buildings. ■

4

EurObserv'ER projection of renewable energy from heat pumps in the EU-27 (in Mtoe)



Renewable energy production according to the criteria set by the Renewable Energy Directive 2009/28/EC.* ***Source: EurObserv'ER*

BIOGAS

Methanation is a natural process in which many micro-organisms (bacteria) break down organic matter in an oxygen-free environment. Methanation biogas from anaerobic fermentation breaks down into three sub-sectors, segmented by waste origin and treatment.

It includes biogas from non-hazardous waste storage facility biogas ("landfill gas"), methanation of wastewater treatment plant sludge ("sewage sludge gas") and methanation of non-hazardous waste or raw plant matter ("other biogas"). Raw plant feedstock may include amounts of energy or food crops limited by incorporation thresholds (e.g.: France applies a 15% threshold).

International institutions also monitor a fourth segment, whose biogas is the product of a heat treatment process ("biogases from thermal processes") by thermal gasification of solid biomass (wood, forest residue, solid and fermentable household waste) or by hydrothermal gasification of liquid biomass. These processes produce a methane-rich syngas that when purified produces biomethane.

14.7 MILLION TOE OF BIOGAS PRODUCED IN THE EUROPEAN UNION

Primary energy production from biogas across the European Union of 27 is recovering. Output, having slipped slightly in 2018 (by 0.3% between 2017 and 2018), picked up both in 2019 (by 2.1% compared to 2018) and in 2020 (by 4% year-on-year) to reach 14 716.1 ktoe in 2020. Methanation biogas from non-hazardous waste or raw plant matter (other biogas) dominates this output (with 80.2%), outstripping landfill biogas (11.2%), sewage sludge gas (7.8%) and thermal biogas (0.8%).

At 569 ktoe, the growth in output between 2019 and 2020 is the highest since 2014. Five countries were mainly behind this recovery with respective increases by France (160.5 ktoe), Germany (151 ktoe), Denmark (115.5 ktoe), the Netherlands (59.5 ktoe) and Spain (32.4% ktoe) over the previous 12-month period. These countries all achieved double-digit growth (29.2% for Denmark, 16.7% for the Netherlands, 16.5% for France, 11.1% for Spain) apart from Germany (2%). Germany produces more than half of the European Union's biogas total (7 744.8 ktoe in 2020), which explains why its growth in output was lower.

If we consider the various biogas source trends, methanation biogas from non-hazardous waste and raw plant matter (the "other biogas" category) remains the main contributor to the 427.1 ktoe increase in biogas production across the European Union between 2019 and 2020), ahead of landfill biogas (which increased by 140,8 ktoe) and sewage sludge biogas (which increased by 21.1 ktoe). "Thermal" biogas output contracted (by 20 ktoe), and this decrease can be primarily ascribed to lower output in Finland, which has spearheaded and concentrated this type of biogas production in the European Union (producing 106 ktoe of the total 116.2 ktoe in 2020). Finland has been operating the European Union's biggest biomass gasification plant at Vaasa since 2013. This 140-MW power plant, owned by Vaskiluodon Voima uses biogas produced from wood waste. The Eurostat database also identifies production data for "biogas from thermal processes" for two other countries – Italy

Solrød Biogas

1

Primary energy production from biogas in the European Union in 2019 and 2020 (in ktoe)

	2019					2020				
	Landfill gas	Sewage sludge gas	Other biogases from anaerobic fermentation	Thermal biogas	Total	Landfill gas	Sewage sludge gas	Other biogases from anaerobic fermentation	Thermal biogas	Total
Germany	103.7	487.6	7 002.5	0.0	7593.7	92.3	481.7	7 170.8	0.0	7 744.8
Italy	328.7	51.0	1 625.7	7.7	2013.2	281.2	51.3	1 678.6	6.7	2 017.9
France	286.4	38.9	648.0	0.0	973.3	311.7	21.4	800.7	0.0	1 133.8
Czechia	20.4	43.6	517.1	0.0	581.2	19.9	42.0	532.6	0.0	594.5
Denmark	395.1	0.0	0.0	0.0	395.1	510.6	0.0	0.0	0.0	510.6
Netherlands	10.4	62.7	283.1	0.0	356.2	9.9	66.7	339.0	0.0	415.7
Spain	72.2	66.7	152.2	0.0	291.0	137.0	115.0	71.3	0.0	323.4
Poland	41.9	120.6	136.0	0.0	298.5	49.6	121.1	151.7	0.0	322.4
Belgium	17.4	26.3	183.2	4.7	231.6	17.1	26.9	196.4	3.4	243.9
Austria	1.2	33.7	179.6	0.0	214.6	1.1	26.1	183.4	0.0	210.6
Sweden	5.9	77.8	97.8	0.0	181.5	5.8	76.2	103.8	0.0	185.8
Finland	15.5	17.8	30.5	123.8	187.5	12.8	17.1	33.0	106.0	169.0
Greece	67.0	20.0	38.0	0.0	125.0	61.1	21.8	52.4	0.0	135.3
Slovakia	4.9	7.9	130.1	0.0	142.9	5.7	7.5	117.6	0.0	130.9
Hungary	10.5	28.8	51.2	0.0	90.4	9.8	29.3	50.3	0.0	89.4
Croatia	5.7	3.3	73.2	0.0	82.2	6.8	2.9	73.5	0.0	83.1
Portugal	65.1	6.4	8.6	0.0	80.1	65.7	6.9	10.1	0.0	82.7
Latvia	7.5	2.2	70.9	0.0	80.6	7.7	1.8	70.7	0.0	80.2
Bulgaria	0.0	5.2	45.7	0.0	51.0	0.0	6.1	47.2	0.0	53.3
Ireland	31.1	11.2	7.6	0.0	50.0	28.9	9.7	13.7	0.0	52.3
Lithuania	8.7	6.8	23.4	0.0	39.0	6.5	7.2	24.9	0.0	38.6
Slovenia	1.5	1.2	19.5	0.0	22.2	1.4	1.2	24.4	0.0	27.0
Estonia	1.5	6.6	5.9	0.0	13.9	1.6	7.4	10.8	0.0	19.9
Romania	0.0	0.0	19.0	0.0	19.0	0.0	0.0	18.4	0.0	18.4
Luxembourg	0.0	1.8	16.2	0.0	18.0	0.0	1.3	16.6	0.0	18.0
Cyprus	1.1	0.7	12.0	0.0	13.8	0.0	0.8	12.5	0.0	13.3
Malta	0.0	0.0	1.6	0.0	1.6	0.0	0.0	1.3	0.0	1.3
Total EU-27	1 503.8	1 128.6	11 378.6	136.2	14 147.2	1 644.6	1 149.7	11 805.7	116.2	14 716.1

Source: Eurostat

and Belgium. While other countries have thermal biogas production segments, statistical confidentiality rules apply because there are too few players, and so this output is not singled out from methanation biogas output.

Once biogas has been produced, it is converted into various energy carriers as needed – heat, electricity or biomethane – and used as final energy. Heat can only be obtained by burning biogas in a suitably adapted methane-friendly gas boiler. Electricity can be produced for injection into the grid when the biogas is burnt in a suitable gas engine or a small turbine. This usually takes place in a CHP plant (that produces heat at the same time) to reduce energy losses. Biogas can also be purified to remove its carbon dioxide and hydrogen sulphide content to produce biomethane, which can then be recovered on site as electricity, heat or even biofuel for bioNGV vehicles that run on natural gas. Furthermore, when economically viable, it can be injected into the grid and used in the same way as natural gas (electricity, heat or fuel). For statistical purposes, the electricity or heat produced from biomethane mixed in the natural gas grid is not directly included in the official biogas electricity or heat indicators that calculate the use of pure biogas, except in Germany. However, special accounting applies to the electricity and heat generated from biomethane mixed into the natural gas grid so that they can be included in the Member States' renewable energy target calculations.

Eurostat reports that biogas electricity output improved

2

Gross electricity production from biogas plant and from biogas blended in the grid in the European Union in 2019 and 2020 (in GWh)*

	2019				2020			
	Electricity only plant	CHP plant	Total pure biogas	Electricity from biogas blended in the grid	Electricity only plant	CHP plant	Total pure biogas	Electricity from biogas blended in the grid
Germany	6 792.0	26 160.0	32 952.0	0.0	6 896.0	26 599.0	33 495.0	0.0
Italy	2 862.9	5 413.7	8 276.6	0.0	2 727.2	5 439.2	8 166.4	0.0
France	338.8	2 250.7	2 589.5	99.7	293.0	2 450.3	2 743.3	172.7
Czechia	41.6	2 486.5	2 528.1	0.0	37.4	2 559.0	2 596.4	0.0
Poland	0.0	1 135.0	1 135.0	0.0	0.0	1 233.9	1 233.9	0.0
Belgium	77.3	869.5	946.8	0.5	68.6	946.0	1 014.6	2.1
Spain	699.0	205.0	904.0	21.1	699.0	182.0	881.0	20.5
Netherlands	21.3	873.8	895.1	197.1	13.9	856.0	869.8	273.2
Denmark	0.8	631.9	632.6	176.5	0.9	676.5	677.4	174.9
Austria	569.8	42.1	611.9	17.3	579.2	49.5	628.7	14.5
Slovakia	115.0	419.0	534.0	0.0	95.0	415.0	510.0	0.0
Croatia	34.5	366.7	401.2	0.0	39.1	380.3	419.4	0.0
Greece	46.8	330.7	377.5	0.0	55.0	348.9	403.9	0.0
Latvia	0.0	352.4	352.4	0.0	0.0	344.7	344.7	0.0
Hungary	82.0	239.0	321.0	4.9	65.0	259.0	324.0	4.9
Finland	161.7	201.5	363.2	15.0	130.3	166.3	296.7	15.8
Portugal	246.1	18.3	264.5	0.0	240.6	18.9	259.5	0.0
Bulgaria	80.2	150.5	230.7	0.0	67.5	158.1	225.6	0.0
Ireland	130.1	55.4	185.5	0.0	116.9	61.7	178.6	0.3
Lithuania	0.0	154.4	154.4	0.0	0.0	149.4	149.4	0.0
Slovenia	1.2	93.1	94.4	0.0	1.3	111.7	113.0	0.0
Luxembourg	0.0	71.2	71.2	0.9	0.0	62.8	62.8	1.4
Cyprus	0.0	57.9	57.9	0.0	0.0	60.6	60.6	0.0
Romania	24.4	29.5	53.8	0.0	32.2	20.9	53.0	0.0
Estonia	0.0	38.8	38.8	0.0	0.0	31.0	31.0	0.0
Sweden	0.0	17.0	17.0	0.0	0.0	10.0	10.0	0.0
Malta	0.0	6.4	6.4	0.0	0.0	5.9	5.9	0.0
Total EU-27	**12 325.5**	**42 670.0**	**54 995.5**	**532.9**	**12 158.1**	**43 596.6**	**55 754.7**	**680.3**

Note: Germany has chosen to reallocate its electricity production from biogas blended in the grid to the production of electricity from power plants using pure biogas. ***Source: Eurostat***

slightly between 2019 and 2020 (by 1.4%), from 55.0 to 55.8 TWh, primarily thanks to increased production in Germany (543 GWh), France (153.8 GWh) and Poland (98.8 GWh). The additional electricity input sourced from biomethane mixed into the natural gas grid is put at 680.3 GWh in 2020 (532.9 GWh in 2019).

Heat production in the transformation sector (conveyed by a heating network) grew at a faster pace between 2019 and 2020 (by 4.4%) and was enough to reach the 1-Mtoe threshold in 2020. The additional production from biomethane mixed into the natural gas grid is put 66.7 ktoe (49.6 ktoe in 2019). Final direct energy consumption in industry and other sectors (farming in particular) increased at a similar pace (4.2%) from 2 461.8 ktoe in 2019 to 2 554.1 ktoe in 2020. Final energy consumption in these two segments that blend biogas into the natural gas grid is put at 430.4 ktoe (265 ktoe in 2019). The European Biogas Association (EBA) claims the number of biomethane plants is surging in Europe, having identified 880 in service in 2020 in its EBA Statistical Report 2021. It puts their output at about 32 TWh (a little less than 2.8 Mtoe). France currently leads the drive to build biomethane plants in the European Union. According to the official Data and Statistical Studies Department (SDES) dashboard data, France had 214 plants injecting biomethane into the natural gas grid on 31 December 2020. Their combined capacity is 3.9 TWh/annum, which is a 73% year-on-year increase. During 2020, 1658 GWh of additional annual capacity was installed, which is significantly

3

Gross heat production in the transformation sector from biogas plant and from biogas blended in the grid in the European Union in 2019 and in 2020 (in ktoe)

	2019				2020			
	Heat only plant	CHP plant	Total pure biogas	Heat from biogas blended in the grid	Heat only plant	CHP plant	Total pure biogas	Heat from biogas blended in the grid
Germany	10.5	382.6	393.1	0.0	10.6	411.6	422.1	0.0
Italy	0.1	274.2	274.3	0.0	0.1	274.1	274.1	0.0
France	1.8	68.1	69.9	4.0	1.5	74.3	75.8	7.8
Denmark	1.9	46.7	48.6	37.6	2.6	51.1	53.7	50.0
Poland	0.4	23.6	24.0	0.0	0.7	21.4	22.2	0.0
Belgium	0.0	12.9	12.9	0.0	0.0	21.2	21.2	0.0
Latvia	0.1	19.2	19.3	0.0	0.4	19.4	19.7	0.0
Finland	5.4	15.5	20.9	2.0	5.4	13.6	19.0	2.1
Slovakia	0.8	15.2	16.0	0.0	0.9	16.4	17.3	0.0
Czechia	0.0	17.0	17.0	0.0	0.0	17.0	17.0	0.0
Croatia	0.0	12.3	12.3	0.0	0.0	12.6	12.6	0.0
Netherlands	0.0	8.9	8.9	4.4	0.0	9.7	9.7	5.0
Sweden	6.0	5.2	11.2	0.0	2.4	3.8	6.2	0.0
Austria	0.7	3.8	4.5	1.1	1.3	4.3	5.6	1.0
Bulgaria	0.0	5.2	5.2	0.0	0.0	4.5	4.5	0.0
Slovenia	0.0	4.4	4.4	0.0	0.0	4.4	4.4	0.0
Romania	3.0	1.7	4.7	0.0	2.6	1.3	3.9	0.0
Hungary	0.0	3.0	3.0	0.4	0.0	3.1	3.1	0.4
Estonia	0.2	1.6	1.8	0.0	0.4	2.4	2.8	0.0
Luxembourg	0.0	2.5	2.5	0.2	0.0	2.6	2.6	0.3
Lithuania	0.0	2.5	2.5	0.0	0.0	2.3	2.3	0.0
Cyprus	0.0	1.2	1.2	0.0	0.0	0.9	0.9	0.0
Ireland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Greece	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spain	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Malta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Portugal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total EU-27	**31.0**	**927.2**	**958.2**	**49.6**	**28.9**	**971.8**	**1000.7**	**66.7**

Note: Germany has chosen to reallocate its electricity production from biogas blended in the grid to the production of electricity from power plants using pure biogas. ***Source: Eurostat***

higher than in 2019 (876 GWh p.a.). The number of new plants rose sharply. There were 47 in 2019, 91 in 2020 and 104 new plants in the first three quarters of 2021. As of 30 September 2021, 317 plants were injecting biomethane in France, with combined capacity of 5.8 TWh p.a., a 40% increase in nine months, while there were 998 projects in the pipeline for 20 TWh of annual production capacity.

THE SECTOR HAS ITS SIGHTS SET ON 5% OF BIOMETHANE BY 2030

After several difficult years on the side lines, biogas appears to have found its way back to growth, and as the sector is focussed on recovering energy from organic waste rather than using food crops, this growth is more sustainable. This momentum will increasingly develop biomethane which is a useful backup to natural gas uses (industrial processes, heating, gas-fired plants, and so on).

The public authorities still have to clarify the role for biogas in the "Fit for 55" legislative package that includes a proposal to revise the Renewable Energies Directive. The current proposal formulated under the FIT for 55 framework to increase the renewable energy share by 1.1% per annum in the heat and cooling sector does not entirely satisfy the sector, which would like more specific goals to be set. The Gas for Climate consortium proposed adding a 11% binding target of renewable gas (8% of biomethane and 3% of green hydrogen) to the recast Renewable Energies Directive (RED II) to the European Commission. The consortium reckons that renewable gas will probably reach a 9.4% share by 2030 under the

4

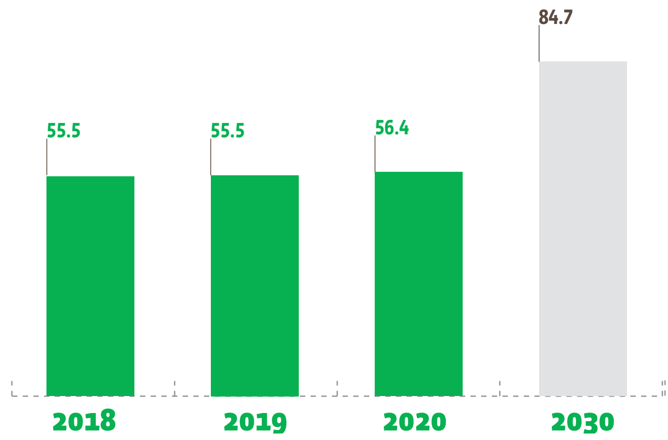
Final energy consumption in industry and other sectors (except transport) from biogas plant and from biogas blended in the grid in the European Union in 2019 and in 2020 (in ktoe)

	2019		2020	
	Pure biogas	Biogas blended in the grid	Pure biogas	Biogas blended in the grid
Germany	1 333.3	0.0	1 351.3	0.0
France	215.7	71.3	249.6	128.4
Czechia	149.5	0.0	152.2	0.0
Netherlands	126.7	45.8	138.9	59.5
Spain	85.6	3.6	121.2	4.0
Belgium	96.0	0.2	96.7	0.7
Poland	92.1	0.0	91.9	0.0
Finland	93.2	2.6	84.1	2.7
Sweden	49.6	0.0	59.9	0.0
Italy	36.3	0.0	36.4	0.0
Greece	35.1	0.0	36.2	0.0
Slovakia	20.9	0.0	24.0	0.0
Denmark	28.6	128.7	18.6	221.2
Austria	24.6	6.9	17.3	6.5
Hungary	12.2	3.0	13.1	3.0
Ireland	10.2	0.0	13.0	0.0
Lithuania	8.8	0.0	9.1	0.0
Latvia	8.0	0.0	7.7	0.0
Portugal	6.8	0.0	7.1	0.0
Bulgaria	7.4	0.0	6.7	0.0
Cyprus	5.7	0.0	5.2	0.0
Romania	7.0	0.0	4.5	0.0
Estonia	3.0	0.0	3.3	0.0
Slovenia	1.3	0.0	3.0	0.0
Luxembourg	3.4	2.8	2.3	4.3
Malta	0.9	0.0	0.7	0.0
Croatia	0.0	0.0	0.0	0.0
Total EU-27	**2 461.8**	**265.0**	**2 554.1**	**430.4**

*Note: Germany has chosen to reallocate its electricity production from biogas blended in the grid to the production of electricity from power plants using pure biogas. **Source: Eurostat***

5

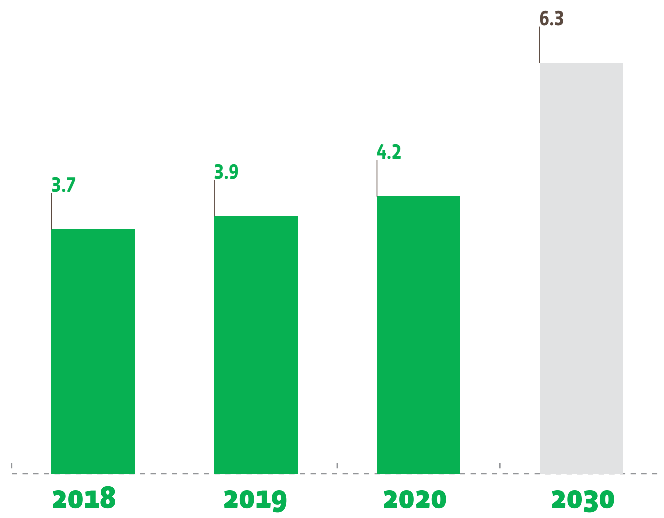
EurObserv'ER projection of electricity production from biogas in the EU-27 (in TWh)*



** Pure biogas and biogas blended in the grid. **Source: EurObserv'ER***

6

EurObserv'ER projection of heat consumption from biogas** in the EU-27 (in Mtoe)*



** Final energy consumption and gross heat production in the transformation sector.*
*** Pure biogas and biogas blended in the grid. **Source: EurObserv'ER***

Fit for 55 framework, namely 5.1% of biomethane and 4.3% of green hydrogen (renewable fuels of non-biological origin). Excluding road transport fuel, this share equates to roughly 279 TWh of biomethane production compared to the 229 TWh envisaged in the European Commission's MIX scenario for rolling out the European Green Deal. EBA (European Biogas association) proposes that two specific targets be integrated into the amended REDII: a target on consumption of renewable gas of at least 11% in terms of energy content by 2030 and a target to reduce the greenhouse gas emission intensity of gas consumption by at least 20% compared to 2018 levels by 2030. The various renewable gas segments' industry players are ready to help the European Commission achieve its ambitions. They stress the advantages of gas distribution grids for smoothing out renewable electricity production fluctuations. They particularly highlight the gas grids' technical ease and capacities for storage, the advantages of a hybrid energy infrastructure, built on the strengthened construction of the gas and electricity grids, which according to them, will form the backbone of a decarbonized European energy system. ■

RENEWABLE MUNICIPAL WASTE

Eurostat reports that renewable municipal waste treated by incineration plants with energy recovery (also known as waste-to-energy or WtE plants) in the EU-27 generated 9.2 Mtoe of primary energy in 2020 (9 207.8 ktoe to be precise). This output indicates a slight increase (1.6%) or an additional 148.5 ktoe on the EU's 2019 performance but only includes the energy production generated from biodegradable urban waste (cartons, paper, kitchen waste, etc.). Non-biodegradable feedstock (miscellaneous plastic packaging, water bottles, and so on) produces a similar amount of energy (9 135.8 ktoe in 2020... a 1.7% increase on the 2019 figure). Convention has it that the waste is put at 50% of all urban waste consigned to incineration, as it is hard to distinguish biodegradable waste from other waste, unless a Member State conducts specific studies.

The trends across the Member States vary wildly. In 2020, 10 of the 27 countries' primary energy output from renewable municipal waste increased, 8 countries' output decreased, and 9 countries posted almost stable output. The clearest increases can be credited to Sweden which produced an additional 69.7 ktoe, for a total of 842.4 ktoe (9.0% growth), the Netherlands with an additional 68.7 ktoe giving a total of 836.6 ktoe (8.9% growth) and Poland with a 41.5-ktoe increase for a total of 143.5 ktoe (40.7% growth). Yet, Germany still recovers more energy from its renewable municipal waste than any other country (3 128.7 ktoe in 2020) and its output has stabilized over the last few years. While it increased slightly in 2020 (by 1.2%, or 37.6 ktoe), its output is below


Syctom

that of 2017 (3 216.9 ktoe). Speaking of which, in those countries where prevention, composting and recycling are practised, the waste volume sent for incineration is naturally lower, which in turn reduces the potential for energy recovery by their WtE plants. Germany falls into this category, as its composting and recycling rate was 67% in 2019, which is the highest of any EU country, leaving only 33% available for energy recovery. The composting and recycling rates of Denmark, the Netherlands, Austria, Belgium are also over 50% and very high in Sweden and Finland... countries that have very low landfill storage levels (about 1%, and 2% for Austria). If we add Luxembourg (4% of waste stored in landfills), these eight countries already meet the new landfill directive's target landfill storage threshold of <10% by 2035. Another goal is to raise the household waste composting and recycling and reuse rate to 65% by 2035.

A wide gap prevails between these countries and the easternmost and southernmost countries of the European Union that

1

Primary energy production of renewable municipal waste in the European Union in 2019 and 2020 (in ktoe)*

	2019	2020
Germany	3 091.1	3 128.7
France	1 259.8	1 244.3
Italy	873.0	843.2
Sweden	772.7	842.4
Netherlands	768.0	836.6
Denmark	471.0	466.8
Belgium	384.0	386.3
Finland	349.8	330.4
Spain	255.7	236.1
Austria	188.7	191.4
Ireland	136.8	145.0
Poland	102.0	143.5
Portugal	118.0	111.6
Czechia	91.4	95.8
Hungary	44.0	58.4
Bulgaria	59.1	41.9
Slovakia	31.6	31.8
Lithuania	17.8	28.2
Estonia	21.4	21.5
Luxembourg	14.1	13.0
Latvia	6.1	6.7
Romania	2.0	2.0
Cyprus	1.2	1.9
Total EU-27	9 059.3	9 207.8

Source: Eurostat

2

Gross electricity production from renewable municipal waste in the European Union in 2019 and 2020 (in GWh)*

	2019			2020		
	Electricity only plant	CHP plant	Total	Electricity only plant	CHP plant	Total
Germany	3 781.0	2 025.0	5 806.0	3 821.0	2 007.0	5 828.0
Italy	1 087.5	1 281.2	2 368.7	1 065.2	1 264.5	2 329.7
Netherlands	0.0	2 081.6	2 081.6	0.0	2 193.1	2 193.1
France	1 100.7	1 071.9	2 172.6	911.5	1 226.2	2 137.7
Sweden	0.0	1 767.0	1 767.0	0.0	1 646.0	1 646.0
Denmark	0.0	964.0	964.0	0.0	944.8	944.8
Belgium	420.6	443.4	864.0	345.6	570.8	916.4
Spain	674.0	96.0	770.0	633.0	70.0	703.0
Finland	55.1	554.2	609.3	34.7	478.5	513.2
Austria	237.7	119.8	357.6	200.7	127.0	327.7
Ireland	320.5	0.0	320.5	326.1	0.0	326.1
Portugal	349.4	0.0	349.4	320.1	0.0	320.1
Poland	0.0	104.8	104.8	0.0	181.8	181.8
Hungary	9.0	128.0	137.0	12.0	155.0	167.0
Czechia	0.0	104.8	104.8	0.0	119.4	119.4
Estonia	16.7	47.4	64.1	48.4	26.2	74.6
Lithuania	0.0	48.1	48.1	0.0	71.3	71.3
Luxembourg	47.2	0.0	47.2	0.0	43.4	43.4
Slovakia	25.0	4.0	29.0	0.0	43.0	43.0
Bulgaria	13.2	31.1	44.3	0.8	0.7	1.5
Total EU-27	8 137.6	10 872.3	19 009.9	7 719.2	11 168.7	18 887.8

Source: Eurostat

rely on very high levels of landfill storage for their municipal waste. There are 13 European Union countries whose storage thresholds range from 43 to 92%. The growth potential for energy recovery through waste incineration (and similarly for recycling) is very high as is their WtE energy plant construction potential.

432 WASTE-TO-ENERGY PLANTS IN THE EU-27

This renewables sector has an advantage in that WtE incineration plants are usually sited close to major urban centres which provide the waste feedstock and are also major energy consumers. This proximity encourages optimum, local use of the energy, be it as heat, electricity, or more commonly both, through cogeneration. Thus, the heat can be easily exported to supply an urban heating network or process heat for an industrial site. The latest CEWEP figures show that Europe had 492 urban waste energy recovery plants in 2018 (432 in the EU-27, 42 in the United Kingdom and 18 in Norway), treating just under 96 million tonnes of renewable and other waste (83 million tonnes in the EU-27).

If we only include the renewable fraction of household waste, WtE plants generated 18.9 TWh of renewable electricity in 2020, which is consistent with the 2019 figure (0.6% less). Cogeneration is the main energy recovery method used by these plants. Electricity accounted for 59.1% of their output in 2020 (57.2% in 2019). Heat sales constitute the other major outlet for these CHP plants. Between 2019 and 2020, sales of renewable heat sourced from urban waste rose by 2.5% to 2 966.5 ktoe (2 894.8 ktoe in 2019), 82.3% of which was produced in CHP plants. Sweden and Poland enjoyed the highest growth in sales of this kind of renewable heat in 2020

3

Gross heat production in the transformation sector from renewable municipal waste in the European Union in 2019 and in 2020 (in ktoe)*

	2019			2020		
	Heat only plant	CHP plant	Total	Heat only plant	CHP plant	Total
Germany	267.3	603.9	871.3	252.1	573.4	825.5
Sweden	62.7	517.5	580.2	77.6	586.5	664.0
Denmark	31.6	353.6	385.2	32.4	361.2	393.5
France	99.4	273.8	373.3	95.8	269.2	365.0
Finland	38.8	138.0	176.8	54.1	120.6	174.7
Netherlands	0.0	174.8	174.8	0.0	174.1	174.1
Italy	0.0	131.8	131.8	0.0	128.2	128.2
Austria	14.4	58.4	72.8	13.9	63.7	77.7
Czechia	0.0	39.4	39.4	0.0	42.4	42.4
Poland	0.2	17.2	17.5	0.0	38.5	38.5
Belgium	0.1	30.8	30.9	0.1	31.9	32.0
Hungary	0.0	12.6	12.6	0.0	17.4	17.4
Lithuania	0.0	11.1	11.1	0.0	16.9	16.9
Estonia	0.0	12.6	12.6	0.0	14.0	14.0
Slovakia	1.5	0.0	1.5	0.0	1.8	1.8
Luxembourg	0.0	0.0	0.0	0.0	0.7	0.7
Bulgaria	0.0	3.2	3.2	0.0	0.0	0.0
Total EU-27	516.1	2 378.6	2 894.8	525.9	2 440.5	2 966.5

Source: Eurostat

4

Final energy consumption of renewable municipal waste in the European Union in 2019 and 2020 (in ktoe)*

	2019	2020
Germany	542.9	579.9
France	58.8	81.1
Poland	52.9	58.1
Denmark	53.5	50.1
Netherlands	43.9	43.8
Ireland	40.4	43.4
Finland	44.4	42.0
Bulgaria	45.2	41.5
Latvia	22.3	35.5
Cyprus	22.4	32.9
Czechia	22.6	21.3
Slovakia	13.1	11.9
Belgium	7.1	7.8
Hungary	17.7	6.0
Spain	4.8	4.7
Romania	2.0	2.0
Estonia	2.6	0.5
Total EU-27	996.6	1 062.6

Source: Eurostat

(83.9 ktoe and 21 ktoe respectively). Poland is now actively investing in new household waste-to-energy plants, backed by specific European Union funding. A new WtE plant with capacity to treat 110 000 tonnes will shortly be built in Olsztyn, in the Warmian-Masurian region (commissioning scheduled for 2023). This investment will guarantee effective waste management in line with EU waste hierarchy and contribute to covering local residents' energy needs by recovering heat and electricity from the treated municipal waste. The investment at Olsztyn amounts to 183.3 million euros, while the European Union Cohesion Fund will add a further 39.6 million euros. Another plant will be built in Warsaw with 265 200 tonnes of treatment capacity and is due to come on stream in 2024. This new plant, whose construction was ordered by the Warsaw waste treatment company, MPO, will supply 20 megawatts of electricity and heat by treating 730 tonnes of the waste discharged every day by 850 000 residents of Warsaw.

THE WTE SECTOR AIMS TO ACHIEVE CLIMATE NEUTRALITY BEFORE 2050

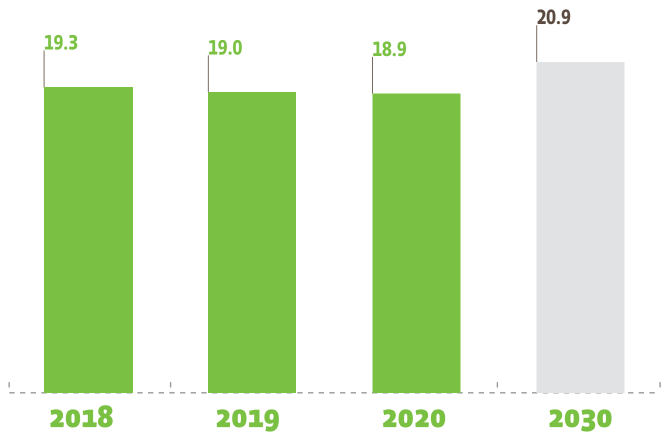
The European waste-to-energy sector is ready to make its contribution to the new EU targets of a 55% reduction in GHG emissions by 2030 and climate neutrality by 2050. It has already started by diverting waste from landfills to avoid methane emissions into the atmosphere, recycling bottom ash metal and by substituting fossil fuels with energy recovered from waste.

CEWEP, the association that represents the sector's players, reckons that if the circular economy targets included in the waste framework directive and the landfill waste directive are met, the total amount of energy (renewable + carbon components) produced by waste-to-energy recovery plants could potentially reach 186 TWh by 2035 (which equates to 16 Mtoe).

The sector is prepared to go even further by putting into practice carbon capture technologies but is mindful of the fact that these technologies will need significant investments that will have to be backed by a market and legislation to sequester and use the captured CO_2. Thus, the issue of funding for these technological developments will be crucial to guarantee that society's waste is treated in a climate-neutral manner. The first installation of this type, AVR-Waste, a CO_2 capture plant with annual capacity of 100 000 tonnes, has been in service at Duiven in the Netherlands since 2019, when the WtE company started capturing and delivering CO_2 to a horticultural greenhouse business. Hydrogen production from WtE plant electrolysers for local use is another innovative way of reducing the sector's emissions. The sector is eager to emphasize that the primary purpose of waste incineration is that of hygiene for society by treating waste that is unavoidable or that cannot be recycled. CEWEP insists that the approach to adopt if CO_2 emissions are to be cut is to prevent waste, improve product quality and potential product reuse. Recycling at source is the best way to slash the fossil CO_2 emissions released by WtE plants, which are essentially caused by incinerating plastic waste. ■

5

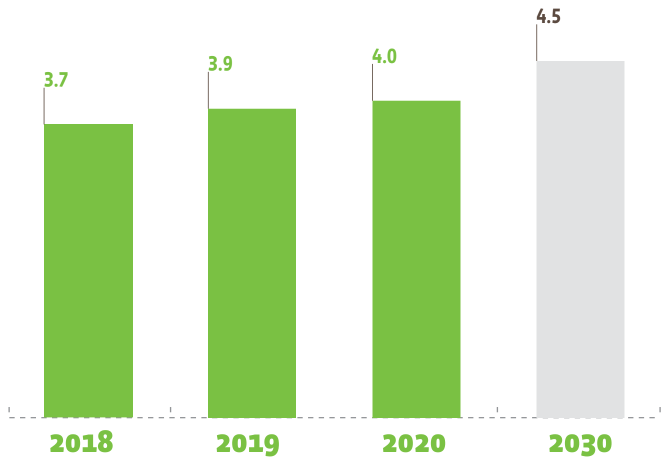
EurObserv'ER projection of electricity production from renewable municipal waste in the EU-27 (in TWh)



Source: EurObserv'ER

6

EurObserv'ER projection of heat consumption from renewable municipal wastes in the EU-27 (in Mtoe)



**Final energy consumption and gross heat production in the transformation sector.*
Source: EurObserv'ER

SOLID BIOFUELS

Solid biofuel is an umbrella term for all solid organic components to be used as fuels. They include firewood, green waste (tree prunings, shrub trimmings, etc.), wood and undergrowth residues (wood chips, sawdust, etc.), wood pellets, black liquor from the paper industry, straw, bagasse, animal waste and other solid plant residues and also the renewable part of industrial solid waste. National statistics offices monitor this last type of waste separately and so is not included in the solid biofuel indicator. Charcoal is generally included as a solid biofuel but is accounted for separately. As it happens, Eurostat assessed charcoal consumption in the European Union of 27 in 2020 at 263 ktoe (299.3 ktoe in 2019).


Stockholm Exergi

EU-27 PRIMARY ENERGY CONSUMPTION STOOD AT 96.8 MTOE IN 2020

The outlook for solid biofuel energy use in 2020 was dull. To start with, the abnormally mild winter and warm weather experienced across Europe curbed the demand for solid biofuels. According to the Copernicus Climate Change Service (C3S) figures, 2020 was the hottest year on record for Europe, and brought the hottest decade ever recorded to a close, while CO_2 concentrations rose relentlessly. In hard terms, Europe's annual temperature was 0.4°C higher than in 2019, and its hottest. The COVID pandemic's economic fallout not only resulted in lower heating needs, but also lower energy needs in the European Union. Solid biofuel energy has enjoyed a much better year in 2021 and Europe's 2020-2021 winter heating season was much longer. Now solid biofuel energy should do much better be it for producing electricity or heat. It has emerged unscathed by the huge fossil fuel price hikes and that of natural gas in particular, because of the economic recovery in Europe and all over the world.

According to Eurostat, EU-27 solid biofuel primary energy consumption remained stable at 96.8 Mtoe in 2020 (96.9 Mtoe in 2019). This data was updated on 25 January 2022 to include statistical revisions (over several years) undertaken by several Member States at the end of 2021, some of which were significant (such as for Poland). The revisions result from more refined surveys of wood consumption and household wood consumption in particular.
Primary energy production from solid biofuel, which accounts for solid biofuel taken from European Union soil, contracted slightly. It is put at 94.3 Mtoe in 2020 (95 Mtoe in 2019), which signifies a 0.8% drop. The difference, made up by net imports, plus or minus stock variations, primarily took the form of wood pellets and wood chips from the United States, Canada and Russia.
While the European Union is an importer, major exchanges also take place between the Member States. Forested countries such as Estonia and Latvia export a significant part of their production. They contrast with countries such as Denmark, the Netherlands, Italy, Belgium, and Poland that import part of the solid biofuel they use.
While primary energy consumption remained almost stable across the EU, individual Member States' variations are more mixed. The strongest increase can be credited to the Netherlands, whose consumption rose from 1.6 Mtoe in 2019 to 2.3 Mtoe in 2020 (by 699 ktoe), posting annual growth of 45%. Much of this can be attributed to higher wood pellet imports for electricity production in its power plants (see further on). Over the same period, solid biofuel primary energy consumption increased in Sweden (by 303 ktoe or 3.2%), Czechia (by 119 ktoe or 3.7%) and Portugal (by 108 ktoe or 4.2%). However, it fell in France (by 496 ktoe or 4.8%), Finland (by 571 ktoe or 6.3%) Germany (by 161.1 ktoe or 1.2%) and Italy (by 159.1 ktoe, or 1.9 %).
The tables differentiate the two uses of final energy derived from solid biofuel, namely electricity (table 2) and heat (for heating or industrial processes). Solid biofuel heat is in turn differentiated, depending on whether it comes from the processing sector and is then distributed via heating networks (table 3) or used directly by the end consumer (in the residential or industrial sectors) (table 4).
Eurostat reports that solid biofuel heat consumption directly used by end consumers across the EU-27, slipped by 1 Mtoe between 2019 and 2020 (by 1.4% compared to 2019) down to 67.5 Mtoe in 2020 (68.5 Mtoe in 2019). Most of this drop can be accredited to the lower residential heating needs of several countries.
Solid biofuel heat sold to heating networks (by the processing sector) dipped by 95 ktoe (by 0.8% year-on-year) to 11.3 Mtoe in 2020 across the EU of 27. The heating networks using much less solid biofuel were those of Sweden (14.1%, 355 ktoe) and France (6.9%, 82 ktoe) in particular. Higher solid biofuel consumption by the heating networks of the Netherlands, Poland, Denmark, Estonia and Luxembourg partly offset this trend.
In the European Union of 27, almost three-quarters of the solid biofuel electricity output, quantified at 83 TWh in 2020, was generated in CHP plants (74.5%). This input continued to increase (by 3%

1

Primary energy production and gross inland consumption of solid biofuels in the European Union in 2019 and 2020 (in Mtoe)*

	2019		2020	
	Production	Consumption	Production	Consumption
Germany	12.764	12.904	12.766	12.743
Sweden	9.458	9.583	9.900	9.886
France	10.376	10.410	9.859	9.914
Poland	9.006	9.394	8.964	9.330
Finland	8.949	9.006	8.327	8.435
Italy	7.262	8.513	7.124	8.353
Spain	5.035	5.035	5.054	5.054
Austria	4.672	4.620	4.804	4.666
Czechia	3.370	3.247	3.522	3.367
Romania	3.456	3.458	3.401	3.395
Portugal	2.830	2.537	2.904	2.645
Latvia	2.455	1.489	2.285	1.407
Hungary	2.053	2.069	2.036	2.053
Estonia	1.763	1.043	1.706	1.135
Bulgaria	1.620	1.524	1.680	1.609
Netherlands	1.440	1.553	1.531	2.252
Croatia	1.487	1.281	1.511	1.312
Denmark	1.493	2.990	1.440	2.993
Slovakia	1.399	1.389	1.321	1.313
Lithuania	1.248	1.263	1.273	1.284
Belgium	1.188	1.868	1.174	1.843
Greece	0.771	0.810	0.741	0.787
Slovenia	0.548	0.548	0.529	0.529
Ireland	0.237	0.263	0.223	0.258
Luxembourg	0.114	0.110	0.172	0.168
Cyprus	0.025	0.027	0.023	0.027
Malta	0.000	0.002	0.000	0.001
Total EU-27	95.018	96.936	94.273	96.759

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

2

Gross electricity production from solid biofuels in the European Union in 2019 and 2020 (in TWh)*

	2019			2020		
	Electricity only plant	CHP plant	Total	Electricity only plant	CHP plant	Total
Germany	5.984	5.055	11.039	6.058	5.169	11.227
Finland	10.999	1.318	12.317	9.730	1.030	10.760
Sweden	11.220	0.000	11.220	9.501	0.000	9.501
Poland	4.877	1.564	6.441	5.376	1.557	6.933
Netherlands	2.300	0.537	2.838	4.773	1.012	5.785
Spain	0.876	3.009	3.885	0.895	3.646	4.541
Italy	2.108	2.132	4.240	2.291	2.180	4.470
Denmark	4.353	0.000	4.353	4.302	0.000	4.302
France	3.375	0.506	3.882	3.289	0.670	3.959
Austria	2.922	0.763	3.686	2.745	0.890	3.634
Belgium	1.301	1.990	3.291	1.285	2.034	3.319
Portugal	1.709	1.040	2.749	1.753	1.453	3.206
Czechia	2.397	0.002	2.399	2.497	0.002	2.499
Estonia	1.015	0.245	1.260	1.426	0.320	1.746
Hungary	1.226	0.543	1.769	1.101	0.563	1.664
Bulgaria	1.232	0.314	1.546	1.300	0.173	1.472
Slovakia	1.130	0.000	1.130	1.120	0.000	1.120
Croatia	0.477	0.000	0.477	0.559	0.000	0.559
Latvia	0.575	0.000	0.575	0.520	0.000	0.520
Romania	0.403	0.047	0.450	0.433	0.061	0.494
Ireland	0.017	0.329	0.346	0.025	0.408	0.433
Lithuania	0.331	0.000	0.331	0.373	0.000	0.373
Luxembourg	0.160	0.000	0.160	0.266	0.000	0.266
Slovenia	0.151	0.000	0.151	0.155	0.000	0.155
Greece	0.016	0.009	0.024	0.038	0.012	0.050
Total EU-27	61.156	19.404	80.560	61.809	21.178	82.987

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

Toshiba Energy

year-on-year) with an additional 2.4 TWh. However, the growth rate was slightly lower (5.6% between 2018 and 2019, or 4.3 TWh).
The biggest increases can be credited to the Netherlands which doubled its output over the 12 months (by 103.8%) to produce 5.8 TWh (2.9 TWh), Spain (by 16.9%, 656 GWh), Poland (by 7.6%, 492 GWh), Estonia (by 38.6%, 486 GWh) and Portugal (by 16.6%, 457 GWh).

THE COMMISSION PROPOSES STRICTER SUSTAINABILITY CRITERIA

The European Commission's recent "Fit for 55" package has underlined the EU's continued commitment to sustainable biofuel energy. To achieve its climate and environmental goals, it plans to introduce sustainability criteria for stepping up bioenergy use and encourage Member States to roll out bioenergy support schemes for wood biofuel that is eligible under the cascade use principle. The principle stipulates that the highest economic and environmental value use of wood biomass must be applied in the following order of priority: the production of wood-based products, the extension of their useful life, their reuse, recycling and only then followed by energy recovery or treatment as waste.
The Commission's proposal for stricter sustainability criteria is also consistent with European strategy for protecting biodiversity, primarily through the ban on using biomass from virgin forests, peat bogs and wetlands for energy purposes. From 2026 onwards, financial support for using forest biomass in all-electric facilities will be curtailed. Likewise, there will be no financial incentive to produce energy from sawlogs, veneer logs, stumps and roots for installations that do not meet the minimum greenhouse gas-saving thresholds. Lastly, the EU's sustainability criteria for biomass usage will apply to ≥ 5 MW heat and electricity facilities.
Implementation of these stricter criteria should enable biofuel energy to contribute fully to the more ambitious

3

Gross heat production in the transformation sector from solid biofuels in the European Union in 2019 and in 2020 (in Mtoe)*

	2019			2020		
	Heat only plant	CHP plant	Total	Heat only plant	CHP plant	Total
Sweden	1.852	0.667	2.519	1.561	0.604	2.165
Finland	0.894	0.747	1.641	0.849	0.784	1.633
Denmark	0.927	0.497	1.424	1.002	0.480	1.482
France	0.595	0.600	1.196	0.567	0.547	1.113
Austria	0.357	0.536	0.893	0.349	0.598	0.947
Germany	0.437	0.156	0.593	0.454	0.154	0.608
Lithuania	0.140	0.397	0.537	0.144	0.368	0.512
Italy	0.432	0.085	0.517	0.409	0.096	0.506
Poland	0.302	0.078	0.380	0.345	0.100	0.446
Latvia	0.165	0.183	0.347	0.163	0.172	0.335
Estonia	0.201	0.086	0.287	0.225	0.106	0.331
Netherlands	0.197	0.056	0.253	0.227	0.095	0.321
Czechia	0.145	0.038	0.183	0.174	0.040	0.214
Bulgaria	0.141	0.009	0.151	0.132	0.009	0.141
Slovakia	0.085	0.041	0.126	0.088	0.041	0.129
Luxembourg	0.055	0.004	0.059	0.092	0.004	0.096
Hungary	0.051	0.033	0.084	0.054	0.032	0.086
Romania	0.043	0.023	0.066	0.061	0.021	0.081
Croatia	0.074	0.000	0.074	0.080	0.000	0.080
Slovenia	0.023	0.012	0.035	0.028	0.012	0.039
Belgium	0.008	0.000	0.008	0.011	0.000	0.011
Total EU-27	7.124	4.248	11.373	7.014	4.264	11.278

Excluding charcoal.* ***Source: Eurostat*

4

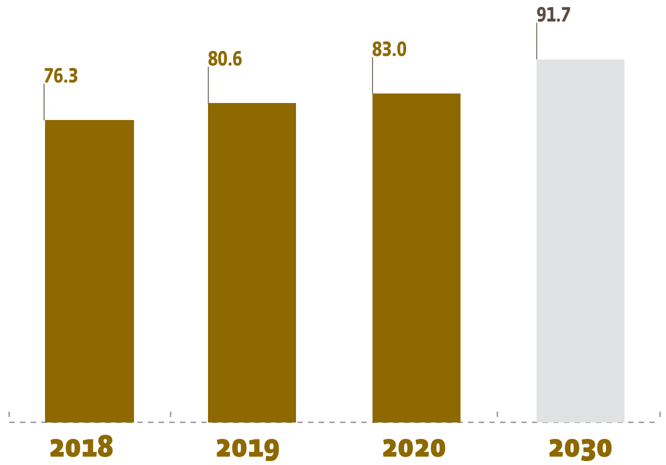
Heat consumption from solid biofuels in the countries of the European Union in 2019 and 2020 (in Mtoe)*

	2019			2020		
	Total	of which final energy consumption	Of which derived heat**	Total	of which final energy consumption	Of which derived heat**
Germany	10.239	9.647	0.593	10.021	9.413	0.608
France	9.342	8.146	1.196	8.821	7.708	1.113
Sweden	7.660	5.140	2.519	8.130	5.965	2.165
Poland	8.073	7.693	0.380	7.892	7.447	0.446
Italy	7.205	6.688	0.517	6.969	6.463	0.506
Finland	7.228	5.587	1.641	6.841	5.208	1.633
Austria	3.950	3.057	0.893	3.966	3.019	0.947
Spain	3.810	3.810	0.000	3.648	3.648	0.000
Romania	3.451	3.385	0.066	3.432	3.350	0.081
Czechia	2.695	2.511	0.183	2.796	2.582	0.214
Denmark	2.460	1.036	1.424	2.465	0.983	1.482
Portugal	1.812	1.812	0.000	1.802	1.802	0.000
Hungary	1.605	1.521	0.084	1.614	1.528	0.086
Bulgaria	1.173	1.022	0.151	1.293	1.152	0.141
Latvia	1.313	0.965	0.347	1.240	0.905	0.335
Belgium	1.211	1.203	0.008	1.147	1.136	0.011
Lithuania	1.150	0.612	0.537	1.143	0.631	0.512
Croatia	1.116	1.043	0.074	1.142	1.062	0.080
Slovakia	1.123	0.997	0.126	1.026	0.897	0.129
Netherlands	0.925	0.672	0.253	1.018	0.697	0.321
Estonia	0.691	0.405	0.287	0.763	0.432	0.331
Greece	0.789	0.789	0.000	0.760	0.760	0.000
Slovenia	0.516	0.481	0.035	0.502	0.462	0.039
Ireland	0.185	0.185	0.000	0.180	0.180	0.000
Luxembourg	0.083	0.024	0.059	0.124	0.027	0.096
Cyprus	0.025	0.025	0.000	0.026	0.026	0.000
Malta	0.002	0.002	0.000	0.001	0.001	0.000
Total EU-27	**79.830**	**68.457**	**11.373**	**78.761**	**67.483**	**11.278**

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

5

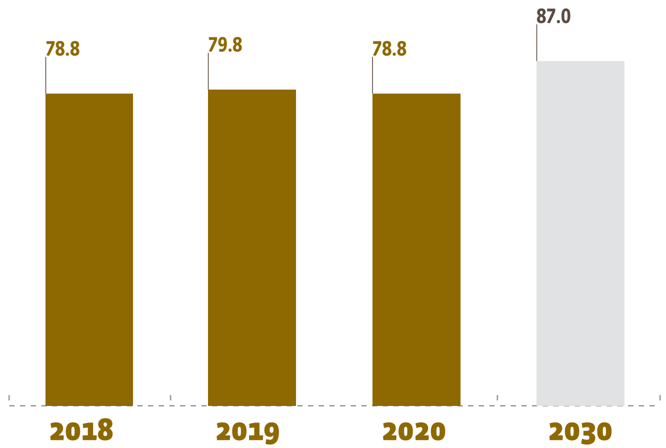
EurObserv'ER projection of electricity production from solid biofuels in the EU-27 (in TWh)



Source: EurObserv'ER

6

EurObserv'ER projection of heat consumption from solid biofuels in the EU-27 (in Mtoe)*



**Final energy consumption and gross heat production in the transformation sector.*
Source: EurObserv'ER

renewable energy targets under the terms of a recast Renewable Energy Directive. The proposal includes an annual binding national 1.1 percentage point increase, an indicative renewable energy target of 2.1 percentage points in heating and cooling networks, a new indicative target of a 1.1 percentage point annual increase in renewable energy use in industry and a reference to achieve at least a 49% renewable energy share of the energy used in buildings. European renewable heat policy in all the key decarbonation sectors will be reset if all these measures are adopted

The contribution of solid biofuels to electricity production in this new arrangement should continue to expand over the next decade but at a slower pace. The use of solid biofuel, and more generally bioenergies (biogas and waste-to-energy) will have a more supportive role, smoothing out variations and contributing to adjusting supply to peaks in demand. Moreover, priority will be given to energy efficiency. Growth will essentially be underpinned by the concomitant development of CHP plants to meet the renewable heat demand coming from heating networks and industry. ■

CONCENTRATED SOLAR POWER

Concentrated solar power (CSP) plants cover all the technologies devised to transform solar radiation energy into very high temperature heat for onward conversion into electricity. There are tower plants, whose heliostat fields (devices fitted with reflectors to track the sun) concentrate sunlight onto a receiver at the top of a tower, parabolic trough plants comprising parallel line-ups of long half-cylindrical reflectors that revolve around a horizontal axis to track the sun and concentrate its rays on a horizontal tube. There are also Fresnel plants comprising rows of flat reflectors that pivot, tracking the sun to redirect and concentrate the sun's rays permanently on an absorbing tube. A fourth, less widespread category, consists of parabolic plants with a parabolic reflector that reflects the sun's rays onto a convergence point, as the reflector's base is automatically orientated opposite the sun to track it. One CSP technology feature is the plants' ability to smooth out electricity production using a thermal storage buffer. This storage is usually achieved by heating molten salts in a tank to keep them at high temperature. In so doing, generating times can be increased by more than ten hours.

GLOBAL CSP CAPACITY OF 6 410.9 MW AT THE END OF 2020

The countries and regions that offer suitably conducive sunlight conditions, such as China, India, Australia, South Africa, the Middle East, and the Maghreb are currently involved in CSP development. The Protermosolar (Spanish Solar Thermal industry Association) website put global CSP plant capacity at 6 410.9 MW at the end of 2020 (6 310.9 MW at the end of 2019, consolidated figure). Protermosolar's scoreboard has just one single entry for a newly-commissioned CSP plant in 2020. The CNNC Royal Tech Urat 100-MW capacity parabolic trough, which is China's biggest plant of this type, started feeding the grid on 8 January 2020. Construction of the plant absorbed a total investment of 2.9 billion RMB (379 million euros). It features a molten salts system that offers 10 hours of storage, and it is expected to produce 350 GWh of electricity per annum. The Cerro Dominador Atacama 1 plant in Chile is the latest plant to go on stream, in April 2021. This 110-MW tower plant breaks new ground with its 17.5-hour storage system that enables it to operate 24 hours round the clock, with enough capacity to supply 380 000 city dwellers. The plant has 10 600 x 140-m^2 reflectors (called heliostats) that concentrate the sun's rays on the top of a 250-metre-high tower. The molten salts circulating in the receiver can be heated to over 560°C and are stored in large tanks for subsequent use to generate electricity through a steam turbine. This far-flung project located on the other side of the world, obtained funding from the European Union's LAIF programme and the German Development Bank KfW. It was constructed by a consortium formed by Acciona-Abengoa.

2 328.8 MW IN THE EUROPEAN UNION

The capacity of the European Union's stock of CSP plants remained static in 2020. The last time a plant was connected to the grid – a 9-MW capacity Fresnel demonstration plant for the eLLO project – was in the summer of 2019 in the Pyrénées Orientales, France. If all the various pilot and demonstration plants are factored in, capacity remains stuck at 2 328.8 MW. Eurostat's net maximum capacity data points to 2 306 MW (2 304 MW in and 2 MW in Germany). The reason for the difference is that certain countries do not publish figures for their demonstrators. This capacity is highly concentrated in Spain whose official installed Concentrated Solar Power capacity stands at 2 304 MW (i.e., 99% of EU capacity taken together). Eurostat reports that Spanish CSP output was measured at 4 992 GWh in 2020, compared to the previous year's 5 683 GWh. The reference year for Spanish CSP is 2017 when its CSP plants generated 5 347 GWh. The Spanish CSP sector will finally begin a new chapter in its history since it connected its last CSP plant in 2014. On 31 December 2021, the Spanish Ministry for the Ecological Transition and the Demographic Challenge (MITECO) announced the launch of its 3rd Renewable Energy Economic Regime (REER) round of tendering for a total of 500 MW of capacity allocating 200 MW


Cerro Dominador

1

Concentrated solar power plant in operation in the European Union at the end of 2020*

Project	Technology	Capacity (MWe)	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		**2 303.9**	
France			
La Seyne sur mer (prototype)	Linear Fresnel	0.5	2010
Augustin Fresnel 1 (prototype)	Linear Fresnel	0.25	2011
SUN CNIM (Ello project)	Linear Fresnel	9	2019
Total France		**9.75**	
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**	
Denmark			
Aalborg-Brønderslev CSP project	Hybrid. Parabolic Trough	5.5	2016
Total Denmark		**5.5**	
Germany			
Jülich	Central receiver	1.5	2010
Total Germany		**1.5**	
Total European Union		**2 328.8**	

HB (Hybrid Biomass). *Pilots and prototypes included. **Source: EurObserv'ER**

Continues overleaf

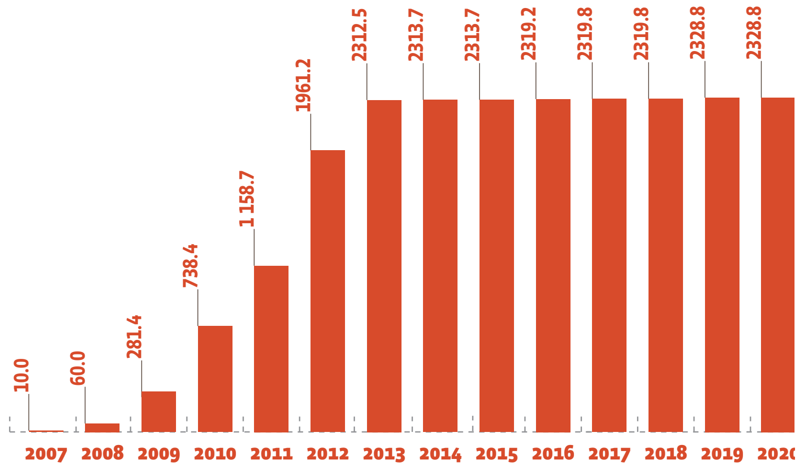
to CSP plants. CSP plant projects will have to provide six hours of storage capacity, enabling them to be hybridized with photovoltaic, biomass or biogas. However, the ministry pointed out that if the auction capacities geared to CSP (200 MW), biomass (140 MW) and other renewable technology plants (20 MW) are not fully allocated, the remaining capacity could be assigned to other bids from these same technologies. Successful bidders will have four years to get their projects on stream. The ministry is also on record for promising that two new rounds of tendering for 200 MW each will be launched in 2023 and 2025. Thus, the Spanish government has guaranteed the launch of three tenders for a total of 600 MW of capacity, which might seem inconsequential in view of Spain's National Energy and Climate Plan (NECP) roadmap. As it stands, the Target Scenario provides for combined capacity of 7 303 MW by the end of 2030 (5 000 MW more than the current capacity), with an intermediate goal of 4 803 MW by the end of 2025. Yet, the new tenders at last offer the sector the opportunity to construct a new generation of plants equipped with the latest technologies (primarily storage) on Spanish soil.

Portugal also has designs on CSP, but the second tender published at the end of August 2020 (when 670 MW of the initial 700 MW target was retained) did not commit to CSP plants despite the fact that part of the procedure covered all types of solar plants with storage and were thus open to CSP plants and hybrid (PV-CSP) plants. The storage requirements for this second innovative category, were at least 20% of the total capacity with 1 hour of storage at nominal rating. Finally, 483 MW of solar systems with storage capacity were retained, but all of them gave preference to PV systems + batteries. Perhaps the next round of tendering will facilitate the roll-out of a CSP sector in Portugal encouraged by the deployment of new projects in neighbouring Spain and the ability of these projects to reduce storage costs. Portugal is without a doubt one of the most promising countries for setting up a CSP sector, as its NECP has a 300-MW target for 2030. Elsewhere in Europe, no new CSP projects or tenders have been announced, leaving aside the demonstration projects we already know of, such as the EOS Green Energy project planned at the earliest for 2022 or 2023 in Cyprus. In the other countries whose sunlight conditions are conducive to CSP technologies, the Greek project (with a 70-MW target by 2030) is currently running late and is more conducive to demonstrator sites. The prospect of developing CSP in Italy has taken a back seat as the Italian government has its attention focussed on developing other sectors. So, for the next few years Spain will continue to lead the European concentrated solar power plant sector. ■


Ecotherm

2

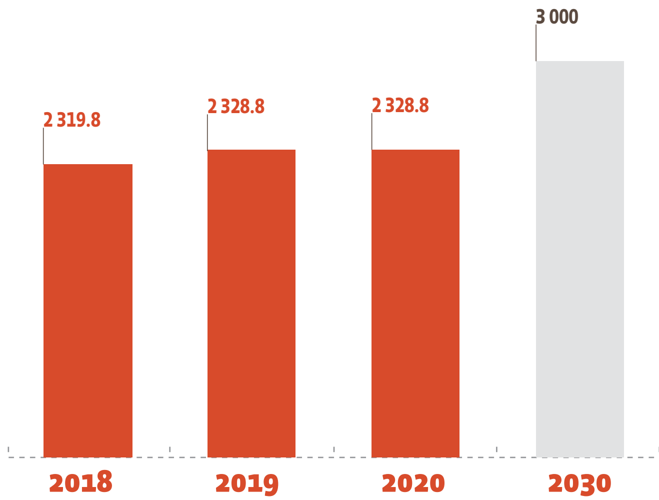
European Union concentrated solar power capacity trend (MW)



Source: EurObserv'ER

3

EurObserv'ER projection of the evolution of CSP capacity installed in the EU-27 (in GW)



Source: EurObserv'ER

OCEAN ENERGY

Seas and oceans offer an invaluable source of energy that can be harnessed in five ways – as tidal energy, marine current power, wave energy, energy recovered from temperature and salt content differences between two bodies of water (thermal and osmotic energy respectively). The European Union is uniquely endowed to develop these technologies thanks to the diverse and complementary nature of its sea basins – the many different areas from the Baltic, Sea in the north, the Atlantic Ocean, the Mediterranean Sea, to the Black Sea. Tens of prototypes are being tested. They exemplify the flourishing expansion of ocean energy also known as marine energies. The segment leading the pack uses marine currents and is gathering feedback from full-scale prototypes, i.e., one-megawatt turbines of "commercial" size while the equipment is still undergoing modification and being perfected. The strategy is to briefly put them through their paces, typically for one or two years, to validate the technological options.

AT LEAST 248 MW OF CAPACITY IN SERVICE IN 2020

It is hard to draw up an inventory of the ocean energy capacity in service because of the myriad test projects. Regardless of whether or not the prototypes are connected to the grid, they are excluded from any regular official monitoring, while the rapid succession of prototypes (immersion, improvement and decommissioning phases) tested over short periods only compounds the task of accurately counting the projects in service.

Official statistical monitoring of the net capacity of projects harnessing wave, tidal and marine current energy, internationally classified as "tide, wave and ocean" energy products is ongoing. Eurostat puts net maximum capacity at 216.6 MW in the EU-27 (218.9 MW in 2019). The official tally for the electricity produced by ocean energies, is 508.8 GWh in 2020 up from 499 GWh in 2019. Now only two European Union countries monitor their output, namely France (481.8 GWh, with a 0.6% rise over the 12-month period to 2020) and Spain (27 GWh, with a 35% rise). The output data for France excludes the Rance power plant's pumped storage contribution to the plant's output, as the only energy acknowledged as renewable is the tidal energy. For the time being, because of the low production levels and statistical confidentiality rules, the other EU countries with an ocean energy sector do not produce statistics.

Installed capacity, the calculated capacity of prototypes and pre-commercial demonstrators in service during 2020, is another monitoring indicator. It shows that the ocean energy capacity of the EU-27 increased to 248.3 MW. This figure includes the Rance tidal power plant's 240 MW of capacity in France and the 4.5 MW of Spain's ocean thermal energy plant operated by Enagas at the Port of Huelva. This latter plant harnesses the temperature differential between the ocean and the liquified natural gas delivered to the terminal. Although the UK is now outside the European Union, our table covers it, because its waters host many prototypes developed by European players. Their combined capacity came to 6.5 MW in 2020.

SIMEC Atlantis Energy

1

List of projects using ocean energies having been active during the year 2020 in the European Union

Summary	Device Developper	Device Name	Technology	Location	Date	Total capacity (MW)
France						
EDF La Rance Tidal Range	Alstom	Bulb Turbine (La Rance)	Tidal_Range	Brittany - La Rance	1966	240.00
Test at SEM REV	GEPS Techno	Wavegame prototype	Wave	SEM REV	2019	0.12
Hydroquest in Paimpol Brehat	Hydroquest	HydroQuest	Tidal_Stream	Brittany - Paimpol Brehat	2019	1.00
Total France						241.12
Spain						
Planta de Huelva	Enagas		OTEC*	Huelva. Andalousia	2013	4.50
Voith Hydro, Ente Vasco de la Energia (EVE) Project	Voith Hydro	Mutriku	Wave	Pais Vasco	2011	0.30
Full scale test	Wavepiston	Wavepiston	Wave	Plocan. Gran Canaria	2020	0.20
Total Spain						5.0
Netherlands	Tocardo	T2	Tidal_Stream	Oosterscheldedam	2015	1.25
Total Netherlands						1.25
Total Netherlands						1.25
Denmark						
Test in Denmark	Crestwing	Tordenskiold	Wave	Port of Fredrikshaven	2018	0.30
First commercial project	Minesto	DG100	Tidal_Stream	Faroe Islands	2020	0.10
Total Denmark						0.40
Portugal						
Swell Project	AW-Energy	WaveRoller	Wave	Peniche	2019	0.35
Total Portugal						0.35

Continues overleaf

Italy						
Messina Strait	ADAG	Kobold	Tidal_Stream	Strait of Messina	2000	0.05
Wavenergy	Wavenergy	REWEC3	Wave	Civittavecchia	2016	0.02
PC80 Platform (Eni)	Wave for Energy	ISWEC	Wave	Ravenna	2019	0.05
Total Italy						0.12
Greece						
Port of Heraklion	SINN Power	SP WEC 3rd Gen	Wave	Heraklion	2017	0.04
Port of Heraklion	SINN Power	SP WEC 4rd Gen	Wave	Heraklion	2018	0.07
Total Greece						0.11
Total EU-27						248.34
United Kingdom						
Eco Wave Power - Gibraltar	Eco Wave Power	Wave Clapper	Wave	Gibraltar	2016	0.10
MeyGen phase 1A	Andritz	HS1500	Tidal_Stream	Pentland Firth	2016	4.50
Shetland tidal array	Nova Innovation	M100	Tidal_Stream	Bluemull Sound. Shetland	2016	0.30
MeyGen phase 1A	SIMEC Atlantis Energy	AR1500	Tidal_Stream	Pentland Firth	2016	1.50
Shetland tidal array	Nova Innovation	M100	Tidal_Stream	Bluemull Sound. Shetland	2020	0.10
Total United Kingdom						6.50

** Ocean thermal energy project (between ocean and Liquified natural gas).* ***Source: Ocean Energy Europe (for wave and tidal stream and tidal range projects), EurObserv'ER (ocean thermal energy projects)***

2

Capacity and electricity production from ocean energy in European Union in 2019 et 2020 (GWh)*

	2019		2020	
	MW	GWh	MW	GWh
France**	214.1	479.0	211.8	481.8
Spain	4.8	20.0	4.8	27.0
Total EU-27	218.9	499.0	216.6	508.8

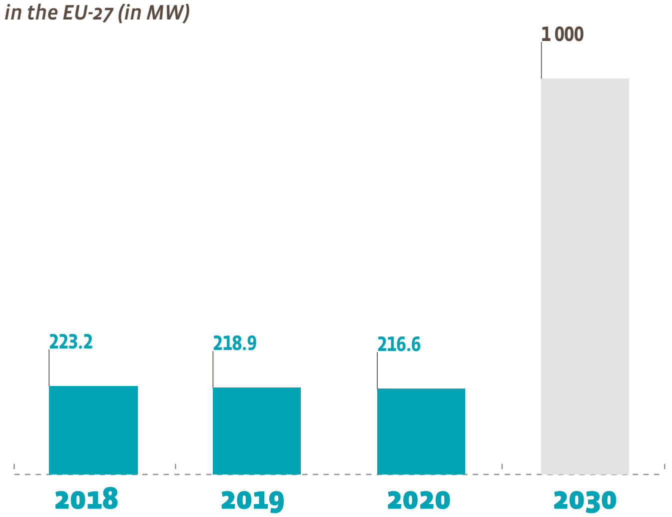
Net maximum electrical capacity. ** Electricity production excluding pumped storage.* ***Source: Eurostat.*

The capacity of the various sites in service is not representative of all the machines tested over the last decade. In its annual publication, Ocean Energy – Key Trends and Statistics 2020, the Ocean Energy Europe association, monitored the tidal and wave energy converter projects installed around Europe. According to the publication, only three projects for a total of 280 kW using ocean currents were immersed in 2020 (two in the UK and one in the Faroe Islands), while a single, 200-kW wave energy converter project was installed in Spain. The only project to be installed in European Union waters was to the very south, off the shores of Gran Canaria (one of the Canary Islands), in the Atlantic Ocean on the same latitude as Morocco. The project's developer, Wavepiston, is developing a piston-type wave energy converter prototype, designed to generate 547 MWh per annum (enough to supply 540 households). The prototype's test programme is scheduled to end in 2023. The company aims to commission a pre-commercial project in 2025 with electricity costing € 200 per MWh and desalinated water at 1 euro per m3 and to reduce these costs to € 40 per MWh and 0.25 euro cents respectively by 2032.

There was a little more activity in 2019, as three ocean current projects were installed with greater capacity (1 520 kW)– two in French and one in UK waters, in addition to 633 kW of combined capacity spread across six wave energy converter projects (two in the UK and one each in Portugal, France, Belgium and Italy). The biggest project installed is that of the French developer HydroQuest. Its 1-MW vertical axis current energy converter called HydroQuest Ocean is immersed at a depth of 35 metres in the Paimpol-Brehat test site, Brittany. The prototype measures 25 metres wide by 11 metres in height and it weighs 1 400 tonnes. It injected electricity in real operating conditions throughout its 2½-year-long test and was raised from the water in September 2021 for expert assessment. This prototype is the precursor to the FloWatt project to be sited at Raz Blanchard in a pilot 17.5-MW farm comprising seven HydroQuest machines due to be immersed in 2025. Finnish developer AW Energy, which is developing its Waveroller technology, installed the highest capacity project in 2019. A 350-kW prototype was immersed and installed on the sea bed, 820 metres off the Portuguese coast at Peniche. It was successfully connected to Portugal's electricity grid for two years and was taken out of the water for assessment in August 2021.

3

EurObserv'ER projection of the evolution of ocean energy net capacity in the EU-27 (in MW)



Source: EurObserv'ER

Ocean Energy Europe ascribes the sector's modest activity in 2020 to the pandemic which delayed several projects by depriving them of certain components but announces a stronger roll-out in 2021 with 2.9 MW of projects slated to use ocean currents (off the coast of Scotland and the Faroe Islands) and 3.1 MW of ready-to-go wave energy converter projects off the coasts of Spain and the UK. Ocean Energy Europe also states that according to their figures 27.9 MW of projects using current energy have been rolled out since 2010, and that of this total, 10.1 MW are currently in the water, which means that 17.8 MW of projects have been decommissioned having finished their test programmes. As for wave energy conversion technology, 12 MW of projects have been rolled out since 2010, but only 1.1 MW of them were in the water in 2020.

THE TARGET SET FOR 2030 IS 1 GW

After years of testing and the proliferation of full-scale prototypes, the commercial phase should not be long in coming. Ocean Energy Europe reckons that the sector will embark on a new project phase between 2023 and 2025 with more robust machines that pave the way to commercial operation in higher capacity farms. For instance, Cor-Power Ocean has invested 16 million euros and is currently setting up a research and development, manufacturing and servicing centre for its wave energy converters at Viana do Castelo, Portugal. The European Commission is particularly committed to developing ocean energies. Thus, developers have access to funding via dedicated projects through the Horizon 2020 research and innovation programme (e.g.: Ocean_2G project, FloTEC project) or via the NER 300 programme (e.g.: Stroma project). Developers can also take up inter-regional project funding through the European Interreg programme.

On 19 November 2020, the European Commission published the EU strategy for offshore renewable energies that covers both offshore wind energy and ocean energies. One of the key actions adopted is that the Commission will collaborate with the Member States and regions, and this extends to the islands, to coordinate the use of the funds available for ocean energy technologies. A forum drawing on national governments, EU authorities and industry will also be created to plan grid deployments and ensure fast access to the sea. The medium- and long-term targets of this strategy for ocean energy are to achieve total EU capacity of 100 MW by 2025, 1 GW by 2030 and 40 GW for 2050. As it stands, only Spain, Portugal and Ireland have adopted wave energy deployment plans of 50 MW by 2030, 70 MW by 2030 and 110 MW by 2035, respectively. ■

RENEWABLE ENERGIES IN TRANSPORT[1]

The Member States of the European Union had an important deadline to meet in 2020, because it marked their success or failure to meet their renewable energy targets as set out in the Directive 2009/28/EC. In addition to the main target for all energy uses made by end users (electricity, heating and cooling, transport), the directive also defined a specific target for the transport sector. It provides for each Member State's transport sector (road, railway and others) to use at least 10% of renewably-sourced energy including liquid (biodiesel, bioethanol etc.) and biogas fuel (biomethane) and also renewably-sourced electricity (in trains, trams, subways, electric cars, electric buses and other vehicles).

THE TARGET WAS REACHED ACROSS THE EUROPEAN UNION

The Eurostat SHARES tool's published results (updated on 1 February 2022) suggests that the transport target was reached across the EU-27, namely a 10.2% share in 2020 (8.8% in 2019). The renewable energies share of transport fuel has gradually increased from 1.4% in 2004 to 10.2% in 2020. Yet, this result was clinched in an unusual context, that of the COVID-19 pandemic, which reduced mobility needs across the European Union. According to Eurostat, total final energy consumption in transport (road, rail and other) which is used as the denominator for calculating the transport target, dropped by 11.6% between 2019 and 2020 from 274.1 Mtoe in 2019 to 242.3 Mtoe (multipliers included for the renewable share). Despite the reduced mobility needs, consumption of renewable energies used in transports, which corresponds to the numerator for target calculations, actually increased between 2019 and 2020. If the multipliers relating to the use of advanced biofuels and renewable electricity in transports are factored in, renewable energy consumption in transports (liquid, gaseous biofuel and renewable electricity) increased from 24.1 Mtoe in 2019 to 24.8 Mtoe in 2020, which represents 2.7% growth. If the multipliers are left out of the calculations, renewable energy consumption in transports was still positive, but rose more slowly from 17.8 to 18 Mtoe (1.3% between 2019 and 2020).

If we go into detail, the biofuel component is entirely responsible for this rise in the renewable energy share used in transport. Biofuel consumption was supported by legal increases in biofuel incorporation rates in the road fuels of countries seeking to achieve their transport target. Across the European Union, sustainable biofuel consumption in transport as per the criteria set out in the Directive 2009/28/EC rose from 15.94 Mtoe in 2019 to just under 16.25 Mtoe in 2020 (by 317 ktoe). According to Eurostat, compliant biofuels account for almost all biofuel

1. In the past this barometer was exclusively dedicated to biofuels. From now on it will cover all the renewable energies used in transport. The Observ'ER team viewed this development as essential, given the growing importance of alternative technologies to combustion engines.

1

Biofuels consumption for transport in the European Union in 2019 (in ktoe)

	Biodiesel*	Biogasoline	Biogas**	Total	Compliant biofuels***
France	2 544.3	653.3	0.3	3 197.9	3 197.9
Germany	1 904.1	732.6	56.8	2 693.4	2 692.4
Spain	1 626.6	140.6	0.0	1 767.1	1 761.5
Sweden	1 185.2	93.2	109.5	1 387.9	1 387.9
Italy	1 245.7	30.4	40.9	1 317.0	1 317.0
Poland	837.8	187.3	0.0	1 025.1	1 025.1
Netherlands	418.2	198.7	18.7	635.6	635.6
Austria	430.8	56.5	0.4	487.7	485.4
Belgium	352.8	106.3	0.0	459.1	459.1
Finland	340.1	89.2	6.8	436.1	424.7
Romania	314.5	97.8	0.0	412.4	412.4
Czechia	266.9	73.5	0.0	340.4	340.4
Portugal	275.6	8.2	0.0	283.8	283.8
Denmark	163.8	43.7	5.2	212.7	212.3
Hungary	155.2	45.7	0.0	201.0	201.0
Ireland	161.9	26.2	0.0	188.1	188.1
Greece	160.7	24.0	0.0	184.6	160.8
Bulgaria	144.7	31.8	0.0	176.5	148.4
Slovakia	132.6	19.8	0.0	152.4	152.4
Luxembourg	111.1	17.1	0.0	128.2	128.2
Slovenia	90.1	4.2	0.0	94.4	94.4
Lithuania	65.4	9.7	0.0	75.1	75.1
Croatia	61.9	1.0	0.0	62.8	62.8
Latvia	26.5	7.3	0.0	33.8	33.8
Estonia	20.3	7.4	5.2	32.8	32.4
Cyprus	11.3	0.0	0.0	11.3	11.3
Malta	11.1	0.0	0.0	11.1	11.0
Total EU-27	13 059.0	2 705.6	243.7	16 008.3	15 935.2

** Including HVO. ** Including biomethane blended in the natural gas grid allocated to the transport sector with appropriate traceability requirements. *** Compliant biofuels (Articles 17 and 18 of Directive 2009/28/EC). Note: Breakdown between types of biofuel has been estimated by EurObserv'ER.* ***Source: Eurostat (Total and compliant biofuels).***

2

Biofuels consumption for transport in the European Union in 2020 (in ktoe)

	Biodiesel*	Biogasoline	Biogas**	Total	Compliant biofuels***
Germany	2 613.0	702.3	76.0	3 391.3	3 388.4
France	2 089.5	554.6	0.6	2 644.8	2 639.9
Spain	1 439.9	98.0	0.0	1 538.0	1 535.7
Sweden	1 212.4	93.2	100.5	1 406.2	1 406.2
Italy	1 245.1	19.6	82.1	1 346.8	1 345.9
Poland	856.5	183.0	0.0	1 039.5	1 039.5
Belgium	568.7	97.3	0.0	666.0	666.0
Netherlands	301.8	226.4	34.6	562.9	562.9
Romania	391.6	91.6	0.0	483.3	483.3
Austria	353.6	55.0	0.4	409.0	406.8
Finland	301.8	93.5	9.5	404.8	390.6
Czechia	307.8	65.8	0.0	373.6	373.6
Hungary	194.1	83.9	0.0	278.0	278.0
Portugal	255.7	6.4	0.0	262.1	262.1
Denmark	172.6	79.8	8.5	260.9	256.3
Greece	150.0	68.3	0.0	218.2	190.0
Ireland	155.1	19.4	0.0	174.5	174.5
Bulgaria	143.4	26.5	0.0	169.9	159.6
Slovakia	127.1	25.9	0.0	153.1	153.1
Luxembourg	126.6	13.8	0.0	140.4	140.4
Lithuania	87.2	15.8	0.0	103.0	103.0
Slovenia	84.9	8.0	0.0	93.0	93.0
Croatia	64.8	0.8	0.0	65.6	65.6
Estonia	32.8	6.2	14.5	53.5	53.4
Latvia	31.5	12.8	0.0	44.2	44.2
Cyprus	26.0	0.7	0.0	26.6	26.6
Malta	13.8	0.0	0.0	13.8	13.3
Total EU-27	13 347.6	2 648.6	326.78	16 323.0	16 251.9

** Including HVO. ** Including biomethane blended in the natural gas grid allocated to the transport sector with appropriate traceability requirements. *** Compliant biofuels (Articles 17 and 18 of Directive 2009/28/EC). Note: Breakdown between types of biofuel has been estimated by EurObserv'ER.* ***Source: Eurostat (Total and compliant biofuels).***

3

Biofuel consumption whose raw materials used are considered to be equivalent to twice their energy content in 2019 and 2020 (in ktoe)

	2019			2020		
	Advanced biofuel[1]	Used cooking oil and animal fats[2]	Total	Advanced biofuel[1]	Used cooking oil and animal fats[2]	Total
Italy	403.2	571.2	974.4	407.6	536.5	944.0
Germany	17.6	605.0	622.6	113.6	591.7	705.3
Spain	9.3	191.3	200.6	66.9	484.7	551.6
Netherlands	88.7	414.1	502.7	98.1	301.3	399.4
Sweden	244.9	58.8	303.8	240.5	58.0	298.4
France	37.4	163.6	201.0	46.1	186.5	232.6
Ireland	5.2	160.9	166.2	10.9	154.1	165.0
Portugal	0.0	177.5	177.5	7.0	153.1	160.1
Hungary	0.0	118.0	118.0	0.1	144.0	144.1
Czechia	0.0	53.3	53.3	6.5	81.2	87.7
Finland	115.4	0.0	115.4	87.1	0.0	87.1
Slovenia	0.2	42.8	43.1	16.2	49.1	65.3
Luxembourg	0.0	28.6	28.6	0.0	60.3	60.3
Bulgaria	6.0	44.8	50.8	16.6	39.2	55.8
Belgium	6.0	11.8	17.8	16.7	38.8	55.5
Greece	0.0	34.9	34.9	0.0	41.2	41.2
Denmark	6.8	13.6	20.4	12.6	25.7	38.4
Estonia	5.7	9.1	14.8	22.5	14.5	37.0
Slovakia	0.0	30.1	30.1	0.0	36.2	36.2
Croatia	0.0	37.8	37.8	0.0	35.2	35.2
Poland	16.5	0.0	16.5	34.8	0.0	34.8
Cyprus	0.0	11.3	11.3	0.0	18.5	18.5
Austria	11.7	3.9	15.5	9.8	3.3	13.0
Latvia	0.0	0.0	0.0	9.9	0.2	10.1
Malta	0.0	10.6	10.6	0.1	7.5	7.6
Lithuania	0.0	0.0	0.0	0.0	0.2	0.2
Romania	0.0	0.0	0.0	0.0	0.0	0.0
Total EU-27	974.6	2 792.9	3 767.5	1 223.7	3 060.8	4 284.4

1. Advanced biofuels means biofuels that are produced from the feedstock listed in Part A of Annex IX of the Directive (EU) 2009/28/EC. 2. Biofuels that are produced from the feedstocks listed in Part B of Annex IX of the Directive (EU) 2009/28/EC.
Source: Eurostat.

consumption in transport (99.6% in 2020), only 71.1 ktoe in 2020 could not demonstrate compliance.

Reduced mobility needs hit the amount of renewable electricity used in transport, which fell by 5% in the European Union from 1.88 to 1.79 Mtoe (see table). The drop in renewable electricity consumption by railway transport was partly offset by the rise in the number of electric vehicles on the road. Renewable electricity consumption in road transport increased by almost 50% (by 47.5% year-on-year) from 76.5 to 112.8 ktoe, but road transport is still only a minor renewable electricity segment compared to the railways that dominates renewable electricity consumption. Incidentally, the increase in biofuel consumption mainly benefited those biofuels subject to double accounting of their energy content (see inset). According to Eurostat, consumption of "advanced" biofuels (not derived from food crops), rose by about 13.7 % (see table) from 3.8 Mtoe in 2019 to 4.3 Mtoe in 2020 (by 516.9 ktoe). Thus, double the amount, i.e., 8.6 Mtoe in 2020, was incorporated into the transport target. This trend indicates a small year-on-year drop in agrofuel consumption across the European Union in favour of biofuel transformed from non food crop feedstock. The latter now accounts for more than a quarter of the biofuels used in European Union (26.4% in 2020 compared to 23.6% in 2019). This trend is in step with the amended 2009/28/EC Directive that capped the agrofuel share at 7% of Member States' final energy consumption in transports in 2020.

THE MEMBER STATES' RESULTS ARE UNEVEN

The SHARES tool is used to take stock of the countries that have met their renewable energy targets in transports. The hard facts are that only 12 countries met or overshot their Renewable Energy Directive transport target. Sweden is way out in front with a 31.9% share, followed by Finland (13.4%), the Netherlands (12.6%), Luxembourg (12.6%), Estonia (12.2%), Hungary (11.6%) and Belgium (11%). Slovenia, Italy, Malta, Austria and Ireland also achieved their targets., while eight other countries with less than a one percentage point difference were very close to achieving their targets with shares ranging from 9.9% for Germany and 9.1% for Bulgaria. The gaps are wider for countries like Croatia (6.6%), Poland (6.6%), Lithuania (5.5%) and Greece (5.3%, provisional figure). Between 2019 and 2020, all the Member States with the exception of France (with no change at 9.2%) and Finland (-0.9 of a percentage point) increased their renewable energy share in transport. Some of the countries waited until the last year to fulfil their commitments by significantly increasing their renewable energy share: Estonia (by 5.9 pp), Luxembourg (by 4.9 pp), Belgium (by 4.2 pp) and Hungary (by 3.5 pp). Because biofuel transport fuels are traded easily, certain Member States with a dearth of this type of resource or that placed production restrictions on their sectors had no trouble procuring biofuels from other countries.

A PARADIGM SHIFT

The minimum renewable energy target in transport stipulated in the RED II for 2030 is 14%. As it stands today, this target looks inconsequential, if not to say obsolete, given the European Commission's Green Deal to raise the binding renewable energy target of the EU's energy mix to 40% in 2030. Effectively, the new focus on road transport carbon neutrality means the gradual abandonment of agricultural biofuel, in favour of using all-electric vehicles, advanced biofuels, renewable fuels of non-biological origin (RFNBO) or fuels based on recycled carbon. This paradigm shift, or sustainable transport energy policy reset will be protracted, given the inertia of past policies. Yet, it will take a sea change over the rest of this decade to turn the European target of becoming the first climate-neutral continent by 2050 into reality. The transport sector will have to make a 90% reduction in GHG emissions by 2050 as indicated in the Green Deal for Europe. The European Commission has already formalized the way ahead and the legal framework. In July 2021, it presented a set of twelve draft regulations and directive revisions to set Europe on track to reduce GHG emissions by 55% in 2030 (compared to 1990 levels). This approach, known as "Fit for 55", is part of the follow-up to the December 2020 vote for this 55% target by the European Parliament and the Green Deal voted in December 2019.

The Commission proposes an increase to match its renewable energy level for transport in this new package, by setting a 13% GHG intensity reduction target (compared to the previous 9% target). Additionally, Europe has raised the advanced biofuel sub-target from at least 0.2%

4

Renewable electricity used in transport (road, rail, other transport modes) in 2019 and 2020 (in ktoe)

	2019				2020			
	Ren. electricity in road transport	Ren. electricity in rail transport	Ren. electricity in all other transport modes	Total	Ren. electricity in road transport	Ren. electricity in rail transport	Ren. electricity in all other transport modes	Total
Germany	10.0	335.4	0.0	345.4	14.4	345.6	0.0	360.0
Italy	4.0	162.7	171.7	338.4	5.6	135.5	154.1	295.1
France	8.8	226.5	34.3	269.6	11.7	192.0	27.1	230.9
Austria	0.9	122.4	78.7	201.9	0.9	117.5	78.9	197.3
Sweden	14.5	140.7	0.0	155.2	28.2	128.8	0.0	157.0
Spain	4.9	109.0	9.6	123.4	6.1	88.5	6.4	101.0
Poland	0.9	84.1	6.3	91.3	2.1	80.1	5.7	87.9
Netherlands	14.3	43.4	0.0	57.7	18.6	41.3	0.0	60.0
Belgium	2.7	42.9	0.5	46.2	3.7	40.5	0.5	44.7
Czechia	1.8	43.8	1.6	47.3	2.0	41.7	1.8	45.5
Romania	1.4	36.2	0.7	38.3	1.5	36.0	1.5	39.0
Hungary	1.1	30.6	0.3	32.1	1.7	31.6	0.3	33.6
Finland	2.2	23.7	0.0	25.9	4.0	21.7	0.0	25.6
Denmark	2.6	21.2	0.0	23.8	5.1	22.7	0.0	27.9
Portugal	0.5	22.2	0.3	23.0	0.5	18.6	0.3	19.3
Slovakia	0.6	11.7	1.8	14.2	0.7	11.6	1.7	14.0
Croatia	0.1	9.6	1.3	10.9	0.1	9.3	1.5	10.8
Bulgaria	1.0	8.3	0.3	9.6	1.0	10.2	0.3	11.5
Slovenia	0.1	6.2	0.2	6.4	0.1	5.6	0.2	5.8
Greece	0.5	4.9	0.0	5.4	0.6	5.0	0.0	5.6
Latvia	1.2	3.2	0.3	4.7	1.3	2.9	0.2	4.3
Luxembourg	0.2	4.0	0.0	4.2	0.5	3.6	0.0	4.1
Ireland	0.7	1.4	0.0	2.1	1.2	1.4	0.0	2.5
Lithuania	1.0	0.4	0.7	2.1	1.1	0.4	0.5	2.0
Estonia	0.5	0.3	0.7	1.5	0.4	0.3	1.2	1.9
Malta	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
Cyprus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total EU-27	76.5	1 494.9	309.2	1 880.6	112.8	1 392.5	282.1	1 787.5

Source: Eurostat.

Renewable targets for transport in the current RED II

The new renewable energy directive (2018/2001) raised the renewable energy target (described as the "minimum share" to be achieved) for the transport sector to 14% in 2030. It reformulated and added new sustainability and GHG reduction criteria and set new specific targets for biofuels produced from waste (oils and fats) and raw materials not sourced from food crops. The RED II directive provides for the energy accounting of the biofuel (andbiogas) energy content share used for transport and produced from certain raw materials2 to be doubled in countries that use them in order to achieve the set target of 14%. This double accounting applies to "advanced biofuels" (and biogas), that are produced from the raw materials listed in Annex IX, part A of the directive (algae, forestry waste and residue, from the timber sector, straw, manure, sewage sludge, raw glycerine, bagasse, and others). It also applies to biofuels (and biogas) produced using other raw materials listed in part B of the same annex, namely, used cooking oils and animal fats. However, biofuels produced from these B-listed materials are not deemed to be "advanced" and therefore do not contribute to the specific minimum share targets vested in advanced biofuels. To encourage the industrial development of "advanced biofuels", the RED II provides for a specific 0.2% target in 2022, and targets of at least 1% in 2025 and at least 3.5% in 2030 for each Member State. The Directive enables the Member States to depart from these limits if they can prove that the sourcing of the relevant raw materials is problematic.

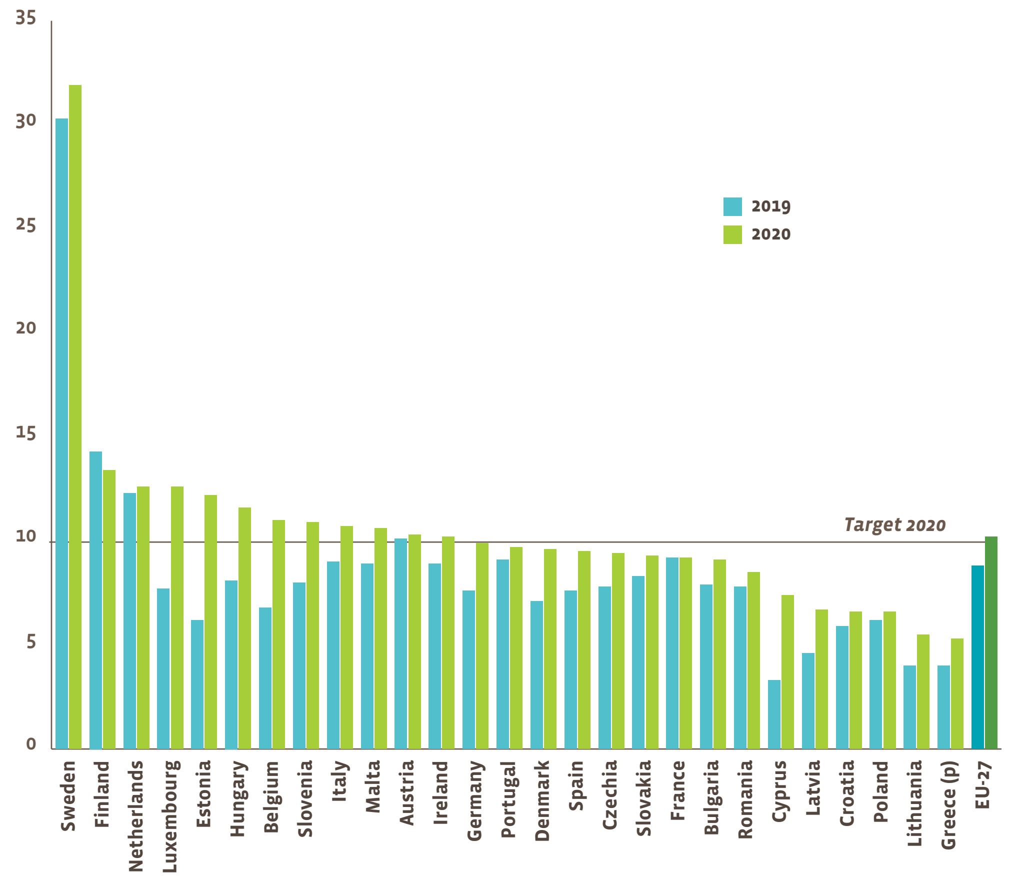
Other incentives have been implemented to encourage more GHG gas sparing modes of transport. The renewable electricity share is deemed to equate to four times its energy content when employed by road transport and 1.5 times its energy content when employed by rail transport. The contribution of fuels suppled to air and maritime transport equates to 1.2 times their energy content, excluding biofuels produced from crops that ordinarily feed humans and animals. These incentives reduce the biofuel volumes required to be physically incorporated to achieve the minimum 14% in 2030. The RED II also set a cap on biofuels produced from crops traditionally intended to feed humans and animals (that are defined as "agrofuels"). Their share in 2030 will face a double constraint: firstly, they will be prohibited from exceeding a maximum share of 7% of final energy consumption in the transport sector and secondly, their share will not be permitted to exceed more than one percentage point more than their 2020 rate. If they wish to, Member States may also set lower limits and make distinctions between types of biofuel. The RED II has finally introduced a contribution limit capped at 1.7% by 2030 for biofuels and biogas produced from used oils and animal fats (Annex IX, part B).

2. The raw materials in question are listed in Annex IX of the RED II.

in 2022 to 0.5% in 2025 and to 2.2% in 2030 and introduced a 2.6% sub-target for renewable fuels of non-biological origin. This sub-target anticipates the fact that RFNBOs will most likely play a major role in such sectors as aviation and maritime transport that will be dependent on liquid fuels in the long term. These synthetic fuels that combine carbon dioxide with hydrogen, will be sourced from green hydrogen produced by water electrolysis exclusively from renewable electricity. The RED II article on renewable fuels of non-biological origin (RFNBO) should shortly be published. It will define the scheme and methodology under which the hydrogen, be it locally produced or imported, could be labelled as renewable hydrogen in Europe, thereby determining its sustainability and eligibility for subsidies. The sun-drenched and semi-desert regions of Spain, Portugal and North Africa

4

Share of energy from renewable sources in transport (in %)



Source: Eurostat

(Morocco, Tunisia and Algeria) capable of accommodating solar farms with capacities of several hundred megawatts should broadly benefit from these new green hydrogen markets because the competitiveness of the photovoltaic solar kWh that these regions can produce cannot be matched. North Sea offshore wind energy offers another significant means of producing renewable hydrogen on a large scale in the United Kingdom, Germany, the Netherlands and Denmark. This sector is aided by the presence of exceptional wind resources, vast underwater gas grid infrastructures and by a major hydrogen support policy. There is another proposal in the pipeline on the implementation of a new regulation to roll out an alternative fuel infrastructure (that repeals Directive 2014/94/EU). This regulation proposes that the electric charging network should be extensively expanded on main trunk roads to provide an electric charging station every 60 km, while there would be a charging station every 150 km for hydrogen vehicles. That should mean 1 million electric charging stations in 2025 and 3.5 million in 2030. Another crucial lever is that the European Commission intends to extend the carbon market to the transport and building sectors. ■

EUROPEAN PLAUDITS FOR RENEWABLE ENERGIES

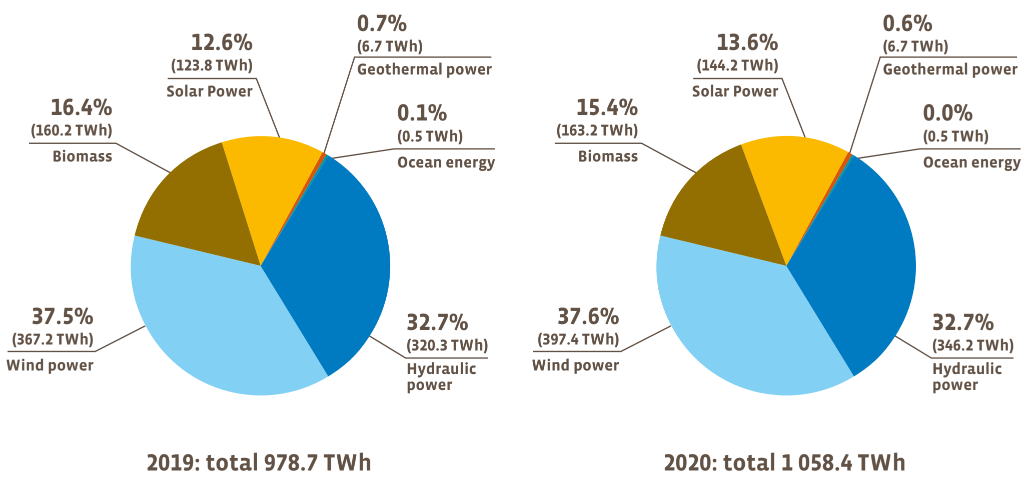
This summary makes a preliminary appraisal of actual renewable electricity production in 2020, i.e., non-normalized for hydroelectricity and wind energy, in addition to the various types of renewable energy used in the EU-27 for heating and cooling before drawing up a more thorough catalogue of the specific Member States' successes in achieving their renewable energy targets set in the Renewable Energy Directive 2009/28/EC.

THE 1000-TWH THRESHOLD FOR RENEWABLE ELECTRICITY CROSSED BY THE 27

It has taken the European Union two years to make up for the equivalent loss of renewable electricity output resulting from the United Kingdom's departure. The EU-27 has again crossed this symbolic 1000-TWh threshold two years after crossing it as the EU-28. According to Eurostat's 25 January 2022 data updates, gross European non-normalized renewable electricity excluding pumped storage output came to 1 058.4 TWh in 2020, posting 8.1% year-on-year growth (978.7 TWh). It beats the 2019 figure by 79.6 TWh. To put this into perspective, this difference is more than the total gross electricity output of a country such as Austria (72.6 TWh in 2020). In 2020, renewable energies provided 38.1% of total gross electricity production in the EU-27 (Eurostat puts this at 2 781.4 TWh). Renewable energies have the valuable assets of diversity and complementarity, which let all the major renewable electricity production sectors to play their part with increases by wind energy of 30.2 TWh; hydropower of 26 TWh; solar of 20.5 TWh and biomass of 3 TWh.
Wind energy consolidated its position with 397.4 TWh of actual output as the leading renewable electricity generating sector in the European Union. Its share of total renewable electricity production increased very slightly between 2019 and 2020 (from 37.5 to 37.6%), and as the year 2020 was a good year for wind energy, its normalized output at 376.4 TWh was higher than the level of the last 5 years.
Wind energy provided 14.3% (12.7% in 2019) of the European Union's total gross electricity output in 2020 measured at 2 781.4 TWh (12.7% share in 2019). This share is much higher in the leading countries that have put wind energy at the centre of their energy transition in the north, south, west or at the heart of Europe. In 2020, wind energy dominated Denmark's electricity mix (56.8% in 2020) and reached 35.8% in Ireland, 29.2% in Lithuania, 23.2% in Portugal, 23.1% in Germany and 21.4% in Spain. At the same time 16 of the 27 countries' wind energy sectors generated more than 10% of their total electricity output.
Between 2019 and 2020, the countries that enjoyed the biggest increases contributing to the rise in wind power production were Sweden (7.7 TWh, for a total of 27.5 TWh), Germany with an additional 6.2 TWh (for a total of 132.1 TWh), France (5.0 TWh, for a total of 39.8 TWh), the Netherlands (3.8 TWh, for a total of 15.3 TWh) and Belgium (3 TWh, for a total of 12.8 TWh). In the case of the Netherlands and Belgium, the sharp growth in wind power output (33.3% and 30.1% respectively) can be ascribed to the grid connection of new offshore wind farms over the last two years. The surge in Swedish and Finnish output (by 38.7% and 31.8% respectively) can be put down to the connection of land-based wind farms and better winds than in 2019. Southern European countries such as Italy and Portugal had poor winds and both of them saw their output drop by 1.4 TWh.
Now, the proportion of wind power generated offshore of the total wind power in the EU-27 increased. Offshore wind power output reached 47.3 TWh in 2020 (40.2 TWh in 2019), amounting to a 11.9% share (compared to 10.9% in 2019). This proportion was over 50% in Belgium (54.6% of wind power), while it was 40.4% in Denmark, 35.7% in the Netherlands and 20.7% in Germany.
Hydropower is the second pillar of renewable electricity production in the European Union. After mediocre results in 2019, 2020 was a good year overall for actual hydropower output (excluding pumping and non-normalized output). European Union hydropower output increased by 26 TWh (320.3 TWh in 2019 to 346.3 TWh in 2020), at the same pace as overall renewable electricity production (by 8.1% year-on-year). As a result, it maintained its 32.7% share of total renewable electricity production. Increases in output were registered in Northern Europe – in Sweden and Finland – and also in France, Spain, Portugal and Italy. Finland enjoyed the sharpest growth of the major European hydropower producer countries (27.9% between 2019 and 2020) which equates to a 3.5-TWh increase and total output of 15.9 TWh. The biggest increase in production was posted in Sweden (7 TWh between 2019 and 2020), which equates to 10.7% growth. In 2020, Sweden was the European Union's top hydropower producer with 72.4 TWh of output excluding pumping. It was followed by France, whose output excluding pumping also shot up (by 9% year-on-year, adding 5.1 TWh) for a total of 62.1 TWh.
Growth remained positive, albeit at a lower level in 2020. Italy kept its third place in the European Union producer rankings, with 47.6 TWh (2.7% year-on-year growth, or 1.2 TWh). Spain and Portugal's hydropower output can vary significantly from one year to the next. Growth was measured at 37% for Portugal (which added 3.3 TWh to make a total of 12.1 TWh) and 23.8% for Spain (which added 5.9 TWh, to make a total of 30.5 TWh).
Further to the east of Europe the output figures were mixed. Between 2019 and 2020, output dropped in Germany (by 7.1%, or 1.4 TWh), Greece (by 16.4%, or 0.7 TWh), Bulgaria (by 3.7%, or 0.1 TWh) and Romania (by 1.3%, or 0.2 TWh) while it increased in Poland (by 8.2%, or 1.2 TWh), Austria (by 2.9%, or 1.2 TWh) and Czechia (by 6.8%, or 0.1 TWh). All in all, this region's output levels were lower than in recent years.
While wind and water contributed most to generating renewable electricity, solar power is expanding faster than any other renewable source. Solar power complements hydropower particularly well, because it allows hydropower generation to be postponed to the end of the day when the demand for electricity is at its highest. Solar energy had a particularly good year in 2020. As it happens, the European continent enjoyed the highest number of sunshine hours since satellite readings began in 1983. This sunshine record, combined with the increase in production capacities, explain the surge in solar power production. Eurostat explains that EU solar electricity output reached 144.2 TWh in 2020 (139.2 TWh of solar photovoltaic and 5 TWh of CSP), posting 16.5% growth and an additional 20.5 TWh. As CSP output contracted

1

Share of each energy source in renewable electricity generation in the EU-27 (in %)



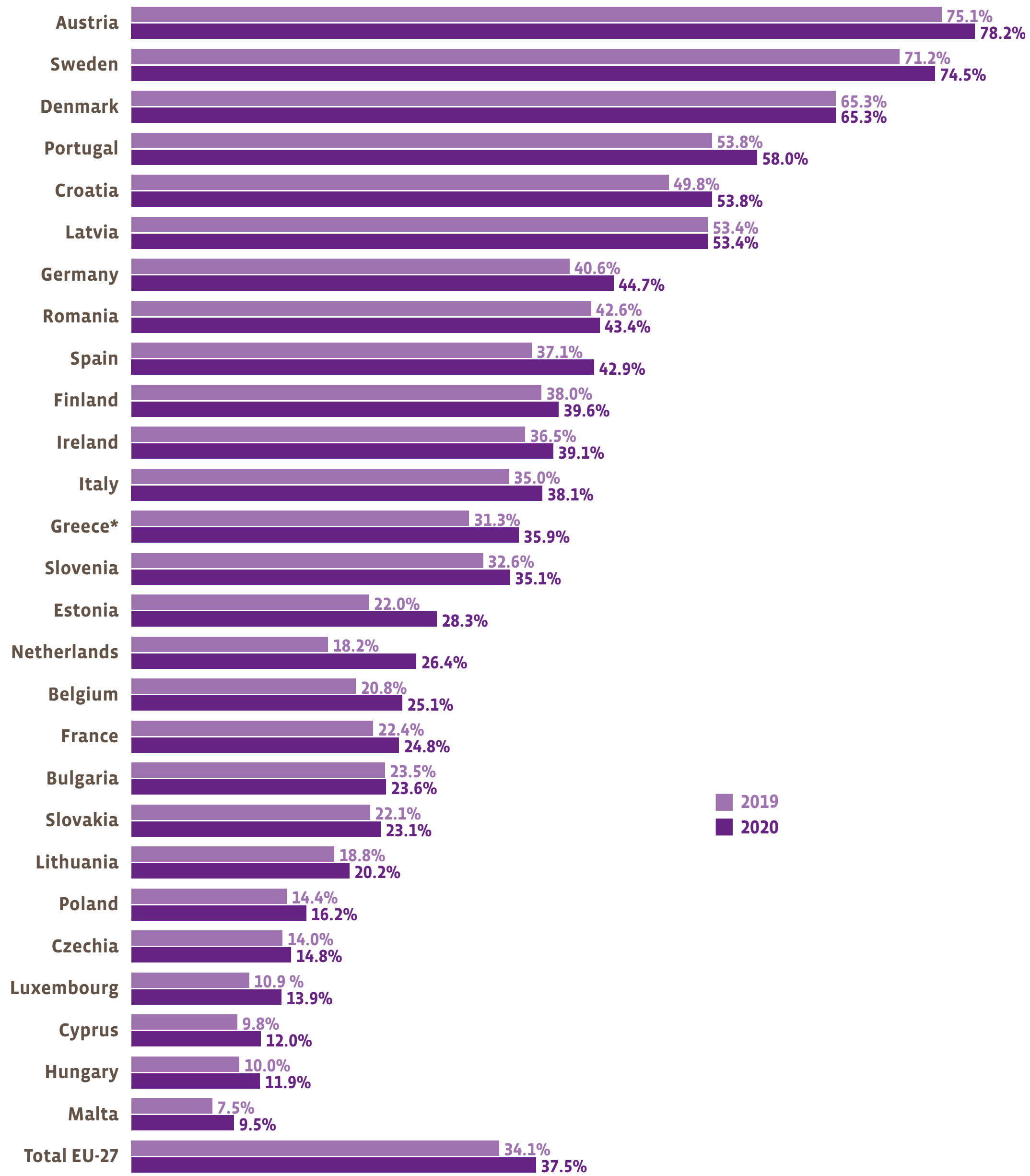
Notes for calculation: Hydro is actual (not normalised) and excluding pumping. Wind is actual (not normalised). All electricity production from bioliquids (compliant and non compliant) is included (non compliant bioliquids electricity production represents 127.7 GWh in 2019 and 127.7 GWh in 2020). Renewable electricity from biogas blended in the gas natural grid is included (it represents 532.9 GWh in 2019 and 680.3 GWh in 2020). ***Source: EurObserv'ER based on Eurostat database.***

slightly in 2020, solar photovoltaic alone can claim all the credit for this growth. Solar energy now underpins electricity production in the European Union. It-accounted for 13.6% of its renewable electricity output and 5.2% of total electricity output. In 2020, this share was as high as 11.1% in Malta (0.2 TWh of solar power generated), 9.2% in Greece (4.4 TWh), 8.9% in Italy (24.9 TWh), 8.5% in Germany (48.6 TWh) and 7.9% in Spain (20.7 TWh).

Biomass energy in all its manifestations (solid biomass, biogas, renewable municipal waste and liquid biomass), generated 163.2 TWh of electricity in 2020, which is a year-on-year 1.9% (3 TWh) increase. The momentum for the growth in electricity production primarily comes from its solid biomass form, which expanded by 3.0% over the year to 83 TWh in 2020 (adding 2.4 TWh). The Netherlands registered the highest increase by doubling its output level between 2019 and 2020 (by 103.8%) to generate 5.8 TWh (or 2.9 TWh). This was achieved by increased use of wood pellets in co-combustion with coal in the RWE Amers 9 and Uniper MPP3 power plants. Biomass electricity outputs increased in Spain (by 16.9%, or 656 GWh), Poland (by 7.6%, or 492 GWh), Estonia (by 38.6%, or 486 GWh) and Portugal (by 16.6%, or 457 GWh) However, these increases were counterbalanced by significant drops in biomass power generation in Sweden (by 15.4%, or 1.7 TWh) and Finland (by 12.6%, or1.6 TWh), both of which can be explained by falls in electricity needs. Biogas electricity was also positive. If in addition to plants that exclusively use biogas produced on site, we include the biomethane (purified biogas) injected into the grid and used remotely in gas-fired power plants, biogas electricity output reached 56.3 TWh, which is a 0.8 TWh rise. As for the other biomass sectors, the input from renewable urban waste slipped to 18.9 TWh in 2020 (by 0.1 TWh) as did liquid biomass electricity production (by 0.1 TWh) to 5 TWh. There was hardly any change in the output of the European Union's geothermal (essentially Italian) and ocean energies (essentially French) electricity generating sectors between 2019 and 2020, whose production levels were 6.7 TWh and 0.5 TWh, respectively.

2

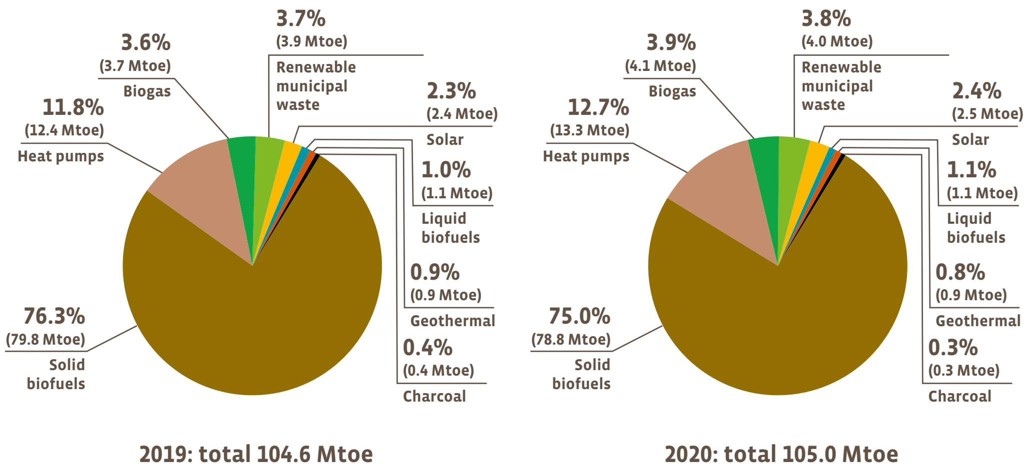
Share of energy from renewable sources in gross electricity consumption, 2019-2020 (%) - Directive 2009/28/EC



Notes for calculation: Hydro is normalised and excluding pumping. Wind is normalised. Solar includes solar photovoltaics and solar thermal generation. All other renewables includes electricity generation from gaseous and liquid biofuels (only the compliant part), renewable municipal waste, geothermal, and tide, wave & ocean. Renewable electricity from biogas blended in the natural gas grid is also included.
** Year 2020 (provisional for Greece).* ***Source: Eurostat SHARES (updated 1st February 2022)***

3

Share of each energy source in renewable heat and cooling consumption in the EU-27 (in %)



Note for calculation: Renewable sources for heating and cooling correspond to the sum of final energy consumption of renewables fuels in Industry and Others Sectors, of production of derived heat from renewable fuels and heat pumps. Final energy consumpion and derived heat from biogas blended in the grid is included. Final energy consumption and derived heat of liquid biofuels (compliant and non compliant) is included. ***Source: EurObserv'ER based on Eurostat database.***

RENEWABLE HEAT HELD FIRM THANKS TO HEAT PUMPS

According to Eurostat data (updated on 25 January 2022), compiled by EurObserv'ER, the amount of renewable energy used for heating and cooling increased slightly from 104.6 Mtoe in 2019 to 105 Mtoe in 2020. This indicator covers the energy consumed directly by industrial end-user and "other sector" users (such as residential, commercial, agriculture, forestry and fishery), heat produced by the processing sector (derived heat) and the renewable production recovered by heat pumps. Final energy consumption and heat production from the processing sector of the biogas injected and blended in the natural gas grid are also included in this indicator.

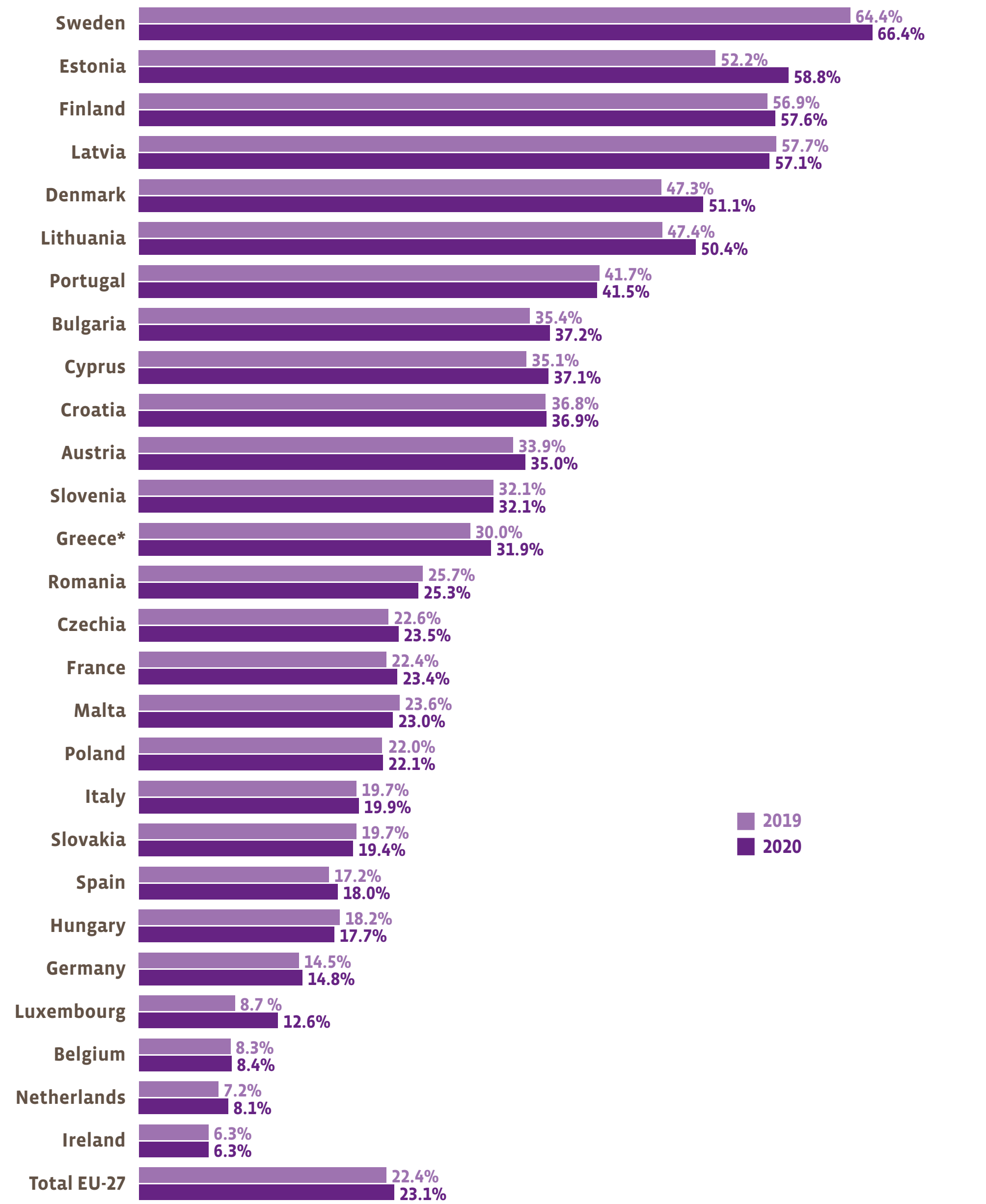
Analysis of the contribution made by each renewable energy sector to total energy consumption for heating and cooling confirms that reliance on solid biomass contracted by 1 Mtoe between 2019 and 2020 (from 79.8 to 78.8 Mtoe). Requirements for solid biofuels fell in the first place because of the abnormally mild winter of 2020, and more generally because of an abnormally hot year across Europe, which reduced the use of heating appliances, primarily in the residential sector. The economic fallout of the Covid-19 pandemic limited the European Union's energy needs, compounding the drop in heating needs, and so did nothing to serve the interests of solid biomass heat consumption.

We should point out that solid biomass heat consumption in the EU-27 was higher than in the previous year, mainly because of the far-reaching statistical consolidation made at the end of 2021 in Poland, which was applied retroactively back to 2018, increasing is solid biomass heat consumption (final energy and derived heat consumption) by about 2.6 Mtoe. Other countries have similarly made consolidations of this type for recent years. They can often be put down to more in-depth studies of wood consumption and the implementation of more accurate calculation methods. However, Poland's consolidation level is particularly significant.

Momentum in the heat pump (HP) sector is much livelier and enough to make up for the loss made by solid biomass (it added 0.92 Mtoe , to finish with

4

Share of energy from renewable sources for heating and cooling, 2019-2020 (%) - Directive 2009/28/EC



*Note for calculation: Renewable sources for heating and cooling correspond to the sum of final energy consumption of renewables fuels in Industry and Other Sectors, of production of derived heat from renewable fuels and heat pumps. Final energy consumpion and derived heat from biogas blended in the grid is included. Only final energy consumption and heat derived from liquid biofuels compliant with the requirements of Directive 2009/28/EC are included. * Year 2020 (provisional for Greece).* ***Source: Eurostat SHARES (updated 1st February 2022)***

5

Share of energy from renewable sources in total gross final energy consumption in 2019 and 2020 and 2020 target

** Year 2020 (provisional for Greece). SHARES tool version 2020 takes into account specific calculation provisions as provided by Directive 2009/28/EC, in addition to the new possibility to allocate domestically produced biomethane to the transport sector on the basis of the mass-balance system (with appropriate traceability requirements).* ***Source: Eurostat SHARES (updated 1st February 2022)***

a total of 13.3 Mtoe in 2020). European Union-wide HP market data for 2020 confirms the inroads made by this technology in the heating and cooling segment. It has taken advantage of the policies of countries that have introduced regulations favourable to electrifying heating needs (France, Finland, Sweden, etc.) and the increase in summer cooling needs (another consequence of climate warming) for the area of reversible heat pumps in cooling mode. Everything is ready for the contribution of HPs to accelerate towards climate targets during this decade, made possible by a much more aggressive building energy renovation policy.

Other sectors apart from HPs have boosted the increase in total renewable heat consumption – biogas (0.32 Mtoe , or 4.1 Mtoe), renewable municipal waste (0.14 Mtoe , or a total of 4 Mtoe), solar energy (0.09 Mtoe , or a total of 4 Mtoe) and liquid biomass (0.06 Mtoe , or a total of 1.1 Mtoe).

Between 2019 and 2020, the distribution between the various renewable heat sectors worked to the detriment of solid biofuel (from 76.3 to 75%) and to the benefit of heat pumps (from 11.8 to 12.7%). The biogas share rose from 3.6 to 3.9%, the renewable municipal waste share from 3.7 to 3.8%, solar from 2.3 to 2.4%, geothermal energy remained at 0.8%, liquid biomass from 1 to 1.1%, and charcoal stayed at 0.4%.

SPECIFIC GOALS OF THE EUROPEAN DIRECTIVE

A 37.5% RENEWABLE SHARE OF GROSS ELECTRICITY CONSUMPTION

The renewable electricity production monitoring indicator used to calculate the Renewable Energy Directive (2009/28/EC) target differs from the above indicator, as it factors in normalized output for hydropower and wind energy (using the normalization formula defined in annex II of the directive), to even out the vagaries of climate as regards rainfall and wind, and thus give a fairer portrayal of the efforts made by each Member State. Furthermore, it only includes the electricity output sourced from liquid biomass that is certified as compliant (see Method and definitions inset). The normalized hydropower output figure adopted for the EU-27 was 345.1 TWh in 2020 (343.2 TWh in 2019), and that of wind energy was 376.4 TWh in 2020 (348.4 TWh in 2019). Total renewable electricity production, namely the numerator used for calculating the renewable energy share of gross electricity consumption, is thus put at 1036 TWh in 2020 (982.7 TWh in 2019), which is a 5.4% year-on-year increase. The total electricity production figure adopted (the denominator) is 2 764 TWh for 2020 (2 882.9 TWh in 2029), which is a 4.1% decrease.

This change raised the renewable electricity share from 34.1% in 2019 to 37.5% in 2020, or a 3.4 percentage point (pp) gain. The "normalized" renewable electricity share has more than doubled (x 2.4) and gained 21.6 pp over the period, if we compare it with 2004 (15.9%), the first reference year when targets were included.

Graph 2 shows that the Member States' renewable electricity shares can vary wildly depending on their renewable energy potential and the support policies set up. Austria has the highest renewable electricity share of the EU (78.2% in 2020), followed by Sweden (74.5%) and Denmark (65.3%). The renewable electricity share is also over 50% in Portugal, Croatia and Latvia (with 58%, 53.8% and 53.4% respectively). The six countries with the lowest renewable electricity shares are Poland (16.2%), Czechia (14.6%), Luxembourg (13.0%), Cyprus (12%), Hungary (11.9%) and Malta (9.5%).

If we consider this reference period (2004–2020), we can see that many EU countries have enjoyed significant increases in their renewable electricity shares, resulting in dramatic changes to the electricity production mix. The renewable share of Denmark's electricity mix, for instance, has risen from 23.8 to 65.3% (41.6 pp), that of Germany from 9.4 to 44.7% (35.3 pp), that of Ireland from 6 to 39.1% (33 pp), that of Portugal from 27.4 to 58% (30.6 pp), that of Estonia from 0.5 to 28.3% (27.7 pp), that of Belgium from

Statistical Transfers and Joint Projects* in 2020

	Total amount to be added (in ktoe)	Total amount to be deducted (in ktoe)	Statistical transfers from
Belgium	333.3	0.0	Denmark (154.8), Finland (165.1), Lithuania (13,1)
Czechia	0.0	40.0	
Denmark	0.0	1 418.8	
Germany	4.4	0.0	Denmark (4.4)
Estonia	0.0	251.0	
Ireland	300.9	0.0	Denmark (86), Estonia (215)
Lithuania	0.0	34.6	
Luxembourg	55.9	0.0	Lithuania (21.5), Estonia (34.4)
Malta	1.7	0.0	Estonia (1.7)
Netherlands	1 173.7	0.0	Denmark (1173.7)
Slovenia	40.0	0.0	Czechia (40)
Finland	0.0	165.5	
Sweden	0.0	227.3	
Norway	227.3	0.0	Sweden**(227.3)
Total	**2 137.3**	**2 137.2**	

** Articles 6 -11 of the Directive 2009/28/CE. ** Joint support schemes between Norway and Sweden (Article 11, Directive 2009/28/CE).*
Source: Eurostat SHARES (updated 1st February 2022)

1.7 to 25.1% (23.4 pp) and that of Italy from 16.1 38.1% (22 pp). This contrasts with the slender increase in the renewable electricity share of Slovenia from 29.3 to 35.1% (5.8 pp), Latvia from 46 to 53.4% (7.4 pp) and Slovakia from 15.4 to 23.1% (7.7 pp).

RENEWABLE ENERGY COVERS 23.1% OF TOTAL HEATING AND COOLING ENERGY CONSUMPTION

The Renewable Energy Directive 2009/28/EC defines a specific indicator for measuring the renewable share of total heating and cooling energy consumption. The numerator used for the calculation differs slightly from the one obtained from the Eurostat database from the Members States' complete energy balances. It amounts to 104.1 Mtoe in 2019 and 104.6 Mtoe in 2020 compared to 104.6 Mtoe of consumption in 2019 and 105 Mtoe in 2020. The reason for the 0.4 Mtoe difference in 2020 is that only liquid biofuels certified as complying with the Renewable Energy Directive criteria were included in the target calculations. The SHARES tool measures the denominator that represents total final heating and cooling energy consumption at 464.3 Mtoe in 2019 and 453 Mtoe in 2020 – a drop of 2.4%, making the 2020 consumption level the second lowest since 2004, arising from the COVID-19 pandemic that slowed down economic activity and the fact that 2020 was a particularly warm year with lower heating requirements. The lowest level, of 447.2 Mtoe was measured in 2014.

Through these elements we arrive at a renewable share of total heating and cooling energy consumption in the EU of 23.1% in 2020 (22.4% in 2019), which is a 0.7 pp increase. Thus in 2020, the fall in energy needs for heating and cooling triggered the rise in the renewable share. If we take 2004 as the reference year (11.7%), the share of renewably-sourced energy in heating and cooling has practically doubled in the European Union. This expansion can be attributed to lower heating needs that decreased from 528.7 Mtoe in 2004 to 453 Mtoe in 2020 (by 14.3%) over the period, but most of all to the increase (68.6%) in renewable heat from 62 to 104.6 Mtoe . While a few million tonnes equivalent of oil have been traced over the years thanks to better statistical monitoring of certain sectors (biomass in particular), most of the increase can be explained by the Member States' determination to substitute the use of fossil energies.

At Member State level, more renewable energy is naturally used in heating and cooling in forest countries, as biomass is far and away the main source of renewable heat. It amounts to two-thirds of Sweden's heat consumption (66.4% in 2020). The country not only exploits its forest potential to the full (industries and heating networks) but has also generalized the use of heat pumps in the home. Renewable heat is also the main heating source in other Norther European countries (57.6% in Finland, 51.1% in Denmark) and the Baltic states (58.8% in Estonia, 57.1% in Latvia, 53.7% in Estonia and 50.4% in Lithuania). In contrast, it has a minority stake in the Benelux countries (12.6% in Luxembourg, 8.4% in Belgium and 8.1% in the Netherlands) and in Ireland (6.3%).

From 2004 to 2020, the biggest increases in the renewable energy shares used for heating and cooling can be credited to Denmark (30.6 pp), Cyprus (27.9 pp), Malta (22 pp), Estonia (25.5 pp) and Bulgaria (23.1 pp). At the other end of the spectrum, we find Ireland (3.4 pp), the Netherlands (5.9 pp) and Belgium (5.5 pp) whose increased use of renewable heating and cooling were the lowest.

A COLLECTIVE, UNIFIED SUCCESS, WITH A CAVEAT

The year 2020 marked a major deadline for the Member States of the European Union, that of achieving or missing the renewable energy targets they set under the terms of Directive 2009/28/EC, and behind these targets, the credibility of the European Union to conduct its energy transition. Collectively, the Eurostat SHARES tool, whose aim is to simplify calculation of the renewably-sourced energy share in line with the Directive, in its version revamped on 1 February 2022, demonstrates the European Union's success. The renewable energy share of gross final energy consumption, defined by the criteria stipulated in the Directive, actually reached 22.1% in 2020 in the EU-27. This is 2.1 percentage points higher than the collective target defined for 2020 and marks a major intermediate stage in the European Union's strategy to be the first climate-neutral continent by 2050.

While the plaudits are legitimate, the target was outstripped to such an extent because of the reduction in fossil energy consumption caused by the COVID-19 pandemic-related slowdown in activity. This performance can also be attributed to the sharp growth in renewable electricity production, slightly higher renewable energy consumption in the transport sector driven by the 10% renewable energy target in transports and maintaining the renewable heat consumption level despite the inauspicious context.

Once it was clear that the UK would be leaving the European Union, any doubts about fulfilling the collective target of 20% were dispelled. From an accounting standpoint, this exit, which came into effect on 1 February 2020, actually boosted the renewable energy share of the new EU-27, as the UK's renewable energy share was much lower than European Union average (12.3% in 2019, according to Eurostat). The EU-27 target was almost reached as early as 2019 without the UK, with a 19.9% share according to the latest Eurostat update (1 February 2022). Incidentally, the 2019 share had been initially measured at 19.7% in the April 2021 Eurostat update. In the interim, this renewable share has had a timely upward statistical consolidation, through the revision of several countries' renewable energy consumption levels, which in the case of Poland was sizable.

The renewable energy share of gross final energy consumption more than doubled between 2004 and 2020 in the current EU-27, from 9.6 to 22.1%. If we look back, and at the effects of past renewable energy directives, such as Directive 2001/77/EC on the promotion of electricity produced from renewable energy and more recently Directive 2009/28/EC on the promotion of the use of energy from renewable sources, repealed as of 1 July2021 by the new Renewable Energy Directive (2018/2001/EC).

If we analyse the national targets, 26 of the 27 Member States exceeded their targets for 2020. The countries with the widest success margins were Sweden (11.1 pp), Croatia (11 pp), Bulgaria (7.3 pp), Finland (5.8 pp) and Estonia (5.1 pp). France is the only European Union not to have reached its target (by 3.9 pp), while the UK, which ceased to be a member state on 1 February 2020, would have found itself in the same boat. As indicated above, Poland revised its final solid biomass energy consumption data, with the outcome that its renewable energy share rose by more than 3 percentage points, thus enabling it to meet target.

To meet their targets, some countries resorted to statistical transfers. The latter are agreements between Member States to transfer a set amount of renewably-sourced energy from one member state to another. Joint aid schemes are another cooperation mechanism recognized by the Directive.

Seven European Union countries, in addition to Norway, used statistical transfers. Under this framework the Netherlands negotiated a transfer of 1 173 ktoe from Denmark, while Belgium negotiated transfers from Finland (165.1 ktoe), Denmark (154.8 ktoe) and Lithuania (13.1 ktoe). Ireland negotiated transfers from Estonia (215 ktoe) and Denmark (86 ktoe), Luxembourg benefitted from a transfer of 21.5 ktoe from Lithuania and 34.4 ktoe from Estonia, Slovenia received a 40-ktoe transfer from Czechia and Malta a 1.7-ktoe transfer from Estonia. Under the terms of its common support scheme with Norway, Sweden transferred 227.3 ktoe to its neighbour and Germany, the only country to have implemented cross-border tenders (photovoltaic as it happens) benefitted from 4.4 ktoe from Denmark. These transfers come at considerable cost for the countries. For example, the Netherlands negotiated a volume of up to 8 000 GWh at € 12.5 per MWh (€ 100 m), Ireland negotiated for a total of 3 500 GWh at € 12.5 per MWh (i.e., € 12.5 m with Denmark and € 37.5 m with Estonia), Flanders took 1 800 GWh for € 12.5 per MWh (€ 22.5 m) and Luxembourg negotiated with Estonia (700 GWh) and Lithuania (400 GWh) at a cost of € 15 per MWh (for total of € 16.5 m).

In France's case, the jury is out as to which sanctions will be levied for missing its target. Financial sanctions are among the harshest measures that can be taken against countries that do not implement European Union law. The European Commission could instigate a sanctions procedure at the European Court of Justice if it considers this appropriate. It could also demand France to implement corrective measures rapidly, for instance by putting it under pressure to negotiate statistical transfers with other countries. France is about 5.4 Mtoe (62.8 TWh) short of its target, which would imply a hefty theoretical statistical transfer cost of € 785 m if we apply the € 12.5 per MWh rate.

The European Union is moving towards a new legislative phase regarding renewable energies, pending its issue of follow-up guidelines. The current Renewable Energy Directive 2018/2001/EC (known as RED II) target of raising the renewable energy share to 32% by 2030, is now considered to be too low given the climate emergency. In its new "Fit for 55" legislative package, the European Commission proposed to raise the GHG emission reduction target to 55% by 2030 compared to the 1990 emissions level and to revamp the Renewable Energy Directive to raise the new renewable energy target to 40%... which means this share needs to rise to just over double its current level within a decade. The great difference with regards to the early days of the millennium is that the European renewable energies industry is now fully mature, in working order and has highly competitive technologies. ■

Methods and definitions (Graphs 2, 4 and 5)

Renewable energy sources cover solar thermal and photovoltaic energy, hydro (including tide, wave and ocean energy), 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. 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 taken into account in the calculation of the main objective of each Member State concerning the share of renewable energies in the total gross consumption of final energy. 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).

Methodology details and additional information is also available: http://ec.europa.eu/eurostat/web/energy/data/shares

Ulrich Wirrwa / Vattenfall

FOCUS: INTEGRATION OF RES IN THE BUILDING STOCK AND URBAN INFRASTRUCTURE

The share of RES in the building stock has already grown strongly in recent years in Europe. RES are particularly successful in the area of electricity generation, but in the heating and cooling sector RES consumption is still lagging somewhat behind. At the same time, the heating and cooling sector is the most important energy demand sector in Europe. It accounts for about 50% of the European total final energy consumption, from which 30% is used for space and water heating.

Heating and cooling demands are mainly satisfied by onsite technologies that are integrated in the respective building. In light of the ambition to further decarbonise the heating and cooling sector, especially in highly populated urban areas, district heating networks are gaining importance.

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

The consumption and market indicators on RES heating integration in the building stock and urban structure are designed to depict the status quo of RES use and the development of RES deployment in this respect. Due to the large and variating building stock and the long life cycle of heating systems and buildings, the consumption shares change slowly while the market shares reflect changes at the margin.

Methodological note

*The **consumption shares of RES** heating and cooling in the building stock displays the degree of usage of the respective RES in the building sector, as well as 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.*

*The **share of RES in district heating** focusses on the type of energy carrier used in district heating networks. The amount of energy generated from RES technologies in district heating is divided by the total energy generation in district heating, including fossil fuels-based generation. Therefore, this indicator provides an overview to what extent district heating networks operate in a sustainable manner.*

*In addition, the **market stock shares of RES** in heating 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 as as a stand alone system. In contrast, electric heating is included in the market stock share as as a stand alone 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** heating technologies depict the dynamics and development of RES at the edge. Market shares show the shares of specific heating technologies sold in relation to the total 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 exchanged systems is assessed based on the change in market stock share. Although solar thermal energy is mainly used in combination with other systems, it is separately listed here to show its significance and dynamics.*

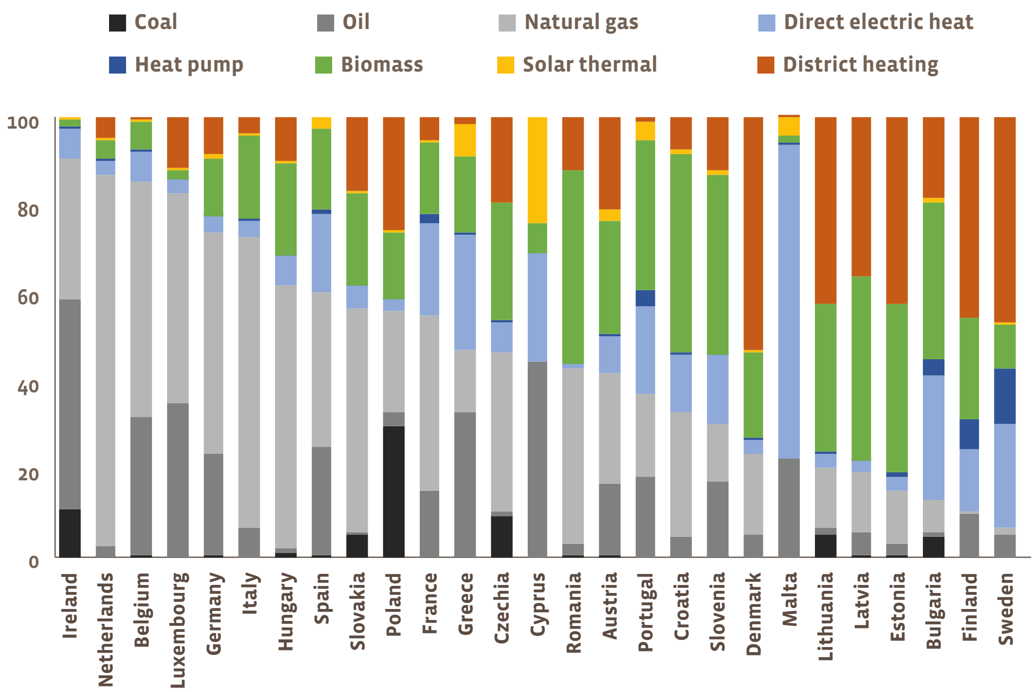
*The **shares of RES electricity for heating** in the building stock is used to track the increasing importance of electricity in the heating sector. By dividing the electricity consumption from RES for direct electric heating as well as for heat pumps by the final heat demand in buildings, this indicator can be used to track developments in the RES electricity for heating deployment.*

More details on the methodological approach can be found in Eurostat's methodology on consumption shares (see e.g. http://ec.europa.eu/eurostat/web/energy/data/shares).

RESULTS AND INTERPRETATION

1

RES consumption shares in 2019



Source: EurObserv'ER - own assessment based on diverse sources. *Notes: 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 IN HEATING AND COOLING

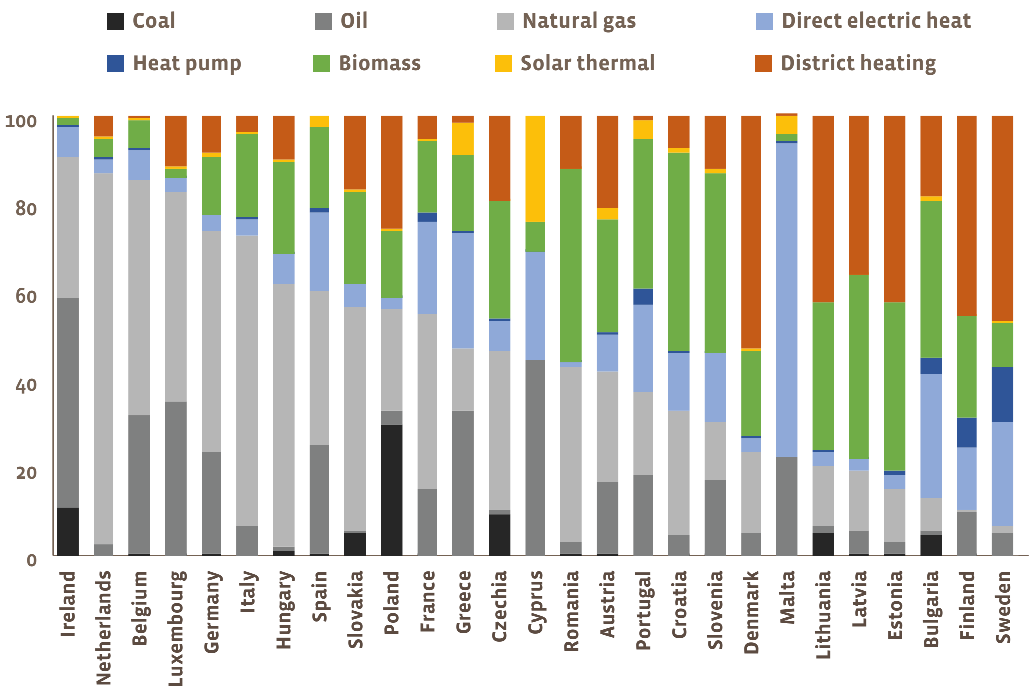
Figure 1 presents the consumption shares of heating and cooling with renewable energies in 2019 for residential buildings and services. This share is a combined indicator for the integration of renewable energies in buildings and urban infrastructure. It depicts the share of renewable energy in the total final energy demand for heating and cooling. Due to low exchange rates and long lifetimes of heating and cooling systems, the consumption share shows only small changes from one year to the other. As a direct consequence it can be expected that the shares in 2020 will be similar to the ones in 2019.

Gas remains a crucial source of heating for most countries. Especially in the Netherlands, Italy, and to a smaller extent in Hungary, Belgium and Slovakia, gas is still dominating the heating system. Oil boilers are an important heating source in Cyprus, Ireland, Luxembourg and Greece. Even though the heating market experiences a constant decrease in oil boilers, other countries such as Malta, Belgium, Spain, Portugal, Germany and Slovenia still have a decent share of this technology in their heating mix. In Poland, a large share of coal is used for heating while direct electric heating plays a role in Malta, Bulgaria, Greece and Cyprus. District heating is especially strong 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.

RES dominate in Croatia (46%), Romania (44%) and Latvia (42%). This domination is due to the high use of biomass, which represents a rather cheap fuel for heating in these countries. Biomass has also a high share in Slovenia (41%), Estonia (39%) and Portugal (34%). Even though heat pumps are slightly growing in importance they are almost exclusively used in Scandinavian countries such as Sweden (13%) and Finland (7%). Solar thermal displays the smallest shares in most countries. It is mainly used in southern Europe countries with high solar radiation potential such as Cyprus (24%) or Greece (7%).

2

District heating supply mix in 2019



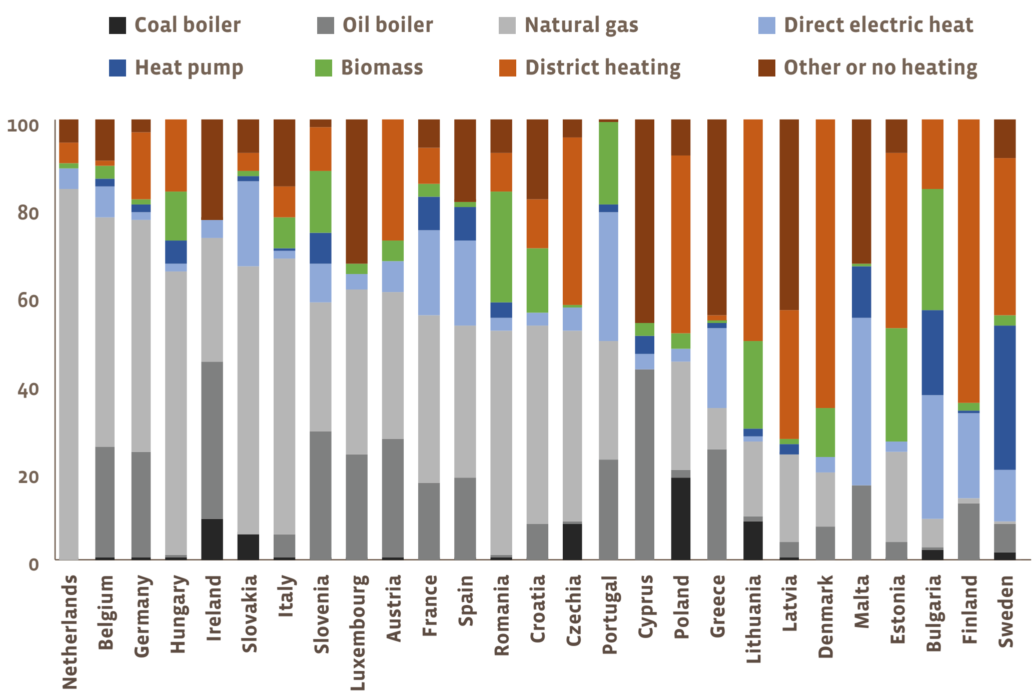
Source: EurObserv'ER - own assessment based on diverse sources. *Notes: Based on 2019 data for: BG, DE, EE, FI, SE; 2018 data for: AT, 2017 data for: SK, CZ, SI, HR, HU, IT, LV, FR, DK, LT, PL and data for 2013: RO and NL. Other includes renewable and non-renewable forms of energy such as (non-renewable waste, solar thermal, etc.).*

SHARE OF RES IN DISTRICT HEATING

Figure 2 depicts the supply mix in the countries where district heating covers at least 3% or more of the heating and hot water demand in 2019. In most countries, the existing district heating networks still rely on fossil fuels with natural gas and coal as the dominant sources. Coal and peat are mostly used in Poland (82%), Czechia (61%) and Slovenia (60%). Even though oil as a source for DH consumption is decreasing in importance in most EU countries, it still plays a relevant role in the supply mix of Slovakia (10%), Estonia (8%) and Croatia (6%). The most dominant renewable energy carrier in district heating are biofuels such as biomass, biogas and renewable waste. Especially in Lithuania,

3

Market stock shares of RES in heating in 2019



Source: EurObserv'ER - own assessment based on diverse sources. *Notes: Solar Thermal plants are not counted as a stand alone system as it is used mainly in combination with other systems. District heating is calculated based on the number of served citizens divided by average household size. Market stock data of coal, oil and gas boilers is based on data from 2015/2016 adjusted with change in consumption (adjusted with HDD).*

Sweden, Denmark, France, Austria, Estonia and Latvia biofuels are used with shares of more than 40%. Large scale heat pumps are mostly used in Finland (11%) and Sweden (7%). Waste heat (i.e. from industrial process) is mainly used in Sweden (8%). Geothermal energy reaches only low shares in a few countries. Solar thermal plays an almost negligible role in the EU wide district heating mix and therefore is included in “Other”. Denmark is the only exception, having a relatively high share of solar thermal energy of up to 2%.

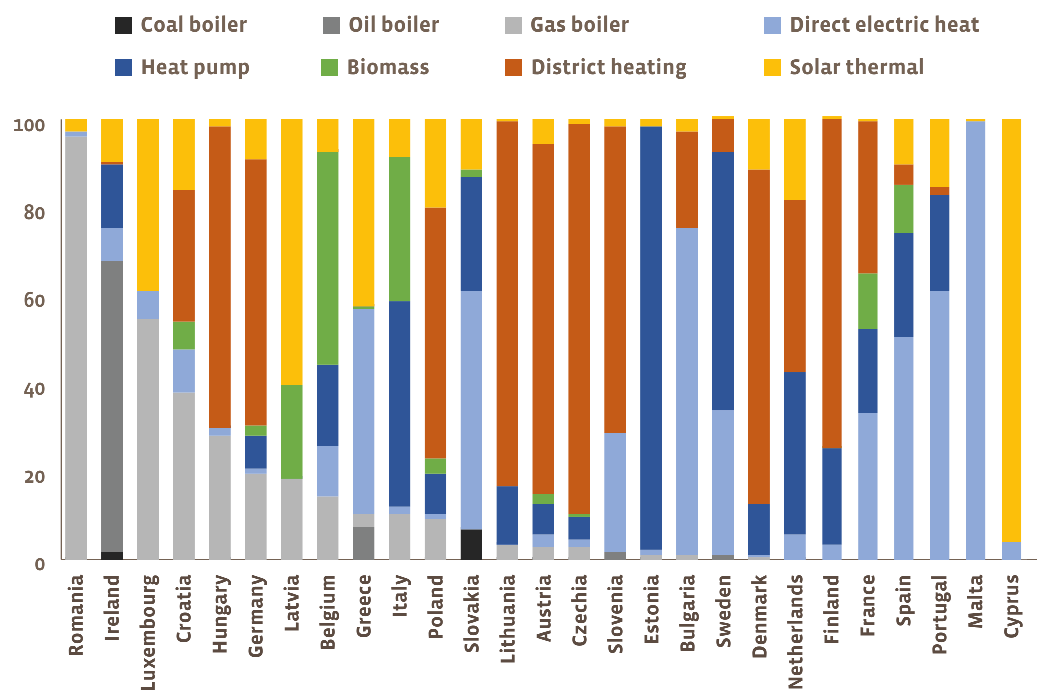
MARKET STOCK AND MARKET SALES SHARES OF RES IN HEATING

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 unknown heating system or no heating system in a further categories called “Other or no heating”. This share is very high for Cyprus, Greece, Malta and Luxembourg. It is also considerable high for Ireland and Spain. Due to climatic conditions, some dwellings might have only a small heater or stove, which is not accounted for in the statistics. Further, the high share of unknown heating reflects 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.

Figure 4 shows the market sales share of RES technologies used for heating and cooling. In contrast to figure 3 above, figure 4 highlights the dynamics in the heating market by illustrating the sales shares of RES heating technologies in the respective year.

4

Market sales shares of RES in heating in 2019



Source: EurObserv'ER - own assessment based on diverse sources. *Notes: One unit of solar thermal contains 4 m2 per household. The category "Solar thermal" also includes solar thermal plants in district heating. Please note that in Latvia a new solar district heating system has been built with over 15 MW. Fossil fuel boilers, electric boilers, district heating and direct electric heating are calculated based on change in market stock share. Thereby, district heating is calculated based on the number of served citizens divided by average household size. Thus, the category "District heating" represents connections of households to district heating grids.*

District heating shows a very high dynamic in almost all countries. Heat pumps show a high dynamic in the markets of Sweden, Estonia, France, Spain, Ireland and Belgium. In addition, direct electric heating technologies have high sales shares in Malta, Portugal, Spain, Greece, Sweden, France and Bulgaria. Solar thermal energy shows high sales rates in countries where it has already a high share, such as Cyprus and Greece. Biomass boilers display a high dynamic in Belgium, Italy, France and Spain. Sales of fossil based heating systems have decreased and are at a low level in many countries except for Romania, Ireland, Luxembourg, Croatia, Hungary, Germany and Latvia. Overall, the RES market sales share shows a higher dynamic compared to the previous years in most MS, and thus, RES in heating is taking off and increasingly contributing to the GHG emission targets.

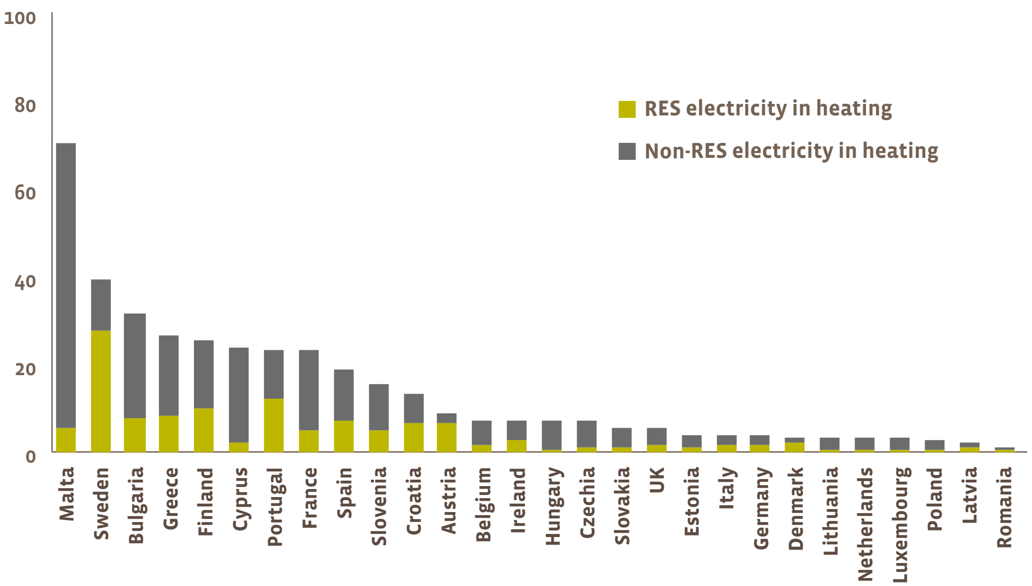
SHARES OF RES ELECTRICITY FOR HEATING

With respect to rising RES shares in the power sector, electric heating gains significance. Figure 5 shows the share of RES electricity used for heating of residential buildings and services, including the share of electricity in district heating. This indicator, thus, shows the share of RES electricity used in direct electric heaters as well as in small and large-scale heat pumps.

The figure shows, that even though electricity as

5

Share of RES and non-RES electricity used in heating in 2019



Source: EurObserv'ER - own assessment based on diverse sources.

a source of heating is gaining in importance, the EU average of RES electricity for heating purposes is still below 5%. Leading countries in using RES electricity in their heating mix are Sweden, Portugal, Finland and Greece. Malta and Bulgaria have also a high share of electricity in their heating mix. However, in Malta and Bulgaria, electricity is to a large extent still generated from fossil fuels. The heat demand in Malta is quite low, thus, the high fossil share in electricity is not significant in absolute terms, while in Bulgaria it is the opposite case.

CONCLUSION

Overall, natural gas boilers remain the most commonly used heating technology, followed by district heating. In recent years district heating gained importance in decarbonising the heating and cooling sector, especially in highly populated urban areas, resulting in higher connection rates.

Coal boilers, as well as oil boilers, are slowly disappearing as the consumption shares as well as the market sale shares reveal. Nevertheless, due to the long life cycle of these boilers and the current dynamic in sales of gas boilers, it can be assumed that they will play a significant role in heating even in the future, and thus counteracting the decarbonisation efforts in the heating and cooling sector. This is especially the case for gas boilers, which still receive financial funding in several countries. Reasons for this state support is the prospect of using synthetic fuels or green hydrogen in such boilers. Albeit the relatively high dynamic of heat pumps in some of the countries, the consumption shares remain low, compared to fossil fuel-based heating. Nevertheless, RES electricity, used in direct electric heaters and heat pumps, has the potential of becoming a dominant option as a renewable source for heating and cooling applications in the residential and service sector. Similarly, solar thermal plants have quite some potentials and their dynamic is quite high in some countries.

In summary, in some countries RES consumption, as well as the dynamic in sales of RES systems, is high. In particular, heat pumps

are increasingly employed in Scandinavian countries while biomass plays a significant role in several eastern European countries. Overall, there is more dynamic in RES heating and cooling, than in the previous years. However, more action is needed to reach the energy and climate targets. ■

FOCUS: MARKET SHARES OF THE POWER GENERATING CAPACITIES INSTALLED IN 2020 BY TECHNOLOGY

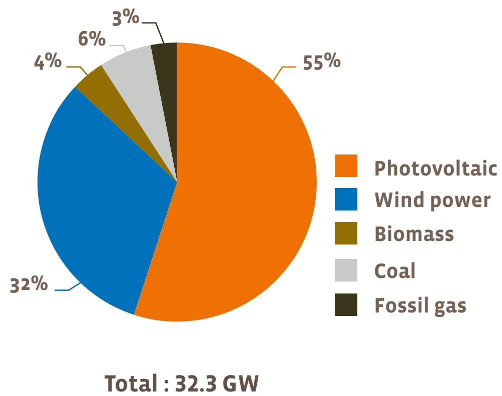
Renewable energies supplied 37.5% of the total electricity consumed in the European Union in 2020. To complement this figure, which is the main market penetration indicator for renewables in Europe's electricity mix, we have examined the renewable sectors' market shares of all the generating capacities (including fossil and nuclear fuels) connected to power grids in 2020.

The market data collected when producing the thematic barometers on the renewable sectors and the data collected for this comprehensive barometer together form the basis of the EurObserv'ER consortium's findings in answer to this question. The fossil fuel and nuclear data has been sourced from the Enerdata databases.
Graph 1 confirms that in 2020, renewable technologies dominated the European Union's mix of newly-connected electrical capacities. Coal-fired power plants constituted 6% of the 32.3 GW of new electrical capacity and gas-fired power plants 3% of the new capacity installed in 2020. Meanwhile, photovoltaic weighed in at 55% and wind energy at 32% of newly-installed capacity. No nuclear units were added to the European mix.

Graph 3 shows the details for the individual Member States in descending order of newly-connected capacity. Only three countries commissioned fossil fuel-fired power plants in 2020. Germany heads this list, having added 1 055 MW of coal-fired capacity and 448 MW of fossil gas capacity. These capacities amounted to 18% of its additional electricity capacity. Poland is another country that connected fossil energy units to its electricity-generating base, by connecting 950 MW of coal-fired and 450 MW fossil gas capacity, i.e., 1 400 MW or 35% of its additional electricity capacity. The third country was France, which commissioned 11 MW of additional fossil gas capacity (0.5% of newly-connected capacity). ■

1

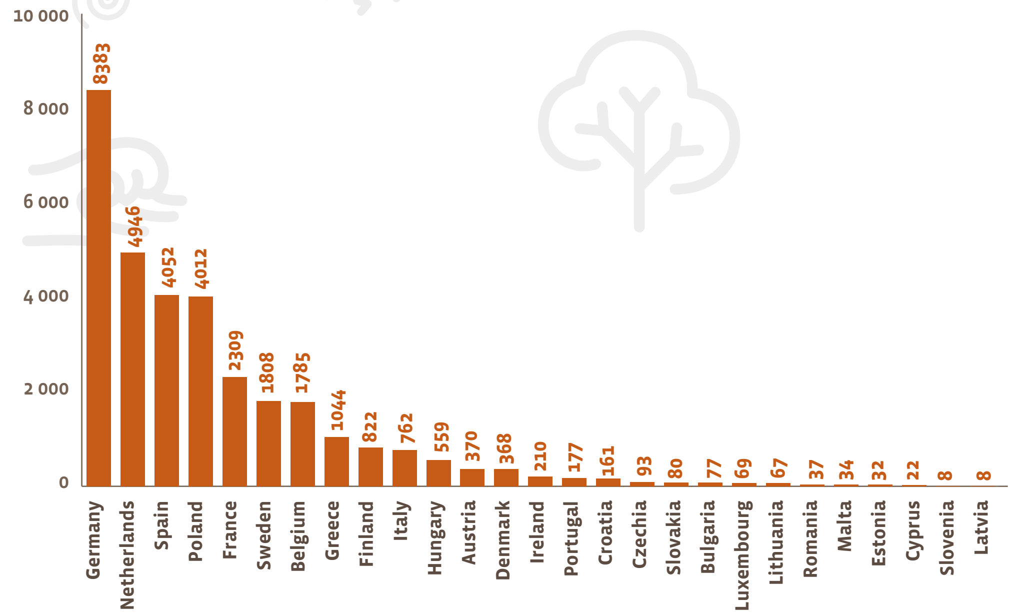
Distribution of additional electrical capacities connected to EU-27 grids in 2020 by technology



Source: EurObserv'ER - Enerdata

2

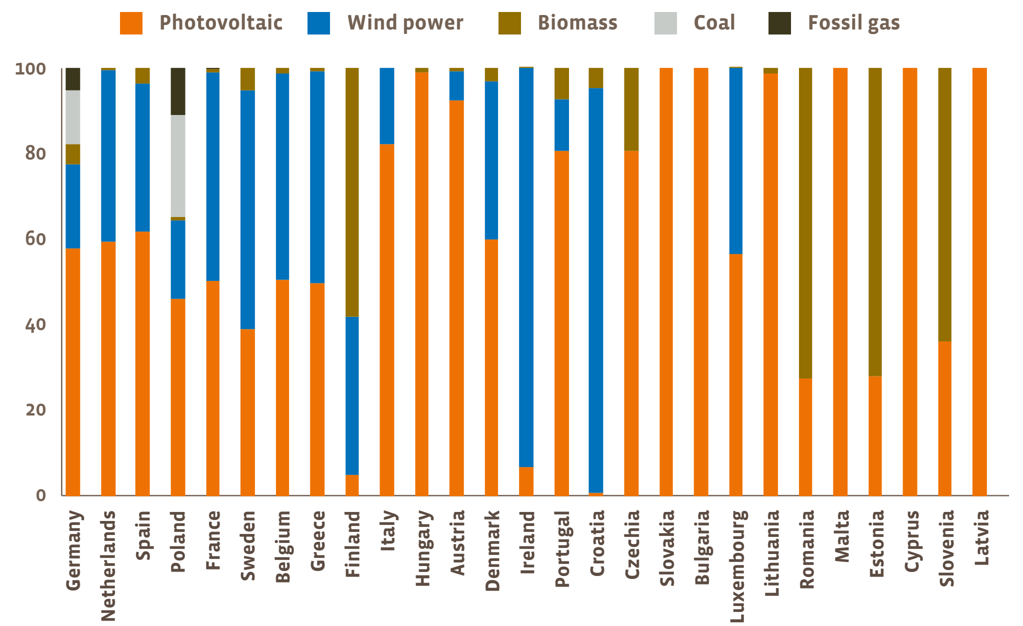
Additional electrical capacities connected to EU-27 grids in 2020 (MW)



Source: EurObserv'ER - Enerdata

3

Distribution of additional electrical capacities connected to EU-27 grids in 2020 by technology



Source: EurObserv'ER - Enerdata

FOCUS: ELECTRICITY STORAGE CAPACITIES

THE CHALLENGES OF ELECTRICITY STORAGE

This is the first monitoring report produced by EurObserv'ER on electricity storage within the European Union's 27 Member States. As the share of renewably-sourced electricity consumption continues to grow in Europe, the challenges posed by this energy's storage have become a core issue. The energy landscapes of the European Union Member States are currently being transformed through the electrification of uses, reduction in fossil energy consumption, and the development of renewable energies on electricity grids. A problem can arise when electricity outputs from variable cycle renewable technologies (e.g. photovoltaic and wind energy) are at odds with consumers' demands of the power grid. This is when electricity storage comes in as a lever to facilitate RES integration into the grids and markets.

Renewable energies have much to gain by increasing their ability to be harnessed to safeguard against certain situations, such as sales price collapse episodes on the wholesale markets partly induced by a surplus in production capacity to consumption. The power grids, over and above their transmission role linking producers to consumers, are responsible for properly running the electricity market. This implies they must supply a number of services to players, producers, aggregators, suppliers, and consumers. The responsiveness offered at certain key points of the grid by storage facilities enables load and frequency fluctuations to be optimised, with the aim of protecting against the risks of local outages, or worse still, generalised blackouts.

The available storage equipment technologies are listed in Table 1, grouped by family. Currently, the most commonly used electricity storage solution in Europe in terms of available capacity is mechanical, specifically in the form of pumped hydro storage (PHS) facilities with two water reservoirs. During low-electricity demand periods, the plant pumps water from the lower to the upper reservoir to capture it, so that when the grid is faced with peak electricity demand, the water can be released through the turbines. This then sends it back to the lower reservoir. They offer the power grid most of its flexibility in conjunction with other hydroelectricity infrastructures. However, not all countries have suitable natural geographical reliefs to develop this type of hydropower facility. The other mature electricity storage solution is the use of batteries harnessing electrochemical reaction. The most widespread technology is lithium-ion battery technology that uses an electrolytic lithium-ion solution and usually cobalt (positive terminal) and graphite (negative terminal) electrodes.

There are also electricity storage technologies in the form of heat that raise the temperature of a fluid or solid, change the physical state of a material, or produce endothermic (heat-absorbing) chemical reactions. Steam turbines use this restored heat by reversing the state change to generate electricity. The main development in Europe has been in molten salts sub-technology, but in a fairly restricted context: that of electricity storage on Concentrated Solar Power (CSP) sites. The last type of technology involving chemical reactions is known ↘

1

Electricity storage technologies and sub technologies

Technologies	Sub technologies
Mechanical	Pumped Hydro Storage (PHS)
	Pumped Heat Electrical Storage (PHES)
	Adiabatic Compressed Air Energy Storage (ACAES)
	Compressed Air Energy Storage (CAES)
	Liquid Air Energy Storage (LAES)
	Flywheel
Electro-chemical	Sodium Sulphur batteries
	Lead Acid batteries
	Sodium Nickel Chloride batteries
	Lithium-ion batteries
	Lithium-S batteries R&D
	Lithium-Metal-Polymer batteries
	Metal Air batteries R&D
	Ni-Cd batteries
	Ni-MH batteries
	Na-ion batteries R&D
	Redow flow batteries Zn Fe
	Redox flow batteries Vanadium
	Redox flow batteries Zn Br
Electrical	Superconducting Magnetic Energy Storage (SMES)
	Supercapacitor
Chemical	Power to Gas, hydrogen (H_2)
	Power to Ammonia - Gasoline
	Power to Methane
	Power to Methanol + Gasoline
Thermal	Molten salts
	Sensible Thermal Energy Storage (STES)
	Phase Change Material (PCM)
	Thermo - Chemical Storage (TCS)

Source: Database of the European energy storage technologies and facilities

2

Electricity storage capacities installed in the EU-27 at the end of 2020 (in MW)

	Mechanical		Thermal		Electro-Chemical		Chemical	
	Pumped hydro storage	Other technologies	Molten salt	Other technologies	Li-ion	Other technologies	Power to gas	Total
Germany	6 719.2	321.0	0.0	1.5	557.3	24.4	15.2	7 638.6
Italy	7 330.6	0.0	4.7	0.4	17.4	39.1	1.2	7 393.3
Spain	4 703.8	0.0	1 069.2	61.0	7.0	0.0	0.0	5 841.0
Austria	5 015.8	0.0	0.0	0.0	2.5	0.0	0.0	5 018.3
France	4 207.3	0.0	9.0	12.0	18.1	1.0	0.0	4 247.4
Portugal	1 951.8	0.0	0.0	0.0	6.0	0.0	0.0	1 957.8
Poland	1 746.2	0.0	0.0	0.0	1.3	0.0	0.0	1 747.5
Bulgaria	1 399.0	0.0	0.0	0.0	0.0	0.0	0.0	1 399.0
Belgium	1 304.0	0.0	0.0	0.0	32.1	1.4	0.0	1 337.5
Luxembourg	1 294.0	0.0	0.0	0.0	0.0	0.0	0.0	1 294.0
Czechia	1 175.0	0.0	0.0	0.0	3.0	0.0	0.0	1 178.0
Slovakia	1 017.3	0.0	0.0	0.0	0.0	0.0	0.0	1 017.3
Lithuania	900.0	0.0	0.0	0.0	0.0	0.0	0.0	900.0
Greece	699.0	0.0	0.0	0.0	0.0	0.0	0.0	699.0
Croatia	619.3	0.0	0.0	0.0	0.0	0.0	0.0	619.3
Ireland	292.0	0.0	0.0	4.6	111.0	0.0	0.0	407.6
Slovenia	185.0	0.0	0.0	0.0	12.6	0.0	0.0	197.6
Sweden	91.0	0.0	0.0	10.0	5.0	0.0	0.0	106.0
Romania	91.5	0.0	0.0	0.0	1.0	0.0	0.0	92.5
Netherlands	0.0	0.0	0.0	0.0	34.4	3.0	0.0	37.4
Hungary	0.0	0.0	0.0	0.0	6.5	0.0	0.0	6.5
Finland	0.0	0.0	0.0	0.0	3.5	2.0	0.0	5.5
Denmark	0.0	0.0	0.0	0.0	1.6	0.0	1.3	2.9
Cyprus	0.0	0.0	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	0.0	0.0
Latvia*	n.c	n.c	n.c	n.c	n.c	n.c	n.c	n.c
Malta*	n.c	n.c	n.c	n.c	n.c	n.c	n.c	n.c
Total EU-27	40 741.7	321.0	1 082.9	89.5	820.3	70.8	17.6	43 143.8

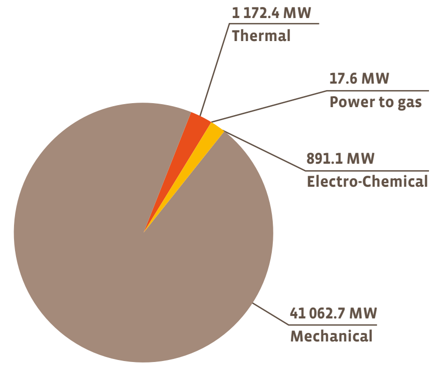
** The database does not include Latvia and Malta facilities projects.*
Source: EurObserv'ER based on the Database of the European energy storage technologies and facilities

as “power-to-gas” (P2G). Power-to-gas (P2G) offers potential even if the capacities used for electricity storage are low. These chemical reactions use electricity to produce synthetic gases (e.g. dihydrogen), which can be combined with different molecules and stored in gaseous form, such as methane that can also be injected into the gas grid, liquid (ammonium), or to a lesser extent, in solid form used to generate electricity on demand. Currently, using the syngas produced directly for industrial uses is generally more expedient than storing it and regenerating the electricity in gas-fired power plants because the electrical yield of power-to-gas-to-power conversion cannot exceed 35%, which explains why only 15.2 MW of all hydrogen facilities in Germany have been developed for the explicit purpose of providing balancing services to the grid, such as electricity storage.. In conclusion, there are many other techniques, but they are not yet industrially developed.

Our reporting is based on the Database of the European energy storage technologies and facilities, a European Commission database produced in 2020 that identifies more than 800 storage facilities across Europe. They are known as “front of the meter” facilities, namely storage equipment connected to the distribution network or transmission network. These generally large facilities are placed before the electricity meter. They differ from “behind the meter” facilities found in the internal networks in the residential, commercial, and industrial sectors; and are thus external to the public electricity grids. For example, electric vehicle battery storage is classified as “behind the meter,” and thus falls outside the scope of this study. At the end of 2020, 43.1 GW of storage capacity total was connected to either the distribution or the transmission networks of the EU-27. Pumped hydro storage technology dominates this capacity with 40.7 GW, and is particularly well developed in Italy, Germany, Austria, Spain, and France as each of the latter has more than 4 GW of storage. Thermal molten salts storage accounts for 1 GW, and almost all of it is installed in Spain, primarily due to Spain being the location of most EU concentrated solar power plants, using this type of storage. Li-ion battery storage accounts for 720 MW, mainly developed in Germany (560 MW). Then there are some pilot electrolyser sites geared to grid balancing (17.6 MW).

3

Installed capacities by technology in the EU-27 at the end of 2020



Source: EurObserv’ER based on the Database of the European energy storage technologies and facilities

4

New electricity storage capacities planned in the EU-27 at the end of 2020 (in MW)

	Mechanical		Thermal		Electro-Chemical			Chemical	
	Pumped hydro storage	Other technologies	Molten salt	Other technologies	Li-ion	Other technologies	Not determined	Power to gas	Total
Spain	9 146.7	0.0	0.0	0.0	343.6	0.0	0.0	0.0	9 490.3
Germany	5 746.0	0.0	0.0	1.5	92.5	0.0	0.0	250.1	6 090.1
Ireland	1 260.0	0.0	0.0	0.0	0.0	0.0	1 245.8	0.0	2 505.8
Austria	1 440.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1 440.0
Portugal	1 430.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1 431.0
Greece	1 182.0	0.0	52.0	0.0	0.0	0.8	15.2	0.0	1 250.0
Finland	1 243.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1 243.7
Romania	1 028.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1 028.8
Bulgaria	864.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	864.0
Belgium	550.0	0.0	0.0	0.0	25.0	0.0	0.0	0.0	575.0
Estonnia	550.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	550.0
Slovenia	420.0	0.0	0.0	0.0	15.0	0.0	0.0	0.0	435.0
Netherland	0.0	320.0	0.0	0.0	0.0	0.0	3.8	0.0	323.8
Lithuania	225.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	226.0
France	12.0	0.0	0.0	0.0	67.7	10.0	10.0	5.0	104.7
Italy	0.0	0.0	0.0	0.0	20.0	4.0	0.7	0.0	24.7
Finland	0.0	0.0	0.0	0.0	11.0	0.0	0.0	0.0	11.0
Czechia	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	10.0
Cyprus	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	5.0
Denmark	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0
Slovakia	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.6
Hungary	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Luxembourg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Poland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sweden	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Latvia*	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Malta*	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Total EU-27	25 098.2	320.0	52.0	1.5	591.4	14.8	1 276.5	256.1	27 610.5

** The database does not include Latvia and Malta facilities projects.*
Source: EurObserv'ER based on the Database of the European energy storage technologies and facilities

Table 4 gives details of the projects in the European Union (licensed, under construction, etc.). The total capacity identified amounts to 27.6 GW. While mechanical storage dominates this capacity (25.4 GW), electro-chemical storage is set to triple with an additional 1.9 GW in the next few years.

SPOTLIGHT ON THE MAJOR COUNTRY PLAYERS

Italy, which has more than 7 300 MW of operating pumped hydropower plants in its Alpine massifs, has the highest mechanical storage capacity in Europe. Yet, it is also one of the Member States to have invested heavily into developing electrochemical storage (57 MW) based on Li-ion and sodium-sulphur battery technologies. The latter are designed for long-term storage and are competitively priced compared to Li-ion batteries, however they offer lower energy density. The Italian electricity grid operator, Terna, has developed NaS battery projects with almost 35 MW of storage capacity. It has developed pilot electrochemical sites following the rapid increase in Italy's renewable energy production, which covered 38.08% of the country's electricity consumption in 2020. Primarily, it wants more flexibility for the high voltage grid in Southern Italy and to supply a frequency service.

Thanks to its geographic location in the Alps, Austria also hosts many PHS plants with around 5 GW of storage capacity. Thus, it also plays a vital role in ensuring grid stability far beyond its borders. Austria demonstrated its capabilities during a widespread blackout incident in January 2021. Following a power failure in Romania and a sharp drop in frequency, the European electricity grid narrowly averted large-scale collapse thanks to emergency intervention by Austria. Many power plants had to supply additional energy immediately to stabilise the grid. On this occasion, the Austrian Pumped Hydro Storage power plants and the gas-fired power plants still available were quickly mobilised to step in. Austria views storage technologies as a vital contribution to the transformation of the energy system. Battery-based storage facilities (also used in regulatory sandboxes) are used for frequency ancillary services (e.g. Prottes battery), in some district storage facilities (e.g. Heimschuh and Lichtenegg battery), and for Energy Communities (e.g. Südstadt Battery).

France, which is one of Europe's major hydropower producers, also has sizable pumping transfer capacities like Italy and Austria. It is ranked fifth in terms of PHS capacity with more than 4 200 MW identified. As it has two of the European Union's largest mountain chains, France has particularly good assets for this type of power plant; the first of which was constructed on the Lac Noir in 1928. However, the country has no short-term plans to develop any new facilities. The reasons are due to both available potential as well as acceptability. Although France has very few storage sites that use the other technologies, the French energy regulator, (Commission de regulation de l'énergie - CRE), selected a handful of small mechanical and electrochemical storage projects as part of a call for projects in 2018 that cover non-interconnected areas, such as islands.

According to updated EurObserv'ER data, Spain hosts nearly 6 GW of energy storage capacity, largely based on pumped hydro systems and also some molten salt capacity. The planned capacities break down into 9.15 GW of PHS and 344 MW of batteries. The Spanish Government plans to develop pumped hydro and battery facilities as well as concentrated solar power plants with concomitant thermal storage capacity in the future. Additionally, Spain expects to have a fleet of 5 million electric vehicles by 2030, including 3.5 million cars, while the remaining 1.5 million vehicles will be motorbikes, trucks, and buses. In the short-term, specific calls for tender may be put out for renewable generation combined with storage. Additionally, a Spanish Technological Platform for Energy Storage, BatteryPlat, has been launched. It will evolve as the national hub for energy storage pilot and demo projects involving all energy storage technologies, not just batteries. One of the largest battery projects announced in the EU-27 is also based in Spain. Endesa plans to develop renewable energy projects with total capacity of 1.725 GW at the Andorra plant site near Teruel, including 1 585 MW of photovoltaic (PV) solar power plants and 140 MW of wind energy capacity. The site's initial battery storage capacity will be 160 MW, followed by 54.3 MW of battery storage during the second construction phase between March 2022 and June 2023, and a further 105 MW of battery storage capacity is set to be added between May 2023 and early 2026.

Germany is one of the largest energy storage solution users in the EU. All in all, it is currently home to 13.7 GW of energy storage capacity in operation or at the planning stage. The majority of this, like in

other EU Member States, consists of PHS plants (6.7 GW). We note growing interest in battery-based solutions, which account for almost 100 MW of capacity. One example is the BigBattery, Lusatia. The utility LEAG broke new ground in 2019 with 66 MW of useful capacity. Commissioning began in March 2020, and in January 2021 the test phase ended with the battery entering commercial service. The BigBattery was built next to the Schwarze Pumpe power station, one of the country's largest (and most polluted) coal power plants in a traditional coal-mining region. The BigBattery Lausitz 110 x 62-metre site, comprises 13 containers that house 8 840 lithium-ion battery modules that can supply 53 MWh of electricity. The system is connected to the 110-kV grid. Approximately €25 million was invested in the project. Another example is the €17 million ENEL/Enertrag Battery Energy Storage System (BESS) with 22 MW of capacity, located in Cremzow, in Brandenburg State. The system underpins the stability of the German electricity network by providing frequency regulation services to the country's Primary Control Reserve (PCR) market. Over and above that, Germany is experimenting with novel types of energy storage. Siemens Gamesa is developing a 1.5-MW Thermal Energy Storage (ETES) in Hamburg. ETES uses electricity to heat lava stones to temperatures of 600°C and above. The company claims that a conventional steam turbine can convert this heat back into electricity. Another one-off project for the EU is the 321-MW compressed air storage system at Huntorf. It plans to take advantage of its proximity to wind farms and nearby underground caverns where compressed air is stored and can be released with hydrogen generated by the nearby wind farm. The largest, most controversial project, is Tesla's Gigafactory in Grünheide on the outskirts of Berlin. The US-based company not only aims to produce 500, 000 cars annually, but also build a huge battery a manufacturing plant with a planned annual output of 100 GWh, possibly to be extended to 250 GWh. To put this into perspective: global annual battery production was 135 GWh in 2020. Power-to-gas (P2G) is another technology thought to have widescale potential for future use. In 2020, the gas industry body, DVGW, identified 35 P2G projects in Germany. The inherent advantages of using P2G, which include physical and technical storability, existing gas grid, and storage infrastructure, can relieve the standard electricity sector through more flexibility and could possibly lead to cost reductions. The Deutscher Verein des Gas- und Wasserfaches (DVGW) believes that in theory, up to 200 TWh of energy could be stored in underground gas caverns in Germany. This equates to roughly 23, 000 times the capacity of a state-of-the-art pumped storage power plant. However, any massive upscaling of fossil gas infrastructures is contentious in the light of decarbonisation efforts and the government's pledge of climate neutrality by 2045.

The landscape of the Netherlands, rules out the installation of pumped storage plants, so it has focused on developing electrochemical storage capacities (37 MW), mainly based on Li-ion batteries. However, if we disregard the country's proximity to Norway's hydropower output, Dutch grid managers have insufficient flexibility capacity to ensure the security of the future grid, which incorporated 26.41% of renewable electricity in 2020 – a figure that attests to strong growth. Accordingly, an innovative 320-MW compressed air energy storage (CAES) project is planned in the former salt caves at Zuidwending. The air will be compressed by enormous compressors and should store up to 2 GWh of electricity every day using a 100% renewably-sourced electricity supply. The compressed air, with an estimated yield of less than 50%, could be decompressed in turbines to provide electrical current. The commissioning of the CAES project is planned for 2025.

Some of Eastern and Southern Europe's countries are rolling out ambitious policies even though their development of electricity storage capacities is in its early days. One such country is Greece, which so far has only 700 MW of PHS capacity and plans to almost triple this figure with an additional 1 250 MW of capacity all technologies taken together. Here we single out two major projects of the 20 STEP facilities announced. One is the construction of two separate upper reservoirs, Agios Georgios and Pyrgos, equipped respectively with 460 MW for four turbines and 220 MW for two turbines. The second is the adaptation of a lower reservoir common to both in the existing Lake Kastraki. These projects have the backing of the regulator and are on the European Commission's Projects of Common Interest (PCI) list, whose programme aims to support the funding of capital- intensive energy transition infrastructures. Between them, these future sites will be able to store more than 800 GWh per annum, enabling better integration of the many renewable resources into the Greek grid. Greece is also developing the MINOS (Minimum intermittency operating system) project, which is a major concentrated solar power plant coupled with a molten salt storage facility. During a diplomatic visit in 2019, the Chinese President entered into a cooperation agreement between the two countries to roll out this project that was developed by the solar specialist Nur Energie in cooperation with the Bank of China and Energy China Group as well as the local firm, PRENETON. It is planned for 2023 and located in Crete, where the legendary name Minos comes from. The project consists of a CSP plant whose production variability will be evened out by heat storage technology using salt, which has the benefit of feedback from many projects in Spain. In practical terms, a salt solution circulates and is heated through the solar heat receptors and can then be stored in a heat-insulated tank. To produce electricity, the stored hot fluid produces steam to drive a turbine. This solution should result in intraday storage that is ideal for high-temperature solar production.

COST IS THE MAIN ISSUE

Economic cost is primarily the reason why electrochemical storage is so underdeveloped today, despite the relatively mature state of the technologies. Other technologies (e.g. thermal or compressed air storage) offer yields that are too low for crucial sub-seasonal uses. Reducing the energy production cost would offset the yield losses. In fact, sometimes the electricity is so abundant and cheap, that the ability to store the energy takes precedence over the conversion yield. The profitability of such a solution is directly affected by the value of the stored electron.

Storage must overcome many regulatory obstacles, in addition to technical obstacles, to find the place it deserves in the energy market. Some of the most recent initiatives are more like pilot or research projects, or they stem from public auctions. However, those that have found an economic model that can be reproduced on a large scale are few and far between. Generally, they are considered to be grid draw-off points and injection points, which have subjected them to double taxation in France. However, in Austria, Germany, and Belgium, the tax on PHS has been waived. Thus, regulation mechanisms in several countries are trying to create a suitable framework for energy storage, so that energy storage can operate as a grid-balancing tool, primarily based on the capacity mechanisms that put less value on the quantity of stored energy than on the installations' quality (namely, the power and responsiveness). The idea is to create a profitable model for infrastructures that generates only a little energy, but that does so at crucial times, which would play the same role as combined cycle gas turbines that can be self-funding, while only operating a few hundred hours per annum. ■

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 27 EU Member States are covered for 2019 and 2020. The reported total employment and turnover is lower than in the 2019 Edition of 'The State of Renewable Energy in Europe', in part due to the exclusion of the U.K. from the results. The U.K. was the fourth largest contributor to employment in renewable energy sectors in the EU-28 with over 130 000 full-time equivalent (FTE) jobs in 2018. Similarly, an adjustment to the model with respect to the calculation of biomass feedstock costs has led to a decrease in the estimates for biomass feedstock related activities compared to the estimates for 2018. In addition, an update of the biofuels technical data based on the ADVANCEFUEL[1] project has similarly lead to a decrease in the estimates for this category. Most notably a higher efficiency assumed for biodiesel production leads to a reduced estimate on yearly feedstock costs, resulting in lower estimates for turnover and employment.

1. www.advancefuel.eu

Methodological note

For this chapter 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-27. 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 2021 edition of "The state of renewable energies in Europe", a new indicator was introduced: Gross Value Added. The Gross Value Added figures are derived from the sectoral turnover figures and value added/input factors per sector from Eurostat input-output tables. A direct GVA figure for one sector in a specific country describes the value of output minus the value of intermediate consumption. These indicators are expressed in current million euros (€M).

The chapter concludes with an indicator on 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

The total new installed wind capacity in 2020 was 10.5 GW in the EU-27. According to Wind Europe – the European Wind Industry Association – the 6% decrease in capacity compared to 2019 was a result of the impact from the COVID-19 pandemic on the onshore wind sector. The Netherlands (2.6 GW) and Belgium (2.3 GW) concluded with a strong year in offshore installations, advancing slowly to Germany, the leader in installed offshore wind capacity with 7.7 GW. For onshore wind, Germany is still leading with 55 GW of total installed capacity, leaving the second largest Spain behind at 27 GW total installed capacity in 2020.

The total installed capacity numbers are fundamental to the total employment numbers that arise from the employment model. EurObserv'ER estimates a significant increase in employment in the wind sector in the EU-27 in 2020, with an increase of 61 700 jobs over 2019. This is coupled with an increase in turnover (€9.4 billion) and gross value added (€3.8 billion). With these increases, the wind sector has become the largest sector in terms of turnover and the third largest in terms of workforce. The greatest increase in jobs (38 700) can be observed in the Netherlands due to the large increase in installed onshore (0.65 GW) and offshore (1.65 GW) capacity.

Next to the big increase in jobs estimated in the Netherlands, two other countries show large growth. Portugal installed 238 MW onshore and 25 MW offshore wind capacity, and in combination with more wind capacity being produced in the country itself, the employment results show an increase of 6 900 jobs, €430 million increase in turnover and €160 million increase in gross value added. Similarly, Poland increased their total installed onshore capacity with 731 MW, yielding 6 700 additional jobs along with a €470 million and €200 million increase in turnover and gross value added respectively.

Traditionally large countries in the wind energy sector, Germany and Denmark, both show an increase in turnover and jobs. Belgium also shows a €1 billion increase in turnover and the addition of almost 5 000 jobs, driven by the continued expansion of the Belgian (offshore) wind capacity.

In Italy, 2020 showed less local production of wind turbine (parts) and lower exports, according to our analysis based on Eurostat data. This yields a 3 400 decrease in jobs, as well as a turnover decrease of €520 million and a GVA decrease of €190 million. ■

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in M€)		Direct GVA (in € m)	
	2019	2020	2019	2020	2019	2020
Germany	78 800	83 500	12 780	13 960	5 690	6 090
Spain	45 900	44 300	5 940	5 860	2 480	2 430
Netherlands	3 400	42 100	620	6 350	250	2 700
Denmark	17 100	22 800	3 820	5 080	1 510	2 000
France	17 300	15 800	2 830	2 640	1 130	1 050
Belgium	7 800	12 700	1 650	2 700	660	1 080
Poland	4 200	10 900	370	840	170	370
Portugal	3 400	10 300	320	750	140	300
Sweden	9 400	9 600	1 820	1 880	920	950
Greece	7 600	6 300	690	590	300	260
Italy	9 400	6 000	1 560	1 040	630	440
Ireland	4 300	3 100	680	520	290	220
Romania	2 000	2 500	170	210	80	90
Finland	1 900	2 300	360	430	160	190
Croatia	1 000	2 100	70	140	30	60
Hungary	700	1 200	40	80	20	30
Austria	1 600	1 100	310	230	130	90
Czechia	800	1 100	70	100	20	30
Estonia	500	800	40	60	20	20
Bulgaria	600	600	40	40	20	20
Lithuania	400	600	30	40	10	20
Luxembourg	100	200	20	40	10	10
Cyprus	100	100	10	10	<10	<10
Latvia	100	100	<10	10	<10	<10
Malta	<100	<100	<10	<10	<10	<10
Slovenia	<100	<100	<10	<10	<10	<10
Slovakia	<100	<100	<10	<10	<10	<10
Total EU-27	**218 700**	**280 400**	**34 280**	**43 630**	**14 720**	**18 500**

Source: EurObserv'ER

PHOTOVOLTAIC

Overall, EurObserv'ER estimates the socioeconomic impacts of photovoltaic turnover at €20.9 billion in 2020 (against €22.6 billion in 2019), gross value added at €8.8 billion (against €9.4 billion in 2019) and employment at 165 700 FTE – a similar decrease as the turnover. While total installed capacity in the EU-27 showed a 12% growth to 137 GW, the 16.6 GW additional capacity increase was lower than the 18.8 GW increase in 2019. As a result, the 2020 employment numbers show a decrease of 9% compared to 2019.
With 55 600 jobs (up from 45 300 in 2019), Germany ranks on top of the PV job table. Following the 4.8 GWp new installed capacity in 2020, this is not surprising. On the contrary, the 2019 leader in jobs, Spain, showed a substantial decrease (62%) in all three categories; jobs, turnover and GVA. This decrease is a result of the very high increase in total installed capacity in 2019 (6.5 GWp, a 137% increase from 2018), which was not repeated in 2020 with an increase of 1.98 GWp. Similarly, France showed a 12% increase of total installed capacity in 2019, and only a 1% increase (+65 MWp) in 2020. Accordingly, the employment model yields a 70% decrease of employment (-8 000 jobs), turnover (-€1.2 billion) and GVA (-€480 million) for 2020.

EurObserv'ER monitors a quite remarkable PV and related socioeconomic growth in Poland for 2020. With 20 200 jobs Poland ranks second in employment in 2020 and sector turnover has doubled compared to 2019 due to the addition of 2.1 GWp of new capacity in 2020. Greece, Sweden and the Netherlands show comparable increases in employment. In Greece, the total installed capacity for 2020 was almost three times higher than in 2019, giving a greater than double increase to 5 500 jobs, €450 million turnover and €180 million GVA. Following a doubling in total installed capacity for Sweden in 2020, employment yielded a more than doubled increase to 4 000 jobs, €700 million turnover and €330 million GVA. The Netherlands has installed 2.9 GWp of solar PV, making it the second largest PV installer in 2020. Unsurprisingly, the employment model shows increases of 13% in employment (18 600 total jobs), turnover (€2.7 billion total) and GVA (€1.0 billion total) for the Netherlands. ■

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in M€)		Direct GVA (in € m)	
	2019	2020	2019	2020	2019	2020
Germany	45 300	55 600	6 860	8 310	3 040	3 700
Poland	10 100	20 200	710	1 410	280	570
Spain	52 200	19 100	5 430	2 040	2 370	890
Netherlands	16 500	18 600	2 380	2 690	900	1 020
Italy	13 200	11 400	1 890	1 650	720	630
Hungary	7 000	6 300	400	360	160	150
Greece	2 600	5 500	220	450	80	180
Belgium	3 600	4 300	710	830	250	300
Sweden	1 700	4 000	290	700	130	330
France	11 600	3 600	1 690	520	690	210
Czechia	2 000	2 900	150	220	50	80
Denmark	2 000	2 500	430	500	170	200
Portugal	3 300	2 400	180	130	70	50
Austria	2 300	2 200	420	400	180	170
Bulgaria	800	1 800	50	90	20	30
Romania	1 400	1 500	100	110	40	40
Finland	1 700	1 300	340	260	130	100
Lithuania	400	800	20	30	10	20
Estonia	1 200	400	90	30	30	10
Malta	200	300	10	20	10	10
Ireland	100	200	10	20	<10	10
Luxembourg	200	200	30	40	10	10
Slovakia	1 100	200	80	20	30	10
Latvia	<100	100	<10	10	<10	<10
Slovenia	400	100	30	10	10	<10
Cyprus	200	<100	20	10	10	<10
Croatia	300	<100	20	<10	10	<10
Total EU-27	**181 500**	**165 700**	**22 570**	**20 870**	**9 420**	**8 760**

Source: EurObserv'ER

SOLAR THERMAL

The EurObserv'ER modelling estimates the turnover and employment in the solar thermal sector at €2.8 billion and 21 400 jobs for 2019. A slight decrease in sector turnover to €2.5 billion is seen for 2020. Employment levels are assessed at 20 100 jobs, also slightly down from the 2019 estimate.

Spain remains the largest European player, in the solar thermal sector with the number of FTE totaling 6 400 and revenues reaching €950 million, a slight increase from 2019 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 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 mainly takes place outside the European Union. In 2019 the only newly installed capacity for CSP was 5.5 MWe in Denmark, which leads to an increase in turnover and employment estimates in 2019. With no new deployments in 2020, the estimates for Denmark decreased again in 2020.

Solar thermal activity in the rest of the Union was limited in 2020, leading to relatively stable estimates in the remaining Member States. Some increases in turnover and employment can be observed for Spain, Germany, and Poland. ■

Employment and turnover

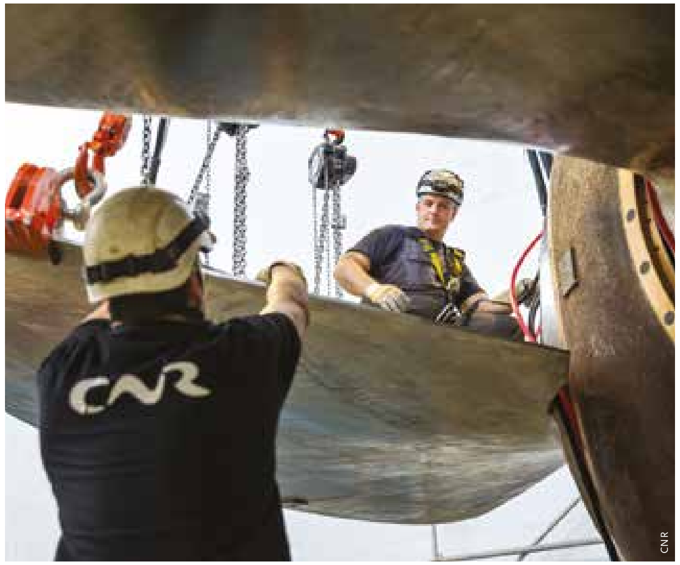
	Employment (direct and indirect jobs)		Turnover (in M€)		Direct GVA (in € m)	
	2019	2020	2019	2020	2019	2020
Spain	5 900	6 400	890	950	430	450
Germany	2 700	3 100	370	430	170	190
Greece	2 100	1 800	190	150	70	50
Poland	1 400	1 500	90	110	40	40
Austria	1 500	1 400	280	260	120	110
Bulgaria	1 100	1 000	50	50	20	20
France	1 200	1 000	170	140	70	60
Italy	1 100	1 000	150	130	60	50
Portugal	700	600	30	30	10	10
Denmark	1 700	300	340	50	130	20
Cyprus	200	200	20	10	10	<10
Croatia	100	200	10	10	<10	<10
Hungary	200	200	10	10	<10	<10
Belgium	100	100	10	20	<10	10
Czechia	200	100	10	10	10	<10
Ireland	<100	100	10	10	<10	<10
Netherlands	100	100	20	10	10	<10
Romania	<100	100	<10	10	<10	<10
Sweden	100	100	10	10	<10	<10
Slovakia	<100	100	<10	<10	<10	<10
Estonia	<100	<100	<10	<10	<10	<10
Finland	<100	<100	10	10	<10	<10
Lithuania	<100	<100	<10	<10	<10	<10
Luxembourg	<100	<100	<10	<10	<10	<10
Latvia	100	<100	10	<10	<10	<10
Malta	<100	<100	<10	<10	<10	<10
Slovenia	<100	<100	<10	<10	<10	<10
Total EU-27	**21 400**	**20 100**	**2 750**	**2 480**	**1 290**	**1 170**

Source: EurObserv'ER

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. Only Italy saw a significant increase in installed capacity in 2020 (+280 MW). We consider the appearance of the observed peaks for hydropower a consequence of the modelling approach. The overall employment level decreased by 8 800 FTE to 35 900 hydro power jobs in the EU-27. And a similar decrease is observed for the turnover part that is estimated at €4.7 billion. The highest hydro power turnover can be observed in the Member States with large hydro power capacities: France (25.7 GW), Italy (22.7 GW), and Spain (20.1 GW). Italy has a large hydro power plant fleet and ranks highest with €1.6 billion in turnover and 11 600 jobs.

France, Spain and Germany follow Italy with over 3 000 jobs each in 2020, despite significant decreases compared to 2019 when more capacity was added in these countries. Similar decreases can be observed for the turnover estimates. Austria and Sweden follow closely behind due to the large existing hydropower capacities, as in these countries also we see no significant increases in installed capacity in 2020. The turnover and employment estimates therefore are driven by the operations and maintenance activities of existing hydropower plants. ■



CNR

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in M€)		Direct GVA (in € m)	
	2019	2020	2019	2020	2019	2020
Italy	7 400	11 600	1 060	1 630	420	660
France	6 800	3 800	990	560	400	220
Spain	5 700	3 600	630	430	280	190
Germany	6 500	3 100	980	480	440	210
Austria	3 500	2 100	620	400	260	150
Portugal	3 100	2 000	180	120	70	40
Sweden	2 600	2 000	470	370	220	170
Romania	1 100	1 100	90	90	30	30
Bulgaria	800	800	50	50	20	20
Greece	800	800	70	70	30	30
Croatia	500	700	40	40	10	20
Czechia	900	600	70	50	20	20
Latvia	1 500	500	90	30	30	10
Poland	600	500	50	40	20	20
Slovakia	500	500	40	40	10	20
Finland	400	400	70	70	30	30
Slovenia	600	400	50	30	20	10
Lithuania	300	300	10	10	10	10
Belgium	200	200	30	40	10	10
Luxembourg	200	200	30	30	10	10
Estonia	<100	100	<10	<10	<10	<10
Ireland	100	100	10	10	<10	<10
Cyprus	<100	<100	<10	<10	<10	<10
Denmark	<100	<100	<10	<10	<10	<10
Hungary	100	<100	<10	<10	<10	<10
Malta	<100	<100	<10	<10	<10	<10
Netherlands	<100	<100	<10	<10	<10	<10
Total EU-27	**44 700**	**35 900**	**5 690**	**4 650**	**2 410**	**1 950**

Source: EurObserv'ER

GEOTHERMAL ENERGY

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. According to the modelling results, overall EU sector turnover remained €810 million. And employment is down to 6 100 in 2020 (from a previous level of 6 300 jobs).

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. In 2020, the largest increase in shallow geothermal capacity for heating occurred in the Netherlands: from 208 MWth to 298 MWth installed capacity. With a turnover of €180 million and 1 100 jobs, the Netherlands is the largest in terms of turnover and employment in the geothermal sector. Italy follows as a historically dominant player with 1 000 jobs and a turnover of €150 million, owing to its large existing geothermal power and heating capacity.
In France the turnover and employment results decreased after a spike in 2019 due to the installation of almost 80 MWth of new geothermal capacity for heating. With a turnover of €120 million and 700 jobs in the geothermal sector, the geothermal sector in France remains the third largest in the EU after the Netherlands and Italy. Germany and Hungary follow with 500 jobs each. ■

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in M€)		Direct GVA (in € m)	
	2019	2020	2019	2020	2019	2020
Netherlands	200	1 100	30	180	10	70
Italy	1 100	1 000	170	150	60	60
France	1 700	700	260	120	100	40
Germany	600	500	100	80	40	30
Hungary	500	500	30	30	10	10
Austria	100	200	10	40	10	20
Spain	<100	100	<10	10	<10	<10
Croatia	<100	100	<10	<10	<10	<10
Poland	100	100	10	10	<10	<10
Portugal	<100	100	<10	<10	<10	<10
Romania	100	100	10	10	<10	<10
Slovenia	<100	100	<10	10	<10	<10
Belgium	<100	<100	<10	<10	<10	<10
Bulgaria	<100	<100	<10	<10	<10	<10
Cyprus	<100	<100	<10	<10	<10	<10
Czechia	<100	<100	<10	<10	<10	<10
Denmark	<100	<100	10	10	<10	<10
Estonia	<100	<100	<10	<10	<10	<10
Greece	100	<100	10	<10	<10	<10
Finland	<100	<100	<10	<10	<10	<10
Ireland	<100	<100	<10	<10	<10	<10
Lithuania	<100	<100	<10	<10	<10	<10
Luxembourg	<100	<100	<10	<10	<10	<10
Latvia	<100	<100	<10	<10	<10	<10
Malta	<100	<100	<10	<10	<10	<10
Sweden	<100	<100	10	10	<10	<10
Slovakia	<100	<100	<10	<10	<10	<10
Total EU-27	**6 300**	**6 100**	**810**	**810**	**440**	**440**

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 €41.0 billion (up nearly €10 billion) and a heat pump employment level of 318 800 workers. This now makes heat pumps the largest renewable energy sector in the EU in terms of employment and second in sector turnover. 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.

Large growth driven by the installation of many new heat pumps was observed in France (+€5.7 billion and +37 700 jobs), Spain (+€2.5 billion and +21 400 jobs), Greece (+€1.9 billion and +21 300 jobs) and Slovenia (+€1.3 billion and +15 200 jobs). In Portugal, more than 925 000 new heat pumps were installed in 2019 leading to a significant increase in turnover and employment compared to 2018. In 2020 new installations amounted to about 325 000 new heat pumps. With the modelling approach this leads to a decrease in activity related in installation compared to 2019 and a subsequent decrease in turnover (-€2.7 billion) and number of jobs (-48 300 jobs). Despite the decrease, 31 700 jobs remain in the heat pump sector in Portugal ranking it third after France (89 000 jobs) and Italy (35 900 jobs) and just ahead of Spain with 30 900 jobs. Germany is also an increasingly large player in the heat pump sector with a turnover of almost €4 billion and 24 400 persons employed in the sector. ■

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in M€)		Direct GVA (in € m)	
	2019	2020	2019	2020	2019	2020
France	51 300	89 000	7 810	13 500	3 160	5 480
Italy	36 100	35 900	5 270	5 320	1 970	1 970
Portugal	80 000	31 700	4 520	1 800	1 720	680
Spain	9 500	30 900	1 110	3 560	480	1 470
Germany	18 900	24 400	3 030	3 930	1 310	1 690
Greece	2 800	24 100	310	2 240	120	870
Slovenia	300	15 500	30	1 300	10	500
Netherlands	9 100	13 700	1 460	2 200	530	800
Sweden	13 700	12 300	2 580	2 360	1 150	1 040
Finland	5 900	6 400	1 040	1 150	420	460
Poland	4 400	5 900	310	410	120	160
Lithuania	100	5 500	<10	240	<10	120
Belgium	3 800	3 900	770	800	280	290
Denmark	2 900	3 500	550	670	220	270
Slovakia	3 300	3 500	260	290	90	100
Malta	3 600	2 600	280	210	110	80
Czechia	1 100	2 000	90	170	30	60
Estonia	1 900	1 900	140	140	50	50
Austria	2 100	1 800	390	340	160	140
Hungary	900	1 500	60	90	20	30
Romania	500	900	30	60	10	20
Ireland	700	800	100	110	40	40
Bulgaria	600	700	40	40	10	10
Cyprus	<100	<100	<10	<10	<10	<10
Croatia	<100	<100	<10	<10	<10	<10
Luxembourg	<100	<100	<10	<10	<10	<10
Latvia	<100	<100	<10	<10	<10	<10
Total EU-27	**253 900**	**318 800**	**30 230**	**40 970**	**12 060**	**16 370**

Source: EurObserv'ER

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 2020, primary energy output from biogas in the European Union has slightly increased to 14 716 ktoe (a 4% increase compared to 2019). The number of jobs in the biogas sector marginally contracted to 48 900 in 2020 – 1 100 full time jobs less than in 2019. The sector produced a turnover of €5.75 billion a slight decline from €5.9 billion recorded in the previous year. The decrease compared to 2018 is larger (€7 billion and 68 800 FTE), mostly due to a decreased estimate in biomass feedstock related activities.

The largest decrease can be observed for Germany, decreasing from 25 400 full time jobs in 2019 to 24 800 in 2020. Sector turnover in Germany decreased slightly to €3.4 billion. Despite this drop, the country remains the biogas leader in the EU-27. Turnover also declined in Italy to €750 million alongside a reduced workforce now standing at approximately 6 900 persons in the anaerobic digestion section in Italy, which makes it the EU's second largest biogas job market. Turnover and employment in the biogas sectors in Czechia and Poland decreased in 2019 compared to 2018, but show recovery in 2020. The gross value added for biogas in the EU-27 decreased in line with the decrease in turnover. Similar to the decrease in turnover and employment in Germany, a decrease in gross value added can be observed. ■

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in M€)		Direct GVA (in € m)	
	2019	2020	2019	2020	2019	2020
Germany	25 400	24 800	3 490	3 400	1 580	1 540
Italy	7 000	6 900	770	750	390	390
Czechia	3 300	3 900	220	260	90	110
France	3 000	3 100	400	410	170	170
Poland	2 000	2 600	100	140	40	50
Spain	800	800	80	80	40	40
Croatia	1 400	800	80	50	40	20
Austria	400	500	60	70	30	30
Denmark	600	500	110	90	50	40
Greece	1 100	500	80	30	30	10
Hungary	400	500	30	30	10	10
Latvia	500	500	30	30	10	10
Netherlands	600	500	90	80	40	40
Slovakia	500	500	40	40	20	20
Belgium	400	400	100	110	30	40
Portugal	400	400	20	20	10	10
Bulgaria	600	300	30	20	10	10
Finland	300	300	40	30	10	10
Lithuania	400	200	20	10	10	10
Slovenia	100	200	10	20	<10	10
Cyprus	100	100	10	10	<10	<10
Ireland	100	100	20	20	10	10
Luxembourg	100	100	10	10	<10	<10
Sweden	200	100	30	<10	10	<10
Estonia	100	<100	<10	<10	<10	<10
Malta	<100	<100	<10	<10	<10	<10
Romania	100	<100	<10	<10	<10	<10
Total EU-27	50 000	48 900	5 900	5 750	2 690	2 640

Source: EurObserv'ER

EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2021 EDITION

BIOFUELS

The European biofuels sector (EurObserv'ER subsumes biodiesel, bioethanol and biogas for transport in the biofuels technologies) saw a small rise in 2020. Overall biofuel consumption increased by 2% between 2019 and 2020 to 16 252 ktoe (+317 ktoe). Substantial biofuel production capacities remain idle in the EU. According to EurObserv'ER calculations, the entire European Union biofuel induced industry turnover decreased slightly to around €11.7 billion, whereas the employment level decreased from 145 600 to 141 600 jobs in 2020. The methodology used to evaluate the biomass industry covers biomass supply activities, i.e. supply in the agricultural sector. As mentioned in the methodology note, the calculation of the feedstock costs and the assumptions about biodiesel production efficiency were improved in the model. The result is a downwards correction in the turnover and employment estimates compared to the 2018 estimates from EurObserv'ER. Biofuels is now the fifth largest renewable energy job creator in the EU, following heat pumps, wind energy, solid biomass, and solar PV.

Also, it should be noted that the leading countries in terms of employment are not necessarily the largest biofuel consumers such as France and Germany. EU Member States with large agricultural land area such as Romania, Hungary, and Poland also have large employment in the biofuels supply chain. And indeed, Romania (20 100 persons employed with a turnover of €830 million) and Poland (17 900 jobs and €820 million) follow closely behind France the biofuels job head count in the EU in 2020.

In turn, large parts of biofuel value creation occur on the production side of the value chain, which explains that economic turnover is highest in Member States with huge biofuel plants (for example France with €2.6 billion). In 2020, France was the second consumer of biofuel in Europe, behind Germany. It is the largest market in terms of biofuel jobs with 21 900 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, while the employment level slightly decreased to 13 900 persons. Germany also had to accept some decline in biofuel induced turnover and employment (€1.57 billion, down from €1.66 billion in 2019) and correspondingly also saw lower job figures with 10 900 persons employed in 2020. ■

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Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in M€)		Direct GVA (in € m)	
	2019	2020	2019	2020	2019	2020
France	23 800	21 900	2 830	2 600	1 200	1 100
Romania	20 400	20 100	840	830	390	380
Poland	18 000	17 900	820	820	310	310
Hungary	16 700	15 800	970	920	460	440
Spain	14 700	13 900	1 460	1 380	760	720
Germany	11 500	10 900	1 660	1 570	740	700
Sweden	6 600	6 500	410	400	180	170
Italy	4 000	5 700	420	600	210	300
Lithuania	4 700	4 800	230	240	100	100
Czechia	4 500	4 300	290	280	120	110
Slovakia	4 200	4 100	340	340	150	150
Greece	2 700	2 700	140	140	70	70
Latvia	2 700	2 600	140	130	40	40
Bulgaria	2 800	2 400	180	150	60	60
Austria	2 300	2 100	360	320	160	140
Belgium	1 500	1 700	410	460	160	170
Croatia	1 400	1 200	90	80	40	40
Netherlands	1 200	1 200	260	260	110	110
Finland	700	600	90	80	40	30
Portugal	400	400	40	40	20	10
Estonia	200	200	10	10	<10	<10
Ireland	100	100	10	20	10	10
Cyprus	<100	<100	<10	<10	<10	<10
Denmark	<100	<100	<10	<10	<10	<10
Luxembourg	<100	<100	<10	<10	<10	<10
Malta	<100	<100	<10	<10	<10	<10
Slovenia	<100	<100	<10	<10	<10	<10
Total EU-27	145 600	141 600	12 050	11 720	5 390	5 220

Source: EurObserv'ER

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 €2.3 billion in 2020, with €1 billion in gross added value. With 12 800 direct and indirect fulltime equivalent jobs, a reduction by 100 jobs compared to 2019 can be observed. The decrease is larger with respect to 2018, where we estimated 31 000 full time equivalent jobs. The decrease is in part due to no new capacity additions being observed, while capacity additions did occur in Germany and Sweden in 2018. Another portion of the decrease is due to the decreased estimate of feedstock related activities.
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 €660 million turnover and 3 200 jobs in the sector. Sweden ranks next with an estimated workforce of 1 400 workers and an industry turnover of €310 million in 2020. Italy and France (both 1 200 full time jobs) follow next. ■

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in M€)		Direct GVA (in € m)	
	2019	2020	2019	2020	2019	2020
Germany	3 200	3 200	660	660	290	290
Sweden	1 400	1 400	310	310	150	150
France	1 200	1 200	230	230	90	90
Italy	1 200	1 200	220	220	80	80
Denmark	800	800	190	190	80	80
Netherlands	800	800	180	180	80	70
Bulgaria	600	500	30	30	10	10
Spain	500	500	70	70	30	30
Portugal	500	500	40	40	10	10
Austria	300	300	60	60	20	20
Belgium	300	300	80	80	30	30
Finland	300	300	70	70	30	30
Poland	300	300	20	20	10	10
Estonia	200	200	20	20	10	10
Hungary	100	100	10	10	<10	<10
Ireland	100	100	30	30	10	10
Slovakia	100	100	10	10	<10	<10
Cyprus	<100	<100	<10	<10	<10	<10
Czechia	<100	<100	<10	<10	<10	<10
Greece	<100	<100	<10	<10	<10	<10
Croatia	<100	<100	<10	<10	<10	<10
Lithuania	<100	<100	<10	<10	<10	<10
Luxembourg	<100	<100	<10	<10	<10	<10
Latvia	<100	<100	<10	<10	<10	<10
Malta	<100	<100	<10	<10	<10	<10
Romania	<100	<100	<10	<10	<10	<10
Slovenia	<100	<100	<10	<10	<10	<10
Total EU-27	**12 900**	**12 800**	**2 330**	**2 330**	**1 050**	**1 040**

Source: EurObserv'ER

SOLID BIOFUELS

Solid biomass remains an important renewable energy source in terms of energy production and renewable employment in the EU-27. 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 feedstock supply. Also here it should be noted that the update of the feedstock cost calculations in the EurObserv'ER model results in lower estimates for jobs and sector turnover compared to the previous EurObserv'ER barometer.
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 use of solid biomass for the production of heat and electricity remained relatively stable in the European Union in 2020 compared to 2019. All in all, the sector's primary energy consumption remained almost stable from 96.9 Mtoe to 96.8 Mtoe. Total electricity production increased from 80.6 TWh to 83 TWh and total heat production decreased from 11.4 Mtoe to 11.3 Mtoe.
With 283 000 persons employed in the corresponding value chains, solid biomass is the second largest renewable energy source in 2020, behind heat pumps and just ahead of wind power. In terms of turnover, biomass is a big player too - with €29.8 billion – ranked third behind wind power and heat pumps. The EurObserv'ER 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.
Germany has the highest solid biomass turnover (€4.7 billion) and with 33 000 jobs is also home to the largest biomass

Statkraft

Employment and turnover

	Employment (direct and indirect jobs)		Turnover (in M€)		Direct GVA (in € m)	
	2019	2020	2019	2020	2019	2020
Germany	37 200	33 000	5 300	4 650	2 780	2 500
Poland	39 100	32 700	1 850	1 360	770	590
France	22 600	24 300	3 480	3 730	1 650	1 740
Sweden	24 500	21 500	4 900	4 320	2 070	1 820
Spain	20 500	20 900	1 510	1 550	690	710
Italy	19 700	19 200	1 450	1 370	830	800
Finland	14 600	12 600	3 700	3 260	2 350	2 090
Czechia	17 900	12 400	1 110	710	400	260
Portugal	11 900	12 400	920	970	490	510
Latvia	11 400	10 800	580	550	220	210
Estonia	6 300	10 300	610	920	240	340
Bulgaria	18 500	9 700	840	410	310	160
Lithuania	10 600	9 500	390	350	190	170
Hungary	8 200	9 200	270	320	110	130
Croatia	10 000	8 600	380	310	180	160
Austria	7 400	8 000	1 620	1 730	750	800
Netherlands	11 100	7 600	1 640	1 090	670	500
Romania	6 100	6 100	290	290	130	120
Denmark	4 300	4 700	670	740	280	310
Slovakia	7 000	4 700	470	300	210	150
Ireland	1 500	1 500	130	130	60	60
Belgium	900	1 300	370	460	110	140
Slovenia	900	800	70	70	40	40
Luxembourg	400	600	60	100	30	40
Greece	500	400	60	40	20	20
Cyprus	100	100	<10	<10	<10	<10
Malta	<100	<100	<10	<10	<10	<10
Total EU-27	**313 300**	**283 000**	**32 690**	**29 750**	**15 600**	**14 390**

Source: EurObserv'ER

work forces. Poland ranks second with 32 700 jobs, although the sector turnover is significantly lower at €1.4 billion. The different ratios between employment and turnover are caused by how different types of activity are modelled. Sweden, France and Finland rank next in terms of turnover (respectively €4.3 billion, €3.7 billion and €3.3 billion). France now also has the third largest solid biomass workforce at 24 300 jobs.

Bulgaria saw a decline of 8 800 jobs compared to 2019, caused by reduced investment activities in 2020 compared to 2019. Capacity additions in Bulgaria slowed in 2020 after a number of years of growth of installed solid biomass energy capacity. A large increase can be observed for Estonia, where the use of solid biomass for energy increased in 2020 compared to 2019, while the number of days where heating was required (heating degree days) was lower in 2020 according to Eurostat data. The model interprets this as an increase in the number of installed biomass boilers and wood stoves, leading to increased turnover and employment related to the production and installation of these boilers and stoves. ■

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 1.3 million persons are directly or indirectly employed in the European Union renewable energy sector. This represents a gross increase of 65 000 jobs (5.2%) from 2019 to 2020.
- 13 out of 27 Member States either increased or maintained their number of renewable energy jobs
- The top 4 countries in terms of employment are: Germany (242 100 jobs, 18% of all EU renewable employment), France (164 400 jobs, 13%), Spain (140 500 jobs, 11%), and Italy (99 900 jobs, 8%).
- The largest growth in employment were found in the Netherlands (+42 700 new jobs, equal to +100%), France (+23 900, equal to +17%), and Greece (+21 900 jobs, equal to +107%). The greatest losses were observed in Portugal (-43 000 jobs, equal to -41%), Spain (-15 300, -10%) and Bulgaria (-8 600 jobs, equal to -32%).
- Heat pumps (318 800 jobs, 24% of the total EU) became the largest sector in terms of renewable energy induced employment, ahead of solid biofuels (283 000 jobs, 22%) and wind power (280 400 jobs, 21%). The most significant upward jump in employment per technology was in the heat pumps sector with an additional 64 900 jobs (+26%), followed by wind power that saw an addition of 61 700 new jobs (+28%). Employment estimates for all other renewable energy sectors decreased in 2020.

TURNOVER

- In total the renewable energy related industry turnover in EU-27 Member States in 2020 amounted to around €163 billion, representing a gross growth of around €13.7 billion against 2019 (+9.2%).
- 13 out of 27 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 (€37.5 billion), France (€24.5 billion), Spain (€15.9 billion), the Netherlands (€13.1 billion), and Italy with €12.9 billion. These are also the countries where the gross value added is largest.
- The largest growth in turnover according to the EurObserv'ER modelling was observed in the Netherlands (+€6.4 billion), France (+€3.7 billion), Germany (+€2.2 billion), and Greece (+€2.0 billion). The largest dips in turnover occurred in Portugal (-€2.4 billion) and Spain (-€1.2 billion).
- The largest renewable energy technologies in terms of industry sector turnover were wind power with €43.6 billion, followed by heat pumps (€41.0 billion), and solid biofuels (€29.8 billion). The gross value added was also largest for these sectors: €18.5 billion for wind power, €16.4 billion for heat pumps and €14.4 billion for solid biofuels. ■

2019 EMPLOYMENT DISTRIBUTION BY SECTOR

	Country total	Solid biofuels	Heat pump	Wind	PV	Biofuels	Biogas	Hydro	Solar thermal	MSW	Geothermal
Germany	230 100	37 200	18 900	78 800	45 300	11 500	25 400	6 500	2 700	3 200	600
Spain	155 800	20 500	9 500	45 900	52 200	14 700	800	5 700	5 900	500	<100
France	140 500	22 600	51 300	17 300	11 600	23 800	3 000	6 800	1 200	1 200	1 700
Portugal	103 800	11 900	80 000	3 400	3 300	400	400	3 100	700	500	<100
Italy	100 200	19 700	36 100	9 400	13 200	4 000	7 000	7 400	1 100	1 200	1 100
Poland	80 200	39 100	4 400	4 200	10 100	18 000	2 000	600	1 400	300	100
Sweden	60 300	24 500	13 700	9 400	1 700	6 600	200	2 600	100	1 400	<100
Netherlands	43 100	11 100	9 100	3 400	16 500	1 200	600	<100	100	800	200
Hungary	34 800	8 200	900	700	7 000	16 700	400	100	200	100	500
Romania	31 900	6 100	500	2 000	1 400	20 400	100	1 100	<100	<100	100
Czechia	30 900	17 900	1 100	800	2 000	4 500	3 300	900	200	<100	<100
Denmark	29 700	4 300	2 900	17 100	2 000	<100	600	<100	1 700	800	<100
Bulgaria	26 500	18 500	600	600	800	2 800	600	800	1 100	600	<100
Finland	26 000	14 600	5 900	1 900	1 700	700	300	400	<100	300	<100
Austria	21 500	7 400	2 100	1 600	2 300	2 300	400	3 500	1 500	300	100
Greece	20 400	500	2 800	7 600	2 600	2 700	1 100	800	2 100	<100	100
Belgium	18 700	900	3 800	7 800	3 600	1 500	400	200	100	300	<100
Lithuania	17 200	10 600	100	400	400	4 700	400	300	<100	<100	<100
Slovakia	17 000	7 000	3 300	<100	1 100	4 200	500	500	<100	100	<100
Latvia	16 700	11 400	<100	100	<100	2 700	500	1 500	100	<100	<100
Croatia	15 000	10 000	<100	1 000	300	1 400	1 400	500	100	<100	<100
Estonia	10 700	6 300	1 900	500	1 200	200	100	<100	<100	200	<100
Ireland	7 200	1 500	700	4 300	100	100	100	100	<100	100	<100
Malta	4 600	<100	3 600	<100	200	<100	<100	<100	<100	<100	<100
Slovenia	2 800	900	300	<100	400	<100	100	600	<100	<100	<100
Luxembourg	1 500	400	<100	100	200	<100	100	200	<100	<100	<100
Cyprus	1 200	100	<100	100	200	<100	100	<100	200	<100	<100
Total EU-27	1 248 300	313 300	253 900	218 700	181 500	145 600	50 000	44 700	21 400	12 900	6 300

Source: EurObserv'ER

2020 EMPLOYMENT DISTRIBUTION BY SECTOR

	Country total	Heat pump	Solid biofuels	Wind	PV	Biofuels	Biogas	Hydro	Solar thermal	MSW	Geothermal
Germany	242 100	24 400	33 000	83 500	55 600	10 900	24 800	3 100	3 100	3 200	500
France	164 400	89 000	24 300	15 800	3 600	21 900	3 100	3 800	1 000	1 200	700
Spain	140 500	30 900	20 900	44 300	19 100	13 900	800	3 600	6 400	500	100
Italy	99 900	35 900	19 200	6 000	11 400	5 700	6 900	11 600	1 000	1 200	1 000
Poland	92 600	5 900	32 700	10 900	20 200	17 900	2 600	500	1 500	300	100
Netherlands	85 800	13 700	7 600	42 100	18 600	1 200	500	<100	100	800	1 100
Portugal	60 800	31 700	12 400	10 300	2 400	400	400	2 000	600	500	100
Sweden	57 600	12 300	21 500	9 600	4 000	6 500	100	2 000	100	1 400	<100
Greece	42 300	24 100	400	6 300	5 500	2 700	500	800	1 800	<100	<100
Denmark	35 400	3 500	4 700	22 800	2 500	<100	500	<100	300	800	<100
Hungary	35 400	1 500	9 200	1 200	6 300	15 800	500	<100	200	100	500
Romania	32 600	900	6 100	2 500	1 500	20 100	<100	1 100	100	<100	100
Czechia	27 500	2 000	12 400	1 100	2 900	4 300	3 900	600	100	100	<100
Belgium	25 000	3 900	1 300	12 700	4 300	1 700	400	200	100	300	<100
Finland	24 400	6 400	12 600	2 300	1 300	600	300	400	<100	300	<100
Lithuania	22 000	5 500	9 500	600	800	4 800	200	300	<100	<100	<100
Austria	19 700	1 800	8 000	1 100	2 200	2 100	500	2 100	1 400	300	200
Bulgaria	17 900	700	9 700	600	1 800	2 400	300	800	1 000	500	<100
Slovenia	17 500	15 500	800	<100	100	<100	200	400	<100	<100	100
Latvia	15 000	<100	10 800	100	100	2 600	500	500	<100	<100	<100
Estonia	14 200	1 900	10 300	800	400	200	<100	100	<100	200	<100
Croatia	14 000	<100	8 600	2 100	<100	1 200	800	700	200	<100	100
Slovakia	13 900	3 500	4 700	<100	200	4 100	500	500	100	100	<100
Ireland	6 200	800	1 500	3 100	200	100	100	100	100	100	<100
Malta	3 700	2 600	<100	<100	300	<100	<100	<100	<100	<100	<100
Luxembourg	1 800	<100	600	200	200	<100	100	200	<100	<100	<100
Cyprus	1 100	<100	100	100	<100	<100	100	<100	200	<100	<100
Total EU-27	**1 313 300**	**318 800**	**283 000**	**280 400**	**165 700**	**141 600**	**48 900**	**35 900**	**20 100**	**12 800**	**6 100**

Source: EurObserv'ER

EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2021 EDITION

2019 TURNOVER BY SECTOR (€M)

	Country total	Wind	Solid biofuels	Heat pumps	PV	Biofuels	Biogas	Hydro	Solar thermal	MSW	Geothermal
Germany	35 230	12 780	5 300	3 030	6 860	1 660	3 490	980	370	660	100
France	20 690	2 830	3 480	7 810	1 690	2 830	400	990	170	230	260
Spain	17 130	5 940	1 510	1 110	5 430	1 460	80	630	890	70	<10
Italy	12 960	1 560	1 450	5 270	1 890	420	770	1 060	150	220	170
Sweden	10 830	1 820	4 900	2 580	290	410	30	470	10	310	10
Netherlands	6 690	620	1 640	1 460	2 380	260	90	<10	20	180	30
Portugal	6 260	320	920	4 520	180	40	20	180	30	40	<10
Denmark	6 140	3 820	670	550	430	10	110	<10	340	190	10
Finland	5 730	360	3 700	1 040	340	90	40	70	10	70	<10
Poland	4 330	370	1 850	310	710	820	100	50	90	20	10
Belgium	4 140	1 650	370	770	710	410	100	30	10	80	<10
Austria	4 130	310	1 620	390	420	360	60	620	280	60	10
Czechia	2 030	70	1 110	90	150	290	220	70	10	<10	<10
Hungary	1 830	40	270	60	400	970	30	<10	10	10	30
Greece	1 780	690	60	310	220	140	80	70	190	<10	10
Romania	1 560	170	290	30	100	840	<10	90	<10	<10	10
Bulgaria	1 320	40	840	40	50	180	30	50	50	30	<10
Slovakia	1 270	<10	470	260	80	340	40	40	<10	10	<10
Ireland	1 010	680	130	100	10	10	20	10	10	30	<10
Estonia	950	40	610	140	90	10	<10	10	<10	20	<10
Latvia	900	<10	580	<10	<10	140	30	90	10	<10	<10
Lithuania	740	30	390	<10	20	230	20	10	<10	<10	<10
Croatia	720	70	380	<10	20	90	80	40	10	<10	<10
Malta	370	<10	<10	280	10	<10	<10	<10	<10	<10	<10
Slovenia	240	<10	70	30	30	<10	10	50	<10	<10	<10
Luxembourg	200	20	60	<10	30	<10	10	30	<10	<10	<10
Cyprus	120	10	<10	<10	20	<10	10	<10	20	<10	<10
Total EU-27	149 300	34 280	32 690	30 230	22 570	12 050	5 900	5 690	2 750	2 330	810

Source: EurObserv'ER

2020 TURNOVER BY SECTOR (€M)

	Country total	Wind	Heat pump	Solid biofuels	PV	Biofuels	Biogas	Hydro	Solar thermal	MSW	Geothermal
Germany	37 470	13 960	3 930	4 650	8 310	1 570	3 400	480	430	660	80
France	24 450	2 640	13 500	3 730	520	2 600	410	560	140	230	120
Spain	15 930	5 860	3 560	1 550	2 040	1 380	80	430	950	70	10
Netherlands	13 050	6 350	2 200	1 090	2 690	260	80	<10	10	180	180
Italy	12 860	1 040	5 320	1 370	1 650	600	750	1 630	130	220	150
Sweden	10 370	1 880	2 360	4 320	700	400	<10	370	10	310	10
Denmark	7 350	5 080	670	740	500	<10	90	<10	50	190	10
Belgium	5 510	2 700	800	460	830	460	110	40	20	80	<10
Finland	5 370	430	1 150	3 260	260	80	30	70	10	70	<10
Poland	5 160	840	410	1 360	1 410	820	140	40	110	20	10
Portugal	3 910	750	1 800	970	130	40	20	120	30	40	<10
Austria	3 850	230	340	1 730	400	320	70	400	260	60	40
Greece	3 730	590	2 240	40	450	140	30	70	150	<10	<10
Hungary	1 860	80	90	320	360	920	30	<10	10	10	30
Czechia	1 820	100	170	710	220	280	260	50	10	<10	<10
Romania	1 630	210	60	290	110	830	<10	90	10	<10	10
Slovenia	1 480	<10	1 300	70	10	<10	20	30	<10	<10	10
Estonia	1 220	60	140	920	30	10	<10	<10	<10	20	<10
Slovakia	1 070	<10	290	300	20	340	40	40	<10	10	<10
Lithuania	950	40	240	350	30	240	10	10	<10	<10	<10
Bulgaria	890	40	40	410	90	150	20	50	50	30	<10
Ireland	880	520	110	130	20	20	20	10	10	30	<10
Latvia	800	10	<10	550	10	130	30	30	<10	<10	<10
Croatia	670	140	<10	310	<10	80	50	40	10	<10	<10
Malta	310	<10	210	<10	20	<10	<10	<10	<10	<10	<10
Luxembourg	270	40	<10	100	40	<10	10	30	<10	<10	<10
Cyprus	100	10	<10	<10	10	<10	10	<10	10	<10	<10
Total EU-27	162 960	43 630	40 970	29 750	20 870	11 720	5 750	4 650	2 480	2 330	810

Source: EurObserv'ER

EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2021 EDITION

2019 GROSS VALUE ADDED BY SECTOR (€M)

	Country total	Solid biofuels	Wind	Heat pump	PV	Biofuels	Biogas	Hydro	Solar thermal	MSW	Geothermal
Germany	16 080	2 780	5 690	1 310	3 040	740	1 580	440	170	290	40
France	8 660	1 650	1 130	3 160	690	1 200	170	400	70	90	100
Spain	7 570	690	2 480	480	2 370	760	40	280	430	30	<10
Italy	5 370	830	630	1 970	720	210	390	420	60	80	60
Sweden	4 850	2 070	920	1 150	130	180	10	220	<10	150	<10
Finland	3 190	2 350	160	420	130	40	10	30	10	30	<10
Netherlands	2 610	670	250	530	900	110	40	<10	10	80	10
Portugal	2 550	490	140	1 720	70	20	10	70	10	10	<10
Denmark	2 470	280	1 510	220	170	<10	50	<10	130	80	<10
Austria	1 820	750	130	160	180	160	30	260	120	20	10
Poland	1 770	770	170	120	280	310	40	20	40	10	<10
Belgium	1 550	110	660	280	250	160	30	10	<10	30	<10
Hungary	820	110	20	20	160	460	10	<10	<10	<10	10
Czechia	760	400	20	30	50	120	90	20	10	<10	<10
Greece	740	20	300	120	80	70	30	30	70	<10	<10
Romania	720	130	80	10	40	390	<10	30	<10	<10	<10
Slovakia	550	210	<10	90	30	150	20	10	<10	<10	<10
Bulgaria	490	310	20	10	20	60	10	20	20	10	<10
Ireland	460	60	290	40	<10	10	10	<10	<10	10	<10
Estonia	400	240	20	50	30	<10	<10	<10	<10	10	<10
Lithuania	370	190	10	<10	10	100	10	10	<10	<10	<10
Latvia	360	220	<10	<10	<10	40	10	30	<10	<10	<10
Croatia	350	180	30	<10	10	40	40	10	<10	<10	<10
Malta	200	<10	<10	110	10	<10	<10	<10	<10	<10	<10
Slovenia	140	40	<10	10	10	<10	<10	20	<10	<10	<10
Luxembourg	120	30	10	<10	10	<10	<10	10	<10	<10	<10
Cyprus	100	<10	<10	<10	10	<10	<10	<10	10	<10	<10
Total EU-27	65 070	15 600	14 720	12 060	9 420	5 390	2 690	2 410	1 290	1 050	440

Source: EurObserv'ER

2020 GROSS VALUE ADDED BY SECTOR (€M)

	Country total	Wind	Heat pump	Solid biofuels	PV	Biofuels	Biogas	Hydro	Solar thermal	MSW	Geothermal
Germany	16 940	6 090	1 690	2 500	3 700	700	1 540	210	190	290	30
France	10 160	1 050	5 480	1 740	210	1 100	170	220	60	90	40
Spain	6 940	2 430	1 470	710	890	720	40	190	450	30	<10
Italy	5 380	440	1 970	800	630	300	390	660	50	80	60
Netherlands	5 330	2 700	800	500	1 020	110	40	<10	<10	70	70
Sweden	4 660	950	1 040	1 820	330	170	<10	170	<10	150	<10
Finland	2 960	190	460	2 090	100	30	10	30	<10	30	<10
Denmark	2 950	2 000	270	310	200	<10	40	<10	20	80	<10
Poland	2 130	370	160	590	570	310	50	20	40	10	<10
Belgium	2 080	1 080	290	140	300	170	40	10	10	30	<10
Austria	1 670	90	140	800	170	140	30	150	110	20	20
Portugal	1 630	300	680	510	50	10	10	40	10	10	<10
Greece	1 510	260	870	20	180	70	10	30	50	<10	<10
Hungary	830	30	30	130	150	440	10	<10	<10	<10	10
Romania	720	90	20	120	40	380	<10	30	<10	<10	<10
Czechia	700	30	60	260	80	110	110	20	<10	<10	<10
Slovenia	620	<10	500	40	<10	<10	10	10	<10	<10	<10
Slovakia	490	<10	100	150	10	150	20	20	<10	<10	<10
Estonia	480	20	50	340	10	<10	<10	<10	<10	10	<10
Lithuania	480	20	120	170	20	100	10	10	<10	<10	<10
Ireland	390	220	40	60	10	10	10	<10	<10	10	<10
Bulgaria	350	20	10	160	30	60	10	20	20	10	<10
Croatia	350	60	<10	160	<10	40	20	20	<10	<10	<10
Latvia	330	<10	<10	210	<10	40	10	10	<10	<10	<10
Malta	170	<10	80	<10	10	<10	<10	<10	<10	<10	<10
Luxembourg	130	10	<10	40	10	<10	<10	10	<10	<10	<10
Cyprus	100	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Total EU-27	70 480	18 500	16 370	14 390	8 760	5 220	2 640	1 950	1 170	1 040	440

Source: EurObserv'ER

RENEWABLE ENERGY DEVELOPMENT AND ITS INFLUENCE ON FOSSIL FUEL SECTORS

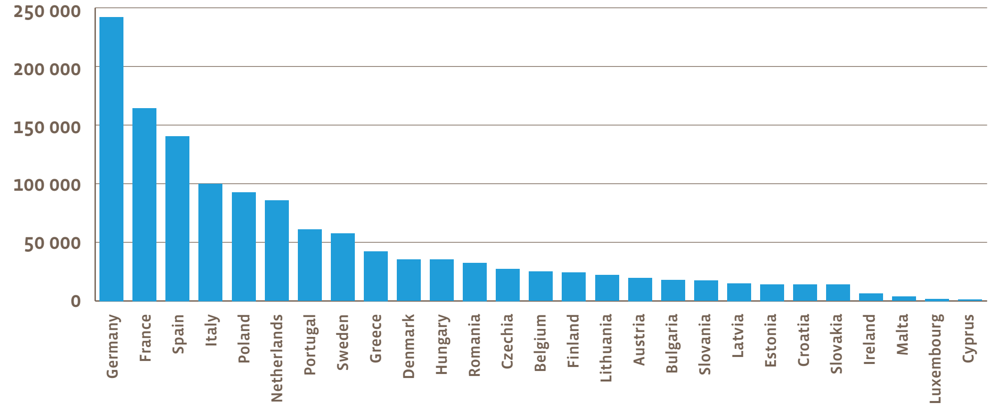
The deployment of renewable energy technologies can have an impact on the economic activity in other sectors and on the fossil fuel based energy sector. In this section EurObserv'ER indicatively estimates this substitution effect, assessing how much employment would be required in the fossil fuel sector 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 2021 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 2020. 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 biofuels, 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

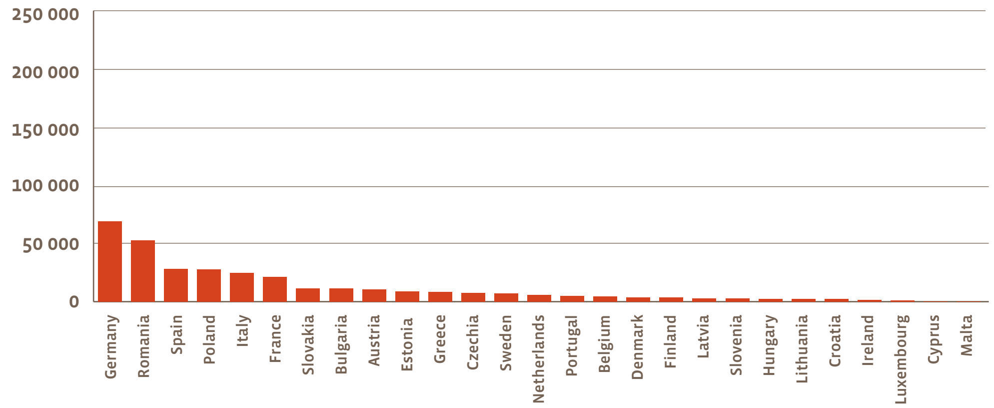
Gross renewable employment as reported in the previous sections (data for 2020)



Source: EurObserv'ER

2

Indicator for equivalent replaced fossil employment, looking at operation, maintenance and fuel production activities only (data for 2020)



Source: EurObserv'ER

RENEWABLE ENERGY COSTS AND ENERGY PRICES

One of the important aspects in renewables becoming mainstream technology is their competitiveness. On the one side are the renewable technologies and the cost of the energy they generate, and on the other side are the conventional energy carriers: fossil fuels and electricity generated from fossil fuels. Through deployment and technology learning the costs of renewable energy may go down, whereas on the long term fossil fuels may get more expensive because of scarcity and geopolitical circumstances, although on the short term we see various fluctuations in conventional energy prices because of market effects (demand versus supply). This section focuses on renewable energy costs and conventional energy prices. To begin, an international comparison of investment costs in the European Union (EU) and major EU trading partners is presented and compared. These regions include Asia, North America, China, Japan, Korea and several other countries and regions, and for most technologies data are reported for the years 2010 and 2020.

Then some ingredients are presented to calculate for renewables the levelized cost of energy (LCoE): renewable technology investment costs based on literature, an approach to estimate the weighted average cost of capital (WACC) and then the resulting LCoE values.

Finally, EU (weighted) average prices for electricity and gas are presented for households and non-households, including their breakdown in price components. These complete the picture of competitiveness: renewable energy costs in the first sections versus actual energy prices in the closing section.

International comparison of investment costs

In this section, RES investment costs in the EU and major EU trading partners are presented and compared. The overview is based on data from the IRENA report 'Renewable Power Generation Costs in 2020' published in 2021. 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 presented for Europe as well as for some major EU trading partners: Asia, North America, China, Japan, Korea and several other countries and regions. The data set however is not identical for all technologies, the reported data differ across RES technologies. For most technologies data are reported for two reference years: 2010 and 2020. Especially for wind power and solar PV this shows an interesting pattern because of the technology innovation and resulting investment cost decrease.

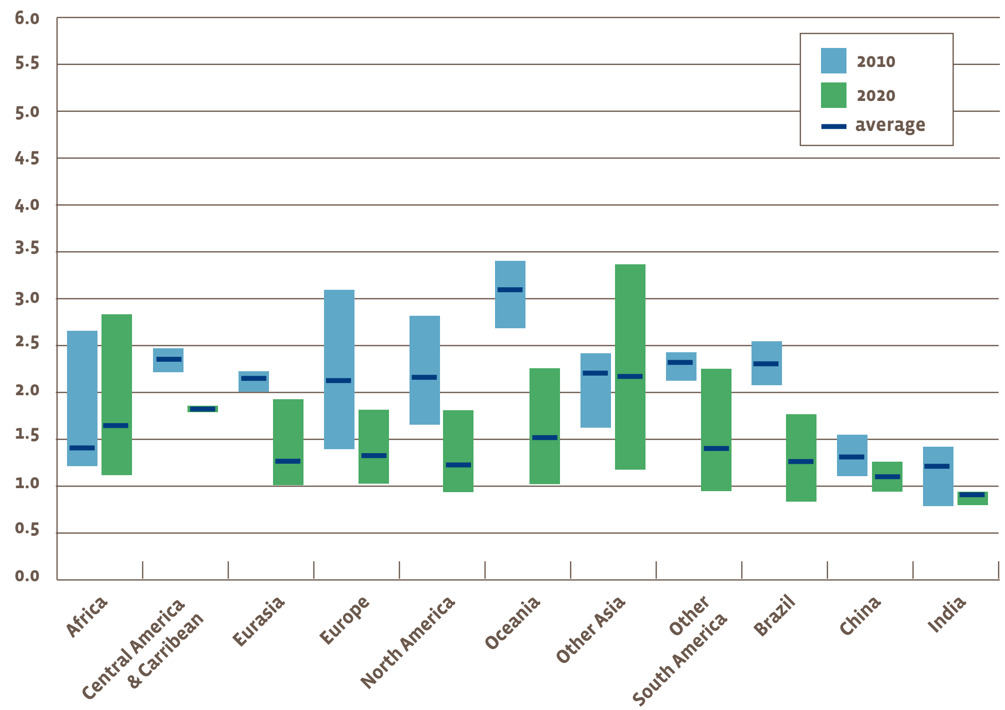
WIND ONSHORE

Based on IRENA (2021) it can be observed that for all countries in Figure 1 average investments costs for wind onshore decreased from 2010 to 2020. Only Africa shows an increase in that period, but it should be noted that in comparison to the other regions the 2010 value for Africa was relatively low. In 2010 the investment costs range from 1.22 M€/MW (in India) to 3.09 M€/MW (in Oceania). In Europe, onshore wind investment costs dropped from 2.13 M€/MW in 2010 to 1.33 M€/MW by 2020. This represents a decrease of 38% in ten years, which is slightly higher compared to the other world regions, of which the average is a 28% investment cost reduction. China and India, the two countries that already had low investment costs in 2010, show even lower costs by 2020, indicating that the cost reduction may also further continue for the other countries.

For wind onshore, costs are quite specific to local circumstances and therefore vary substantially per country. Additionally, China and India have more mature markets and lower cost structures than their neighbours. Finally, it can be seen that North America has very similar costs to the EU, although slightly lower with an average of 1.23 M€/MW in 2020.

1

Onshore wind investment costs worldwide according to IRENA (M€/MW)



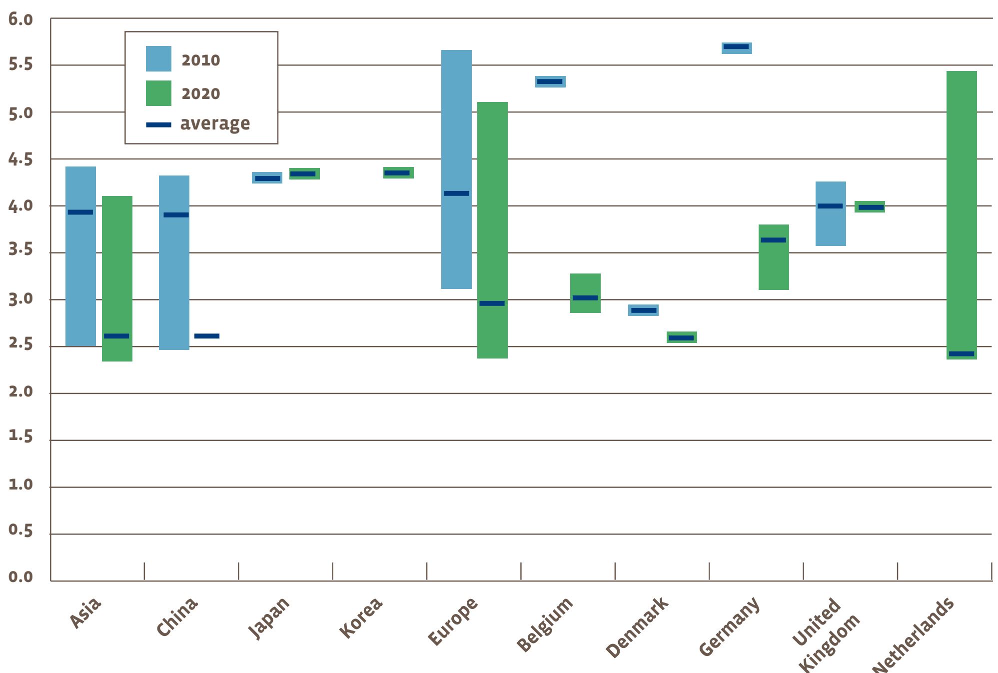
Note: The region 'Other Asia' represents Asia excluding China and India. The region 'Other South America' excludes Brazil.
Source: IRENA

WIND OFFSHORE

With respect to offshore wind, investment cost data are not available for all countries in 2010. Offshore wind has been emerging over the past two decades, resulting in a sparser dataset than the onshore wind data. Between 2010 and 2020, global weighted average total installed costs fell 32%, as follows from Figure 2. Global cumulative installed capacity of offshore wind increased more than ten-fold between 2010 and 2020, a significant change mostly driven by installations in China and Europe. According to IRENA (2021), the investment cost reductions have been driven by both technology improvements and the growing maturity of the industry. Developer experience, product standardisation, manufacturing industrialisation and the regionalisation of manufacturing and service hubs have contributed to the cost declines, and economies of scale. IRENA (2021) observes that the global weighted-average total installed cost of offshore wind farms increased from the year 2000 to 2008, then remained at equal level up to 2015 with projects farther from shore and into deeper waters. The global weighted-average total installed costs began to decline after 2015 up to 2020. On average Asia, China and Europe show similar investment cost trends. Within Europe, the data show differences among the member states: Belgium was able to significantly lower costs compared to 2010, whereas the United Kingdom decreased only slightly, and Denmark saw a small decrease. The average European offshore wind costs in 2020 were 2.98 M€/MW, higher than China (2.60 M€/MW) but lower than Japan and Korea (both approximately 4.35 M€/MW).

2

Offshore wind investment costs worldwide according to IRENA (M€/MW)



Source: IRENA

SOLAR PV

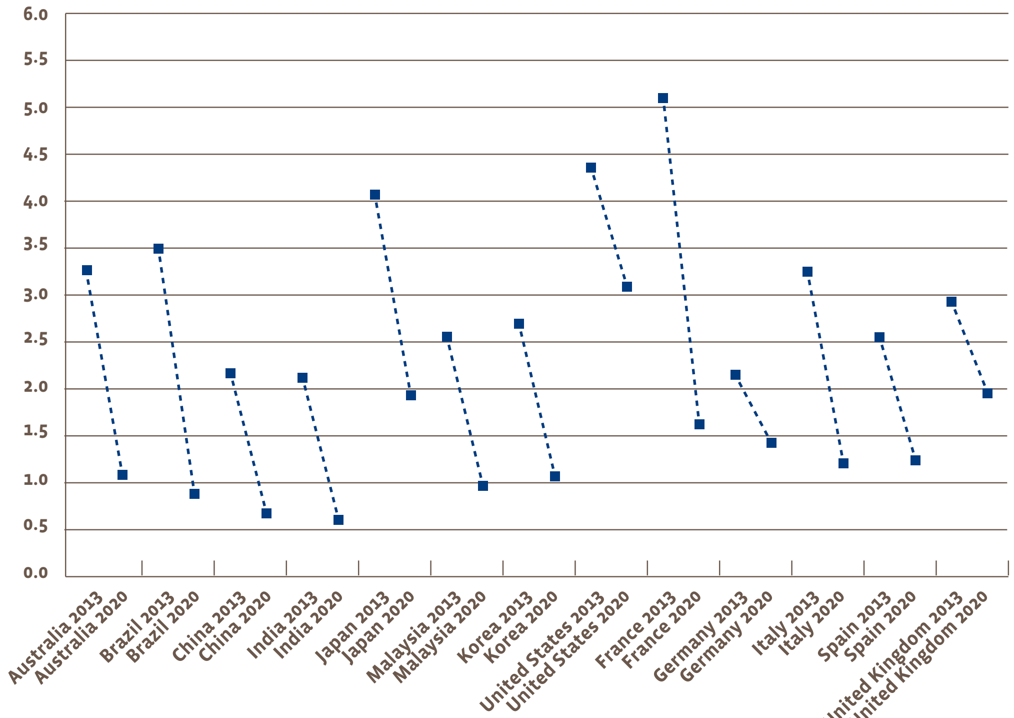
According to IRENA (2021), the global capacity weighted-average total installed cost of projects commissioned in 2020 was 81% lower than in 2010, while solar PV capacity grew 16-fold between 2010 and 2020, with over 700 GW installed at the end of 2020. Total installed system costs in the commercial rooftop markets, of which data is available, decreased between 69% and 88% in the period from 2010 to 2020. Solar PV total installed cost reductions are related to the optimisation of manufacturing processes, reduced labour costs, enhanced module efficiency and developers getting more experience and better supply chain structures. In 2020, significant total installed cost reductions occurred across all the major historical markets, such as China, India, Japan, the Republic of Korea, the United States and Germany.

RESIDENTIAL SOLAR PV

In the residential PV sector, a declining cost trend in installed costs since 2010 is registered for a wide range of countries. The residential rooftop solar PV market generally has higher costs than the utility-scale market, due to the smaller scale of its systems. The residential PV costs decreased by between 46% and 85% between 2010 and 2020, depending on the market. The dataset from IRENA (2021) is not complete for 2010, therefore in Figure 3 a comparison is made from 2013 onwards. In the residential sector, depending on the market, the total installed system costs in 2013 ranged from 2.11 M€/MWp (both India and Germany) to 5.12 M€/MWp (France), decreasing from 0.58 M€/MWp (India) to 3.09 M€/MWp (United States) in seven years. Within the European Union, it can be observed that residential PV costs converged: whereas in 2013 the range was quite wide as mentioned above (namely 3 M€/MWp from lowest to highest observation), it narrowed down to 1.19 M€/MWp in Italy to 1.61 M€/MWp in France (a difference of 0.4 M€/MWp). This convergence shows that markets are getting more efficient and more mature. Even in the market with lowest costs in 2013, the estimate for 2020 reveals a cost decrease of 34% in seven years. In comparison, solar PV investment costs in India declined 73% between 2013 and 2020. This sharp cost decline emphasises the difference of India towards less competitive markets. For 2020 residential PV costs in Japan and the United Kingdom were more than 3 times those of India, while residential costs in US markets were around 6 times higher than in India.

3

Residential Solar PV investment costs according to IRENA (M€/MWp)



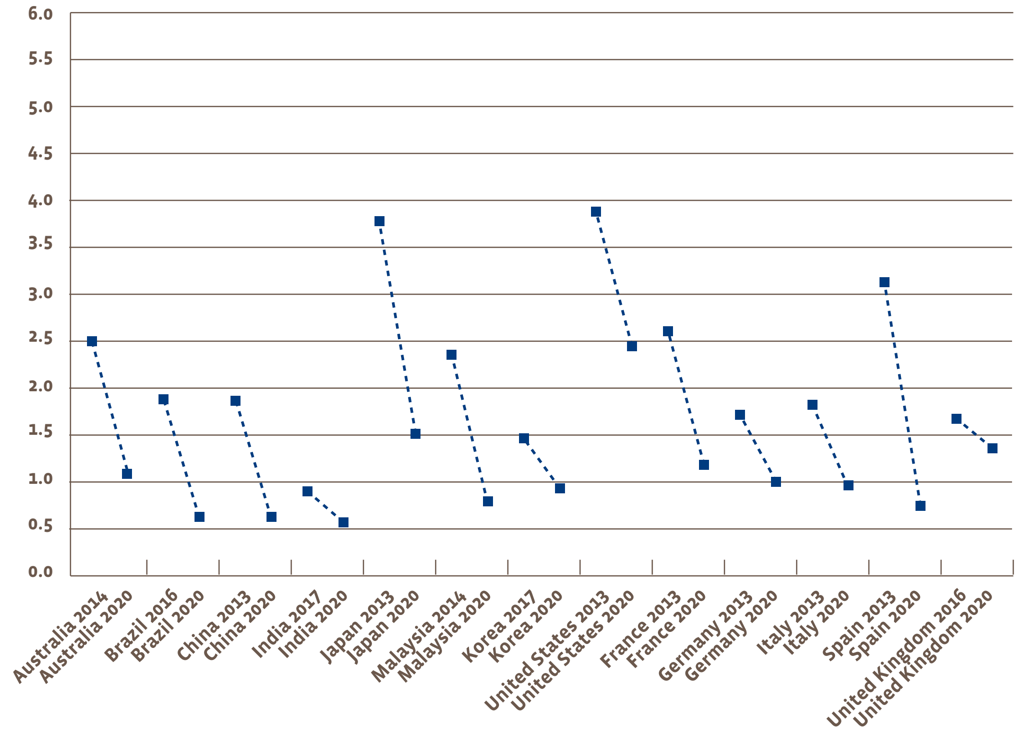
Source: IRENA

COMMERCIAL SYSTEMS

Similar to the residential PV systems, the total installed system costs in the commercial markets decreased around 51% from 2013 to 2020, and according to IRENA (2021) a decline of between 69% and 88% was seen from 2010 to 2020. Looking back to the year 2017, for which IRENA (2021) also reports data, commercial solar PV costs in all the markets evaluated declined between 12% (United Kingdom) and 55% (Brazil). As shown in Figure 4, in the utility scale market, the highest costs in 2013 are observed in Japan (3.74 M€/MWp) and the United States (3.87 M€/MWp). Conversely, the cost decreases of 60% and 37% respectively have resulted in lower costs for these countries: 1.51 M€/MWp in Japan and 2.44 M€/MWp in the United States (average of four states). Interestingly, the value reported for the United States in 2020 is the highest value for all countries. At the lower end India can be found with costs just below 0.57 M€/MWp.

4

Commercial Solar PV investment costs according to IRENA (M€/MWp)



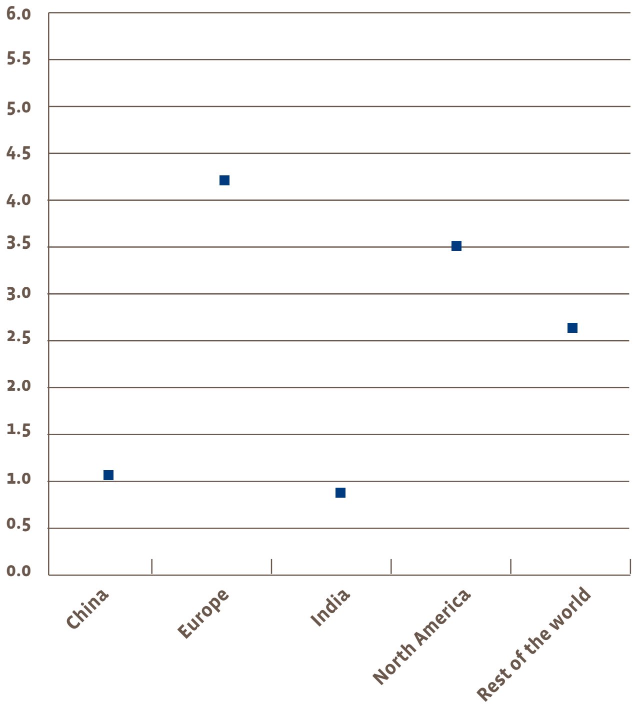
Source: IRENA

BIOENERGY

For bioenergy there are multiple technologies, multiple biomass resource types and multiple processes. In cases where low-cost feedstock is available (agricultural or forestry by-products for example) electricity can be generated at relatively low costs. For bioenergy projects newly commissioned in 2020, the global weighted-average total installed cost was USD 2.2 M€/MW, a 1.9 M€/MW decrease from the 2019 weighted-average (source: IRENA 2021). Variability in these prices may be caused by the fact that there is limited data available. But it certainly is true that biomass power generation costs differ across regions. The investment costs have a technology component and a local cost component in total cost. Projects in emerging economies show lower investment costs compared to projects in the OECD countries, since emerging economies often benefit from lower labour and commodity costs, allowing the deployment of lower cost technologies with reduced emission control investments. As a result, higher local pollutant emissions may occur. From the data in Figure 5 it can be concluded that commercial bioenergy power production has the highest costs in Europe, followed by North America. Costs in India and China are at the lower end of the spectrum. ■

5

Commercial Solar PV investment costs according to IRENA for 2020 (M€/MW)



Source: IRENA

EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2021 EDITION

Investment costs data for Europe

INVESTMENT COSTS

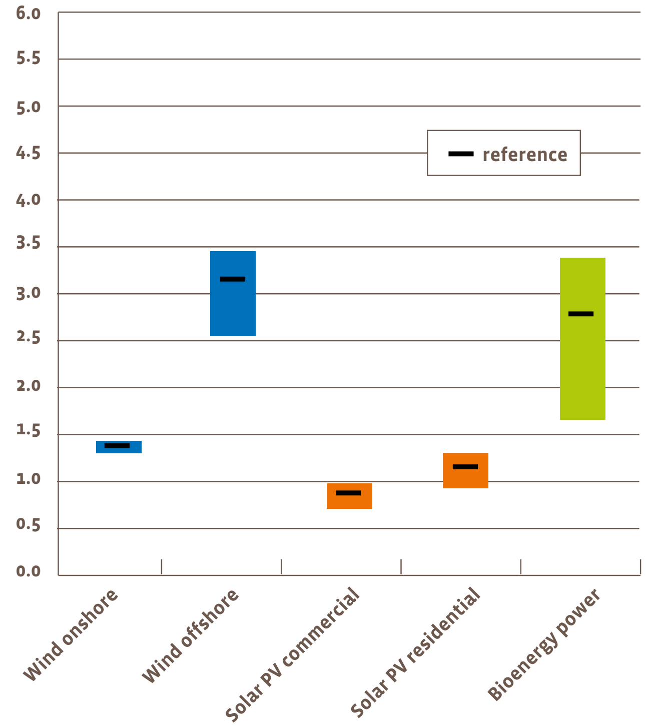
Renewable energy production in the form of electricity, heat or fuels, requires technical installations, converting the renewable energy (wind, solar irradiation, biomass feedstock, geothermal heat) to secondary energy carriers (electricity, heat, liquid fuels, gas or even feedstocks). These installations need to be produced, installed and commissioned, resulting in investment costs that differ per technology. Over the past few years, technology learning has resulted in renewable energy investment costs reductions, an effect that is most pronounced for solar PV and wind power, but also applies to other technologies. As demonstrated in the preceding section, investment costs strongly differ across countries, and there are always data ranges, never distinct single data points. Deployment of renewables is one of the mechanisms that has a positive effect on reducing the investment costs. In previous EurObserv'ER Overview Barometers, investment costs were borrowed from a JRC report (JRC 2018). These numbers were cross-checked with other literature sources, notably the IRENA (2021) report introduced in the previous section, and were found to still be representative for the renewable technology costs for the year 2020. An overview of the investments costs that are used for the calculation of the levelized costs of energy (LCoE) is depicted in Figure 1. It can be seen that also in this report, all technologies are characterised by data ranges. These ranges refer to the technology in general and do not exclusively target technologies in the European Union. It can be observed that the investment costs vary significantly across technologies. But note that the investment costs are not the only factor determining the resulting renewable energy costs. Although per installed unit of capacity the costs might be relatively high for a certain technology, the resulting energy generation costs may be low because the yield per unit of installed capacity differs across technologies. Base-load plants like geothermal, biomass combustion or renewable municipal waste incineration are operating more hours in a year (if at full load) than renewable sources that are dependent on, for example, the availability of sunlight or on the local wind conditions.

It can be observed from Figure 1 that the data ranges are larger for certain technologies compared to others. Wider ranges occur for the innovative technologies such as offshore wind, for which multiple countries are developing farms. Furthermore, local, national and regional circumstances also influence the project investment cost level. Onshore wind power has a narrow bandwidth, but surely projects will exist that fall outside the depicted range. For solar PV two variants are depicted: large scale commercial PV and residential PV. Economies of scale determine the lower investment costs for large PV project, whereas residential PV has, considered over time, seen important investment cost decreases. The ranges are relatively narrow for solar PV. For bioenergy power generation a fluidised bed boiler is taken as a reference, which burns biomass feedstock and provides steam to a steam turbine, and for which investment costs vary considerably.

Another parameter that influences the resulting energy generation costs is the way financing is organised. For calculating the levelized cost of energy (LCoE) project financing is assumed. Project financing is a possible way in which renewable energy technologies are set up: a loan from a bank and own funds (equity) are applied to develop the project and start producing renewable energy. The sales of the renewable electricity, heat or bio-based energy carriers generate income that is used to pay back the loan and to give a reasonable financial return to the investors. The conditions against which loans can be obtained differs from country to country, and differs between different technologies. The weighted average cost of capital is a parameter that describes this, and it is introduced in the next section. ■

1

Renewable energy investments costs for the year 2020 according to JRC as used in LCoE section (M€/MW)



Source: JRC

Weighted average cost of capital (WACC)

The Weighted Average Cost of Capital (WACC) is used to measure the financing costs for a company or project. It is the average, after-tax cost of raising debt and equity capital from different sources. The WACC is not typically a value that is publicly available for individual companies or projects. It is built up of various underlying parameters: equity and debt proportions to total capital; the cost of equity and cost of debt; and the corporate tax rate. Most renewable energy projects for power production are characterised by high up-front capital expenditures, which means that the level of the WACC has a critical impact on the indicators such as the Levelized Cost of Energy (LCoE). Estimating the WACC for different renewables energy technologies across the 27 EU Member States provided a basis for the LCoE calculations in the next section.

Our approach to estimating the WACC is a combination of bottom-up data collection and expert judgement about the various WACC components. An alternative approach would be to carry out a pan-European survey of projects that are implemented with the different technologies in different Member States. However, since the WACC also changes over time depending on various factors, such as prevailing economic conditions, policy consistency, technological developments, etc, the selected estimation approach allows for consistency in results over time, which is an important advantage.

Methodology breakdown

We collect data for bottom-up parameters to build the debt and equity components of the cost of capital. The debt interest rate[1], corporate tax rate[2] and the debt share[3] are multiplied as percentages to build up the total cost of debt. For the cost of equity, we start with the cost of equity calculations that are used in the Dutch support scheme Stimulation of sustainable energy production and climate transition (SDE++)[4], which are based on data and expert judgement[5]. In our approach, we assume the same technology risk division for all member states as is applied for the Netherlands in the SDE++ calculations. We use the cost of equity for the Netherlands as the starting point for calculating the cost of equity for other member states. We adjust the cost of equity for each member state by subtracting the risk-free rate[6] of the Netherlands from the cost of equity of the Netherlands, then we add the risk-free rate of each member state. The resulting percentage is then multiplied by the equity share to calculate the cost of equity for each member state. This is the formula used for calculating the cost of equity for each member state:

$$CoE_{MS} = CoE_{NL} - r_{f\_NL} + r_{f\_MS}$$

where CoE is the cost of equity, r_f is the risk-free rate, MS stands for Member State and NL for the Netherlands.

1. *Euro-area-statistics.org. 2021. Euro area statistics. Averaged bank lending rates over small and large loans*
2. *KPMG. 2021. Corporate Tax Rates Table.*
3. *Source: Eindadvies basisbedragen SDE++ 2021, PBL, 2021, https://www.pbl.nl/publicaties/eindadvies-basisbedragen-sde-plus-plus-2021. Debt share of low, medium and high risk technologies.*
4. *Source: Netherlands Enterprise Agency (RVO), Stimulation of sustainable energy production and climate transition (SDE++). Cost of equity of low, medium and high risk technologies.*
5. *Source: Eindadvies basisbedragen SDE++ 2021, PBL, 2021, https://www.pbl.nl/publicaties/eindadvies-basisbedragen-sde-plus-plus-2021*
6. *Body of European Regulators for Electronic Communications (BEREC), 2020. BEREC Report on WACC parameter calculations according to the European Commission's WACC Notice of 7th November 2019. European Commission. Risk free rates for all EU-27 countries based on S&P country credit ratings.*

Further explanation of SDE++ risk distinctions

*In the SDE++ a distinction is made between low, medium and high risk technologies when calculating the cost of equity. Technologies categorised as **low risk** are mainstream technologies such as onshore wind and solar PV. There is a pipeline of projects being developed and both project developers and financiers have gained extensive experience in developing and structuring projects, reducing risks over time to current low levels. **High risk** are innovative technologies such as aquathermal, geothermal, biomass fermentation and CCS that still need further development, have not yet been widely deployed and/or where there is strong dependence on third parties and at the same time scarcity of supply (e.g. in biomass procurement). These technologies are characterised by higher operational risks and sometimes policy risks. Technologies with an **average risk** (e.g. hydropower, solar thermal) are well developed but can be deployed to a limited extent or only on a small scale, making project risks higher. For offshore wind, no financing parameters are set within the SDE++. As indicated below, the risk of offshore wind is considered to be low to medium, but on reflection we assume medium rather than low risk for this technology. This is because larger and more technologically innovative wind turbines are installed offshore in comparison to onshore. More innovative turbines entail greater risks, and the marine environment increases the risk of failure. The higher the risks, the higher the required return, and this is reflected in our cost of equity calculations for offshore wind.*

The technology risk categories, cost of equity percentages and debt shares that are used in our cost of capital calculations are shown in Table 1:

1

Technology risk categories, cost of equity percentages and debt shares by technology

	Wind onshore	Solar PV	Wind offshore	Hydropower	Bioenergy and other technologies
Technology risk	Low	Low	Average	Average	High
Cost of equity	6%	6%	8%	8%	12%
Debt share	70%-80%-90%	70%-80%-90%	60%-70%-80%	60%-70%-80%	50%-60%-70%

Source: EurObserv'ER

DISCUSSION ON METHODOLOGY

The current methodology is a best effort bottom-up approach based on literature review and expert judgement. To improve the methodology assumptions and data, further research is required to identify better data sources and make more accurate estimates of some of the WACC components, in particular the cost of equity. It is important to use reliable data sources, and preferably sources that are annually updated. Furthermore, the key assumptions underlying our current approach involve similar technology risks across different member states. For future research, these simplifying assumptions should be addressed. In 'The State of Renewable Energies in Europe' of 2022, the methodology will be evaluated and improved based on new research and data sources.

We observe that for the low-risk technologies, such as wind onshore and solar PV, the WACC values range from as low as between 2-3% in some Member States (e.g., Germany, Netherlands, Denmark) to above 4% in other Member States (e.g., Greece, Romania, Poland). For the higher risk technologies, such as bioenergy, the WACC estimates range from between 4-7% in some Member States (e.g., Austria, Belgium, Germany) to 6-9% in other States (e.g., Poland, Hungary, Romania). This can be interpreted as follows: for technologies that are considered relatively mature, and have been deployed at scale, and in Member States that have stable economic and political conditions, the WACC is typically lower. The WACC is higher in Member States that have low deployment rates for technologies and where the economic and political conditions are less favourable.

The financing conditions are most favourable for onshore wind and solar PV in western European Member States, such as Germany, Denmark, Belgium and the Netherlands. At the other side of the spectrum, less favourable financing conditions appear to be available for all technologies in Eastern European Member States, in particular in Greece, Poland and Romania, and especially for technologies that are considered riskier to deploy.

The WACC values are used, together with the assumptions on investment costs, operation and maintenance costs, energy yield and lifetime assumptions to estimate the Levelized Cost of Energy (LCoE), which will be presented next. ■

2

Estimates for national values for the Weighted Average Cost of Capital (WACC), broken down into technology and per Member State.

	Wind onshore			Wind offshore			Solar PV			Hydropower			Bioenergy and other technologies*		
	Low estimate	Averate estimate	High estimate	Low estimate	Averate estimate	High estimate	Low estimate	Averate estimate	High estimate	Low estimate	Averate estimate	High estimate	Low estimate	Averate estimate	High estimate
Austria	1.7%	2.2%	2.7%				1.7%	2.2%	2.7%	2.6%	3.3%	4.0%	4.5%	5.6%	6.7%
Belgium	1.6%	2.1%	2.6%	2.5%	3.2%	3.9%	1.6%	2.1%	2.6%	2.5%	3.2%	3.9%	4.4%	5.5%	6.6%
Bulgaria	2.9%	3.4%	3.8%				2.9%	3.4%	3.8%	3.8%	4.4%	5.1%	5.6%	6.7%	7.7%
Croatia	2.3%	2.9%	3.6%				2.3%	2.9%	3.6%	3.3%	4.2%	5.0%	5.4%	6.6%	7.9%
Cyprus	3.4%	3.9%	4.5%				3.4%	3.9%	4.5%	4.3%	5.1%	5.8%	6.3%	7.4%	8.5%
Czechia	2.8%	3.3%	3.7%				2.8%	3.3%	3.7%	3.7%	4.3%	4.9%	5.5%	6.5%	7.6%
Denmark	1.8%	2.3%	2.7%	2.7%	3.3%	4.0%	1.8%	2.3%	2.7%	2.7%	3.3%	4.0%	4.5%	5.6%	6.7%
Estonia	3.0%	3.4%	3.8%				3.0%	3.4%	3.8%	3.8%	4.4%	5.0%	5.6%	6.6%	7.7%
Finland	1.9%	2.4%	2.9%	2.8%	3.5%	4.1%	1.9%	2.4%	2.9%	2.8%	3.5%	4.1%	4.7%	5.7%	6.8%
France	1.5%	2.1%	2.6%	2.5%	3.2%	3.9%	1.5%	2.1%	2.6%	2.5%	3.2%	3.9%	4.4%	5.5%	6.6%
Germany	1.7%	2.1%	2.6%	2.5%	3.2%	3.9%	1.7%	2.1%	2.6%	2.5%	3.2%	3.9%	4.4%	5.5%	6.5%
Greece	3.6%	4.5%	5.3%				3.6%	4.5%	5.3%	4.9%	5.9%	7.0%	7.1%	8.6%	10.0%
Hungary	3.1%	3.7%	4.3%				3.1%	3.7%	4.3%	4.1%	4.9%	5.7%	6.1%	7.3%	8.5%
Ireland	3.8%	4.1%	4.3%	4.5%	4.9%	5.4%	3.8%	4.1%	4.3%	4.5%	4.9%	5.4%	6.1%	7.0%	7.9%
Italy	1.9%	2.5%	3.2%				1.9%	2.5%	3.2%	2.9%	3.8%	4.6%	5.0%	6.2%	7.4%
Latvia	4.1%	4.3%	4.6%				4.1%	4.3%	4.6%	4.7%	5.2%	5.6%	6.4%	7.2%	8.1%
Lithuania	2.5%	2.9%	3.3%				2.5%	2.9%	3.3%	3.3%	3.9%	4.6%	5.1%	6.2%	7.2%
Luxembourg	1.6%	2.1%	2.6%				1.6%	2.1%	2.6%	2.5%	3.2%	3.9%	4.4%	5.5%	6.5%
Malta	1.9%	2.5%	3.0%				1.9%	2.5%	3.0%	2.9%	3.6%	4.3%	4.8%	5.9%	7.1%
Netherlands	1.7%	2.1%	2.6%	1.7%	2.1%	2.6%	1.7%	2.1%	2.6%	2.5%	3.2%	3.9%	4.4%	5.5%	6.6%
Poland	2.8%	3.5%	4.1%				2.8%	3.5%	4.1%	3.9%	4.7%	5.5%	5.9%	7.1%	8.4%
Portugal	2.4%	3.0%	3.6%	3.4%	4.2%	5.0%	2.4%	3.0%	3.6%	3.4%	4.2%	5.0%	5.4%	6.6%	7.8%
Romania	2.4%	3.3%	4.1%				2.4%	3.3%	4.1%	3.7%	4.7%	5.7%	5.9%	7.3%	8.7%
Slovakia	2.6%	3.0%	3.4%				2.6%	3.0%	3.4%	3.4%	4.0%	4.6%	5.2%	6.2%	7.2%
Slovenia	2.1%	2.6%	3.1%				2.1%	2.6%	3.1%	3.0%	3.7%	4.4%	4.9%	6.0%	7.1%
Spain	1.9%	2.4%	3.0%	2.8%	3.6%	4.3%	1.9%	2.4%	3.0%	2.8%	3.6%	4.3%	4.8%	5.9%	7.1%
Sweden	1.9%	2.4%	2.9%	2.8%	3.5%	4.1%	1.9%	2.4%	2.9%	2.8%	3.5%	4.1%	4.7%	5.7%	6.8%

*Other technologies include geothermal, biogas and solid biomass. **Source: EurObserv'ER***

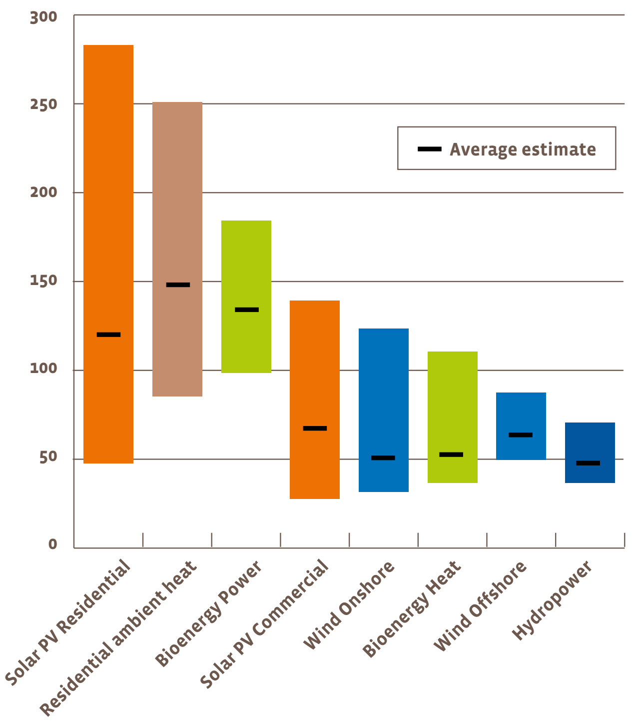
Levelised cost of energy

In this section, levelised costs of energy (LCoE, in €/kWh or €/MWh) are estimated for various renewable energy technologies, based on the investment costs and WACC estimates presented above. In addition to the WACC estimates and the investment costs, the renewable energy technology LCoE analysis requires a significant amount of data and assumptions on operational expenditures, fuel costs (for biomass technologies), economic life, annual energy production, auxiliary energy requirements (for heat pumps), fuel conversion efficiency and the project duration. All input parameters are defined as data 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 2014 and 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. Furthermore, locational and operational aspects, but also design choices and energy yields vary across member states, and therefore LCoE values are presented in data ranges. To give an example: electricity from wind is usually cheaper in areas with high average wind resources, simply because the turbine produces more electricity compared to an area with lower wind speed. This results in roughly the same costs, but higher electricity production, hence lower values for the LCoE.

The technologies addressed are: residential ambient heat from heat pumps (an average of ground source, air source and water source heat pumps), bioenergy (power and heat derived from solid biomass), hydropower, solar photovoltaics (PV, commercial and residential), and wind energy (both onshore and offshore). The data ranges for the calculated levelised cost of renewable energy for the European Union are depicted in Figure1. The technologies generating renewable electricity are solar PV, biomass and wind power and hydropower. Heat generating technologies are biomass heat and ambient heat.

1

Estimated Levelised cost of renewable energy in the European Union (€/MWh)



Source : EurObserv'ER

RENEWABLE ELECTRICITY

The LCoE from solar PV has continued to decrease over the past few years, which has been demonstrated in previous versions of 'The State of Renewable Energies in Europe'. Solar PV in the residential sector is small in system size (it should fit on rooftops) and therefore is relatively expensive. There are less benefits from economies of scale for modules and inverters, and in relative terms, more labour is involved to install the PV system. Although all cost components in a PV system have seen significant cost reductions over the past decades, it remains the most expensive renewable technology, although that varies strongly from country to country. On the EurObserv'ER website the calculated LCoE for solar PV is presented, from which it follows that residential PV is cheapest in Spain and Portugal, producing power at very competitive prices compared to household electricity prices (see next section). The average estimated cost level is 120 €/MWh. From the calculations it follows that bioenergy power generation is roughly between 100 and 185 €/MWh across Europe. Commercial solar PV does benefit from economies of scale and at the lower range is very competitive, at prices that occur in Spain, Portugal, Italy and Greece. According to the calculations, commercial solar PV should be possible to generate electricity at costs below 150 €/MWh in all EU member states. The average costs for onshore wind power are slightly lower than for commercial PV, with a similar cost bandwidth. It is clear that Denmark is the country with the lowest costs of electricity for onshore wind. Offshore wind has a smaller range because not all 27 member states have projects in place. The lowest LCoE values for offshore wind occur in Denmark, the Netherlands and Spain, while the highest LCoE values are in Germany, Belgium and Finland. Hydropower traditionally has been a cost competitive technology for many years in many countries. It is capital intensive, but due to the usually high number of running hours, the produced electricity can be found at the lower LCoE levels, in our estimates between 35 and 70 €/MWh.

Note that for individual renewable projects, observed cost ranges may be outside the presented data ranges indicated here. The country variations among Member States are a result of differences in assumed yield (for solar energy and wind power) and financing conditions. The country specific LCoE estimates are available for multiple technologies from the EurObserv'ER website. The graph depicted here show aggregate values for the European Union as a whole.

RENEWABLE HEAT

For the technologies producing heat, bioenergy heat LCoE is relatively low, indicating it is competitive in many countries. 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 further. ■

Prices of energy

MULTIPLE COMPONENTS IN ENERGY PRICES

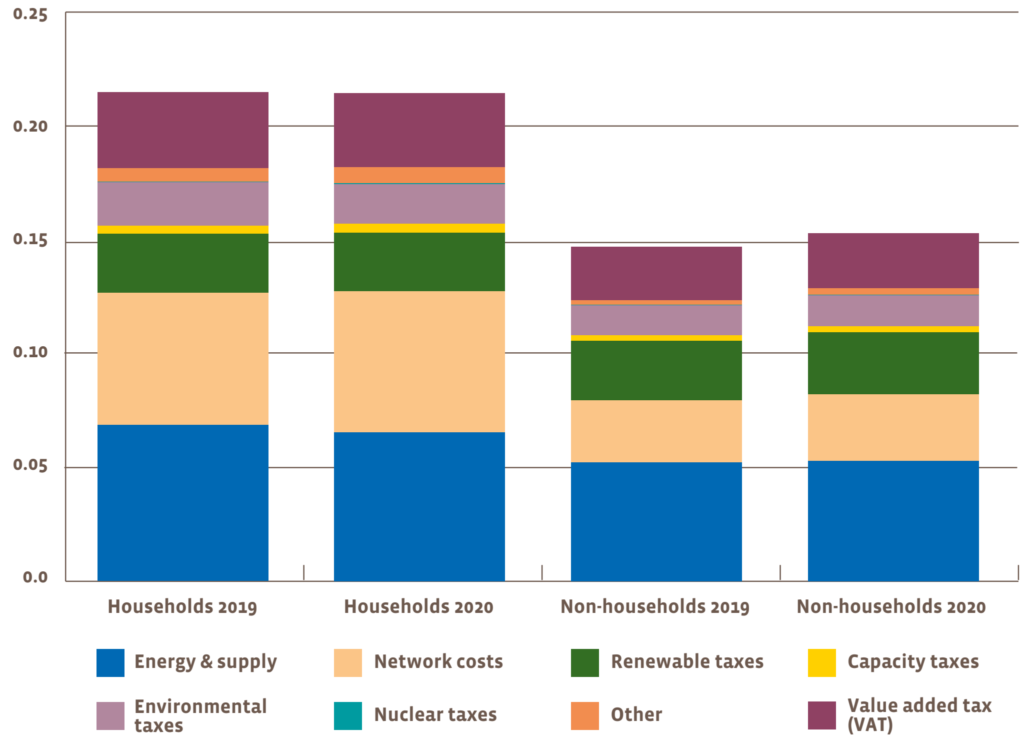
Energy prices for electricity and natural gas are monitored by Eurostat. These prices are listed in Figures 1 and 2 here for the years 2019 and 2020. Energy prices consist of multiple cost components: the cost of the energy carrier itself (energy and supply), network charges and various taxes, fees, charges and levies.

For both electricity and natural gas, several price add-ons are imposed on the energy price. Costs related to the network are imposed by the transmission and distribution companies, and represent the upkeep costs for delivering electricity and natural gas to consumers. Taxes, fees, charges and levies are charged by the authorities, which can have different purposes. For example, renewable taxes are imposed on consumers to acquire funds to be redistributed among developers of renewable energy in the form of subsidies. Environmental taxes are usually policy instruments aimed at changing consumer energy use patterns and they mostly flow into the general budget. Capacity taxes refer to the capacity of the consumer's connection. Nuclear taxes are specific to nuclear power generation and only occur in electricity prices in a few countries: Belgium, Italy and Slovakia. Usually, taxes imposed on household consumers (small consumers compared to most non-household consumers) are relatively high. Renewable and environmental taxes are most important in all taxes, and comparable to the average value of the value added tax (VAT), which is imposed on all cost components. The ranges of electricity and natural gas prices observed in the European Member States in 2019 and 2020 are depicted in Figure 1 and Figure 2 respectively. ■

Matthias Duschner

1

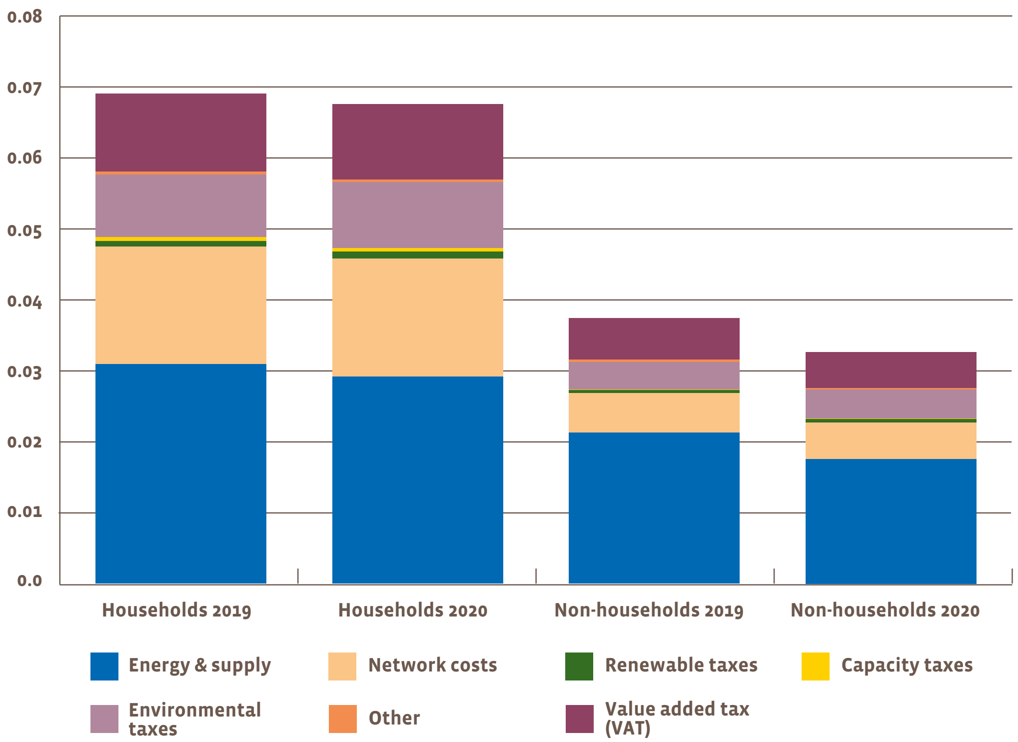
Weighted average electricity prices observed in the European Union in 2019 and 2020 (€/kWh)



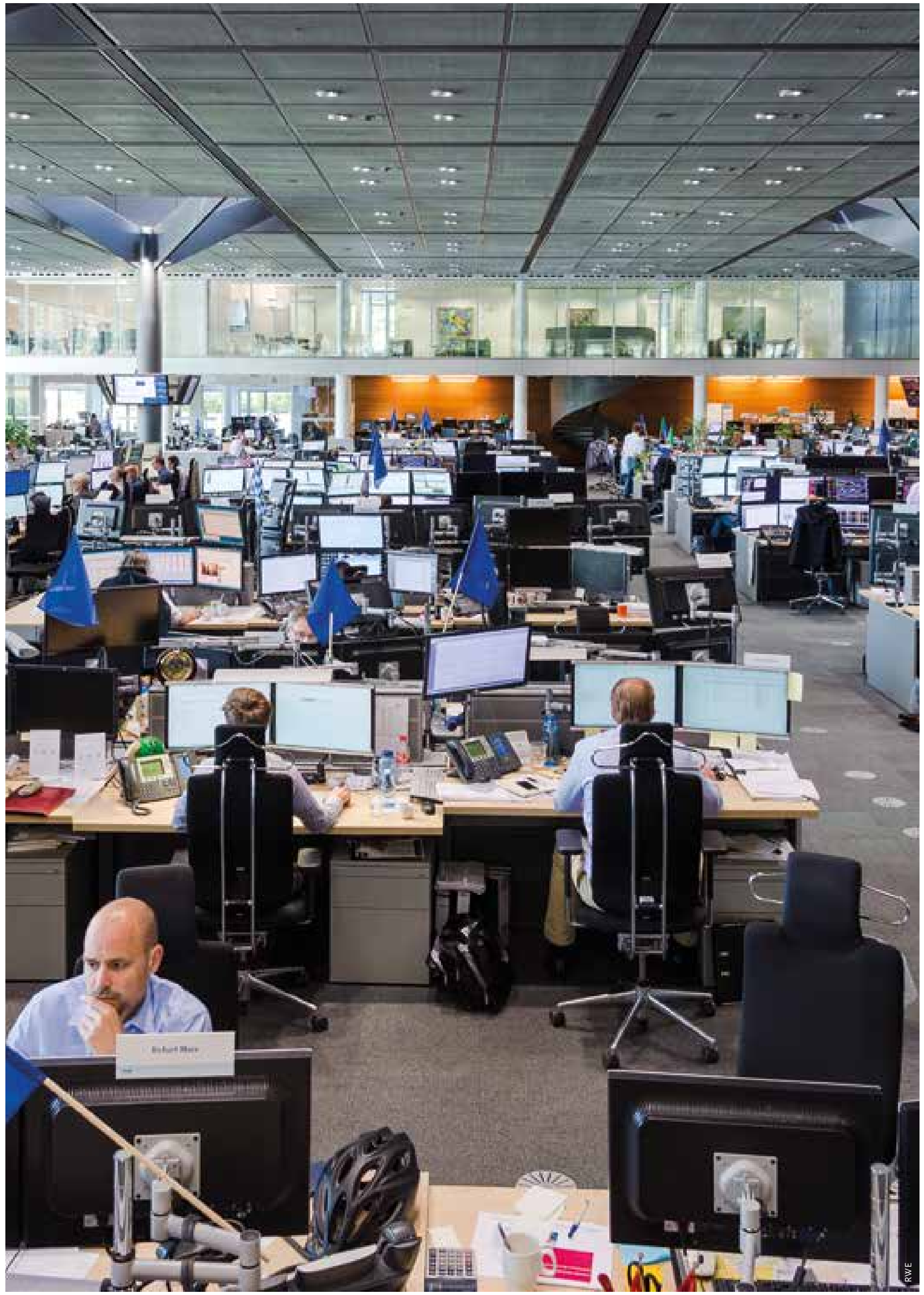
For the year 2019 all data refer to EU-28, for the year 2020 data refer to EU-27 (excluding United Kingdom). Household electricity prices: all electricity price components [EUR/kWh] for medium-sized household consumers with an annual electricity consumption between 2 500 kWh and 5 000 kWh. Non-household electricity: all electricity price components [EUR/kWh] for medium-sized non-household consumers with an annual electricity consumption between 500 MWh and 2 000 MWh. ***Source: EurObserv'ER based on Eurostat.***

2

Weighted average natural gas prices observed in the European Union in 2019 and 2020 (€/kWh)



For the year 2019 all data refer to EU-28, for the year 2020 data refer to EU-27 (excluding United Kingdom). Household natural gas prices: all gas price components [EUR/kWh] refer to an average of all household consumption bands. Non-household natural gas prices: all gas price components [EUR/kWh] refer to an average of all non-household consumption bands.
Source: EurObserv'ER based on Eurostat.



AVOIDED FOSSIL FUEL USE AND RESULTING AVOIDED COSTS AND GHG EMISSIONS

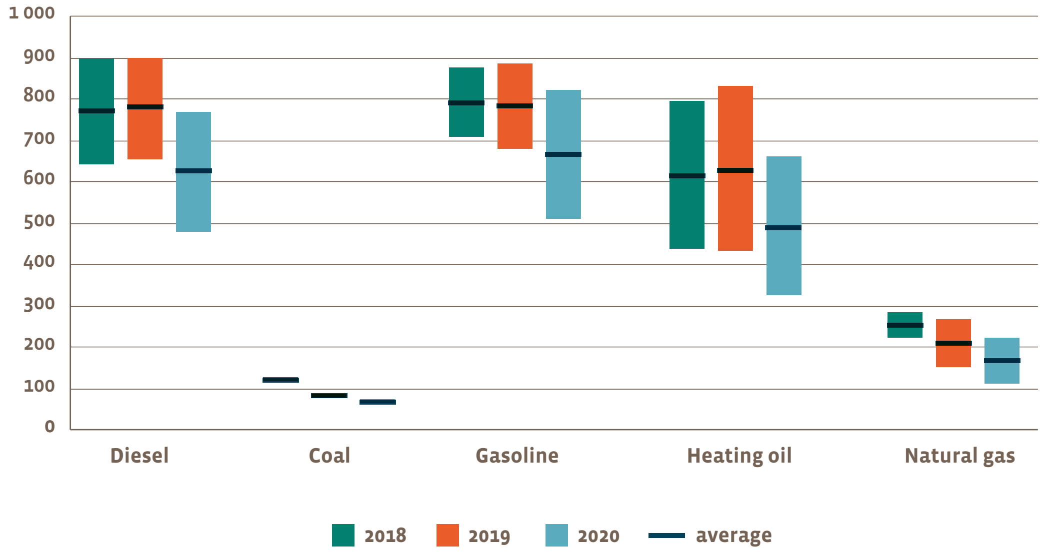
MORE RENEWABLE ENERGY MEANS LESS FOSSIL FUELS AND ASSOCIATED COSTS

Progress achieved in EU-wide renewable energy deployment since 2005 is largely attributed to the presence of mandatory national targets for 2020, first set under the Renewable Energy Directive, or RED (Directive 2009/28/EC) which has been recast under the 'Clean Energy for all Europeans' package: REDII (Directive 2018/2001/EU), entered into force in December 2018. In response to these targets national support instruments were put in place, such as feed-in tariffs, feed-in premiums, auction/tender systems, quotas, tax credits and grants.
The increase in the use of renewable energy leads to less consumption of fossil fuels, both domestic and imported. 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.
The amount of avoided fossil fuels are annually analysed by the European Environment Agency ('*Renewable energy in Europe 2021 - Recent growth and knock-on effects*', (EEA 2021)). 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, Nasdaq). The figure below highlights the fuel price ranges observed in the 27 EU Member States for 2018, 2019 and 2020 for five energy carriers: coal, diesel, gasoline, natural gas and oil. Prices for coal and natural gas refer to wholesale prices. For coal no country specific prices are available from the consulted sources and therefore the European price has been taken. For gas no prices for 2020 are available from the consulted source and therefore the evolution 2019-2020 of prices in band I5[1] for non-household consumers has been applied to the prices from 2019. For 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, 2021). 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 liquid fossil fuel end user prices in 2019 are more or less in the same range as in 2018 while coal and natural gas wholesale prices decreased in 2019 compared to 2018 because of the slowdown in economy and for natural gas prices were also impacted by abundant LNG supply to Europe[2]. In 2020 all prices decreased significantly due to the COVID crisis. Observed fuel prices for diesel, gasoline and fuel oil differ widely across member states and along the year.

1. Band I5 : 1 000 000 GJ < Consumption < 4 000 000 GJ, nrg_pc_203, Eurostat
2. Quarterly gas and electricity report, Market Observatory for Energy, DG Energy, Volume 12 (issue 4, fourth quarter of 2019) Market analysis | Energy (europa.eu)

1

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



Source: Eurostat, European Commission, Nasdaq

EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2021 EDITION

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 the year 2005, since progress achieved in EU-wide renewable energy deployment since 2005 is largely attributed to the presence of mandatory national targets for 2020. Note that this is a methodology change compared to the previous EurObserv'ER Overview Barometer, which included also the pre-2005 renewables in the analysis. With this change the EurObserv'ER estimates are in line with the ones from the European Environment Agency (EEA 2021).*
- *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 2020 estimates are proxies, borrowed from EEA (2021).*
- *Gross effects of renewable energy consumption on GHG emissions are based on data available from Eurostat for primary energy consumption and on CO2 emission factors per fuel type (t CO2/TJ; see Annex VI of Commission Regulation 601/2012). The term 'gross avoided GHG emissions' illustrates the theoretical character of the GHG effects estimated this way, as these contributions do not necessarily represent 'net GHG savings per se' or are not based on life-cycle assessment or full carbon accounting. Considering life-cycle emissions could lead to substantially different results.*
- *It is assumed that the contributions from renewable energy carriers (RES-E, RES-H/C and RES-T[1]) to the overall energy mix have replaced contributions that would have otherwise been obtained from initial energy carriers (electricity, heating and transport fuels).*
  - *For RES-E, a generation-weighted average emission factor is determined, i.e. an emission factor weighed on the basis of the type of fuel used to produce electricity in each country, on an annual basis. For this the next technologies/fuels are excluded: nuclear (usually operated as must-run capacity); renewable electricity generation (currently it is unlikely that renewable energy plants are to be displaced by new renewable capacity); blast furnace gas (considered a residue that can be utilised or flared). All other technologies and fuels are included*
  - *For RES-H/C, country-specific emission factors for heat (EFh) are calculated similarly to the approach applied to determine the reference values for the initial energy carrier electricity, so as to reflect the differences in the fuel mix between Member States.*
  - *For RES-T, the assumption is straightforward that renewable transport fuels (essentially biodiesel and bioethanol) replace the conventional transport fuels petrol and diesel on a one-to-one basis, according to their specific energy content.*
- *In the absence of specific information on current bioenergy systems, CO2 emissions from the combustion of biomass (in solid, liquid and gaseous forms) were not included in national GHG emission totals, a zero emission factor has been applied to all energy uses of biomass.*
- *A detailed description of the method to estimate avoided GHG emissions can be consulted in the first report on Renewable energy in Europe (2015)[2] on p.40 (chapter 3.3.1 The Eurostat based method).*

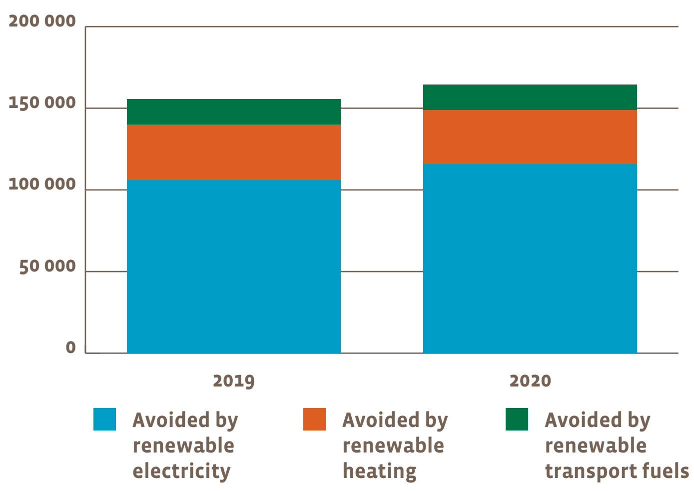
1. RES-E: Renewable electricity; RES-H/C: Renewable heating and cooling; RES-T: Renewable energy consumed in transport

2. Renewable energy in Europe —approximated recent growth and knock-on effects, EEA Technical report No 1/2015, Renewable energy in Europe - Approximated recent growth and knock-on effects — European Environment Agency (europa.eu)

In 2020 and 2019 the increase in the use of renewable energy substituted around 164.6 Mtoe and 155.6 Mtoe of fossil fuels respectively, compared to the level of use of renewable energy in 2005. These figures correspond to an avoided annual cost of EUR 43.5 billion for EU-27 collectively in 2019, decreasing to EUR 34.6 billion in 2020. In 2019 the largest financial contributions derive from renewable electricity and renewable transport (at approximately equal contributions together representing about 84% of the avoided expenses). For 2020 the picture is different: renewable electricity and renewable transport show again the largest financial contributions (together representing about 77% of the avoided expenses) but the contribution from renewable transport dropped to about half of the contribution from renewable electricity because of the sharper decrease in end-user prices for fossil transport fuels compared to wholesale natural gas and coal prices.

2

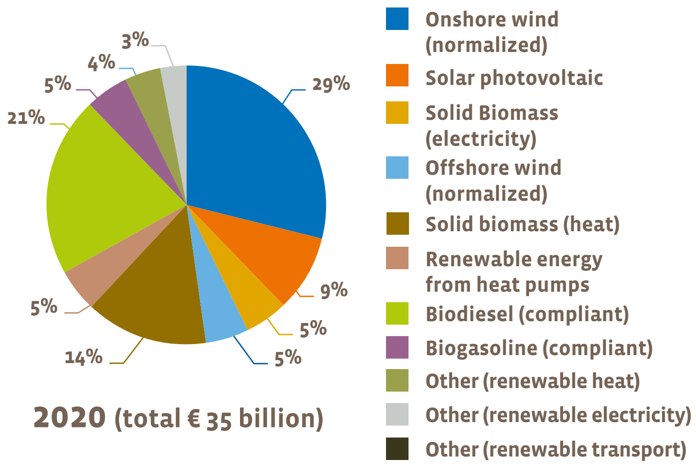
EU-27 avoided fossils fuels per sector (ktoe)



Note: Reference year 2005. Note: for 2020 proxy data are used.
Source: EurObserv'ER based on EEA data.

3

EU-27 avoided expenses through renewables



Note : Reference year 2005. Note: for 2020 proxy data are used.
Source: EurObserv'ER based on EEA data.

AVOIDED FOSSIL FUEL USE & AVOIDED COSTS PER TECHNOLOGY

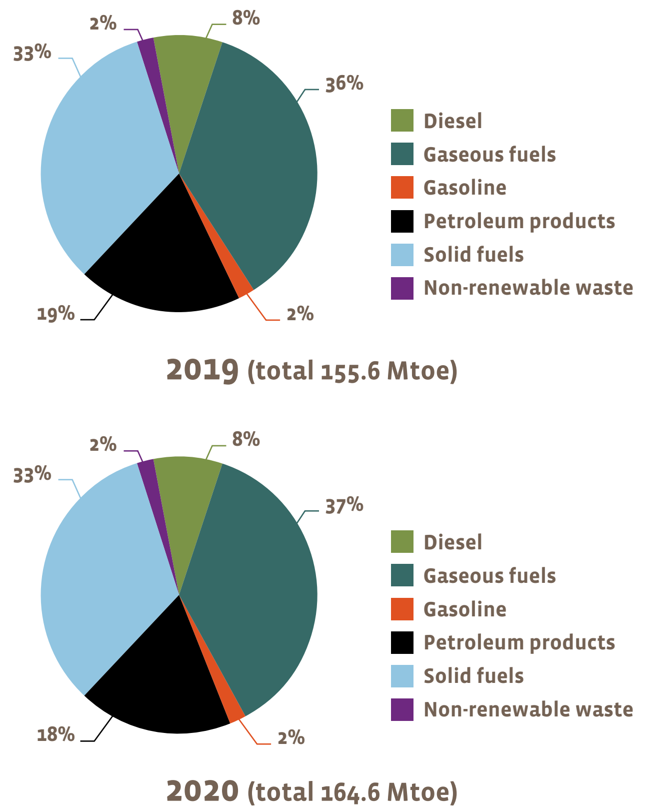
The use of renewable electricity contributed to 70% of the total avoided fossil fuels in 2020 (in terms of energy). This is followed by renewables in the heating and cooling sector contributing to 20% of the total avoided fossil fuels and the remaining share was substituted through renewable transport fuels (around 10%, only fuels compliant with Directive 2009/28/EC are included). In monetary terms, the avoided costs were EUR 21.9 billion in 2019 and EUR 17.7 billion in 2020 in the electricity sector. Second, renewable transport contributed to avoided costs reaching to EUR 11.5 billion in 2019 while in 2020 this decreased to EUR 9.2 billion. Third is renewable heat which contributed to avoided costs of EUR 11.0 billion in 2019 and EUR 8.1 billion in 2020. 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 5.8% from 2019 to 2020, the effect of the avoided fossil fuel expenses is, with a 21% decrease (from EUR 44.5 billion to EUR 35 billion) more pronounced and opposite from the growth in renewable energy. Reason for this is the strong decrease in fossil fuel prices in 2020 compared to 2019. Among the RES technologies, onshore wind avoided the purchase of fossil fuels at an amount of EUR 10 billion in 2020 (EUR 12.2 billion in 2019, both for normalised production) compared to the level in 2005. Next biodiesels in transport has been responsible for EUR 7.4 billion in 2020 (EUR 9.4 billion in 2019, both for compliant fuels). Solid biomass for heat purposes is third in the row with EUR 4.8 billion in 2020 (EUR 6.8 billion in 2019). The pie chart in graph 4 shows how each technology contributes to the total avoided fossil fuels in 2020.

The largest share of avoided fossil fuels comes from natural gas (respectively 36% and 37% for 2019 and 2020), followed by solid fuels (mainly coal, 33% both for 2019 and 2020). Next are oil products, with a contribution of respectively 19% and 18% in 2019 and 2020. The remaining fuels (transport fuels and non-renewable waste) cover the remaining share.

4

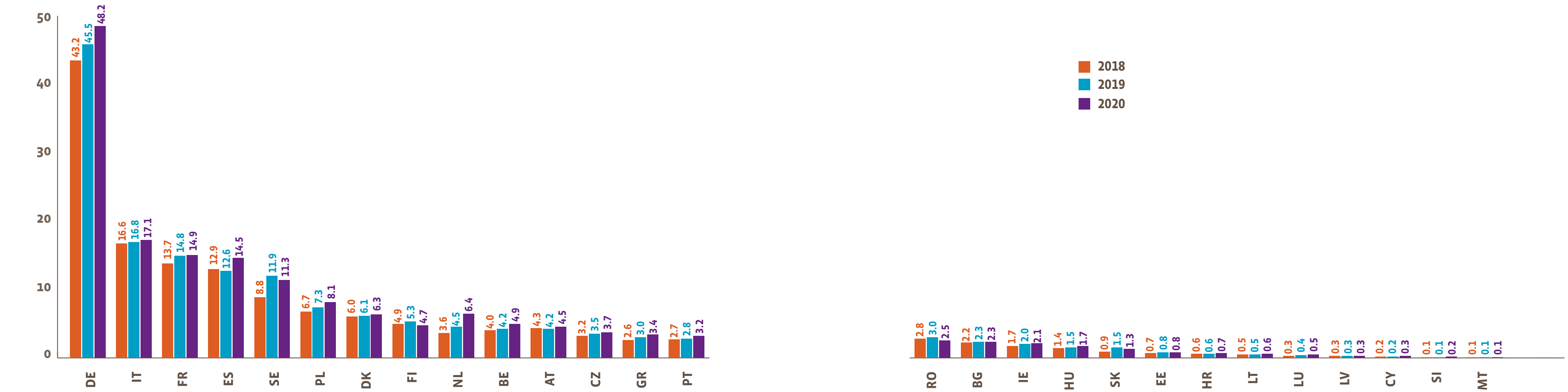
EU-27 substituted fossil fuels during 2019 and 2020



Note : reference year 2005. Note: for 2020 proxy data are used.
Source: EurObserv'ER based on EEA data.

5

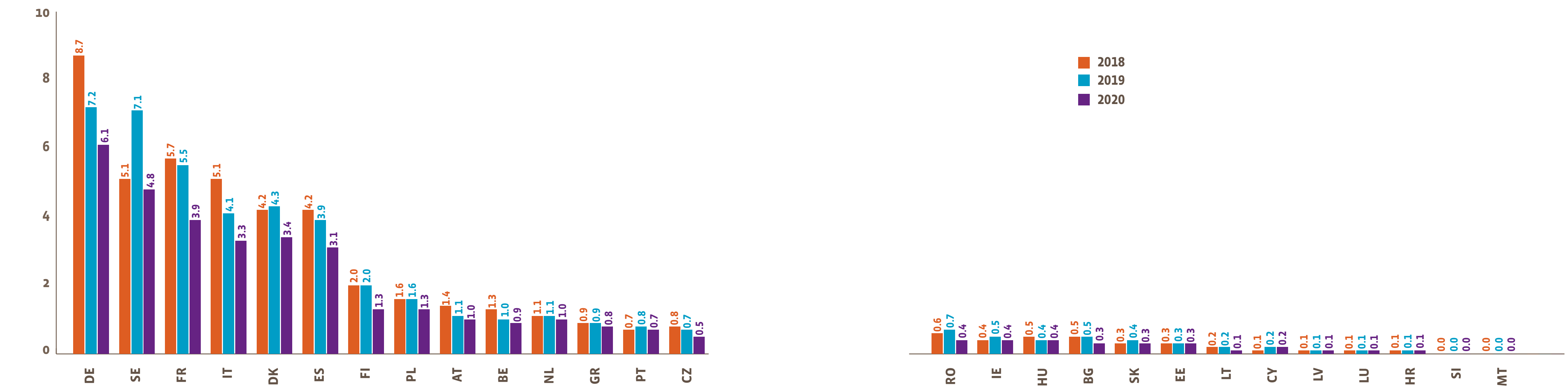
Avoided fossil fuels per country (Mtoe)



Note : Reference year 2005. Note: for 2020 proxy data are used. ***Source: EurObserv'ER based on EEA data.***

6

Avoided expenses per country (€ billion)



Note : Reference year 2005. Note: for 2020 proxy data are used. ***Source: EurObserv'ER based on EEA data.***

AVOIDED FOSSIL FUELS & EXPENSES PER MEMBER STATE

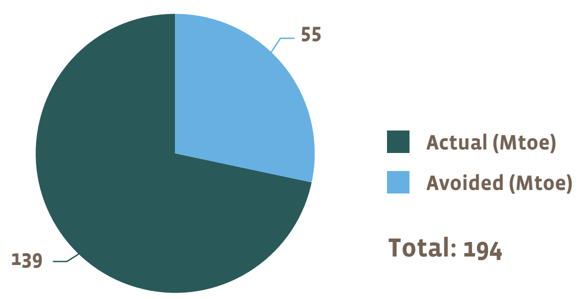
At Member State level, the amount of avoided fossil fuels and the avoided costs have been estimated as described in the methodological notes. Note that there is a strong correlation between the avoided amount and the size of a country. As can be expected, the avoided cost follows the fuel price development with fossil fuel prices lower in 2020 compared to 2019.

It can be observed from the results that countries with higher avoided fossil fuels figures not necessarily end up with higher avoided expenses, which is because these countries usually show a relatively lower growth in biogenic transport fuels which displace expensive fossil fuels, such as diesel and gasoline. The data have been displayed graphically in the figures 5 and 6.

Next, the figures 7 and 8 indicate how the amounts of estimated avoided fuel due to increased RES consumption since 2005 relate to the total EU-27 fuel use. The relevant parameter for comparing the avoided fuel use with is the primary energy consumption, which indicates the gross inland consumption excluding all non-energy use of energy carriers (e.g. natural gas used not for combustion but for producing chemicals). For the transport fuels a comparison is not possible because these are not primary fuels (but instead secondary fuels). Reference year depicted is 2020.

7

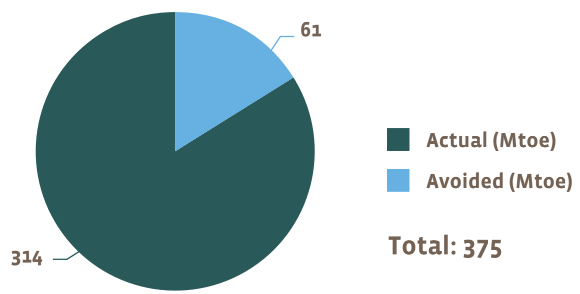
Effect on solid fuels in EU-27 in 2020 (Mtoe)



Note: reference year 2005. Note: for 2020 proxy data are used.
Source: Eurostat, EurObserv'ER based on EEA data.

8

Effect on gaseous fuels in EU-27 in 2020 (Mtoe)



Note: reference year 2005. Note: for 2020 proxy data are used.
Source: Eurostat, EurObserv'ER based on EEA data.

AVOIDED GHG EMISSIONS IN EU-27 AND PER MEMBER STATE

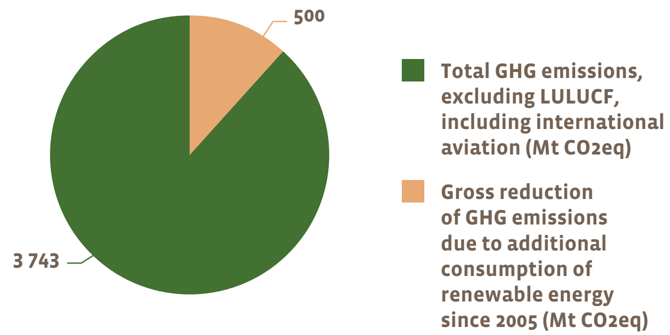
Finally, the figures 9 to 11 indicate the estimated savings in GHG emissions in 2019 and 2020 due to increased RES consumption since 2005, for the EU as a whole and per Member State.

For the EU-27 a gross reduction of 528 Mt CO_2eq of GHG emissions has been realised due to the additional consumption of renewable energy. While total EU-27 GHG emissions were approximately 3377 Mt CO_2eq in 2020, the additional uptake of renewable energy has led to a gross reduction of GHG emissions of 13.5% in 2020.

The gross reduction of GHG emissions due to the additional consumption of renewable energy has increased from 500 Mt CO_2eq in 2019 to approximately 528 Mt CO_2eq in 2020.

9

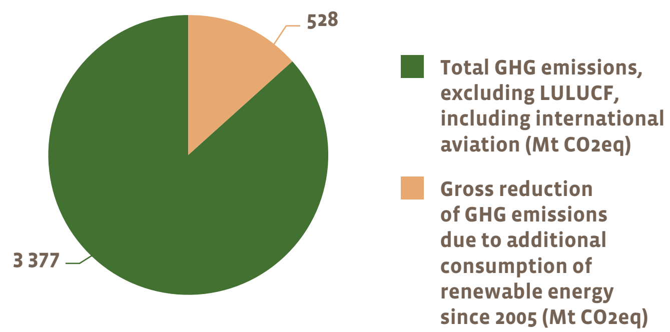
Effect on GHG emissions in EU-27 in 2019



Note: Reference year 2005. Note: for 2020 proxy data are used.
Source: Eurostat, EurObserv'ER based on EEA data.

10

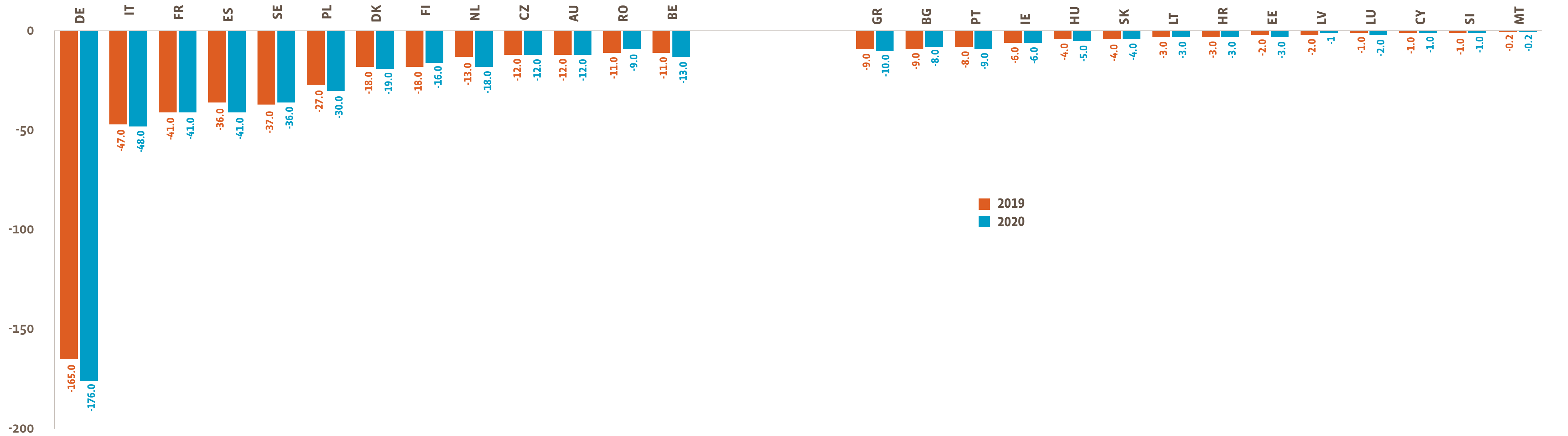
Effect on GHG emissions in EU-27 in 2020



Note: Reference year 2005. Note: for 2020 proxy data are used.
Source: Eurostat, EurObserv'ER based on EEA data.

11

Estimated gross reduction of GHG emissions, due to RES uptake since 2005, per country (Mt CO_2)



Note: Reference year 2005. Note: for 2020 proxy data are used. ***Source: Eurostat, EurObserv'ER based on EEA data.***

In terms of gross avoided GHG emissions in 2020, the countries with the largest estimated gross reductions were Germany (176 Mt CO2), Italy (48 Mt CO2), Spain and France (both 41 Mt CO2). ■

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INDICATORS ON INNOVATION AND COMPETITIVENESS

The Energy Union strives to provide a secure, sustainable, affordable energy supply by increasing renewable energy use, energy efficiency, internal energy market integration and competitiveness. The energy transition results in new jobs, growth and at the same time it is an investment in the future of Europe, as stated by the European Commission. This under-standing 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 increase market shares and strengthen competitiveness of firms, sectors and nations. Regarding renewable energy technology (RET), research and development (R&D) investments drive 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 investments of countries with respect to RET, patent applications reflecting the output of R&D efforts and finally trade shares in RET displaying how competitive a country is in RET products.

R&D Investments

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 macroeconomic 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 regarding innovation.

Methodological approach

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

R&D investments from the public sector are supposed to boost 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 rely on IEA statistics , which collects and depicts national R&D investments, with varying regularity and granularity of technology detail. However, there is a 2-year time delay in reporting for most Member States, thus data for 2019 is by and large complete, while the data for 2020 contain gaps and is (still) incomplete. For the data on private R&D, the time delay is even longer (2017 and 2018) as JRC's assessment is based on patent data. The methodology is described in more detail in the JRC Science for Policy Report "Monitoring R&D in Low Carbon Energy Technologies: Methodology for the R&I indicators in the State of the Energy Union Report, - 2016 Edition". Data gaps are supplemented by the Member States through the SET Plan Steering Group or through targeted data mining. Note that, because of the incomplete data set for 2020, the text in this chapter refers to the most complete data, being 2019. When data for some countries are not available, the countries are not integrated in the table. Besides providing absolute figures for R&D expenditures (Euro) of the given countries, the share of R&D expenditures by 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	Private sector	Public sector	
Performing sectors	Business	Government	Higher education

1. IEA. International Energy Agency RD&D Online Data Service. Available from: http://www.iea.org/statistics/RDDonlinedataservice/

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-27 in 2017 and 2018.

PUBLIC R&D INVESTMENTS

WIND ENERGY

		Public R&D Exp. (in € m)		Share of Public R&D Exp. by GDP	
		2019	2020	2019	2020
EU-27	Germany	69.2	68.9	0.0020%	0.0020%
	Netherlands	40.5	n.a.	0.0050%	n.a.
	Spain	26.6	n.a.	0.0021%	n.a.
	Denmark	14.7	15.6	0.0047%	0.0050%
	France	14.3	n.a.	0.0006%	n.a.
	Belgium	7.3	5.2	0.0015%	0.0011%
	Sweden	2.2	3.9	0.0005%	0.0008%
	Finland	1.1	n.a.	0.0005%	n.a.
	Austria	1.0	n.a.	0.0003%	n.a.
	Czechia	0.8	0.3	0.0004%	0.0002%
	Ireland	0.8	n.a.	0.0002%	n.a.
	Poland	0.5	2.5	0.0001%	0.0005%
	Lithuania	0.2	0.1	0.0003%	0.0002%
	Hungary	0.0	n.a.	0.0000%	n.a.
	EU-27	179.1	96.6	0.0013%	0.0007%
	EU Commission	43.1	46.7	n.a.	n.a.
Other Countries	Norway	166.1	4.9	0.0467%	0.0015%
	Japan	109.1	128.4	0.0024%	0.0029%
	United States	62.8	74.2	0.0003%	0.0004%
	Korea	47.8	n.a.	n.a.	n.a.
	United Kingdom	13.2	n.a.	0.0005%	n.a.
	Canada	4.5	4.3	0.0003%	0.0003%
	Switzerland	3.8	3.9	0.0006%	0.0006%
	Australia	0.1	n.a.	0.0000%	n.a.

Source: JRC SETIS, Eurostat, WDI Database

Wind energy is one of the three biggest public investment areas (next to solar energy and biofuels). The largest investments (2019) are committed by the EU-27, Norway, Japan, US, Korea (in that order). Within the EU-27, the most significant national investments occur in Germany, the Netherlands and Spain. On top of that the European Commission contributes additional funding (approximately on the level of the level of second biggest national investor, i.e., the Netherlands). In terms of GDP shares, Japan stands out in 2020 with the largest value, followed by Norway. The EU-27 share of GDP is similar to the share of Switzerland, both larger then the United States and Canada. ■

PUBLIC R&D INVESTMENTS

SOLAR ENERGY

		Public R&D Exp. (in € m)		Share of Public R&D Exp. by GDP	
		2019	2020	2019	2020
EU-27	Germany	105.2	90.2	0.0030%	0.0027%
	France	43.9	n.a.	0.0018%	n.a.
	Spain	17.0	n.a.	0.0014%	n.a.
	Netherlands	13.5	n.a.	0.0017%	n.a.
	Poland	11.7	9.0	0.0022%	0.0017%
	Belgium	9.7	8.9	0.0020%	0.0019%
	Austria	7.1	n.a.	0.0018%	n.a.
	Finland	4.9	n.a.	0.0021%	n.a.
	Sweden	3.8	6.8	0.0008%	0.0014%
	Czechia	2.4	1.7	0.0011%	0.0008%
	Denmark	2.1	1.4	0.0007%	0.0005%
	Lithuania	2.1	0.6	0.0042%	0.0013%
	Estonia	0.4	0.1	0.0014%	0.0002%
	Ireland	0.3	n.a.	0.0001%	n.a.
	Slovakia	0.2	0.3	0.0002%	0.0003%
	Hungary	n.a.	0.36	n.a.	0.0003%
	EU-27	224.3	119.3	0.0016%	0.0009%
	EU Commission	117.5	59.2	n.a.	n.a.
Other Countries	United States	168.4	216.5	0.0009%	0.0012%
	Korea	60.1	n.a.	n.a.	n.a.
	United Kingdom	27.6	n.a.	0.0011%	n.a.
	Japan	26.3	24.0	0.0006%	0.0005%
	Switzerland	26.2	26.4	0.0041%	0.0040%
	Canada	11.7	16.7	0.0008%	0.0012%
	Australia	9.1	n.a.	0.0007%	n.a.
	Norway	5.4	6.7	0.0015%	0.0021%
	New Zealand	0.2	n.a.	0.0001%	n.a.

Source: JRC SETIS, Eurostat, WDI Database

In the field of solar energy, the EU-27 is the largest player in terms of national R&D investment in 2019 while the US is at the top of this list in 2020. Countries that follow next on the list for 2019 are Korea, with the UK, Japan and Switzerland as runners-up. The table displays a significant rise in national R&D investments in the US. Figures for China as well as some other countries are not available. Within the EU-27, the largest part of public R&D investments is provided by the European Commission. National investments by individual EU countries are dominated first and foremost by two countries, i.e., first Germany and France to a lesser extent (value for 2019). These realized 67% of the EU-27 public investments (in 2019). Next are Spain, Poland, the Netherlands and Belgium (values for 2019). When looking at the normalization of the R&D figures by GDP, the share of the EU-27 is on a similar level, although slightly lower, as that of the US and Canada. Furthermore, it is worthwhile to point out the high relative level of engagement in Switzerland. Norway also has a higher relative share of their GDP invested than the EU-27. Within the EU-27, Germany, Finland and Belgium have the largest budget share for solar energy, followed by France and Austria. ■

PUBLIC R&D INVESTMENTS

HYDROENERGY

		Public R&D Exp. (in € m)		Share of Public R&D Exp. by GDP	
		2019	2020	2019	2020
EU-27	Austria	2.5	n.a.	0.0006%	n.a.
	Sweden	2.1	1.8	0.0004%	0.0004%
	Spain	1.9	n.a.	0.0002%	n.a.
	Germany	1.6	2.0	0.0000%	0.0001%
	Belgium	0.8	n.a.	0.0002%	n.a.
	Poland	0.5	0.9	0.0001%	0.0002%
	France	0.4	n.a.	0.0000%	n.a.
	Czechia	0.3	0.1	0.0001%	0.0000%
	Finland	0.1	n.a.	0.0000%	n.a.
	Denmark	0.1	n.a.	0.0000%	n.a.
	Estonia	0.0	n.a.	0.0001%	n.a.
	EU-27	10.2	4.8	0.0001%	0.0000%
	EU Commission	23.4	10.0	n.a.	n.a.
Other Countries	United States	71.7	101.2	0.0004%	0.0006%
	Canada	11.2	10.9	0.0007%	0.0008%
	Switzerland	10.0	10.1	0.0016%	0.0015%
	Norway	5.0	4.6	0.0014%	0.0014%
	Korea	2.1	n.a.	n.a.	n.a.
	Australia	0.1	n.a.	0.0000%	n.a.
	New Zealand	0.0	n.a.	0.0000%	n.a.

Source: JRC SETIS, Eurostat, WDI Database

Hydro energy is a small field with regard to public R&D investment when compared, for example, to solar energy. Among the assessed countries, the US has the largest public R&D investment (71,7 million Euros in 2019). Remarkable engagements (though much lower than that of the US) are noted for Switzerland and Canada. Within the EU-27, the European Commission provides the largest part of the funding (23.4 million Euros). The national commitments of the EU-27 in this area are smaller (10.2 million Euros in 2019), with the largest contributions from Austria, Sweden and Spain. Also the GDP shares show that the engagement by the US is significantly higher than by the EU-27. Switzerland and Norway stand out with the largest GDP shares. ■

PUBLIC R&D INVESTMENTS

GEOTHERMAL ENERGY

		Public R&D Exp. (in € m)		Share of Public R&D Exp. by GDP	
		2019	2020	2019	2020
EU-27	Germany	12.8	13.9	0.0004%	0.0004%
	Netherlands	9.5	n.a.	0.0012%	n.a.
	France	7.3	n.a.	0.0003%	n.a.
	Czechia	0.8	0.2	0.0004%	0.0001%
	Belgium	0.6	0.3	0.0001%	0.0001%
	Slovakia	0.6	0.3	0.0006%	0.0003%
	Ireland	0.4	n.a.	0.0001%	n.a.
	Poland	0.1	0.2	0.0000%	0.0000%
	Sweden	0.1	1.9	0.0000%	0.0004%
	Austria	0.0	n.a.	0.0000%	n.a.
	Lithuania	0.0	n.a.	0.0000%	n.a.
	Hungary	n.a.	1.8	n.a.	0.0013%
	EU-27	32.2	18.7	0.0002%	0.0001%
	EU Commission	17.9	12.8	n.a.	n.a.
Other Countries	United States	57.4	71.5	0.0003%	0.0004%
	Switzerland	13.7	13.8	0.0021%	0.0021%
	Japan	11.8	13.9	0.0003%	0.0003%
	Canada	9.8	4.6	0.0006%	0.0003%
	New Zealand	5.1	n.a.	0.0027%	n.a.
	Korea	1.7	n.a.	n.a.	n.a.
	Norway	1.1	1.1	0.0003%	0.0003%
	United Kingdom	0.8	n.a.	0.0000%	n.a.
	Australia	0.1	n.a.	0.0000%	n.a.

Source: JRC SETIS, Eurostat, WDI Database

With regard to geothermal energy, the U.S. is found to have by far the largest public R&D investments of all assessed countries. With 57.4 million Euros in 2019 this is almost double the value of the entire EU-27 (32.2 million Euros). Within the EU-27, the European Commission is the largest single provider of R&D funding. On the level of individual countries three of them dominate the national investments, i.e., Germany, the Netherlands and France. Further countries with significant investments are Switzerland and Japan. Compared to solar energy, the public R&D expenditures are rather low. In terms of GDP normalization, the US shows a larger engagement than the EU-27.
New Zealand and Switzerland stand out with the largest shares of public R&D investment by GDP. Within the EU-27, Hungary shows the highest share of public R&D investment by GDP, followed by the Netherlands. ■

PUBLIC R&D INVESTMENTS

BIOFUELS

		Public R&D Exp. (in € m)		Share of Public R&D Exp. by GDP	
		2019	2020	2019	2020
EU-27	France	50.6	n.a.	0.0021%	n.a.
EU-27	Germany	37.4	44.7	0.0011%	0.0013%
EU-27	Sweden	14.2	14.4	0.0030%	0.0030%
EU-27	Denmark	10.6	9.4	0.0034%	0.0030%
EU-27	Finland	10.5	n.a.	0.0044%	n.a.
EU-27	Austria	9.2	n.a.	0.0023%	n.a.
EU-27	Czechia	8.7	10.1	0.0039%	0.0047%
EU-27	Netherlands	7.1	n.a.	0.0009%	n.a.
EU-27	Spain	5.7	n.a.	0.0005%	n.a.
EU-27	Poland	3.9	2.4	0.0007%	0.0005%
EU-27	Ireland	1.9	n.a.	0.0005%	n.a.
EU-27	Lithuania	1.8	2.1	0.0037%	0.0042%
EU-27	Belgium	0.8	3.2	0.0002%	0.0007%
EU-27	Estonia	0.1	0.1	0.0005%	0.0005%
EU-27	Slovakia	0.0	0.0	0.0000%	0.0000%
EU-27	Hungary	n.a.	0.5	n.a.	0.0004%
	EU-27	162.6	87.0	0.0012%	0.0006%
	EU Commission	67.8	70.9	n.a.	n.a.
Other Countries	United States	163.9	181.5	0.0009%	0.0010%
Other Countries	Japan	45.1	66.3	0.0010%	0.0015%
Other Countries	Canada	28.8	43.9	0.0019%	0.0030%
Other Countries	Korea	19.9	n.a.	n.a.	n.a.
Other Countries	United Kingdom	14.7	n.a.	0.0006%	n.a.
Other Countries	Switzerland	13.1	13.1	0.0020%	0.0020%
Other Countries	Norway	11.1	19.8	0.0031%	0.0062%
Other Countries	Australia	2.0	n.a.	0.0002%	n.a.
Other Countries	New Zealand	1.2	n.a.	0.0006%	n.a.

Source: JRC SETIS, Eurostat, WDI Database

In terms of public R&D investment, biofuels remains a large field within renewables, but since recently it became a bit smaller than solar energy and wind energy. The commitment of the EU-27 and the US was virtually the same in 2019 (EU-27: 162.6, US: 163.9 million Euros). However, within the EU-27 additional funding is provided by the European Commission (67.8 million Euros). The largest national contributions in the EU-27 come from France and Germany. Other listed countries with significant investments are Japan and Canada. With regard to the GDP shares, the EU-27 is slightly ahead of the US. Finland, Czech Republic, Denmark and Norway show particularly high GDP shares. ■

PUBLIC R&D INVESTMENTS

OCEAN ENERGY

		Public R&D Exp. (in € m)		Share of Public R&D Exp. by GDP	
		2019	2020	2019	2020
EU-27	France	6.3	n.a.	0.0003%	n.a.
EU-27	Ireland	4.0	n.a.	0.0011%	n.a.
EU-27	Sweden	3.4	4.3	0.0007%	0.0009%
EU-27	Spain	1.1	n.a.	0.0001%	n.a.
EU-27	Denmark	0.5	4.3	0.0002%	0.0014%
EU-27	Belgium	0.2	0.2	0.0000%	0.0000%
EU-27	Poland	0.1	0.1	0.0000%	0.0000%
EU-27	Netherlands	0.0	n.a.	0.0000%	n.a.
	EU-27	15.7	9.0	0.0001%	0.0001%
	EU Commission	23.8	13.7	n.a.	n.a.
Other Countries	United Kingdom	18.3	n.a.	0.0007%	n.a.
Other Countries	Japan	6.7	4.9	0.0001%	0.0001%
Other Countries	Australia	4.1	n.a.	0.0003%	n.a.
Other Countries	Korea	1.9	n.a.	n.a.	n.a.
Other Countries	Canada	1.2	2.8	0.0001%	0.0002%
Other Countries	Norway	0.1	0.1	0.0000%	0.0000%

Source: JRC SETIS, Eurostat, WDI Database

Ocean energy is a comparably small field in terms of public R&D investment. The most significant investments (2019) are due to the EU-27 and the UK. Within the EU-27, it is first and foremost the European Commission which contributes the largest R&D funds in this area. On the national level, France (2019), Ireland (2019), Sweden (2020) and Denmark (2020) are investing the largest amounts. GDP shares are dominated by Denmark, reaching 0.0014% of its investments in R&D per trillion euros of GDP. The next highest GDP shares on public R&D came from Ireland (2019) and Sweden (2020). In gerenal, the EU-27 have invested a mere 0.0001% of their GDP to public R&D. ■

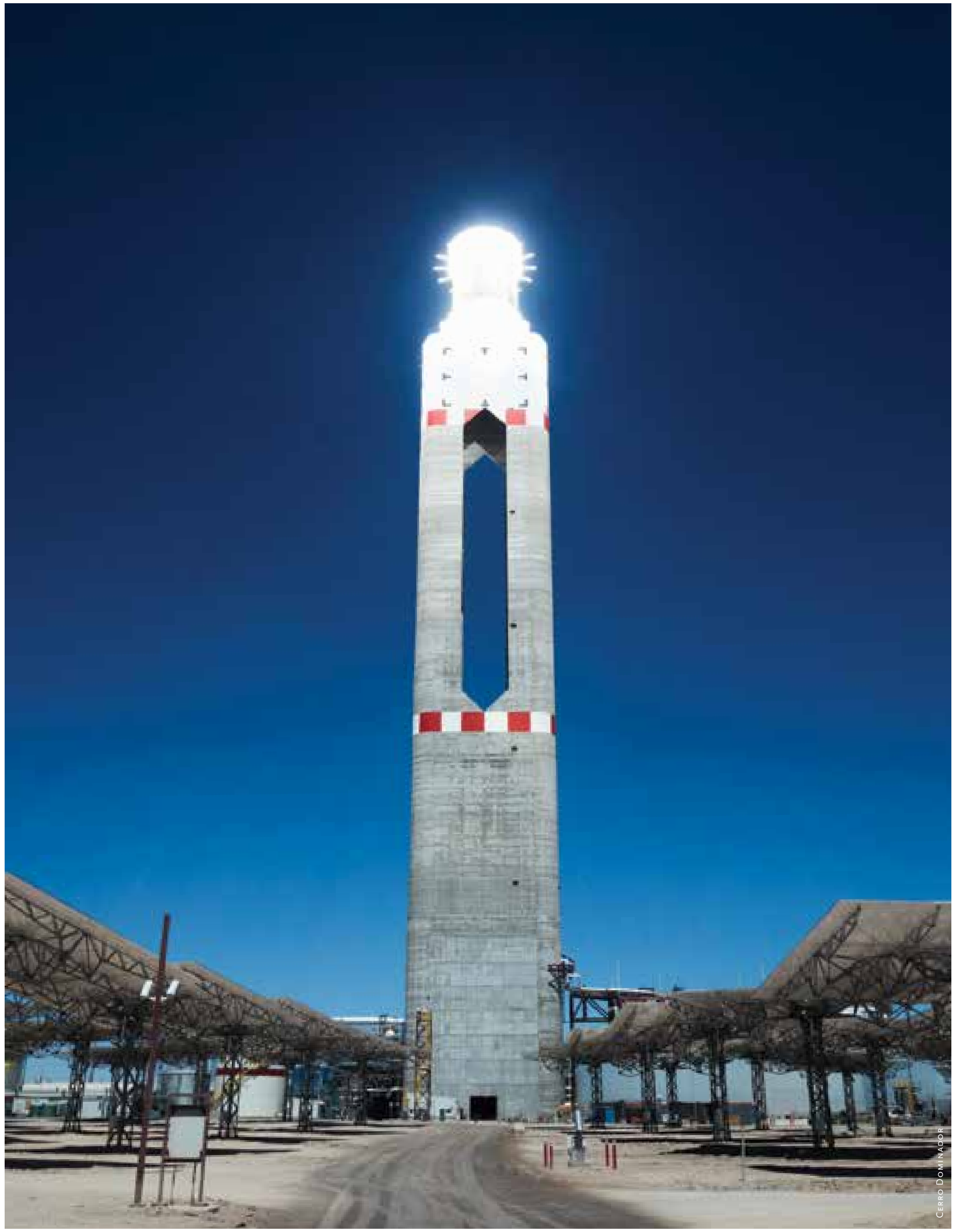
PUBLIC R&D INVESTMENTS

RENEWABLE ENERGY TECHNOLOGIES IN TOTAL

		Public R&D Exp. (in € m)		Share of Public R&D Exp. by GDP	
		2019	2020	2019	2020
EU-27	Germany	226.1	219.8	0.0065%	0.0065%
	France	122.8	n.a.	0.0050%	n.a.
	Netherlands	70.5	n.a.	0.0087%	n.a.
	Spain	52.4	n.a.	0.0042%	n.a.
	Denmark	27.9	30.8	0.0090%	0.0099%
	Sweden	25.8	33.2	0.0054%	0.0070%
	Austria	19.8	n.a.	0.0050%	n.a.
	Belgium	19.4	17.7	0.0041%	0.0039%
	Poland	16.8	15.1	0.0032%	0.0029%
	Finland	16.6	n.a.	0.0069%	n.a.
	Czechia	13.0	12.4	0.0058%	0.0058%
	Ireland	7.4	n.a.	0.0021%	n.a.
	Lithuania	4.1	2.8	0.0083%	0.0056%
	Slovakia	0.8	0.6	0.0009%	0.0006%
	Estonia	0.6	0.2	0.0020%	0.0007%
	Hungary	0.0	2.7	0.0000%	0.0020%
	EU-27	624.0	335.3	0.0045%	0.0025%
	EU Commission	293.4	213.3	n.a.	n.a.
Other Countries	United States	524.2	645.0	0.0028%	0.0035%
	Japan	199.1	237.5	0.0044%	0.0053%
	Norway	188.8	37.2	0.0530%	0.0117%
	Korea	133.5	n.a.	n.a.	n.a.
	United Kingdom	74.6	n.a.	0.0030%	n.a.
	Canada	67.3	83.2	0.0044%	0.0058%
	Switzerland	66.9	67.3	0.0104%	0.0102%
	Australia	15.5	n.a.	0.0013%	n.a.
	New Zealand	6.6	n.a.	0.0035%	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.

The aggregated results of public R&D investments for all renewable energy technologies in the EU-27 reveals a strong position in 2019 with a grand total at almost 1 billion Euros when accounting for the national contributions (624.0 million Euros) and those of the European Commission (293.4 million Euros) together. The second largest contribution of public R&D investments in renewable energy technologies came from the United States, with just over 50% of the EU-27 and European Commission total. In general, the EU-27 has invested 0.0025% of the GDP in public R&D in 2020. Among the countries with more than 50 million Euros of total investments, in particular Norway, Switzerland and Denmark stand out with the highest GDP shares. ■



PRIVATE R&D INVESTMENTS

WIND ENERGY

		Private R&D Exp. (in € m)		Share of Private R&D Exp. by GDP	
		2017	2018	2017	2018
EU-27	Germany	868.0	1 395.9	0.0266%	0.0414%
	Denmark	538.4	941.5	0.1826%	0.3114%
	Netherlands	84.9	56.5	0.0115%	0.0073%
	Spain	43.7	93.3	0.0038%	0.0078%
	France	42.0	21.6	0.0018%	0.0009%
	Belgium	20.1	38.7	0.0045%	0.0084%
	Sweden	18.4	30.2	0.0038%	0.0064%
	Finland	17.3	7.2	0.0076%	0.0031%
	Austria	10.3	34.3	0.0028%	0.0089%
	Romania	7.3	n.a.	0.0039%	n.a.
	Italy	6.3	4.7	0.0004%	0.0003%
	Latvia	3.1	n.a.	0.0116%	n.a.
	Slovenia	3.1	n.a.	0.0073%	n.a.
	Luxembourg	1.6	8.5	0.0027%	0.0141%
	Poland	0.1	4.7	0.0000%	0.0010%
	EU-27	1 664.6	2 637.2	0.0127%	0.0195%

Source: JRC SETIS, Eurostat, WDI Database

Since 2017, wind energy attracts the largest private R&D investment volumes (2.6 billion euros in 2018) in the EU-27 (closely followed by solar energy). Germany is responsible for over 50% of the EU-27 investments (1.4 billion euros), leaving Denmark behind at just under 1 billion euros. All other EU-27 countries spend less than 100 million euros on wind energy, with Spain having the largest investments, followed by the Netherlands, Belgium, Austria and Sweden. In total, a significant further rise of investments is noted for 2018, mainly due to increased commitments by Germany and Spain. In terms of GDP shares, Denmark stands out with by far the largest value (0.31%), followed by Germany. With a total of 0.020% of the EU-27 GDP spent on private R&D wind energy investments, the remaining countries spend a lower share of their GDP on wind energy. ■

PRIVATE R&D INVESTMENTS

SOLAR ENERGY

		Private R&D Exp. (in € m)		Share of Private R&D Exp. by GDP	
		2017	2018	2017	2018
EU-27	Germany	823.1	644.8	0.0252%	0.0191%
	France	171.5	212.8	0.0075%	0.0090%
	Italy	121.5	115.6	0.0070%	0.0065%
	Sweden	73.2	64.9	0.0152%	0.0138%
	Netherlands	68.8	73.8	0.0093%	0.0095%
	Spain	46.2	48.7	0.0040%	0.0041%
	Finland	30.7	21.1	0.0136%	0.0090%
	Austria	23.1	29.9	0.0063%	0.0078%
	Ireland	18.1	4.8	0.0061%	0.0015%
	Belgium	16.2	13.0	0.0036%	0.0028%
	Poland	13.3	16.8	0.0028%	0.0034%
	Portugal	9.8	n.a.	0.0050%	n.a.
	Denmark	7.6	13.5	0.0026%	0.0045%
	Hungary	7.2	4.8	0.0057%	0.0035%
	Czechia	6.0	n.a.	0.0031%	n.a.
	Malta	4.9	n.a.	0.0410%	n.a.
	Estonia	3.3	n.a.	0.0137%	n.a.
	Greece	0.8	2.4	0.0005%	0.0013%
	Romania	n.a.	4.8	n.a.	0.0023%
	Luxembourg	n.a.	0.6	n.a.	0.0010%
	EU-27	1 445.2	1 272.4	0.0111%	0.0094%

Source: JRC SETIS, Eurostat, WDI Database

In the field of solar energy within the EU-27, Germany is by far the largest player in terms of private R&D investment, accounting for more than 50% of the total EU-27 investments. With a large gap to Germany, the following countries rank next on the list: France, Italy, Sweden and the Netherlands (in that order).

Among the GDP normalized investments in private R&D, Germany, unsurprisingly, has the largest share (2018). Following with a slight lower percentage, Sweden has invested 0.0138% of their GDP into private R&D, leaving the rest of the EU-27 under the 0.01% GDP share. The total GDP share of the EU-27 showed a minor drop to 0.0094% in 2018. ■

PRIVATE R&D INVESTMENTS

HYDRO ENERGY

		Private R&D Exp. (in € m)		Share of Private R&D Exp. by GDP	
		2017	2018	2017	2018
EU-27	Germany	19.3	10.4	0.0006%	0.0003%
	France	7.4	35.6	0.0003%	0.0015%
	Spain	3.0	n.a.	0.0003%	n.a.
	Finland	2.6	4.8	0.0011%	0.0021%
	Italy	2.4	1.3	0.0001%	0.0001%
	Greece	1.7	n.a.	0.0010%	n.a.
	Belgium	1.7	2.6	0.0004%	0.0006%
	Sweden	1.6	6.4	0.0003%	0.0014%
	Austria	1.2	5.2	0.0003%	0.0013%
	Romania	0.9	1.3	0.0005%	0.0006%
	Slovenia	0.5	4.2	0.0012%	0.0091%
	Czechia	n.a.	3.9	n.a.	0.0019%
	Ireland	n.a.	2.6	n.a.	0.0008%
	Netherlands	n.a.	1.3	n.a.	0.0002%
	EU-27	42.3	79.5	0.0003%	0.0006%

Source: JRC SETIS, Eurostat, WDI Database

Like geothermal energy, hydro energy is also a rather small field with regard to private R&D investments. As in earlier reporting periods private R&D investments remain larger than public ones. Germany commits by far the largest investments (2017) followed by France, Spain, Finland and Italy. In 2018, a remarkably high investment volume by France is registered, which would make France the biggest private investor in 2018. Significant investments in 2018 are also listed by Sweden, Austria and Finland. Although total investments of the EU-27 in hydro energy have dropped since 2015, there was a significant increase of 37 million euros in 2018. Similarly, the total share of GDP investments in private R&D for the EU-27 almost doubled to 0.0006%. With a remarkable increased investment in hydro energy, Slovenia leads the GDP share of the EU-27 with 0.0091%. The next biggest normalized GDP investments, with similar shares, were from Finland, Czech Republic, France, Sweden and Austria. ■

PRIVATE R&D INVESTMENTS

GEOTHERMAL ENERGY

		Private R&D Exp. (in € m)		Share of Private R&D Exp. by GDP	
		2017	2018	2017	2018
EU-27	Sweden	5.9	4.3	0.0012%	0.0009%
	Germany	4.2	13.5	0.0001%	0.0004%
	Finland	3.6	0.3	0.0016%	0.0001%
	Denmark	2.1	2.1	0.0007%	0.0007%
	France	1.3	n.a.	0.0001%	n.a.
	Italy	1.0	6.4	0.0001%	0.0004%
	Belgium	0.8	n.a.	0.0002%	n.a.
	Netherlands	n.a.	4.3	n.a.	0.0006%
	EU-27	18.9	30.8	0.0001%	0.0002%

Source: JRC SETIS, Eurostat, WDI Database

In geothermal energy, the private (as well as the public) R&D expenditures are around two orders of magnitude lower than in solar energy. The largest investments (2018) are due to Germany, followed by Italy, the Netherlands and Sweden. Italy and the Netherlands committed significant R&D investments in this area compared to 2017, sharing about one-third of the total EU-27 investments (30.8 Meuro). Conversely, Finland showed a significant decrease in geothermal energy private R&D expenditure, dropping their normalized GDP investments from highest to lowest (0.0001% in 2018). Sweden leads the share of GDP invested in private R&D, not by far, before Denmark and the Netherlands. ■

PRIVATE R&D INVESTMENTS

BIOFUELS

		Private R&D Exp. (in € m)		Share of Private R&D Exp. by GDP	
		2017	2018	2017	2018
EU-27	Denmark	101.8	72.9	0.0345%	0.0241%
	Finland	66.6	52.8	0.0294%	0.0226%
	Germany	55.6	32.2	0.0017%	0.0010%
	France	51.6	24.0	0.0022%	0.0010%
	Netherlands	31.4	34.4	0.0042%	0.0044%
	Italy	19.8	13.8	0.0011%	0.0008%
	Spain	19.7	5.5	0.0017%	0.0005%
	Belgium	12.5	8.3	0.0028%	0.0018%
	Hungary	8.6	33.2	0.0068%	0.0244%
	Sweden	8.2	6.8	0.0017%	0.0015%
	Austria	5.7	6.6	0.0015%	0.0017%
	Slovakia	5.2	n.a.	0.0061%	n.a.
	Poland	4.3	4.4	0.0009%	0.0009%
	Czechia	4.3	2.2	0.0022%	0.0011%
	Latvia	2.1	n.a.	0.0080%	n.a.
	Luxembourg	0.8	n.a.	0.0014%	n.a.
	Ireland	n.a.	5.9	n.a.	0.0018%
	Portugal	n.a.	2.2	n.a.	0.0011%
	EU-27	398.3	305.6	0.0030%	0.0023%

Source: JRC SETIS, Eurostat, WDI Database

Biofuels remains the third largest field in terms of private R&D investments after wind energy and solar energy. The highest private investments (2018) within the EU-27 were made by Denmark, Finland, the Netherlands, Hungary and Germany (in that order). Hungary has made a significant investment in private R&D of 25 million euros in 2018. Other increased investments came from Ireland, the Netherlands, Portugal, Austria and Poland. The remaining countries decreased their total private R&D investments, yielding a 23% drop in total EU-27 investments to 306 million Euros. There are three top countries that have spent a significant amount (more than 0.02%) of their GDP on private R&D in 2018; Hungary, Denmark and Finland. Together with The Netherlands (0.0044%), these countries raise the total EU-27 GDP share expenditure to 0.0023%. ■

PRIVATE R&D INVESTMENTS

OCEAN ENERGY

		Private R&D Exp. (in € m)		Share of Private R&D Exp. by GDP	
		2017	2018	2017	2018
EU-27	France	17.1	5.0	0.0007%	0.0002%
	Italy	13.9	n.a.	0.0008%	n.a.
	Sweden	11.9	7.2	0.0025%	0.0015%
	Spain	6.3	0.6	0.0005%	0.0001%
	Finland	5.6	2.5	0.0025%	0.0011%
	Germany	4.8	6.7	0.0001%	0.0002%
	Ireland	4.2	n.a.	0.0014%	n.a.
	Denmark	3.2	2.5	0.0011%	0.0008%
	Netherlands	n.a.	3.8	n.a.	0.0005%
	Romania	n.a.	1.3	n.a.	0.0006%
	EU-27	67.0	29.6	0.0005%	0.0002%

Source: JRC SETIS, Eurostat, WDI Database

Ocean energy is again one of the smaller field in terms of private R&D investment. France, Italy and Sweden were most committed in this technology in 2017. These countries accounted for almost two thirds of the total EU-27 investments. In 2018, a big decrease in private R&D investments was noted, with less than half (30 million euros) the investments of 2017. The largest shares of GDP spent on ocean energy in the private R&D sector were from Sweden, Finland and Denmark. Similarly to biofuels and geothermal energy, the total normalized GDP expenditure of the EU-27 was 0.0002% for private R&D ocean energy in 2018. ■

PRIVATE R&D INVESTMENTS

RENEWABLE ENERGY TECHNOLOGIES IN TOTAL

	Private R&D Exp. (in € m)		Share of Private R&D Exp. by GDP	
	2017	2018	2017	2018
Germany	1 775.1	2 103.5	0.0543%	0.0625%
Denmark	653.0	1 032.6	0.2215%	0.3415%
France	290.9	298.9	0.0127%	0.0126%
Netherlands	185.1	174.1	0.0251%	0.0225%
Italy	165.0	141.9	0.0095%	0.0080%
Finland	126.3	88.7	0.0558%	0.0380%
Sweden	119.2	119.7	0.0248%	0.0254%
Spain	118.9	148.2	0.0102%	0.0123%
Belgium	51.3	62.6	0.0115%	0.0136%
Austria	40.3	76.0	0.0109%	0.0197%
Ireland	22.3	13.3	0.0075%	0.0041%
Poland	17.7	26.0	0.0038%	0.0052%
Hungary	15.8	38.0	0.0124%	0.0280%
Czechia	10.3	6.1	0.0053%	0.0029%
Portugal	9.8	2.2	0.0050%	0.0011%
Romania	8.2	7.4	0.0044%	0.0036%
Latvia	5.3	n.a.	0.0196%	n.a.
Slovakia	5.2	n.a.	0.0061%	n.a.
Malta	4.9	n.a.	0.0410%	n.a.
Slovenia	3.6	4.2	0.0085%	0.0091%
Estonia	3.3	n.a.	0.0137%	n.a.
Greece	2.5	2.4	0.0014%	0.0013%
Luxembourg	2.4	9.2	0.0041%	0.0152%
EU-27	3 636.3	4 355.1	0.0278%	0.0322%

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 in 2018 shows a strongly dominant position of Germany with a remarkable second position for Denmark, followed by France, the Netherlands and Spain. The wind energy sector received more than 60% of the total private R&D investments in the EU-27, whereas the solar energy sector placed second with 29% of total private R&D .The GDP share is by far the highest in Denmark (0.033%). Among the other countries with significant investments, Germany, Finland, Hungary, Sweden and the Netherlands display the highest values. The total GDP share of the EU-27 has increased from 0.028% in 2017 to 0.032% in 2018, which is in line with the total increase in private R&D investments. Due to missing data for non-EU-27 countries, the investments cannot be compared to the rest of the world. ■

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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 on a global scale. China is currently the largest investor in RET installations (wind and solar power), followed by the U.S. Furthermore, China is the main exporter in PV as well as in hydro power. Based on the rationale that competitiveness is correlated with innovation, China can be assumed 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:

- For solar energy, the EU-27 (2019/2020) and the US are the frontrunners in public R&D spending, followed by Korea (data for China is not available). Within the EU-27, the largest investments are due to the European Commission, Germany and France. For private R&D investments within the EU-27, Germany, France and Italy are the leading countries.
- With regard to geothermal energy, the U.S. ranks first with a substantial difference from the subsequent EU-27 countries; Germany, the Netherlands and France. Private R&D expenditures in the EU-27 are highest in Sweden, Germany and Finland.
- In hydro energy, the U.S. ranks first in public R&D investments, followed by the EU-27. Within the EU-27, the European Commission is in the lead, followed by Austria, Sweden and Spain. As for the private R&D investments in the EU-27, the largest values are noted for Germany, France and Spain.
- Within biofuels, the U.S. is in the head position regarding public R&D investments, followed by Japan and Canada. Within the EU-27, the largest contributions are due to the European Commission, France and Germany. As for the private R&D investments within the EU-27, Denmark, Finland and Germany are in the lead.
- In wind energy, the EU-27 shows the largest public R&D spending, followed by Norway and Japan. Within the EU-27, the largest contributions come from Germany, the European Commission and the Netherlands. With regard to private R&D spending in the EU-27, Denmark, Germany and the Netherlands are on the top of the list.
- In ocean energy – also a rather small field in terms of public R&D – the European Commission and the UK show the largest public R&D expenditures. Within the EU-27, the largest contributions are provided by France, Ireland and Sweden. Concerning private R&D investments within the EU-27, France Italy and Sweden are the most committed countries.
- Regarding the total public R&D expenditures the EU-27 and the US are clearly the two most significant among the assessed regions worldwide. With some distance behind, Japan, Norway, and Korea follow.
- Overall, this analysis shows that private R&D financing by far exceeds public R&D financing. Within the EU-27, Germany and Denmark are leading, followed by France, the Netherlands and Italy. ■

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, macroeconomic 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]. The PATSTAT database 2021 spring version was used (JRC update: May 2021). 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].
The number of patent applications - domestic or international -, the patent specialization as well as patent per GDP are depicted by RE technologies for 2017 and 2018. Note that in the non-EU countries, "Rest of the world" includes UK values.

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 cov-ering 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	
	2017	2018	2017	2018	2017	2018
EU-27						
Denmark	249.6	287.6	25.3	25.1	846.6	951.3
Germany	263.2	240.9	1.9	1.7	80.6	71.5
Spain	26.5	29.9	4.9	5.6	22.8	24.8
France	31.0	28.3	0.8	0.7	13.5	12.0
Netherlands	41.8	23.3	3.9	2.3	56.7	30.0
Belgium	7.6	12.1	1.7	2.5	17.0	26.3
Autria	5.5	11.5	0.9	1.6	15.0	29.8
Poland	8.8	8.3	1.5	1.5	18.9	16.7
Sweden	10.1	6.8	1.2	0.7	21.0	14.5
Romania	7.5	3.3	4.9	2.5	39.9	16.3
Finland	3.5	3.2	0.7	0.6	15.5	13.6
Italy	5.7	3.0	0.7	0.3	3.3	1.7
Luxembourg	1.0	3.0	1.2	4.4	17.2	49.7
Greece	0	0.8	0	4.9	0	4.6
Hungary	0.5	0.4	1.2	0.8	3.9	2.8
Bulgaria	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0
Czechia	0	0	0	0	0	0
Estonia	0	0	0	0	0	0
Croatia	0	0	0	0	0	0
Ireland	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0
Latvia	2.0	0	12.7	0	74.1	0
Malta	0	0	0	0	0	0
Portugal	1.0	0	2.0	0	5.1	0
Slovenia	1.0	0	4.6	0	23.2	0
Slovakia	1.0	0	3.0	0	11.8	0
Total EU-27	**667.4**	**662.4**	**2.7**	**2.5**	**52.8**	**50.7**
Other Countries						
China	1 525.0	1 864.8	1.0	1.0	141.1	152.9
United States	220.2	172.5	1.0	0.8	20.4	14.1
Korea	147.7	131.8	0.5	0.4	0	0
Japan	143.2	139.0	0.4	0.3	33.1	31.4
Rest of the world	120.0	117.4	1.1	1.0	2.0	1.9

Continues overleaf

Note : The value 0 signals that there is no patent application. N.a. signals that the data was not available. Note: single patent families (singletons) have been included. ***Source: Joint Research Centre (JRC) based on data from the European Patent Office (EPO). Eurostat. WDI Database.***

In wind energy, it is China that has the largest number of patent filings in our comparison. Behind China, the EU-27 follows and then the US, Korea and Japan. Within the EU, Denmark and Germany are most active, followed by the Netherlands, France and Spain. A noteworthy fact is, that the EU-27 shows a significant specialization in wind energy patent filings compared to China (and also compared to other RET's). Especially Denmark stands out in this regard very strikingly.
In terms of patents per GDP in wind energy, Denmark is very clearly in the top position worldwide. With a large distance behind, China, Germany and the Netherlands follow. Of the countries with significant patent filings, Japan has the next highest expenditure of their GDP on patent filing, followed by Spain. The EU-27 clearly showed the highest indices on specialization compared to the rest of the world, with its main specialization coming from Denmark. Next, of the significant patent filing countries, Spain and the Netherlands show relatively high specialization index numbers (higher than Germany, the 2nd leader in patent filings for wind energy). ■

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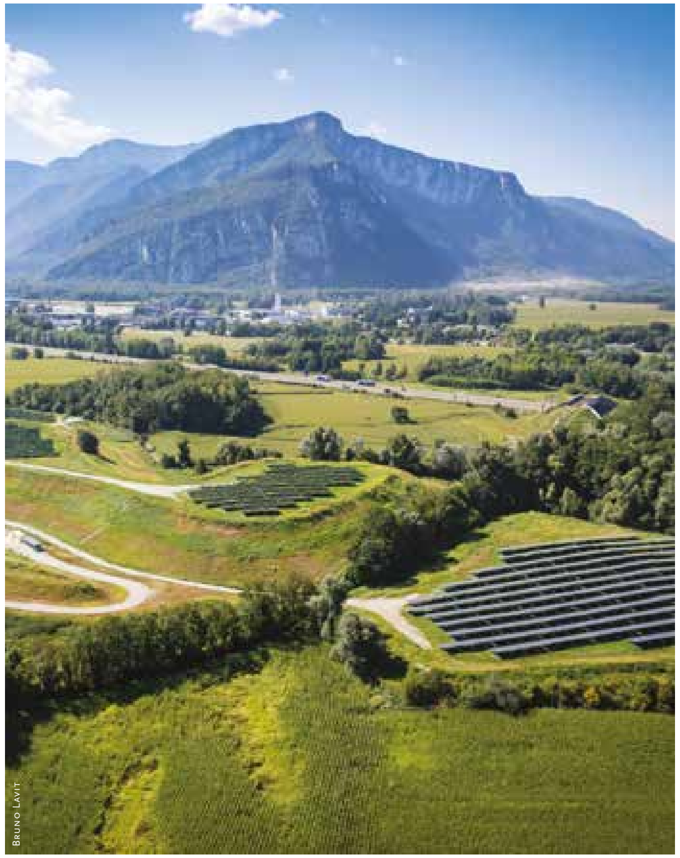
SOLAR ENERGY

	Number of patent families		Patent specialization		Patents per € trillion GDP	
	2017	2018	2017	2018	2017	2018
EU-27						
Germany	217.6	196.6	0.5	0.4	66.6	58.4
France	100.5	113.7	0.7	0.8	43.8	48.1
Netherlands	42.2	33.0	1.2	1.0	57.1	42.6
Spain	37.1	32.7	2.0	1.8	31.9	27.2
Italy	38.1	32.7	1.3	1.1	22.0	18.5
Poland	15.7	27.6	0.8	1.5	33.5	55.4
Sweden	18.4	14.3	0.6	0.5	38.3	30.3
Autria	10.7	10.8	0.5	0.5	29.0	28.0
Belgium	8.6	8.9	0.6	0.6	19.3	19.4
Romania	7.5	8.7	1.5	1.9	39.9	42.4
Finland	9.7	5.9	0.6	0.3	42.9	25.3
Denmark	2.7	4.8	0.1	0.1	9.3	15.8
Czechia	2.2	2.5	0.7	0.7	11.2	11.9
Hungary	2.5	2.0	1.8	1.3	19.5	14.7
Ireland	6.9	2.0	1.3	0.3	23.4	6.1
Slovakia	0	2.0	0	1.4	0	22.4
Luxembourg	0	1.3	0	0.6	0	22.1
Greece	1.3	1.3	1.6	2.2	7.5	7.0
Lithuania	0	1.0	0	2.8	0	22.0
Latvia	0	1.0	0	3.2	0	34.3
Bulgaria	0	0	0	0	0	0
Cyprus	0.5	0	0	0	24.7	0
Estonia	0.7	0	0.9	0	28.0	0
Croatia	0	0	0	0	0	0
Malta	1.0	0	5.0	0	83.7	0
Portugal	2.5	0	1.5	0	12.8	0
Slovenia	0	0	0	0	0	0
Total EU-27	526.4	502.8	0.6	0.6	41.7	38.5
Other Countries						
China	5 785.6	6 830.5	1.1	1.1	535.3	559.9
Korea	1 270.2	1 407.7	1.3	1.4	0	0
Japan	996.2	719.8	0.8	0.5	230.1	162.8
United States	431.1	418.9	0.6	0.6	39.9	34.3
Rest of the world	418.1	429.7	1.1	1.1	7.1	6.9

Continues overleaf

Note : The value 0 signals that there is no patent application. N.a. signals that the data was not available. Note: single patent families (singletons) have been included. ***Source: Joint Research Centre (JRC) based on data from the European Patent Office (EPO). Eurostat. WDI Database.***

In the field of solar energy, China is the uncontested frontrunner in terms of patents (filed domestically or internationally) as well as on patents per GDP. China is followed by Korea and Japan and then the EU-27 and the US. Within the EU-27, Germany has filed the largest number of patents, followed by France, the Netherlands, Spain and Italy. Among the more significant patent filing countries, Germany, the Netherlands, France and Finland are scoring highest in terms of patents per GDP within the EU-27.
In comparison to 2017, the EU-27 showed a similar amount of patent specialization, with Latvia, Lithuania and Greece showing the highest specialization indices. Outside the EU-27, only China showed a small increased specialization in solar energy patent filings, while Japan showed a decrease in specialization in 2018. ■



EUROBSERV'ER – THE STATE OF RENEWABLE ENERGIES IN EUROPE – 2021 EDITION

HYDROENERGY

	Number of patent families		Patent specialization		Patents per € trillion GDP	
	2017	2018	2017	2018	2017	2018
EU-27						
France	6.2	15.4	0.7	1.7	2.7	6.5
Germany	15.5	5.9	0.5	0.2	4.7	1.8
Poland	3.0	4.5	2.3	3.9	6.4	9.0
Finland	1.5	3.8	1.4	3.7	6.6	16.4
Autria	0.5	3.0	0.4	2.1	1.4	7.8
Sweden	0.8	2.5	0.4	1.3	1.7	5.3
Slovakia	0	2.3	0	26.0	0	25.2
Slovenia	0.3	1.6	6.3	22.6	7.0	34.9
Czechia	0	1.5	0	6.7	0	7.1
Italy	1.9	1.2	1.0	0.6	1.1	0.7
Belgium	1.3	1.0	1.3	1.0	3.0	2.2
Ireland	1.0	1.0	3.0	2.8	3.4	3.1
Romania	2.0	1.0	5.9	3.7	10.7	4.9
Lithuania	0.3	0.5	15.8	23.1	5.9	11.0
Netherlands	0.6	0.5	0.3	0.2	0.8	0.6
Portugal	0	0.5	0	5.1	0	2.4
Spain	2.0	0.4	1.7	0.4	1.7	0.3
Hungary	0	0.1	0	1.4	0	0.9
Bulgaria	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0
Denmark	0.1	0	0.0	0	0.3	0
Estonia	0	0	0	0	0	0
Greece	1.0	0	18.4	0	5.7	0
Croatia	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
Total EU-27	38.0	46.7	0.7	0.9	3.0	3.6
Other Countries						
China	398.7	427.1	1.2	1.2	36.9	35.0
Japan	79.8	62.5	0.9	0.8	18.4	14.1
Korea	45.3	43.5	0.7	0.7	0	0
United States	11.8	10.7	0.2	0.3	1.1	0.9
United Kingdom	4.0	3.1	1.0	0.7	1.7	1.2
Rest of the world	45.2	35.0	1.8	1.5	0.8	0.6

Continues overleaf

Note : The value 0 signals that there is no patent application. N.a. signals that the data was not available. Note: single patent families (singletons) have been included. ***Source: Joint Research Centre (JRC) based on data from the European Patent Office (EPO). Eurostat. WDI Database.***

In hydro energy, the patent filings are much lower than in solar energy. Again, China is the (clear) frontrunner, followed by Japan, Korea and the EU-27. Within the EU-27, Germany and France are in the head position followed by Poland and Finland. No significant specialization can be observed among the most active countries. In relation to its economic size, China and Japan reveal the highest patent filing figures per GDP. Within the EU-27, from the significant patent filing countries, Germany and France show the highest GDP expenditure on patent filings. ■

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GEOTHERMAL ENERGY

	Number of patent families		Patent specialization		Patents per € trillion GDP	
	2017	2018	2017	2018	2017	2018
EU-27						
Poland	1.0	6.0	2.4	19.5	2.2	12.1
Germany	4.2	5.2	0.4	0.7	1.3	1.5
Italy	1.4	1.5	2.4	3.0	0.8	0.8
Netherlands	0.5	1.5	0.7	2.7	0.7	1.9
Finland	2.5	1.2	7.1	4.3	11.0	5.1
Denmark	0.9	1.0	1.3	1.6	2.9	3.3
Spain	0	1.0	0	3.4	0	0.8
Sweden	3.2	1.0	5.3	1.9	6.7	2.1
France	3.2	0.3	1.1	0.1	1.4	0.1
Autria	0	0.3	0	0.7	0	0.6
Belgium	1.3	0	4.2	0	3.0	0
Bulgaria	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0
Czechia	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
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
Slovakia	0	0	0	0	0	0
Total EU-27	**18.3**	**18.9**	**1.1**	**1.3**	**1.4**	**1.4**
Other Countries						
China	100.5	81.0	0.9	0.8	9.3	6.6
Korean	34.8	33.8	1.7	2.1	0	0
Japan	21.7	12.8	0.8	0.6	5.0	2.9
United States	12.4	7.6	0.8	0.7	1.1	0.6
Rest of the world	9.0	14.4	1.1	2.2	0.2	0.2

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Note : The value 0 signals that there is no patent application. N.a. signals that the data was not available. Note: single patent families (singletons) have been included. ***Source: Joint Research Centre (JRC) based on data from the European Patent Office (EPO). Eurostat. WDI Database.***

In terms of the number of patent filings, geothermal energy is a far less significant field than solar energy and even than hydro energy. Within the EU-27 countries less than 20 patents were filed in 2017 (as well as in 2018). Germany, Sweden, Finland, France, Poland and Italy are the most active countries in terms of patents within the EU-27. Outside the EU-27, China is the clear frontrunner with 100 patents in 2017 and 81 in 2018. Korea and Japan follow with double digit patent filings, individually filing more patens than the EU-27 combined. Furthermore, the number of patents filed per GDP expenditure was highest for Finland in 2017 and for Poland in 2018, surpassing China and Japan. The next highest GDP expenditure on patent filings in the EU-27 were in Sweden, Belgium and Denmark. Among the most significant patent filing countries, in 2017 Finland, Sweden, Belgium and Denmark show a high amount of specialization and in 2018 these are Finland, Spain and the Netherlands. Outside the EU-27, only Korea shows a meaningful specialization. ■

BIOFUELS

	Number of patent families		Patent specialization		Patents per € trillion GDP	
	2017	2018	2017	2018	2017	2018
EU-27						
France	28.4	28.2	1.1	1.2	12.4	11.9
Germany	34.4	21.3	0.4	0.3	10.5	6.3
Poland	12.2	19.0	3.2	6.5	26.0	38.2
Netherlands	20.8	16.0	3.1	3.0	28.2	20.6
Finland	19.1	14.6	6.0	5.5	84.5	62.5
Denmark	10.9	9.9	1.7	1.7	36.9	32.9
Hungary	2.0	8.0	7.5	34.3	15.7	58.8
Italy	8.7	6.2	1.6	1.3	5.0	3.5
Ireland	0	3.3	0	3.7	0	10.2
Belgium	8.9	3.0	3.1	1.2	20.0	6.5
Autria	2.6	2.5	0.7	0.7	7.0	6.5
Spain	12.8	2.3	3.7	0.8	11.0	1.9
Czechia	2.0	2.0	3.3	3.5	10.3	9.5
Romania	2.0	2.0	2.0	2.9	10.7	9.8
Sweden	3.3	1.5	0.6	0.3	6.9	3.3
Lithuania	0	1.0	0	18.0	0	22.0
Latvia	0.5	1.0	5.0	20.3	18.5	34.3
Portugal	0	1.0	0	4.0	0	4.9
Slovenia	0	1.0	0	5.5	0	21.8
Slovakia	1.2	0.5	5.7	2.3	14.3	5.6
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
Luxembourg	0.5	0	1.0	0	8.6	0
Malta	0	0	0	0	0	0
Total EU-27	**170.4**	**144.2**	**1.1**	**1.1**	**13.5**	**11.0**
Other Countries						
China	1 121.1	999.6	1.1	1.1	103.7	81.9
Japan	131.4	147.7	0.5	0.7	30.3	33.4
Korea	156.1	131.0	0.9	0.8	0	0
United States	100.8	80.8	0.7	0.7	9.3	6.6
Rest of the world	109.7	105.1	1.5	1.7	1.9	1.7

Note : The value 0 signals that there is no patent application. N.a. signals that the data was not available. Note: single patent families (singletons) have been included. ***Source: Joint Research Centre (JRC) based on data from the European Patent Office (EPO). Eurostat. WDI Database.***

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Also in biofuels, China has filed by far the largest number of patents in 2017 and 2018. Behind China, Japan, the EU-27, Korea, and the US are next on the list. Within the EU-27 the most active countries in patent filing are France, Germany, Poland and the Netherlands. In relation to their respective GDP, in particular Poland and Finland stand out. In the rest of the world, Japan has the next significant GDP expenditure on patent filings.
With regard to the specialization among the more significant patent filing countries Poland is most notable, followed by Finland and the Netherlands. Outside the EU-27, there are no significant or notable countries with a high specialization index. ■

EDF

OCEAN ENERGY

	Number of patent families		Patent specialization		Patents per € trillion GDP	
	2017	2018	2017	2018	2017	2018
EU-27						
France	14.3	8.5	2.9	1.5	6.2	3.6
Sweden	4.3	3.8	4.0	3.1	9.0	8.1
Germany	3.3	3.7	0.2	0.2	1.0	1.1
Netherlands	0.3	1.5	0.2	1.1	0.3	1.9
Portugal	1.0	1.5	16.3	23.5	5.1	7.3
Spain	1.5	1.3	2.2	1.8	1.3	1.0
Italy	4.6	1.2	4.3	1.0	2.6	0.7
Denmark	0.9	1.0	0.7	0.7	2.9	3.3
Finland	4.0	1.0	6.4	1.5	17.7	4.3
Romania	0	0.5	0	2.8	0	2.4
Autria	0	0	0	0	0	0
Belgium	0.3	0	0.6	0	0.7	0
Bulgaria	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0
Czechia	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
Hungary	0	0	0	0	0	0
Ireland	1.0	0	5.2	0	3.4	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
Poland	0	0	0	0	0	0
Slovenia	0	0	0	0	0	0
Slovakia	0	0	0	0	0	0
Total EU-27	35.4	23.9	1.1	0.7	2.8	1.8
Other Countries						
China	203.3	274.0	1.0	1.2	18.8	22.5
Korean	44.2	39.8	1.2	1.0	0	0
United States	13.2	30.5	0.5	1.1	1.2	2.5
Japan	18.6	15.4	0.4	0.3	4.3	3.5
Rest of the word	36.1	24.2	2.6	1.5	0.6	0.4
Out of which United Kingdom	*7.9*	*3.0*	*3.4*	*1.0*	*3.3*	*1.2*

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Note : The value 0 signals that there is no patent application. N.a. signals that the data was not available. Note: single patent families (singletons) have been included. ***Source: Joint Research Centre (JRC) based on data from the European Patent Office (EPO). Eurostat. WDI Database.***

Ocean energy is again a smaller field in terms of patent filings. But the general observation for the other RET's that China is the frontrunner also applies here. After China, Korea and the EU-27 closely follow, leaving Japan and the US behind. Within the EU-27, in particular France is most active, followed by Sweden and Germany. China and Sweden are in the lead in terms of patent filings per GDP. In the EU-27, Portugal and Finland show the next highest GDP expenditure on patent filings. Outside the EU-27, Japan showed the second largest number of patent filings per trillion GDP expenditure. Portugal shows by far the highest specialization index within this field. Sweden, the country with the second highest amount of patent filings in the EU-27, comes next in the ranking of specialization indices within the EU-27. With a relatively low amount of patents filed, the UK does show a significant specialization index, higher than France. ■

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RENEWABLE ENERGY TECHNOLOGIES IN TOTAL

	Number of patent families		Patents per € trillion GDP	
	2017	2018	2017	2018
EU-27				
Germany	538	473	164.7	140.6
Denmark	265	304	898.9	1 006.6
France	184	194	79.9	82.3
Netherlands	106	76	143.9	97.8
Spain	80	68	68.8	56.1
Italy	60	46	34.8	25.8
Poland	41	65	87.1	131.4
Finland	40	30	178.3	127.2
Sweden	40	30	83.7	63.7
Belgium	28	25	63.1	54.4
Austria	19	28	52.4	72.7
Romania	19	16	101.2	75.8
Ireland	9	6	30.1	19.4
Hungary	5	11	39.2	77.2
Portugal	5	3	23.0	14.6
Czechia	4	6	21.5	28.4
Latvia	3	2	92.6	68.6
Greece	2	2	13.2	11.6
Slovakia	2	5	26.2	53.1
Luxembourg	2	4	25.8	71.8
Slovenia	1	3	30.2	56.7
Malta	1	n.a.	83.7	n.a.
Estonia	1	n.a.	28.0	n.a.
Cyprus	1	n.a.	24.7	n.a.
Lithuania	0	3	5.9	54.9
Bulgaria	n.a.	n.a.	n.a.	n.a.
Croatia	n.a.	n.a.	n.a.	n.a.
Total EU-27	**1 456**	**1 399**	**115.3**	**107.0**

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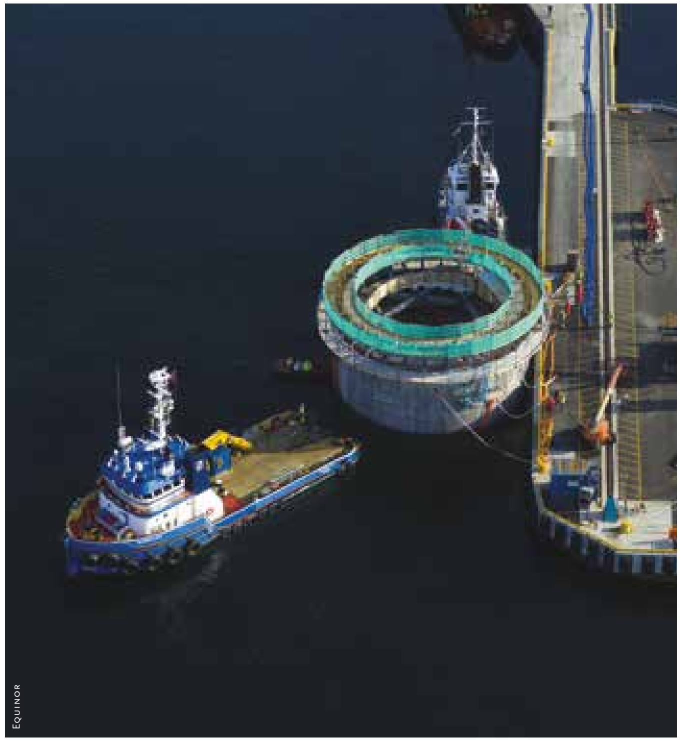
Other Countries				
China	9 134	10 477	845.1	858.8
Korea	1 698	1 788	n.a.	n.a.
Japan	1 391	1 097	321.3	248.1
United States	789	721	73.0	59.1
Rest of the world	738	726	12.6	11.6
Out of which United Kingdom	*93*	*85*	*39.3*	*33.4*

Note : The value 0 signals that there is no patent application. N.a. signals that the data was not available. Note: single patent families (singletons) have been included. ***Source: Joint Research Centre (JRC) based on data from the European Patent Office (EPO). Eurostat. WDI Database.***

A final look at the patenting figures in all renewable energies technologies shows that China has filed by far the largest number of patents in 2018, followed by Korea, the EU-27, Japan and the US. Within the EU-27, a strong position of Germany is noted, followed by Denmark, France and the Netherlands. When measured in terms of GDP shares, this ranking changes with Denmark being (far) ahead, followed by Germany, Poland and Finland. ■



CONCLUSIONS

Across nearly all fields in renewable energies technologies, the Asian countries, in particular China, display the highest patenting activities in absolute and relative (GDP) numbers when including patent filings that refer only to the domestic market (singletons). The EU-27 is in a good position behind the Asian countries but ahead of the US. Within the EU-27, it is mostly Germany that files the largest number of patents. However, this is also due to its large size. Analysis in terms of patents per GDP shows Denmark in an uncontested first position 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 the Netherlands, for example, show remarkable filing figures in wind energy, while Finland shows a lot of activity in biofuels. With the Brexit, the EU has lost a country which was in the top 5 of the main patent filers. Regarding RE technologies, solar energy has the largest number of patent filings worldwide, while in the EU-27, wind energy ranks highest in number of patent filings. 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. ■

References:

*Data source: Joint Research Centre (JRC) based on data from the European Patent Office (EPO)**

- *Patent data based on PATSTAT database 2021 spring version (JRC update: May 2021). The methodology behind the indicators is provided in Fiorini et al. (2017), Pasimeni et al. (2019), Pasimeni (2019), and Pasimeni et al. (2021)*

SOVEC

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 energy 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 analysis 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.

$$RCA_{ij} = 100 \cdot \text{tanhyp}\left(\log \frac{E_{ij} / \sum_{k=1}^{J} E_{ik}}{\sum_{h=1}^{I} E_{hj} / \sum_{h=1}^{I} \sum_{k=1}^{J} E_{hk}} \right)$$

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 energies within their total trade portfolio, all values would be negative. In contrast, some countries e.g. Denmark, Japan, China and Spain have in relation to all exported goods an above average share of RET in their export portfolio.

The analysis looks at renewable energy technologies 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 2019 and 2020. 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*

Note regarding the maps in the chapter: *the relation between the sizes of the circles and the volume of the trade differs from one map to the other.*

ALL RES

EU-27 trade (incl. intra-EU trade), 2019 - all RES

	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
Denmark	421	2 731	2 310	4,1%	68
Germany	3 758	4 589	831	7,0%	-7
Hungary	284	438	154	0,7%	-1
Slovakia	55	96	41	0,1%	-49
France	1 114	1 132	19	1,7%	-25
Slovenia	80	82	3	0,1%	-22
Croatia	43	34	-9	0,1%	-25
Malta	9	0	-9	0,0%	-98
Luxembourg	73	63	-10	0,1%	7
Bulgaria	62	49	-13	0,1%	-37
Estonia	26	13	-14	0,0%	-60
Latvia	20	5	-15	0,0%	-78
Cyprus	24	0	-24	0,0%	-100
Lithuania	66	36	-29	0,1%	-48
Ireland	79	24	-55	0,0%	-89
Austria	389	327	-62	0,5%	-27
Czechia	233	160	-72	0,2%	-57
Finland	120	9	-111	0,0%	-90
Portugal	447	265	-183	0,4%	4
Italy	668	438	-230	0,7%	-57
Romania	244	9	-235	0,0%	-91
Greece	380	19	-361	0,0%	-69
Sweden	565	201	-365	0,3%	-43
Belgium	709	341	-367	0,5%	-48
Poland	545	133	-413	0,2%	-68
Netherlands	3 094	2 602	-492	3,9%	9
Spain	1 537	850	-687	1,3%	-16
Total EU-27	15 044	14 647	-397	22%	-13

Main EU partners' trade with the rest of the world (including EU-27), 2019 - all RES

	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
China	6 452	22 141	15 689	33,6%	37
Switzerland	297	128	-170	0,2%	-74
Turkey	555	165	-390	0,3%	-54
Russia	540	69	-471	0,1%	-87
Japan	3 806	3 185	-621	4,8%	9
Brazil	1 618	959	-659	1,5%	8
Norway	806	5	-801	0,0%	-95
Canada	1 136	255	-881	0,4%	-67
United Kingdom	1 230	286	-944	0,4%	-65
India	2 494	371	-2 123	0,6%	-46
USA	8 411	4 300	-4 111	6,5%	-14
Rest of the world	23 186	19 476	-3 710	29,5%	1

In 2019, the largest importers of photovoltaics, wind energy equipment, biofuels and hydropower equipment in the EU-27 were Germany (€3 758 million), the Netherlands (€3 094 million) and Spain (€1 537 million). Germany and the Netherlands also exported large quantities of RET in 2019 with €4 589 and €2 649 million respectively. Denmark is the second largest exporter in the EU-27 with €2 731 million in 2019, owing mostly to large exports in wind energy technology. From the main trading partners, China is the largest by far with €6 452 million in imports and €22 141 in exports in 2019.
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, i.e. the largest balance among the countries in comparison. China is followed by Denmark, Germany, Hungary, Slovakia, France, and Slovenia. Since these countries exported more RET goods than they imported in 2019, their trade balance is positive. All other countries in this comparison have negative trade balances. The countries with the most negative trade balances are the U.S., India, the U.K., Canada, Norway, and Spain.
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 2019 with 34%. The EU-27 follow with export shares of 22% in 2019. Germany, the U.S., Japan, Denmark and the Netherlands display the largest shares after China. The countries with the smallest shares in the comparison are Malta, Cyprus, Latvia, Finland, Romania and Ireland.
In a final step, we take a closer look at the export

EU-27 trade (incl. intra-EU trade), 2020 - all RES

	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
Denmark	423	1 891	1 469	2,8%	57
Germany	3 749	4 664	915	6,9%	-7
Hungary	273	434	162	0,6%	-4
Slovakia	48	76	29	0,1%	-58
France	1 243	1 252	9	1,9%	-19
Bulgaria	73	76	3	0,1%	-22
Slovenia	114	114	0	0,2%	-12
Malta	5	0	-5	0,0%	-97
Luxembourg	50	43	-7	0,1%	-10
Latvia	27	5	-21	0,0%	-78
Cyprus	22	0	-21	0,0%	-94
Estonia	111	50	-61	0,1%	-13
Lithuania	110	45	-65	0,1%	-43
Ireland	85	18	-67	0,0%	-92
Austria	384	309	-75	0,5%	-31
Czechia	226	138	-88	0,2%	-63
Netherlands	3 538	3 437	-100	5,1%	19
Croatia	159	45	-113	0,1%	-17
Finland	128	10	-119	0,0%	-89
Portugal	386	229	-157	0,3%	-3
Italy	658	470	-188	0,7%	-55
Romania	250	7	-243	0,0%	-92
Spain	1 266	996	-270	1,5%	-10
Belgium	845	522	-324	0,8%	-34
Sweden	570	212	-357	0,3%	-43
Greece	491	36	-455	0,1%	-53
Poland	1 034	211	-823	0,3%	-59
Total EU-27	16 266	15 293	-973	22,6%	-13

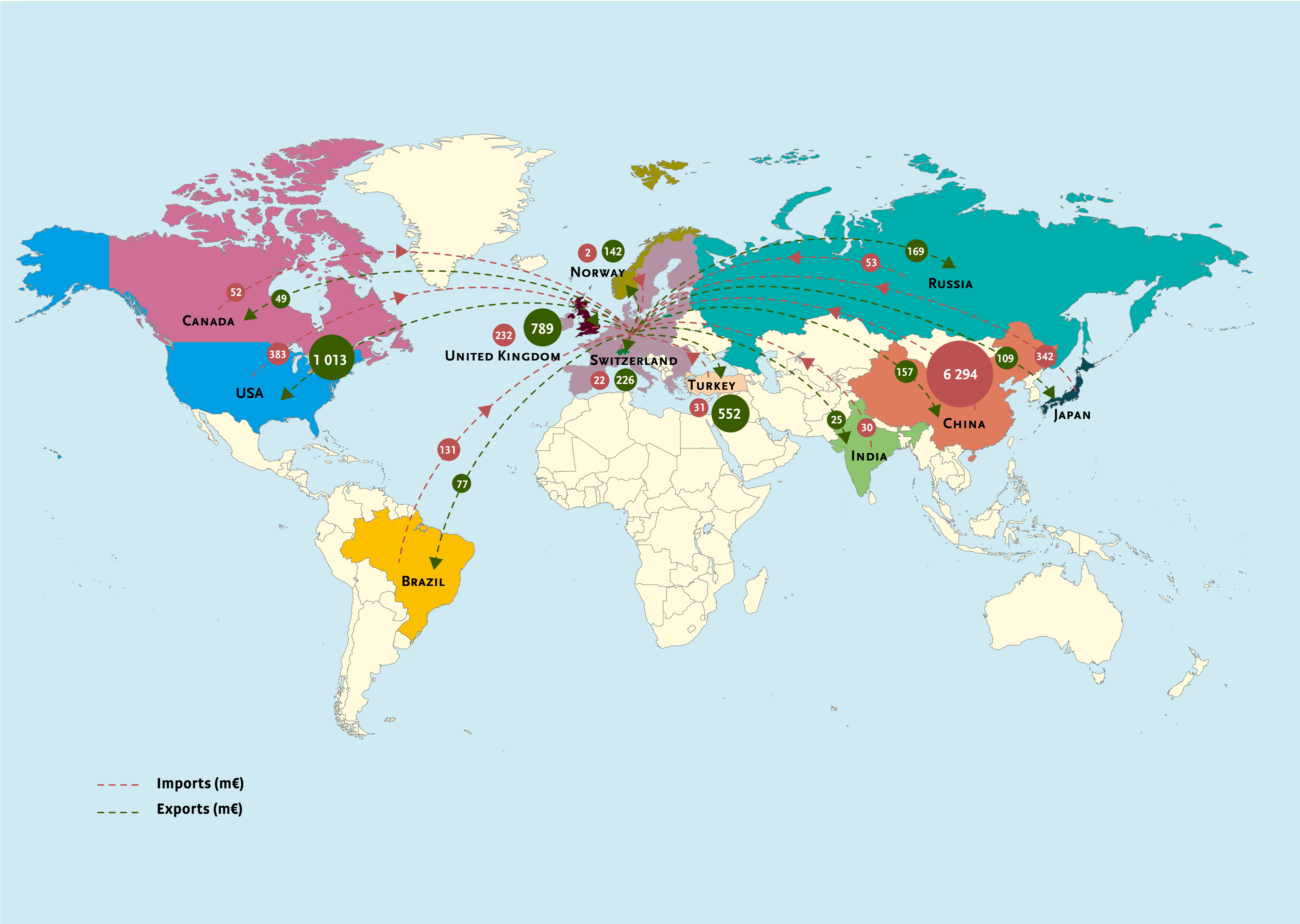
Main EU partners' trade with the rest of the world (including EU-27), 2020 - all RES

	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
China	6 379	22 228	15 849	32,9%	32
Switzerland	360	194	-166	0,3%	-67
Brazil	1 435	1 257	-179	1,9%	18
Japan	3 364	3 111	-253	4,6%	9
Norway	334	4	-330	0,0%	-96
Russia	461	112	-349	0,2%	-79
Canada	1 098	365	-733	0,5%	-56
United Kingdom	1 147	285	-862	0,4%	-63
Turkey	1 125	164	-961	0,2%	-55
India	1 618	420	-1 198	0,6%	-39
USA	10 305	4 179	-6 125	6,2%	-13
Rest of the world	23 507	20 027	-3 481	29,6%	-1

specialisation (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 specialisation values can also be found for Brazil, China, the Netherlands, and Japan while all other countries (including the «rest of the world» group) show a negative specialisation regarding the export of goods related to RET technologies in 2020.

Both the total RET import and RET export values for the EU-27 increased in 2020 compared to 2019. The imports increased more than the exports, leading to a larger negative trade balance in RET in 2020 for the EU-27. The most significant relative increases in imports can be observed for Poland (€489 million), the Netherlands (€444 million) and Belgium (€384 million). The imports in Spain decreased most of all the EU-27 (€271 million). A few countries also show a large relative increase in imports, most notably Austria, Croatia, Estonia and Poland. On the other hand, exports increased significantly in the Netherlands (€835 million) and modestly in Belgium (€180 million), Spain (€146 million) and France (€120 million). Large relative increases in exports can be seen in Cyprus, Estonia and Greece, although the export volumes of these member states remain limited to up to €50 million. Net exports declined significantly in Denmark, due to a decrease in wind energy exports. On the other hand, both the Netherlands and Spain reduced their negative trade balances. Bulgaria went from a negative trade balance in 2019 to a positive one in 2020.
When looking at the main trading partners we see a large increase in imports in the U.S. (€1 893 million) and Turkey (€570 million) in 2020 compared to 2019. Large decreases in imports can be seen for India (€875 million), Norway (€473 million), Japan (€442 million) and Brazil (€183 million). For exports we see the largest shifts in Brazil (€298 million increase), Canada (€110 million increase) and the U.S. (€121 million decrease). The trade balances follow these trends, with the U.S. showing the largest increase in the negative trade balance. Turkey also

EU-27 trade with its main trading partners, 2020 - all RES



has a larger negative trade balance in 2020 compared to 2019. India, Norway, Japan and Brazil still have a negative trade balance, but have improved their positions between 2019 and 2020.

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 2020 with 33%. For the EU-27, we see a slight increase in export shares from 22% in 2019 to nearly 23% in 2020.

The trade in RET between the EU-27 and main trading partners is illustrated in the figure. The net trade balance with China is very negative, i.e. much more is imported from China to the EU-27 than the reverse. Imports from China increased by almost €1 000 million in 2020 compared to 2019. The EU-27 also has a negative RET trade balance with Japan and Brazil. On the other hand the EU-27 has a significant positive RET trade balance with the U.S., the U.K., Turkey, Switzerland, Norway and Russia. Net exports to these countries also increased in 2020 compared to 2019. In Canada net exports of €70 million in 2019 changed to net imports of €3 million in 2020. ■

WIND ENERGY

EU-27 trade (incl. intra-EU trade), 2019 - wind energy

	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
Denmark	274	2 700	2 426	38,4%	95
Germany	84	2 036	1 952	29,0%	50
Spain	97	551	454	7,8%	56
Netherlands	429	628	199	8,9%	42
Portugal	0	22	21	0,3%	-8
Estonia	1	9	8	0,1%	12
Lithuania	4	8	4	0,1%	-21
Ireland	4	5	1	0,1%	-81
Croatia	0	0	0	0,0%	-87
Latvia	0	0	0	0,0%	-98
Slovakia	0	0	0	0,0%	-100
Cyprus	0	0	0	0,0%	0
Slovenia	0	0	0	0,0%	0
Hungary	0	0	0	0,0%	-100
Malta	0	0	0	0,0%	-100
Bulgaria	0	0	0	0,0%	-99
Italy	2	1	0	0,0%	-97
Romania	1	0	-1	0,0%	-100
Czechia	4	1	-3	0,0%	-95
Luxembourg	8	0	-8	0,0%	0
Austria	34	1	-34	0,0%	-96
Finland	41	0	-41	0,0%	-100
Poland	75	1	-73	0,0%	-95
Sweden	159	0	-159	0,0%	-100
France	182	3	-179	0,0%	-95
Greece	274	14	-260	0,2%	-3
Belgium	289	3	-286	0,0%	-92
Total EU-27	1 961	5 983	4 022	85%	42

Main EU partners' trade with the rest of the world (including EU-27), 2019 - wind energy

	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
China	10	848	837	12,1%	-6
India	7	38	30	0,5%	-48
USA	100	118	18	1,7%	-62
Brazil	9	20	12	0,3%	-55
Switzerland	0	0	0	0,0%	-100
Russia	162	0	-162	0,0%	-100
Japan	204	12	-192	0,2%	-87
Canada	220	1	-219	0,0%	-97
Turkey	235	0	-234	0,0%	-99
United Kingdom	358	1	-357	0,0%	-97
Norway	714	0	-714	0,0%	-100
Rest of the world	2 005	9	-2 235	0,1%	-98

In wind power, Denmark (38%) and Germany (29%) are the major players in terms of export shares. They are followed by the Netherlands, which also shows large export shares in wind energy of nearly 9%. Spain is another large player with 8% of the global export share. Over 80% of worldwide exports in wind technologies originate from these four countries. Chinese export shares have increased from 7.5% in 2017 to 12.1% in 2019, showing an increasingly large role for China in global wind energy exports. The U.S. follows at quite some distance with 1.7% of the global wind energy export share.

Similar patterns can also be observed for the trade balance. Here, the largest values can be found for Denmark, followed by Germany, China, the Netherlands and Spain. In terms of export specialisation (RCA), Denmark is the most highly specialised in trade of wind technology related goods. Germany, Spain and the Netherlands are also highly specialised in wind technology exports. China's export specialisation in wind technology increased from -52 in 2017 to -6 in 2019, again showcasing the rapidly changing position of China in the global trade of wind technology goods.

EU-27 trade (incl. intra-EU trade), 2020 - wind energy

	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
Germany	77	2 116	2 039	30,1%	51
Denmark	170	1 851	1 681	26,3%	92
Netherlands	449	972	524	13,8%	56
Spain	113	582	469	8,3%	57
Estonia	0	13	13	0,2%	26
Portugal	6	12	6	0,2%	-31
Czechia	0	1	1	0,0%	-96
Latvia	0	0	0	0,0%	-92
Hungary	0	0	0	0,0%	-99
Slovakia	0	0	0	0,0%	-100
Austria	1	1	0	0,0%	-97
Malta	0	0	0	0,0%	-97
Slovenia	0	0	0	0,0%	0
Cyprus	0	0	0	0,0%	0
Luxembourg	0	0	0	0,0%	0
Romania	2	1	0	0,0%	-87
Bulgaria	1	0	-1	0,0%	-100
Lithuania	6	5	-1	0,1%	-39
Ireland	21	0	-20	0,0%	-99
Italy	23	1	-22	0,0%	-98
Finland	27	0	-27	0,0%	-100
Croatia	107	0	-107	0,0%	-99
France	124	2	-122	0,0%	-97
Sweden	182	7	-175	0,1%	-75
Greece	194	18	-176	0,3%	10
Poland	195	7	-188	0,1%	-83
Belgium	308	2	-306	0,0%	-95
Total EU-27	2 004	5 591	3 587	80%	39

Main EU partners' trade with the rest of the world (including EU-27), 2020 - wind energy

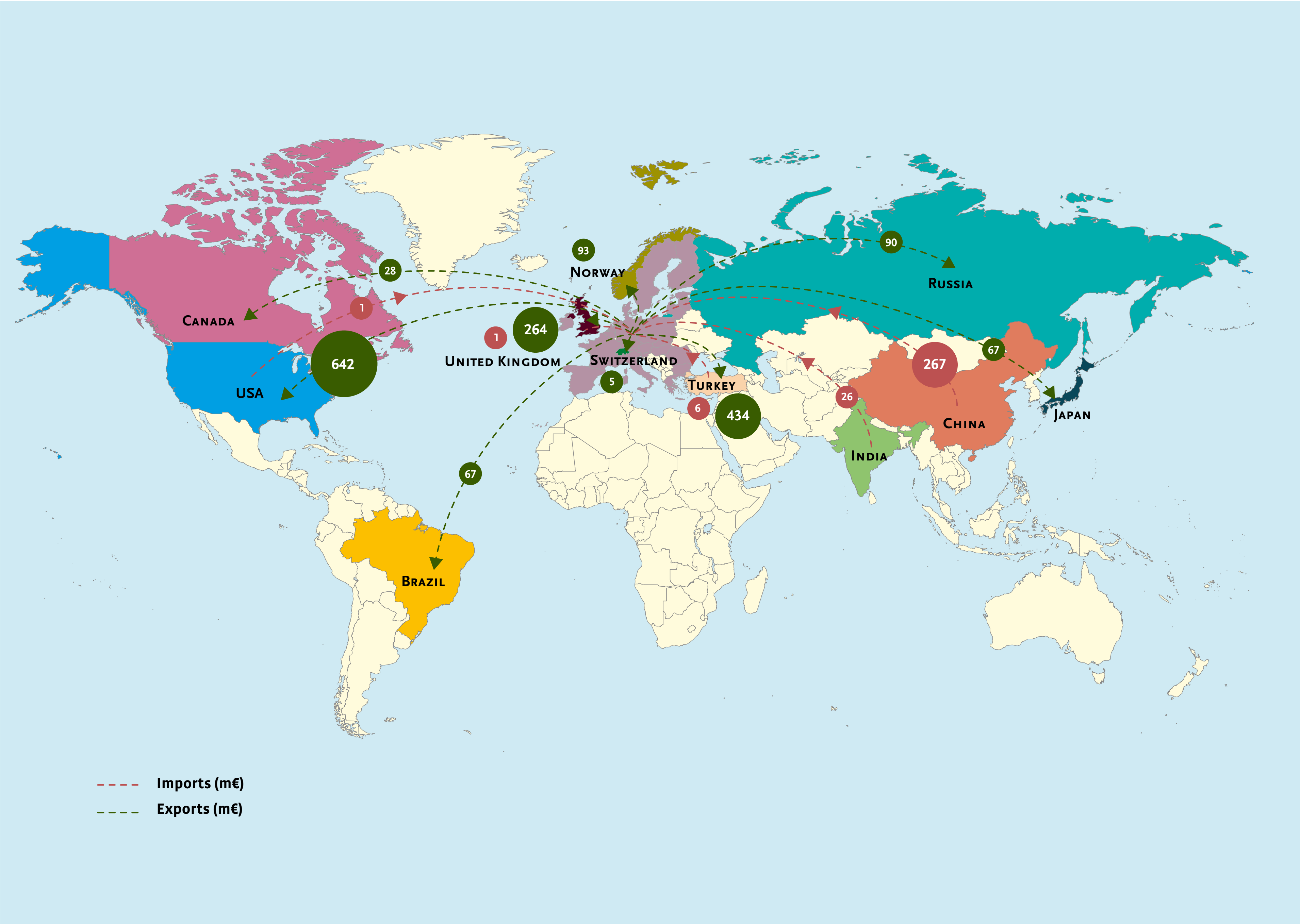
	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
China	3	972	969	13,8%	-4
India	1	171	170	2,4%	17
Brazil	8	172	163	2,4%	29
Japan	92	91	-1	1,3%	-43
Switzerland	7	0	-7	0,0%	-100
Russia	146	0	-146	0,0%	-100
Canada	206	1	-204	0,0%	-97
Norway	246	0	-246	0,0%	-100
USA	418	20	-398	0,3%	-90
United Kingdom	445	1	-444	0,0%	-98
Turkey	606	4	-602	0,1%	-86
Rest of the world	2 685	5	-3062	0,1%	-99

In 2020, Germany (30%) and Denmark (26%) remain major players in terms of export shares, despite a significant decrease in exports from Denmark compared to 2019 (€750 million less than in 2019). The Netherlands increased its exports by over €344 million, increasing its export share to nearly 14%. Spain maintained an export share of 8%. In total, the net exports of the EU-27 decreased in 2020. Even with the decreased exports from Denmark, almost 80% of worldwide exports in wind technologies originate from the EU-27. Chinese export shares have increased to 13.8% in 2020, continuing the growth of the role China has in global wind energy exports. Exports from the U.S. decreased significantly in 2020, while exports from India, Brazil and Japan increased to modest shares of the global exports.

In 2020, Germany increased its positive trade balance to over €2 billion, while Denmark fell below the €2 billion mark. China follows at nearly €1 billion in net exports. The Netherlands increased net exports to over €500 million, surpassing Spain where net exports increased slightly to €469 million in 2020.

Denmark remains the most specialised wind energy exporter, followed by Spain, the Netherlands and Germany. China's export specialisation in wind technology increased to -4 in 2020. In 2020 we also observe a positive RCA in wind energy for both Brazil and India.

EU-27 trade with its main trading partners, 2020 - wind energy



In terms of trade balance we observe a positive trade balance for the EU with most of the main trading partners, including the U.S., Turkey, the U.K., Norway, Russia, Japan and Canada. Net exports to the U.S. more than doubled compared to 2019 and net exports to Turkey increased by over 70%. Net exports to the remaining countries all decreased compared to 2019. The EU was a net importer from China and India in 2020. Net imports from China increased by about €60 million compared to 2019, while net imports from India remained more or less stable. ■

PHOTOVOLTAIC

EU-27 trade (incl. intra-EU trade), 2019 - photovoltaic

	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
Luxembourg	61	63	1	0,1%	0
Latvia	3	1	-3	0,0%	-95
Croatia	34	31	-3	0,1%	-18
Malta	8	0	-8	0,0%	-99
Ireland	28	18	-10	0,0%	-89
Slovakia	44	27	-17	0,1%	-75
Slovenia	69	51	-18	0,1%	0
Estonia	22	3	-19	0,0%	-82
Cyprus	20	0	-20	0,0%	0
Lithuania	48	25	-23	0,1%	-51
Denmark	62	27	-36	0,1%	-79
Bulgaria	50	4	-46	0,0%	-88
Finland	54	7	-47	0,0%	-89
Czechia	158	94	-63	0,2%	-65
Greece	75	5	-69	0,0%	-86
Sweden	122	47	-75	0,1%	-75
Romania	125	4	-121	0,0%	-93
France	637	514	-124	1,0%	-44
Austria	285	116	-169	0,2%	-54
Portugal	420	237	-183	0,5%	11
Hungary	261	42	-218	0,1%	-72
Belgium	306	81	-225	0,2%	-77
Italy	537	310	-227	0,6%	-59
Poland	342	26	-317	0,1%	-89
Germany	2 730	2 207	-523	4,4%	-27
Netherlands	1 835	1 039	-797	2,1%	-18
Spain	1 339	55	-1 284	0,1%	-84
Total EU-27	9 677	5 036	-4 641	10%	-45

Main EU partners' trade with the rest of the world (including EU-27), 2019 - photovoltaic

	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
China	6 392	21 072	14 680	41,8%	45
Norway	32	2	-31	0,0%	-98
Japan	3 193	3 153	-40	6,3%	20
Turkey	228	154	-74	0,3%	-47
Switzerland	190	112	-78	0,2%	-71
United Kingdom	343	154	-189	0,3%	-73
Canada	367	147	-220	0,3%	-73
Russia	313	17	-296	0,0%	-95
Brazil	1 018	3	-1 015	0,0%	-98
India	2 195	247	-1 948	0,5%	-51
USA	7 525	1 942	-5 583	3,9%	-35
Rest of the world	19 165	18 341	-922	36,4%	10

In photovoltaics, China remains the largest player with almost 42% of global exports. They are followed at quite some distance by Japan (6%), Germany (4%) and the U.S. (4%). In total, the EU-27 reached a 10% share in 2019. The share of the «rest of the world» category is also very high (36% in 2019), showing that there are large exporters not included in the above list.

Regarding net exports in PV, only China has a significant positive balance. Luxembourg also has a positive trade balance in 2019, yet it is only €1 million. This is likely an indicator of Luxembourg importing and re-exporting PV. 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 U.S., followed by the EU-27, India and Brazil, implying that these countries are highly dependent on imports from other countries in PV technologies. These trends are also reflected in the RCA values. China is most highly specialised in goods related to PV, followed by Japan. In the EU only Luxembourg and Portugal have a positive RCA.

EU-27 trade (incl. intra-EU trade), 2020 - photovoltaic

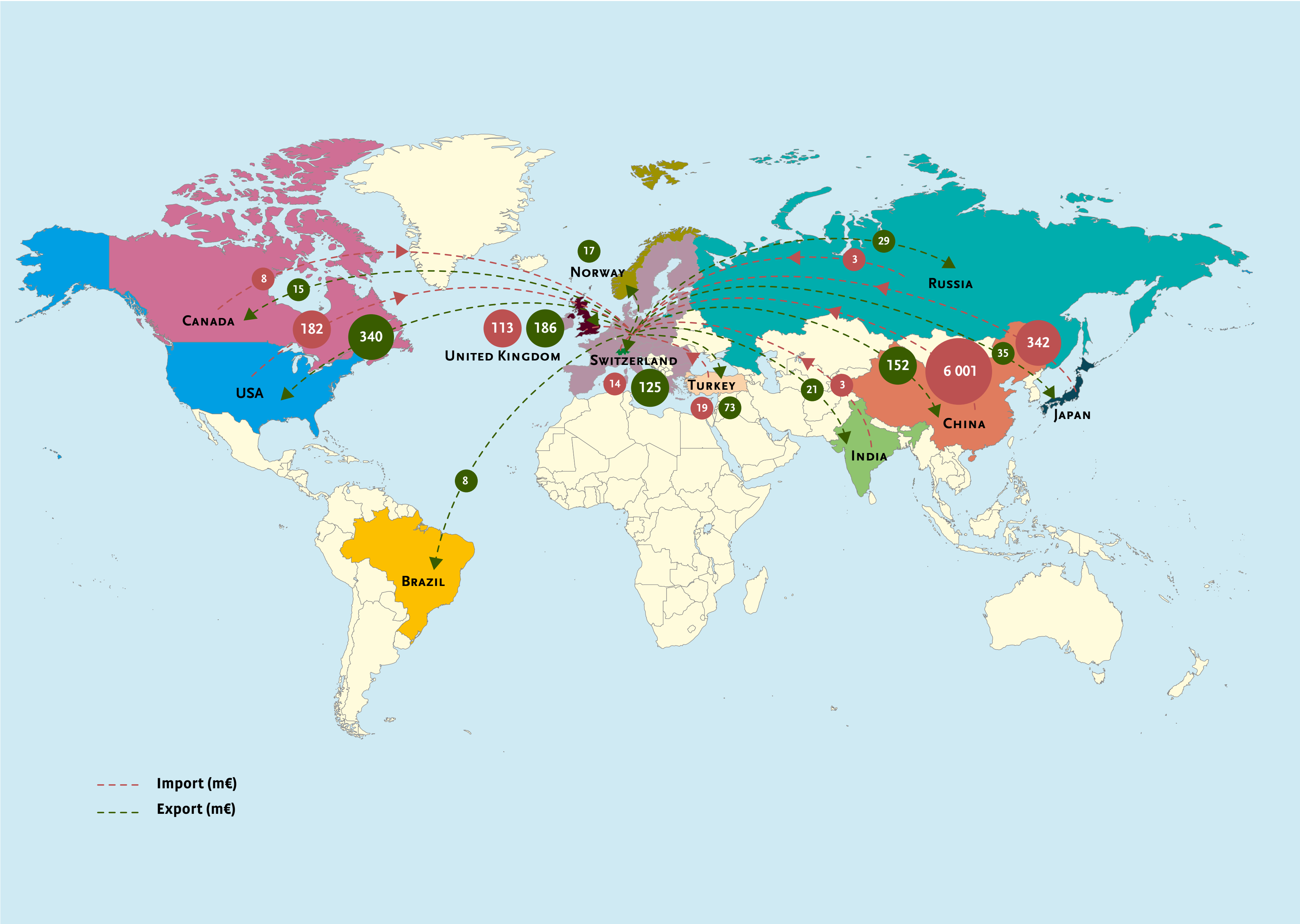
	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
Croatia	38	41	3	0,1%	-9
Luxembourg	46	42	-4	0,1%	0
Malta	4	0	-4	0,0%	-98
Latvia	5	1	-4	0,0%	-96
Ireland	26	17	-9	0,0%	-91
Slovenia	100	88	-11	0,2%	0
Cyprus	18	0	-18	0,0%	0
Slovakia	38	15	-22	0,0%	-84
Italy	412	371	-41	0,7%	-54
Lithuania	60	12	-48	0,0%	-73
Finland	56	7	-49	0,0%	-90
Bulgaria	55	6	-50	0,0%	-85
Czechia	148	72	-76	0,1%	-72
Estonia	79	3	-76	0,0%	-83
Denmark	110	29	-81	0,1%	-78
Sweden	133	36	-97	0,1%	-81
Romania	127	4	-123	0,0%	-94
Portugal	344	211	-133	0,4%	6
France	768	615	-153	1,2%	-36
Austria	296	104	-192	0,2%	-58
Greece	218	17	-201	0,0%	-66
Hungary	256	44	-211	0,1%	-72
Belgium	380	140	-240	0,3%	-67
Germany	2 733	2 124	-610	4,2%	-28
Poland	674	33	-640	0,1%	-88
Netherlands	2 069	1 304	-765	2,6%	-10
Spain	1 015	167	-848	0,3%	-63
Total EU-27	**10 210**	**5 505**	**-4705**	**11%**	**-42**

Main EU partners' trade with the rest of the world (including EU-27), 2020 - photovoltaic

	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
China	6 343	20 869	14 526	40,9%	40
Japan	2 790	3 014	224	5,9%	19
Norway	27	2	-26	0,0%	-98
Switzerland	231	147	-84	0,3%	-67
Canada	358	201	-157	0,4%	-64
Turkey	315	146	-168	0,3%	-49
United Kingdom	315	142	-173	0,3%	-73
Russia	246	50	-196	0,1%	-86
Brazil	1 024	2	-1 022	0,0%	-99
India	1 343	100	-1 243	0,2%	-73
USA	9 165	2 004	-7 161	3,9%	-32
Rest of the world	18 630	18 842	243	36,9%	9

The top position of China can be confirmed again in 2020, with almost 41% of worldwide exports in PV originating from China. They are once more followed by Japan (6%), Germany (4%) and the U.S. (4%). The EU-27 increased its share of exports to 11% in 2020. Regarding net exports in PV, China still maintains a significant positive value. Japan is the only other country with a significantly positive trade balance. In the EU only Croatia has a positive trade balance of €3 million. All other countries in this comparison have a negative trade balance. The U.S. increased net imports by over €1.5 billion. Net imports for the EU-27 and Brazil remained similar to 2019. India, on the other hand, decreased net imports by about €700 million compared to 2019. China remains the most highly specialised in goods related to PV, followed by Japan. Portugal and Luxembourg retain their positive RCA.

EU-27 trade with its main trading partners, 2020 - photovoltaic



The figure illustrates that the EU is a large net importer of photovoltaics from China. In fact, net imports from China increased by about €900 million compared to 2019. The EU also has a negative trade balance in PV with Japan. On the other hand, the EU is a net exporter of PV to the remaining countries in the comparison. The most positive trade balances observed are with the U.S., Switzerland, the U.K. and Turkey. ■

BIOFUELS

EU-27 trade (incl. intra-EU trade), 2019 - biofuels

	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
Hungary	23	392	369	5,1%	71
France	277	576	299	7,5%	37
Belgium	114	257	143	3,3%	28
Spain	97	222	126	2,9%	19
Netherlands	830	932	102	12,1%	52
Austria	31	94	63	1,2%	11
Slovakia	11	69	58	0,9%	25
Bulgaria	12	39	27	0,5%	41
Malta	0	0	0	0,0%	0
Luxembourg	2	0	-2	0,0%	0
Estonia	4	1	-3	0,0%	-78
Cyprus	4	0	-4	0,0%	0
Slovenia	5	0	-4	0,0%	0
Latvia	12	4	-8	0,1%	-19
Croatia	9	0	-8	0,0%	-88
Lithuania	13	3	-10	0,0%	-57
Portugal	17	2	-15	0,0%	-82
Finland	24	0	-24	0,0%	0
Poland	127	97	-30	1,3%	-4
Greece	30	0	-30	0,0%	-98
Czechia	65	26	-39	0,3%	-48
Ireland	47	1	-46	0,0%	-97
Italy	118	49	-69	0,6%	-58
Denmark	85	4	-81	0,1%	-79
Sweden	267	153	-114	2,0%	34
Romania	117	1	-116	0,0%	-92
Germany	927	289	-637	3,8%	-33
Total EU-27	3 264	3 211	-53	42%	14

Main EU partners' trade with the rest of the world (including EU-27), 2019 - biofuels

	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
USA	748	2 209	1462	28,7%	46
Brazil	587	891	305	11,6%	75
Russia	1	46	46	0,6%	-53
China	48	12	-36	0,2%	-96
Norway	38	0	-38	0,0%	0
Turkey	57	4	-53	0,1%	-86
Switzerland	82	2	-80	0,0%	-95
India	283	33	-250	0,4%	-55
Japan	401	1	-400	0,0%	-99
United Kingdom	521	120	-401	1,6%	-21
Canada	503	93	-410	1,2%	-30
Rest of the world	1 545	1 079	-465	14,0%	-31

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-27, the U.S. and Brazil score the top positions when looking at the shares on global exports. Around 80% of worldwide exports in biofuels originate from these three regions (2019 as well as 2020). The largest EU countries in terms of trade shares are the Netherlands, France, Hungary, Belgium, and Germany. When looking at net exports, the large positive value for the U.S. implies that the U.S. is exporting far more biofuels than they import. The next largest net export values can be observed for Brazil, Hungary, France and Belgium. The most negative trade balance becomes visible for Germany, Japan, the U.K. and Canada, 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. Brazil is the country that is most highly specialised in goods related to biofuels, followed by Hungary, the Netherlands, the U.S., and Bulgaria.

EU-27 trade (incl. intra-EU trade), 2020 - biofuels

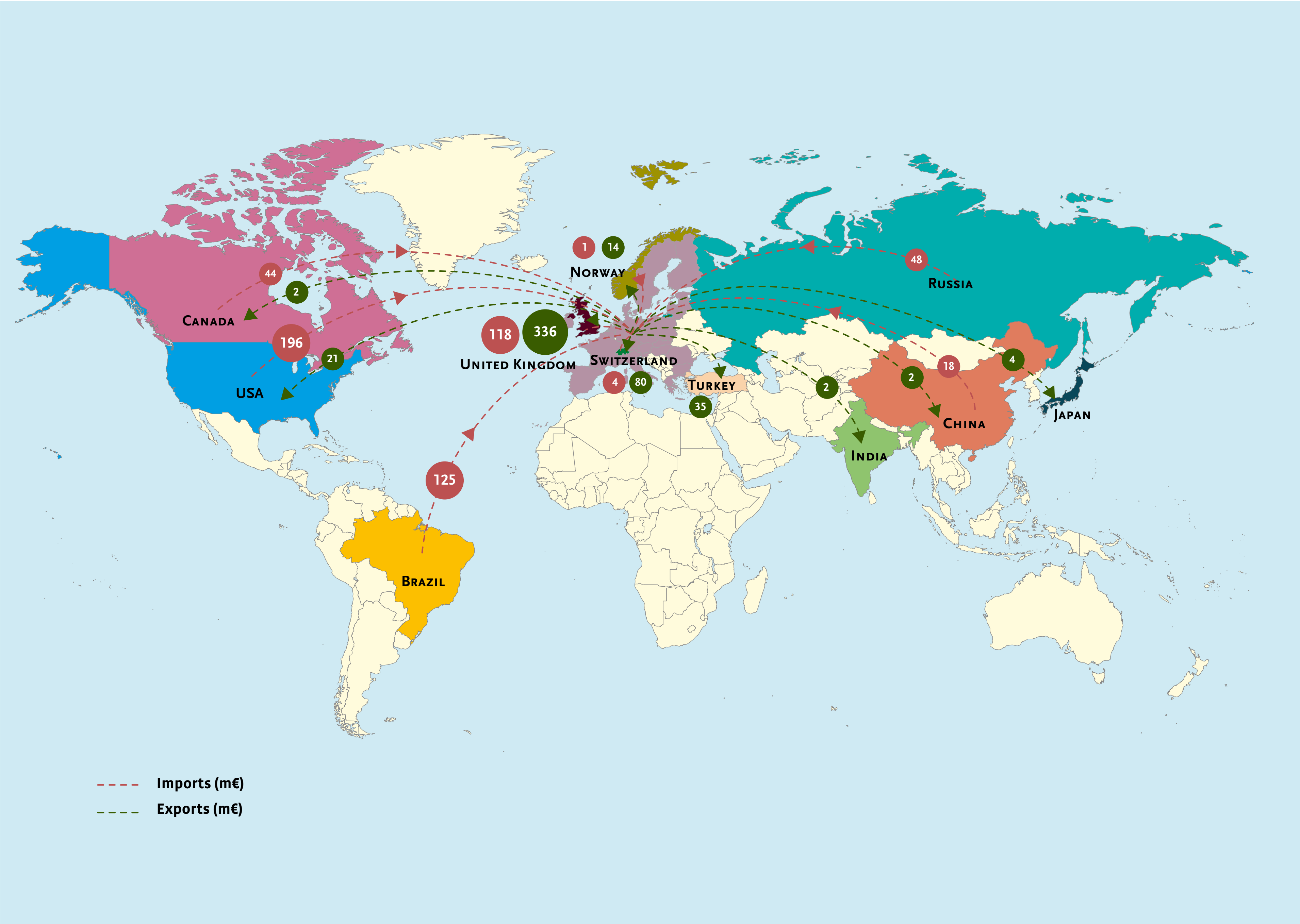
	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
Hungary	17	388	372	4,4%	66
France	332	605	274	6,9%	36
Belgium	157	379	223	4,3%	37
Netherlands	1 020	1 158	138	13,2%	54
Spain	134	231	97	2,6%	15
Slovakia	10	61	51	0,7%	13
Austria	51	99	48	1,1%	7
Bulgaria	15	61	45	0,7%	51
Estonia	32	34	2	0,4%	53
Malta	0	0	0	0,0%	-95
Luxembourg	3	0	-3	0,0%	0
Poland	166	163	-3	1,9%	9
Cyprus	3	0	-3	0,0%	0
Slovenia	8	2	-6	0,0%	0
Latvia	15	5	-11	0,1%	-22
Croatia	13	2	-11	0,0%	-55
Lithuania	43	27	-16	0,3%	20
Portugal	31	3	-27	0,0%	-75
Ireland	37	1	-37	0,0%	-97
Finland	43	0	-43	0,0%	0
Czechia	72	24	-48	0,3%	-55
Greece	77	1	-76	0,0%	-91
Sweden	248	166	-81	1,9%	31
Romania	117	1	-116	0,0%	-95
Denmark	143	11	-132	0,1%	-60
Italy	216	48	-168	0,5%	-62
Germany	927	363	-564	4,1%	-29
Total EU-27	3 929	3 833	-96	44%	15

Main EU partners' trade with the rest of the world (including EU-27), 2020 - biofuels

	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
USA	683	2 121	1438	24,1%	43
Brazil	401	1 043	642	11,8%	75
China	31	220	189	2,5%	-66
Russia	1	55	54	0,6%	-46
Norway	35	0	-35	0,0%	0
Switzerland	106	6	-100	0,1%	-89
India	269	95	-174	1,1%	-18
Turkey	182	5	-177	0,1%	-86
United Kingdom	376	134	-242	1,5%	-18
Canada	513	150	-364	1,7%	-13
Japan	468	1	-467	0,0%	-99
Rest of the world	1 787	1 143	-645	13,0%	-35

In 2020, both imports and exports of biofuels increased in the EU, yet net imports increased to €96 million. The share of global exports increased from 42% in 2019 to 44% in 2020. The U.S., the Netherlands and Brazil remain the largest biofuel exporters. Brazil more than doubled its net exports compared to 2019, due to an increase in exports and a decrease in imports. Brazil remains the most specialised in biofuels trade.

EU-27 trade with its main trading partners, 2020 - biofuels



In 2020 the EU was a net importer of biofuels from the U.S., Brazil, Russia, Canada, and China. Net imports increased from all of these countries except for Russia, when compared to 2019. Of the biofuels exported by the EU, the largest amounts go to the U.K., Switzerland and Turkey. The EU also has a positive trade balance with these countries. ■

HYDROELECTRICITY

EU-27 trade (incl. intra-EU trade), 2019 - hydroelectricity

	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
Austria	38	115	77	11,8%	82
Italy	11	78	67	7,9%	44
Germany	17	57	40	5,8%	-10
Czechia	6	39	33	4,0%	55
Slovenia	5	30	25	3,1%	0
France	17	40	22	4,1%	17
Spain	5	22	17	2,2%	13
Poland	1	9	7	0,9%	-15
Bulgaria	0	7	6	0,7%	54
Netherlands	0	4	4	0,4%	-69
Hungary	0	3	3	0,3%	-25
Romania	1	4	3	0,4%	-2
Croatia	0	2	2	0,3%	45
Finland	1	2	0	0,2%	-31
Denmark	0	0	0	0,0%	-82
Estonia	0	0	0	0,0%	0
Cyprus	0	0	0	0,0%	0
Malta	0	0	0	0,0%	-79
Belgium	0	0	0	0,0%	-93
Lithuania	0	0	0	0,0%	-96
Ireland	1	0	0	0,0%	-86
Slovakia	0	0	0	0,0%	-100
Greece	1	0	-1	0,0%	-95
Luxembourg	2	0	-1	0,0%	0
Latvia	5	0	-5	0,0%	-95
Portugal	10	4	-6	0,4%	9
Sweden	18	0	-17	0,0%	-84
Total EU-27	141	417	275	43%	19

Main EU partners' trade with the rest of the world (including EU-27), 2019 - hydroelectricity

	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
China	2	210	208	21,4%	24
India	8	52	44	5,3%	48
Brazil	5	45	40	4,6%	56
Japan	8	19	12	2,0%	-24
United Kingdom	8	10	3	1,0%	-33
USA	38	30	-8	3,1%	-40
Switzerland	25	14	-11	1,4%	-4
Norway	22	3	-19	0,3%	-17
Turkey	35	7	-28	0,7%	-9
Canada	46	14	-32	1,4%	-18
Russia	64	6	-58	0,6%	-48
Rest of the world	472	46	-425	4,7%	-63

In hydropower, we can see a more balanced picture than in the case of PV and wind energy. Within the EU-27, the largest export shares can be found for Austria (12%), Italy (8%), Germany (6%), Czechia (4%), France (4%) and Slovenia (3%). In sum, the EU-27 is responsible for more than 40% of the worldwide exports within hydropower. As a single country, China also shows a large value of 21%. China is followed by India and Brazil, at 5.3% and 4.6% respectively. The largest positive net export values within the EU-27 are displayed for Austria, Italy, Germany, Czechia, Slovenia, France, and Spain. Yet, the largest value globally can be found for China. The U.S. display a negative trade balance. The specialisation values in hydroelectricity show a rather positive picture for Europe, with eight EU-27 members having a positive RCA value. Austria is most highly specialised in the export of hydropower goods. China also shows positive RCA values, but its specialisation in PV is still higher than it is in hydroelectricity.

EU-27 trade (incl. intra-EU trade), 2020 - hydroelectricity

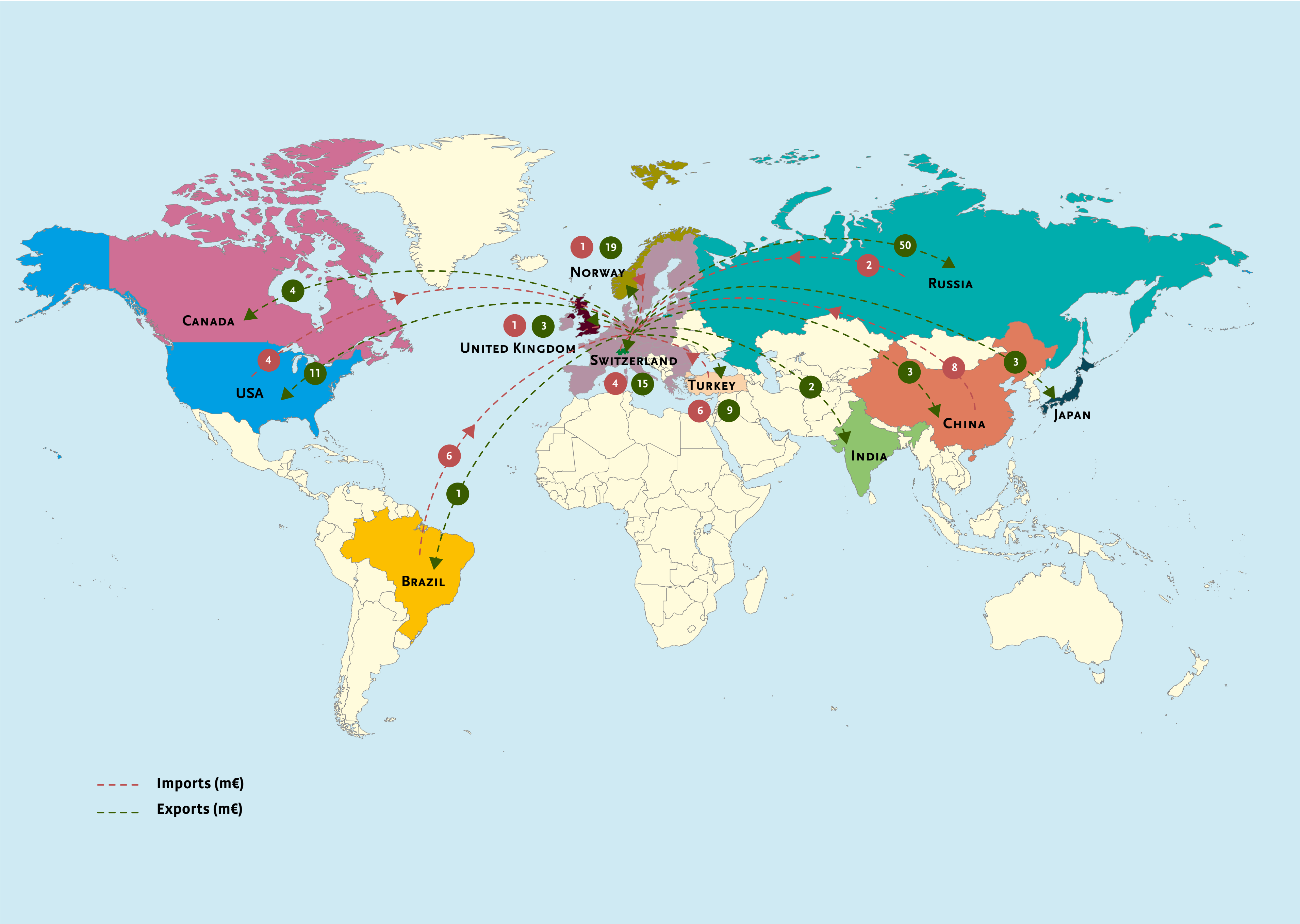
	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
Austria	36	106	70	11,9%	82
Germany	12	61	50	6,9%	-2
Italy	7	50	43	5,6%	33
Czechia	6	41	35	4,6%	58
Slovenia	6	24	18	2,7%	82
Spain	4	16	12	1,8%	6
France	19	30	11	3,3%	12
Bulgaria	2	10	8	1,1%	68
Poland	0	8	8	0,9%	-17
Netherlands	0	2	2	0,3%	-77
Croatia	0	2	2	0,2%	39
Hungary	0	2	1	0,2%	-50
Denmark	0	0	0	0,1%	-77
Belgium	0	0	0	0,1%	-89
Estonia	0	0	0	0,0%	0
Malta	0	0	0	0,0%	-100
Lithuania	1	1	0	0,1%	-43
Cyprus	0	0	0	0,0%	0
Slovakia	0	0	0	0,0%	-98
Finland	3	3	0	0,3%	-1
Ireland	0	0	0	0,0%	-100
Luxembourg	1	0	0	0,0%	-40
Portugal	5	2	-2	0,3%	-6
Greece	3	0	-3	0,0%	-90
Sweden	7	3	-3	0,4%	-31
Romania	5	1	-4	0,1%	-50
Latvia	6	0	-6	0,0%	-97
Total EU-27	**124**	**364**	**241**	**41%**	**18**

Main EU partners' trade with the rest of the world (including EU-27), 2020 - hydroelectricity

	Imports (in € m)	Exports (in € m)	Net exports (in € m)	Share of global exports	Exports specialisation (RCA)
China	2	166	164	18,6%	14
India	5	54	50	6,1%	56
Brazil	2	40	38	4,5%	55
Switzerland	16	41	25	4,6%	42
United Kingdom	11	7	-3	0,8%	-37
USA	39	34	-5	3,8%	-28
Canada	20	13	-8	1,4%	-15
Japan	13	4	-8	0,5%	-68
Turkey	23	9	-13	1,1%	8
Norway	25	2	-22	0,3%	-19
Russia	68	8	-61	0,8%	-30
Rest of the world	405	37	-368	4,2%	-66

In 2020, exports and net exports of hydropower goods in the EU-27 decreased compared to 2019. The export share of the EU decreased to 41% of global exports. The largest decrease is observed for Italy.
China's exports also deceased, as did its share of global exports. India and Switzerland, on the other hand increased their exports and export shares. Switzerland especially shows a relatively large share of exports, surpassing even Brazil. Besides Italy's decreased exports and Switzerland's increase, there are no large shifts in net exports.
When it comes to export specialisation, two countries stand out: Switzerland and Bulgaria. Switzerland went from a negative RCA in 2019 to a positive one in 2020. Bulgaria moved up to the second most specialised country in hydropower goods exports, with just €10 million in export value.

EU-27 trade with its main trading partners, 2020 - hydroelectricity



The figure illustrates that the trade flows for hydropower are small compared to photovoltaics, wind energy and biofuels. The EU has a positive trade balance with most of the main trade partners. Largest surpluses are observed for trade with Russia, Norway, Switzerland, and the U.S. Negative trade balances for hydropower are observed with China and Brazil. ■

CONCLUSIONS

The export data in RET technologies provide evidence of the strong position of China in the last years. The Chinese strength in RET exports mostly originates from its strengths in photovoltaics and to a lesser extent hydropower. China is also the country the EU-27 imports the largest amount of RET from, led by large imports of photovoltaics. When it comes to photovoltaics, the EU-27 share in world exports is small (11%) compared to China's share (41%).

In wind energy, especially Germany and Denmark, but also the Netherlands and Spain can be seen as strong competitive countries, with large roles in the worldwide export markets. These four countries in sum generate a worldwide export share of almost 80%. The role of China in wind energy technology exports has grown in recent years, with a world export share comparable to the Netherlands (14%) and now ranking third in net exports behind Germany and Denmark.

The EU is a large player in the biofuels market, with a 44% share in global exports. The U.S. and Brazil are responsible for another 36% of global exports, showing the large role of these countries and the EU. In the EU, the Netherlands and France are the largest exporters. They are followed by Hungary, Belgium and Germany. Germany, however, imports much more biofuels than they export and therefore has a negative trade balance. The other four EU countries have a positive trade balance.

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. The EU's share in global exports is fairly constant in recent years at just over 40%.

Overall, the EU displays a strong competitiveness in all RET fields, and seems at least keeping its shares at a high level in 2020. 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. The EU has a positive trade balance with the U.S., the U.K., Turkey, Switzerland, Norway and Russia. ■

Hendrik Mzyk

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- EBB – European Biodiesel Board *(www.ebb-eu.org)*
- EGEC – European Geothermal Energy Council *(www.egec.org)*
- EHPA – European Heat Pump Association *(www.ehpa.org)*
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- Eurostat – Statistique européenne/European Statistics *(www.ec.europa.eu/eurostat/fr)*
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BELGIUM

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BULGARIA

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CYPRUS

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- MCIT – Ministry of Commerce, Industry and Tourism *(meci.gov.cy/gr/)*
- CERA – Cyprus Energy Regulatory Authority *(www.cera.org.cy)*

CROATIA

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- HROTE – Croatian Energy Market Operator *(www.hrote.hr)*

CZECHIA

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- Czech Wind Energy Association *(www.csve.cz/en)*

DENMARK

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ESTONIA

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- STAT EE – Statistics Estonia *(www.stat.ee)*

FINLAND

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- VTT – Technical Research Centre of Finland *(www.vtt.fi)*

FRANCE

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- DGEC – Energy and Climat Department *(https://www.ecologique-solidaire.gouv.fr)*
- Enerplan – Solar Energy organization *(www.enerplan.asso.fr)*
- FEE – French Wind Energy Association *(www.fee.asso.fr)*
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GERMANY

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- 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)*
- BDEW – Bundesverband der Energie und Wasserwirtschaft e.V *(www.bdew.de)*
- BMWi – Federal Ministry for Economics Affairs and Climate Action *(www.bmwi.de)*
- BWE – German Wind Energy Association - Bundesverband Windenergie *(www.wind-energie.de)*
- BSW-Solar – German Solar Industry Association - Bundesverband Solarwirtschaft *(www.solarwirtschaft.de)*
- BWP – German Heat Pump Association – Bundesverband Wärmepumpe *(www.waermepumpe.de)*
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GREECE
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- HWEA – Hellenic Wind Energy Association *(www.eletaen.gr)*
- Ministry of Environment and Energy and Climate Change *(https://ypen.gov.gr/)*
- Energy Centre – Energy Efficiency, Environment and Energy Information Agency *(www.energycentre.hu)*

IRELAND
- EIRGRID *(www.eirgridgroup.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
- Assotermica -Associazione produttori apparecchi e componenti per impianti termici *(https://www.anima.it/associazioni/elenco/assotermica/)*
- ENEA – Italian National Agency for New Technologies *(www.enea.it)*
- GSE – Gestore servizi energetici *(www.gse.it)*
- Terna – Electricity Transmission Grid Operator *(www.terna.it)*

LATVIA
- CSB – Central Statistical Bureau of Latvia *(www.csb.gov.lv)*

LITHUANIA
- LS – Statistics Lithuania *(www.stat.gov.lt)*

LUXEMBOURG
- 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
- MRA – Malta Resources Authority *(www.mra.org.mt)*
- NSO – National Statistics Office *(www.nso.gov.mt)*

NETHERLANDS
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- CBS – Statistics Netherlands *(www.cbs.nl)*
- ECN – Energy Research Centre of the Netherlands *(https://www.tno.nl/en/)*

POLAND
- URE / EROURE – Energy Regulatory Office of Poland *(htpp://www.ure.gov.pl)*
- GUS – Central Statistical Office *(www.stat.gov.pl)*
- Ministry of Energy, Renewable and Distributed Energy Department *(https://www.gov.pl/web/aktywa-panstwowe)*
- National Fund for Environmental Protection and Water Management *(https://www.gov.pl/web/nfosigw/)*
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PORTUGAL
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ROMANIA
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SPAIN
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SLOVAKIA
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SLOVENIA
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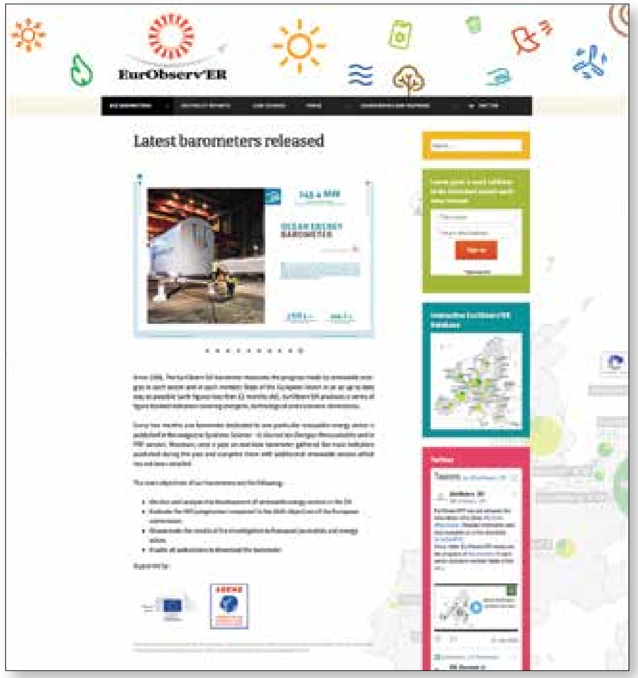

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