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Barriers for Large Integration of PV and Onshore Wind Energy in the Distribution Network on the Selected European Union Electricity Markets

Bariery integracji dużej ilości źródeł PV i lądowej energetyki wiatrowej z siecią dystrybucyjną na wybranych rynkach energii elektrycznej krajów Unii Europejskiej

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Abstract: The European Union (EU) has adopted ambitious and wide-ranging binding targets for the reduction of greenhouse gas emissions, energy systems' transformation, and becoming climate neutral. The transformation of the energy sector towards more sustainable electricity production increases the importance of distributed generation from renewable sources, such as solar photovoltaics (PV) and wind energy. Large integration of PV and onshore wind energy in the EU distribution network is key to success in the energy transition. Despite significant progress in the field of renewable energies' regulations, in particular, due to the implementation of the RES Directive, several barriers remain, and still, the development of photovoltaics and wind energy are being slowed by various types of market, regulatory barriers, as well as technological and social obstacles. The aim of this article is to investigate the main barriers to the development of distributed generation from renewable sources, such as solar photovoltaics and wind energy, in order to increase their share in the EU electricity market. This paper is focused on the most common regulatory, technological, administrative, financial, social, and environmental barriers, which slow down the large-scale deployment of PV and wind energy into the distribution networks in 5 European Union countries: Austria, Greece, France, Poland, and Spain, as well as in Norway.

Keywords: photovoltaic, wind energy, energy market, barriers of PV and wind energy

Streszczenie: Unia Europejska (UE) przyjęła ambitne i wiążące cele w zakresie redukcji emisji gazów cieplarnianych, transformacji systemów energetycznych i osiągnięcia neutralności klimatycznej. Transformacja sektora energetycznego w kierunku bardziej zrównoważonej produkcji energii elektrycznej zwiększa znaczenie generacji rozproszonej ze źródeł odnawialnych (OZE), w tym z fotowoltaiki (PV) i energii wiatru. Duża integracja PV i lądowej energii wiatrowej z siecią dystrybucyjną UE jest kluczem do pomyślnej transformacji energetycznej. Pomimo znacznego postępu w zakresie regulacji OZE, w szczególności w związku z implementacją Dyrektywy OZE, nadal rozwój fotowoltaiki i energetyki wiatrowej jest spowalniany przez różnego rodzaju bariery rynkowe, regulacyjne, technologiczne i społeczne. Celem artykułu jest zbadanie głównych barier hamujących rozwój generacji rozproszonej ze źródeł odnawialnych, takich jak fotowoltaika i energetyka wiatrowa, w celu zwiększenia ich udziału na rynku energii elektrycznej krajów UE. W artykule przedstawiono bariery regulacyjne, technologiczne, administracyjne, finansowe, społeczne i środowiskowe, które hamują integrację dużej ilości źródeł PV i lądowej energetyki wiatrowej z siecią dystrybucyjną w 5 krajach Unii Europejskiej: Austrii, Grecji, Francji, Polsce i Hiszpanii oraz w Norwegii.

Słowa kluczowe: fotowoltaika, energetyka wiatrowa, rynek energii, bariery rozwoju PV i energetyki wiatrowej

Introduction

The European Union has adopted ambitious and wide-ranging binding targets for the reduction of greenhouse gas emissions and the transformation of energy systems. The EU goals are set to make Europe the world's first climate-neutral continent by 2050, and a climate resilient society (European Commission 2022a).

In December 2020, the EU and the Member States submitted an enhanced Nationally Determined Contribution (NDC), which aims to reduce GHG emissions by at least 55% by 2030, from 1990 levels (European Commission 2022c). These updated NDCs are part of the EU's climate action and the European Green Deal. Solar PV and wind energy have become a key climate component of NDCs and climate solutions, by reducing CO_2, SO_2, NO_x and other polluting emissions from power generation, and one of the most important sources of electricity generation, in transition towards a low-carbon energy system.

In order to successfully meet the EU's ambitious 2050 greenhouse gas emission reduction targets, and significantly increase installed renewable energy capacity, additional work is needed to overcome the existing barriers.

The European solar, PV, and wind energy sectors have developed rapidly over the last decades. Solar energy resources in Europe are significant but characterised by very uneven distribution of radiation and market penetration, considerable in Southern Europe and lower in Northern and Eastern parts of Europe.

Europe also has large, onshore wind energy resources, with the majority of the capacity located in Western European countries. The higher wind speeds are observed along the Atlantic Ocean, North Sea and Baltic Sea coasts, as well as throughout the UK, Iceland, Ireland, and Denmark. There are also strong wind speeds along the southern coast of France, and along the coastlines of the Aegean Sea. Wind speeds are significantly lower in the southern part of Germany, the central, southern, and eastern sections of Spain, the central – eastern regions of France, the central regions of Italy, the Balkans, the central part of Eastern Europe, the south-eastern part of Norway, and the Northern part of Sweden (Enevoldsena et al. 2019).

This article is focused on the regulatory, legal, financial, social, and environmental barriers that slowdown large-scale deployment of PV and wind power energy into the distribution networks. The article is based on the work carried out and financed by the EU DRES2Market project (Barriers for large integration of renewable energies in electricity and ancillary services markets. Deliverable D2.3. 2021). The project team identified these barriers in 6 European countries i.e.: Austria, Greece, France, Norway, Poland and Spain. The aim of the study was to identify barriers, and to propose the most promising solutions to mitigate them, in order to enhance penetration of renewable energy sources relating to electricity.

The EU countries have made significant progress in the field of RES regulations, and in particular, implementation of the RED Directive, and have gradually overcome many barriers. However, several barriers still remain, and development of photovoltaics and wind has been slowed by regulatory, administrative, economic and social obstacles. Some hurdles are intended to ensure that the system functions properly, and customers benefit from high standards of service, which may be excessively complex and time consuming (Lewis et al. 2021, 9).

1. Regulatory and legal barriers

Regulatory and legal stability are of key importance for all investments. Uncertainty for investors regarding levels of support in the coming years, as well as the decisions of financial institutions, granting loans for solar PV, and wind installations, and frequent changes to the applicable legal regulations, significantly increase the risk of implementing long-term development strategies, and hampers the market's development. Transparent, unambiguous and stable regulatory systems favour investments in solar, PV, and wind energy, especially in the initial stages.

The following main obstacles related to regulatory issues are more common: (Lewis et al. 2021, 14).

- Advantage of vertically integrated market players, these barriers result from the dominance of former incumbents on the market;
- Uncertainty around the current regulatory environment or its development;
- Uncertainty about the future of digitisation regulation and new technologies is related to the goals of smart meters, progress, and related rights and obligations;
- Price regulations – can discriminate against certain suppliers.

There are still some Member States in EU countries that have maintained regulated end-user prices to protect households, and even commercial consumers. In some cases, this regulation has led to below-cost prices, and to low margins, to cover the supplier activity risk, discouraging investments and the emergence of newcomers. Price regulation may discriminate against certain suppliers.

An example of a regulatory barrier may be the Spanish system of price regulation, the so-called "Voluntary price for small consumers" (for electricity – PVPC in Spanish) which is offered by the "reference suppliers". These prices include the cost of energy, applicable access tariffs (including network tariffs, and so-called fees) and the trade margin. Regulated tariffs, based on PVPC, appear to be below cost, hindering competition in the regulated segment (currently accounting for 95% of consumers). Low PVPC tariff margins may favour high penetration of regulated offers (Rademaekers et al. 2018, 158).

Electricity prices are not regulated in Greece, but there exists a social tariff (equal to all vulnerable customers, that meet the requirements set by Ministerial Decree) and the prices offered under the "Supplier of Last Resort" and "Universal Service Supplier", that may distort market development and functioning.

France has regulated electricity tariffs for residential consumers and small enterprises with subscribed power lower than 36 kVA (exception for all power subscription in French overseas territories). Social tariffs protecting vulnerable consumers were adopted under the law of 10 February, 2000, and they are included in the Energy Code in Articles L. 121-5, L. 337-7 (Rademaekers et al. 2018, 186). The French energy regulator, the Commission de regulation de l'energie (CRE), following a fair and transparent design defines the regulated price. It integrates the price for historical nuclear electricity price and a part from the wholesale market, capacity market participation, grid fees, taxes, supplying cost, and reasonable margin for supplier. From the end of 2017, social tariffs were gradually replaced by energy checks, i.e., "chèque énergie" (Rademaekers et al. 2018, 187).

Following Article 5 of EU Directive 2019/944/EU (and Article L337.9 of the French Code de l'energie), the scheme of regulated tariffs for electricity will be evaluated at the beginning of 2022 and 2025, (then every 5 years), regarding its impact on retail electricity prices, consumers eligible for it, social and spatial cohesion, price stability and security of supply.

There is also a price regulation for households in Poland. The Polish Energy Regulatory Office (Polish: Urząd Regulacji Energetyki) regulates household tariffs (Group 'G'). In December, 2018, a "Price-Freezing Act" was adopted by the Polish Parliament in order to protect end customers against extremely high retail prices, due to an unpredictable, extremely high increase of electricity prices on the wholesale electricity market (Act 2018).

High penetration of price regulation – this results in parts of the markets being unavailable for new market participants. Price regulation maintains an old market structure.

Regardless of improvements and simplification of the administrative procedures, related to connecting prosumers to the power grid in all analysed European Union countries, the shortening of times to obtain permission to install and operate a PV, onshore system, and energy storage device, the administrative procedures can still be a complicated, uncertain and slow process for many investors.

In the analysed countries, obstacles related to administrative and legal procedures that delay development of the PV and wind installations, are as follows:

- Frequent changes in law, as well as interpretative uncertainties related to newly introduced regulations;
- Insufficient spatial planning or RES insufficiently taken into account;
- Lack of coordination between involved authorities;
- Lack of stable legal and financial regulations;
- Too slow and not optimised approval process for renewable energies;
- Administrative hurdles such as planning delays;
- Large amount of administrative processing and long deadlines in time;
- Long-lasting environmental impact assessment and zoning plan.

Administrative requirements and interconnected legal procedures have a large impact upon the sustainable development of solar PV, and wind markets, in many countries.

Key barriers, specific to Austria, relate to the uncertainty about a regulatory future for digitalisation and new technologies, as well as to the ambiguity of environmental obligations and non-renewable generation capacity (Hirschbichler et al. 2021, 12). The delay of smart meter rollout may be the main source of uncertainty in the field of new demand-side and aggregation services based upon smart meter data, and may pose a barrier for new market entrants, whilst also hampering investment in PV and wind energy (Hirschbichler et al. 2021, 12-27).

The French administrative framework for Decentralised Energy Resources (DER) developments, was simplified in past years, but it still requires a long, administrative process to build a new DER production plant. Other administrative measures, which could be considered as barriers, are set to avoid competition between DER and farming, or between DER and tourism.

There is also limited volumes of Call for Tender procedures (regulated by the Commission de régulation de l'energie, regarding the articles L311-10 to L311-13, and R311-13 to R311-25 of the Code de l'energie) for PV plant, with power above 100 kWp, as well as for onshore wind power plant, inhibiting their faster development.

Norway is a part of the Nordic electricity market, and the first fully liberalised electricity market in Europe. Nonetheless, a few barriers to entry in the market remain.

Key barriers specific to Norway: (Lewis et al. 2021, 25)

- Strategic behaviour of incumbent or other market players. These barriers are related to the dominance in the Norwegian market, a large number of small, local, vertically integrated with Distribution System Operators' suppliers. This may cause e.g., incumbent advantages in access to customers;
- Uncertainty around a regulatory future for digitalisation and new technology, mainly related to unclear regulation around demand response and other novel services.

Complicated rules and procedures for issuing building permits, and delays in issuing building permits for new wind farms, are the main barriers to the development of onshore wind energy in Poland. On the 16 July, 2016, the Act on Investments in Wind Farms (the so-called "Distance Act") entered into force, establishing the 10H rule, which means that investors cannot build wind farms closer than 10 times the total height of the turbine from a residential building (or mixed-use building, which includes residential functions) (Act 2016). Pursuant to the Act, the location of wind farms, with a capacity greater than 50 kW, may only take place, on the basis of a local, spatial development plan. As a result of the introduced limits, the spatial potential for the location of large wind farms has significantly decreased.

Also, in France, the minimal distance between a wind turbine (higher than 50 metres) and any homes (living areas) is 500 metres (Code de l'environnement L515-44).

In turn, Austria has experienced an excessively slow and non-optimised approval process for new solar and onshore wind farms.

The key barrier to the development of photovoltaics and wind energy in Poland, is also volatility of legal regulations, including changes in basic mechanisms of support for photovoltaic and wind installations, and construction law. This has a significant impact upon the low sense of security and level of investor confidence in the stability of the investment rule, as well as decisions of financial institutions that credit PV and wind installations. Regulatory instability causes uncertainty of investors, as to the conditions of support in the coming years, and the level of their operating costs.

Regulatory unpredictability leads to uncertainties for suppliers, related to unclear and unknown future developments of the regulatory framework, including the attitude of the institutions that regulate the energy market.

Bureaucracy, the prolonging of administrative procedures, by both authorities and grid operators, still pose barriers to the rapid deployment of PV and wind installations in many European countries.

In Greece, there are certain bureaucratic barriers for those intending to start up a PV or wind installation. The long and costly administrative process for licensing, and other grid related issues, has hampered the development of wind power in Greece.

In France, the development time of a ground PV plant is approximately 4 years. Public consultation is required for every ground PV plant of power higher than 250 kWp (Articles L123-1 to L123-2 of Code de l'environnement). Being awarded in Call-for-Tenders procedures does not mean a positive evaluation of administrative requirements (administrative authorisation).

Insufficient spatial planning has also been named as an important barrier in other analysed countries, especially for wind power, as for example, in Poland.

2. Technological barriers

Technically, PV and wind systems are matured, so there are no technical barriers regarding the systems themselves, but more regarding integration of these systems within the local grid. Some questions of technical grid management with a very high penetration of renewables (new flexibility needs) are still open, alongside market challenges, but up to now, renewables' penetration rates are still too low in most of the European countries.

The technical condition of distribution networks, and limitations of the infrastructure, are a basic factor determining development potential of photovoltaics and onshore wind energy in many European countries.

Another concern, which may hinder development of PV and onshore wind, with regards to the grid, is the delays, which may occur due to the time needed to obtain planning permission, and also the high level of ambiguity, which surrounds the grid connection process.

In Poland, technical barriers include:

- Barriers in the access of new DER to the distribution network, due to problems with system stability;
- Limited number of energy storage units;
- Insufficient growth rates of smart meters;

In many grid configurations with PV and wind installation grid congestion, and therefore, over-voltage issues, the malfunctioning of inverters and electronic equipment, as well as transformer overloading, can occur.

In the case of Austria, barriers relate to a lack of standardisation, and due to nine federal states, there are different requirements in each federal state.

Also in France, standards for electric vehicle (EV) recharging infrastructure, do not allow dynamic power profile, in order to provide ancillary services. This standard is still under development, and is not expected to apply until April, 2022.

In Spain, access to the network at nodal level is determined via system-wide studies and pre-defined stability and security criteria, that may be considered conservative, when compared to international practices (e.g., case-by-case grid connection studies). Transmission and distribution system operators are liable to develop grid expansion and reinforcement proposals, but final decision-making in grid planning rests with the Ministry of Energy. This makes it difficult for system operators to invest in and implement grid optimisation technologies (e.g., FACTS, DLR,). Limited capacity in cross-border interconnections take place between Spain-France, Spain-Portugal, and Spain-Morocco.

Solar PV and wind investors must meet applicable rules of the local operator, regarding safety and reliability. High PV solar, and wind energy penetrations can have positive impacts on the network, but also negative, if integrations are not properly managed.

Potential positive impacts on grid operation can include reduced network flows, and hence, reduced losses and voltage drops. Potential negative impacts at high penetrations, include voltage fluctuations, voltage rise, and reverse power flow, power fluctuations, power factor changes, frequency regulations and harmonics, unintentional islanding, faulty currents and grounding issues (Passey et al. 2011, 6280).

The negative impacts affecting local grids, may be solved by implementing smarter electric grids and flexible management of the system. The distribution system in many EU countries needs to be reinforced by creating new lines, or by increasing their cross-sections, which requires financial expenditure for development of smart grids, network management technologies, and interconnections.

In general, modernisation of the existing network, and development of smart grids, allows for optimal use of PV systems and wind power plants, reduction of network load, and minimisation of blackout and emergency threats.

3. Economic barriers

Capital restrictions constitute a significant economic barrier to the development of photovoltaics and wind energy, occurring mainly in the case of households and small and medium-sized enterprises, which is most often observed in the countries of Central and Eastern Europe. Prosumers may not always be able to cover the investment costs from their savings, they may also have problems with showing a sufficiently high own contribution, to apply for an investment loan. Due to the high cost of obtaining a loan, or lack of creditworthiness, financial support may not be available to a large group of interested people.

Relatively high initial costs of the solar PV, and wind energy, a long payback time, high costs of maintenance, as well as insufficient economic mechanisms, in particular, fiscal mechanisms, which would enable obtaining appropriate financial benefits, may be the most important barriers to their rapid development.

Lack of financial incentive policy measures, along with a lack of technical support, can also be a major barrier for conducting novel technologies.

In Austria, barriers are related to uncertainties in the investment, based upon doubts regarding future electricity costs. In addition, a security payment is needed, in order to receive a proposal for funding, and this leads to high financial and administrative overheads for small PV plants (Komendantova et al. 2018).

In the case of Greece, significant economic incentives, together with other forms of stimulus, have been launched for propagating the implementation of RES systems in the field, and in buildings. Efforts were made on the Greek market to reduce the final price of PVs, but the initial cost is still too high, both for commercial and domestic use, to make them attractive, without any form of subsidies.

In France, we have seen high photovoltaic development, financing and insurance costs, higher than in other European countries, such as Germany, possibly due to longer development times, and a smaller market. For a project within the call-for-tender framework, a Feed-in Premium is awarded, but only for a 20year duration, although PV modules have time and life expectancy of 30 years.

In Poland, the main obstacles are inadequately selected economic (tax) mechanisms, which would enable expected financial benefits to be obtained, in relation to the size of an investment, installation, and equipment costs. The high cost of investing in a PV system has been a major obstacle to transforming an electricity consumer into a prosumer, and the cost of PV systems is still generally considered high. The above was confirmed by surveys carried out in 2015 and 2016. The biggest barrier to installing renewable energy in Poland was the financial barrier, i.e. high installation costs – as indicated by over 67% of respondents (Federacja Konsumentów 2016, 89; Ropuszyńska-Surma et al. 2017).

Based upon a survey on solar PV, carried out among Norway residents, the important factor that influenced the decision to install a home photovoltaic system, was the high initial cost, as well as limited financial support. In this survey, 34.6% respondents stated that installing the PV system is too expensive, therefore, the high cost was the main barrier for installing solar PV (Xue et al. 2021, 4).

In the case of Spain, the uncertainty of the sector rests in the medium long-term: some retroactive policies of the past have caused problems of confidence, and financing of renewable projects is identified as an economic barrier.

The policy of the European Union and the member states supports projects in the field of renewable energies' installations. To increase the number of consumers willing to engage in prosumer activity, various types of incentives, subsidies, and low-interest loans were introduced, which shorten payback periods, and increase the attractiveness of the investment opportunity.

At the same time, more PV projects are being implemented without support. In many EU countries, solar-PV investments are competitive, and can be justified, based upon market revenues alone, without the need for additional subsidies (Banja et al. 2017, 181).

4. Social and environmental barriers

Solar PV and wind energy play a key role in combatting climate change by reducing CO_2, SO_2, NO_x and other pollutants emitted during power generation, however, wind energy, more than photovoltaics, could have a negative impact on the local environment, residents, wildlife, landscapes, and sustainable land use (including protected areas), etc.

The level of investment in photovoltaics and wind energy is directly influenced, not only by political and legal conditions, economic or technological, but also by social factors, environmental and energy consciousness of society, approach to energy saving, and the development of renewable energies.

Solar PV investments are generally accepted by local communities, and social protests associated with planned investments, are rare. The approach of societies to photovoltaics is shaped by the ecological and renewable nature of this form of energy, i.e., clean energy, whose use in local and global dimensions, brings several social and environmental benefits.

Wind energy projects have a wider landscape impact than PV installation. Wind turbines may result in effects, such as: shadow flicker, audible noise, low-frequency noise, electromagnetic fields, and many others. There is complex research in this field.

Social acceptance can have a significant impact in respect of implementing wind energy, in many cases, lack of local political – decision-makers, stakeholders, populations i.e., local citizens, household organisations, and individual end-users' acceptance, can limit the overall wind energy resource.

Social acceptance of wind energy is a potential barrier to faster expansion of onshore wind energy, and appears to be more challenging, than in respect of solar PV energy.

In Greece, public opposition often focuses on the environmental impact caused by the installation and operation of wind farms, such as the visual impact, the impact on bird populations, and migration, the noise emissions, the change in land use, the moving shadows in the nearby vicinities, etc.

In France, environmental authorisation required previously a 3month public consultation period, regarding the Code de l'environnement (L181-9). There are strong local protests for each wind farm project, supported by about 1,300 local associations, protesting against onshore wind farm projects. The major concerns are focused on landscape degradation, especially in touristic areas, or areas closed to historical buildings, on financial depreciation of buildings, and on noise generation.

Local crowdfunding (open to residents of the province where the PV plant is installed, and to neighbouring provinces) and shared governance with local residents, is a strong means for increasing local support, but it is more difficult for wind power projects than for PV projects, due to high capital costs for wind power projects. It is often seen as advisable to give a higher share of governance to local residents, than the due share regarding their financial participation.

Also, in Norway, there is high public opposition regarding the extension of energy infrastructure in transmission lines, as well as wind farms.

Social opposition to new energy infrastructure development is present in many countries. The opposition, ranging from spontaneous neighbourhood protests to professional campaigns, and legal suits at the national level, is perceived as a barrier to wind energy growth.

It should be noted that in recent years, significant technological progress has been made in the development of wind energy production. As a result of this, the negative impact of wind farms on the environment has been significantly reduced. This progress relates to the implementation of modern construction technologies of wind farms and methods of their operation, as well as the development of software, in order to optimise the location and estimate their potential impact on the environment, etc.

Ecological influences of wind energy facilities can vary, depending on the spatial scale of investment, location, seasons of the year, weather, ecosystem types, and other factors. A number of people residing close to wind energy facilities complain about a high volume of unpleasant sounds, electromagnetic interference, vibration issues, shadow flickers, etc.

Photovoltaic systems are more environmentally friendly, compared to wind farms. PV installations do not emit greenhouse gases into the atmosphere, do not cause noise or vibrations. They do not cause any negative influence on landscapes, and a large part of the local residents and local government institutions accept photovoltaics.

Concluding remarks

The transformation of the energy sector towards more sustainable electricity production increases the importance of distributed generation from renewable sources, such as solar, photovoltaics, and wind energy.

Achieving EU energy goals and climate targets requires overcoming existing barriers and regulatory frameworks. Several barriers have been identified that hamper the development of PV and wind energy implementation, including regulatory, technical, administrative, financial and social factors in the analysed counties.

Legal and administrative requirements for photovoltaic and wind installations are perceived as limiting the possibilities for the development of distributed generation, in many analysed countries. Each country has different objectives and is free to decide how to remove the remaining hurdles.

Technological barriers also have a significant influence on the deployment of PV and wind energy. The technical condition of distribution networks – stable, secure, and high capacity is a basic factor for high levels of electricity to be generated from PV and onshore wind.

Economic barriers are also ranked highly, as PV and wind systems are often not economically profitable, without policy support.

Public opposition to onshore wind farms is still prevalent in European countries, and public acceptability is a significant barrier to their development.

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References

Banja, Manjola, Martin Jégard, Fabio Monforti-Ferrario, Jean-François Dallemand, N. Taylor, Vincenzo Motola, and Richard Sikkema. 2017. *Renewables in the EU: the support framework. towards a single energy market*. Luxembourg: Publication Office of the European Union.

Bartoszewicz-Burczy, Hanna. 2019. "Barriers for the secure and reliable connection of distributed solar PV." *Polska Energetyka Słoneczna* (1-4): 57-64. http://ptes-ises.itc.pw.edu.pl/art/2018_10.pdf.

Bartoszewicz-Burczy, Hanna, Przemysław Starzyński, and Maciej Wachowiak. 2019. "Solar PV on the Distribution Grid: Smart Integrated Solutions of Distributed Generation based on Solar PV, Energy Storage Devices and Active Demand Management." In *36th European Photovoltaic Solar Energy Conference and Exhibition*, edited by Fanny Lambert, R. Kenny, and P. Helm, 1994-1999. Munchen: WIP – Renewable Energies.

Barriers for large integration of renewable energies in electricity and ancillary services markets. Deliverable D2.3. 2021. Technical, business, and regulatory approaches to enhance renewable energy capabilities to take part actively in the electricity and ancillary services markets. Horizon 2020-LC – SC3 – 2020 – RES-IA-CSA. July, 2021.

Barriers for secure and reliable connection of distributed solar PV. iDistributedPV: Solar PV on the Distribution Grid: Smart Integrated Solutions of Distributed Generation based on Solar PV, Energy Storage Devices and Active Demand Management Horizon Deliverable 2.3. 2020-LCE-2017-RES-CSA. Project Number 764452. November, 2018.

Diógenes, Jamil R. F., Joao Claro, Jose C. Rodrigues, and Manuel V. Loureiro. 2020. "Barriers to onshore wind energy implementation: A systematic review." *Energy Research & Social Science* 60: 101337. https://doi.org/10.1016/j.erss.2019.101337.

Directive 2018/2001/EU of the European Parliament, and of the Council of 11th of December, 2018, on promotion of the use of energy from renewable sources.

Directive 2019/944 of the European Parliament and of the Council of 5th of June, 2019, on common rules for the internal market for electricity and amending Directive 2012/27/EU.

Enevoldsena, Peter, Finn-Hendrik Permienb, Ines Bakhtaouicd, Anna-Katharina von Kraulande, Mark Z. Jacobsone, George Xydisa, Benjamin K. Sovacoolaf, Scott V. Valentineg, Daniel Luechth, and Gregory Oxleyi. 2019. "How much wind power potential does Europe have? Examining European wind power potential with an enhanced socio-technical atlas." *Energy Policy* 132: 1092-1100. https://doi.org/10.1016/j.enpol.2019.06.064.

European Commission. 2018. *A Clean Planet for All: a European Long-Term Strategic Vision for a Prosperous, Modern, Competitive and Climate Neutral Economy. Communication COM(2018) 773 final.* Brussels: European Commission. Accessed February 21, 2022. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0773&from=EN.

European Commission. 2022a. *European Green Deal.* Accessed February 16, 2022. https://ec.europa.eu/clima/eu-action/european-green-deal_en.

European Commission. 2022b. *A European Green Deal. Striving to be the first climate-neutral continent.* Accessed January 05, 2022. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.

European Commission. 2022c. *European Green Deal. The EU is fighting climate change through ambitious policies at home and close cooperation with international partners.* Accessed January 06, 2022. https://ec.europa.eu/clima/eu-action/european-green-deal_en.

Federacja Konsumentów. 2016. *Jak zostać prosumentem. Raport Federacji Konsumentów.* [How to become a prosumer. Consumers' Federation Report]. Accessed February 15, 2020. http://www.federacja-konsumentow.org.pl/n,159,1307,91,1,raport-federacji-konsumentow.html.

Hirschbichler Florian, R. Löw, and D. Presch. 2021. *European Barriers in Retail Energy Markets Project: Austria Country Handbook.* Luxembourg: Publications Office of the European Union. https://doi.org/10.2833/214989.

Karakaya, Emrah, and Pranpreya Sriwannawit. 2015. "Barriers to the adoption of photovoltaic systems. The state of the art." *Renewable and Sustainable Energy Reviews* 49: 60-66. https://doi.org/10.1016/j.rser.2015.04.058.

Komendantova, Nadejda, Markus Manuel Schwarz, and Wolfgang Amann. 2018. *Economic and regulatory feasibility of solar PV in the Austrian multi-apartment housing sector.* AIMS Energy 6(5): 810-831. https://doi.org/10.3934/energy.2018.5.810.

Lewis, Philip, Hanna Granroth-Wilding, L. Napolitano, Chema Zabala, A. Vékony, Balazs Felsmann, and Florian Hirschbichler. 2021. *European Barriers in Retail Energy Markets Project: Final Report.* Luxembourg: Publications Office of the European Union. https://doi.org/10.2833/5217.

Lewis, Philip, and Hanna Granroth-Wilding. 2021. *European Barriers in Retail Energy Markets Project: Norway Country Handbook.* Luxembourg: Publications Office of the European Union. https://doi.org/10.2833/97471.

Masson, Gaëtan, Izumi Kaizuka, E. Bosch, Johan Lindahl, and Eddy Blokken. 2021. *Trends in Photovoltaic Applications 2021.* Report IEA-PVPS T1- 41:2021. Accessed February 16, 2022. https://iea-pvps.org/wp-content/uploads/2022/01/IEA-PVPS-Trends-report-2021-1.pdf.

O'Keeffe, Juliette, Daniel J. Gilmour, and Edward Simpson. 2016. "A network approach to overcoming barriers to market engagement for SMEs in energy efficiency initiatives such as the Green Deal." *Energy Policy* 97: 582-590. https://doi.org/10.1016/j.enpol.2016.08.006.

Passey, Robert, Ted Spooner, Iain MacGill, Muriel Watt, and Katerina Syngellakis. 2011. "The potential impacts of grid-connected distributed generation and how to address them: a review of technical and non-technical factors." *Energy Policy* 39(10): 6280-6290. https://doi.org/10.1016/j.enpol.2011.07.027.

Ropuszyńska-Surma, Edyta, and Magdalena Węglarz. 2017. "Bariery rozwoju rozproszonej energetyki odnawialnej w świetle badań ankietowych." [The barriers to the development of the dispersed renewable energy in the light of survey]. *Przegląd Elektrotechniczny* 93(4): 90-94. https://doi.org/10.15199/48.2017.04.23.

Sæle, Hanne, Todd L. Cherry. 2017. *Attitudes and perceptions about becoming a prosumer: results from a survey among Norwegian Residential customers – 2016.* Trondheim: SINTEF Energy Research. Accessed February 16, 2022. https://sintef.brage.unit.no/sintef-xmlui/bitstream/handle/11250/2448126/2017-00078.pdf.

Rademaekers, Koen, Matthew Smith, Jessica Yearwood, Yamina Saheb, Joris Moerenhout, Karine Pollier, Nathalie Debrosses, Thierry Badouard, Aurelien Peffen, Hector Pollitt, Sophie Heald, and Matthias Altman. 2018. *Study on Energy Prices, Costs and Subsidies and their Impact on Industry and Households. Final Report.* Rotterdam: European Commission – DG Energy. https://doi.org/10.2833/825966.

Act 2018 – Ustawa z dnia 28 grudnia 2018 r. o zmianie ustawy o podatku akcyzowym oraz niektórych innych ustaw. Dziennik Ustaw z 2018 r. poz. 2538, z 2019 r. poz. 412, 1210, 1495, 1532, z 2021 r. poz. 1093, z 2022 r. poz. 202. [Act of 28 December 2018 on the act amending the act on excise duty and certain other acts. Journal of Laws of the Republic of Poland 2018 item 2538, 2019 items 412, 1210, 1495, 1532, 2021 item 1093, 2022 item 202].

Act 2016 – Ustawa z dnia 20 maja 2016 r. o inwestycjach w zakresie elektrowni wiatrowych. Dziennik Ustaw z 2016 poz. 961. [Act of 20 May, 2016 on investments in wind farms].

Xue Yan, Carmel Margaret Lindkvist, and Alenka Temeljotov-Salaj. 2021. "Barriers and potential solutions to the diffusion of solar photovoltaics from the public-private-people partnership perspective – Case study of Norway." *Renewable and Sustainable Energy Reviews* 137: 110636. https://doi.org/10.1016/j.rser.2020.110636.