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REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL

Progress on competitiveness of clean energy technologies
2 & 3 - Windpower

{COM(2021) 950 final} - {COM(2021) 952 final}

OFFSHORE WIND

INTRODUCTION

Today, offshore wind produces clean electricity that competes with, and is sometimes cheaper than existing fossil fuel-based technology. It is a story of European technological and industrial leadership.

With the European Climate Law now in force, the EU's new and significantly more ambitious 2030 climate target – of a net domestic reduction of at least 55% in greenhouse gas emissions compared to 1990 levels – is now a legal obligation, which must be implemented through binding legislation applicable across all Member States and sectors of the economy. This will require a scale up of the offshore wind industry. In the offshore renewable energy strategy, it is foreseen that 60 GW offshore wind capacity will be installed by 2030 and 300 GW by 2050, which is estimated to require less than 3% of the European maritime space and can therefore be compatible with the goals of the EU Biodiversity Strategy[1].

3. TECHNOLOGY ANALYSIS – CURRENT SITUATION AND OUTLOOK

3.1. Introduction/technology maturity status (TRL)

The world's first offshore wind farm was installed in Vindeby, off the southern coast of Denmark, in 1991. At the time, few believed this could be more than a demonstration project[2]. 30 years later, offshore wind energy is a mature, large-scale technology providing energy for millions of people. New installations have high capacity factors up to 65% and the costs have steadily fallen over the last 10 years.

The Communication on the "EU strategy to harness the potential of offshore renewable for a climate neutral future"[3] proposes a strategy to make offshore renewable energy a core component of Europe's energy system by 2050. The strategy presents a general enabling framework, addressing barriers and challenges common to all offshore technologies and different sea basins but also sets out specific policy solutions adapted to the different state of development of technologies and regional contexts.

3.2. Capacity installed, generation/production

The cumulative installed capacity of the entire wind energy sector (both onshore and offshore wind) in the EU increased by 123% from 80 GW in 2010 to 178.7 GW in 2020. On a global level, the EU ranks second, only superseded by China (288 GW) since 2015[4].

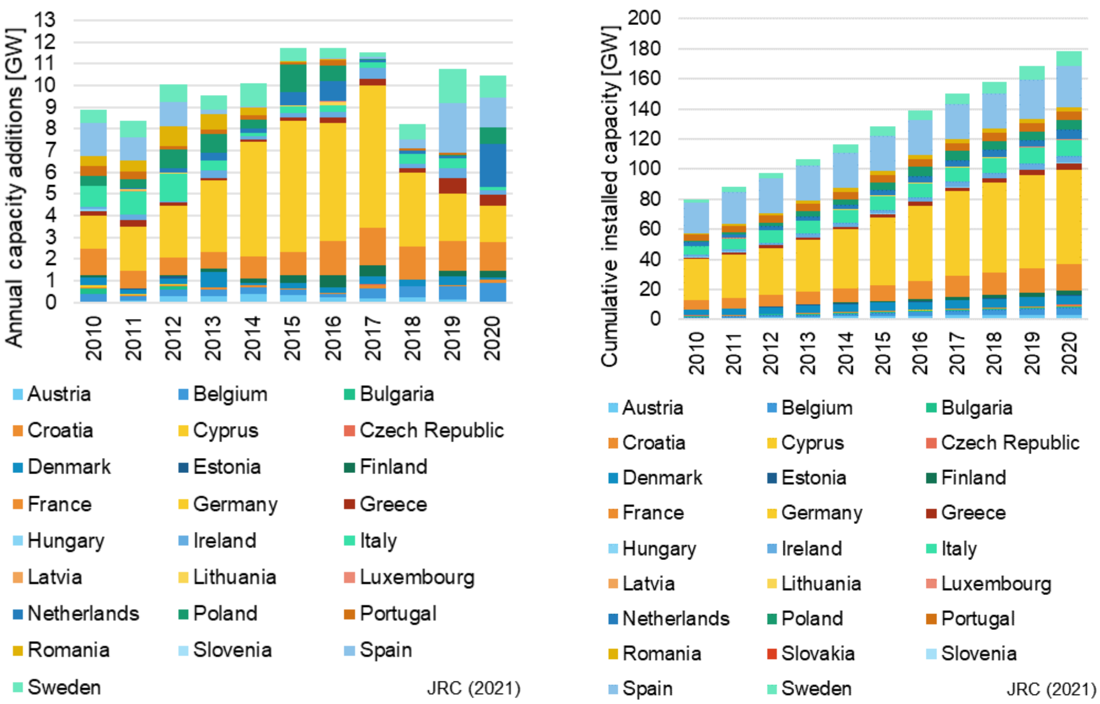
The increase in deployment was even more pronounced for the offshore wind sector, surging form 1.6 GW in 2010 to 14.6 GW in 2020.

The European Commission estimates wind producing half of Europe's electricity by 2050, with wind energy capacity rising from 178.7 GW today to up to 1 300 GW (EU in 2050, CTP-MIX: 1 253GW). That entails a 25x increase in offshore wind in the EU between 2020 and 2050. The committed capacity

[1] EU Biodiversity Strategy for 2030. Bringing nature back into our lives. COM/2020/380 final.
[2] The farm generated 5MW and covered the annual energy consumption of 2 200 households during 25 years.
[3] COM(2020) 741 final.
[4] GWEC (2021), Global Wind Statistics 2020.

of offshore wind installations in Member States' National Energy Climate Plans (NECPs) until 2030 amounts to (at least) 62.5 GW, while the expected offshore wind projects in EU sea basins based on latest announcements/industry is 84.2 GW.

Figure 1: Annual capacity additions (left) and cumulative installed capacity (right) of wind energy (both onshore and offshore) in the EU.

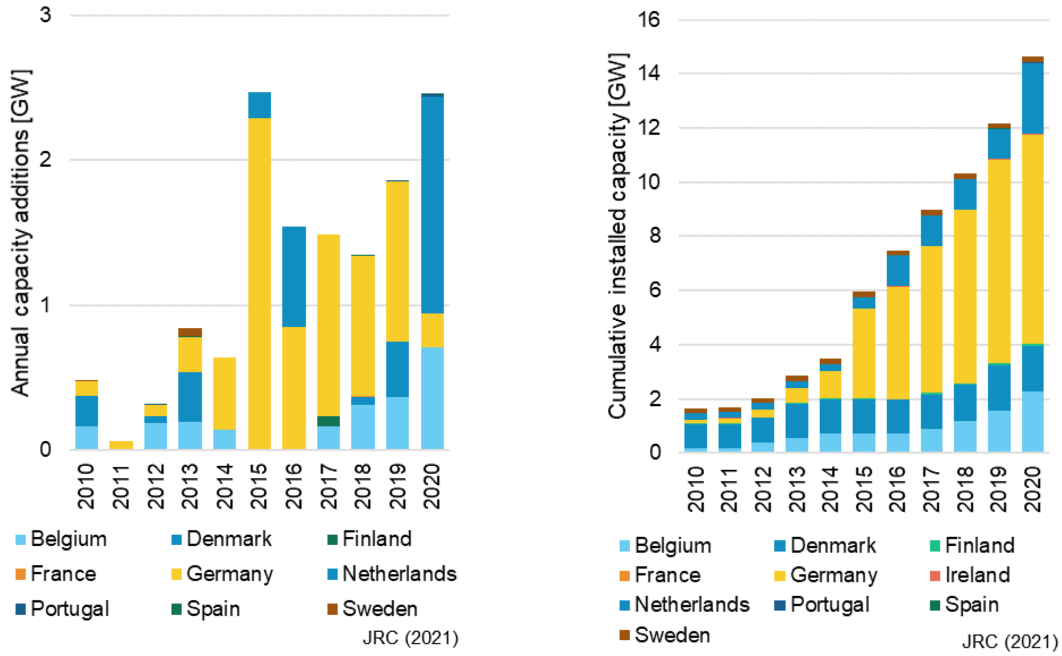


Source: JRC based on GWEC (2021)

In 2020, the entire European offshore wind market represented 71% (24.8 GW) of the global market in terms of cumulative installed capacity. The global installed capacity of the EU MSs accounts for about 42% (or 14.6 GW). Stimulated by the ending of its Feed-in-Tariff by end of 2021, China saw another record year in capacity additions (3.1 GW) resulting in a cumulative offshore wind capacity of about 9.9 GW, ranking second behind the United Kingdom (10.2 GW). EU Member States installed 2.5 GW in 2020, making it the second best year in deployment in the last decade. In 2020 the Netherlands (1.5 GW), Belgium (0.7 GW), the UK (0.5 GW) and Germany (0.22 GW) were the leading countries in terms of the capacity deployed in European waters. The remaining capacity (0.017 GW) was deployed in Portugal, when two of the three floating offshore wind turbines of the Windfloat Atlantic demonstration project were connected to the grid in the beginning of 2020.[5]

[5] JRC, Telsnig T: Wind Energy - Technology Development Report 2020, JRC123138. EUR 30503 EN. Luxembourg. URL: https://ec.europa.eu/jrc/en/publication/wind-energy-technology-development-report-2020 (updated 2020 data)

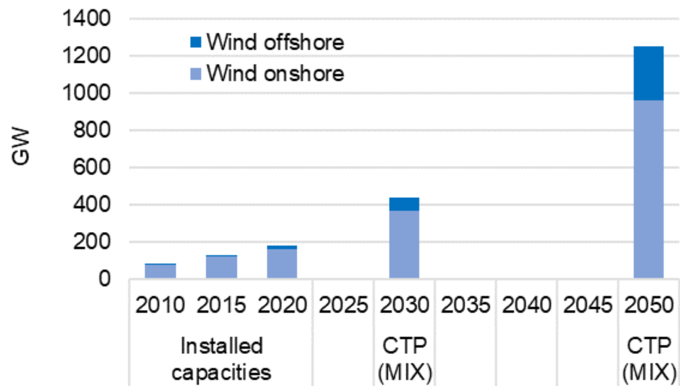
Figure 2: Annual capacity additions (left) and cumulative installed capacity (right) of offshore wind energy in the EU.



Source: JRC based on GWEC (2021)

Projected capacities in onshore wind and offshore wind according to CTP-MIX scenario: Onshore: 366 GW in 2030, 963 GW in 2050; OFFSHORE: 73 GW in 2030, 290 GW in 2050.

Figure 3: Installed wind capacities and wind capacity targets in the EC CTP-MIX scenario



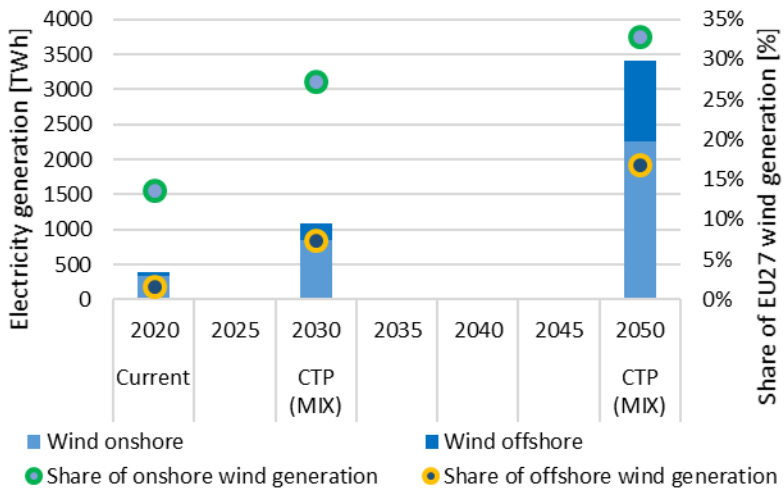
Source: JRC based on 2030 Climate Target Plan Impact Assessment[6]

Projected electricity generation in onshore wind and offshore wind according to CTP-MIX scenario: Onshore: 847 TWh in 2030 (share of total electricity generation: 27.3%), 2 259 TWh in 2050 (share:

[6] SWD(2020) 176 final, PART 2/2

32.9%); Offshore: 229 TWh in 2030 (share: 7.4%), 1 154 TWh in 2050 (share: 16.8%). Current share of total electricity generation (2020): Onshore wind 13.7%; Offshore wind (1.7%)[7 8 9]

Figure 4: Current and future electricity generation from onshore and offshore wind and its share in total electricity generation of the EU



Source: JRC based on 2030 Climate Target Plan, BEIS and WindEurope[10],[11],[12]

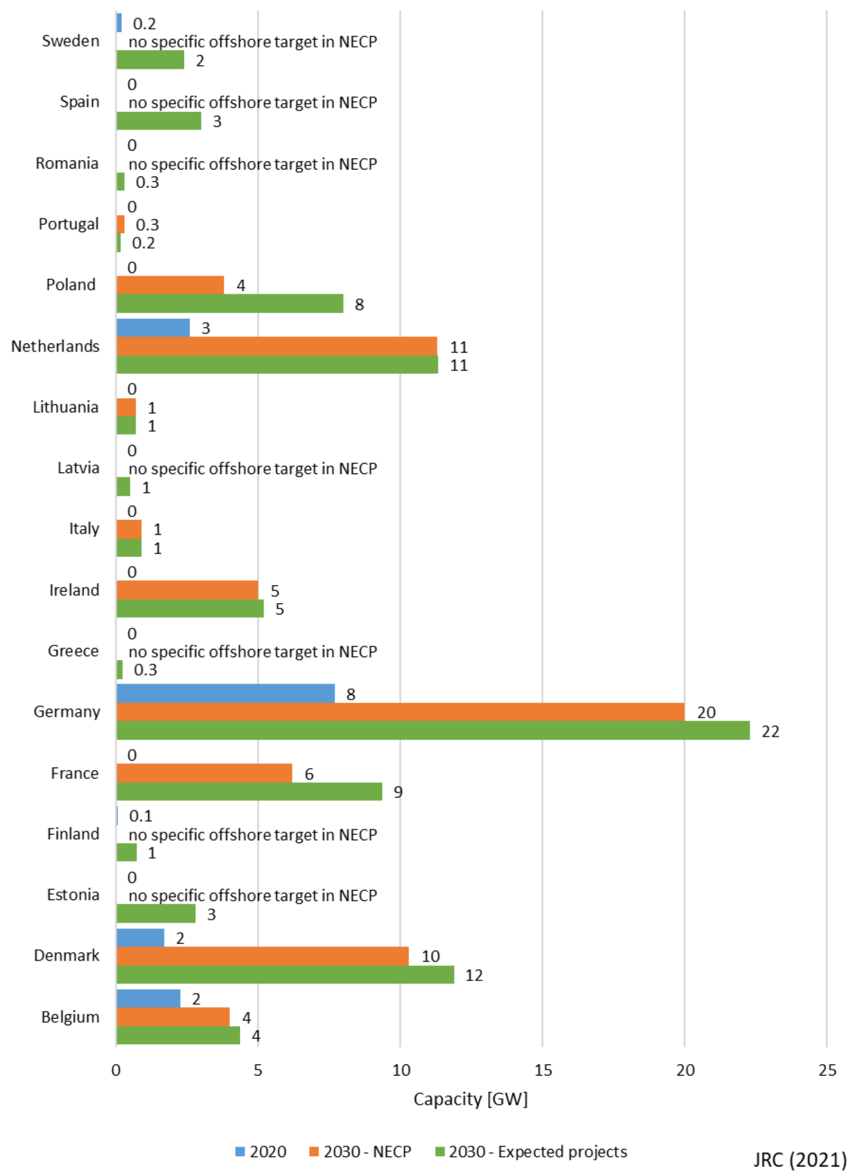
The EU Strategy on Offshore Renewable Energy (ORES) proposes to increase Europe's offshore wind capacity from its current level (14.6 GW in 2020) to at least 60 GW by 2030 (and to 300 GW by 2050)[13]. Following current national targets as expressed in the MSs National Energy Climate Plans (NECPs) suggest that the ORES target for 2030 can be achieved. Multiple NECPs do not differentiate between onshore and offshore wind, however limiting to those countries that formulated a specific offshore wind target for 2030 would lead to a cumulated offshore wind capacity of 62.5 GW. With 20 GW in 2030, Germany is the country with the highest NECP offshore wind target followed by the Netherlands, Denmark, France, Ireland, Belgium and Poland. Offshore wind targets at limited scale were formulated by Portugal, Lithuania and Italy. Even though not explicitly mentioned in their NECPs, a set of MSs is expected to deploy substantial offshore wind capacities until 2030. If all MSs targets and expected offshore wind projects are commissioned until 2030 a total of about 84.2GW could go online in EU Member States.

Following this path EU countries would still see most of the offshore wind installations deployed until 2030 in the North Sea (47 GW), yet substantial capacities can be expected in other sea basins particularly in the Baltic Sea (21.6 GW) and in the Atlantic Ocean (11.1 GW). Moreover, first offshore wind

7 WindEurope ,Wind energy in Europe – 2020 Statistics and the outlook for 2021 – 2025, 2021
8 BEIS (2021), National Statistics Energy Trends: UK renewables, https://www.gov.uk/government/statistics/energy-trends-section-6-renewables
9 UK shares in onshore and offshore electricity generation were deducted from figures given in WindEurope (2021) based on reported data in BEIS (2021)
10 SWD(2020) 176 final, PART 2/2
11 WindEurope (2021), Wind energy in Europe - 2020 Statistics and the outlook for 2021-2025.
12 UK share was deducted based on: BEIS Energy Trends - Statistical Release 25 March 2021, https://www.gov.uk/government/collections/renewables-statistics#digest-of-uk-energy-statistics-(dukes):-annual-data
13 COM(2020) 741 final

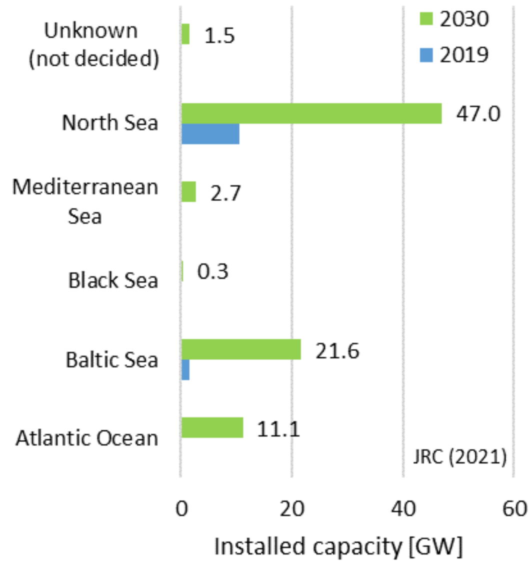
capacities are expected in the Mediterranean Sea (2.7 GW) and the Black Sea (0.3 GW). The move to new sea basins is expected to bring an uptake of floating offshore wind projects. About 3 to 4.4 GW of floating offshore wind capacity is expected in EU MSs (France, Greece, Ireland, Italy, Portugal and Spain) by 2030.

Figure 5: Offshore wind capacities as committed in EU MSs National Energy Climate Plans (NECPs) until 2030 versus expected offshore wind projects in EU MSs based on latest announcements/industry



Sources: JRC analysis of NECPs and future expected offshore wind projects (2021)

Figure 6: Expected offshore wind projects in EU sea basins until 2030 based on latest announcements/industry



Sources: JRC analysis of NECPs and future expected offshore wind projects (2021)

3.3. Cost / Levelised Cost of Electricity (LCoE)

Offshore LCoE (bottom fixed): Bottom-fixed offshore wind LCoE declined rapidly to today's values ranging from EUR 67 per MWh to EUR 140 per MWh (Figure 7). Particularly since 2014 an upscaling in project and turbine size can be observed in order to capitalise on the decrease of the unit costs (economies of size). Following current projections on the future costs of bottom-fixed offshore wind expects LCoE levels in the range of EUR 30 EUR per MWh to EUR 60 EUR per MWh by 2050. The cost of offshore wind installations is therewith reaching similar levels as the one of onshore installations.

As for all other capital intensive RES technologies the cost of finance (weighted average cost of capital (WACC)) impacts LCoE considerably. The WACC is mainly influenced by country risks and interest rates (see also section 1.3 of onshore wind chapter). Although there is not much data on offshore wind WACC, a recent study finds generally higher values for offshore wind (ranging from 3.5% to 9%) than for onshore wind as the technology is at an earlier stage of development thus having a higher risk profile. Evidence suggests that a further decrease (and convergence among countries) in WACC could be achieved by focusing on de-risking debt financing of wind energy projects by policies that implement support schemes decreasing the volatility of a projects cash flow (e.g. a sliding feed-in premium scheme (Contract for Difference))[14] [15].

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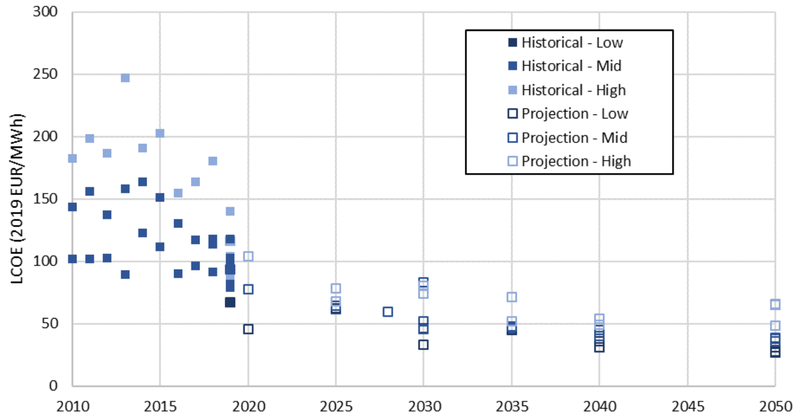
14 AURES II (2021), Renewable energy financing conditions in Europe: survey and impact analysis, D5.2, March 2021, H2020 project: No 817619

15 JRC, Low Carbon Energy Observatory, Wind Energy Technology Market Report, European Commission, 2019, JRC118314.

Figure 7: Range of historical and projected offshore wind LCoE estimates



Source: Chart reproduced from Beiter et al. 2021[16]

Operation & maintenance costs[17] (O&M) are decreasing. Global average annual O&M costs for offshore wind were about USD 90[18]/kW in 2018, and are projected to go down by one-third by 2030 and further decline towards USD 50[19]/kW in 2040 (a decrease of 40% compared to 2018). These reductions will mainly be due to economies of scale, industry synergies, along with digitalisation and technology development, including optimised maintenance concepts [20].

CAPEX for offshore wind projects are declining rapidly and depend on the rated turbine capacity, depth of the site (and the foundation technology pursued) and the size of a project and range in the established European markets between EUR 2 500 per kW and EUR 3 900 per kW[21]. IEA estimates CAPEX in 2018 of EU projects averaging around EUR 3 400 per kW[22,23].

Globally, investment in offshore wind would need to grow substantially over the next three decades, with overall cumulative investment of over USD 2 750 billion[24] from now until 2050. Annually, average investment would need to increase more than three-fold from now until 2030 and five-fold until 2050. Major investments are required for rapid installation of new OW power capacities[25].

More recent studies calculate with an offshore wind deployment ranging between 177 GW and 346 GW in European waters by 2050 and estimate offshore and wind investments at EUR 360 billion to EUR 750

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16 Beiter P., Cooperman A., Lantz E., Stehly T., Shields M., Wiser R., Telsnig T., Kitzing L., Berkhout V., Kikuchi Y. (2021) Wind power costs driven by innovation and experience with further reductions on the horizon, WIREs Energy Environ. 2021;e398. https://doi.org/10.1002/wene.398.

17 These usually represent about 25 to 30% of total lifecycle costs for offshore wind farms (source: Röckmann C., Lagerveld S., Stavenuiter J. (2017) Operation and Maintenance Costs of Offshore Wind Farms and Potential Multi-use Platforms in the Dutch North Sea. In: Buck B., Langan R. (eds) Aquaculture Perspective of Multi-Use Sites in the Open Ocean. Springer, Cham).

18 EUR 75.83 (1 USD = 0.84 EUR).

19 EUR 42.13 (1 USD = 0.84 EUR).

20 IEA, Offshore Wind Outlook 2019 - World Energy Outlook Special Report, 2019.

21 BNEF 2020 Interactive Datasets.

22 IEA, Offshore Wind Outlook 2019 - World Energy Outlook Special Report, 2019.

23 Excluding transmission costs.

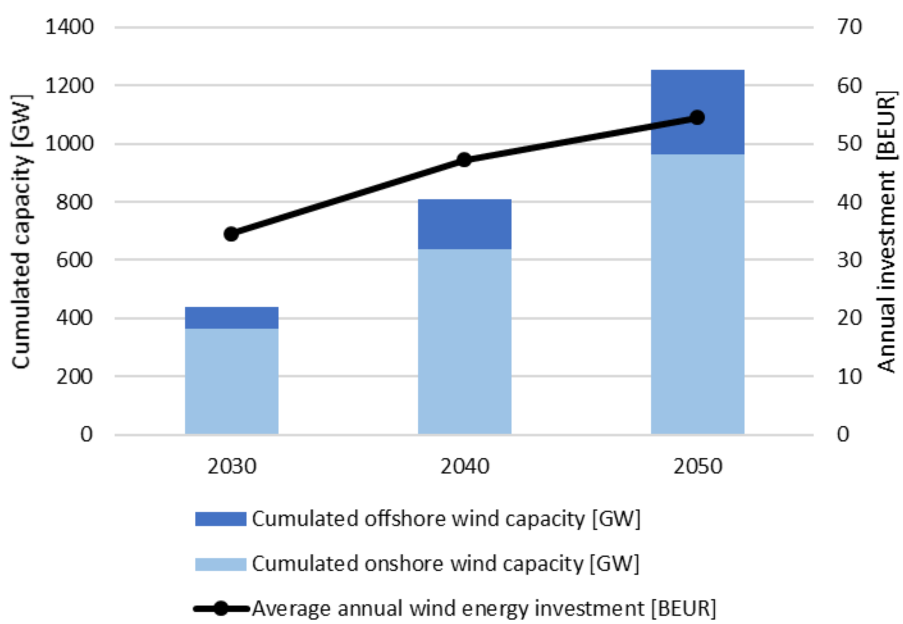
24 EUR 2310 billion (1 USD = 0.84 EUR).

25 IRENA, Future of wind: Deployment, investment, technology, grid integration and socio-economic aspects (A Global Energy Transformation paper), International Renewable Energy Agency, Abu Dhabi, 2019.

billion (of which EUR 200-500 billion are the grid part transmission and interconnection; and EUR 160-250 billion are the generation assets) being in line with the EU Offshore [26]Strategy estimating EUR 800 billion.

The clean energy transition and 2050 climate target will require a total EU investment in wind energy of up to EUR 1 360 billion in the period 2020-2050 under current policy projections. [27,28, 29].

Figure 8: Investment needs until 2050 for both onshore and offshore wind in the EC CTP-MIX scenario



Source: JRC analysis based on the EC CTP—MIX scenario

3.4. Public R&I funding

At the EU level, the R&I priorities include all aspects aimed to provide secure, cost-effective, clean and competitive energy supply, such as new turbine materials and components, resource assessment, grid integration, offshore technology, floating offshore wind, logistics, assembly, testing and installation, maintenance and condition-monitoring systems and airborne wind energy systems.

Offshore wind energy received the largest part of funding awarded to the wind energy related projects. Within the offshore wind funded projects, one area that is still in the early stages of development globally

[26] Guidehouse/Sweco (2020), R Recommendations for an integrated framework for the financing of joint (hybrid) offshore wind projects Final report Prepared for the European Commission, Reference No.: 212597.

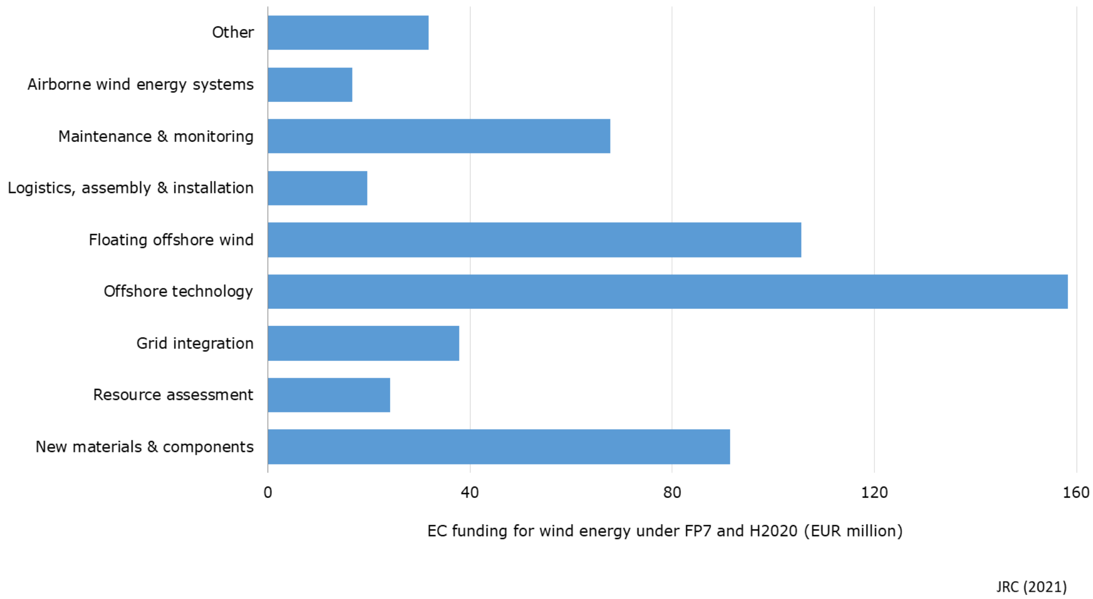
[27] These figures are based on the capacity deployment of the CTP-MIX scenario and the average of the investment expenditure assumptions for onshore and offshore wind towards 2050 as reported in the EU Reference Scenario 2020.

[28] COM(2021) 557 final, Amendment to the Renewable Energy Directive to implement the ambition of the new 2030 climate target, July 2021.

[29] DG ENER, EU Reference Scenario 2020, Energy, transport and GHG emissions - Trends to 2050, Accompanying excel file on technology assumptions, https://ec.europa.eu/energy/data-analysis/energy-modelling/eu-reference-scenario-2020_en.

but carries significant environmental and economic upsides, floating offshore wind, was mostly targeted. [30] [31].

Figure 9: EC funding on wind energy R&I priorities in the period 2009 -2020 under FP7 and H2020.



Source: JRC

Apart from EC-funded projects, the EC-funded SET plan Implementation Working Group (IWG) for Offshore Wind reported a significant number of nationally funded projects (17 out of 24, with single project budgets up to EUR 35 million) with a main focus on the R&I priorities 'Wind Energy Offshore Balance of Plant', 'Floating Offshore Wind' and 'Wind Turbine Technology'[32,33]. Other joint industry programmes related to the SET-Plan include projects from the Dutch GROW programme, and DNV GL's Joint Industry Projects (JIP) on Wind Energy.

Cost reduction through increased performance and reliability, development of floating substructures for deeper waters and the added value of offshore wind energy (system value of wind) were pivotal elements of the SET plan Implementation Plan (IP). In order to achieve these targets, the IP proposes to focus R&I activities on system integration, offshore wind energy – Balance of Plant, floating offshore wind, wind energy O&M, wind energy industrialisation, wind turbine technology, basic wind energy sciences, ecosystem and social impact and the human capital agenda. The IWG estimated that projects addressing these priorities need a combined investment of EUR 1090 million until 2030 with a split in contributions of Member States 34%, EU 25% and Industry 41%.

In 2020 the IWG Offshore Wind updated the targets in its second SET-Plan Implementation Plan for Offshore Wind. Based on current developments in industry, policy and research, the IWG Offshore Wind

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[31] JRC, Telsnig T: Wind Energy - Technology Development Report 2020, JRC123138. EUR 30503 EN. Luxembourg. URLt: https://ec.europa.eu/jrc/en/publication/wind-energy-technology-development-report-2020 (updated 2020 data).

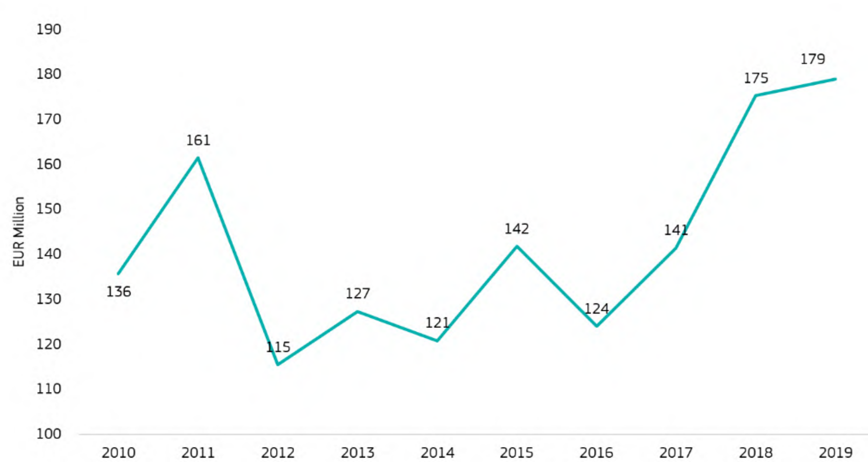
[32] https://setis.ec.europa.eu/system/files/setplan_wind_implementationplan_0.pdf.

[33] JRC, Implementing the SET Plan - Progress from the Implementation working groups, 2020, JRC118272.

foresees the main challenges to be addressed by offshore wind energy R&I in the areas of cost reduction, the increase of the system value of wind, the need to fully integrate sustainability (both from an environmental and social perspective) and the adaptability to regional conditions and regional cooperation (e.g. the North Seas Energy Cooperation, the Baltic Sea Offshore Wind, the Atlantic Action Plan, the Blue-Med). This is in line with the scientific challenges for R&I in the wind energy domain which aim for a) an improved understanding of atmospheric and wind power plant flow physics, b) the interaction between aerodynamics, structural dynamics and hydrodynamics of enlarged floating wind turbines and c) research on systems science for integration of wind power plants into the future electricity grid[34].

EU public investment has remained roughly constant, between 2012 and 2016 around EUR 120-145 million with an increasing trend since then, reaching EUR 179 million by 2019 (Figure 10). Preliminary numbers for 2020 on selected EU MSs indicate that this increase of public investments continues [35].

Figure 10: Public R&I investments in wind energy in the EU



Source: JRC

Japan led the public RD&D investments in wind energy, for the period 2017-2019, followed by Germany. The Netherlands, Denmark, Spain and France were also amongst the top ten countries investing in wind energy [36].

[34] Veers P. et al, 2019, Grand challenges in the science of wind energy, Science, doi: 10.1126/science.aau2027.

[35] JRC, commissioned by DG GROW - European climate-neutral industry competitiveness scoreboard(CIndECS) (Draft, 2021). IEA codes: 32 Wind Energy.

[36] JRC, commissioned by DG GROW -European climate-neutral industry competitiveness scoreboard(CIndECS) (Draft, 2021). IEA codes: 32 Wind Energy.

Figure 11: R&I investments in wind energy of the top EU countries compared to global competitors in the period 2017-2019[37]

Source: JRC

3.5. Private R&I funding

In Europe around 90% of the R&I funding in (onshore and offshore) wind energy comes from the private sector[38]. R&I investments in Europe are highly concentrated in Germany, Denmark and Spain, accounting for 77% and 69% of EU corporate and total R&D funding respectively[39].

Private investment into wind rotors is responsible for 1% of total investment in wind in RoW markets but ~ 20% in European markets over a 5-year period[40].

Private investment in wind energy in the EU follow closely the one of China and are much higher compared to the other major economies.

Over the last decade private R&D spending held a relatively constant level between EUR 1.6 billion and EUR 1.9 billion. Moreover, private R&D investments topped public R&D investments by a factor of 10 during this period.[41]

Patenting trends - including high value patents

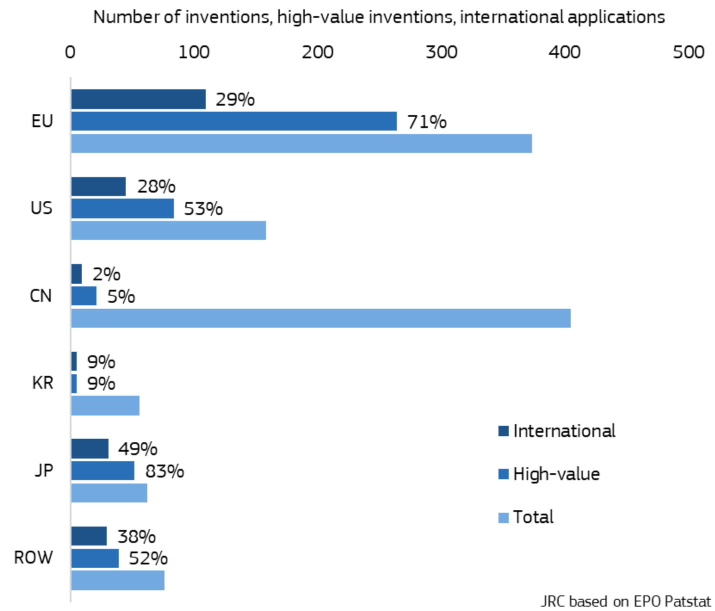
With its annual growth rate of 50% in 2000-2016, China ranks first in wind energy inventions after overtaking from the EU in 2009, which had been world leader since 2006. However, Chinese patenting

37 IEA reporting countries. IEA data on wind energy public R&I investments does not include China.
38 JRC, Low Carbon Energy Observatory, Wind Energy Technology Market Report, European Commission, 2019, JRC118314.
39 JRC, Low Carbon Energy Observatory, Wind Energy Technology Market Report, European Commission, 2019, JRC118314.
40 ICF, commissioned by DG GROW - Climate neutral market opportunities and EU competitiveness study (Draft, 2020).
41 WindEurope, Local Impact Global Leadership (2017, 2020 data update).

activity is aimed for protection in its national market. Of the more than 70% of patenting inventions filed on wind energy technologies, about 5% were high value inventions[42] (vs around 71% of high value inventions for Europe).

Europe has the highest specialisation index (indicating the patenting intensity) in wind energy compared to the rest of the world[43]. The EU wind rotors accounted for most of the high value patent application between 2015 and 2017[44].

Figure 12: Number of inventions and number/share of high-value inventions and international activity[45] in the period 2015 - 2017



Source: JRC

In the period 2015 – 2017, Denmark and Germany are the leading countries in terms of high-value inventions followed by the United States, Japan and China. 71% of all EU's inventions are high value inventions, a value only matched by Japan (83%) which however shows significantly lower invention counts in absolute terms. In this period the EU share in high-value inventions accounts for 57% followed by the US (18%), Japan (11%), China (5%) and Korea (1%). However, the EU's leadership position in high-value patents (with the major EU OEMs filing most of the inventions) is experiencing a decrease since 2012, due to strong performance in high-value patents by major companies from the US (e.g. General Electric) and Japan (e.g. Mitsubishi Heavy Industries, Hitachi).

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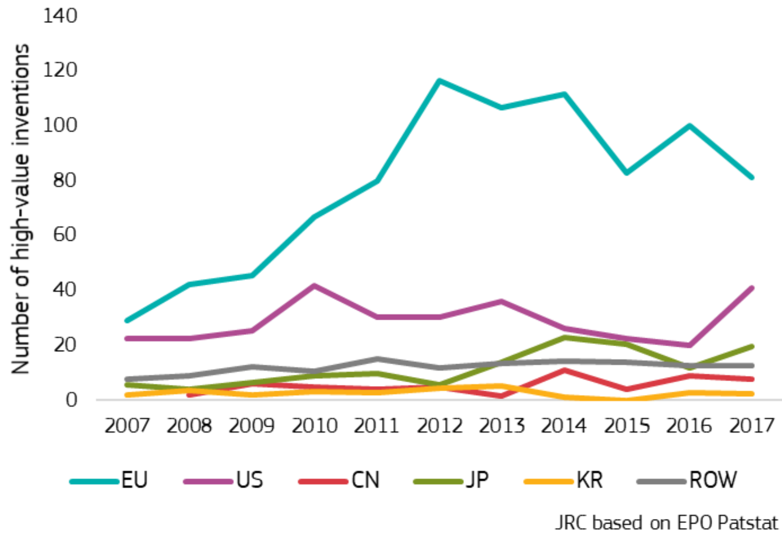
42 This means that the patents are protected in other patent offices outside of issuing country and refer to patent families that include patent applications in more than one patent office.

43 JRC, Low Carbon Energy Observatory, Wind Energy Technology Market Report, European Commission, 2019, JRC118314.

44 ICF, commissioned by DG GROW - Climate neutral market opportunities and EU competitiveness study (Draft, 2020).

45 An invention is considered of high-value when it contains patent applications to more than one patent office. Patent applications protected in a country different to the residence of the applicant are considered as international.

Figure 13: Number of high value inventions in wind energy by country

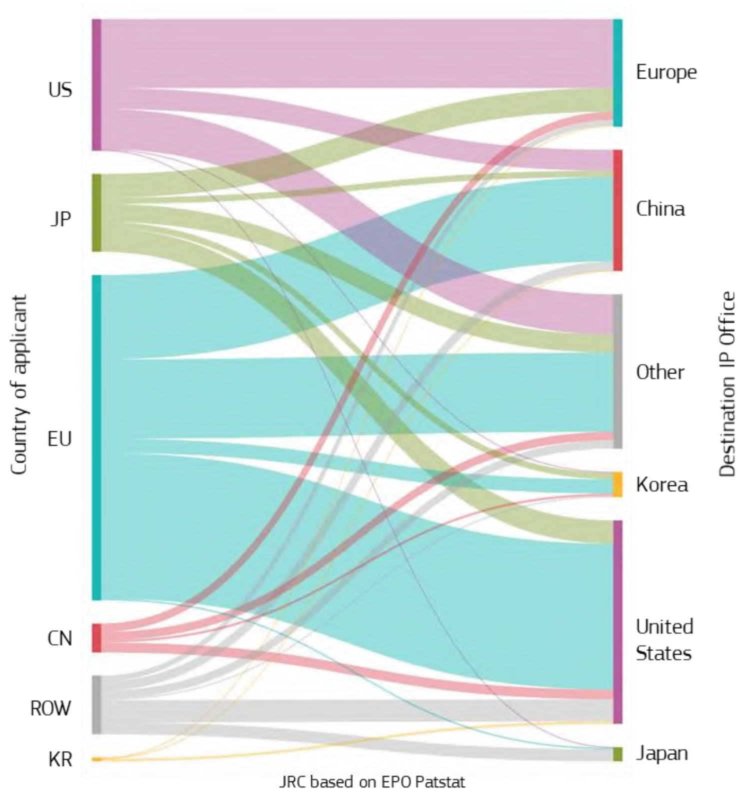


Source: JRC

Figure 14 shows the flow of high value inventions from the major economies to the main patent offices in the period 2015-2017. EU applicants show the highest share of inventions protected in United States and China, whereas the United States and Japan protect a substantial share of their inventions in Europe[46].

[46] JRC, commissioned by DG GROW -European climate-neutral industry competitiveness scoreboard (CIndECS) (Draft, 2021).

Figure 14: International protection of high-value inventions (2015-2017)



Source: JRC

3.6. Level of scientific publications

Publications in the wind sector are based on data from Scopus in the period 2015 to 2019[47,48].

The overall number of wind energy publications grew from 3 526 publications in 2015 to 4 299 publications in 2019 (+22%).

Although publication counts seem to indicate a stronger activity outside the EU countries on country level, the EU as a whole ranks first (5 406 publications, 27%). Moreover, publications from the EU countries leading in wind energy deployment and research show high citation impacts indicating a higher recognition of their scholarly outputs than those from their global competitors. Exemplarily the field weighted citation impact (FWCI)[49,50] of wind energy publications in Germany, Denmark, France, Italy,

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47 Data from Scopus, the world's largest abstract and citation database for peer reviewed publications. 2019 is the latest complete year for Scopus. Based on a citation network-based approach the research performance in the wind energy sector is measured by three main metrics: the prominence of a topic cluster, its scholarly output and the relative citation impact (FWCI) to identify relevant topic clusters to define the field of energy research.

48 JRC/Elsevier 2020, Energy research - A bibliometric analysis of topic clusters A report commissioned by the Knowledge for the Energy Union Unit (C.7) of the European Commission Joint Research Centre, Invitation to tender - JRC/PTT/2020/VLVP/1016.

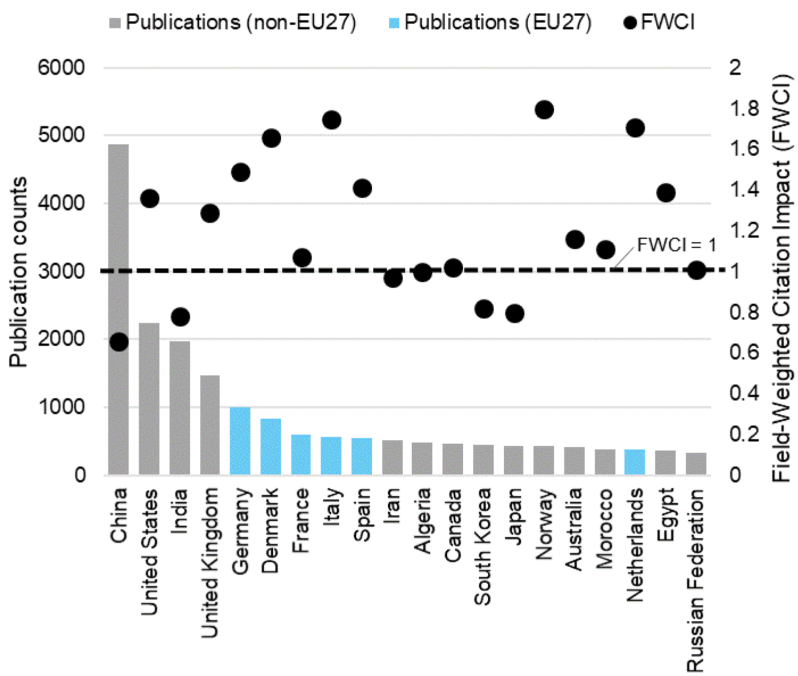
49 Field-Weighted Citation Impact is the ratio of the total citations actually received by the denominator's output, and the total citations that would be expected based on the average of the subject field.

50 Field Weighted Citation Impact (FWCI) is an indicator of the citation impact of a publication. It is calculated by comparing the number of citations actually received by a publication with the number of citations expected for a publication of the same

Spain and the Netherlands ranges between 1.1 and 1.75, whereas only the United States (1.36), Norway (1.8) and the United Kingdom (1.3) show comparable values. Notably research from major other global wind markets such as China (0.66), India (0.78), South Korea (0.82) and Japan (0.8) perform significantly below the average FWCI (Figure 15).

Among EU countries, Germany (1 002) ranks first in terms of publication counts, followed by Denmark (828) and France (599). Moreover multiple Member States are recognised as having a high impact with their publication activity, with 12 Member States scoring above the average FWCI (Figure 16).

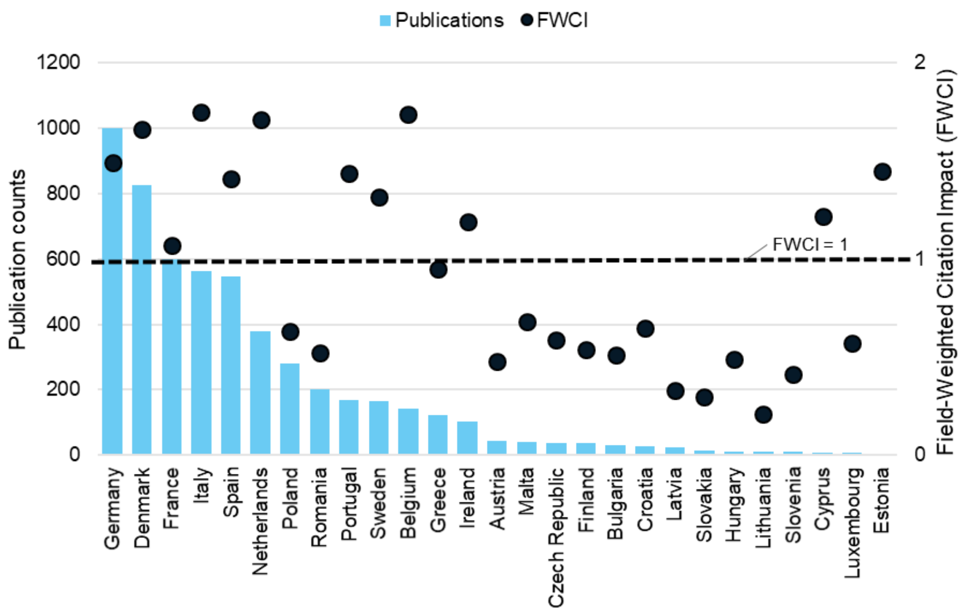
Figure 15: Global wind energy research outputs and their respective recognition (based on FWCI) in the period 2015 to 2019



Source: JRC/Elsevier 2020

document type, publication year, and subject. The indicator is always defined with a world average baseline of 1.0. An FWCI of 1.0 indicates that the publications have been cited the same amount, on average, as the world average for similar publications.

Figure 16: Wind energy research outputs in EU countries and their respective recognition (based on FWCI) in the period 2015 to 2019

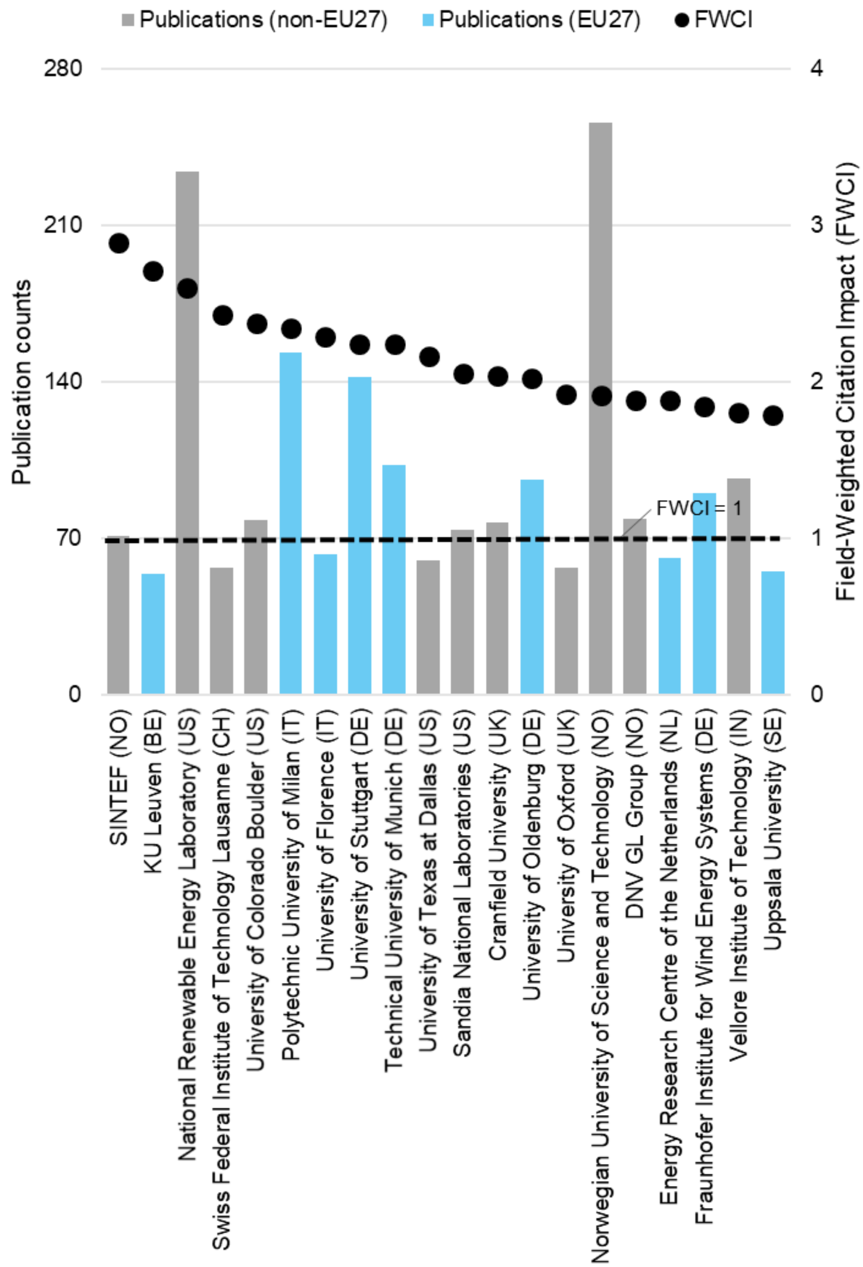


Source: JRC/Elsevier 2020[51]

Research of EU organisations active in wind energy are among the most recognised in the field. In terms of citation impact 9 organisations within the Top20 stem from the EU countries. The Norwegian SINTEF (2.89) ranks first in terms of FWCI followed by KU Leuven (2.71) from Belgium and the US National Renewable Energy Laboratory (NREL) (2.6).

[51] JRC/Elsevier 2020, Energy research - A bibliometric analysis of topic clusters A report commissioned by the Knowledge for the Energy Union Unit (C.7) of the European Commission Joint Research Centre, Invitation to tender - JRC/PTT/2020/VLVP/1016.

Figure 17: Recognition of scientific output (based on FWCI) of the leading wind energy research organisations in the period 2015 to 2019



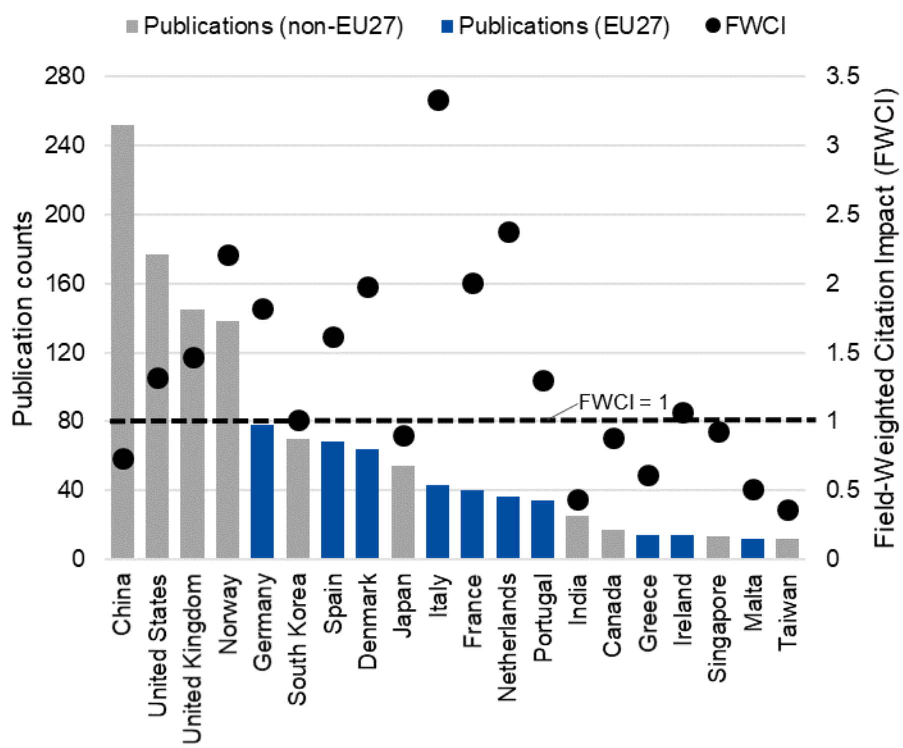
Source: JRC/Elsevier 2020[52]

[52] JRC/Elsevier 2020, Energy research - A bibliometric analysis of topic clusters A report commissioned by the Knowledge for the Energy Union Unit (C.7) of the European Commission Joint Research Centre, Invitation to tender - JRC/PTT/2020/VLVP/1016[52] Publications which include the three keyphrases 'offshore wind turbine' 'semisubmersible', tension leg platform'.

Within the wind sector, offshore wind related research is the most published in the period 2015 to 2019. Topics containing offshore wind related key-phrases (e.g. combinations of 'offshore wind farm', 'offshore wind turbine', 'condition monitoring, 'semisubmersible', tension leg platform') see an increased publication activity (about 2 200 scholarly outputs) and have a relatively high citation impact as compared to the average world citation impact.

As an example, the number of publications which include the three key-phrases 'offshore wind turbine' 'semisubmersible', tension leg platform' are depicted in Figure 22 and Figure 23. Similar as in the entire wind energy topic the leading countries can be found outside the EU, with China, the United States, the United Kingdom and Norway publishing significantly more than single EU countries. Again the EU as a whole outnumbers its competitors with about 420 publications in the period 2015 -2019. Moreover 8 out of 10 MSs are recognised as high impact publishers which can only be matched by competitors from the United States, the United Kingdom and Norway (Figure 18).

Figure 18: Global offshore wind energy research outputs (in the area of WT and support structures) and their respective recognition (based on FWCI) in the period 2015 to 2019[53]



Source: JRC/Elsevier 2020[54]

This trend can be also be observed when analysing the leading organisations publishing scientific output in offshore wind in the period 2015 to 2019. The Norwegian University of Science and Technology (NO) leads with 93 publications followed by Shanghai Jiao Tong University (CN, 87) and University of

[53] Publications which include the three keyphrases 'offshore wind turbine' 'semisubmersible', tension leg platform'.

[54] JRC/Elsevier 2020, Energy research - A bibliometric analysis of topic clusters A report commissioned by the Knowledge for the Energy Union Unit (C.7) of the European Commission Joint Research Centre, Invitation to tender - JRC/PTT/2020/VLVP/1016

Strathclyde (UK, 43). With SINTEF (NO) a Norwegian organisation is also leading in terms of citation impact (3.86), followed by National Renewable Energy Laboratory (NREL) (2.76) and the Technical University of Denmark (DK) (2.51).

3.7. Final Considerations

In 2020, the EU installed 10.5 GW of wind power capacity (both onshore and offshore), bringing its cumulative wind power capacity to 178.7 GW.

The increase in deployment was even more pronounced for the offshore wind sector surging from 1.6 GW cumulative capacity in 2010 to 14.6 GW in 2020. Projected capacity in offshore wind according to CTP-MIX scenario is of 73 GW in 2030, 290 GW in 2050. Following current national targets as expressed in the MSs National Energy Climate Plans (NECPs) suggest that the ORES targets for 2030 (at least 60 GW) can be achieved. Most of the offshore wind installations deployed until 2030 will be located in the North Sea (47 GW), yet substantial capacities can be expected in other sea basins particularly in the Baltic Sea (21.6 GW) and in the Atlantic Ocean (11.1 GW) and to some extent in the Mediterranean Sea (2.7 GW) and the Black Sea (0.3 GW). The move to new sea basins will require further developments of floating technology and the development of port infrastructure.

4. VALUE CHAIN ANALYSIS OF THE ENERGY TECHNOLOGY SECTOR

4.1. Introduction/summary

This section includes the EU subsidiaries of non EU multinationals (as they also create employment and value added here); this section excludes non-EU subsidiaries of the EU multinationals; for companies manufacturing a large portfolio of products, it includes only the part of their activities related to the segment.

Since the value chains of offshore and onshore wind largely overlap, this section addresses both of them. For the onshore-specific part of the value chain, please refer to Value chain analysis in the chapter on onshore wind.

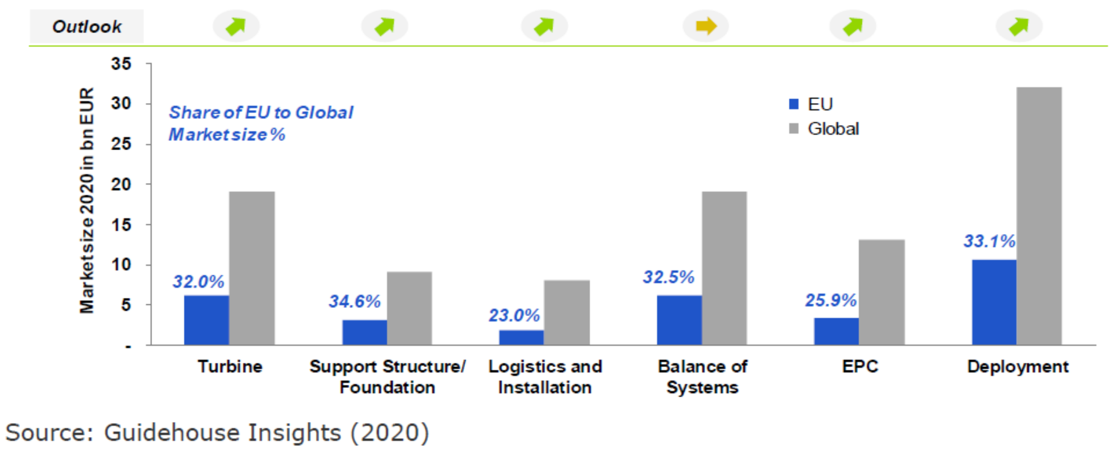
Europe is a recognized market leader in the wind energy: 48% of active companies in the wind sector are headquartered in the EU compared to the RoW[55]. European manufacturers capture around 35% to 40% of the global wind turbine value chain (China almost 50%). The European OEMs in the wind energy sector have held a leading position in the last few years although their market share has decreased in 2018 mainly in favour of the Chinese OEMs. Within the next decade, Europe will maintain its leadership position in annual growth, yet China, Asia Pacific and North America are expected to develop a significant market size (i.e. installed capacity) of more than 50%[56]. Among the top 10 OEMs in 2018, European OEMs led with 43 % of market share, followed by the Chinese (32 %) and North American (10 %) companies. EU offshore wind turbine OEMs held a leading market share (in terms of WT deployed) in the last decade, however in 2020 China overtook EU for the first time securing a market share of 47% compared to EU OEMs with 39%.

A recent study estimates the annual market size (in terms of revenues) of the EU in offshore wind to almost double from about EUR 31.3 billion in 2020 to about EUR 59.2 billion in 2030. In 2020 this

[55] ICF, commissioned by DG GROW - Climate neutral market opportunities and EU competitiveness study (Draft, 2020).
[56] GWEC, Global Offshore Wind Report 2020, 2020.

represents about 31.2% of the global market. Across the different value chain segments the global share of the EU market ranges from 23% (Logistics & Installation) to 34.6% (Support Structures) (Figure 19)[57].

Figure 19: Share of EU Market Size to Global Market, Value Chain Segment: 2020



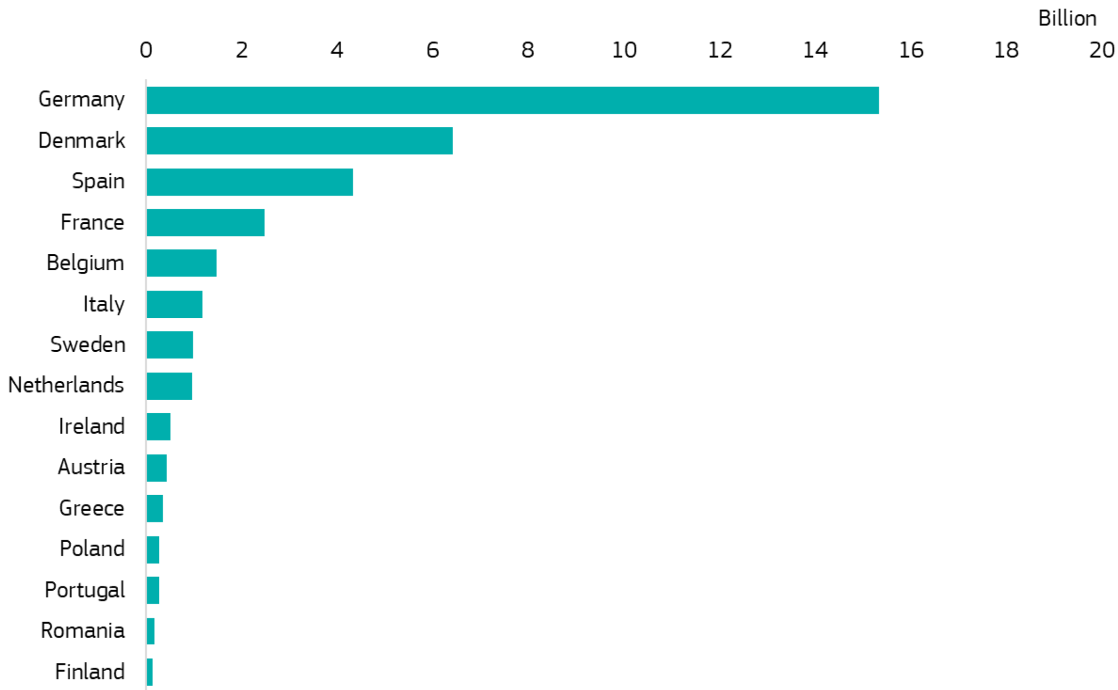
Source: ASSET Study commissioned by DG ENERGY - Gathering data on EU competitiveness on selected clean energy technologies (Draft, 2020)

4.2. Turnover

In 2018, the EU turnover amounted to EUR 36 billion, a 2% drop since 2015.

[57] EC/Guidehouse 2020, ASSET Study on Gathering data on EU Competitiveness on selected Clean Energy technologies, ISBN 978-92-76-27325-7 doi: 10.2833/94919 MJ-03-20-496-EN-N.

Figure 20: Turnover of the wind energy value chain in the Top15 EU countries in 2018



Source: JRC[58]

4.3. Gross value added growth

Most European manufacturing facilities are located in the country of the company's headquarter or countries with increased wind energy deployment. 48% of active companies in the wind sector are headquartered in the EU. Specifically for wind rotors, the share of EU companies is 58%, with most headquartered in Germany, Denmark and France. Europe is leading in all parts of the value chain for sensing and monitoring systems for onshore wind turbines, including research and production[59].

OEMs also locate their manufacturing facilities in countries where they supply wind turbine components and services, except for Gamesa (ES) and Senvion SE (DE), whose manufacturing facilities are only placed in their country of origin. Smaller OEMs tend to locate their facilities around their headquarters[60] [61].

The EU wind sector has shown its ability to innovate: the EU is leading in the parts of the value chain dealing with sensing and monitoring systems for onshore wind turbines, including research and production. Also, the EU wind industry has high manufacturing capabilities in components with a high

58 JRC, commissioned by DG GROW -European climate-neutral industry competitiveness scoreboard (CIndECS) (Draft, 2021). IEA codes: 32 Wind Energy.

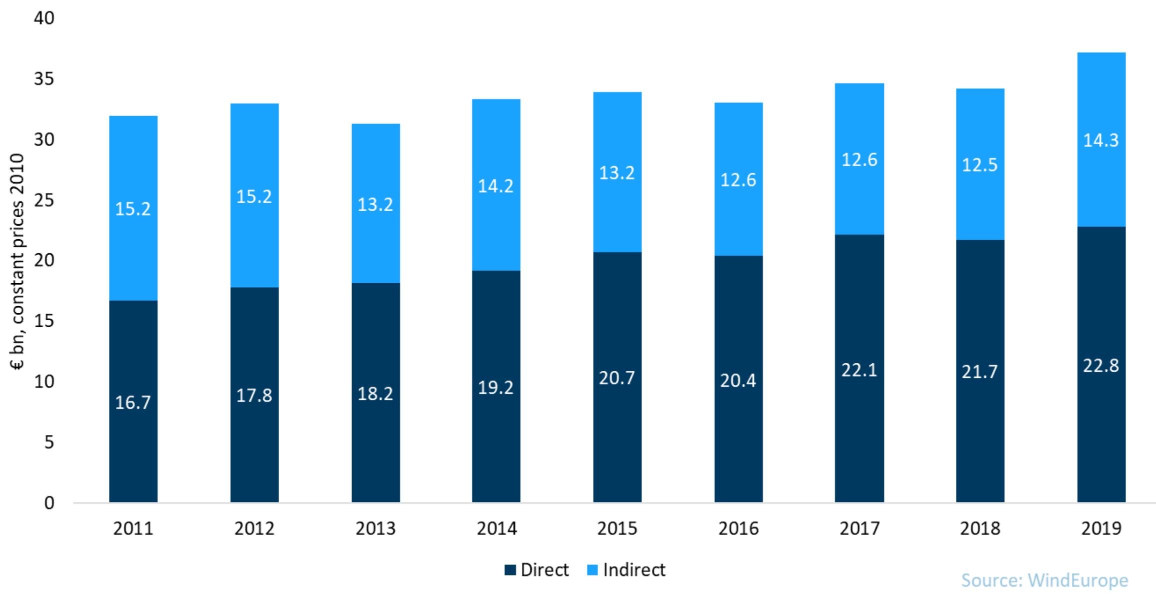
59 ASSET Study commissioned by DG ENERGY - Gathering data on EU competitiveness on selected clean energy technologies (Draft, 2020).

60 WindEurope.

61 WindEurope, Local Impact Global Leadership (2017, 2020 data update).

value in wind turbine cost (towers, gearboxes and blades), as well as in components with synergies to other industrial sectors (generators, power converters and control systems).

Figure 21: Gross Value Added of the European wind energy industry



Source: WindEurope

4.4. Number of EU companies

In the last years the EU offshore market further consolidated following Senvion's insolvency at the end of 2019 and Vestas buying out Mitsubishi Heavy Industries (MHI) from their offshore wind joint venture in 2020 [62] [63]. With SiemensGamesa RE, Vestas and General Electric RE there are currently three offshore original equipment manufacturers (OEMs) with manufacturing capabilities in EU waters. So far, offshore wind OEMs located their factories mainly around the North Sea and Baltic Sea; however, suppliers of subcomponents can be found all over Europe, even in landlocked countries (Figure 24). In January 2021, Chinese offshore wind manufacturer MingYang entered the EU offshore wind market by securing a deal to supply 10 offshore wind turbines to the 30MW Port of Taranto (Beleolico) offshore wind project (replacing the previously planned Senvion turbines) which will be the first commercial EU offshore wind farm in the Mediterranean Sea (end of 2021). MingYang will execute the project from its EU HQ in Germany while turbines seem to be shipped from China. Moreover, monopiles will be provided by a Spanish manufacturer (Haizea Wind Group)[64] [65].

[62] WPM 2020a, Windpower Monthly review of 2019 -- part 2 https://www.windpowermonthly.com/article/1669604/windpower-monthly-review-2019-part-2#Senvion, (accessed on 04/01/2021)

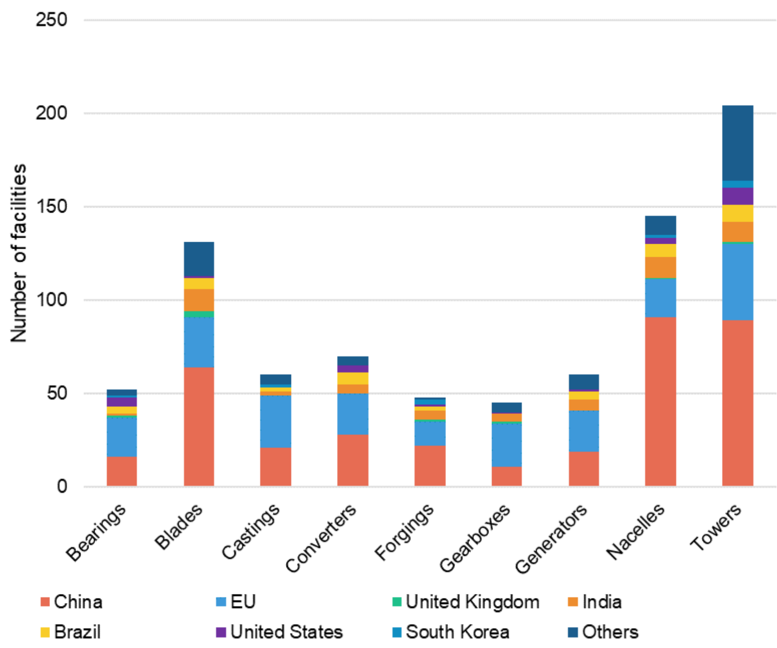
[63] WPM 2020b, Vestas closes deal to buy out MHI from offshore wind venture https://www.windpowermonthly.com/article/1698632/vestas-buys-mhi-offshore-wind-joint-venture, (accessed on 04/01/2021)

[64] https://www.offshore-energy.biz/first-mediterranean-sea-offshore-wind-project-switches-turbine-supplier/ (accessed on 28/01/2021).

[65] https://www.windpowermonthly.com/article/1705391/mingyang-enters-european-offshore-wind-market (accessed on 28/01/2021).

In total, 155 facilities are dedicated to onshore wind and a further 66 supply to both onshore and offshore wind.[66, 67, 68].

Figure 22: Operational manufacturing facilities of wind energy components in 2019



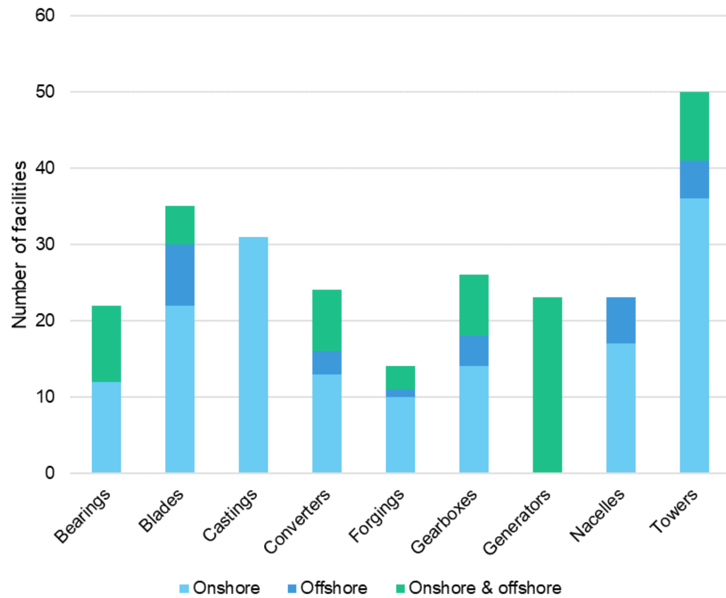
Source: WindEurope

66 WindEurope/Wood Mackenzie (2020), Wind energy and economic recovery in Europe - How wind energy will put communities at the heart of the green recovery, October 2020.

67 WindEurope, Local Impact Global Leadership (2017, 2020 data update).

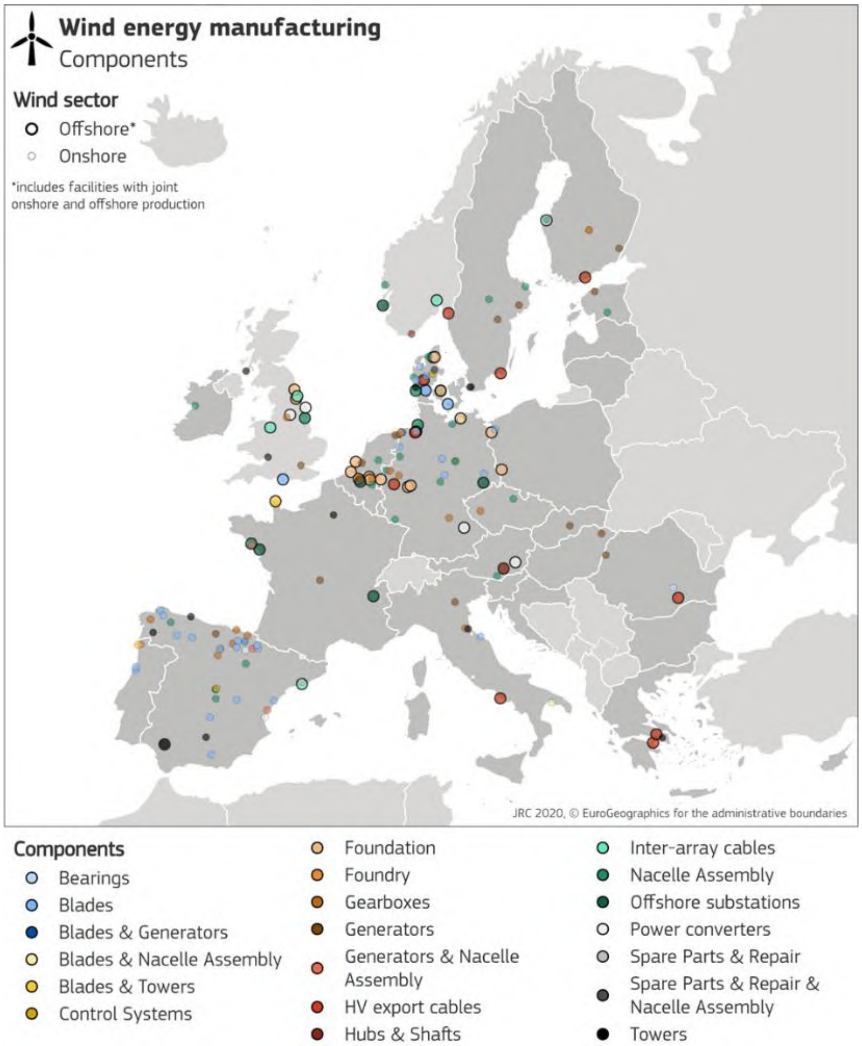
68 JRC, Low Carbon Energy Observatory, Wind Energy Technology Market Report, European Commission, 2019, JRC118314 (data update July 2020).

Figure 23: Number of European facilities split by value chain segment in 2019



Source: WindEurope

Figure 24: Location of manufacturing facilities of onshore and offshore wind energy components in Europe in 2020



Source: JRC

The increase in rated capacity and blade size of offshore wind turbines further amplifies the need to upsize the infrastructure in existing and future ports hosting manufacturing facilities of large subcomponents (blades and nacelles) or final nacelle assembly. Today the three main offshore OEMs have an estimated 6.5 to 8 GW of nacelle assembly capacity at European ports[69].

This means that European offshore manufacturing at ports will need to grow substantially to serve annual capacity additions up to an estimated 16 GW to satisfy the demand in the period 2030-2050.

[69] WindEurope/Wood Mackenzie (2020), Wind energy and economic recovery in Europe - How wind energy will put communities at the heart of the green recovery, October 2020.

Table 1: Location and production capacity of the leading offshore wind manufacturers (nacelles and blades).

Offshore manufacturer	**Location/port of Blade or Nacelle assembly factories**	**Country**	**Sea basin**	**Offshore nacelle production capacity estimate [GW/year]**
Siemens Gamesa	Bremerhaven	Germany	North Sea	4
	Cuxhaven	Germany	North Sea	
	Aalborg	Denmark	North Sea (Kattegat)	
	Alexandra -Green port Hull	United Kingdom	North Sea	
Vestas	Port of Lindø (Munkebo)	Denmark	Baltic Sea (Danish straits - Great Belt)	2
	Nakskov (Zealand)	Denmark	Baltic Sea	
	Esbjerg (Sydjylland)	Denmark	North Sea	
	Isle of Wight	United Kingdom	North Sea (English Channel)	
GE Renewable & LM Wind Power	Cherbourg	France	North Sea (English Channel)	0.5 (2)
	Saint Nazaire	France	Atlantic Ocean	
	Lunderskov	Denmark	Baltic Sea (not at coast, close to Kolding)	
	Castellón	Spain	Mediterranean Sea (not at coast)	

Sources: JRC Wind manufacturer database (2021) and WindEurope (2020)

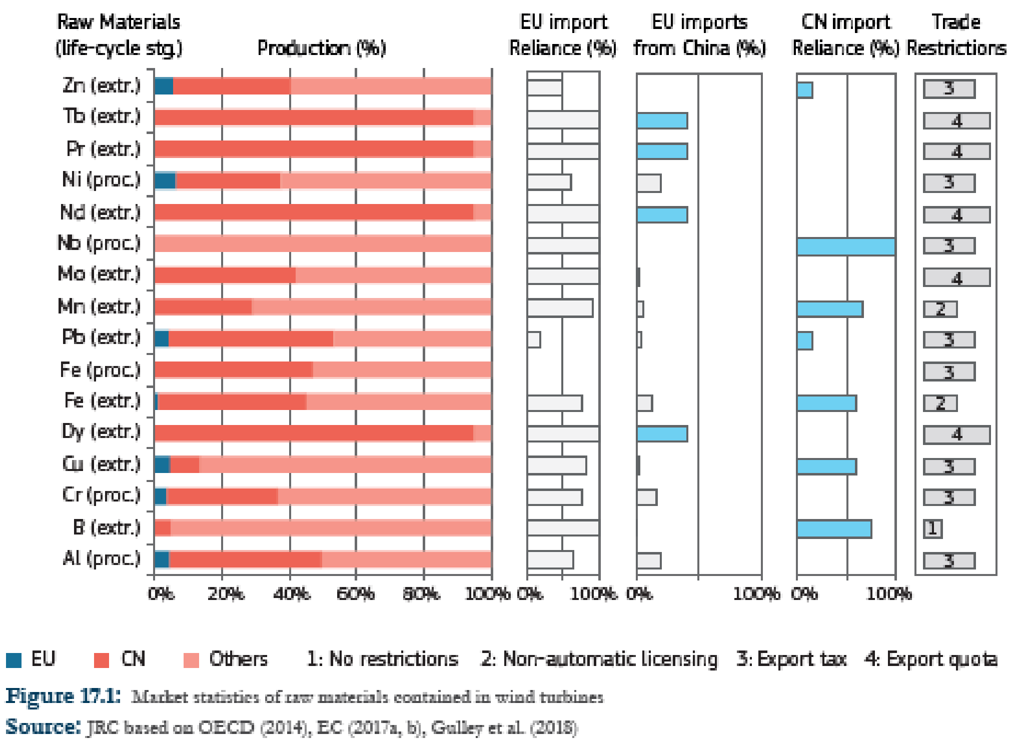
Critical raw material dependence

A potential risk of offshore wind energy concerns the supply of raw materials. This paragraph considers the critical raw material dependence of both offshore and onshore wind energy since their raw material usage is similar to a large extent. EU companies are ahead of their competitors in providing offshore generators of all power ranges, due to a well-established European offshore market and the increasing size of newly installed turbines[70]. Wind turbine blades are often made up of composite materials, which are difficult to recycle/re-manufacture. 2.5 million tonnes of composite material are in use in the wind sector globally. 14 000 wind turbine blades will be decommissioned in Europe the next five years. This is a major challenge, both environmentally and economically. Because there is a need to reduce polluting extraction of raw materials and to decrease dependency of the European economy may on raw materials produced in third countries. Applying circular economy approaches, along the life-cycle of installations, is of key importance.

[70] JRC, Low Carbon Energy Observatory, Wind Energy Technology Market Report, European Commission, 2019, JRC118314.

Currently, there is no European production of the four main materials used for the production of wind rotors (i.e. boron, molybdenum, niobium and Rare Earth Elements (REEs)). For other raw materials, the EU share of global production is below 1%[71]. China is the largest global supplier for about half of the raw materials needed for wind generators. The EU import reliance for processed REEs (especially neodymium, dysprosium, and praseodymium) used for permanent magnets, is 100%, with 98% being supplied by China (Figure 25). Future materials shortage or supply disruptions could prove to be a risk, given the low substitutability for many raw materials, especially those in high-tech applications[72]. The European Commission proposes an action plan in its communication on critical raw materials[73] to address the issues of overdependence on single supplier countries. Likewise, circularity, recycling and substitution are key R&I technological priorities. In 2022, a call for projects is expected under the Horizon Europe programme, particularly dealing with the R&I challenges of the wind community on large-scale recycling and innovative substitution approaches towards full circularity.

Figure 25: Market statistics of raw materials contained in wind turbines



Source: JRC[74]

4.5. Employment in the selected value chain segment(s)

Wind is a strategic industry for Europe. It is estimated the sectors offers between 240 000 and 300 000 quality jobs[75], 77 000 of which related to offshore wind, contributing EUR 37 billion to EU GDP. Each new

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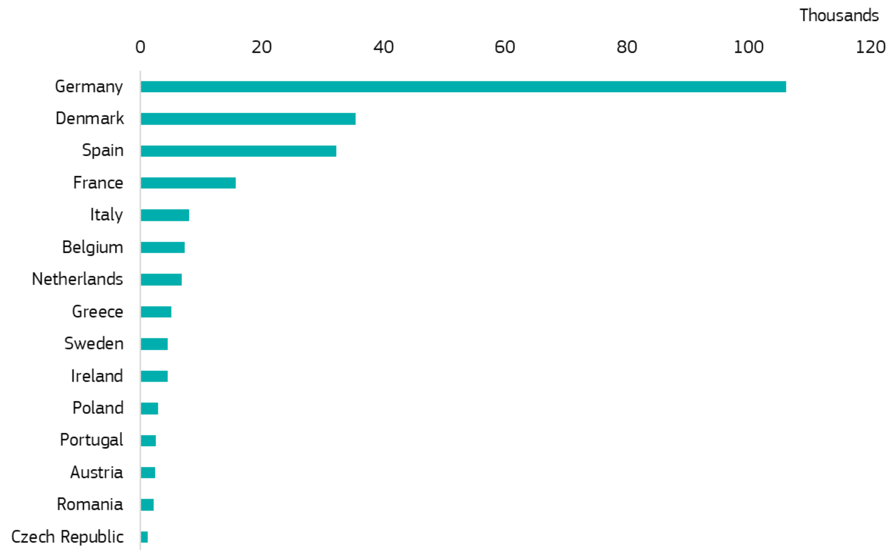
71 JRC, China – Challenges and Prospects from an Industrial and Innovation Powerhouse, 2018, JRC116516.
72 JRC, interactive tool: Materials that are critical to our green future.
73 COM(2020) 474 final.
74 JRC, China – Challenges and Prospects from an Industrial and Innovation Powerhouse, 2018, JRC116516.

turbine generates on average EUR 10 million economic activity. Its 248 factories are all over Europe including in economically-deprived regions. Wind is a major European exporter: half the world's wind power comes from turbines made by European companies. A growth of 2% was observed between 2015 and 2017[76].

Figure 26: Direct and indirect jobs in the EU wind energy value chain in 2018

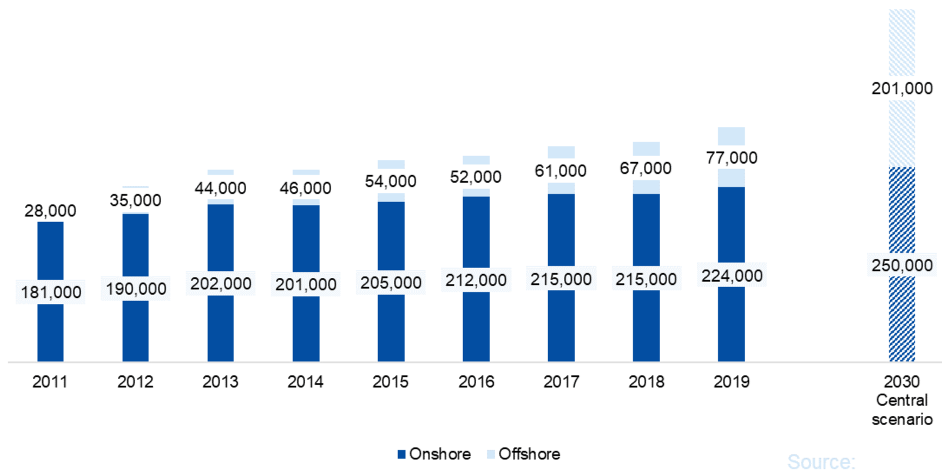


Source: JRC, commissioned by DG GROW -European climate-neutral industry competitiveness scoreboard(CIndECS) (Draft, 2021). IEA codes: 32 Wind Energy

[75] These are estimates using different methods WindEurope estimates the figure to be 300 000 (https://windeurope.org/about-wind/wind-energy-today/) while Eurobarometer estimates the figure to be 243 000 jobs.

[76] JRC, commissioned by DG GROW -European climate-neutral industry competitiveness scoreboard(CIndECS) (Draft, 2021). IEA codes: 32 Wind Energy.

Figure 27: Jobs in the European onshore and offshore wind energy industry (in full-time equivalents)



Source: WindEurope

4.6. Energy intensity considerations, and labour productivity considerations

<u>Labour productivity</u>

Figures on labour productivity in the offshore wind sector measured in direct full term equivalents (FTE) per MW installed are declining over the latest years as the learning effect improves with more capacity installed in the sector. Yet the scope and boundary conditions of these studies differ significantly ranging from case studies on project level to econometric models and scenario based projections estimating the employment factor on country or sector level (Figure 28). Direct job estimates on single projects (given in full time equivalent years) range from 16.3 – 15.8 $FTE/MW_{project}$ for projects in the period 2013-2016[77] [78]. Due to productivity improvements some studies estimate a further decrease in specific direct labour requirements to 9.5 $FTE/MW_{project}$ by 2022[79]. Although these numbers show the expected learning effect they cannot directly be used to estimate the number of total jobs in the entire industry as the extrapolation from project-level capacity to installed capacity in the market would lead to double counting and thus an overestimation.

Current econometric models estimating the number of jobs using employment factors, trade data and/or contribution to the GDP of the sectors involved show direct employment figures declining from about 4 $FTE/MW_{Installed}$ in 2010 to a range of 1.8 to 2.9 $FTE/MW_{Installed}$ in 2020. When including indirect employment effects range between 2.2 to 5.1 $FTE/MW_{Installed}$ seems plausible [80] [81] [82] [83] [84]. Scenario-based analyses estimate a further decline in direct labour productivity to about 1.2 $FTE/MW_{Installed}$ by 2050.

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77 QBIS (2020) Socio-economic impact study of offshore wind.

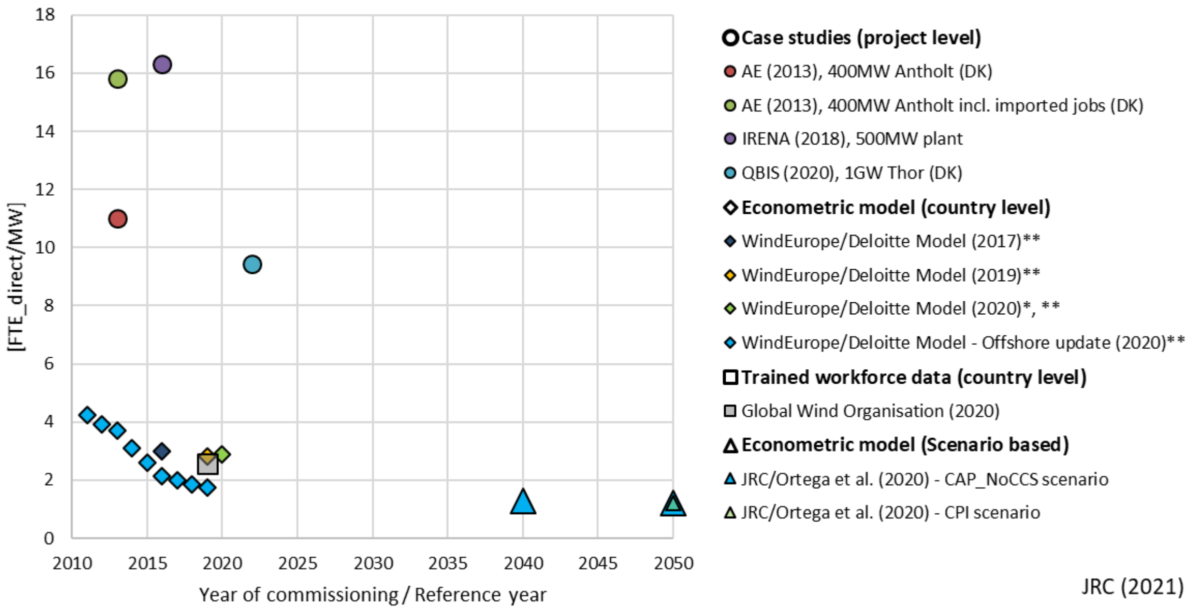
78 IRENA (2018), Renewable Energy Benefits: Leveraging Local Capacity for Offshore Wind, IRENA, Abu Dhabi.

79 QBIS (2020), Socio-economic impact study of offshore wind.

80 Deloitte/WindEurope (2017), Local impact, global leadership – The impact of wind energy on jobs and the EU economy.

81 WindEurope (2020), The EU Offshore Renewable Energy strategy, June 2020. Updated figures on employment using the Deloitte/WindEurope model.

Figure 28: Estimated direct person years (FTE/MW) for offshore wind based on different case studies and modelling approaches



** Includes direct jobs from wind turbine component manufacturers where a split between onshore& offshore is not possible*
*** Direct jobs estimated based on contribution to the GDP of the sectors involved in the industry and annual reports*

Source: JRC

Energy intensity

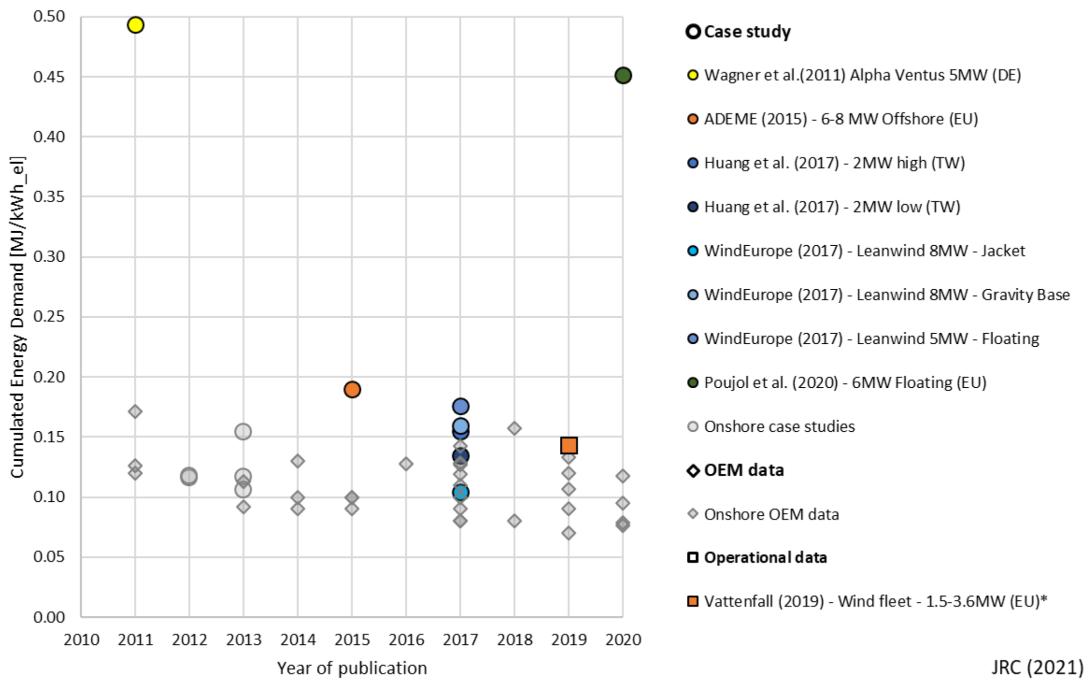
The energy intensity is analysed based on the cumulated energy demand (CED) along the lifecycle of offshore wind. The majority of life cycle analyses finds the cumulated energy demand between 0.1 and 0.19 MJ_{input}/kWh_{el}, a comparable order of magnitude when compared with the cumulated energy demand of current onshore wind turbines (see grey dots in Figure 29). Notably data points on floating offshore show higher values than bottom fixed offshore wind in terms of cumulated energy demand. However, a decisive factors influencing the CED, besides the life cycle inventory data used, is the chosen system boundary and assumed geographical reference (e.g. countries electricity mix and wind resource, which becomes apparent in the outlier value of Wagner et al (2011) which includes also the connection of the Alpha Ventus wind farm to the electricity grid). Given the small amount of available LCA data in offshore wind no clear trend in the CED can be observed, neither in terms of evolution in time nor in respect to the growth in turbine size (Figure 29).

[82] Ortega et al. (2020), Analysing the influence of trade, technology learning and policy on the employment prospects of wind and solar energy deployment: The EU case. Renewable and Sustainable Energy Reviews 122 (2020) 109657, Available https://doi.org/10.1016/j.rser.2019.109657.

[83] JRC 2020, Facts and figures on Offshore Renewable Energy Sources in Europe, JRC121366.

[84] GWO (2020), Powering the Future – Global Offshore Wind Workforce Outlook 2020-2024.

Figure 29: Evolution (top) of Cumulated Energy Demand (MJ_primary energy/kWh_el) of offshore wind turbines and the respective rated capacity (bottom) based on different case studies and OEM data



* includes 57% electricity generation from offshore wind

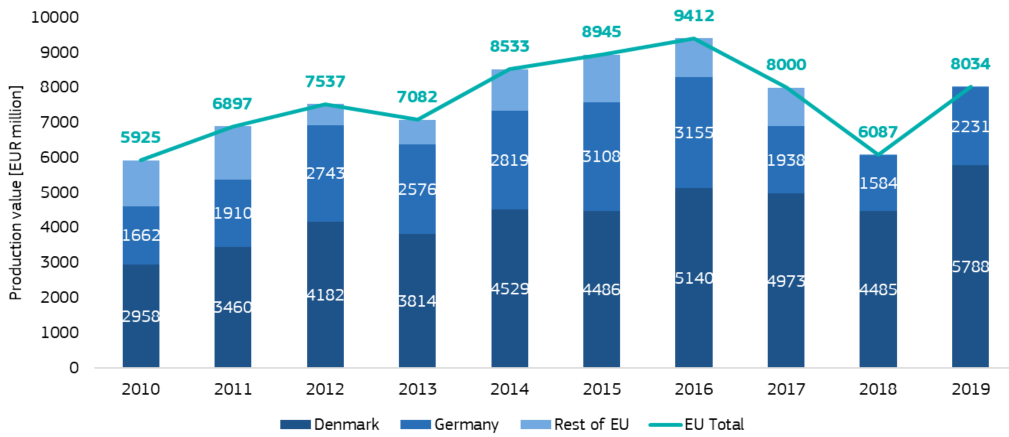
Source: JRC

4.7. Community Production (Annual production values)

The total production value of the wind energy value chain in the EU is shown in Figure 30. It remains at a relatively high level in the order of EUR 8 billion per year, since 2014[85].

[85] JRC, commissioned by DG GROW -European climate-neutral industry competitiveness scoreboard(CIndECS) (Draft, 2021). IEA codes: 32 Wind Energy.

Figure 30 Total Production Value of the wind energy value chain in the EU



Source: JRC[86]

4.8. Final Considerations

Wind is a strategic industry for Europe. It is estimated the sectors offers between 240 000 and 300 000 jobs. Most European manufacturing facilities are located in the country of the company's headquarter or countries with increased wind energy deployment. 48% of active companies in the wind sector are headquartered in the EU. There are 248 operational manufacturing facilities in Europe (30% of all facilities). 155 facilities are dedicated to onshore wind and a further 66 supply to both onshore and offshore wind.

In 2018 the wind energy value chain in the EU produced a turnover of EUR 36 billion.

The EU wind sector has shown its ability to innovate: the EU is leading in the parts of the value chain dealing with sensing and monitoring systems for onshore wind turbines, including research and production. Also, the EU wind industry has high manufacturing capabilities in components with a high value in wind turbine cost (towers, gearboxes and blades), as well as in components with synergies to other industrial sectors (generators, power converters and control systems).

IWG Offshore Wind foresees the main challenges to be addressed by offshore wind energy R&I in the areas of cost reduction, the increase of the system value of wind, the need to fully integrate sustainability (both from environmental and social perspective) and adaptability to regional conditions and regional cooperation (e.g. the North Seas Energy Cooperation, the Baltic Sea Offshore Wind, the Atlantic Action Plan, the Blue-Med).

5. Global Market Analysis

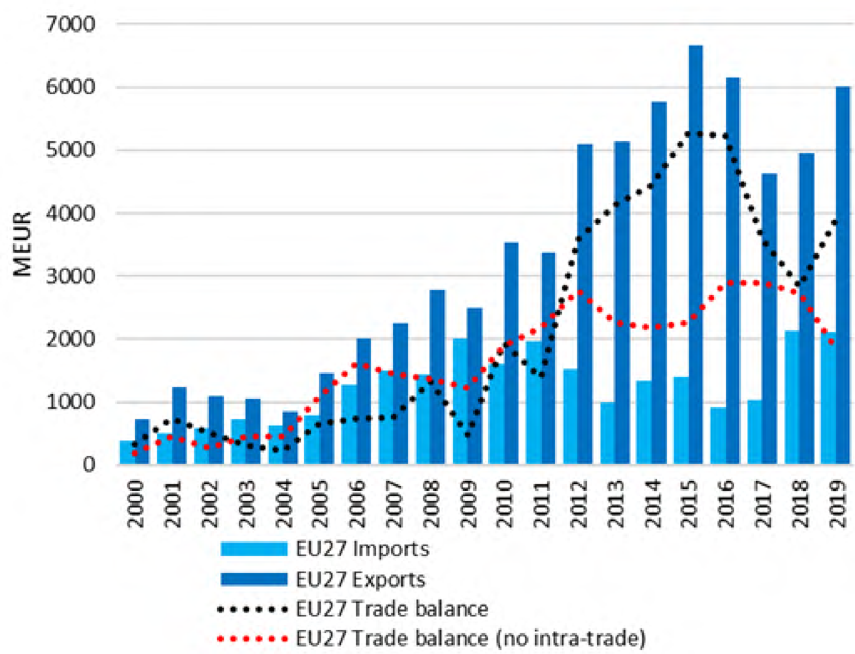
5.1. Trade (imports, exports)

The EU has had a positive trade balance in wind energy related equipment in the last 20 years. Yet there is some stagnation in the growth of this indicator (Figure *31*). This is partially explained by third

[86] JRC, commissioned by DG GROW -European climate-neutral industry competitiveness scoreboard(CIndECS) (Draft, 2021). IEA codes: 32 Wind Energy.

countries catching up on the EU's first mover advantage, but also by third country policies aimed at protecting their domestic market or forcing EU companies to localise production capacity (e.g. through local content requirements). To illustrate, exports of wind generating sets to China have fallen drastically since 2007 after local content requirements were introduced, and have not recovered. On the opposite, 21% of Chinese wind-related exports in 2018 were destined for the EU market.

Figure 31: Import, export and trade balance in wind energy related equipment (850231, Electric generating sets; wind-powered) of the EU

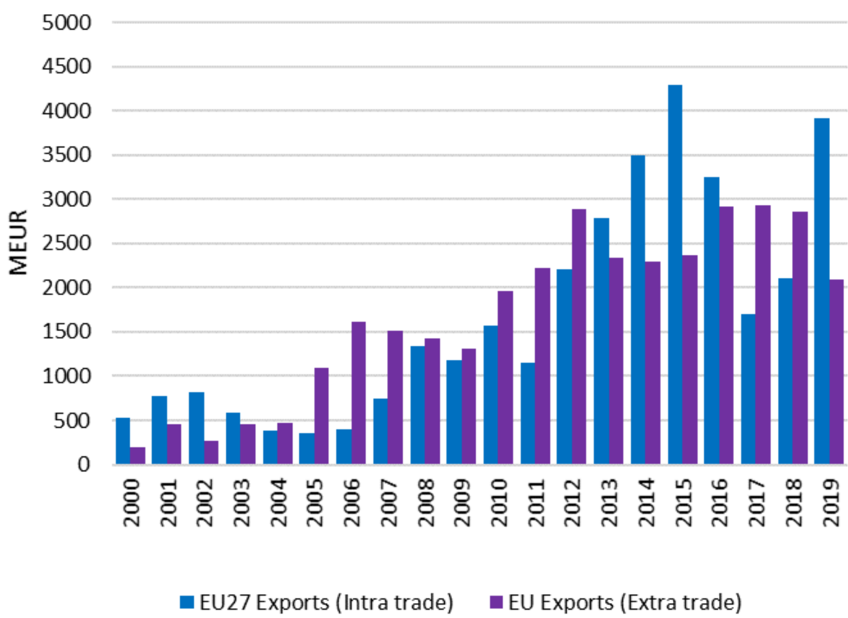


Source: JRC based on Eurostat (Comext)

Imports of wind related goods is mainly done among EU countries (intra trade). In 2019 only 11% of wind related goods came from countries outside the EU, with the majority stemming from China (87%) and India (12%). Imports from the US ranging in the last decade from 3% to 9% dropped in 2019 to 0.2%.

Exports of wind related goods to countries outside the EU (extra trade) show a positive development since 2000. However in the last decade some stagnation can be witnessed (Figure 32). Since 2010 most EU exports are shipped to the UK (25%) followed by the United States (13%), Turkey (9%) and Canada (9%). Only 0.6% of all EU exports on wind related goods are exported to China in the period 2010-2019.

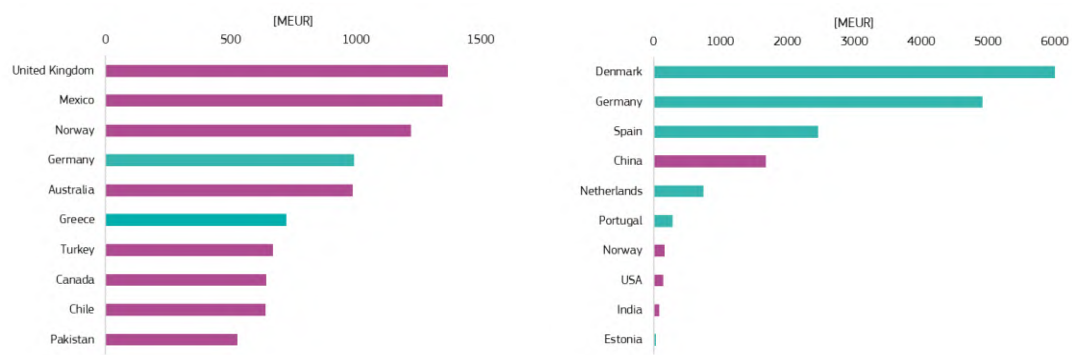
Figure 32: Export of wind energy related equipment (850231, Electric generating sets; wind-powered) among EU countries (intra-trade) and export to countries outside the EU (extra-trade)



Source: JRC based on Eurostat (Comext)

On a single country level the United Kingdom, Mexico and Norway rank among the top importers of wind related goods in the period 2017 – 2019. On the contrary six EU countries can be found among the Top10 global exporters of wind related goods during that period (Figure 33)[87].

Figure 33: Top10 global importers (left) and Top10 global exporters of wind energy related equipment (850231, Electric generating sets; wind-powered) in the period 2017 - 2019



Source: JRC

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87 JRC, commissioned by DG GROW -European climate-neutral industry competitiveness scoreboard (CIndECS) (Draft, 2021).

5.2. Global market leaders vs. EU market leaders (market share)

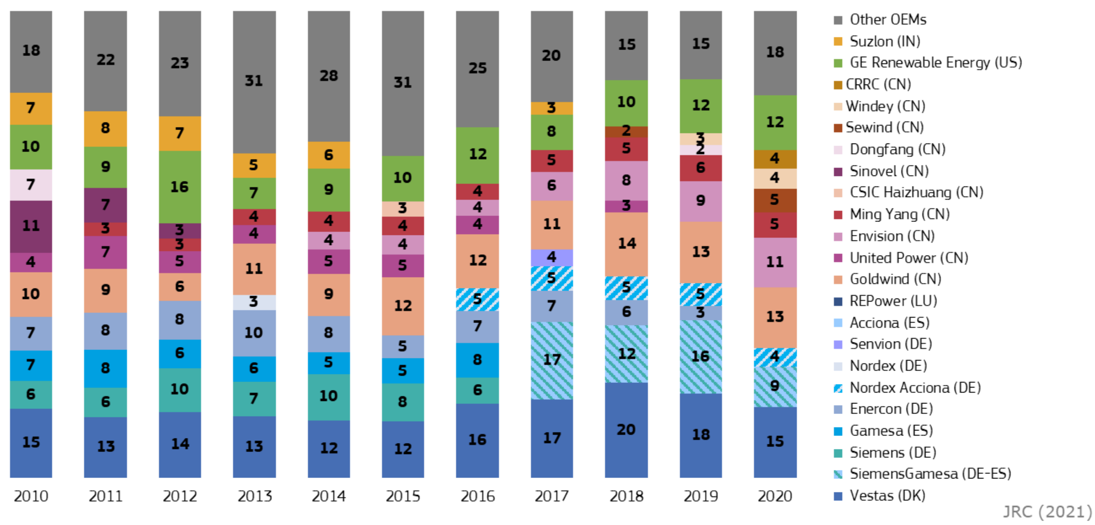
The European Original Equipment Manufacturers (OEMs) in the wind energy sector have held a leading position in the last few years. In 2020 they lost for the first time their first rank to the Chinese OEMs when analysing the Top10 OEMs in terms of market share. Among the top 10 OEMs in 2020, Chinese OEMs led with 42 % of market share, followed by the European (28 %) and North American (12 %) companies. [88]

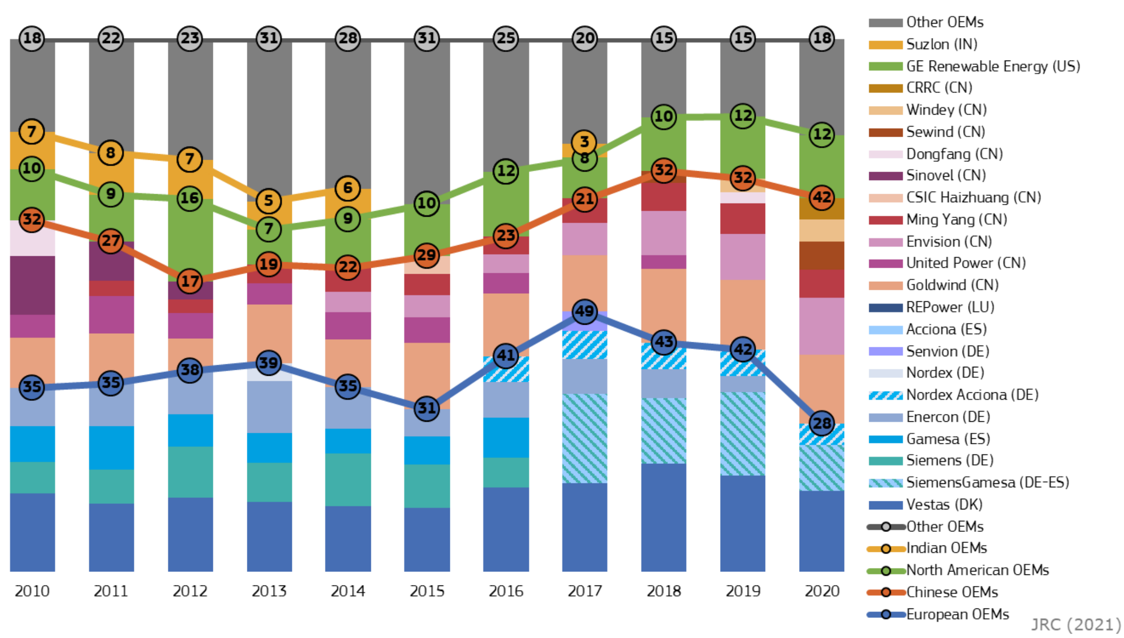
Danish Vestas remained in first place, yet a strong increase in new deployments using turbines from both Chinese OEMs and GE Renewable Energy from the US can be witnessed. This can be explained by a surge in new installations in the Chinese and US wind market.

This latest surge in Chinese wind deployment can, to some extent, be explained through a set of new policies targeting renewable energy integration and a shift from Feed-in-Tariffs towards a tender-based support scheme. This necessitates projects approved before 2018 to be grid-connected latest by the end of 2020 in order to receive the expiring Feed-in-Tariff.

[88] JRC, Low Carbon Energy Observatory, Wind Energy Technology Market Report, European Commission, 2019, JRC118314 (data update May 2021).

Figure 34: Market share (%) of the top 10 OEMs in wind energy (top) over the period 2010 – 2020 and their respective origin (bottom)





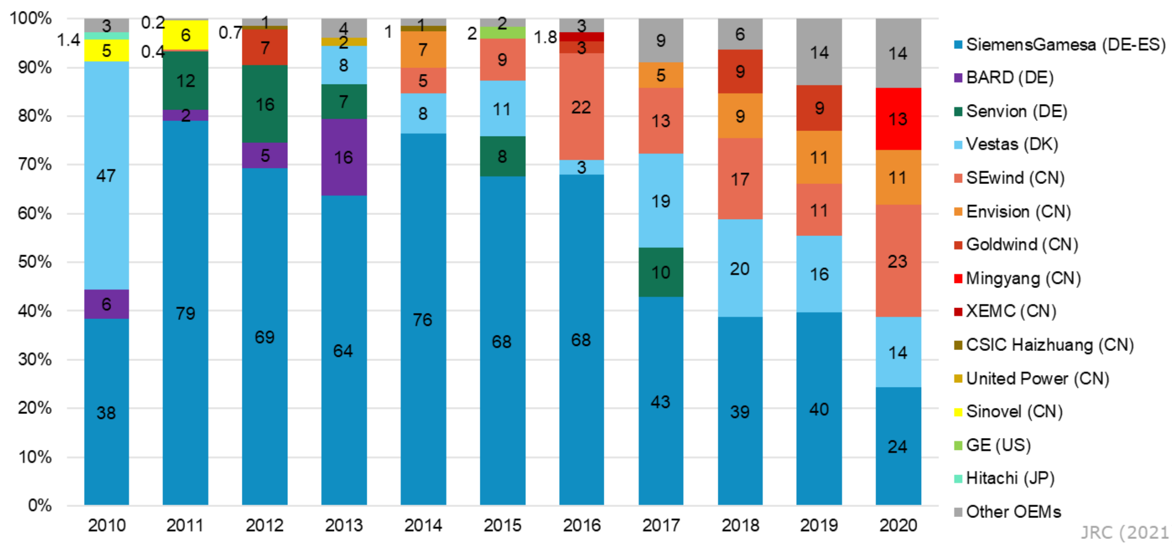
Source: JRC

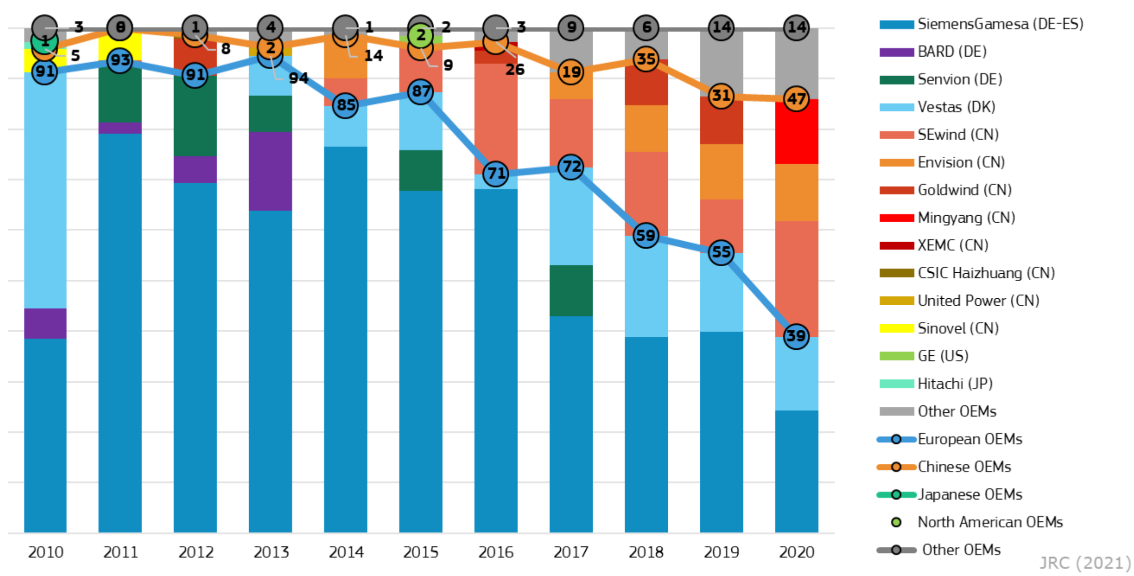
Similarly as in the onshore case, offshore wind projects approved before 2018 and grid connected by end of 2021 still receive a Feed-in-Tariff whereas auctions in the following two years will implement a price cap. Thus an increased deployment activity in China (more than 3GW) led to a strong increase in the market share of Chinese OEMs (47%) leading ahead of the European manufacturers (39%) when assessing their cumulative market share[89].

Yet the European Original Equipment Manufacturers in offshore wind rank among the Top 3. SiemensGamesa RE is leading in first place (24%), closely followed by Goldwind (23%) from China while the second European manufacturer Vestas ranks in third position (14%).

[89] JRC, Low Carbon Energy Observatory, Wind Energy Technology Market Report, European Commission, 2019, JRC118314 (data update May 2021).

Figure 35: Market share (%) of the top 5 OEMs in offshore wind energy (top) over the period 2010 – 2020 and their respective origin (bottom)





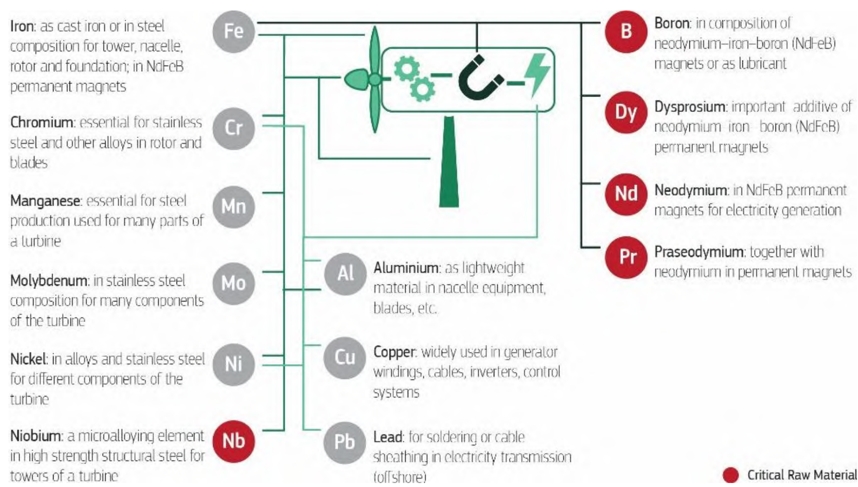
Source: JRC

5.3. Resource efficiency and dependence

A key component of a wind turbine is the generator, which converts the mechanical energy to electrical energy. There are three main types of wind turbine generators: direct current, alternative current synchronous and asynchronous. Considering the fluctuating nature of wind, it is advantageous to operate the generators at variable speed to reduce the mechanical stress on the turbine blades and drive train. Permanent magnet (PM) generators have been introduced in the recent decades in wind turbines applications due to their high power density and low mass. In particular, the Direct Drive PMSG offers certain advantages in terms of efficiency, weight, dimension and maintenance. However, this type of turbine is associated with a high demand for Rare Earth Elements (REEs).

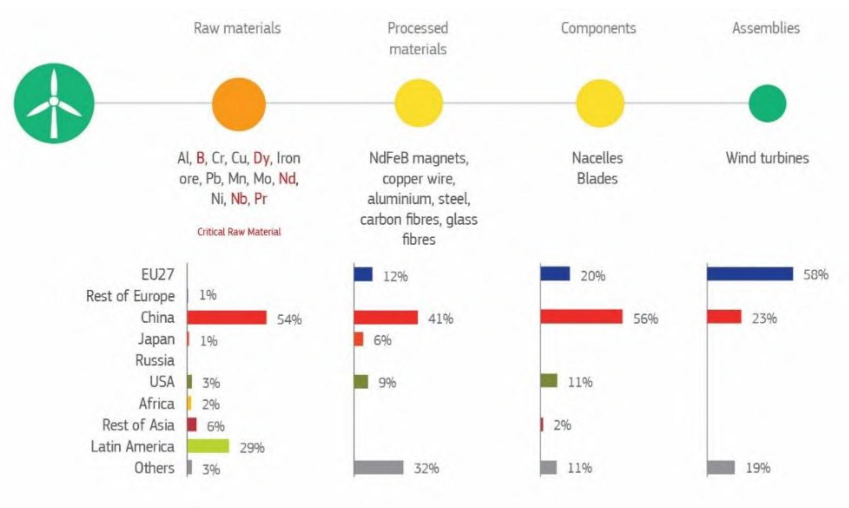
The REEs, i.e. neodymium, praseodymium and dysprosium, are key ingredients in the most powerful magnet material, namely neodymium-iron-boron (NdFeB). This magnet is used to manufacture permanent magnet synchronous generators (PMSG), which are used in the major wind turbine configurations. The most relevant materials required in wind power generation are listed in Figure 36.

Figure 36: Critical raw materials used in wind turbines



Source: European Commission, Critical Raw Materials in strategic technologies and sectors – a foresight study, 2020

Figure 37: Supply risks, bottleneck along the supply chain of wind turbines



Source: European Commission, Critical Raw Materials in strategic technologies and sectors – a foresight study, 2020

A bottleneck assessment performed in EC (2020)[90] for wind turbines shows that the risk to the supply of raw materials is the highest along the supply chain. This risk diminishes downstream through a medium risk for the supply of processed materials and component, until an undetectable risk for assemblies. Indeed, the European share increases from 1% for the raw materials, to 12% for processed materials, 18% for components, until 58% for assemblies.

The blade is another key component of a wind turbine. Its performance requirements lead to a selection of materials that combine high strength-to-weight with high stiffness and fatigue resistance (Reinforced composites such as glass-fibre composites or carbon fibres)[91]. It is estimated that about 4 700 turbines (or 14 000 blades) could be decommissioned by 2023 and would need to be sustainably disposed. Although several recycling routes for glass fibre and carbon fibres exist (e.g. fluidised bed, solvolysis, high voltage pulse fragmentation, pyrolysis, mechanical grinding) and are at a high TRL, competitiveness as compared to new material sourcing has not been reached yet. The current preferred route for composites recycling is co-processing in the cement industry to produce clinker cement, thus not a recovery of the initial material. Future innovation in composite blade recycling might necessitate large scale demonstration plants, synergies with other sectors (e.g. use of recycled blades in manufacturing processes) among others [92] [93]. Moreover new 100% recyclable materials replacing composites gain more attention (e.g. blade manufacturer LM Wind Power and chemical company Arkema using a thermoplastic resin to produce 60 to 80 meter fully recyclable blade prototype).[94] Lately a Vestas led consortium announced a novel chemical recycling process which would allow to fully recycle thermoset composites[95].

5.4. Final Considerations

For offshore wind fixed-bottom and floating installations, the challenge is to create the optimum environment to maintain and accelerate the momentum created in the North Sea, extending best practice and experience to other sea basins, starting from the Baltic Sea, and supporting global expansion.

Making a success of offshore wind energy can yield great benefits for Europe, it can ensure the EU delivers a sustainable energy transition, and bring the Member States on a realistic path to zero pollution and climate neutrality by 2050. It can also make a major contribution to the post COVID-19 recovery, as a sector where Europe's industry has world leadership and which is forecast to grow exponentially in the coming decades.

6. SWOT AND CONCLUSIONS

Strengths:

[90] European Commission, Critical materials for strategic technologies and sectors in the EU - a foresight study, 2020.

[91] European Commission, Critical materials for strategic technologies and sectors in the EU – a foresight study, 2020.

[92] WindEurope, Cefic and EuCIA, Accelerating Wind Turbine Blade Circularity May 2020, https://windeurope.org/wp-content/uploads/files/about-wind/reports/WindEurope-Accelerating-wind-turbine-blade-circularity.pdf

[93] ETIPWind (2019), How wind is going circular blade recycling, https://etipwind.eu/files/reports/ETIPWind-How-wind-is-going-circular-blade-recycling.pdf

[94] LMWind Power (2020) https://www.lmwindpower.com/en/stories-and-press/stories/news-from-lm-places/zebra-project-launched.

[95] Vestas (2021), New coalition of industry and academia to commercialise solution for full recyclability of wind turbine blades, https://www.vestas.com/en/media/company-news?l=22&n=3974601#!NewsView

Wind energy is one of the most promising, clean energy source, a reliable, cost effective, large-scale technology with a steadily increasing installation rate, and with the potential of substantial contribution to the European energy mix and to and the achievements of the EU climate and energy targets.

Weaknesses:

In order to be viable, wind energy installations should be placed in high wind potential sites, therefore there are geographical limitations which should be taken into account. In addition, important wind potential is often observed in sites where the grid is not strong enough or is not existent, necessitating important investment in grid infrastructure. Concerns of environmental, visual and noise impact of wind installations still exist, and in some cases, like offshore installations, are not well known. The intermittent and variable nature of wind is also a concern when wind reaches high grid penetration levels, nevertheless this can be managed through grid interconnection, wind forecast and transmission planning. For offshore wind, the multiple uses of the ocean (e.g. fisheries, biodiversity, energy production) is a matter of concern, which requires Maritime Spatial Planning and collaboration between Member States.

Opportunities:

With the world markets shifting to green energy and away from conventional energy sources there will be an increasing market for wind turbines in the coming years. The growth of smart grids infrastructure and interconnections will permit higher penetration levels of wind energy. Floating offshore structures offer the potential of economic sustainability and improved public acceptance. With 48% of the active companies in the wind sector headquartered in the EU, holding a leading market position, the above present a unique opportunity for further expansion and competitiveness. The age structure of the EU onshore and offshore wind fleet indicates that repowering will also play a crucial rule in the coming years.

Threats:

Despite the numerous examples showcasing that wind can be competitive compared to conventional energy sources, the technology is still perceived as being expensive. It also requires a high initial investment. There is intensive competition from manufacturers based in China and the US. Differing and changing rules, regulations and support schemes in different countries also poses a threat to the expansion of wind energy. In addition, EU companies are increasingly faced with third country governments putting in place market access barriers, local content requirements or other discriminatory or otherwise trade & investment restrictive measures aimed at promoting their domestic industry. A further risk for wind energy is the supply of raw materials which are mainly imported from China. Circularity of wind installations is still to be further developed. Wind blades, for instance, are often made in composite materials hard to re-use or recycle. Circularity requires R&I and deployment, but the industry is already very committed for circularity.

WIND ONSHORE

7. TECHNOLOGY ANALYSIS – CURRENT SITUATION AND OUTLOOK

7.1. Introduction/technology maturity status (TRL)

Onshore wind is a crucial part of the energy mix, as it is a highly cost-effective renewable technology, set to grow further as more sites are under development. It is expected to deliver the main part of EUs renewable electricity by 2030[96]. EU onshore wind deployment in deep decarbonisation scenarios until 2050 range from about 370 GW to 950 GW[97] Deploying and integrating this amount of wind energy will bring about both environmental benefits and economic opportunities; stimulating research and innovation is key in this regard.

7.2. Capacity installed, generation/production

Cumulative installed onshore wind capacity in the EU increased by 109% from 78.4 GW in 2010 to 164.1 GW in 2020. Since 2018 reduced annual onshore wind additions can be observed mainly originating from moderate deployments in Germany due to complex permitting rules and potential exposure to legal challenges (regional siting plans are not robust). Moreover Germany's Renewables Law aims for a relatively modest increase in onshore wind (to 71 GW as compared to today's 55 GW) until 2030.

The cumulative installed capacity of wind energy globally grew from 198 GW in 2010 to about 743 GW in 2020. Since 2015, the majority of global installed capacity is located in China (39% in 2020), followed by the EU (24%) and the US (16%)[98] [99]. The global wind power industry is expected to install more than 600 GW of new capacity over the next ten years, becoming a market worth EUR 77 billion in 2019 to EUR 1 trillion over the next decade[100].

In 2020, the EU installed 10.5 GW of wind power capacity, bringing its cumulative wind power capacity to 178.7 GW[101]. Based on the ambitions set in European Member States' National Energy and Climate Plans (NECPs), in 2030 the installed capacity of EU should be 295 GW.

The age structure of the EU onshore wind fleet indicates that repowering will play a crucial rule in the coming years. About 18% of the EU onshore fleet is older than 15 years, approaching quickly their design lifetime (20-25 years). This trend is even more pronounced for the leading MS in terms of installed capacity (e.g. Germany, Spain) and first-mover countries (Denmark) (Table 2) [102]. Repowering of onshore wind plays a crucial role in reaching the countries NECP targets and offers the possibility to optimise the resource potential of onshore wind sites with the best wind resource while using more powerful but fewer turbines.

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96 Wind Europe.

97 BNEF NEO.

98 JRC, Telsnig T: Wind Energy - Technology Development Report 2020, JRC123138. EUR 30503 EN. Luxembourg. URL: https://ec.europa.eu/jrc/en/publication/wind-energy-technology-development-report-2020 (updated 2020 data).

99 GWEC (2021), Global Wind Statistics 2020.

100 Guidehouse Insights Estimates (from ASSET study, 2020).

101 GWEC (2021), Global Wind Statistics 2020.

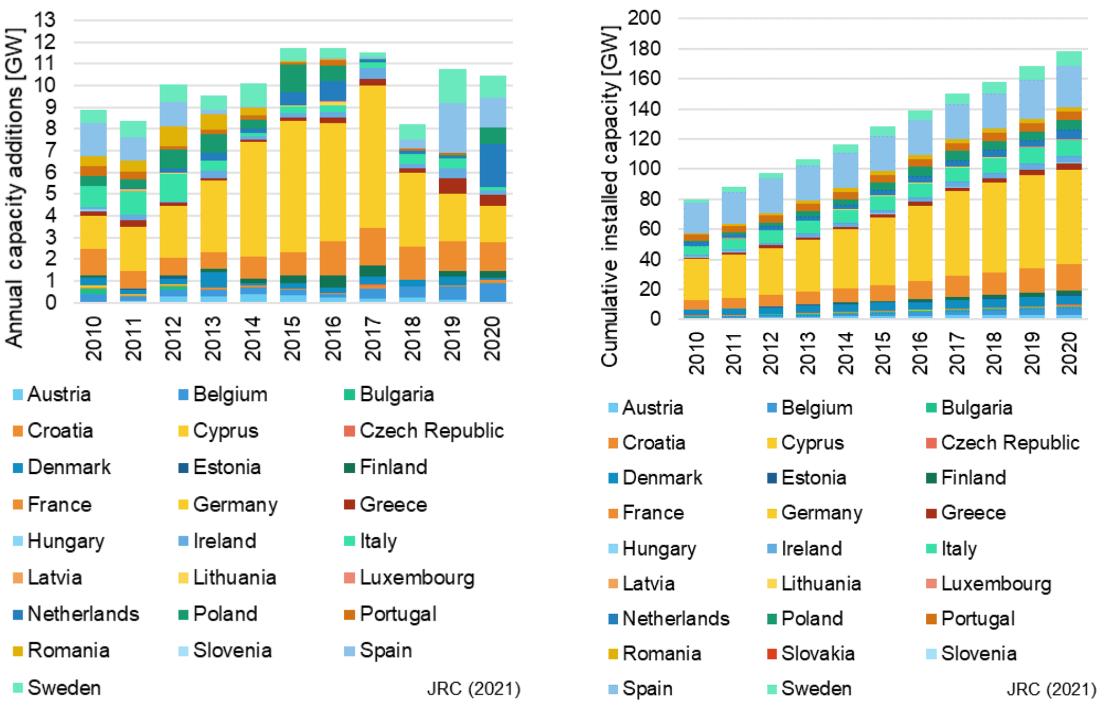
102 JRC (2019) Uihlein, A., Telsnig, T. & Vazquez Hernandez, C. JRC Wind Energy Database.

Table 2: Onshore wind fleet age structure and the EU, China and the United States

	EU	**Selected EU Member States**					**China**	**United States**
		Germany	Spain	France	Italy	Denmark		
Share of cumulative capacity (%)								
older than 10 years	41%	43%	73%	22%	45%	55%	7%	25%
older than 15 years	18%	26%	27%	2%	9%	53%	0.4%	6%
older than 20 years	3%	4%	3%	0%	1%	23%	0.2%	1%

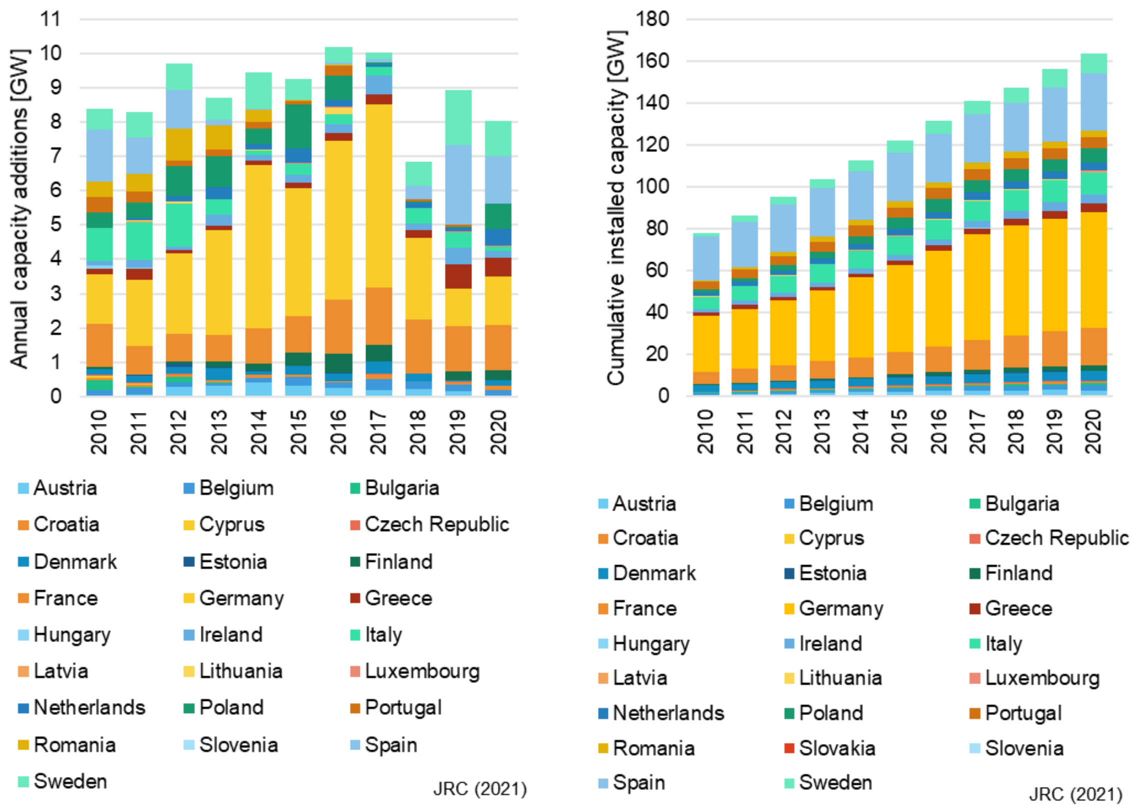
Source JRC

Figure 38: Annual capacity additions (left) and cumulative installed capacity (right) of wind energy (both onshore and offshore) in the EU.



Source JRC based on GWEC (2021)

Figure 39: Annual capacity additions (left) and cumulative installed capacity (right) of onshore wind energy in the EU.



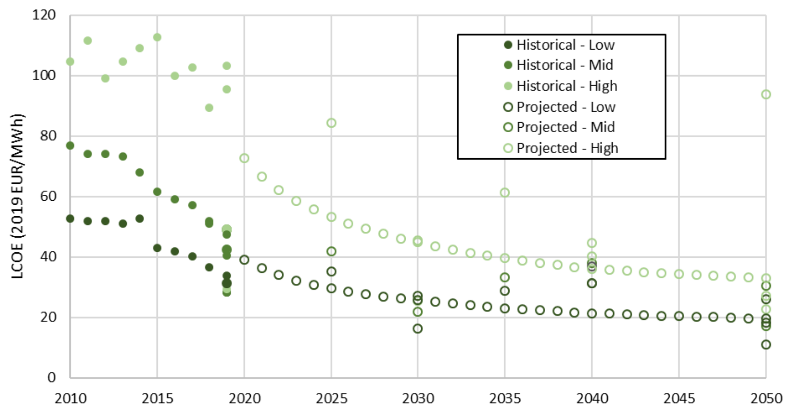
Source JRC based on GWEC (2021)

Projected electricity generation in onshore wind and offshore wind according to CTP-MIX scenario: Onshore: 847 TWh in 2030 (share of total electricity generation: 27.3%), 2 259 TWh in 2050 (share: 32.9%).

The current share of onshore wind in total electricity generation (2020) is 13.7%.

7.3. Cost / Levelised Cost of Electricity (LCoE)

Figure 40: Range of historical and projected onshore wind LCoE estimates



Source Chart reproduced from Beiter et al. 2021[103]

Based on the main cost estimates and projections on onshore wind, Figure 40 identifies a LCoE range spanning from EUR 34 per MWh to EUR 74 per MWh in 2019 which is expected to further decline to values between EUR 19 per MWh to EUR 33 per MWh in 2050.

According to WindEurope data, the LCOE of onshore wind will decrease from EUR 40 per MWh in 2019, to EUR 26 per MWh in 2030, to EUR 19 per MWh in 2050. BNEF estimates the LCOE of onshore wind in EU countries between EUR 24 and 55 per MWh, depending on for example location and financing conditions[104].

Although a decrease in the cost of finance (weighted average cost of capital (WACC)) of onshore wind projects can be observed in the last years this indicator varies considerably among EU countries. Whereas many central EU countries benefit from low WACC (1.3%-4.3%), less developed markets such as Greece, Romania and the Baltic States show a WACC range of about 7% to 10%. This spread can to some extent be explained by diverging interest rates and country risks faced by investors. Evidence suggests that a further decrease (and convergence among countries) in WACC could be achieved by focussing on de-risking debt financing of wind energy projects by policies that implement support schemes decreasing the volatility of a projects cash flow (e.g. Contracts for Difference)[105].

Cost assumptions on onshore wind within the PRIMES model see investment costs dropping to about EUR 850 per kW until 2050. According to WindEurope data, investment costs are expected to decrease from EUR 1300 per kW in 2019, to EUR 1 000 per kW in 2030, to EUR 850 per kW in 2050[106].

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[103] Beiter P., Cooperman A., Lantz E., Stehly T., Shields M., Wiser R., Telsnig T., Kitzing L., Berkhout V., Kikuchi Y. (2021) Wind power costs driven by innovation and experience with further reductions on the horizon, WIREs Energy Environ. 2021;e398. https://doi.org/10.1002/wene.398.

[104] BNEF, Interactive datasets - LCOE data, 2020.

[105] AURES II (2021), Renewable energy financing conditions in Europe: survey and impact analysis, D5.2, March 2021, H2020 project: No 817619.

[106] WindEurope.

7.4. Public R&I funding

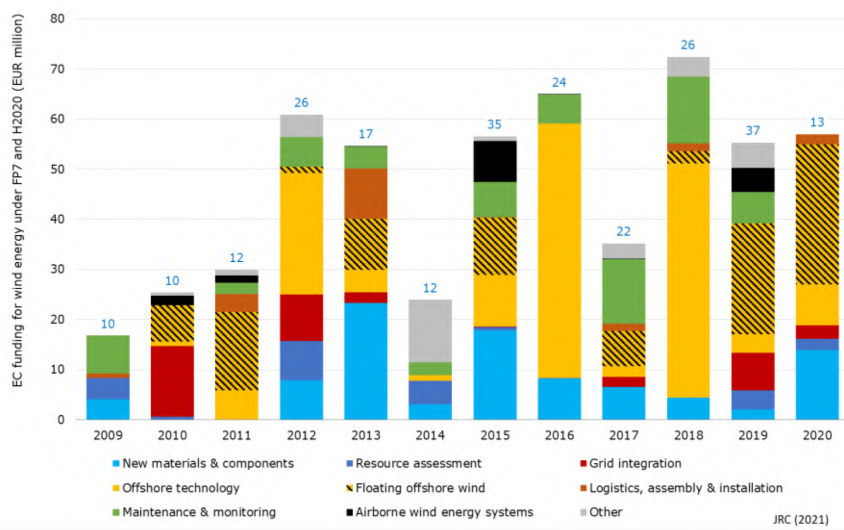
According to the JRC-TIMES 'Zero Carbon' scenario, investment in wind energy clearly dominates among the different low carbon energy technologies with about EUR 2 640 billion until 2050 (of which EUR 1851 billion are deployed onshore).

EU public investment has remained roughly constant, between 2012 and 2016 around EUR 120-145 million with an increasing trend since then, reaching EUR 179 million by 2019 (Figure 41). Preliminary numbers for 2020 on selected EU MSs indicate that this increase of public investments continues.

Although most of the EU R&I funds was spent of offshore or floating offshore wind in 2020, about 37% of the EU R&I funding was also awarded to projects addressing the broader wind categories which also facilitate innovations in the onshore wind sector. Since 2009 about 52% of the EU R&I funding was granted through FP7 and H2020 to these projects addressing R&I priorities apart from the offshore dimension (see Figure 9 in offshore chapter).

Japan is by far the largest investor, followed by Germany the US, and Norway. Total investment of EU countries over the past 3 years totalled EUR 496 million. Five out of the ten top countries where these investments occurred are in the EU.

Figure 41: Evolution of EU R&I funding categorised by R&I priorities for wind energy under FP7 (2009-2013) and H2020 (2014-2020) programmes and the number of projects funded in the period 2009-2020



Source: JRC[107]

7.5. Private R&I funding

This section is common with the offshore wind chapter.

[107] JRC, Telsnig T: Wind Energy - Technology Development Report 2020, JRC123138. EUR 30503 EN. Luxembourg. URL: https://ec.europa.eu/jrc/en/publication/wind-energy-technology-development-report-2020 (updated 2020 data).

7.6. Patenting trends - including high value patents

The patenting trends indicators are for the entire wind sector and cannot be split between onshore and offshore wind. Please see the offshore chapter.

7.7. Level of scientific publications

The indicators are for the entire wind sector and cannot be split between onshore and offshore wind. Please see the offshore chapter.

7.8. Final Considerations

Over the last decade private R&D spending held a relatively constant level between EUR 1.6 billion and EUR 1.9 billion. Moreover, private R&D investments topped public R&D investments by a factor of 10 during this period.

The EU is leading in high value patents (with the major EU OEMs filing most of the inventions), yet experiencing a decrease since 2012, due to strong performance in high-value patents by major companies from the US (e.g. General Electric) and Japan (e.g. Mitsubishi Heavy Industries, Hitachi).

Although publication counts seem to indicate a stronger activity outside the EU countries on country level, the EU as a whole ranks first (5 406 publications, 27%). Moreover, publications from the EU countries leading in wind energy deployment and research show high citation impacts indicating a higher recognition of their scholarly outputs than those from their global competitors.

8. VALUE CHAIN ANALYSIS OF THE ENERGY TECHNOLOGY SECTOR

8.1. Introduction/summary

Europe is a recognized market leader in the wind energy: 48% of active companies in the wind sector are headquartered in the EU compared to the RoW[108]. The European OEMs in the wind energy sector have held a leading position in the last few years although their market share has decreased in 2018 mainly in favour of the Chinese OEMs. Within the next decade, Europe will maintain its leadership position in annual growth, yet China, Asia Pacific and North America are expected to develop a significant market size (i.e. installed capacity) of more than 50%[109]. Among the top 10 OEMs in 2018, European OEMs led with 43 % of market share, followed by the Chinese (32 %) and North American (10 %) companies. In 2020 Chinese OEMs (42%) overtook for the first time their competitors from EU-27 (28%) and the US (12%), following the ongoing transition in China from a Feed-In Tariff towards a tender based support system.

A recent study estimates the annual market size (in terms of revenues) of the EU in onshore wind to grow from about 25.3 BEUR in 2020 to about 35.4 BEUR in 2030. In 2020 this represents about 15.2% of the global market. Across the different value chain segments the global share of the EU market ranges from 9.6% (Logistics & Installation) to 18.7% (Turbine) (Figure 42)[110].

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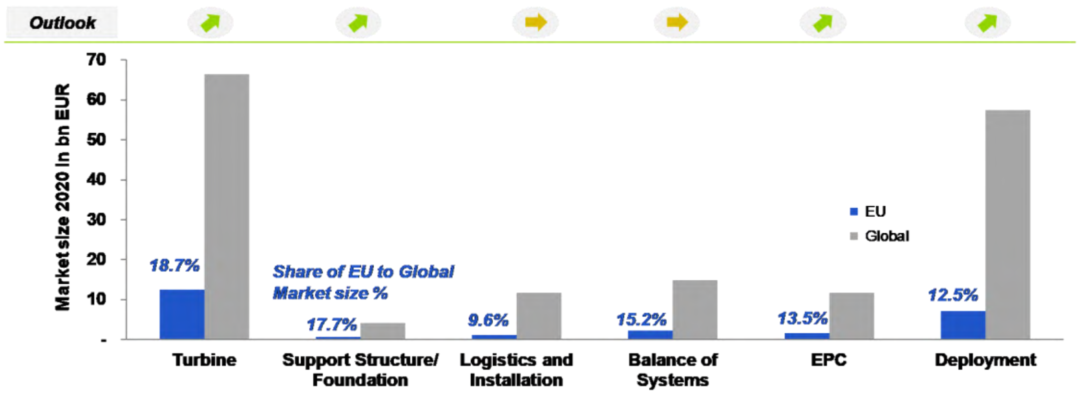
[108] ICF, commissioned by DG GROW - Climate neutral market opportunities and EU competitiveness study (Draft, 2020).
[109] GWEC, Global Offshore Wind Report 2020, 2020.
[110] EC/Guidehouse 2020, ASSET Study on Gathering data on EU Competitiveness on selected Clean Energy technologies, ISBN 978-92-76-27325-7 doi: 10.2833/94919 MJ-03-20-496-EN-N.

Figure 42: Share of EU Market Size to Global Market, Onshore Wind Value Chain Segment: 2020



Source ASSET Study commissioned by DG ENERGY - Gathering data on EU competitiveness on selected clean energy technologies (2020)

8.2. Turnover

The turnover indicators are for the entire wind sector. Please see the offshore chapter.

8.3. Gross value added growth

The gross value added growth trends indicators are for the entire wind sector and are not split between onshore and offshore wind. Please see the offshore chapter.

8.4. Number of EU companies

There are 248 operational manufacturing facilities in Europe (30% of all facilities, 214 (26 %) in EU countries). 155 facilities are dedicated to onshore wind and a further 66 supply to both onshore and offshore wind.[111] Onshore wind projects necessitate large investments with strong pricing competition, which drives down margins. As a consequence, economies of scale provide a competitive advantage, meaning that the incumbents of the established industry create an adverse environment for newcomers throughout the value chain: in 2019, only 15 start-ups received private funding. 40% of these companies were headquartered in the EU[112].

8.5. Employment in the selected value chain segment(s)

This section concerns the entire wind sector and is not split between onshore and offshore wind. Please see the offshore chapter.

8.6. Energy intensity considerations, and labour productivity considerations

Labour productivity:

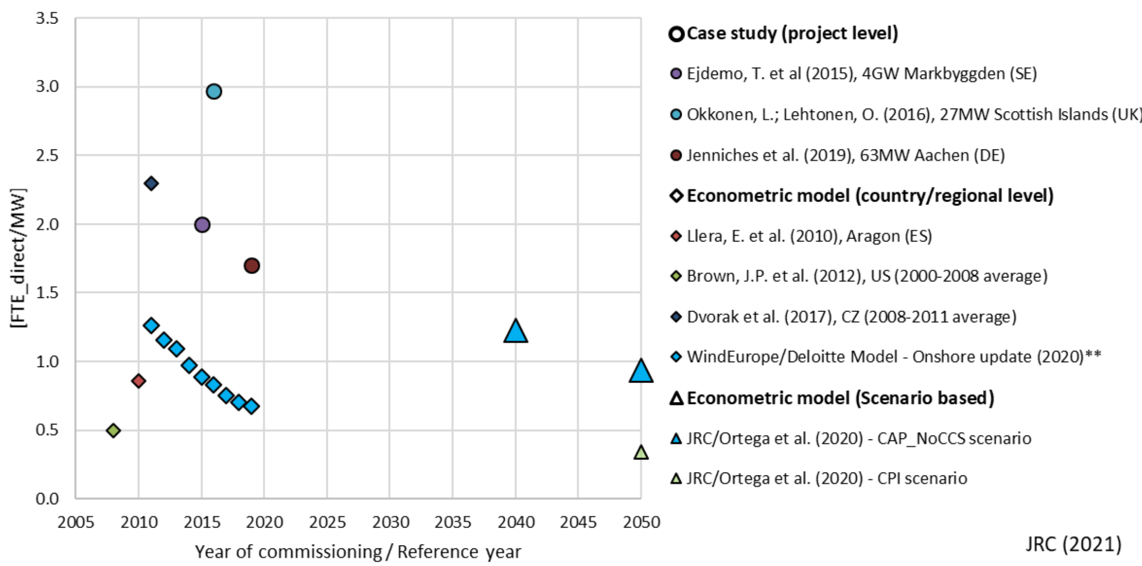
[111] WindEurope/Wood Mackenzie (2020), Wind energy and economic recovery in Europe - How wind energy will put communities at the heart of the green recovery, October 2020.

[112] ASSET Study commissioned by DG ENERGY - Gathering data on EU competitiveness on selected clean energy technologies (Draft, 2020).

As compared to offshore wind, the onshore wind sector shows a lower specific labour productivity when referring to latest case studies and econometric models (Figure 43). Direct job estimates on single onshore wind projects (given in full time equivalent years) range from 1.7 – 3.0 $FTE/MW_{project}$ for projects in the period 2015-2019. Differences in this spread seem to originate from project size and geographical scope[113 114].

Econometric models on regional and national level estimate the number of direct jobs between 0.5 to 2.3 $FTE/MW_{Installed}$ with European estimates declining to about 0.7 $FTE/MW_{Installed}$ in 2019 [115 116 117 118]. Long term scenario models estimate future labour productivity for onshore wind at a similar scale with values ranging from 0.35 to 0.9 $FTE/MW_{Installed}$[119].

Figure 43: Estimated direct person years (FTE/MW) for onshore wind based on different case studies and modelling approaches



*** Direct jobs estimated based on contribution to the GDP of the sectors involved in the industry and annual reports*

Source JRC

113 Ejdemo T., Söderholm P., (2015) Wind power, regional development and benefit-sharing: The case of Northern Sweden, Renewable and Sustainable Energy Reviews, Volume 47, 2015, https://doi.org/10.1016/j.rser.2015.03.082.

114 Lasse Okkonen, Olli Lehtonen, Socio-economic impacts of community wind power projects in Northern Scotland, Renewable Energy, Volume 85, 2016, https://doi.org/10.1016/j.renene.2015.07.047.

115 Eva Llera S. E. et al. (2010), Local impact of renewables on employment: Assessment methodology and case study, Renewable and Sustainable Energy Reviews, Volume 14, 2010, https://doi.org/10.1016/j.rser.2009.10.017.

116 Brown J.P. et al (2012), Ex post analysis of economic impacts from wind power development in U.S. counties, Energy Economics, Volume 34, Issue 6, 2012, https://doi.org/10.1016/j.eneco.2012.07.010.

117 Dvořák P. et al (2017), Renewable energy investment and job creation; a cross-sectoral assessment for the Czech Republic with reference to EU benchmarks, Renewable and Sustainable Energy Reviews, Volume 69, 2017, https://doi.org/10.1016/j.rser.2016.11.158.

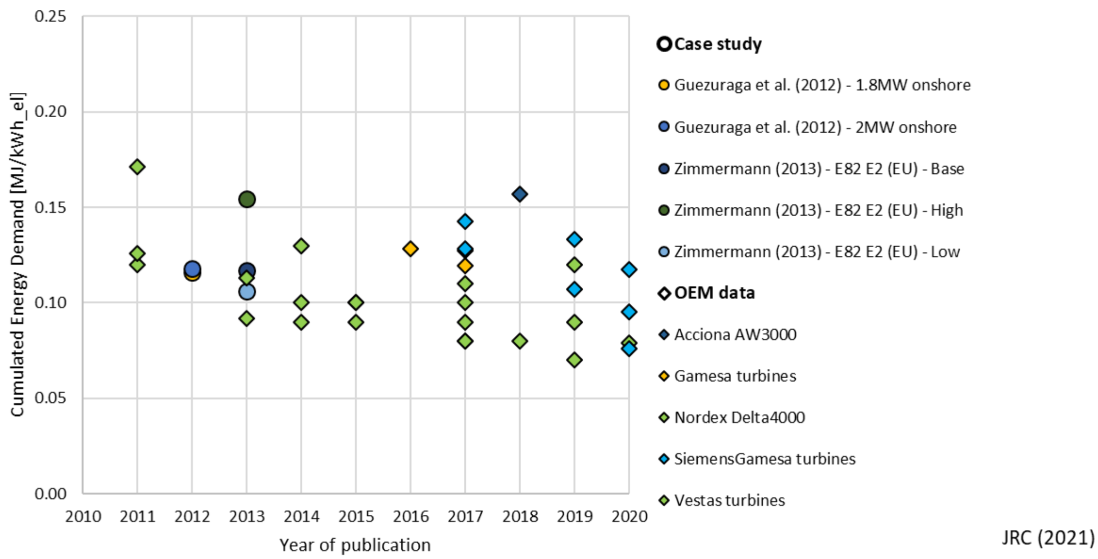
118 WindEurope, Local Impact Global Leadership (2017, 2020 data update)

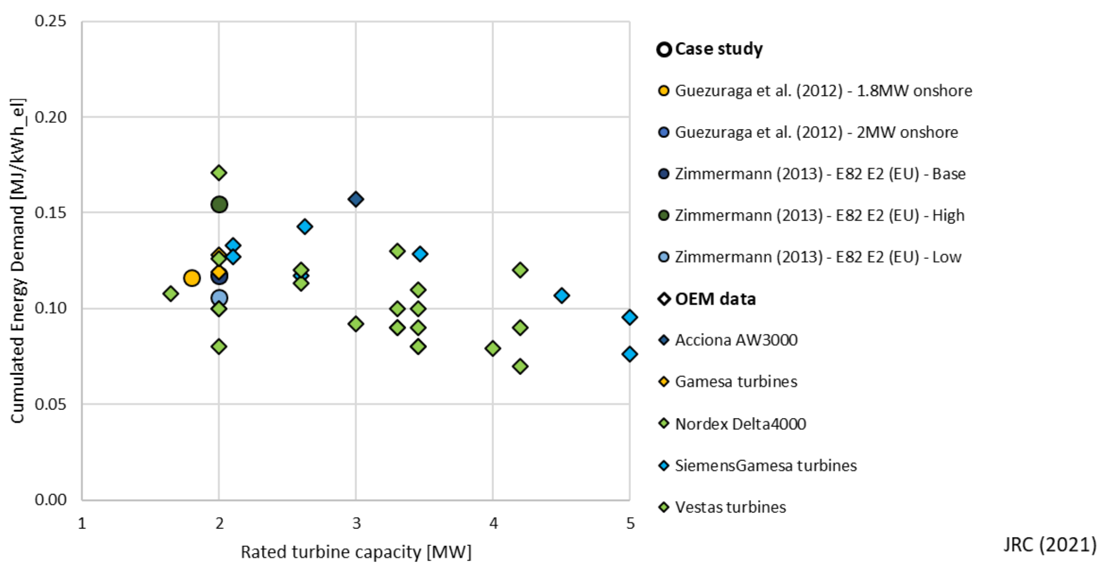
119 Ortega et al. (2020), Analysing the influence of trade, technology learning and policy on the employment prospects of wind and solar energy deployment: The EU case. Renewable and Sustainable Energy Reviews 122 (2020) 109657, Available https://doi.org/10.1016/j.rser.2019.109657

Energy intensity considerations:

The energy intensity is analysed based on the cumulated energy demand (CED) along the lifecycle of onshore wind. Life cycle analyses from both, specific case studies and OEM data (SiemensGamesa, Vestas, NordexAcciona) indicate a decrease in the CED from 0.12 - 0.17 MJ_{input}/kWh_{el} in 2011 to current levels a range of about 0.08 - 0.12 MJ_{input}/kWh_{el}. Figure 44 shows that this decrease is driven by the continuous development of more powerful turbines up to the 5MW scale which allow to generate more electricity per input of primary energy than their predecessors.

Figure 44: Evolution (top) of Cumulated Energy Demand (MJ_primary energy/kWh_el) of onshore wind turbines and the respective rated capacity (bottom) based on different case studies and OEM data





Source JRC

8.7. Community Production (Annual production values)

The community production indicators are for the entire wind sector and are be split between onshore and offshore wind. Please see the offshore chapter.

8.8. Final Considerations

Europe is a recognized market leader in the wind energy. As onshore wind projects necessitate large investments with strong pricing competition, driving down margins, economies of scale provide a competitive advantage. It is estimated that the sector offers between 240 000 and 300 000 jobs. With the annual market size (in terms of revenues) of the EU in onshore wind expected to grow from about 25.3 BEUR in 2020 to about 35.4 BEUR in 2050 wind energy can make a substantial contribution, not only in the energy mix but can also contribute to the new challenge of the European industry in its transition towards climate neutrality and digital leadership. The trade indicators are for the entire wind sector are not split between onshore and offshore wind. Please see the offshore chapter.

9. GLOBAL MARKET ANALYSIS

9.1. Trade (imports, exports)

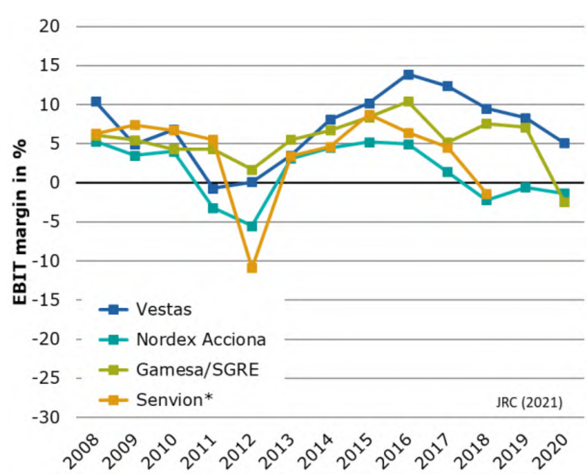
The trade indicators are for the entire wind sector are not split between onshore and offshore wind. Please see the offshore chapter.

9.2. Global market leaders vs. EU market leaders (market share)

This section is common for the entire wind sector and cannot be split between onshore and offshore wind. Please see the offshore chapter.

Since 2016 EBIT margins of EU OEMs are declining due to high competition in turbine orders particularly in the period 2017-2018 and increased material costs for main turbine components. In 2020 these factors were further intensified through the impact of Covid-19 which created logistic challenges for all manufacturers. As a result only Vestas could present a positive EBIT margin (+5.1%), whereas NordexAcciona (-1.3%) and SiemensGamesa RE (-2.5%) reported negative figures.

Figure 45: EBIT margin (Operating profit/Revenues) of the leading listed EU OEMs



Source JRC[120]

9.3. Resource efficiency and dependence

The resource efficiency and dependence indicators are for the entire wind sector and cannot be split between onshore and offshore wind. Please see the offshore chapter.

9.4. Final Considerations

According to WindEurope, European wind turbine manufacturers have a 42% share of the global market for wind turbines. Of the 10 biggest wind turbine manufacturers in the world, 5 are EU-based. Among the top 10 Original Equipment Manufacturers (OEMs) in 2018, European OEMs led with 43 % of market share, followed by the Chinese (32 %) and North American (10 %) companies. The European OEMs in the wind energy sector held a leading position in the last few years. In 2020 they lost for the first time their first rank to the Chinese OEMs when analysing the Top10 OEMs in terms of market share (EU: 28%; China: 42%). This can mainly be explained by a surge in new installations in the Chinese wind market following China's shift from Feed-in-Tariffs towards a tender-based support scheme necessitating projects approved before 2018 to be grid-connected latest by the end of 2020 in order to receive the expiring Feed-in-Tariff.

The EU has had a positive trade balance in wind energy related eqipment in the last 20 years. Yet there is some stagnation in the growth of this indicator. This can be connected to the Chinas trade policy. Following a set of policies protecting China's domestic market (e.g. local content requirements, import tariffs and local VAT exemption), since 2007 imports of wind generating sets to China fell drastically, and did not recover until today. 21% of Chinese wind-related exports in 2018 were destined for the EU market.

Since 2016, EBIT margins of EU OEMs are declining due to high competition in turbine orders particularly in the period 2017-2018 and increased material costs for main turbine components. Despite the record year in installations in 2020[121], these factors were further intensified through the impact of Covid-19 which created logistic challenges for all manufacturers.

Supply of critical raw materials for wind generators are mainly imported from China. Material shortages and disruptions pose a potential risk to EU wind energy production industry. Circularity, recycling and substitution are therefore priority areas of innovation to abate these risks, while improving the overall sustainability of the sector and are included in the 2021-2022 Work Programme of Horizon Europe.

Within the next decade, it is expected that Europe will maintain its leadership position in annual growth of offshore wind, yet China, Asia Pacific and North America are expected to develop a significant market size (i.e. installed capacity) of more than 50% (average market shares in the period 2025 – 2030: China 21%, Asia Pacific 19%, North America 13%). With respect to onshore wind China will remain the largest market (average annual market share of about 50% in the period 2020-2025) followed by the Europe (18%), North America (14%) and Asia (excluding China) (8%).

The committed capacity of wind energy installations (268.4 GW) in the EU Member States National Energy and Climate Plans (NECP) until 2030 will form a good basis streamlining investments to the wind

[120] JRC, Low Carbon Energy Observatory, Wind Energy Technology Market Report, European Commission, 2019, JRC118314 (data update April 2021).

[121] GWEC, Global Wind Report, 2021.

sector while on the same time contributing to the clean energy transition and 2050 climate targets. The committed capacity of wind energy installations (268.4 GW) in the EU Member States National Energy and Climate Plans (NECP) until 2030 will form a good basis streamlining investments to the wind sector.

10. SWOT AND CONCLUSIONS

The SWOT analysis presented in the offshore wind chapter applies to the onshore wind as well. An additional threat for onshore wind turbines are in the build environment and there is more resistance to the build of new wind farms. Considering that the overall capacity is expected to be 5-6 times higher in 2050, land use and public acceptance will become potential threats. Continuous effort to reduce environmental and social impact will be needed.