# GREEN DEAL IMPLEMENTATION - WIND ENERGY DEVELOPMENT, WHAT ARE THE CHALLENGES?

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## Contents

**Abbreviations used**

| | |
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| BEMIP | Baltic Energy Market Interconnection Plan |
| CfD | Contract for Differences |
| CHP | Combined Heat and Power |
| COP | Conference of the Parties |
| dB(A) | A-weighted decibels |
| EC | European Commission |
| EIA | Environmental Impact Assessment |
| ENTSO-E | European association for the cooperation of transmission system operators for electricity |
| EAA | European Environment Agency |
| EU | European Union |
| GW | Gigawatt |
| GWh | Gigawatt-hours |
| ICT | Information and Communication Technologies |
| IEA | International Energy Agency |
| IRENA | International Renewable Energy Agency |
| LCOE | Levelized cost of energy |
| LFN | Low frequency noise |
| LULUCF | Land Use, Land-Use Change and Forestry |
| kW | Kilowatt |
| kWh | Kilowatt-hours |
| MSP | Maritime Spatial Plan |
| MW | Megawatt |
| MWh | Megawatt hours |
| Mtoe | Million tons of oil equivalent |
| NECP | National Energy Climate Plan |
| OEM | Original Equipment Manufacturers |
| PV | Photovoltaics |
| PSSA | Particular Sensitive Sea Area |
| RED | Renewable Energy Directive |
| REEs | Rare Earth Elements |
| RES | Renewable energy sources |
| TTF | Title Transfer Facility |
| TW | Terawatt |
| TWh | Terawatt- hours |
| WESR | Wind energy scarce regions |
| WHO | World Health Organization |
| WPP | Wind power plants/ Wind power parks |

## Introduction

On 14 July 2021, the European Commission (EC) adopted a set of proposals to make the EU's climate, energy, transport, and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels. Achieving these emission reductions in the next decade is crucial to Europe becoming the world's first climate-neutral continent by 2050, and making the European Green Deal a reality.

The production, and use of energy, including transport across the economy account for more than 75 per cent of the EU's greenhouse-gas emissions. The EC's 2050 long-term strategy foresees that wind will be far and away the largest source of power generation by mid-century. 'By 2050, more than 80% of electricity will be coming from renewable energy sources (increasingly located off-shore)'.[1] According to WindEurope, offshore wind could meet the EU's electricity demand[2], while on-shore wind could meet almost twice as much[3]. The EC's most ambitious scenario, which would put the EU on track to carbon neutrality, would see 1,200 GW of wind energy in 2050 – up from today's 189 GW. Onshore wind would represent close to two thirds of total wind capacity in 2050 up to 760 GW.[4] However, the actual long-term deployment of wind, and the possibility to access the full theoretical resource, will be highly dependent on competing land or seabed uses, including agriculture, forestry and fishing, biodiversity conservation, tourism, transport activity, and military.

In July 2021, the EC presented Europe's new 2030 climate targets, including a proposal for amending the Renewable Energy Directive. It seeks to increase the current EU-level target of 'at least 32%' of renewable energy sources in the overall energy mix being raised to at least 40% by 2030, which represents doubling the current renewables share in just a decade.[5] According to WindEurope, it means the EU will need 451 GW of wind power capacity by 2030, up from 180 GW today. Presumably, the EU will need to install 30 GW of new wind farms every year between now and 2030 – a major acceleration in the expansion of wind energy.[6] The Commission proposal is now with the European Parliament and the Council.

At the same time, on 2 February 2022, the EC proposed including nuclear and gas power in the bloc's sustainable finance taxonomy, recognising their contribution to the EU's 2050 climate neutrality goal subject to clear limits and phase out periods. The Taxonomy classification does not determine whether a certain technology will or will not be part of Member State energy mixes.[7] Given that the

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[1] European Commission (2018), A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, COM(2018) 773 final, Brussels, 28.11.2018.
[2] Between 2600 TWh and 6000 TWh under 65 EUR/MWh according to WindEurope (2017)
[3] JRC (Joint Research Centre) (2018), Wind potentials for EU and neighbouring countries, Luxembourg, Publications Office of the European Union (Publications Office), available at: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC109698/kjna29083enn_1.pdf.
[4] European Commission (2018), In-Depth Analysis in Support of the Commission Communication COM(2018) 773 A Clean Planet for all. A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy, Brussels, 28 November 2018.
[5] European Commission (2021). Commission presents Renewable Energy Directive revision. 14 July 2021.
[6] WindEurope (2021). It's official: The EU Commission wants 30 GW a year of new wind up to 2030, available at: https://windeurope.org/newsroom/press-releases/its-official-the-eu-commission-wants-30-gw-of-new-wind-a-year-up-to-2030/.
[7] European Commission (2022). EU Taxonomy: Commission presents Complementary Climate Delegated Act to accelerate decarbonisation. 2 February 2022, available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_22_711.

energy mix is a Member State competence, they could re-evaluate the role of different primary energy sources in the national energy-mix.

As long as climate and renewable energy targets are set politically at the EU level, achieving them is a matter for the Member States. A Governance Regulation[8] installs a harder form of soft governance to coordinate national energy policies by National Energy and Climate Plans (NECPs). The cumulative impact of all 27 NECPs submitted by Member States in 2020 shows that measures foreseen in the EU-27 would amount to a 33,1-33,7% renewables share.[9] The updated version of NECPs is due in 2023, which gives Member States another year to assess to what extent to include wind energy in the national energy mix.

Effective implementation of policies requires efficient cooperation between policy makers, investors, local public communities, customers, environmental sectors, civil society organizations, and other stakeholders. In the context of wind energy policy formation, we know little about to what extent stakeholders are informed about activities and how and why they participate in the decision-making process. But in the light of EU policies, investors have become very enthusiastic regarding investing in renewables, however, some national planning documents and procedures are still lagging behind.

Wind energy has many benefits, it is cost-effective, sustainable, reduces dependence on fossil fuels; however, there is no denying that it has its drawbacks. Investors and supporting associations widely highlight the benefits[10] [11], while much less attention is being paid to the challenges. Until these challenges are overcome, wind energy is not expected to grow at the projected rate.

The aim of this research is to analyse possible challenges of the future of wind energy by compiling the most pertinent results of various studies and assess their applicability for reaching the EU Green Deal objectives.

The paper proceeds as follows: Section 1 focuses on the global fight against climate change. Sections 2 and 3 present the latest developments of the EU energy policy and energy sector trends in the EU. Section 4 deals with wind energy and conflicting industries. Section 5 focuses on important factors of wind energy, like technological, environmental, financial, and economic, as well as social. Section 6 briefly describes the case of Latvia, while the conclusion presents policy decisions and recommendations.

# 1. Global fight against climate change

The fight against climate change has become one of the top priorities across almost all policy sectors including energy. Global warming is considered to be the main reason for why many changes in the climate system increase in severity. They include increases in the frequency and intensity of hot extremes, marine heatwaves, heavy precipitation, and, in some regions, agricultural and ecological droughts; an increase in the proportion of intense tropical cyclones; and reductions in Arctic Sea ice, snow cover, and permafrost.

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[8] Regulation (EC) No. 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action.

[9] European Commission (2020). Driving forward the green transition and promoting economic recovery through integrated energy and climate planning. An EU-wide assessment of National Energy and Climate Plans, COM(2020) 564 final, Brussels, 17 September 2020.

[10] WindEurope. Wind delivers the energy society wants, available at: https://windeurope.org/about-wind/wind-energy-today/.

[11] Latvian Wind Association. Myths and Facts, available at: https://wea.lv/en/wind-energy/.

Globally, the use of energy represents by far the largest source of greenhouse gas emissions from human activities. About two thirds of global greenhouse gas emissions are linked to burning fossil fuels for energy to be used for heating, electricity, transport, and industry. It is estimated that the burning of fossil fuels – including coal, gas, and oil – was responsible for 86% of carbon dioxide emissions in the past 10 years. In Europe, too, the energy processes are the largest emitter of greenhouse gases, being responsible for 78% of total EU emissions in 2015.

For nearly three decades, the United Nations has been bringing together almost every country for global climate summits to fight climate change. During COP21 in Paris the commitment was reached to work together to limit global warming to well below 2 degrees C, with the aim for 1,5 degrees C, to adapt to the impacts of a changing climate and to make money available to deliver on these aims.[12] It requires cutting global emissions by 45% by 2030 and to zero overall by 2050.[13] If the pledges made at Glasgow are fully implemented, warming will be kept below 2 degree C. With the commitment to further action over the next decade 1,5 degrees C could also be achieved.[14] During COP26 in Glasgow, nations adopted the Glasgow Climate Pact[15], aiming to turn the 2020s into a decade of climate action and support. The package of decisions includes strengthened efforts to build resilience to climate change, to curb greenhouse gas emissions, and to provide the necessary finance for both. Nations collectively agreed to work to reduce the gap between existing emission reduction plans and what is required to reduce emissions, so that the rise in the global average temperature can be limited to 1,5 degrees C.

For the first time at a COP26 in Glasgow, nations are called upon to phase down unabated coal power and inefficient subsidies for fossil fuels. There was an explicit plan to reduce use of coal - which is responsible for 40% of annual $CO_2$ emissions.[16] More than 40 countries have made new commitments to phase out coal power, including five of the world's top 20 coal power-using countries. These are South Korea (5th), Indonesia (7th), Vietnam (9th), Poland (13th), and Ukraine (19th).[17] Although the world's biggest users like China and the US did not sign up. In addition, a group of 25 countries including COP26 partners Italy, Canada, the United States and Denmark together with public finance institutions have signed a UK-led joint statement committing to ending international public support for the unabated fossil fuel[18] energy sector by the end of 2022 and instead prioritising support for a clean energy transition. Eleven countries formed a new alliance - the Beyond Oil and Gas Alliance (BOGA). Ireland, France, Denmark, and Costa Rica among others, launched a first of its kind alliance to set an end date for national oil and gas exploration and extraction. These countries were committed to ending all new concessions, licensing, and leasing rounds. World leaders agreed to phase-out subsidies that artificially lower the price of coal, oil, or

[12] United Nations (UN), The Paris Agreement to the United Nations Framework Convention on Climate Change, 12 December 2015.
[13] United Nations (UN), The Paris Agreement to the United Nations Framework Convention on Climate Change, 12 December 2015.
[14] UN Climate Change Conference UK 2021. COP26 The Glasgow Climate Pact, available at: https://ukcop26.org/wp-content/uploads/2021/11/COP26-Presidency-Outcomes-The-Climate-Pact.pdf
[15] UN Glasgow Climate Pact, 13 November 2021, available at: https://unfccc.int/sites/default/files/resource/cop26_auv_2f_cover_decision.pdf
[16] It is estimated that the burning of fossil fuels – including coal, gas, and oil – was responsible for 86% of carbon dioxide emissions in the past 10 years.
[17] UN Climate change Conference UK 2021. Global coal to clean power transition statement, available at: https://ukcop26.org/global-coal-to-clean-power-transition-statement/
[18] Unabated coal is coal produced without the use of technology to capture the emitted carbon.

natural gas. However, no firm dates have been set, but this issue will be at the top of the next COP negotiations.

Although greenhouse gas emissions are projected to drop about 6 per cent in 2020 due to travel bans and economic slowdowns resulting from the COVID-19 pandemic, this improvement is considered to be only temporary.

# 2. Latest developments of EU Energy Policy

The European Union is among the world's top three CO2 emitters after China and the United States, being responsible for 7,52% of global emission in 2018. Greenhouse gas emissions in the EU decreased by 31% between 1990 and 2020 — exceeding the EU's 2020 target by 11 percentage points. Steep emission cuts were observed in 2019 and 2020. While the cut in 2019 was strongly driven by fossil fuel price effects and policy measures, the decline in 2020 was additionally related to the Covid-19 pandemic. EU greenhouse gas emissions are expected to further decline until 2030.[19]

## 2.1. European Green Deal

On 11 December 2019, the EC presented a communication on the European Green Deal that sets out a detailed vision to make Europe the first climate-neutral continent by 2050. The EC promised to present an impact assessment plan to increase the EU's greenhouse gas emission reductions target for 2030 to at least 50%, and towards 55% compared with 1990 levels, in a responsible way.[20]

The new climate target to reduce the EU's net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels, was agreed to in the EU Climate Law[21]. The Law was adopted in June 2021 after the Parliament had been pushing for more ambitious EU climate and biodiversity legislation and declared a climate emergency on 28 November 2019.

As part of the European Green Deal, with the European Climate Law, the EU has set itself a binding target of achieving climate neutrality by 2050. This requires current greenhouse gas emission levels to drop substantially in the next decades. As an intermediate step towards climate neutrality, the EU has raised its 2030 climate ambition, committing to cutting emissions by at least 55% by 2030. To ensure that EU policies are in line with the climate goals agreed by the Council and the European Parliament a set of proposals, the so called 'Fit for 55' package, to revise and update EU legislation and to put in place new initiatives was issued. The European Green Deal covers all sectors of the economy; notably, energy, transport, agriculture, buildings, and industries such as steel, cement, ICT, textiles, and chemicals.

The Action Plan foresees amendments to several energy related legal acts, for example the Energy Efficiency Directive, Renewable Energy Directive, Energy Taxation Directive, the Trans-European Network – Energy Regulation, and the relevant State aid guidelines. The EC has to issue a new communication on Strategy on offshore wind.

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[19] European Environment Agency (EEA) (2021). Total greenhouse gas emission trends and projections in Europe. 18 November 2021, available at: https://www.eea.europa.eu/ims/total-greenhouse-gas-emission-trends.

[20] European Commission (2019). The European Green Deal. COM(2019) 640 final, Brussels, 11 November 2019.

[21] Regulation (EU) No. 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality.

## 2.2. FIT for 55 package

On the 22 of July 2021 the European Commission launched the first tranche of its *Fit for 55*[22] package. It refers to the EU's target of reducing net greenhouse gas emissions by at least 55% by 2030 and net-zero-emissions by 2050. As further decarbonizing the energy system is critical to reach climate objectives in 2030 and 2050, among other legislative proposals the *Fit for 55* package includes a proposal for a review of the Renewable Energy Directive (RED II). Under RED II, the EU is currently obliged to ensure at least 32% of its energy consumption comes from renewable energy sources (RES) by 2030. The revised RED II strengthens these provisions and sets a new EU target of a minimum 40% share of RES in final energy consumption by 2030, together with new sectoral targets.

## 2.3. Offshore wind strategy

The decarbonisation of the power sector through renewable energy is one of the key elements of the European Green Deal. To help meet the EU's goal of climate neutrality by 2050, the EC presented the EU Strategy on Offshore Renewable Energy.[23] The Strategy proposes to increase Europe's offshore wind capacity from its current level of 12 GW to at least 60 GW by 2030 and to 300 GW by 2050. The Commission aims to complement this with 40 GW of ocean energy and other emerging technologies such as floating wind and solar by 2050.

According to this strategy, all EU countries will benefit, both those bordering the coastline and those inland. The North Sea, the Baltic Sea, EU Atlantic coast, the Mediterranean Sea, the Black Sea, and EU islands have potential for offshore wind and tidal and/or wave energy. Inland countries, at least some of them, like Austria and Czechia, are manufacturers of wind turbine components.

Regulatory changes will be needed as the current regulatory framework was not designed with cross-border offshore renewable projects and their specific challenges in mind. An additional assessment might be needed how the existing electricity market framework supports offshore renewable energy development. The capability of offshore bidding-zones for hybrid projects with the electricity market rules and the redistribution effects of the given approach would have to be addressed in the future. In addition, the physical challenge of connecting projects to several markets with different connection rules exists.

Offshore renewable energy will only be sustainable if it does not have adverse impacts on the environment as well as on the economic, social, and territorial cohesion. The strategy calls for early involvement of all groups concerned, calling regional or national authorities to proactively inform them about projects, rules and the potential for the development of multi-uses of the maritime space. The EC has promised to analyse the interactions between offshore renewable energy and other activities at sea, such as fisheries, aquaculture, shipping, and tourism.

## 2.4. Hydrogen strategy

Production of hydrogen is meant to be a key priority in different sectors like energy and industry to achieve the European Green Deal. The priority for the EU is to develop renewable hydrogen, produced using mainly wind and solar energy.[24] In the first phase, from 2020 up to 2024, the strategic objective is to install at least 6 GW of renewable hydrogen electrolysers in the EU and the

[22] The Fit for 55 package is a set of proposals to revise and update EU legislation and to put in place new initiatives with the aim of ensuring that EU policies are in line with the climate goals agreed by the Council and the European Parliament.

[23] European Commission (2020). An EU Strategy to harness the potential of offshore renewable energy for a climate neutral future. COM(2020) 741 final, Brussels, 19 November 2020.

[24] European Commission (2020). A hydrogen strategy for a climate-neutral Europe. COM(2020) 301 final, Brussels, 8 July 2020.

production of up to 1 million tonnes of renewable hydrogen. In a second phase, from 2025 to 2030, hydrogen needs to become an intrinsic part of an integrated energy system with a strategic objective to install at least 40 GW of renewable hydrogen electrolysers by 2030 and the production of up to 10 million tonnes of renewable hydrogen in the EU. In the third phase, from 2030 onwards and towards 2050, renewable hydrogen technologies should reach maturity and be deployed at a large scale to reach all hard-to-decarbonise sectors where other alternatives might not be feasible or have higher costs.

The hydrogen sector will require significant investments both in production and in the consumption side. Cumulative investments in renewable hydrogen in Europe could be up to EUR 180-470 billion by 2050. Investments in electrolysers could range between €24 and €42 billion, scaling up and directly connecting to 80-120 GW of solar and wind energy production capacity to the electrolysers - €220-340 billion. Investments in retrofitting half of the existing plants with carbon capture and storage are estimated at around €11 billion. Investments of €65 billion will be needed for hydrogen transport, distribution and storage, and hydrogen refuelling stations. Adapting end-use sectors to hydrogen consumption and hydrogen-based fuels will also require significant investments. For instance, it takes roughly €160-200 million to convert a typical EU steel installation coming to end-of-life to hydrogen. In the road transport sector, rolling out an additional 400 small-scale hydrogen refuelling stations (compared to 100 today) could require investments of €850-1000 million.

## 2.5. EU Energy Policy governance

To help the EU reach its 2030 climate and energy targets, the Regulation on the Governance of the Energy Union sets common rules for planning, reporting, and monitoring.[25] EU countries need to establish a 10-year integrated national energy and climate plan (NECP) for the period from 2021 to 2030 and submit to the EC by the end of 2019. NECPs must be updated to reflect an increased ambition by the end of June 2023 and by 30 June 2024 in a final form submitted to the EC. This will provide the opportunity to build on lessons learned from the first years of implementation and adapt plans to the changed climate and energy targets and economic circumstances, reflecting the agenda for green investment developed at a national level in the context of the Recovery and Resilience Plans. Until then, Member States can adapt national policies and measures at any time, provided such changes are included in the biennial integrated national energy and climate progress reports to the EC. Along with the new ambitions related to climate change, the renewed plans are also expected to include aspects of rising energy prices, as energy prices were very low at the time the first plans were written.

The cumulative impact of all 27 National Energy and Climate Plans (NECPs) submitted by Member States in 2020 shows that measures already foreseen in the EU-27 would amount to a **33,1-33,7%** renewables share.[26] The analysis for the Communication on stepping up Europe's 2030 climate ambition shows that higher shares of renewables are fundamental to achieve higher greenhouse gas emissions reduction targets. As set out in the impact assessment, reducing greenhouse gas emissions by at least 55% would require a share of renewable energy in the EU **of 38-40% by 2030**.[27]

[25] Regulation (EU) No. 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action Regulation.

[26] European Commission (2020). Driving forward the green transition and promoting economic recovery through integrated energy and climate planning. An EU-wide assessment of National Energy and Climate Plans, COM(2020) 564 final, Brussels, 17 September 2020.

[27] European Commission (2020). Stepping up Europe's 2030 climate ambition. Investing in a climate-neutral future for the benefit of our people. COM(2020) 562 final, Brussels, 17 September 2020.

Current national targets as expressed in the NECPs suggest that the offshore renewable energy targets for 2030 (at least 60 GW) can be achieved. Most of the offshore wind installations deployed until 2030 will be in the North Sea (47 GW), yet substantial capacities can be expected in other sea basins particularly in the Baltic Sea (21,6 GW), the Atlantic Ocean (11,1 GW), 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.

NECPs already provide a vast number of matured wind projects. Denmark reported offshore wind projects of 4 GW capacity, Poland - 3,8 GW, France expects the launch of six offshore wind tenders by 2023 aiming at 3,7 GW capacity.

Most NECPs acknowledge the role of hydrogen in the energy transition reflecting on the status of matured hydrogen projects. For example, Denmark and Germany are building, at Bornholm, a 3-5 GW offshore wind energy production, including an electrolysis facility to fuel trucks, busses, ships, and aircraft. Spain is planning the construction of a 100 MW PV plant, 20 MWh ion lithium battery storage system and hydrogen production system through electrolysis in Puertollano.

Sector coupling has been indicated as a vital part of developing a decarbonized energy system. This means linking together previously separate systems in such sectors as electricity, heating, mobility, and industry. In future, more flexible energy systems will have to integrate different energy sources (solar, wind, biogenic sources) and various means of transport and storage (electricity, heating, gas) and make available different energy products for the corresponding domains in which they are applied like mobility, heating, and industrial applications. The Austrian NECP suggests that new energy storage technology with a capacity of some 5 TWh will be required, in particular for electricity and heating in the housing, industry, and mobility sectors.

Member States have also pointed out the investment needs relating to the internal energy market in their NECPs. On interconnections, Germany indicated that it needs €55 billion to upgrade its existing electricity transmission system and to build new onshore transmission infrastructure by 2030. A further €21 billion is needed for offshore electricity transmission infrastructure to allow for the installation of 17-20 GW offshore wind by 2030. Spain planned to strengthen and expand transmission and distribution lines, including between islands, and interconnections with neighboring countries, in particular France.

The new ambitions in the EU climate change policy will require more ambitious, revised NEPCs. The EC assessment[28] concludes that GHG reductions surpass the EU target of -40% by 2030 compared to 1990 levels. Under existing and planned measures, GHG reductions would decrease by 41%, excluding the LULUCF sink. It requires more effort to reach 55% GHG reduction. The share of renewable energy goes well beyond the current 2030 target of at least a 40% share of renewable energy. The plans already indicate that almost all Member States are phasing out from coal or have set a phase-out date. The use of coal is projected to decrease by 70% compared to 2015, with renewable electricity set to reach 60% of electricity produced by 2030. At the same time, Member States need to step up efforts to phase out fossil fuel subsidies.

[28] Regulation (EU) No. 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action Regulation.

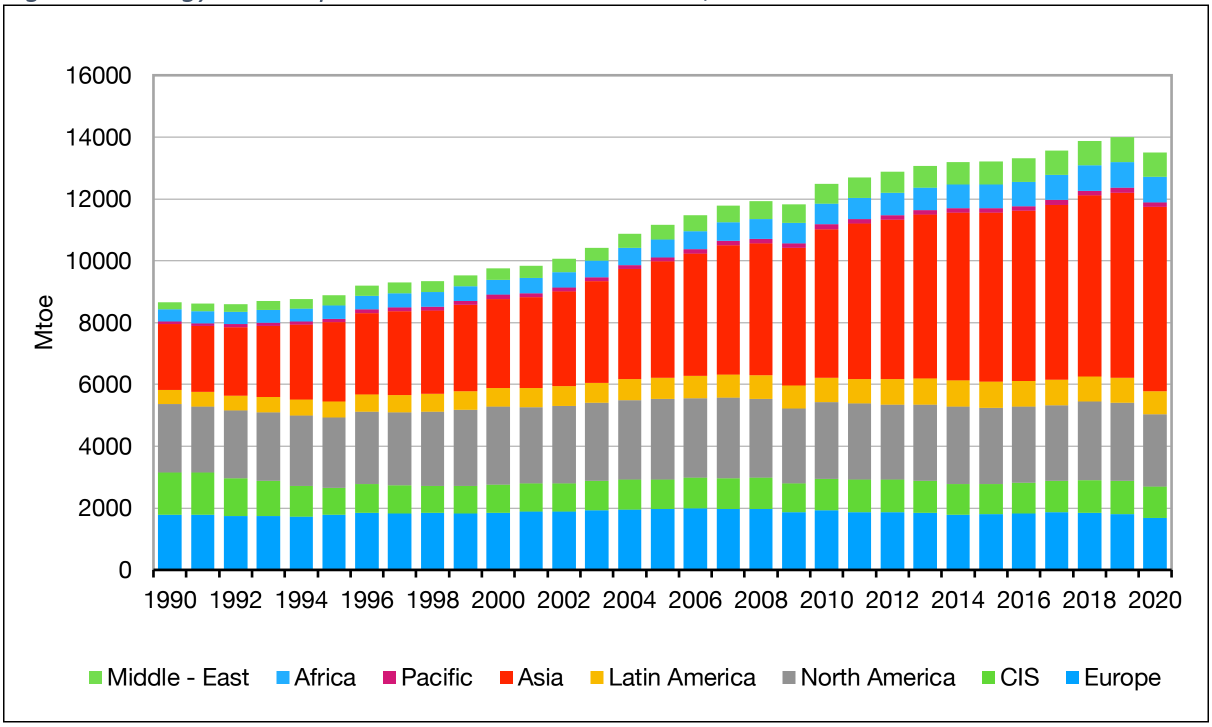
# 3. Energy sector and wind energy development

To fight the climate change, a more rapid switch to renewables has been identified as one of the keys. Many national, regional, and international policies mandate for an ever larger renewables share in electricity generation. Wind turbines along with solar photovoltaic panels have been mentioned as the biggest drivers of the rapid increase in renewable energy electricity generation.

## 3.1. Global trends

Global energy consumption has increased around 1,8 times over the last twenty years, while in China it grew almost 4 times (see Figure 1). The consumption trend has been growing, only in the context of a global pandemic did energy consumption growth decline by 4% in 2020 compared to the previous year. In 2020, energy consumption fell in most countries, except in China, the largest energy consumer – 24% of the global energy consumption in 2020. Lockdown measures and reduced economic activity had a severe impact on energy consumption in 2020. It decreased significantly by 7.6% in the United States, by around 7% in the EU (strong drops in the largest markets such as Spain, France, Italy, and Germany), Japan, and Canada, and by 4.8% in Russia. At the same time, China's energy consumption rose by 2.2%.

*Figure 1. Energy consumption trend over 1990 to 2020, Mtoe.*

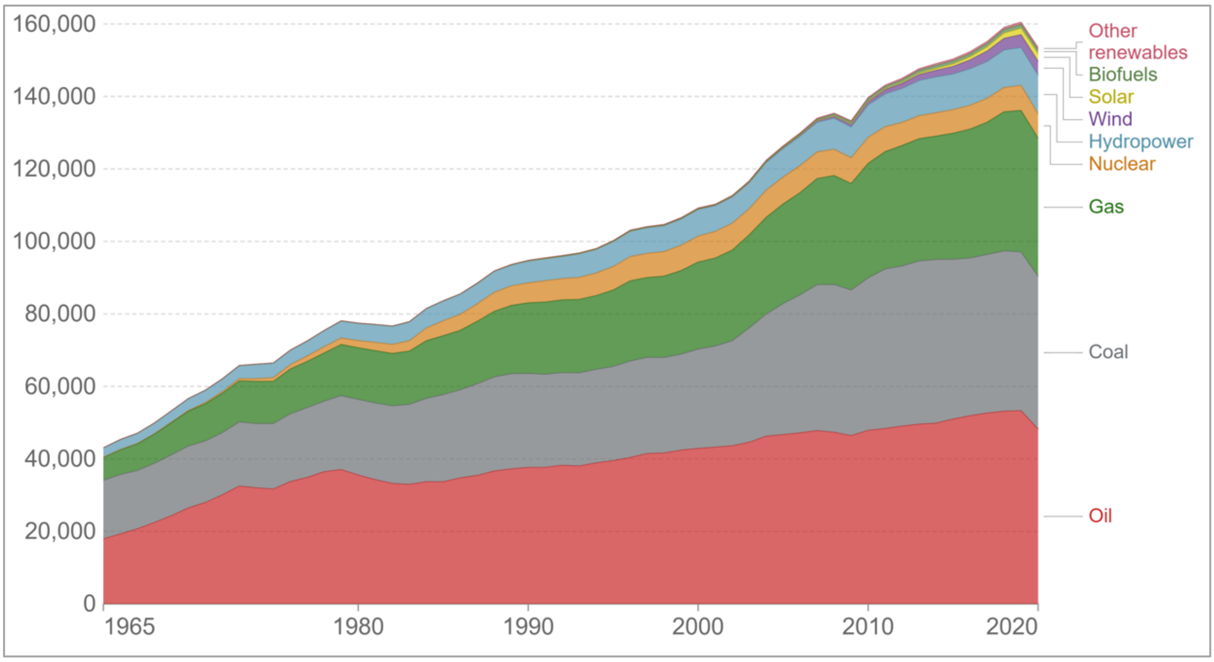



*Source: Enerdata. World Energy & Climate Statistics – Yearbook 2021*

In the global energy mix the largest amount of our energy is from oil, followed by coal, gas, then hydroelectric power. Fossil fuels account for more than 80% of energy consumption (see Figure 2).

The share of renewables in global electricity generation is much higher. Renewables made up 29 % of global electricity generation by the end of 2020. Renewable electricity generation in 2021 is set to expand by more than 8% to reach 8 300 TWh, the fastest year-on-year growth since the 1970s. Solar PV and wind are set to contribute two-thirds of renewables growth. China alone should account for almost half of the global increase in renewable electricity in 2021, followed by the United States, the European Union and India.

*Figure 2. Energy consumption by source, TWh.*



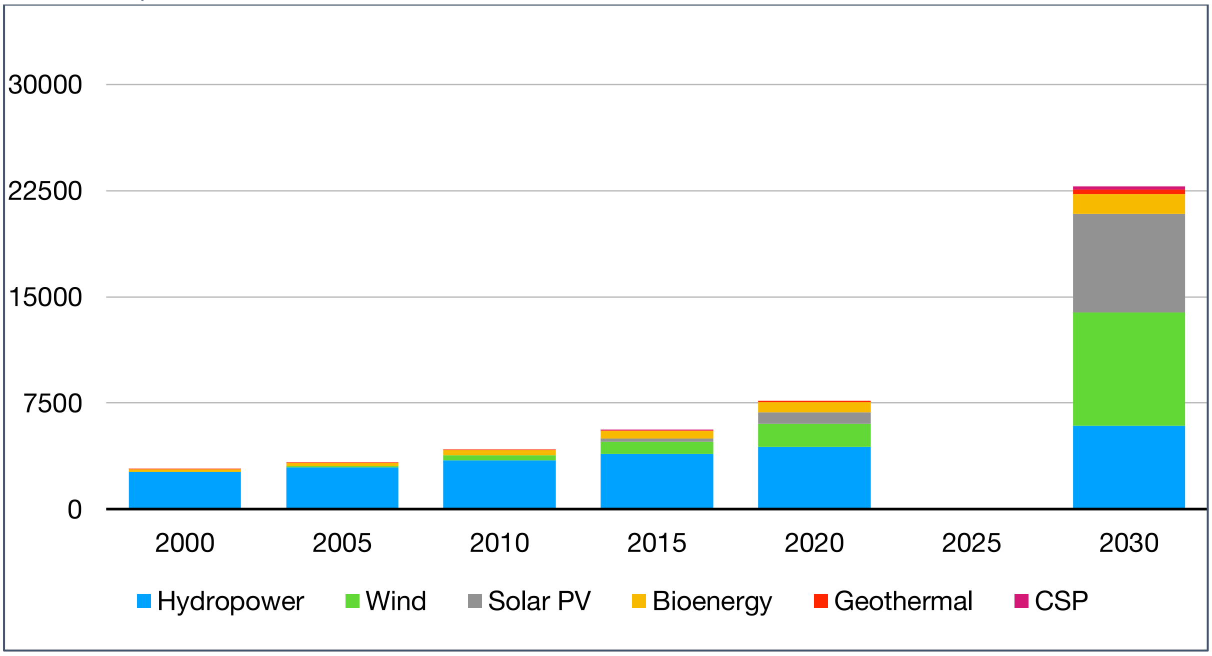

*Source: Our World in Data. Energy mix.*

There is a rapid increase in energy generated from wind. Overall, 1 592 TWh of electricity were generated from wind installations in 2020, 12% more than in 2019. According to the International Energy Agency (IEA)[29] global onshore wind additions doubled in 2020, reaching an exceptional level of almost 110 GW installed capacity twice as much as in 2019, mainly owing to a commissioning rush in China, where developers hurried to complete projects before subsidies expired, and the United States, which together accounted for 79% of global wind deployment. While annual additions in the coming years are not expected to match 2020's record, IEA forecast is that they will average 75 GW per year over the 2021-2026 period.

According to the IEA assessment under the Net Zero Emissions 2050 Scenario (see Figure 3) there is a need to attain the 8 000 TWh generated from wind power in 2030, almost 5 times more compared to 2020. It means that generation must increase an average 18% per year during 2021-2030. To reach goals it is required to raise annual capacity additions to 310 GW of onshore wind and 80 GW of offshore wind.

[29] International Energy Agency (2021). Renewable power generation by technology, historic and in the Net Zero Scenario, 2000-2030, available at: https://www.iea.org/data-and-statistics/charts/renewable-power-generation-by-technology-historic-and-in-the-net-zero-scenario-2000-2030

*Figure 3. Renewable power generation by technology, historic and in the Net Zero Scenario, 2000-2030, TWh.*




*Source: International Energy Agency*

*The key actions between now and 2050: no new oil and gas fields, and no new coal mines or mine extensions; halting construction of all new coal plants, unless they are built with carbon-capture technology; closing all coal-fired power plants not fitted with carbon-capture technology by 2040, coal exit in the OECD by 2030; increasing the use of renewable sources of energy from 29% in 2020 to 90% in 2050; implementing a ban in 2025 on the sale of new oil and gas boilers to heat buildings; Net zero emission electricity in advanced economies; phasing out internal combustion engine car sales by 2035; 60% of global car sales are electric by 2030 and conversion of vehicle fleets to either electric or hydrogen fuel sources by 2050; shifting power plants away from carbon emissions to renewable sources of energy by 2035; transitioning half of all plane-travel energy sources to hydrogen or biofuels by 2040; 70% of global electricity is generated from solar PV and wind by 2050.*

## 3.2. Energy in Europe

The European energy system faces several important challenges. First, the energy sector is currently the largest emitter of greenhouse gases in Europe, being responsible for 28% of GHG (excl. transport) in 2019.[30] Therefore, the decarbonisation of the energy sector will play a central role in achieving a climate-neutral economy in Europe. Many decarbonisation measures can also reduce other environmental impacts, such as air pollution, but some measures could add to more externalities in other sectors, like industry, tourism, shipping. Second, Europe's energy supply is highly dependent on imports from outside Europe, including from politically unstable regions. As a result, geopolitical tensions can threaten the security of the energy supply. Third, modern societies and economies are gradually more dependent on a reliable energy supply, electric power in particular. Most communication, transport, economic and financial activities rely on information and communication technologies powered by electricity. Therefore, even short interruptions in electricity supply can lead to soaring economic and social costs.

[30] Statista (2022). Annual greenhouse gas emissions in the European Union from 1990 to 2019, by sector (in million metric tons of CO2-equivalent), available at: https://www.statista.com/statistics/1171183/ghg-emissions-sector-european-union-eu/.

The energy sector has played the major role allowing the EU to achieve its three 2020 climate and energy targets of reducing GHG emissions by 20% compared to 1990 levels, increasing the share of renewable energy use to 20%, and improving energy efficiency by 20%.[31] According to EEA estimates, in 2020, EU-27 greenhouse gas emissions were 31% lower than in 1990. The EU achieved a 21,1 % share of renewables in its energy consumption in 2020.[32] The overall positive progress is mainly due to the increased use of renewables for electricity, heating, and cooling. Achieving a 20% reduction in energy consumption seemed unlikely for many years, but the widespread lockdowns in 2020, due to COVID-19, appear to have pushed the EU's primary and final energy consumption below target levels, by 5% and 3% margins, respectively.

The EU and its Member States are all net importers of energy. EU dependency on energy imports did not substantially change over the last decade, from 55,8 % of gross available energy in 2010 to 57,5% in 2020. The main origins of EU energy imports have changed somewhat in recent years, although Russia has maintained its position as the leading supplier to the EU of the main primary energy commodities covering 34,5% of natural gas, 25,7% of crude oil, and 49,1% of hard coal needs.

Primary energy production in the EU in 2020 was spread across a range of different energy sources, the most important of which in terms of the size of its contribution were renewable energy sources, with more than one third (40,8 %) of the EU's total production (see Figure 4). Nuclear energy was second, with 30,5 % of the total primary energy production. The share of nuclear energy was particularly high in France where it accounted for 75,2% of the national production of primary energy, while in Belgium it was over three fifths (62,8%) and in Slovakia 59,8%.[33] Germany and Poland are heavily dependent on coal - the most polluting fossil fuel. Although emissions from coal use in Germany and Poland have fallen in recent decades, they are still two of the biggest producers of coal emissions worldwide.[34]

With a population of around 740 million inhabitants, or roughly ten percent of the global population, Europe is one of the world's largest electricity consumers. Nordic countries are the most intense consumers in the region, with Iceland (54605 kWh per capita), Norway (24047 kWh per capita), and Finland (15804 kWh per capita) recording the highest electricity consumption per capita.[35]

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[31] European Environment Agency (2021). The EEA report 'Trends and Projections in Europe 2021'. EAA report, No 13/2021, available at: https://www.eea.europa.eu/.

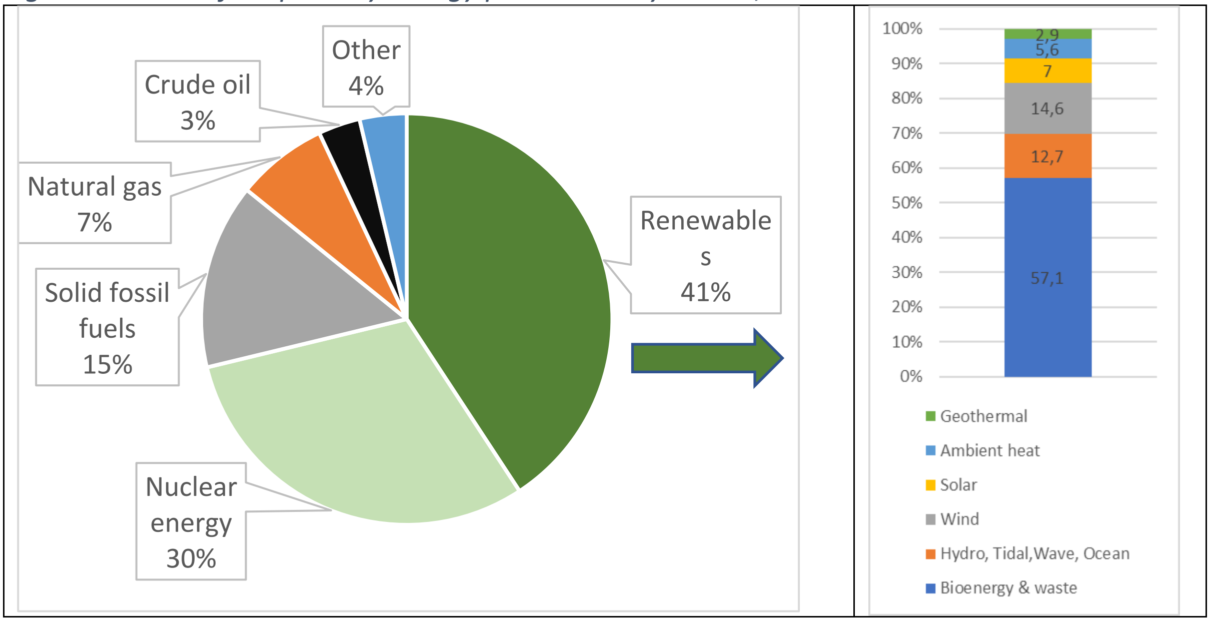
[32] Eurostat (2022). Share of renewable energy more than doubled between 2004 and 2020, available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable_energy_statistics

[33] Eurostat (2022). The EU and its Member States are all net importers of energy, available at: https://ec.europa.eu/eurostat/statistics-explained/.

[34] Statista (2021). Tiseo I., Biggest carbon polluters in the European Union 2020. 9 November 2021.

[35] Statista (2022). Leading countries in per capita electricity consumption in Europe in 2018 (in kilowatt hours), available at: https://www.statista.com/statistics/1262218/per-capita-electricity-consumption-europe-by-country/.

*Figure 4. Share of EU primary energy production by source, 2020.*




*Source: Eurostat.*

The promised expansion of electrification and falling costs for a range of clean technologies place power generation at the heart of the European energy transition. At the same time, the power sector in the EU presents a set of challenges:[36]

- power-generation plants are ageing; many nuclear and thermal power plants are nearing the end of their lifetime and need to be replaced or refurbished;
- coal remains the backbone of power generation in several countries; this is no longer consistent with environmental objectives;
- the first generation of wind turbines is also reaching the end of its operational lifetime and will soon be decommissioned;
- solar and wind generate highly variable amounts of energy, which pose threats to system stability and reliability.

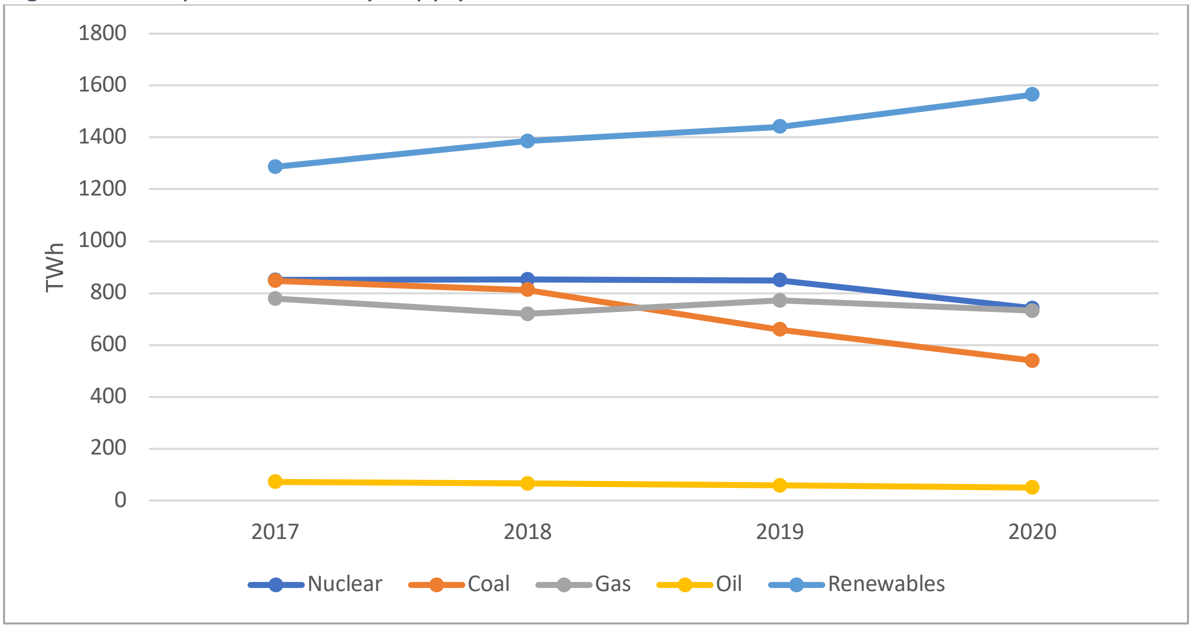
Total net electricity generation in the EU has been stable in recent years. It was 2 778 TWh in 2019, similar to the year before. The level of net electricity generation in the EU in 2019 was 2,3% lower than its relative peak of 2008, when total output stood at 2 844 TWh. Germany had the highest level of net electricity generation in 2019 among the EU Member States, accounting for 20,8% of the EU total, just ahead of France (19,7%); Italy (10,2 %) was the only other Member State with a double-digit share. During the period covering 2009 to 2019, there was an overall increase of 3,1% in the level of EU net electricity generation. The generation increase was observed in 15 of the 27 EU Member States. The largest overall increases were registered in Sweden (24,2%), Latvia (14,9%), and Ireland (11,4%). By contrast, among 12 EU Member States where there was a lower level of electricity generation in 2019 (compared with 2009), double-digit contractions were recorded in Lithuania, Luxembourg, Greece, Denmark, and Estonia.

There is an increasing role for renewables in electricity generation reaching up to 37% of gross electricity consumption in the EU, up from 34% in 2019 (see Figure 5). Wind and hydropower

[36] Deloitte (2021). Schlaak T., Trüby D., The future of power Scenarios to evolve the European electricity sector. 19 July 2021, available at: https://www2.deloitte.com/us/en/insights/industry/power-and-utilities/renewable-power-generation-in-europe.html.

accounted for over two-thirds of the total electricity generated from renewable sources (36% and 33%, respectively). The remaining one-third of electricity came from solar power (14%), solid biofuels (8%), and other renewable sources (8%).

*Figure 5. European electricity supply in 2020.*




*Source: IEA, European electricity supply in 2020, IEA, Paris https://www.iea.org/data-and-statistics/charts/european-electricity-supply-in-2020nternational Energy Agency.*

According to WindEurope data in 2020, Europe's wind farms generated 458 TWh of electricity, which covered 16% of the EU electricity demand. Share of wind in electricity consumption varies greatly. The top five countries amongst the highest rate are Denmark: 48%, Ireland: 38%, Germany: 27%, Portugal: 25%, Spain: 2%. Slovakia, Slovenia, Malta' rate is 0 %, Czechia – 1%, Hungary and Latvia – 2%.[37]

Some wind turbines had reached the end of their operational lifetime, consequently 388 MW of wind power were already decommissioned in 2020. This decommissioning took place in Germany (222 MW), Austria (64 MW), Denmark (61 MW), Belgium (25 MW), France (15 MW), and Luxembourg (2 MW). All decommissioned capacity came from onshore wind. Out of the 14,7 GW of onshore wind installed in 2020, 345 MW were through repowering projects.

## 4. Industries conflicting with wind energy

Potential wind farms usually conflict with other commercial sectors, such as tourism, fisheries, forestry, and non-commercial sectors such as defence. Furthermore, the energy system may compete for water and land including arable land with other sectors and systems, such as agriculture, forestry, and natural ecosystems. There are both synergies and trade-offs between wider sustainability objectives. The important connections between energy and other sectors, systems, and policy areas call for a comprehensive policy approach that considers multiple societal and policy objectives jointly. Spatial planning is a rational way of resolving conflicts, although even in

[37] WindEurope (2021). Wind energy in Europe - 2020 Statistics and the outlook for 2021-2025. WindEurope Intelligence Platform, available at: https://windeurope.org/intelligence-platform/product/wind-energy-in-europe-in-2020-trends-and-statistics/.

these cases, it is difficult to find consensus among all stakeholders. In the light of EU decarbonisation plans, the struggle for space and resources will deepen with each decade.

Regarding onshore wind, the energy-land-nexus is of growing importance, because many renewables, including wind parks, have a large land footprint. The term 'energy-land nexus' describes the interaction between energy and other land uses, such as food production, forestry, and nature protection.[38] Onshore wind parks are mainly the subject of national plans rather than cross-country policy.

Offshore wind typically affects multi-country planning. Nowadays, the European sea basins host an increasing variety of commercial activities – renewable energy production; oil and gas extraction; pipelines; cables for telecommunications and electricity; shipping; cruise industry; fishery; aquaculture and blue biotechnology; sand and mineral extraction; coastal and maritime tourism. Moreover, the seas host a number of important non-commercial activities, such as marine, defence, the coastguard and include areas designated for the protection of marine ecosystems and biodiversity. The more users compete for a share of the space, the scarcer and more valuable this space becomes.

The EU Maritime Space Planning (MSP) Directive[39] establishes a framework for maritime spatial planning aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources. The twenty-two coastal Member States developed and submitted their national maritime spatial plans by March 2021, with a minimum review period of 10 years.

## 4.1. Tourism

Visibility is the major factor which poses challenges to future wind park development both onshore and offshore. Wind farms change the character and appearance of the landscape. In case the quality and aesthetics of nature are the key elements for the success of the tourism industry, wind energy development is considered as a threat to the tourism industry.

Visual conflicts arise when planning the construction of offshore wind farms. Stakeholders related to beach and coastal tourism are often concerned that the visibility of offshore wind farms from the coast reduces the attractiveness of the place. This could negatively influence the number of visitors, and with this – the local economy. Offshore wind farms can block potential sailing routes, or restrict the available space for other recreational activities, such as windsurfing or diving. Local property owners including residents and second homeowners can be concerned that offshore wind farms might decrease the value of their property.

A recent study on Iceland[40] proved that the tourism service providers identified visual pollution as the most severe impact of wind farms on nature-based tourism. It was recognized that wind park development would have a negative impact on the image of the country, thereby affecting both individual businesses as well as the tourism industry as a whole. Wind energy development in such

[38] European Environment Agency (2019). Adaptation challenges and opportunities for the European energy system. EAA Report. No. 01/2019, available at: https://www.eea.europa.eu/publications/adaptation-in-energy-system.
[39] Directive No. 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning.
[40] Sæþórsdóttir, A.D.; Wendt, M.; Tverijonaite, E. (2021), Wealth of Wind and Visitors: Tourist Industry Attitudes towards Wind Energy Development in Iceland. Land 2021, 10, 693. https://doi.org/10.3390/land10070693.

areas will therefore raise important public policy questions with regard to the trade-offs between land use for nature-based tourism and for wind energy harnessing.

## 4.2. Transport

The transportation sector is most often in conflict with offshore wind farms. Maritime transport and offshore wind can come into conflict when new offshore wind farms are to be built or existing ones expanded – e.g. into areas where shipping activity is intense. Most of the conflicts are triggered by concerns about possible accidents and diversion.[41]

The risk of accidents is boosted by increased traffic density and reduced sea space, which might lead to the creation of choke points. Certain layouts of offshore wind farms are also riskier in terms of accidents than others, which can become an issue in case there are problems with a ship's on-board navigation equipment. Operations and maintenance vessels might also pose a risk – and be at risk themselves - while crossing major shipping routes en route to an offshore wind farm. Maritime accidents can lead to large financial losses for all parties involved. In the worst-case scenario, such accidents can lead to human casualties or serious environmental damage.

Offshore wind farms may lead to additional costs for the maritime industry — if, for example, vessels have to be diverted to take a longer route. Diversion can lead to following problems for the shipping sector: increased time and fuel spent; more greenhouse gas emissions; higher wages for the crew; financial penalties from the charter; higher insurance costs due to riskier routes; compliance with national and international law. Some countries have areas where certain restrictions apply, such as PSSAs[42] in the Baltic Sea. In the case of short sea shipping, longer transit times may make short sea services unable to compete with land-based transport services.

Conflicts between offshore wind farming and shipping occur mainly in the North Sea, Irish Sea and Baltic Sea where a large number of offshore wind farms already exist or are the planning stage. In small sea spaces such as Belgium and potentially the English Channel, limited spatial alternatives is a major issue.

## 4.3. Commercial Fisheries

### 4.3.1. Wind farms

Given that offshore wind energy potential is most utilized in the North Sea, Baltic Sea and Eastern Atlantic, conflicts between offshore wind farming and commercial fisheries have mostly been relevant in these sea basins.[43]

Accidental damage and ship strikes are a major concern. Snagging fishing gear is also a serious danger to fishers as it can cause a vessel to tip over or capsize. The construction and operation of offshore wind farms can disturb mobile and sessile species, leading to the displacement of, or reduction, in fish and shellfish resources. Spatial exclusion, even if it is voluntary in terms of risk aversion, can lead to a reduction in or loss of access to traditional fishing grounds. This in turn leads to the displacement of activity to other (potentially less profitable and/or less reliable) fishing grounds, leading to increased fishing pressure there. Obstruction of navigation routes to and from

[41] European MSP Platform. Transport and offshore wind. Last update 23 February 2021, available at: https://maritime-spatial-planning.ec.europa.eu/sector-information/transport-and-offshore-wind.
[42] A Particularly Sensitive Sea Area (PSSA) is an area that needs special protection through action by the International Maritime Organization because of its significance for recognized ecological or socio-economic or scientific reasons and which may be vulnerable to damage by international maritime activities.
[43] European MSP Platform. Conflict fiche 5: Offshore wind and commercial fisheries. Available at: https://maritime-spatial-planning.ec.europa.eu/sites/default/files/5_offshore_wind_fisheries_3.pdf.

fishing grounds can lead to increased steaming times. Small scale fisheries may not be able to compensate for the increasing cost of operation, and some fishing grounds may no longer be accessible for small boats at all. But there are also higher initial costs for developers if they have to agree on how to co-exist with fisheries as a prerequisite to obtaining their license.[44]

In some cases, conflicts between offshore wind farming and fishing masks a deeper conflict. Fisher people may perceive offshore wind farming as the last arrival in a long line of restrictions, threatening not only livelihoods, but also a traditional way of life.

In many countries, fishing vessels are not permitted to enter offshore wind farms. Changes in risk perceptions models may soften these spatial restrictions in the future.

### 4.3.2. Cables

Conflicts between cables, which are a constituent part of a wind farm, and fisheries are mostly related to accidental damage to cables and pipelines by anchors and fishing gear. There are also concerns arising from spatial restrictions around cables and pipelines.[45]

Damage to cables can occur from pulling fishing gear over them, or from fishing gear getting stuck underneath. The first case usually affects a longer stretch of cable and can cause cables to be moved or dragged along, in the worst case leading to breakages.

Vessels stranding on a cable is a relatively rare occurrence as it would involve a vessel sinking onto a cable, e.g. after having been involved in a collision. A direct hit like this affects the outer protective layers of the cable or pipeline, but it tends to be a localised impact.

Anchors being dropped directly onto a cable or pipeline can also cause localised damage. Further damage can occur if the anchor is moved and hooks the cable or pipeline. As above, this is an issue for vessels generally, and not just fishing vessels.

Fisher people cannot cross cables and pipelines while trawling. They either need to lift their gear to cross a particular cable, which is expensive in terms of lost catch, and time-consuming or find alternative fishing grounds or routes to the fishing grounds.

Currently, over a third of all cable damage is caused by fishing activity. This is because of changes in the shape and weight of trawl shoes, as well as the steady increase of the average horsepower of beam trawls. A potential hit is also a danger for the fisher people themselves. In areas with substantial fishing activity, cable owners and fisher people have, therefore, been concerned with finding solutions to this problem for some time.

## 4.4. Forestry

As trees store carbon, but a wind farm produces power, the assessment of which of these to prefer is quite controversial. Deforestation would contradict environmental and social values. Another option is the deployment of wind turbines in forest areas and leaving forest stands uncut as landscape shields to hide the turbines and stop them from spoiling the scenery. Even then, conflict situations arise due to forest degradation and restrictions on forest use.

The most important aspects to consider, when giving preference to forest or wind energy, are forest landscape, environmental values, forest types and conditions, existing road, and electricity

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[44] European MSP Platform. Offshore wind fisheries. Last update 15 November 2021, available at: https://maritime-spatial-planning.ec.europa.eu/sector-information/offshore-wind-and-fisheries

[45] European MPS Platform. Cables and Fisheries. Last update 23 February 2021, available at: https://maritime-spatial-planning.ec.europa.eu/sector-information/cables-and-fisheries.

infrastructure. One noteworthy aspect is that in reality the area for wind energy farms differs from the area required for the installation and maintenance of wind turbines. The difference can be as much as a thousand times larger because land for wind farms in wooded areas is usually leased rather than bought. Since small plots of forest land needed to install a wind generator is usually not leased, wind energy developers lease the entire forest land unit. Tree felling is a concern, especially when supervision and control are insufficient or weak. The actual physical impact of felling trees on installed MW capacity can vary significantly depending on the density and type of forest, the existing infrastructure, laws, and regulations and how these parameters are actually complied with.

## 4.5. Defence

Military use of the sea, or the use of marine and coastal areas for purposes of security and defence, is a reality in all coastal countries. The spatial needs and interests of national defence and security at sea are complex, so potential conflicts may not be immediately obvious.[46]

Maritime activities could get in the way of military infrastructure. For example, there have been concerns that wind turbines could interfere with defence radar or military underwater cables. There may also be negative impacts on optical, radio, and hydroacoustic observation and the possibilities of veiling. Maritime activities can impede the proper functioning of marine infrastructure that is considered indispensable for national safety and security, such as pipelines, transmission cables, data cables, etc. Maritime activities can interfere with naval training areas, artillery ranges or airbases, in other words, areas that need to be free of obstacles.

Acute spatial conflicts usually arise when defence interests restrict other permanent uses. Coexistence is often possible with more fleeting uses that do not impede military activities in principle, such as tourism, fishing, or even shipping; in these cases, measures such as temporary closures can often be used.

## 4.6. Impact on Radar for weather service

Some experts claim that huge wind turbines, in a large wind farm development, impact weather services by sending the signals back to the service station indicating a disturbance in the air. It may also affect the meteorological ability to detect storms and high tides.

According to research from the National Weather Service, this has the potential to negatively impact weather forecast accuracy in several ways[47]:

- The blades on wind turbines can block portions of the “energy beam” that NWS radar systems project to gather weather data, which could delay thunderstorm tracking and tornado warnings.
- Wind turbine “clutter” can create false positives that indicate severe weather during non-storm times.
- Turbines can interfere with a radar’s ability to accurately predict rainfall amounts – the result is typically an underestimation of precipitation totals.
- The movement of the turbines themselves can interfere with a radar’s ability to monitor wind speeds, negatively impacting wind, hail, and tornado warnings.

[46] European MPS Platform. Defence and other uses. Last update 23 February 2021, available at: https://maritime-spatial-planning.ec.europa.eu/sector-information/defence-and-other-uses.
[47] NNY360 (2018). Kenmore A., NWS fears turbine trouble. April 27 2018, available at: https://www.nny360.com/news/nws-fears-turbine-trouble/article_3f7a32d9-db87-5240-94a0-f67d75cf72e8.html.

Rotating wind turbine blades can impact a radar in several ways. Wind turbines can impact the NEXRAD radar base data, algorithms, and derived products when the turbine blades are rotating and located in the radar's line of sight; and, if turbines are situated very near to the radar, their large nacelles and blades can also physically block the radar beam or reflect enough energy back to the radar to damage the radar's receiver hardware.[48]

# 5. Important factors of the wind energy

Considering that planet earth's resources are limited, especially when considering its multiple demands of use, it becomes important to identify the most suitable locations for the installation of wind turbines. The most important factors determining the development of wind farms can be grouped as technological, economic, environmental, and social.

## 5.1. Technological factors

### 5.1.1. Natural conditions - Wind speed and wind density

The most important natural factors influencing wind energy production are wind speed and wind density. Turbines are designed to operate within a specific range of wind speeds. The limits of the range are known as the cut-in speed and cut-out speed. The cut-in speed is the point at which the wind turbine is able to generate power. It is around 12-14 km/h for larger turbines and around 8 km/h for smaller turbines. The maximum power is generated at around 40-60 km/h which is known as the rate speed. Between the cut-in speed and the rated speed, where the maximum output is reached, the power output will increase cubically with wind speed. For example, if wind speed doubles, the power output will increase 8 times. This cubic relationship is what makes wind speed such an important factor for wind power. The cut-out speed is the point at which the turbine must be shut down to avoid damage to the equipment which is around 90 km/h. The cut-in and cut-out speeds are related to the turbine design and size and are decided on prior to construction. A modern wind turbine produces electricity 70-85% of the time, but it generates different outputs depending on the wind speed.

The generation capacity will decrease, if the turbine is located lower to the ground, within the turbulent airspace downwind of an obstacle (for example, trees, hills, buildings, structures) and a distance from an upwind obstacle of more than 10 times an obstacles height.[49] In the case that a wind turbine is located in a forest, the wind flow over the forested terrain is characterized by a slowdown in wind speeds, higher wind shear, and increased turbulence.[50]

Wind power density is also an important indicator for selecting the location for wind turbines. It is calculated as the mean annual power available per square meter of swept area of a turbine, and it is determined for different heights above ground. It includes the effect of wind velocity and air density.

While it is possible to identify areas where wind speeds are relatively high, wind does not always blow with the same force; therefore, backups when the wind speed is slow are required. As a result, relying more heavily on wind farms for energy, increasing amounts of fossil fuels will also be required for balancing purposes. Low or zero-emissions back-up capacity for periods of low wind or

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[48] Radar Operations Center. NOAA's National Weather Service. NEXRAD WSR-88D, available at: https://www.roc.noaa.gov//.

[49] Wind turbine systems. Level, the authority on sustainable building, available at: https://www.level.org.nz/energy/renewable-electricity-generation/wind-turbine-systems.

[50] Meventus. Wind power in forest – the effects of clearings, available at: https://meventus.com/portfolio/wind-power-in-forest-the-effects-of-clearings/.

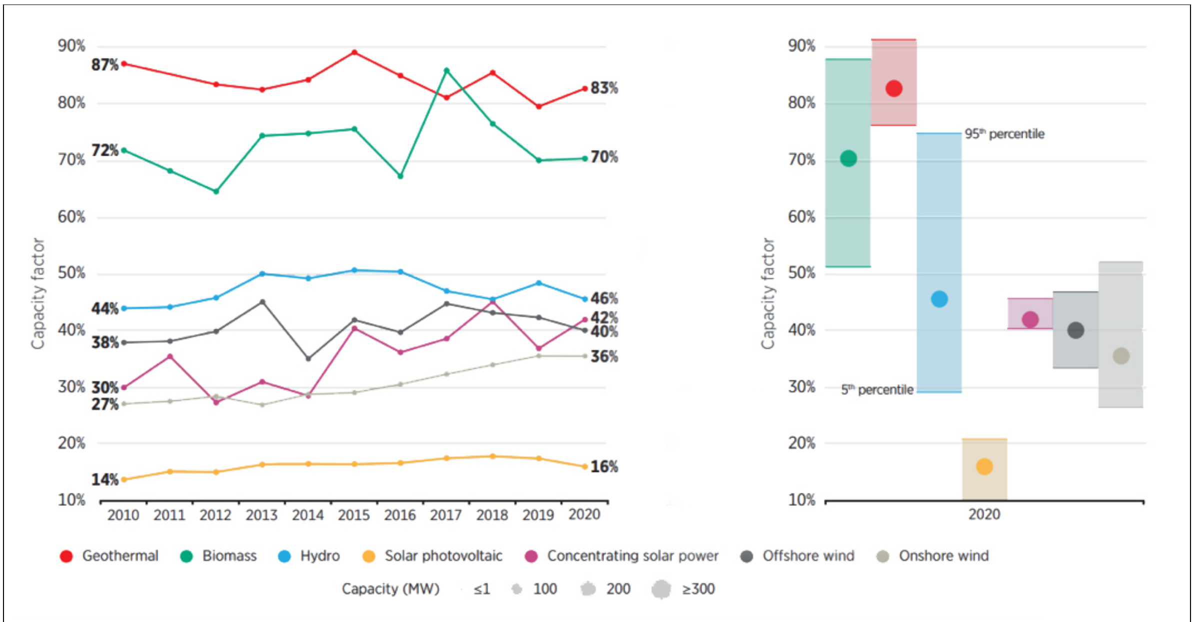
solar supply such as batteries, hydrogen or carbon capture and storage are still more than a decade away from being available at scale.

### 5.1.2. Efficiency

The efficiency of wind turbines is still one of the lowest among all sources of electricity generation, despite the difference being narrowed (see Figure 6). Most conventional wind turbine's efficiency rating is between 30% to 40%. In addition, if the reliability of wind power is considered, efficiency could be drastically reduced to 20% to 25%, during the slowest speed of wind.

Bioenergy for power and geothermal power plants has the highest capacity factors when it comes to renewables. Geothermal projects are typically designed to achieve high lifetime load factors, although this necessitates significant investment over their lifetime to re-work production wells or drill new ones as the reservoir responds to the extraction and reinjection of fluids. The capacity factors of bioenergy plants depend heavily on the availability of feedstocks. Plants with steady year-round supplies (e.g., municipal solid waste plants and those utilising forestry product residues) can achieve capacity factors to compete with those of geothermal plants. Plants reliant on seasonal supplies of agricultural residues tend to have lower capacity factors. While efficiencies vary for CHP installations based on site-specific parameters, a properly designed CHP system will typically operate with an overall efficiency of 65–85%; however, it can also reach up to 95%. To compare, a typical boiler's efficiency is 80% for natural gas-fired boilers, 75% for biomass-fired boilers, and 83% for coal-fired boilers.

*Figure 6. Global weighted-average utility-scale capacity factor by renewable technology, 2010-2020.*




*Source: IRENA, Renewable power generation costs in 2020.*

### 5.1.3. Grid connection and integration

Grid connection is one of the most important prerequisites for a successful wind farm operation. EU Member States apply different approaches for sharing the costs of grid connection between producers and grid operators:

- Super-shallow approach: plant developers only have to bear the costs of the inner electrical infrastructure, including the plant substation. All costs of expansion of the grid to the connection point and reinforcement are socialised via the tariff, no costs are charged to the connecting entity.

- Shallow cost approach. The plant developer bears the cost of the equipment necessary to connect the generator to the nearest point on the already existing grid network. On the other hand, the grid owner will bear the cost of any grid reinforcement that would be necessary to integrate the new generator.
- Deep cost approach: plant developers have to bear all connection costs, as well as any further reinforcement expenses that can arise as a consequence of integrating the generator in the electrical system.
- Mixed shallow–deep approach: this model is a hybrid of the two above-mentioned methodologies. Mainly, the plant developer bears the cost of grid extension to the assigned connection point, plus a proportion of the reinforcement costs.

Denmark, Germany, Portugal, and Slovakia are countries which apply the super shallow to shallow approaches for connection charges, and they are usually socialised in the tariffs. Charging is commonly based on actual costs. Grid users pay for their own connection line and substation. A deep connection charge type is applied in Croatia, Sweden, and the Baltic countries – Estonia, Latvia, Lithuania. It means that grid users also pay for grid extension. Other countries apply a shallow or mixed approach. In fact, there is a big difference between countries in how the connection fee is calculated and charged to the potential network user. This could be one of the challenges in the development of cross-border wind parks.

Some countries have a specific subsidy for wind generator connection to the grid. In Belgium, the shallow approach is used, but in addition there is a differentiation between regular connections and onshore and offshore connections. Regarding onshore connection, everything is socialised in the tariff, except all installations between the grid user and the connection bay at the substation. For offshore wind farms with a direct onshore connection, a support mechanism foresees an additional subsidy for the cable connection up to 25 million EUR. A RES support mechanism allows to charge energy off-take from the grid (load) 7,45 EUR/MWh for financing connection of offshore wind turbine parks and for financing green certificates.[51]

Support for the connection of new generators to the grid is not very comparable between countries, as in some cases, it is included in the transmission tariff, but in some cases, it is an extra charge to energy consumers. In Germany, a subsidy to the wind park connection was taken out of the transmission tariff in 2019, and is now an extra charge to consumers.

Some Member States establish conditions for priority access to the grid by renewable installations by either the priority access (in the presence of purchase contracts with transmission operators) or guaranteed access (when the wind generators participate in the market). In some Member States, wind operators are required to cover balancing responsibilities, and in some not.

Grid development is a common challenge for the further deployment of wind. Usually, the growth rate of the installed renewable sources is higher than the rate of development or reinforcement of the electrical grid. This problem is particularly compounded if wind resources (and therefore wind farms) are located far from consumption centres.

[51] ENTSO-E (2020). Overview of Transmission Tariffs in Europe: Synthesis 2019. November 2020, available at: https://www.entsoe.eu/.

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## 5.2. Economic and market barriers

### 5.2.1. Levelized costs of energy

Wind power is the one that has been demonstrating high competitiveness against conventional power generation for the longest time, and its global market penetration is correspondingly strong.

The levelized costs of energy (LCOE)[53] allows for the comparison of different technologies like wind, solar, natural gas, of unequal life spans, project size, different capital cost, risk, return, and capacities. LCOE for wind projects is highly dependent on the initial capital cost and capacity factor, but a discount rate and annual operating expenses also play a significant role. Manufacturers are striving to construct taller towers, and to increase the rotor surface area in proportion to the generator power output. This corresponds with an effort to increase yield, enabling profitable operation also at locations with less favourable wind conditions. Taller towers and longer rotor blades, however, lead to greater material and installation costs that can only be justified by a significant increase in full load hours.

Several studies compare the levelized cost of electricity (LCOE) of renewable energy technologies for electricity generation with conventional power plants.[54] [55] While the Lazard report focuses on the costs worldwide, the Fraunhofer Institute has concentrated on the renewable energy production plants in Germany. Both reports demonstrate that the costs of renewable energy technologies continue to decline, albeit at an ever slowing pace, reflecting reductions in capital costs, increased competition as the sector continues to mature, and continued improvements in scale and technology.

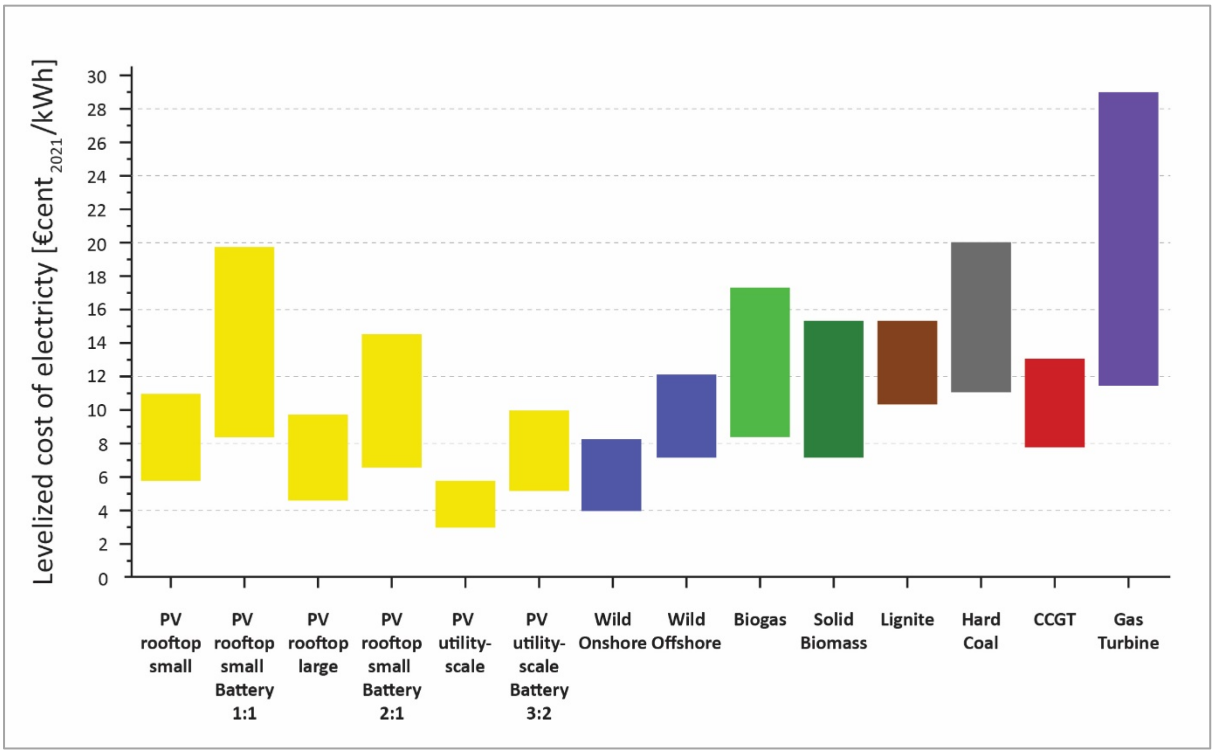
According to the Lazard report, LCOE for onshore wind is in the limits 26-50 USD/MWh or 23-44 EUR/MWh (see Figure 7), while LCOE in Germany is between 40-80EUR/MWh. Regarding offshore, wind LCOE is higher between 70-120 EUR/MWh in Germany and around 73 EUR/MWh globally. Offshore wind parks are more expensive because there is the necessary use of more resistant and expensive materials, the elaborate anchoring in the seabed, cost-intensive installation, and logistics of the plant components and higher maintenance expenditure. Sites, which are often located far from the coast, are subject to the disadvantage of a complex and expensive grid connection, as well as the need to bridge the greater ocean or sea depth.

[53] Levelized cost of electricity (LCOE) refers to the estimates of the revenue required to build and operate a generator over a specified cost recovery period.

[54] Kost C., Shammugam S.,Fluri V., Peper D., Memar A.,D., Schhlegl T., Levelized cost of electricity renewable energy technologies. Fraunhofer Institute for Solar Energy Systems ISE. June 2021, available at: https://www.ise.fraunhofer.de/en/publications/studies/cost-of-electricity.html.

[55] Lazard (2021). Lazard's levelized cost of energy analysis – version 15.0. October 2021, available athttps://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf.

*Figure 7. LCOE of renewable energy technologies and conventional power plants at different locations in Germany in 2021.*




*Source: Fraunhofer Institute for Solar Energy Systems ISE.*

### 5.2.2. Financing wind power projects

The estimated investment needed for the large-scale deployment of offshore renewable energy technologies by 2050 is at almost EUR 800 billion[56], around two thirds to fund the associated grid infrastructure, and a third for offshore power generation. Annual investment in onshore and offshore grids in Europe over the decade to 2020 have amounted to around EUR 30 billion, but need to increase to above EUR 60 billion in the coming decade, and then increase further after 2030.[57]

It is foreseen that the lions' share will come from private investors, but EU funding instruments can play a strategic role in the roll-out of renewable technologies:

- The Recovery and Resilience Facility (RRF) of €672.5 billion will channel 37% of its funds to the green transition and can be used to support reforms and investments in wind energy under the 'Power up' flagship initiative. The RRF can also support investments in port infrastructure as well as grid connections and reforms needed to facilitate the deployment of offshore renewable energy and integration to energy systems;
- The InvestEU Fund aims to mobilise more than €372 billion of public and private investment through an EU budget guarantee of €26.2 billion that backs the investment of implementing partners such as the European Investment Bank (EIB) Group and other financial institutions.

[56] European Commission (2020). An EU Strategy to harness the potential of offshore renewable energy for a climate neutral future. COM(2020) 741 final, Brussels, 19 November 2020.
[57] European Commission (2020). Impact Assessment. Accompanying the document Stepping up Europe's 2030 climate ambition. Investing in a climate-neutral future for the benefit of our people. SWD(2020) 176 final. Brussels, 17 September 2020.

- The Connecting Europe Facility, which aims to promote the development of high-performing and environmentally sustainable interconnected transport, energy, and communications networks across Europe.
- The Renewable Energy Financing Mechanism will allow Member States, as of 2021, to provide financial contributions to renewable energy projects and receive statistical benefits in return.
- Horizon Europe – the EU's flagship Research and Innovation programme with a budget of €95,5bn (including €75,9bn from the MFF and €5bn from the Next Generation Europe) to spend over a seven-year period (2021-2027).
- The Innovation Fund under the EU Emission Trading System (EU ETS),
- The Modernisation Fund under the EU ETS (10 eligible Member States).

Part of the risk of wind projects and insufficient revenue from market prices has been compensated through support schemes. Various policy instruments are used to support renewable electricity deployment through different stages of technological maturity. Options include administratively set feed-in tariffs or premiums, renewable portfolio standards, quotas, and tradeable green certificate schemes, net metering, tax rebates, and capital grants. Some of these instruments have been introduced simultaneously. Recently, auctions and contracts for difference have been used to support wind energy production.

Auctions for the centralised competitive procurement of renewables have become increasingly widespread and have been instrumental in discovering renewable energy prices and containing policy costs in many countries. However, the success of such policies in achieving deployment and development objectives relies on their design and ability to attract investment and competition. Recently, the Netherlands started conducting offshore wind farm auctions. In these public tenders, companies compete to secure a permit and associated subsidy to build and operate a wind farm. The company with the lowest bid (in eurocents per kilowatt hour) wins the auction. In February 2022, the Norwegian Government announced the country's first-ever offshore wind auction for the first half of the Southern North Sea 2 zone. The auction will be technology-specific and award up to 1.5 GW of bottom-fixed offshore wind capacity. According to the Norwegian Government, the electricity will be used to power up to 460,000 households in mainland Norway. The Norwegian Government decided against a hybrid offshore wind farm, with grid connections to two or more countries, but it will only be connected to the Norwegian electricity grid.[58]

The Contracts for Difference (CfD) scheme incentivises investment in renewable energy by providing developers of projects with high upfront costs and long lifetimes with direct protection from volatile wholesale prices, and they protect consumers from paying increased support costs when electricity prices are high. This support for wind farms is used in the UK. Successful developers are paid a flat (indexed) rate for the electricity they produce over a 15-year period. The difference between the 'strike price' (a price for electricity reflecting the cost of investing in a particular low carbon technology) and the 'reference price' (a measure of the average market price for electricity in the UK market).[59]

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[58] WindEurope (2022). Norway announces first offshore wind auction, 17 February 2022, available at: https://windeurope.org/newsroom/news/norway-announces-first-offshore-wind-auction/.

[59] Department for Business, Energy & Industrial Strategy. Contracts for Difference (CfD): allocation Round 5. 4 February 2022, available at: https://www.gov.uk/government/collections/contracts-for-difference-cfd-allocation-round-5.

The available funding for support to wind parks for technology development, network development, and running costs will play a vital role in the implementation of NECPs, namely developing wind farms.

### 5.2.3. Supply Chain Management

The relationships between manufacturers and their component suppliers have become increasingly crucial, and have come under increasing stress in the past years as soaring demand has required faster ramp-up times, larger investments, and greater agility to capture value in a rapidly growing sector. Supply chain issues have dictated delivery capabilities, product strategies, and pricing for every turbine supplier.

Multiple segments, including blades, bearings, and gearboxes, are highly concentrated and produce pinch points in the supply chain. These segments have high entry barriers based on the size of the investment and manufacturing ramp-up time. At the same time, controls, generators, castings, and tower segments have lower entry barriers, with a larger number of players.[60] Most of the European manufacturing facilities are located in Germany, Spain (the MSs with the largest installed wind power capacity), and Denmark (the MS with the largest share of wind energy in its electricity demand).[61]

The EC Joint Research Centre assessed the future demands for the materials needed for the deployment of wind energy until 2050. And the assessment is not very optimistic regarding the availability of raw materials.[62] Steel and iron materials are the major raw materials used in wind turbines. According to the World Steel Association, about 85% of wind turbines around the world are manufactured primarily from steel. Concrete and steel are essential materials for wind turbine foundations. On average, concrete makes up 93-95% of onshore foundations. In addition, the availability of aluminium, rare-earth elements, boron, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel are essential materials in wind turbine production. While some materials are close to current availability (Figure 8), others are strongly below current global supply (Figure 9).

Even if the material is available globally, the EU's dependence on imports makes the sector risky. 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%[63]. 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. 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.[64]

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[60] Intelligent Energy. Supply Chain Key to Delivery. 6 November 2021, available at: https://www.wind-energy-the-facts.org/supply-chain-key-to-delivery.html

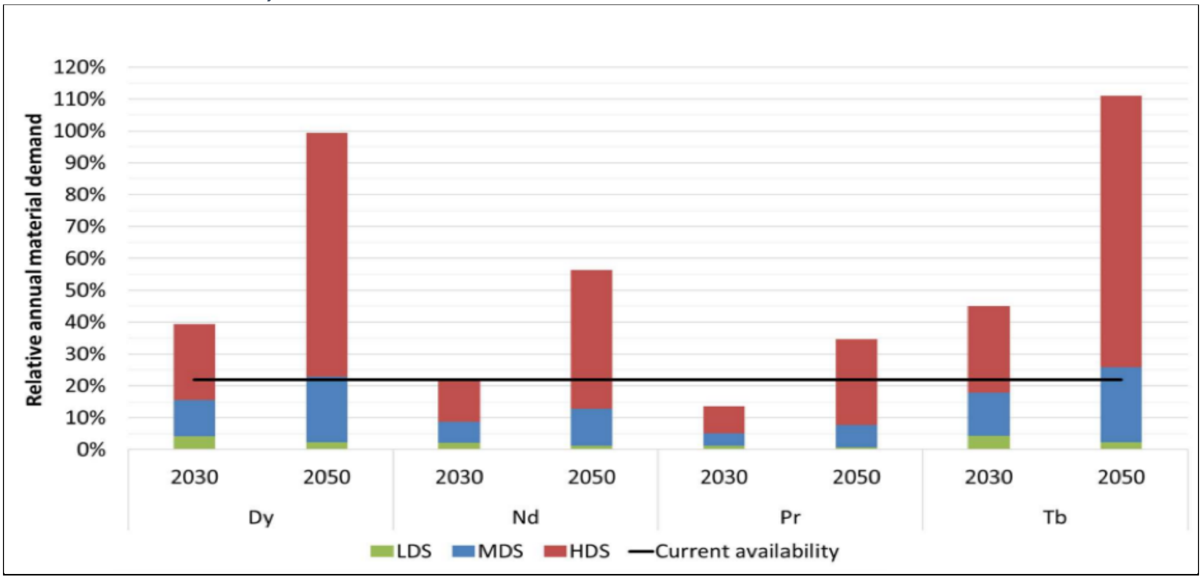
[61] Telsnig, T. and Vazquez Hernandez, C., Wind Energy: Technology Market Report, EUR 29922 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-12570-9, doi:10.2760/260914, JRC118314.

[62] Carrara, S., Alves Dias, P., Plazzotta, B., Pavel, C. Raw materials demand for wind and solar PV technologies in the transition towards a decarbonised energy system. European Commission. Joint Research Centre. 2020. ISBN 978-92-76-16225-4 ISSN 1831-9424 doi:10.2760/160859.

[63] JRC, interactive tool: Materials that are critical to our green future.

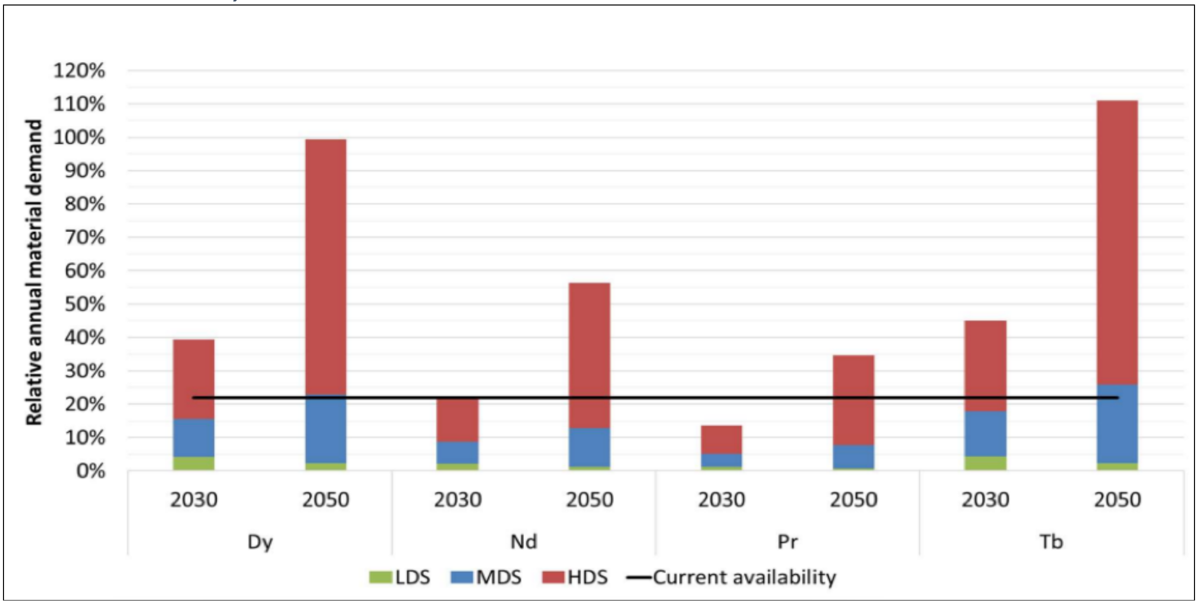
[64] European Commission (2021). Commission staff working document Accompanying the document Report Progress on competitiveness of clean energy technologies 1 – Macroeconomic. SWD/2021/307 final Brussels, 26 October 2021.

*Figure 8. EU wind demand-to-global supply ratio for 2030 and 2050 – levels of demand close to current availability.*



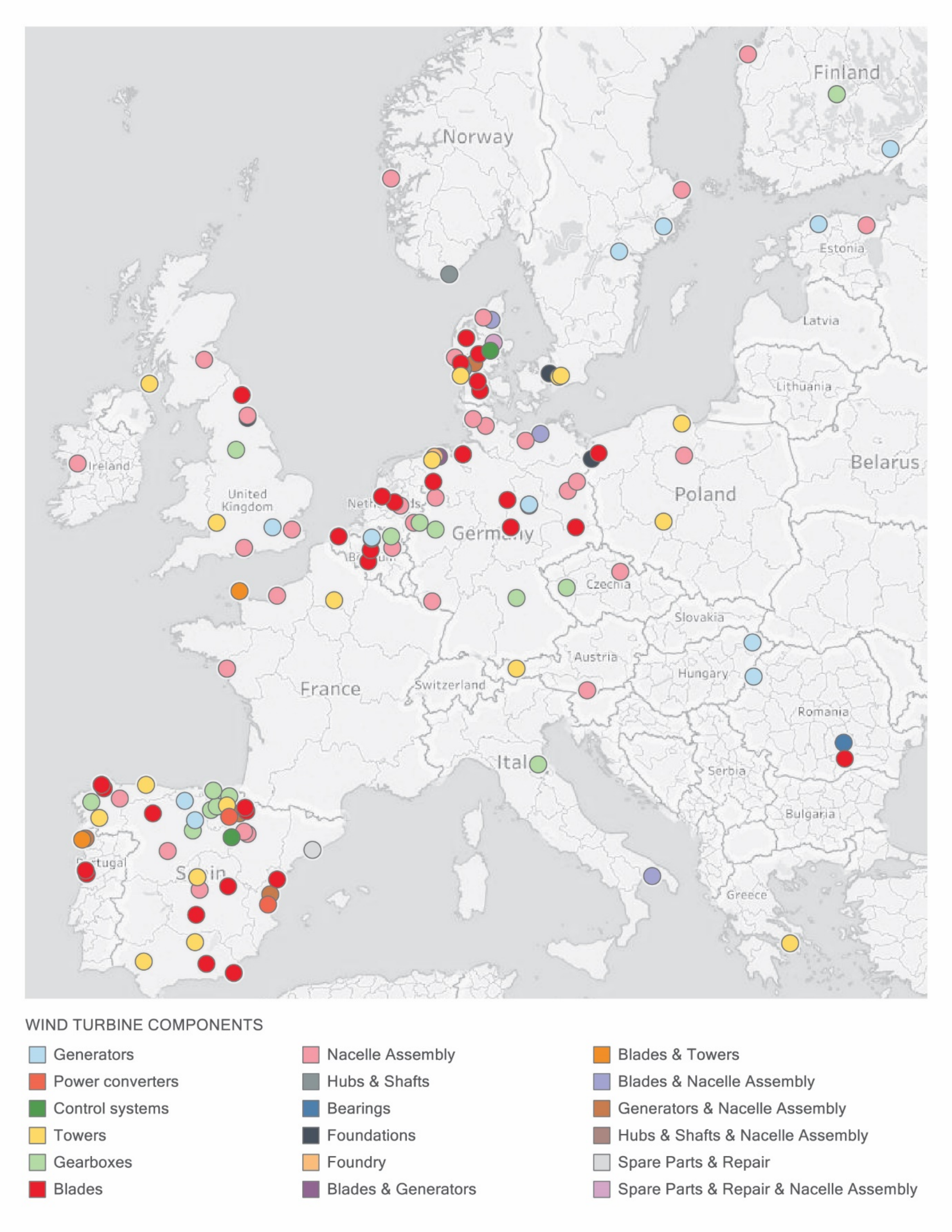

*(Dy – Dysprosium, Nd – Neodymium, Pr – Praseodymium, Tb – Terbium)*
*Different policy-relevant electricity generation scenarios for the EU and the world by combining power generation capacities, plant lifetime, sub-technology market shares and material intensity were considered - Low Demand Scenario (LDS), Medium Demand Scenario (MDS), High Demand Scenario (HDS).*
*Source: European Commission. Joint Research Centre.*

*Figure 9. EU wind demand-to-global supply ratio in 2030 and 2050 – levels of demand below current availability.*




*Source: European Commission. Joint Research Centre.*

*Map 1. Manufacturing facilities of wind OEMs in the EU28 according to wind turbine component produced.*



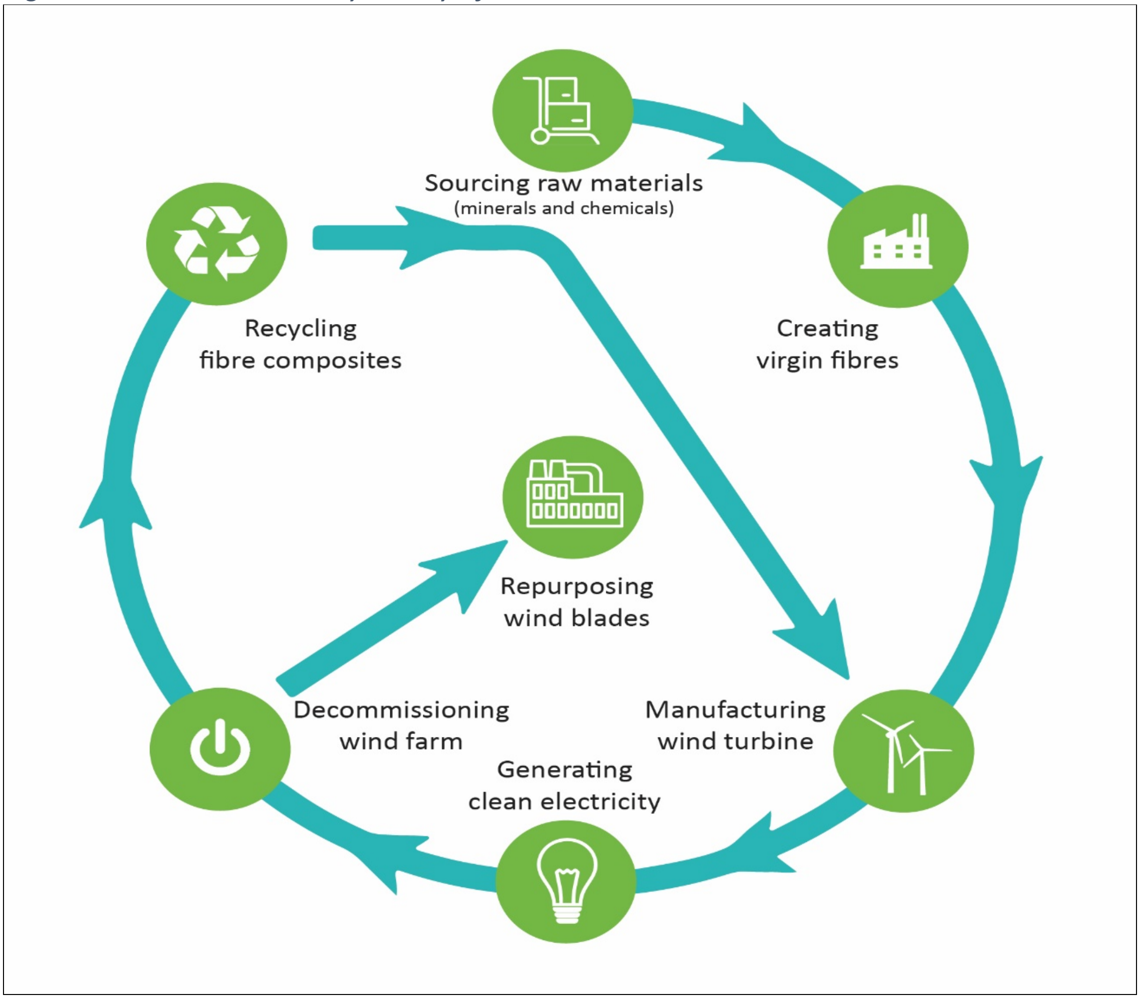

*Source: JRC Wind Manufacturing Facilities Database 2018.*

### 5.2.4. Decommissioning and Circularity

The age structure of the EU onshore and offshore wind fleet indicates that repowering will play a crucial role in the coming years. The standard lifetime of a wind turbine is approximately 20-25 years (with some wind turbines now reaching up to 35 years). Today 34,000 turbines are 15 years or older, representing 36 GW of onshore wind capacity. Out of the 36 GW, some 9 GW are 20-24 years old and around 1 GW is 25 years or older. Most of the ageing capacity is in Germany, followed by Spain, Italy, and France.[65] This is a significant volume that needs certain logistics in place to proceed with dismantling, collection, transportation, waste management treatment, and finally site restoration in a sustainable way.

The blades are made of fiberglass, and unlike the steel towers they rest on, the material can't be recycled. As a result, thousands of blades that reached the end of their lifespan end up as landfill. A landfill site can quickly fill up as more of these massive structures are being deposited each year as older wind turbines reach the end of their life.

*Figure 10. Circular economy theory of wind turbine blades.*




*Source: Global Wind Energy Council*

An international standard for decommissioning wind turbines does not exist today. Dismantling of wind turbines should be regulated by national legislation or the requirements should be included in the Environmental Impact Assessment (EIA) for each project. For example, in Denmark the municipality typically sets the conditions for decommissioning in the building and operating permit initially issued. Decommissioning must start 1 year after the wind farm has stopped operating at the latest. In Spain and UK requirements are project specific. Once a wind farm is decommissioned, the

[65] WindEurope (2020). Decommissioning of Onshore Wind Turbines. Industry Guidance Document. November 2020, available at: https://proceedings.windeurope.org/.

site should be restored to a greenfield. Health and safety requirements should always be a top priority throughout the whole process of decommissioning a wind farm. That, and a solid communication plan with the local authorities, are key factors for a sustainable decommissioning of a wind farm. In general, the owner of the wind turbine generators bears the overall responsibility for the decommissioning and dismantling measures to be carried out. It is responsibility of asset owners to fulfil dismantling requirements.

The decommissioning and renewal of current wind energy installations represents a challenge in terms of resource efficiency, supply of raw materials and waste production, because many components of the current wind turbines cannot be reused or recycled yet. This is a major challenge, both environmentally and economically. 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 (see Figure 10). Circularity of wind mills still requires research and investment, and deployment efforts.

## 5.3. Environmental factors

The contribution of wind energy is considered be central to achieve the EU climate neutrality goal by 2050, but it should not have a negative impact on nature. The European Commission published its updated guidance on wind energy developments and EU nature legislation.[66] The document covers the whole life cycle of wind energy developments, both on land and at sea, and explains the necessary steps to ensure that the activities related to wind energy are compatible with EU environmental policy in general and EU nature legislation in particular. The document is not binding and it would be the best practise of Member States to follow the recommendations.

### 5.3.1. Threat to Wildlife and Biodiversity

Setting up a wind farm can drastically affect the life cycle of birds, additionally bats, and other flying creatures. As a result, more and more people are becoming vocal about this persistent issue, especially wildlife conservation groups. This is also regarded as one of the biggest reasons that people are still being reluctant to switch to wind power.

Effects from onshore wind energy developments may arise in one or more of the five typical phases of wind energy development:[67]

- pre-construction (e.g. meteorological equipment, land clearance);
- construction (construction of access roads, platform, turbine, etc. and transport of material);
- operation (including maintenance);
- repowering (adapting the number, typology and/or configuration of turbines in an existing wind farm);
- decommissioning (removing the wind farm or individual turbines).

The major receptor groups are habitats, bats, birds, and other species.

In 2020, the EC issued a Guidance document on wind energy developments and EU nature legislation. The document is not legally binding, it is intended to assist citizens, businesses, and national authorities in the application of the Birds and Habitats Directives.

[66] European Commission (2020). Commission notice. Guidance document on wind energy developments and EU nature legislation, C(2020) 7730 final, Brussels, 18 November 2020.
[67] European Commission (2020). Commission notice. Guidance document on wind energy developments and EU nature legislation, C(2020) 7730 final, Brussels, 18 November 2020.

### 5.3.2. Impact on marine life and species

Conflicts between offshore wind farming and area-based marine conservation mostly arise on account of noise disturbance and displacement. Noise disturbance during the construction phase can lead to changes in the behaviour of a range of sea animals. Research in Germany and Denmark confirms that porpoises temporarily migrate to other areas during pile driving, but that population density returns to normal after the pile driving is finished. Some species of offshore seabirds avoid areas where offshore wind farms have been constructed, and neighbouring areas. Mammals such as porpoises, bottlenose dolphins, Northern Right whale, harbour seals, and baleen whales can be disturbed by specific frequencies of underwater noise. Apart from collision, the erection of offshore wind turbines may affect birds as follows: short-term habitat loss during construction, long-term habitat loss due to disturbance by turbines, formation of barriers on migration routes, and disconnection of ecological units, such as roosting and feeding sites. Cumulative effects may arise in connection with other pressures on birds such as shipping. Offshore piling and cable laying also influence the sea floor. For fish and fish larvae, pile driving can have a negative effect, but recent research found this to be extremely small. Electromagnetic fields seem to have minor effects on certain fish species.[68]

International environmental policy sets out ambitious targets for area-based marine conservation. The Aichi targets for the Convention on Biological Diversity stipulate that by 2020, 10% of marine areas, especially those of high biological and ecological significance, should be managed as protected areas. Other political drivers include the UN Sustainable Development Goals, especially Goal 14 “Life under water”, as well as EU-wide and national biodiversity and climate polices. The Marine Strategy Framework Directive’s Descriptor 11 specifies that the “Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment”. There are also species-specific conservation targets at the population level. Uncertainty remains a key driver of conflict, as a precautionary approach may dominate in the absence of sound knowledge. This is particularly the case for cumulative effects of human activities, where offshore wind farming may only be one factor among many.

### 5.3.3. Noise pollution

The noise pollution produced by a wind farm can have severe negative effects on people’s sleeping pattern, as well as psychological and physical health. Wind turbine noise level has wrecked the lifestyles of many local residents.

There are mainly two sources of noise in a wind turbine:

- aerodynamic: the motion of air around the blades, and
- mechanical: the motion of the mechanical and electrical components.

At a distance from the base of a turbine equal to one rotor length (43m) where the turbine generates 100 dB(A), one can experience a sound level of approximately 55 to 60 dB(A). The sound intensity drops relative to the square of the distance to the sound source.[69]

The World Health Organisation (WHO) released Environmental Noise Guidelines for the European Region in 2018. This publication conditionally recommends reducing outdoor noise levels produced

[68] European MSP Platform. Offshore wind and conservation. Last update 8 March 2021, available at: https://maritime-spatial-planning.ec.europa.eu/sector-information/offshore-wind-and-conservation.

[69] Windmeasurmentinternational. Measuring and Calculating Sound Levels. Available at: http://www.windmeasurementinternational.com/wind-turbines/turbine_sound-measurement.php

by wind turbines to which people are exposed to below an $L_{den}$ of 45 dB(A).[70] In reality, noise limits vary from jurisdiction to jurisdiction; however, generally speaking, it is 40 to 45 dB(A) at a distance of 300 metres. This generally sets a distance of 300 metres for any wind farm of more than ten turbines, but as with many aspects of wind energy, it varies from place to place. Some countries (Denmark) apply limits to the total noise from all wind turbines and they might be set for both weak winds, when noise is found to be most annoying, and stronger winds.

Low frequency noise (LFN), also known as infrasound, is used to describe sound energy in the region below about 200 Hz. LFN may cause distress and annoyance to sensitive people. For this reason, LFN has been widely analysed. The most important finding is that modern wind turbines with the rotor placed upwind produce very low levels of infrasound typically below the threshold of perception. Some studies still prove that wind turbines generated low-frequency noise (LFN, 20–200 Hz) poses health risks to nearby residents.

The objective of limiting noise is to avoid annoyance or interference in the quality of life of the nearby residents. Noise levels can be measured and predicted but public attitude towards noise depends heavily on perception. Due to the wide variation in the levels of individual tolerance for noise, there is no completely satisfactory way to measure the subjective effects of noise, or the corresponding reactions of annoyance and dissatisfaction. Dose-response relationship studies have demonstrated a correlation between noise annoyance with visual interference and the presence of intrusive sound characteristics. In the same way, the annoyance is higher in a rural area than in a suburban area, and higher also in complex terrain in comparison with flat ground. It was also proved that exposure to wind turbine sound significantly impairs individuals' well-being, because it strongly affects their decision to spend, or consider spending, resources in retrofitting their houses.

Another important aspect to be looked at is the underwater noise from offshore wind generators. The cumulative contribution to the soundscape from multiple turbines within a wind farm (in some cases, many hundreds) and the fact that wind farms occupy larger and larger fractions of coastal and shelf waters means that their combined contribution of noise cannot be ignored. The contribution from wind turbines can, in particular, be expected to be significant in areas with low natural ambient noise and low levels of ship traffic, possibly large enough to raise concern for negative effects on species of fish and marine mammals. Such large-scale cumulative effects should be addressed in both strategic impact assessments in connection to maritime spatial planning and in environmental impact assessments of individual projects.[71]

### 5.3.4. Visual pollution

Unlike noise pollution, visual aesthetics cannot be measured, but they both play an important role in determining acceptance of windmills. The addition of any structure to environment can drastically alter a landscape or seascape.

With regards to wind energy and marine renewable energy devices, some people appreciate their presence as they may attract tourism, while others dislike the new addition as an imposition on the natural environment. Land-based wind energy and offshore wind energy projects are more likely to impact aesthetics and create visual pollution than marine renewable energy projects due to wind turbines' heights, proximity to people, and visibility at greater distances. Marine renewable energy

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[70] World Health Organisation (2018). Environmental Noise Guidelines for the European Region. World Health Organisation Regional Office for Europe, Copenhagen.

[71] Tougaard J., Hermannsen L., MadsenT. P. How loud is the underwater noise from operating offshore wind turbines? The Journal of the Acoustical Society of America 148, 2885 (2020); https://doi.org/10.1121/10.0002453

devices are typically lower profile, closer to the surface, or submerged underwater–all of which reduce their visibility and perceived visual impacts.

Most countries with a wind power industry have established rules which exclude certain areas from development, such as national parks or nature reserves.

#### 5.3.5. Shadow flicker

Shadow flicker is the effect of the sun (low on the horizon) shining through the rotating blades of a wind turbine, casting a moving shadow. It will be perceived as a "flicker" due to the rotating blades repeatedly casting the shadow. Although in many cases shadow flicker occurs only a few hours in a year, it can potentially create a nuisance for homeowners in close proximity to turbines. The flicker effect is a particular concern for people who suffer from photosensitive epilepsy and experience seizures in response to certain environmental triggers.

There are actions that can be taken to mitigate the effects of shadow flicker. Because shadow flicker can only occur for brief periods of time during limited times of the year, the turbines can simply be shut off for those periods, thereby eliminating any possibility of shadow flicker.

Most, but not all, countries now have zero-tolerance planning regulation policies around shadow flicker from wind farms.

### 5.4. Social aspects – involvement of local population, local communities

The opposition to the wind farm is not monolithic, but the result of multiple individually contributing factors which can be related to a wide range of actual, potential or perceived, impacts of a wind energy project. Concerns include impacts on landscape, bio-diversity, health, noise, and property values and they contribute to the way people frame the value of a project, which influences social acceptance.[72] The attitudes of people living near wind energy projects have been formulated much stronger. Some studies demonstrate that wind turbines have a negative impact on the value of neighbouring residential properties. According to the study visual pollution reduces the residential sales price by up to about 3%, while noise pollution reduces the price between 3% and 7%.[73]

The way in which projects are regulated and the perceived distribution of costs and benefits that arise from a wind energy project also shape levels of social acceptance. This includes the degree of procedural justice that is promoted through public participation, the degree of community stake in a project through ownership or as recipients of other benefits and the effectiveness of the broader policy environment to take account of community concerns.

As a result, levels of social acceptance can have a significant impact on the nature of the wind industry and, potentially, limit the ultimate scale of the wind energy sector and its contribution to national energy systems. It has also given rise to new forms of community tension and social innovation. Those involved in the wind energy industry, in conjunction with a range of state actors, have attempted to influence social acceptance through new practices and policies, including enhanced public participation programmes, community benefit schemes, share ownership regulations, and other initiatives. It is still unclear whether such approaches have had significant impacts in specific contexts, but levels of opposition appear to be generally increasing. The review of

[72] Geraint E., Gianluca F., The social acceptance of wind energy. Where we stand and the path ahead. European Commission. European Atomic Energy Community, 2016. ISBN 978-92-79-63210-5 ISSN 1831-9424 doi: 10.2789/696070.

[73] Jensen C., U., Panduro T.E., Lundhede T.H. The Vindication of Don Quixote: The Impact of Noise and Visual Pollution from Wind Turbines. Land Economics. University of Wisconsin Press Volume 90, Number 4, November 2014, pp. 668-682.

social acceptance has highlighted that it is informed by structural issues related to trust in state institutions, political cultures, and citizen relationships with the energy system.

# 6. From global to national level – the case of Latvia

While the EC has the competence to elaborate the EU's sustainable energy and climate policy, Member States have the right to determine their own energy mix. National governments play an important role in influencing the development of the energy sector. The framework of the National Energy and Climate plans are designed to develop a policy and set the achievable targets at the national level.

There are relatively few studies available on Latvia's situation in particular. The potential of offshore wind has been studied within the Baltic Sea region framework.[74] [75] Regarding onshore wind, there are some studies focusing somewhat on the interests of investors.[76] To enhance the socially inclusive and environmentally sound market uptake of wind energy by increasing its social acceptance in 'wind energy scarce regions' (WESR) the WinWind project was launched. The project analysed regional and local communities´ specificities, socioeconomic, spatial and environmental characteristics and the reasons for the slow market deployment in the selected target regions. The project considers cases of WESR in Germany, Spain, Italy, Latvia, Norway and Poland from a multidisciplinary perspective.[77]

## 6.1. State of play of the energy sector

While the overall target for raising the share of renewable energy for the EU for 2020 was 20%, the shares of the different energy sources in the total energy consumption vary significantly between Member States. Latvia has taken on binding target for raising RES share to 40%.[78] The RES target was exceeded by reaching 42,1 % of renewable energy in gross final energy consumption in 2020. It was the third highest share of RES after Sweden (56,4%), and Finland (43,1%).

The highest share in the primary energy generation from renewables is fuelwood – around 80% (see Figure 11). It is mainly used for heating and district heating. Given the gradual transition from natural gas to fuelwood, especially when the price of natural gas at the end of 2021 was particularly high and remained in the limits of 90-180 EUR/MWh TTF, it is expected that this share will increase.

[74] European Commission (2019), Directorate-General for Energy, Study on Baltic offshore wind energy cooperation under BEMIP : final report, Publications Office, 2019, available at: https://data.europa.eu/doi/10.2833/864823.

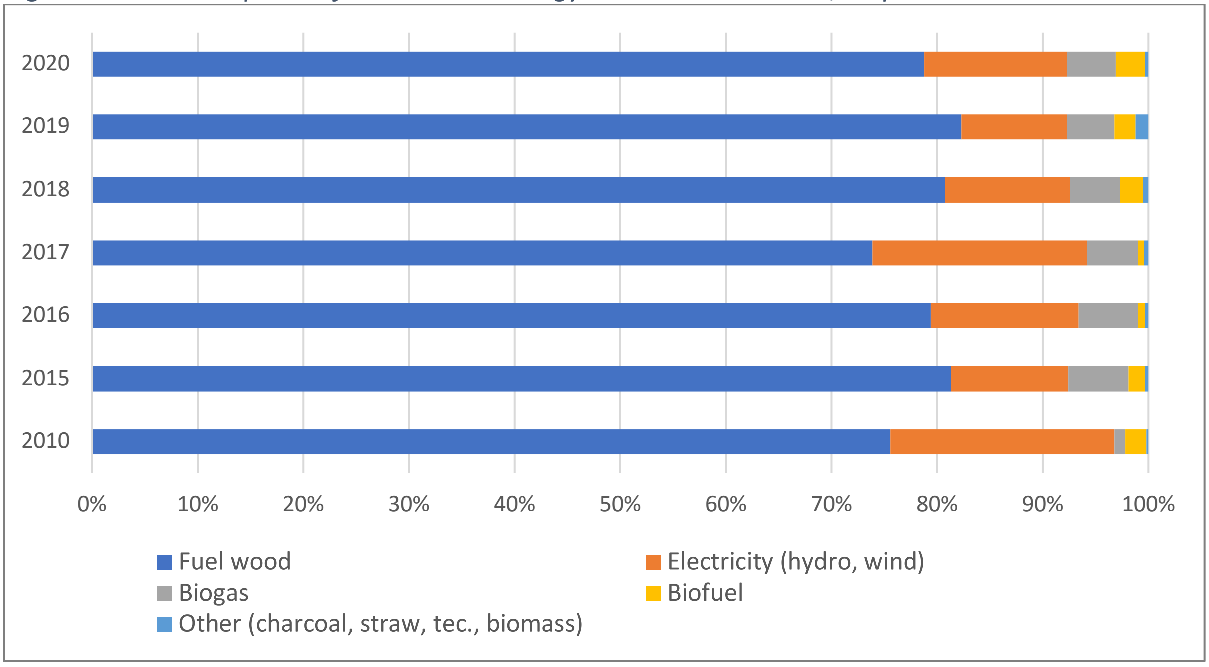
[75] Baltic Sea Region Energy Cooperation (BASREC) (2012). Conditions for deployment of wind power in the Baltic Sea Region Analysis part II. Strategic Outline offshore wind promotion, available at: http://basrec.net/wp-content/uploads/2013/09/BASREC-wind-2_strategic-outline_120424.pdf.

[76] CEE Bankwatch Network (2019). Āboltiņš R., Analysis of factors affecting deployment of wind energy in Latvia and potential solutions. December, 2019, available at: https://www.zalabriviba.lv/wp-content/uploads/wind_study_latvia.pdf.

[77] WinWind (2020). Project outputs, Recommendations for policy, 31 March 2020, available at: https://winwind-project.eu/resources/outputs/.

[78] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources.

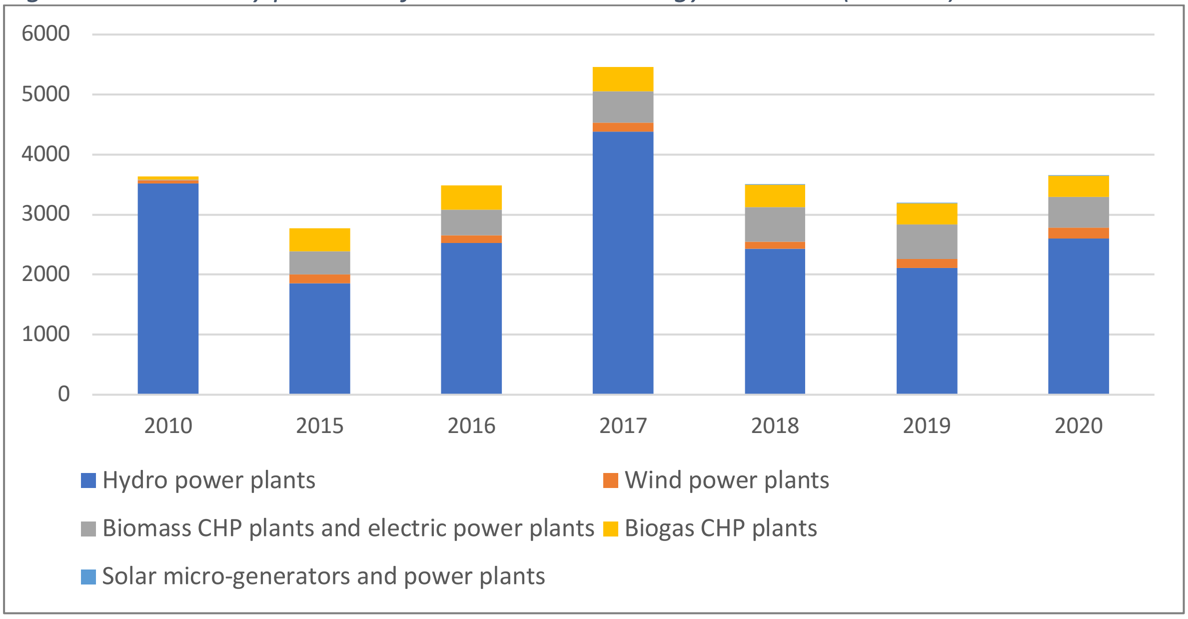
*Figure 11. Consumption of renewable energy resources in Latvia, as per cent.*




*Source: Official statistics of Latvia.*

In Latvia, more than 60% of the total electricity is generated from renewable resources (see Figure 12). As the majority is generated by run-of-the-river hydro power plants, the amount of electricity produced is seasonal and depends on the inflow of water into the Daugava. Electricity produced by wind farms is of minor importance - not exceeding 2,5% of the total electricity consumption. In 2021, wind power plants produced 20% less than in 2020. The total installed capacity of onshore wind farms is about 78 MW, which is slightly more than 3% of the total installed capacity in the country. There was no capacity increase between 2018 and 2020.

*Figure 12. Electricity produced from renewable energy resources (in GWh)*




*Source: Official statistics of Latvia.*

## 6.2. Potential for wind generation

### 6.2.1. Offshore wind parks

According to the study on Baltic offshore wind, the BEMIP[79] countries have the identified potential capacity of 93,5 GW installed offshore wind energy capacity and 325,9 TWh potential total net annual energy production. Latvia alone has a potential of 14,5 GW installed capacity and 49,2 TWh net annual electricity production.[80] This is a very technical assessment of the maximum potential. The study does not take into account the economic, environmental, or social interests of other sectors.

More realistic sites subject to preliminary research for offshore wind parks are defined in the Maritime Space Plan (MPS)[81]. In this plan, research for wind park development and a potential electricity cable corridor together with shipping, national defence, and nature values are among priority uses. Sustainable fisheries and tourism and recreation falls under the general use where all types of sea uses are allowed in the general use areas, as long as they do not contravene the restrictions prescribed by regulatory enactments and do not cause damage to the marine environment.

To ensure the success of large-scale offshore renewable energy planning and deployment, regional cooperation is essential. A new work programme in the Baltic Sea region dedicated to offshore wind has been adopted by the end of 2021.[82] The ELWIND project is a practical example. It is an Estonian-Latvian concept of a joint hybrid offshore wind energy project in the Baltic Sea. The total capacity of the planned offshore wind farm is 700 – 1000 MW, which will provide over 3 TWh of energy per year. This could generate up to 20% of both countries' current electricity consumption per year. It is expected that the offshore wind installation will be operational until 2030. Both transmission system operators AST (Latvia) and Elering (Estonia) are responsible for the transmission infrastructure development, construction, and connection issues to the mainland transmission network of the project. Much will depend on what auction conditions the state will define for potential investors. While the site prepared by the state for a private investor to come and install the turbines will be auctioned for the Elwind project, other auctions will be simply on the unprepared site at sea without a connection to the network.

### 6.2.1. Onshore wind parks

In Latvia, the possible location of onshore wind farms is determined by national and local spatial planning documents. At present, however, local governments are not obliged to designate potential areas to be used for renewable energy sources, including wind parks. Conflict is sometimes caused

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[79] The Baltic energy market interconnection plan (BEMIP) initiative is to achieve an open and integrated regional electricity and gas market between EU countries in the Baltic Sea region. The initiative's members are Denmark, Germany, Estonia, Latvia, Lithuania, Poland, Finland and Sweden. Norway participates as an observer.

[80] European Commission (2019), Directorate-General for Energy, Study on Baltic offshore wind energy cooperation under BEMIP: final report, Publications Office, 2019, available at: https://data.europa.eu/doi/10.2833/864823.

[81] Cabinet of Ministers, Order No. 232 of 21 May 2019. The Maritime Spatial Plan for the Marine Inland Waters, Territorial Sea and Exclusive Economic Zone Waters of the Republic of Latvia. National level long-term spatial development planning document.

[82] BEMIP Offshore Wind Work-program. To be reviewed in 2024, available at: https://ec.europa.eu/info/sites/default/files/energy_climate_change_environment/news/documents/final_bemip_offshore.pdf.

by the fact that there are no specific bans in the spatial plans to build wind farms in specific areas. This can be explained by the fact that during the public consultation of the draft local planning document, no one even thought that anyone in the close area would ever want to build wind turbines.

In the territory of Latvia, the places where the wind speed is advantageous for the installation of wind turbines are rather limited (see Map 2). Given the significant differences in wind speeds, competition is expected for those areas where wind speeds are more economically advantageous.

*Map 2. Yearly average wind speed in Latvia.*

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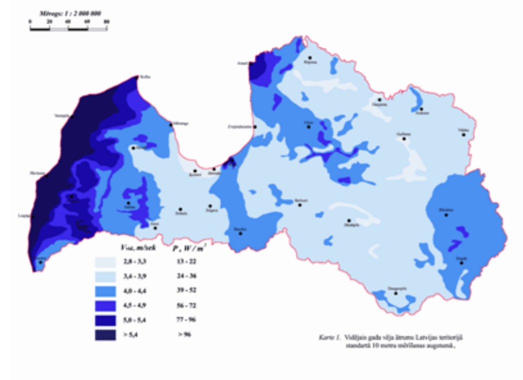
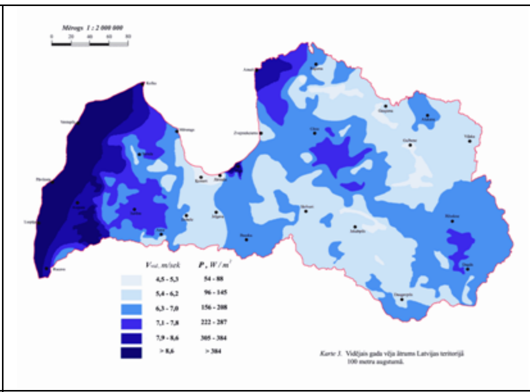
|---|---|
|  |  |
| 10 meters high | 100 meters high |

*Source: http://www.windenergy.lv/*

The potential interest of investors in onshore wind farms is enormous. Competition is high in those places where wind speed is more advantageous for offshore wind projects. There are about 15 projects in pipeline in different stages of development with a total potential capacity of about 2300 MW[83], which is comparable to the currently total installed capacity of power plants. Given that most potential projects are concentrated in the western part of Latvia, it is likely that some projects will remain on paper. To connect additional 2300 MW the network requires strengthening of internal network and interconnections with neighbouring electricity systems, ensuring fast capacity reserves and solve operational issues. It can also affect users' system tariffs. There is an evident need for better spatial planning and a more efficient approach to the issuing of technical requirements by the transmission system operator for new connections.

An environmental impact assessment is a mandatory requirement for onshore wind projects, with public consultation on the project as an integral part. There is a high resistance by the local governments and local populations against wind parks nearby. Firstly, a large industrial installation polluting the environment is located in the local community in the long term. Secondly, at least so far, the economic benefits to the community and local population have been very limited. Options to incentivize local communities are different. In Germany, one option is to offer at least a 20% stake in the wind farm to residents living within a radius of at least five kilometres from the turbine. In the Netherlands and Belgium, 30-50% of new wind projects are owned by the local community; an amount of, for example, 5000 euros goes into a community fund.[84] While there are no incentives in Latvia, why would anyone want a wind farm in their backyard.

[83] Information compiled from the State Environmental Monitoring Bureau homepage, available at: https://www.vpvb.gov.lv/lv.

[84] Šveicars R. (2021), "Like" or "dislike" are not arguments. Why are the critics against the construction of wind farms in Zemgale and North Kurzeme?(in Latvian). Newspaper “Lauku avīze”, 2 December 2021, available at: https://www.la.lv/pretvejs-iii-ietekmes-uz-vidi-novertejums-ierasts-veja-parku-stopkrans.

The construction of small-scale wind farms within the framework of energy communities could be another viable direction, however, there is an EU legislative framework in place, but transposition in Latvia is still under way.

Country specific policy recommendations for the national government are provided by the WinWind project. Among other suggestions the Latvian government should consider the following proposals:[85]

- Establish a legal and regulatory framework which facilitates and ensures economic viability of community wind projects.
- Establish an independent advisory system for wind energy and community.
- Establish clear framework criteria for elaboration of wind energy zoning in regional spatial plans.
- Ensure transparent communication and inclusive public participation in wind energy zoning and early stages of wind project development.
- Require wind farm developers/operators and municipal administration to publish regular statements concerning wind project contributions to socio- economic development of the municipality.
- Ensure that a share of the economic benefits is retained in the local host municipality. Ensure, for instance, that host municipalities benefit from tax payments accruing from wind farm operation.
- Develop an enabling framework promoting active financial participation of local stakeholders.
- Develop framework conditions enabling passive financial participation of local stakeholders.
- Develop a support fund for start-up of renewable energy community projects.
- Provide dedicated support for community wind energy pilot projects.
- Promote community energy projects through capacity development.
- Ensure that wind farm operators continuously monitor the effects of wind turbines on the environment (acoustic emissions, birds and bats etc.);
- Ensure public availability of corresponding monitoring reports.
- Develop a legal framework ensuring that developers/operators guarantee for decommissioning/dismantling works.

The latter proposal is relevant not only to up-coming projects but also to existing ones, and the importance of it is currently the least discussed.

And finally, if more attention were paid in the future to the development of wind energy-related industries, either through the production of spare parts or the provision of services, there would be added value for the Latvian economy. A good example is the company Aerones[86], a Latvian company which delivers innovative robotic wind turbine blade inspections, cleaning, coating and repair services.

Efforts done by the policy makers towards a comprehensive assessment of all aspects of wind energy will appreciated by all stakeholders.

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[85] WinWind (2020). Project outputs, Recommendations for policy, 31 March 2020, available at: https://winwind-project.eu/resources/outputs/.
project.eu/fileadmin/user_upload/Resources/Deliverables/Deliverable_6.5_Recommendations_for_policy.pdf
[86] Aerones. Available at: https://www.aerones.com/.

# 7. Conclusion

Wind energy has many benefits, such as cost-effectiveness, sustainability, security of supply by reducing dependence on fossil fuels, but it also has many challenges that could hamper viable sustainable growth of wind energy consumption and achieving the EU Green Deal objectives. Compromises must be sought at the political level to reconcile interests between wind energy and other sectors, such as tourism, transport, commercial fisheries, forestry, agriculture, and defence. Spatial planning is a rational way of resolving conflicts; however, it is sometimes difficult to find consensus among all stakeholders. Ignoring the challenges is the biggest enemy in the development of the wind projects themselves. Thus, this study provides a broad insight into what aspects should be respected and addressed.

In the light of EU decarbonisation plans, the struggle for space and resources will deepen not only between different sectors, but also within the sector itself. Considering that planet earth's resources are limited, especially when thinking about its multiple demands of use, it becomes important to identify the most suitable locations for the installation of wind turbines. Technological, economic, environmental, and social factors must play a major role for the project to succeed in the end.

While technological developments have made wind production more efficient and less expensive, the future demands for the material resources needed for the deployment of wind installations could increase the cost of components. Even if the material is available globally, the EU's dependence on imports makes the sector at risk. In addition to high upfront investments, the circularity of wind energy technology plays a crucial role. Nearly all of today's onshore wind parks will need to be repowered by 2050. The blades are made of fiberglass, and unlike the steel towers they rest on, the material cannot be recycled as of yet. Environmental issues are a separate enormous block that need further research both when elaborating local spatial plans, and when evaluating specific projects. Additionally, monitoring is highly important. Appropriate monitoring during project implementation, operation, and dismantling would provide a better understanding of ecosystem change. And finally, relatively little attention has been paid to the social aspects, as the local community may be left with a large-scale installation, but with few or no benefits.

While the EC has the competence to elaborate the EU’s sustainable energy and climate policy, Member States have the right to determine their own energy mix. Latvia has taken on a binding target for raising renewable energy share up to 40% in 2020 and up to 50% in 2030. Wind energy is expected to play a significant role in electricity generation in the future. A lack of clear framework criteria for the elaboration of wind energy zoning in regional spatial plans has created disagreements between investors and local communities. A share of the economic benefits retained in the local host municipality, and framework conditions promoting active and passive financial participation of local stakeholders would speed up project implementation.  And finally, a legal framework ensuring that developers guarantee for decommissioning works is essential, not only to up-coming projects, but also to existing ones, and the importance of it is currently the least discussed.

Wind energy challenges from the perspective of policy makers, investors, the local communities, and public differ depending on the stakeholder group. While one group of stakeholders were worried about the deadline for building permits and connections to the grid, others were bothered with the visual and acoustic effects. Joint work and understanding are needed for creating effective policies that create opportunities for growth.