# MORE RENEWABLES In The Grid

Methods to increase the connection capacity of the Polish electricity system.

POLSKIE STOWARZYSZENIE ENERGETYKI WIATROWEJ

POLITECHNIKA LUBELSKA
WYDZIAŁ ELEKTROTECHNIKI I INFORMATYKI

REPORT - SHORT VERSION

**JANUARY 2023**

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More Renewables In The Grid. Methods to increase the connection capacity of the Polish electricity system.


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This report has been supported by the European Climate Foundation. Responsibility for the information and views set out in this report lies with the authors. The European Climate Foundation cannot be held responsible for any use which may be made of the information contained or expressed therein.

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***Improving the capacity of grid infrastructure should be a fundamental element and the starting point for a wide-ranging energy transition. The Report suggests the measures to be taken with regard to boosting the development of renewables in Poland.***

# Let's optimise conditions for RES grid connections

Dear Readers,

The report 'More Renewables In The Grid' is a publication about an issue that is becoming of primary importance in the context of energy transition.
This comprehensive study, previously missing from the energy market, analyses the current challenges faced by Polskie Sieci Elektroenergetyczne S.A. (the Polish TSO) and by Distribution System Operators in the face of the ongoing energy transition.
Experts from the Polish Wind Energy Association and the Faculty of Electrical Engineering and Information Technology at the Lublin University of Technology prepared recommendations for the effective use of existing grid infrastructure in a way that does not require high financial outlays, translating into the possibility of rapid implementation of the proposed solutions, paving the way for new investments in generation sources.

At the time of Russia's aggression on Ukraine and the resulting energy crisis, and the consequently drastically high electricity prices, solutions to build Poland's energy independence and security have become of key importance. The war in Ukraine has not only caused a shock in Europe, but also had a major impact on the continent's economic situation, from hydrocarbons to the energy market and food. The European Union has realised that energy security has to be rebuilt on the basis of local resources, resulting in accelerated investment in renewable sources and improvement of energy efficiency.
Since renewable energy sources have become a desirable and necessary part of the energy mix, companies in this sector have been working intensively to change their strategies, accelerating the

green transition. However, hampering the development of new zero-carbon investments, the problem of insufficient capacity in the electricity grid appears, already being one of the main reasons slowing down the energy transition in Poland.
*More Renewables In The Grid* is a multidimensional look at the current state of transmission and distribution networks, as well as the regulations affecting the limited connection capabilities.
The report presents a number of solutions that can be implemented without unnecessary delays, to replace or defer at least some of the costly network investments, bringing the desired results in a short time. Last year, Polskie Sieci Elektroenergetyczne S.A. ("PSE" – the Polish TSO) have published the *Development Plan for meeting current and future electricity needs for 2023-2032*', in which they point to the significant, real potential of renewable energy sources that can actually be built.

Based on the total capacity of existing sources, the connection agreements concluded or connection conditions issued and the capacity of offshore wind farms as specified in the Offshore Wind Act, within the next ten years alone, a total of 25 GW of onshore and offshore wind power plants with a generation potential of 77 TWh per year can appear in the Polish electricity system, as well as over 20 GW of solar sources (not including prosumer sources built after 31 December 2021) with a generation potential of 21 TWh. PSE's document indicates the possibility to generate more than 100 TWh of renewable energy per year by 2030, significantly exceeding 50% of Poland's electricity needs based on ***current projections and representing a significant increase in electricity demand above the levels assumed in the national strategic documents.***

PSE's calculations confirm the importance of the development potential of renewables in Poland, however, despite ambitious assumptions, in line with the EU's "REPowerEU" package, there are serious barriers that result in a missed opportunity for dynamic development of green energy in our country.
It is clear that large financial resources are needed to modernise electricity grids and build completely new connections (which is also a time-consuming investment). Poor technical condition of existing lines, grid congestion and the need to reserve connection capacities for offshore wind farms are the factors that effectively prevent the connection of new renewable energy sources.
However, the number of refusals to connect RES sources to the grid is a reason for concern.
In 2020 and 2021 alone, the largest Distribution System Operators issued a total of 5,037 refusals of connection conditions for a total capacity of more than 20 GW.

The report has been prepared with focus on the actions that, in our opinion, can and should be taken by PSE, Distribution System Operators and the Polish Government to increase the connection capacity of the Polish electricity system as soon as possible, in the context of the ultimate objective of dynamic development of renewable energy sources in Poland. The improvement of network infrastructure capacity should be a fundamental element and the starting point for a wide-ranging energy transition.

We hope that this publication will stimulate discussion about necessary changes to transmission and distribution networks and that our analyses will contribute to optimising grid connection conditions in the coming years.

I wish you an interesting read.

**Janusz Gajowiecki**
President, Polish Wind Energy Association

***Electricity grids face enormous challenges and the need for change, requiring a multi-year and multi-directional investment process on an unprecedented scale.***

# Let's adapt distribution networks to the new energy market architecture

Dear Readers,

Due to ambitious climate policies, but also consumers who increasingly understand and realise the need for green, affordable energy, the energy industry is developing in a greener, low-carbon and more efficient direction.
As a consequence, enormous changes lie ahead of the Polish electricity system between now and 2030. It will be necessary to connect:

- at least 20 GW of solar sources with a generation potential of 21 TWh per year,
- more than 14 GW of onshore wind with a generation potential of 37 TWh per year, almost 11,
- GW of offshore wind, capable of producing 40 TWh per year.

That we need and want more and more renewable energy sources in the national electricity system is indisputable. However, this direction of the sector's development generates many challenges for all stakeholders. Challenges are also posed by regulations, which should not only enable, but also facilitate measures to support the climate and energy transition.
So far, these activities have mainly focused on the generation sector, for which various support schemes have been earmarked. However, a major bottleneck for the development of green energy sources today is the grid infrastructure of the electricity system, which – in my opinion – has not been given enough attention to date. Electricity grids face enormous challenges and the need for change, requiring a multi-year and multi-directional investment process on an unprecedented scale.

The latest report by the Polish Wind Energy Association and the Lublin University of Technology is a very valuable voice in the discussion on the necessary directions of change and the actions to be taken. For the industry regulator, such actions are invaluable. All the more so because the most important conclusions and recommendations formulated by the report's Authors are mostly consistent with what the Energy Regulatory Office presented to the public in November 2022, when we completed the first stage of work on the *Charter for Efficient Transformation of Poland's Power Distribution Networks*.

Recognising the need to urgently diagnose and implement the necessary changes, the Energy Regulatory Office has already been actively working for many years with the infrastructure sector, carrying the major part of the burden of meeting the need to connect green generation to the grid. A response to the needs and challenges of electricity networks is, in my opinion, the aforementioned project of the *Charter for Efficient Transformation of Poland's Power Distribution Networks* (KET), which has been carried out for almost two years on the initiative of the ERO. The document was adopted and signed by the five largest DSOs and the ERO President last autumn. This agreement, which is open to new signatories, is part of the process of adapting distribution networks to a new energy market design based increasingly on distributed sources with a significant share of renewables.

The signing of this sectoral agreement is the end of the first phase of work. However, in order to fulfil the provisions of the Charter, subsequent steps will require the development of proposals for the necessary changes to the distributors' regulatory model and a consistent implementation of investment programmes. The members of the Steering Committee also committed to initiate legislative changes to take into account the new regulatory requirements and to provide, among other things, support measures for DSOs. This will require continuous monitoring of the progress of transition and analysis of its results in order to be able to react and adequately shape the appropriate course and direction of investment processes.

I think that the readers do not need to be encouraged to read the report. Anyone following the directions and pace of changes in the Polish energy sector will know that *More RES In The Grid. Methods to increase the connection capacity of the Polish electricity system*, is a must-read.
I congratulate the authors on such an exhaustive analysis and wish them perseverance in implementing its most important proposals. For my part, I pledge my support and willingness to cooperate.

**Rafał Gawin**
President, ERO

# Definitions and abbreviations

| | |
|---|---|
| **DISE** | Lower Silesian Institute for Energy Studies |
| **GPZ** | Main Substation |
| **IRiESD** | Distribution Grid Code |
| **IRiESP** | Distribution Grid Code |
| **NCEP** | National Energy and Climate Plan for 2021-2030 |
| **NES** | National Electricity System, National Power System |
| **LFW** | Onshore Wind Farm |
| **OWF** | Offshore Wind Farm |
| **DSO** | Distribution System Operator |
| **TSO** | Transmission System Operator |
| **PEP2040** | Poland's Energy Policy until 2040 |
| **PLANS** | Computer software used for power flow analysis |
| **OLL** | Offshore Location Licence / Seabed Permit |
| **PTPiREE** | Polish Power Transmission and Distribution Association |
| **PV** | Photovoltaics |
| **EU** | European Union |
| **ERO** | Energy Regulatory Office |
| **EL Act** | Energy Law Act |
| **Offshore Wind Act** | Act of 17 December 2020 on the promotion of electricity generation in offshore wind farms |
| **RES Act** | Act of 20 February 2015 on renewable energy sources |
| **ZiWWE** | a document specifying prerequisites and conditions for an expert report, submitted to the contractor by the operator |

# 1. Key findings and recommendations

## Energy security in times of war

Russia's aggression on Ukraine has irrevocably re-evaluated the concept of energy security in EU Member States' policies.
The new approach to energy independence and security envisages, in the long term, a complete elimination of imports of energy (from outside the EU) and its carriers and a complete switch to domestic resources (ultimately, exclusively to renewable resources).

For this to be possible, there must be a significant increase in investment in renewable energy sources, which do not require energy resources, relying only on natural and widely available resources such as wind and solar. In the short term, measures will be needed to diversify the supply of energy resources to EU countries, but these measures should not obscure the ultimate target of relying entirely on renewable sources.

### Why we need new investments in renewables

- **Making Poland independent from imported raw materials** and in the long term a complete transition to domestic
- **Accelerating the energy transition** supported by the EU, which involves the transition to a zero-carbon economy
- **Multidimensional energy security,** including the economic security of individual Member States and the EU as a whole
- **Meeting the ambitious EU climate targets** included in the package of measures called REPowerEU, aiming to increase the share of renewables at EU level from 40% to 45% in 2030.
- **Building a strong, modern industrial sector,** supporting the functioning of the entire European economy, including supply chains
- **Preparedness for the upcoming economic crisis caused by the energy crisis** – the best response to the economic slowdown is to increase investment, which in the long term will protect us from a similar crisis related to electricity shortage

# Objective of the Report:

**The purpose of this Report was to identify the key barriers in the area of grid connection of renewables and to propose non-investment and low-investment methods to increase the connection capacities in the Polish electricity system, with possibly quick implementation and a potential to bring tangible results in a short period of time, replacing or deferring at least some of grid investments.**

The report identifies the main barriers in the area of connecting renewable energy sources to the grid and proposes non-investment and low-investment methods to increase the connection capacity of the Polish electricity system. These activities include:

1. urgent revision of strategic government documents, including Poland's Energy Policy of Poland until 2040 (accelerating the energy transition);
2. harmonizing the methodology for determining the possibility to connect sources to the grid and publishing it in a regulation-level document[1];
3. harmonizing the system to inform stakeholders about currently available connection capacities in the transmission and 110 kV networks;
4. interpretation of power flow analyses' results and the resulting line load condition consistent with the metrological realities and the physical basics of the conductor heating process;
5. legal regulation of permissible tolerance levels in the interpretation of the results of calculations preceding the issuance of a decision on connection conditions; taking into account the approximate nature of these calculations;
6. eliminating investment barriers to the ability to effectively increase the current-carrying capacity of power lines to 80°C, creating plans to eliminate lines with a design temperature of 40°C;

[1] e.g. by updating the regulation of the Minister of Economy of 4 May 2007 on the detailed conditions of operation of the electricity system

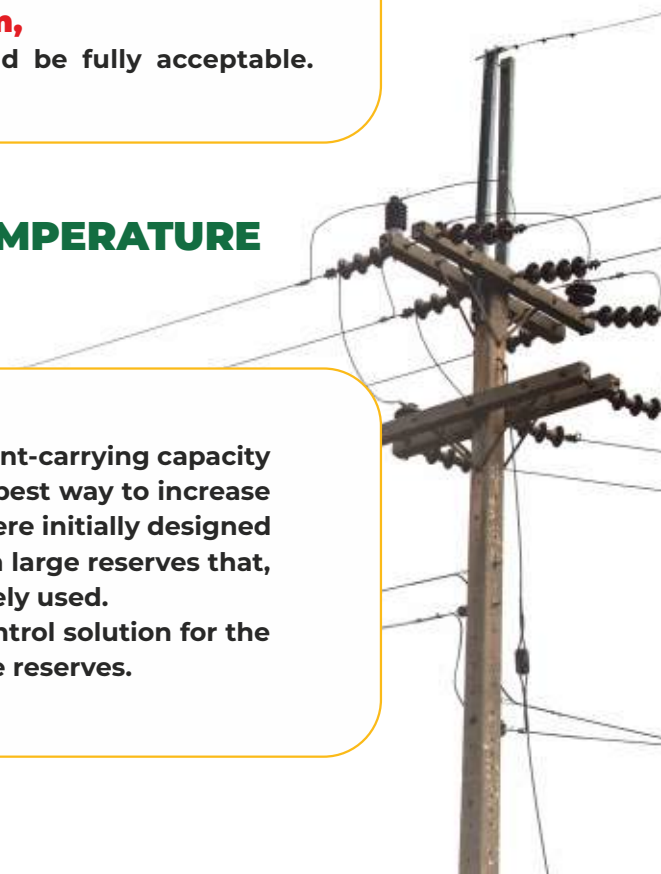
7. implementing the concept of sharing network infrastructure between different RES technologies – so-called "cable pooling";
8. implementation of regulations allowing large-scale use of direct lines;
9. introducing financial incentives for DSOs to reduce the number of refusals to connect renewable energy sources to the grid;
10. introducing mechanisms to curtail RES generation both in the event of a global balancing surplus and in the event of local surpluses causing periodic overloading of lines or exceeding permitted voltage levels;
11. modifying and providing more flexibility for the criteria for connection to the medium-voltage grid, using the possibilities to control RES installations;
12. improving the operating conditions of the low-voltage networks, reducing the number of switching operations of prosumer installations.

## CURRENT-CARRYING CAPACITY OF OVERHEAD LINES

**Also problematic for the connection of new capacity is the interpretation of the load condition of overhead lines, where exceeding the long-term current-carrying capacity of the line by 0.5% excludes the possibility of adding new capacity. However, analyses show that even overloading by 5%-10% does not result in endangering the security of the electricity system, therefore, such a margin of tolerance should be fully acceptable.**

## INCREASING THE OPERATING TEMPERATURE OF LINES TO 60°C OR 80°C

**Increasing the thermal limit for line current-carrying capacity to 60°C or 80°C is the simplest and cheapest way to increase transmission capacity. Old power lines were initially designed for a maximum temperature of 40°C with large reserves that, after careful calculations, can be effectively used.**
**Another possibility is to use a tension control solution for the conductors, which also have considerable reserves.**



## ELECTRICITY NETWORKS – A MAJOR BARRIER TO THE DEVELOPMENT OF RENEWABLES

**The problem of connecting new generation units has been particularly visible in recent years. As indicated by the report prepared by ClientEarth based on data from the ERO, in 2020 and 2021 alone, the largest DSOs issued a total of 5,037 refusals to issue connection conditions, for a total capacity of over 20 GW. With 3,751 refusals issued in 2021 (for a total capacity of approximately 15 GW), it is an increase of 70% compared to 2020.**

The connection prospects for 2025 clearly indicate that the connection capacity of the distribution network will be exhausted.

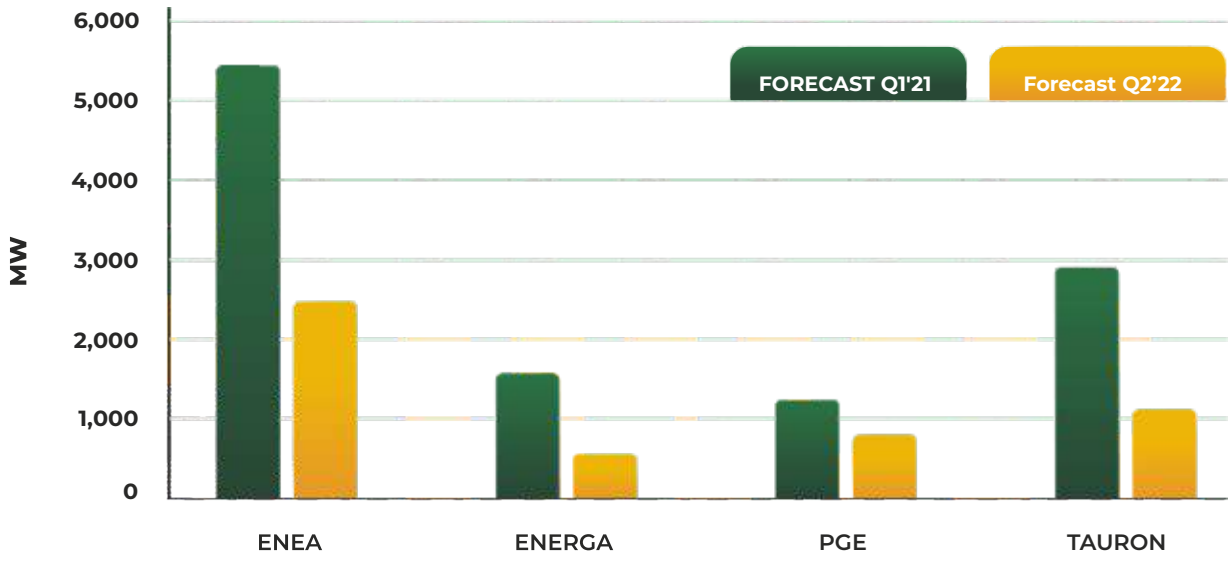
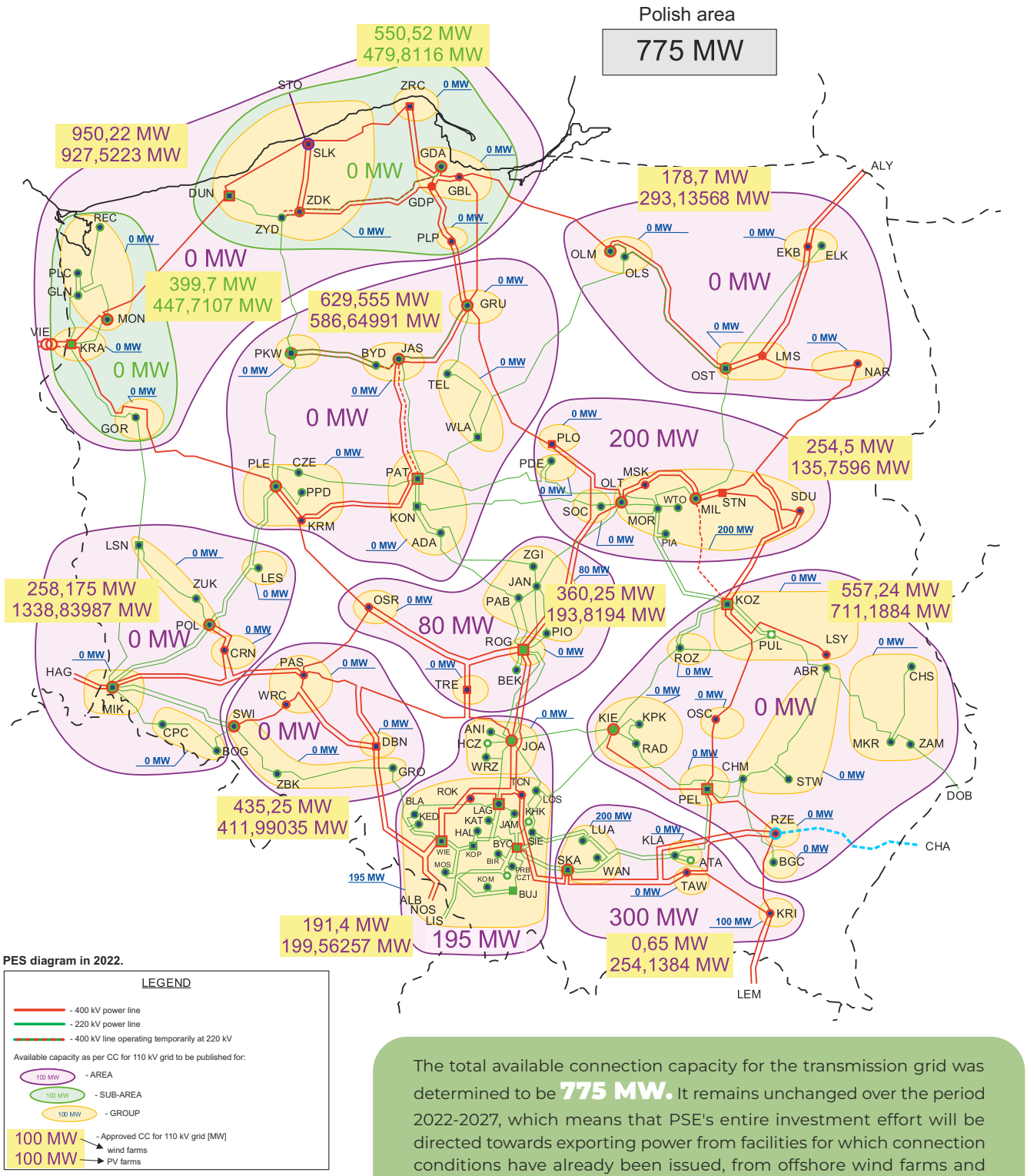



*Figure 1 Comparison of available connection capacity in 2025 – forecasts of 2021 and 2022 (compiled by IEO according to ERO statistics [2])*

[2] PV Market In Poland, Institute of Renewable Energy IEO EC BREC, May 2022, Warsaw.

## Diagram of the transmission grid of the Polish Electricity System with available connection capacities.




**PES diagram in 2022.**

The total available connection capacity for the transmission grid was determined to be **775 MW.** It remains unchanged over the period 2022-2027, which means that PSE's entire investment effort will be directed towards exporting power from facilities for which connection conditions have already been issued, from offshore wind farms and upgrading the interconnectors.

*Figure 1 Graphical representation of the Transmission System Operator's information on available connection capacities for the years 2022-2027*

# Current limitations of the electricity system in Poland:

**Connection capacity reserved for offshore wind farms** *with a total capacity of 10.9 GW expected in 2031 – this problem may worsen with the increase in planned capacity of offshore wind farms (in line with the proposed amendment to the RES Act);*

**Poor technical condition of electricity grids,** *need to invest large financial resources to modernize existing lines and build new ones*

**Overloading of lines due to connection** *of new generation capacity;*

**Shortage of information on available capability to connect new sources –** *unclear system to inform about grid connections, available connection capacity and planned changes;*

# Ambitious development plan for Polish TSO

Last year, PSE published a development plan for 2023-2032 indicating a significant, realistic potential for RES sources that could possibly be built. In the next 10 years there may be the following additions to the Polish power system:

25 GW IN ONSHORE AND OFFSHORE WIND FARMS

AND

OVER 20 GW IN SOLAR SOURCES.

PSE's document assumes that by 2030, renewables will significantly exceed **50%** of electricity demand in Poland.

# 2. Need to develop RES sources

The report *More Renewables In The Grid. Methods to increase the connection capacity of the Polish electricity system* is a response to the challenges Poland will have to face in connection with the Russian aggression on Ukraine.
Energy independence and energy security are buzzwords appearing in the public domain on a daily basis. The meaning of these slogans may vary, nevertheless their common denominator is undoubtedly the elimination of imports of energy carriers from the East (and ultimately the elimination of all fossil fuel imports to Poland). In order to achieve this, investments in fuel-free renewables must be accelerated.

## 2.1 Why we need new investments in renewables – responding to the energy crisis

Eliminating dependence on Russian energy carriers (and, in the long term, on fossil fuels) will require the energy transition to accelerate.
The energy and climate policy that has been pursued at EU level for many years is gradually bringing the expected results, but its pace must nevertheless be increased if the 2030 targets are to be achieved. The pace of transformation in light of Russia's aggression against Ukraine gains new significance – a rapid energy transition is no longer just a climate issue, but a necessity to maintain electricity supplies at a level consistent with the needs of end-users.

Today, a rapid increase in investment in renewable energy sources is a necessity in order to ensure multi-dimensional energy security, as well as the economic security of individual Member States and the European Union as a whole.
Therefore, one of the main areas of EU's actions after 24 February 2022 is boosting investment in renewable

energy sources – and the REPowerUE package is designed to do just that. The package includes a proposal to increase the RES target at EU level from 40% to 45% in 2030 – an increase in the installed capacity of renewable energy sources to 1,236 GW compared to 1,067 GW envisaged for 2030 under the "Fit for 55" package (it should also be noted that Directive 2018/2001 of 11 December 2018 on the promotion of the use of energy from renewable sources set the target at 32%, so in less than 4 years the expectations of the RES target level for 2030 have been significantly increased).

The EU's growing ambition to invest in renewables is not only a necessity arising from the need to become independent from Russian resources, the sale of which finances the war against Ukraine.
Accelerating the energy transition is also an opportunity for Europe to build a strong, modern industrial sector, which is essential for the proper functioning of the entire European economy – in this context, the experience of the COVID-19 pandemic, which disrupted the supply chains of many key components and thus slowed the economy, proved crucial.

Last but not least, the upcoming economic crisis caused by the energy crunch is an important argument for accelerating the development of renewables – the best response to an economic slowdown is to increase investments; this, in the long term, will also protect us from a similar energy crisis that could occur if such measures are not taken.

## 2.2 Starting point – the situation in Poland with regard to development of renewables

In recent years, there has been a real investment boom in the development of renewable energy sources – unfortunately, the new investments have mainly been in the PV sector (mainly prosumer installations), as the development of onshore wind power has been completely blocked by the Wind Turbine Investments Act of 20 May 2016, introducing the so-called 10H rule (the capacity of PV installations increased from 611 MW in January 2019 to 11,924 MW in November 2022, i.e. by almost 20 times in less than four years. At the same time, the installed capacity of renewables in that period increased from 8,529 MW to 22,015 MW, which means that during the analysed period the installed capacity of all RES increased by 13,486 MW, with as much as 11,313 MW in PV sources[3]). The development possibilities limited exclusively to PV have contributed to the introduction of a large imbalance, meaning that connection capacities are used in a way that is inefficient from the point of view of electricity generation, while at the same time limiting connection capacities for future projects (including wind projects, which will be possible after the liberalisation of the 10H rule). The problem of connecting new generation units has been particularly visible in recent years. As indicated by the report prepared by ClientEarth using the data from ERO, only in the

3. Based on *Statistical Information on Electricity* monthly bulletins, Agencja Rynku Energii S.A.

last two years (2020 and 2021), the largest DSOs issued a total of 5,037 refusals to issue connection conditions, for a total capacity of more than 20 GW. With 3,751 refusals issued in 2021 (for a total capacity of approximately 15 GW), the increase is 70% compared to 2020. The largest numbers of refusals were issued by Energa Operator, owned by PKN Orlen, with 1,341 refusals.
The second DSO in terms of the number of connection refusals issued in 2021 was Enea Operator, with 1,081 connection refusals. Tauron Dystrybucja refused to issue connection conditions in 491 cases and PGE Dystrybucja in 71 cases[3] (the rate of increase in number of refusals granted by grid operators to entities applying for connection is presented in Fig. 1).

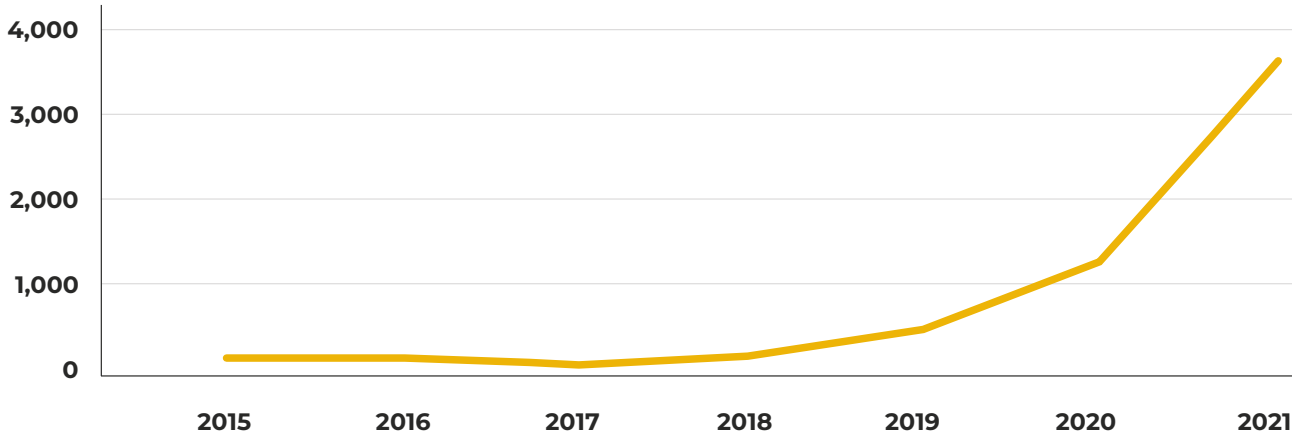



***Figure 1 Number of negative decisions received by entities applying for grid connection in 2015-2021 (according to ERO statistics[4])***

The scale of the increase in the number of refusals is impressive, although it is worth noting that it has not been compared to the number of positive decisions. However, another summary provided by the Institute for Renewable Energy clearly identifies the capacity of PV sources that have not obtained connection conditions and compares it with the capacity of sources that have obtained such conditions – Figure 2. The capacity of sources with refusals is more than four times higher than the capacity of sources that have received connection conditions (for 2021). The outlook for 2025 clearly shows that the connection capacity of the distribution network will be exhausted – see Figure 3.

4. ClientEarth. Prawnicy dla Ziemi - Sieci – Wąskie gardło polskiej transformacji energetycznej, [Lawyers for the Earth - Grids - The Bottleneck Of Poland's Energy Transition], July 2022.
5. Modzelewski W., Sieci – Wąskie gardło polskiej transformacji energetycznej, ClientEarth, Prawnicy dla Ziemi, July 2022, Warszawa.

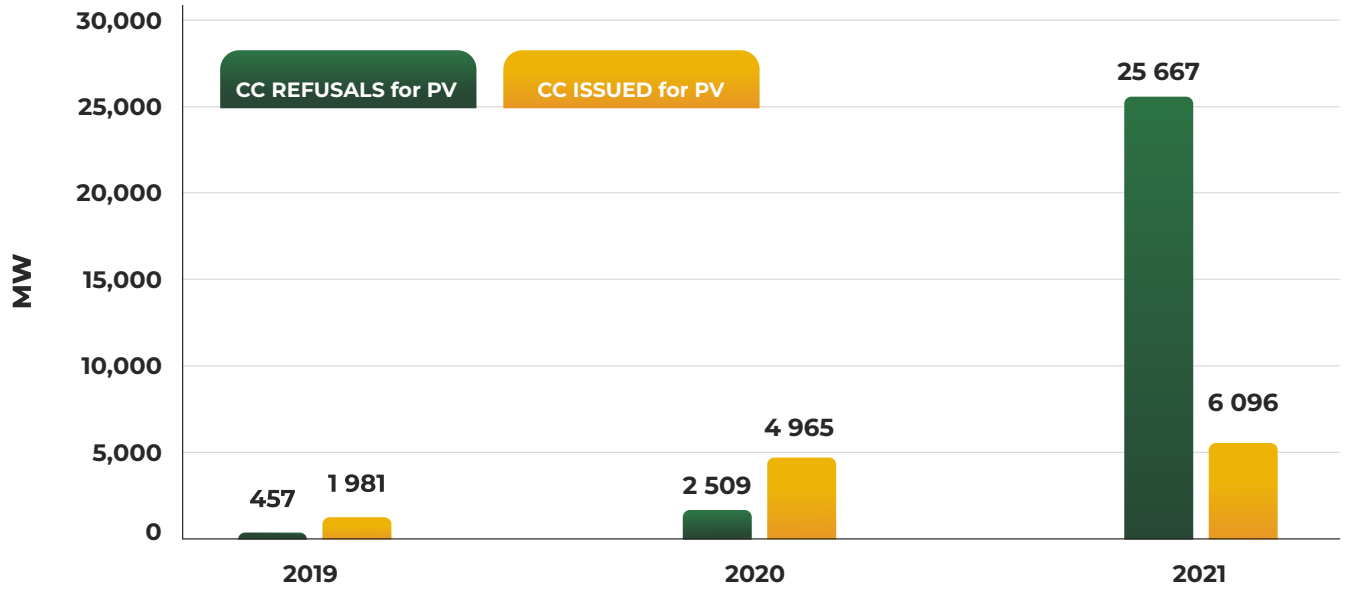



*Figure 3 Comparison of the capacities of PV sources to which connection conditions were granted and the capacities of sources which received a refusal decision from grid operators (drafted by IEO according to ERO statistics [6])*

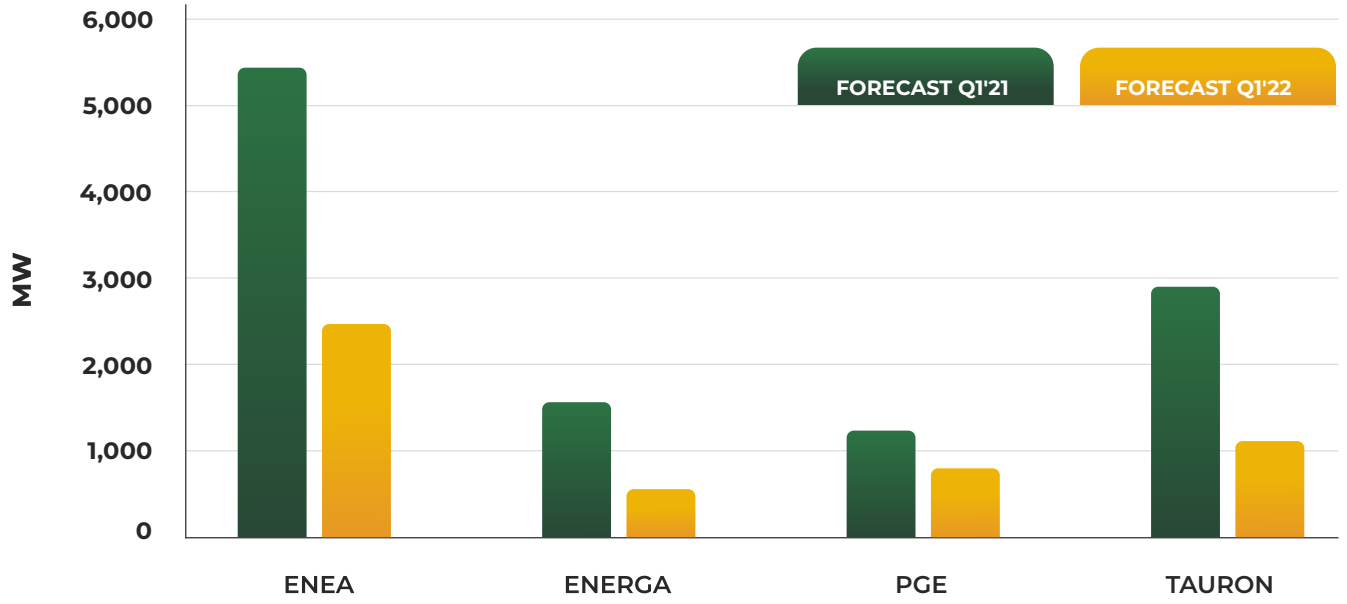



*Figure 4 Comparison of available connection capacity in 2025 – according to 2021 and 2022 forecasts (compiled by IEO based on ERO statistics [7])*

6. PV Market in Poland, Institute of Renewable Energy IEO EC BREC, May 2022, Warsaw.
7. PV Market in Poland, Institute of Renewable Energy IEO EC BREC, May 2022, Warsaw.

The operators, referring to the critical assessment of the extremely limited connection possibilities, justify the situation with the poor technical condition of the electricity grids and the large financial resources required for their modernisation. On the other hand, the amount of PLN 100 billion required for network investments specified by the President of the ERO appears in many statements[8]. The opinion about the poor technical condition of the grid preventing further RES connections is usually met with understanding.
A statistic indicating the current age of the energy infrastructure components given in the already cited report by ClientEarth can support this position – see Figure 5.
As can be seen, particularly for overhead lines, the age structure analysed is clearly unfavourable (only 21% of lines are less than 20 years old).

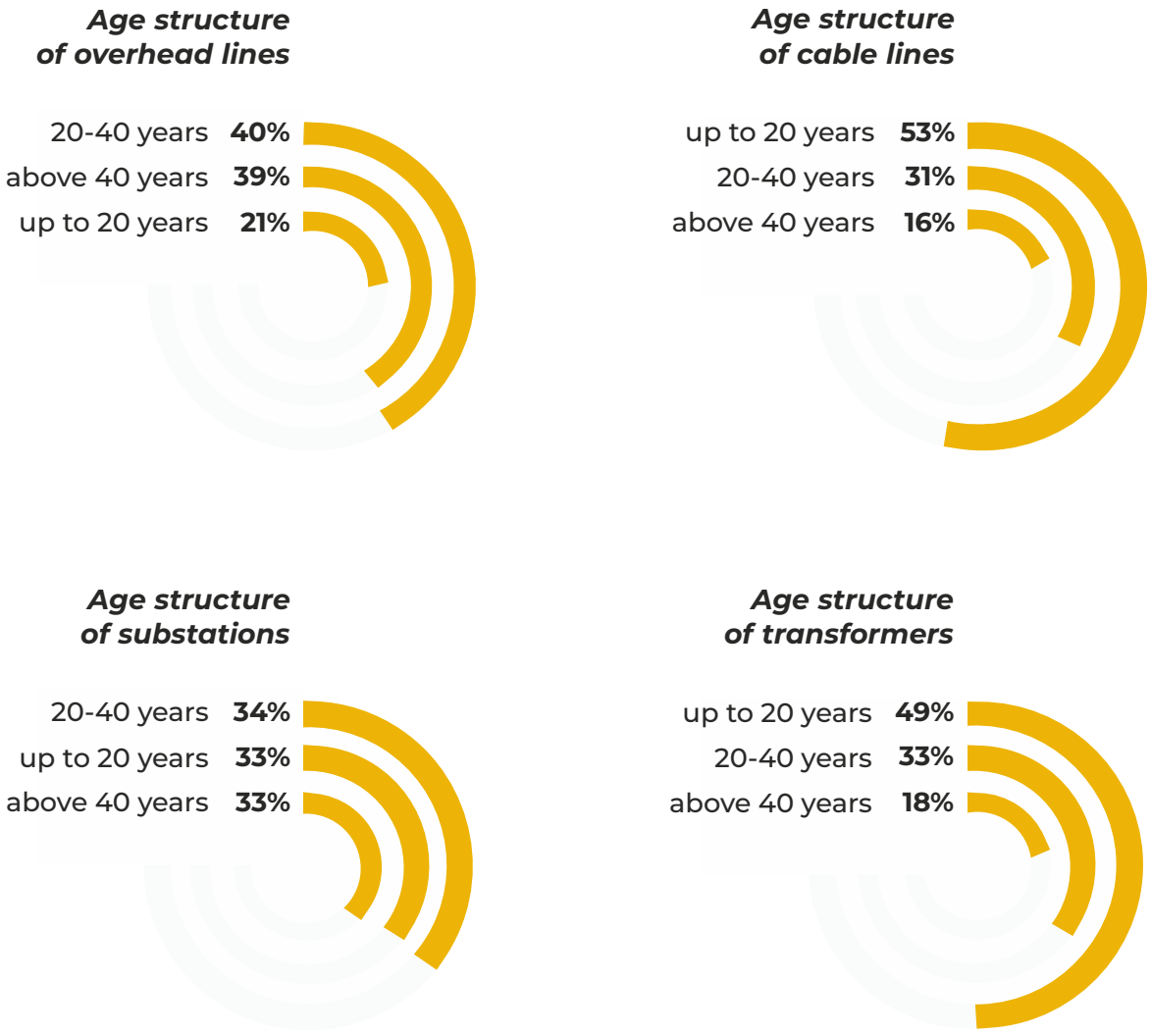



***Figure 5 Age structure of power infrastructure components operating in the Polish grid*** [9]

8. https://www.ure.gov.pl/pl/urzad/informacje-ogolne/edukacja-i-komunikacja/ure-w-mediach-1/10282,Polacy-nie-zaakceptuja-jesli-doliczymy--100-mld-zl-na-sieci-do-rachunkow.html, retrieved on 10 January 2023.
9. Modzelewski W., Sieci – Wąskie gardło polskiej transformacji energetycznej, ClientEarth, Prawnicy dla Ziemi, Warsaw, July 2022.

Another argument justifying the difficulties in obtaining connection conditions (and currently, in many cases, the complete lack of such possibility) is the necessity to reserve connection capacities for offshore wind farms with a capacity of 10.9 GW expected in 2031 (the above results directly from the Offshore Wind Act of 17 December 2020 ) and, more specifically, the wording introduced to the Energy Law on the basis of the Act stating that the connection of any facility must not restrict the export of power from these farms to the grid).
Significantly, this problem may become even more pronounced by the proposed changes to the Offshore Wind Act (included in the amendment to the Renewable Energy Sources Act – draft UC99), including a significant increase in offshore wind development in the auction system from 5 GW to 12 GW (which, in principle, is the right move requested by the offshore wind industry for a long time).

Despite the above-mentioned problems, it should be noted that as per Article 7(1) of the current Energy Law, an energy transmission or distribution company is obliged to conclude a grid connection agreement with entities applying for grid connection on a non-discriminatory basis and to give priority to connections of renewable energy source installations if there are technical and economic conditions for grid connection and supply of energy.
The term 'technical and economic conditions' is well-known to anyone who has applied for connection of a new source to the grid. However, it does not have a statutory definition and has always generated significant controversy with regard to its interpretation.

The current practice of the President of the Energy Regulatory Office and the courts considering appeals against decisions of the President of the Energy Regulatory Office regarding connection refusals fills this gap, although this may lead to suboptimal solutions (from the point of view of development of renewables). While the lack of economic conditions rarely constitutes grounds for grid connection refusals, the absence of technical conditions is a common practice. In particular, electricity system operators consider the absence of technical conditions to be a situation where a grid impact assessment for planned generation facilities (this applies in particular to the 110 kV grid and the transmission grid) indicates that overloading of certain grid components could occur or be exacerbated.

***Unfortunately, these assessments usually neglect the fact that:***

- **these overloading conditions occur for a very limited time per year,**
- **they could be eliminated in a relatively easy way (e.g. by generation curtailment during overload periods),**
- **overloading itself must not automatically result in significant impacts on the grid, in particular for overhead lines.**

This approach is accepted in decisions by the President of the Energy Regulatory Authority and in court rulings issued on the basis of appeals against these decisions.
This report will show that such restrictive positions are unjustified, especially in today's technological reality.

At this point, it should also be recalled that, under Article 58(e) of Directive 2019/944, the regulator should take all reasonable measures to facilitate grid access for new sources and to remove the barriers for renewable energy. The above-mentioned current practice of rulings of the President of the Energy Regulatory Office, accepting connection refusals due to absence of technical connection conditions based on theoretically possible overloading of lines, is unfortunately not in the spirit of the above-mentioned directive, but the exact opposite.

> Firstly, however, it should be pointed out that an approach in which the existence of a grid connection obligation depends on the existence of the aforementioned technical and economic conditions is not a self-evident approach. Formulating this obligation in this way is more of a prosthesis which, for a lack of a better idea, allows excessive discretion on the part of operators as to whether or not to connect installations to the grid.

In countries that have had considerable success in building and connecting new, distributed energy sources, the connection obligation is formulated quite differently. For example, the German regulation does not provide for such prerequisites. It does, however, provide for a more detailed procedure after submission of the connection application than the Polish law.

Translation of §8 of the German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz (BGBl. I S. 1066) of 21 June 2014, as amended) is presented in Appendix 2.

The authors of this report are aware that domestic operators are unlikely to be ready to implement such a strong rule in Polish reality, providing for an essentially unconditional obligation to connect sources to the grid.
This is partly because, in principle, the operators themselves do not have real knowledge of the connection possibilities, i.e. knowledge based on non-deterministic models that reflect real conditions as closely as possible, and on data taking into account the actual operating characteristics of the generation facilities and the current-carrying capacities of grid components. Therefore, in the medium term, it may be necessary to maintain the procedure for assessing the technical conditions for connection. Nevertheless, it is worthwhile to take the German regulations as a point of reference and to indicate that using the vague criterion of the presence of technical and economic conditions for connection is not necessary to ensure the effective and secure connection of RES installations. On the contrary, the criteria formulated in this way are, in practice, a trick that now allows connection refusals to be almost automatic. Transparent rules for the determination of available connection capacities and the connection of new sources based on the current state of technical knowledge and on a secure yet modern approach should be implemented in the Polish legal system, in the grid codes and in the practice of operators.

At a minimum, these rules should take into account the current technical and organisational capabilities for dynamic analysis of load conditions of grid components and the introduction of temporary genera-

tion curtailment due to possible congestion in certain areas of the network – in line with the possibilities already provided by the European law. It is also necessary to replace outdated and simple deterministic methods used in grid analysis with stochastic methods, which are incomparably better suited to reality. These rules should at least take into account the current technical and organisational possibilities for dynamic analysis of load condition of grid components and introducing temporary generation curtailment due to possible congestion in certain areas of the grid – in line with the possibilities already provided by European law.

## 2.3 Potential for development of RES sources in the coming years

A document issued in March 2022 (and approved in November 2022) by the transmission grid operator (PSE S.A.[10]) includes information on the total capacity of the connection conditions issued, which is estimated at 30 GW. According to PSE S.A., this value of capacity, in conjunction with the PEP2040 document, will allow for implementation of RES development plans formulated therein by 2040 (PV - 16 GW, onshore wind - 9.6 GW and offshore wind - 11 GW) and commitments towards the EU regarding the share of renewables in electricity generation. The TSO (PSE S.A.) also estimates, based on the number of sources connected to the grid, connection conditions issued and connection agreements concluded, that by 2032, 20 GW in PV installations, 14 GW in onshore wind farms and 10.9 GW in offshore wind farms will operate in the Polish electricity system. At the same time, the TSO denies that "the electricity grid restricts the development of renewable energy sources"[11]. It could therefore be argued that the dissatisfaction and business disappointment of applicants who cannot obtain grid connection conditions are not justified from the point of view of the need to carry out the energy transition in Poland, and are the result of applying for them too late (when a "sufficient" number of connection conditions have already been issued). Similar situations (limited access to attractive investment sites, licences, sales markets) are inherent risks for many types of businesses. It might seem that entities dissatisfied with their limited room for operation (certainly including the lack of grid connection possibilities for renewables) are using the general public to put pressure on grid operators and institutions supervising their activities, in order to obtain favourable business decisions despite objective constraints. In fact, the development of renewables is unquestionably one of the pillars of energy security that is so important for the functioning of the society.

The lengthy development process of the document defining Poland's energy policy (PEP2040) was in itself burdened with politics, and its forecasts, even just after their publication, were considered too conservative (especially with regard to PV and onshore wind).

10. PSE S.A. *Development plan for meeting the current and future electricity demand for 2023-2032*, main document, November 2022.
11. PSE S.A. *Development plan for meeting the current and future electricity demand for 2023-2032*, main document, November 2022.

Contrary to some opinions, the high level of installed renewable capacity required in Poland is not solely due to the desire to meet obligations towards the European Union. Replacing hydrocarbons in Europe's future energy mix will require very large installed capacities in renewables and storage of surplus energy produced under favourable weather conditions.

This will be the basis of a hydrogen economy, where hydrogen produced in RES-powered electrolysers will replace natural gas, which is currently very expensive and burdened with a risk of shortage (according to EU forecasts, hydrogen production from RES in 2030 will be more than 10 million tonnes, equivalent to 300 TWh of energy[12]). According to many forecasting institutions, closing Poland's energy balance in 2035-2040 will require significantly more RES capacity than that indicated in PEP2040 and NECP (National Energy and Climate Plan 2021-2030). In fact, these alternative forecasts are as follows: McKinsey[13] (PV - 25 GW, onshore wind - 28 GW, offshore wind - 29 GW), Instrat[14] (PV - 36 GW, onshore wind - 18 GW, offshore wind - 25 GW), DISE[15] (PV - 20 GW, onshore wind - 20 GW, offshore wind - 20 GW). The consequences of adopting the latter scenario (for 2040) are illustrated in Figure 6 – only such a policy (high RES generation and energy storage) will be able to balance demand with generation capacity, given the annual variability of these processes. The annual demand shown in a structured form (green) will require (after taking into account conventional and partly RES generation) balancing capabilities (triangular area above the time axis – yellow), which must be provided for an important part by the surplus variable generation shown as a second area in yellow below the axis.

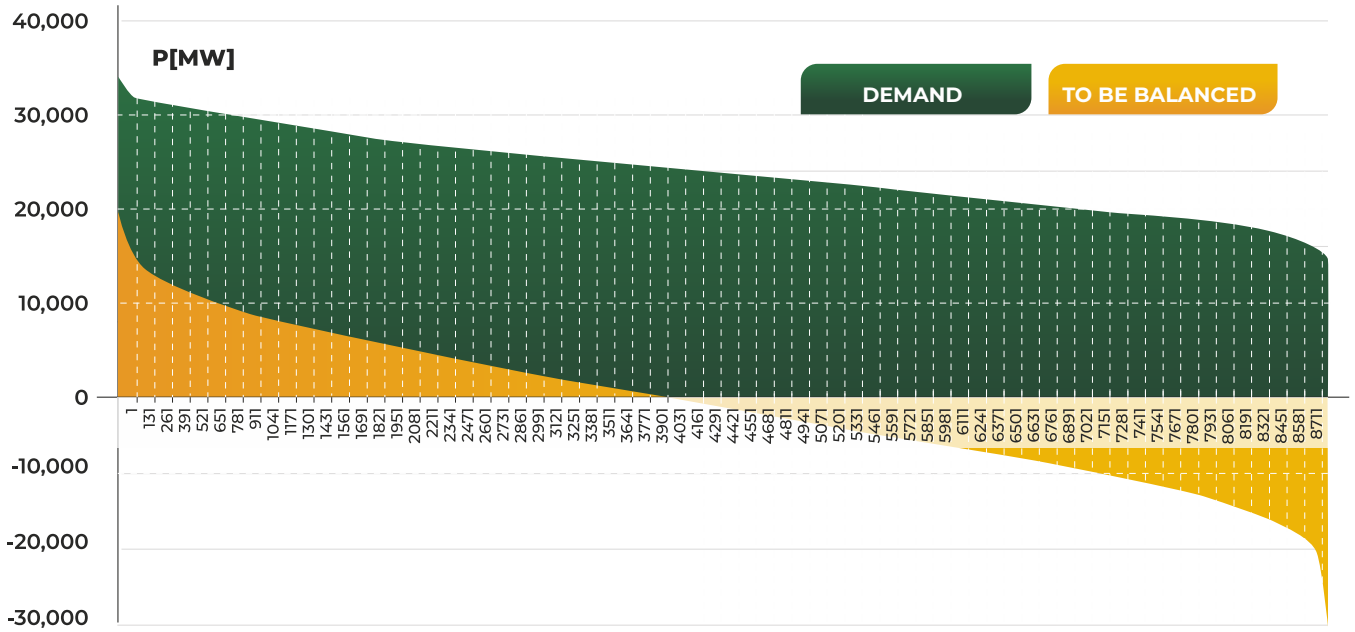
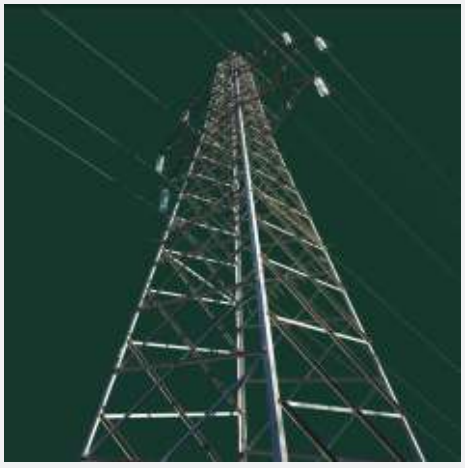



***Figure 5 Power demand graph for 2040 – yellow colour corresponds to balancing power requirements and projected surpluses from RES***

12. European Commission, *Hydrogen generation in Europe: Overview of costs and key benefits*, 2020, https://op.europa.eu/en/publication-detail/-/publication/7e4afa7d-d077-11ea-adf7-01aa75ed71a1/language-en.
13. McKinsey & Company: *Carbon-neutral Poland 2050*, 2020.
14. Instrat Policy Paper 09/2021. The missing element. Energy security considerations.
15. DISE report, 2021: *Green hydrogen from RES in Poland.*

Thus, there is a need for more grid connection capacity than that currently resulting from the connection conditions issued and agreements concluded, and the problem of power export from offshore wind farms, currently limited to 11 GW (but this capacity may potentially be doubled), should not have a destructive impact on the connection capacity of onshore facilities. It can be predicted that for 2035-2040, it is entirely feasible to reach a level of 60-70 GW of total RES installation capacity. Taking into account the current capacity of existing sources (22 GW) and those which have obtained connection conditions according to the information from PSE S.A. indicated above (30 GW), the demand for connection capacity will remain a key problem related to maintaining the upward trend in RES development. It is also worth noting that in this respect the estimates of the authors of this report coincide with the conclusions of the study prepared for the Charter for the Efficient Transformation of Poland's Power Distribution Networks (Appendix 1), where in Scenario 2, entitled "PEP2040 investments", it is assumed that its implementation will enable an increase in RES installed capacity well beyond that defined in PEP2040, i.e. up to 70 GW.

*Contrary to some opinions, the high level of installed capacity in renewable sources necessary to achieve in Poland does not result solely from the desire to meet its obligations towards the European Union.*



# 3. Recommendations for action at national level

The implementation of ambitious plans for the energy transition requires a number of measures at the national level – with regard to investments, legislation and organization. After a number of analyses, the authors of this report have defined the following areas of legislative and organisational actions, the implementation of which will enable the increase of connection capacity of the Polish electricity system in a non-investment or low-investment manner. A brief summary of key recommendations is presented below.

## 3.1 Urgent revision of government's strategic documents, including PEP2040 (accelerating the energy transition)

Poland's Energy Policy 2040 was adopted by the Council of Ministers on 2 February 2021, and already at that time its assumptions were seen as too conservative and often outdated. Although the PEP2040 envisaged an increase in the share of RES in all sectors and technologies, it was still significantly underestimated.

The authors of the document assumed that in 2030 the share of RES in gross final energy consumption will be at least 23%, with no less than 32% in the electricity sector (to be achieved mainly through wind and solar power).

The example of PV can illustrate how far the projections have fallen short of reality: the PEP2040 assumes an increase in installed capacity to around 5-7 GW in 2030 and around 10-16 GW in 2040, while at the end of November 2022, this capacity had already reached nearly 12 GW, meaning that the maximum level of installed PV capacity projected by the government for 2040 is likely to be achieved

already in 2023, i.e. 17 years ahead of schedule and in less than 3 years after the adoption of PEP2040.

An similar situation exists for wind energy, where, with regard to onshore wind turbines, PEP2040 assumes nothing beyond what is currently under construction.
In the case of offshore wind, on the other hand, the creators of the government's strategy assumed only 11 GW by 2040, despite the fact that the potential of the sites for which offshore location permits (OLL/PSZW) have been issued and those for which the OLL issuance procedures are currently under way is estimated at more than 15 GW (the Polish legislator has recognized the need for changes in this area and proposed in the RES Act amendment – draft UC99 a significant increase in the development of offshore wind under the auction scheme from 5 GW to 12 GW).

In view of the above, urgent action should be taken to update PEP2040 and make the adopted assumptions more realistic, which will be in line with both market expectations and the need to accelerate the energy transition necessary to ensure Poland's energy security.

## 3.2 Harmonising the methodology to determine the possibility to connect sources to the grid and publishing it in a regulation-level document

The key element of the assessment procedure for the grid connection conditions application (under Article 7 (8)(e) of the Energy Law) is the grid impact assessment for the generation (or consumption) facilities.

These assessment reports carried out several years ago provided an in-depth and comprehensive study assessing the systemic consequences of the connection under consideration.
Currently, their role has been degraded to routine computerised grid calculations, which are based on assumptions and models prepared by the operators (ZIWWE document), which essentially determine the outcome of the analyses performed.

> Operators base their decisions on the results of grid impact assessment reports, often without reading the entire contents of the reports, limiting themselves to the binary conclusions contained in the last pages (connection is possible or not). For the transmission network and for the 110 kV network, the issues of overhead line overloads (much less so for transformers) are the main criterion for assessing the possibility to connect the source to the grid. A more detailed analysis of this criterion leads to the conclusion that it does not properly reflect the assessment of the connection possibilities for the grid point under consideration.

Overloading of overhead lines is a phenomenon that began to be addressed mainly as a result of the calculations carried out as part of the aforementioned connection studies.

## 3.3 Harmonising the system to inform stakeholders about currently available connection capacities in the transmission and 110 kV networks

Currently, under Article 7(8)(l) of the Energy Law, companies dealing with transmission or distribution of electricity are obliged to prepare and publish information on their websites about: (l) entities applying for connection of sources, connection conditions issued and connection agreements concluded, and (ll) the value of available connection capacity for sources and planned changes to that capacity.

However, this provision is not precise enough. This results in different operators having different practices and the information they provide generally not allowing for an accurate reconstruction of the actual situation regarding the connection of sources or is even misleading in this respect. Only the information presented by the transmission system operator is available in a legible graphical form.

An engineering assessment of the results published by network operators as available connection capacity is of critical importance. Neither the Energy Law nor the implementing regulations provide specific guidelines on how to determine the available connection capacity, nor do they specify what is the formal rank of the information presented by operators (values of available connection capacity for sources).
The question is whether it is possible to determine, according to a uniform methodology, the value of the available connection capacity for the entire Polish electricity system. This is probably possible, but at the level of the entire transmission network including the 110 kV network, using appropriate advanced IT tools, of which PSE S.A. would be the holder and operator. The capacity values determined in such a way would be of real informative value, but would certainly not replace the individual assessment necessary to be carried out as part of the consideration of the application for connection conditions.

## 3.4 Interpretation of the results of power flow analyses and the resulting line load conditions in accordance with the metrological realities and the physical basics of the conductor heating process

It can be stated that considering a condition defined by the term "overhead line overload" as a danger to the "security of grid operation" is to a large extent a manifestation of the operators' technocratic advantage over investors who lack precise information about the operator's network.

Meanwhile, in the light of the analysis of overhead line heating processes described in the standards and the assumptions for the power flow calculation algorithms, it is apparent that both these processes and the power flow calculations have a large stochastic component. Therefore, a 5-10% margin of tolerance for the results should be fully acceptable.

Simply put – exceeding the long-term current-carrying capacity of line by 5%-10% shown in the calculations does not result in a threat to the security of the power system. The way in which power flow calculations are interpreted and network risks are realistically identified should be legally standardised in a regulatory act.
However, the "tightening" of the criteria for assessing overload capacity adopted by the operators on the PTPiREE [Polish Power Transmission and Distribution Association] forum to 1% and 0.5% (it is actually even a matter of percentage points) directly contradicts not only the principles of physics, but also engineering logic.

# 3.5 Eliminating investment barriers in terms of the ability to increase the thermal limit of lines to 80°C

When determining the current-carrying capacity of overhead line conductors, a distinction must be made between the capacity of the line as a single technical structure and the conductors themselves used in the line. The first value is dependent on the sag of the conductors and their distance from the ground or objects on the ground, while the second value depends the maximum permissible temperature of the conductors (for steel-aluminium AFL-type conductors it is 80°C).

***Increasing the thermal limit for line current-carrying capacity to 60°C or 80°C is the simplest and cheapest way to increase transmission capacity. This can be achieved through:***

- **adjustment of conductor tension; use is made of reserves in the strength of the towers (if any) by increasing the tension in selected sections.**
  **Once the towers have been raised, tension and sag adjustments should also be made;**
- **raising of support structures; "old" power lines were designed for a maximum permissible temperature of 40°C and with quite a large margin in terms of the permissible distance between the conductors and the ground under the line.**
  **It is therefore possible to determine this 'distance reserve' on the basis of the "line passport" (or on the basis of specially taken measurements) and then, by increasing the design temperature from 40°C to 60°C or, more often, to 80°C, to determine which towers must be raised so that the permissible distance from objects under the line is maintained.**
  **These procedures can be carried out online in cases where, for operational reasons, it is not possible to take the upgraded line out of service.**

The approach of changing the operating temperature of an overhead line obviously involves some financial outlays, but these are lower than, for example, the outlays involved in replacing conductors, building a new line or, for example, using sophisticated temperature, stress or dynamic load monitoring equipment.
In practice, it appears that the costs of projects included in the latter group (tower raising, tension adjustment) need to be looked at very carefully, as in some cases they can be relatively low. This is due to the fact that some lines have been designed with certain "reserves" of conductor distance from the ground under the line. After a detailed analysis of the line alignment in the field, it turns out that only some towers need to be raised or only in some sections the tension of conductors needs to be adjusted.

In the case of such investments, in the current state of the law they will be categorised as reconstruction, as they exceed the definition of renovation. In certain circumstances, such a change may require a number of administrative and legal permits. Often, however, this would not be justified, as in practice such developments will not noticeably change the architectural order, land use or environmental impact of the line. Meanwhile, the need to obtain permits can cause redevelopment to take a long time, potentially even for many years, and then the benefits of a relatively small amount of work would be partially put to waste.

In this regard, a statutory definition should be advocated for in case of permissible parameters for such line alterations, which in principle will not require typical permits. Such parameters could take the form of the maximum permissible elevation of line towers and be expressed in absolute terms in metres or, relatively, as a specified fraction of the original height of the towers.

## 3.6 Implementing the concept of sharing network infrastructure between different RES technologies – cable pooling

The sharing of connection infrastructure, particularly by wind and PV sources, is a proven way of not only unlocking the possibility to connect additional installations to the grid where there is no more connection capacity available, but also of improving the balancing of electricity grids by smoothing the generation profile at a given grid connection point at different times. Wind and PV sources are complementary to each other in the sense that, as a rule, they produce energy at different times – PV sources have high energy production during the day and, on an annual basis, in late spring, summer and early autumn, while wind sources generate energy at night and in late autumn, winter and early spring.

Smoothing the generation profile by combining different types of generation sources at a given connection point should therefore make it easier for operators to balance generation and demand in the electricity system. The introduction of solutions allowing renewable energy installations to share connection infrastructure will therefore allow for further development of the RES sector and also have a positive impact on the operational security of electricity grids, which is crucial for Poland to meet its climate targets and reduce electricity prices. With this in mind, the authors of this report have prepared a package of legal proposals to implement solutions based on cable pooling.

# 3.7 Implementing regulations allowing for large-scale use of direct lines

The creation of legal conditions allowing for the use of direct line (or "private wire") solutions is a necessary and expected (especially by the energy-intensive industry) measure, which does not require significant financial outlays that could burden end users of electricity. Such requests have long been made by representatives of industry associations representing energy-intensive technologies, for which the possibility of purchasing electricity directly from the generator using a direct line is an attractive method to reduce costs.

However, the most important argument, in the long term, will be the need to reduce the carbon footprint of manufactured goods – in this case, renewable energy supplied via private wire will be a necessity for in order to confirm its origin. This type of approach is gaining importance (especially for large multinational corporations and their sub-suppliers; however, it should be expected for relevant legislation to be developed at EU level in the near future).

In the future, the failure to adapt to the changing reality may jeopardise the competitiveness of the Polish economy on international markets.

Taking these arguments into account, the authors of this study have prepared a package of legal solutions aimed at implementing solutions that would be in line with expectations of the industry and enable actual implementation of solutions based on direct line (private wire).

# 3.8 Introduction of financial incentives for DSOs to reduce the number of grid connection refusals for RES sources

In the case of a natural monopoly, such as the operation of an electricity system operator in a certain area, the greatest motivation to act is usually through financial incentives stimulating certain behaviour and potentially, financial penalties discouraging undesirable behaviour. With the above in mind, in order to increase the possibility of to connect new renewable generation sources, it is recommended that a mechanism of financial incentives should be created for a more rational assessment of connection possibilities and to stimulate investment in the development of the electricity grid, thus limiting the issuance of refusals to connect new RES sources to the grid.
One possibility is to impose an obligation on DSOs to limit the number of refusals to connect new RES sources to the grid and to introduce penalties for non-fulfilment of the above obligation. At the same time, in order to ensure adequate financing for grid investments allowing for connection of new RES sources to the grid, appropriate measures should be introduced, to be used by the entities covered by this obligation.

With regard to the difficult situation of electricity consumers due to the current high energy prices, it is not recommended to create additional fees or charges putting additional pressure on electricity prices increases in Poland.

Therefore it is proposed to use two streams of funds that are already available and should be used to increase the pace of energy transition in Poland.

The first of the available streams are the funds from the RES fee and the funds from the so-called positive balance under the RES auction support scheme, which will not be consumed to cover the negative balance. It should be noted that when creating the support scheme for renewables, the legislator envisaged the accumulation of funds for the purpose of settling the so-called negative balance, i.e. a situation when the price of electricity at which the generator sells it on the market is lower than the value indicated in the auction contract.

Article 95(1) of the Renewable Energy Sources Act of 20 February 2015 clearly indicates that:

> *The electricity system operator shall charge a fee, hereinafter referred to as the "RES fee", related to ensuring the availability of energy from renewable sources in the national electricity system.* ***The RES fee shall be used exclusively to cover the negative balance*** *referred to in Article 93(1)(4) or (2)(3), and the negative balance referred to in Article 40(1)(3) of the Act of 17 December 2020 on the promotion of electricity generation in offshore wind farms, the costs of the activities of the renewable energy settlement operator referred to in Article 106, carried out pursuant to this Act and the Act of 17 December 2020 on the promotion of electricity generation in offshore wind farms,*
> ***and expenditures to cover the costs of maintaining, expanding and modifying the online auction platform*** *referred to in Article 78(7a).*[16]

16. Retrieved on 10.10.2022. – https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20150000478/U/D20150478Lj.pdf.

When designing the new support scheme, it was not assumed that in such a short time the prices in the electricity market would change so significantly that there would not only be no need to collect the RES fee, but also that there would be a surplus in the system, financed by generators in the form of the so-called positive balance, i.e. a situation where the electricity price at which the generator sells it on the market is higher than the value indicated in the auction contract. Given the low values indicated by generators in previous years' auctions and the current and projected electricity prices, we should expect a large surplus of funds in the auction support scheme that cannot be consumed under the existing mechanism. This situation favours the possibility to spend these funds on other measures aimed at further developing renewable energy sources. Problems with connecting new generation sources to the grid (in the near future it will be the greatest barrier to the development of such installations) indicate that the best way to invest the positive balance funds will be for financing investment projects carried out by DSOs in order to increase the connection capacity for renewables. The second available financing stream is the Energy Transformation Fund, envisaged in the government's draft *amendment to the act on the greenhouse gas emissions trading scheme (the "ETS Act") and certain other acts* (UA 7).

> According to this draft (paragraph (2)(e) added in Article 49), *"the funds obtained from the sale by auction of 40% of emission allowances in the years 2023-2030, less the funds referred to in (2)(d)(3)* (authors' note: PLN 18,760,000 annually in the years 2023 - 2030), shall be transferred to a separate bank account of the *National Fund, hereinafter referred to as "the Energy Transformation Fund account."* [17]

The Fund will be able to support investment projects aimed at modernization, diversification or sustainable transformation of the energy sector, with a very broad spectrum, including in the area of transmission and distribution networks (Article 50(r)(1)(3) added to the ETS Act).

In view of the currently observed high prices of emissions allowances, it should be expected for the new Fund to have enormous financial resources at its disposal (the draft's authors assume that the Fund will obtain nearly PLN 109 billion from auctioning 40% of emissions allowances in the years 2022-2030[18]); grid investments should be highly ranked, and priority should be given to entities that are most efficient in fulfilling the obligation to limit the number of refusals to connect new RES sources to the grid.
This will require, among other things, the development of a formula to assess/calculate such efficiency over a given period. It is advisable for such a formula to include at least factors such as: (I) the volume of energy that will come from new RES sources connected by the operator in this period in relation to the energy consumed by the users of its system, and (II) the proportion of connection capacity resulting from successful applications for connection of RES sources to such capacity resulting from all applications.

17. Draft act amending the act on greenhouse gas emissions allowance trading scheme and certain other acts, draft dated 21 March 2022 - *https://legislacja.rcl.gov.pl/projekt/12352303/katalog/12822402#12822402.*
18. Regulatory impact assessment of the act amending the act on the greenhouse gas emissions trading scheme and certain other acts, draft of 21 March 2022 - *https://legislacja.rcl.gov.pl/projekt/12352303/katalog/12822402#12822402.*

We could also consider introducing a certain penalty for operators who are not efficient in connecting new RES, e.g. by introducing a coefficient leading to a lower level of return on capital (currently referred to in Article 45(1)(1) of the Energy Law) to be accepted by the President of ERO when approving tariffs. As a last resort, an additional reverse mechanism could also be considered, i.e. the inclusion of preferential conditions (higher accepted return on capital) for more efficient operators in the approval of tariffs by the ERO President. However, this should not be a preferred solution compared to those indicated above, as it will lead to an increased burden on the customers connected to the given operator's grid.

## 3.9 Introduction of a curtailment mechanism for renewables

The increasing share of electricity generation from renewables may lead to the need for curtailment during periods of excessive generation from these sources. Such a need was clearly visible in the last week of 2022, with high winds and low demand.

Generation curtailment by DSOs is one of the elements affecting the possibility to connect new RES sources to the grid. Contacts with investors implementing their renewable energy projects have shown that it is becoming increasingly common for a connection agreement to be concluded on the condition that the generator agrees to provisions on uncompensated *curtailment*.

On the one hand, such a solution is favourable for operators (and for end consumers of electricity, who do not have to bear the costs of curtailment), but on the other, it increases the investors' risk while reducing the incentive for DSOs to make investments to improve the situation (the possibility of cost-free curtailment is more attractive than undertaking investment activities related to grid development).

Moreover, DSOs exploit their dominant position and investors wishing to realise their projects have no alternative and therefore agree to the solution in question.

It should be pointed out that this solution is acceptable, particularly with regard to occurrence of periods when the supply of energy from renewables will exceed demand.
To meet the expectations of investors (reduced risk leads to lower investment costs and thus lower electricity prices for consumers), as well as DSOs (for whom the cost of curtailment may be significant), it is proposed to introduce a solution for newly connected sources to curtail generation at no cost, but only up to a certain threshold (number of hours per year or volume of energy lost). Once the first (zero-cost) threshold is exceeded, the generator would have to be compensated for further curtailment.

Nevertheless, in order to meet the needs of DSOs, it is recommended to create a second threshold, under which the compensation for the generator would not come from the DSO's funds, but from external funds (e.g. from the funds collected under the RES fee or from the so-called positive balance – the possibilities in this respect are presented above with regard to solutions aimed at reducing the number of connection conditions refusals). It is also proposed to create a third threshold, beyond which the compensation would be fully covered by the DSO. Such a solution will prevent a situation where one generator is curtailed every time such curtailment is necessary due to the zero cost of such curtailment to the DSO.

In addition, the proposed model will, on the one hand, encourage DSOs to evenly curtail different sources, thus looking for optimal solutions, and on the other hand, will not discourage investment in the modernisation and expansion of the power grid.

## 3.10 Modification and improving flexibility of the criteria for connection to the medium-voltage grid, using the control capabilities of RES installations

Back in 2014, the Polish Power Transmisstion and Distribution Association (PTPiREE) developed conditions for the connection of renewable sources to the medium-voltage grid, and their application by all DSOs should be viewed favourably. However, these conditions should be updated, without allowing individual DSOs to start doing this on their own (which is already happening). These criteria should take into account the provisions of Regulation 2016/631 [19]; some modifications should also be made to ensure more flexibility.

When considering the maximum power generated in installations connected to a single substation, it is not appropriate to perform algebraic addition of their rated capacities.

In the short-circuit analysis, the PN EN 60909 [20] standard should be used, which, among other things, should result in the omission of the short-circuit criterion with regard to PV installations (they are not responsible for the values of short-circuit currents). The $Q = f(U)$ and $P = g(U)$ characteristics should be activated on a mandatory basis for individual installations (this is the responsibility of the investors, enforced by the DSOs). The settings of the voltage control systems in 110/MV transformers should take into account the annual and daily profile of generation in wind and PV installations, and ultimately form a smart control system with these installations [21].

19. Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators. Official Journal of the European Union L 112/1.

20. PN-EN 60909-0:2016-09 Short-circuit currents in three-phase AC systems - Part 0: Calculation of currents; English version.

21. Pijarski, P.; Kacejko, P., Wancerz, M.: Voltage Control in MV Network with Distributed Generation – Possibilities of Real Quality Enhancement, Energies 2022, No. 2081, pp. 1-22.

# 3.11 Measures to improve the operating conditions of low-voltage networks, reducing the number of automatic switching of prosumer installations

Exceeding one million prosumer installations in Poland is certainly reflected in the technical operating conditions of low-voltage networks. In this case, there are no restrictions from the network operators, although in many industry forums they express reservations about this. The only limitation on the installed capacity of a RES installation (usually PV installations) is that it should be less than the capacity ordered to meet offtake needs.
As the fee for this power is not very high, it is in many cases a weak limiting factor for prosumers' investment plans. Economic issues are another constraint, but the change in billing (from *net metering to net billing*) has only temporarily halted the growth rate of installations connected to the low-voltage grid.

An opinion is often presented in the media and on social media forums that these networks are 'bursting at the seams' as a result of RES generation. Such a term falsely suggests a state of overload of network components, which is not usually the case.
Negative effects consist of an increase in voltage (entirely justified in electricity terms) at the source locations, which results in exceeding the permissible level, i.e. 1.1 $U_n$ (440 V three-phase system, 252 V single-phase system).
Since such values can be dangerous for both the network and the PV installations, (via operation of inverter protection); these installations are periodically disconnected and attempts are made to reconnect them. As a result, there is an unstable voltage state in the grid, which is an unfavourable phenomenon and results in economic losses for prosumers due to the numerous switching operations. It is possible for network operators to take a number of measures to improve voltage conditions, but they show little determination to do so, pointing primarily to a lack of economic considerations.
However, it seems that the possibility of using other measures than those derived from tariff charges should lead to the "targeted" use of solutions such as MV/LV transformers with on-load tap changers (OLTC), periodic change of turn ratios of conventional transformers, introduction of power-electronic serial transformers, mandatory activation of $Q = f(U)$, $P = g(U)$ characteristics by installers, dealing with the pathology of increasing the operating thresholds for overvoltage protections. Above all, however, it is necessary to introduce local monitoring systems in low-voltage networks, allowing for identification of relevant areas of intervention[22] and to introduce a legal basis and technical possibilities for grid operators to control the parameters of PV installations (embedded in prosumers' home installations).

[22] MiniLv-s_OZE supervision of grid areas saturated with distributed generation, Alfa Power sp. z o.o. 2020.

# 3.12 Long-term planning of distribution network development

Based on analyses and observations in the field of grid planning and development (both at TSO and DSO level), the authors of this argue that one of the significant barriers in this respect is the excessively short time horizon for grid development planning at DSO level.

Both the construction of new lines and the modernisation of existing lines is a complex, long-term investment process, requiring many years of planning and financing. Implementing the right policy in this area is the key to success, as can be seen in this respect by the approach of the TSO, which, on the basis of Article 16 of the Energy Law, prepares a 10-year network development plan (the currently applicable document is dated November 2022). - *Development plan for meeting the current and future electricity demand for 2023-2032).*

> *A long-term time horizon for network development planning – in this case of 10 years – also seems appropriate for DSOs, who are currently only obliged to draw up, under Article 16(1) of the Energy Law,* ***a development plan for meeting current and future needs for gaseous fuels or energy, for a period of not less than three years,*** *for their area of operation.*

In addition, in order for long-term planning to bring adequate results, it is also recommended to use a objective-driven approach when planning network development. This means that the main measure of success should be the achievement of the intended target – e.g. the connection of specific values of new RES capacities (rather than the upgrading of one or another line or the reduction of a specific overload at one or another location). The objective function is crucial in this context, as it will lead to the optimisation of investments both from a cost point of view (which is particularly important for end users today) and also with regard to

time optimisation of individual investment projects (appropriate prioritisation of tasks – key investments from the point of view of achieving the objective should be implemented first).

An important role in the process of network development planning should be played by the President of ERO, at whose level the entire planning process should be coordinated – this will be much easier if the objective function of network development becomes the key component, rather than the mere modernisation of selected sections of network infrastructure, which does not bring a global, positive effect in the form of increased connection capacity.

In order to achieve the planned objectives by implementing the above-mentioned recommendations, a multi-level cooperation of all stakeholders – investors, DSOs, government administration, industry organisations, etc. – is necessary. In this context, a very important, positive signal is the Charter for the Efficient Transformation of the Polish Power Grid signed by the Energy Regulatory Office and the five largest DSOs, envisaging significant actions aimed at reinforcing the power grid in order to connect new RES installations with very large installed capacity. We express our hope that the signatories of the Charter recognise the need for a major acceleration of the energy transition in Poland.

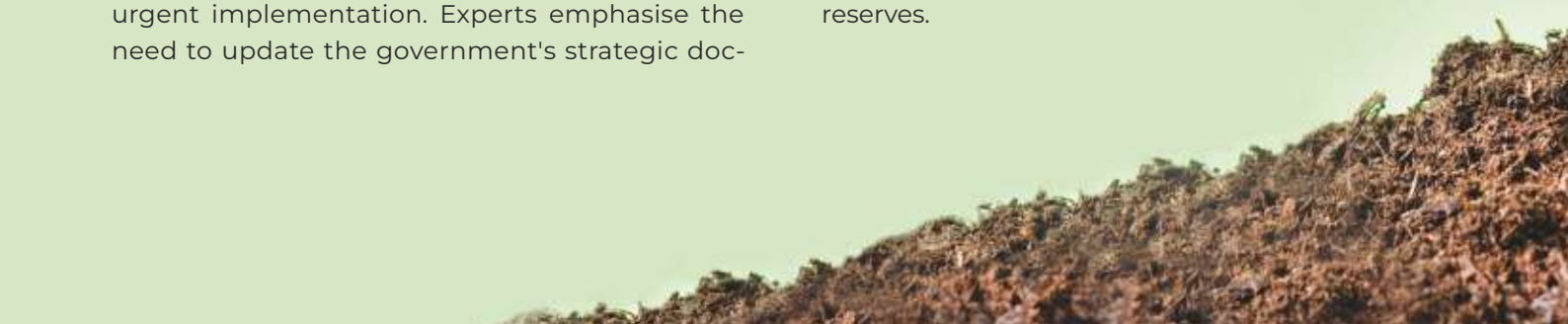
# Conclusion

Renewable energy sources in Poland are a necessary and desirable component of the ongoing energy transition. However, in order for this transition to gain momentum and gradually transform the Polish energy market into a "greener" one, it is necessary to address the current grid problems that have become a bottleneck for the development of renewable energy in our country. These issues include insufficient transmission capacity, poor technical condition and age of the electricity infrastructure, most of which was built more than 40 years ago, and now requires comprehensive modernisation. However, in order to implement solutions relatively quickly to open up for a rapid increase in RES investments, this report by the Polish Wind Energy Association and the Lublin University of Technology presented low-cost and zero-cost methods to optimise the existing grid infrastructure.

The data clearly shows that the current process of expanding and increasing grid connection capacity is not sufficient to meet the growing demand for renewable energy in Poland.
It is worth noting that the existing pressure for changes in the energy mix is caused not only by the EU's ambitious targets and directives aimed at reducing carbon emissions, but also by the need to make our country independent of imported raw materials. Multidimensional energy security is a priority at the time of war beyond Poland's eastern border.
Today's investments in renewables are a step towards a complete transition to domestic resources in the long term. The opportunity to invest in green energy capacity is also an excellent response to the ongoing economic slowdown caused by the energy crisis. Capital involvement in new RES projects would protect the Polish economy from a similar electricity shortage crisis in the future.

The report *More Renewables In The Grid. Methods to increase the connection capacity of the Polish electricity system* identified the main barriers in the area of connecting RES sources to the grid and proposed a number of measures recommended for urgent implementation. Experts emphasise the need to update the government's strategic documents defining the pace and scale of energy transition, including PEP2040. The publication also highlights the need to standardise information systems and methodologies for determining connection capacities in generally accepted practices. Currently, there is an information chaos that does not allow for a clear determination of connection capacities in the transmission and 110 kV networks.

Another problem for the connection of new capacity is the interpretation of the load status of overhead lines, where exceeding the line's long-term current capacity by 0.5% disqualifies the possibility of adding capacity, while analyses show that even a 5%-10% overload does not result in a threat to the security of the power system.
A similar omission occurs when increasing the line current-carrying capacity with regard to temperature. Increasing the line's temperature limit for current capacity to 60°C or 80°C is the simplest and cheapest way to increase transmission capacity. The old power lines were originally designed for a maximum temperature of 40°C with large reserves that can be used in an efficient manner following precise calculations. A solution can also be found to adjust the tension of conductors, which also have considerable
reserves.



The report points to the need for grid infrastructure sharing, particularly by wind and PV sources (cable pooling). This method has been proven in other countries to unlock the possibility of connecting further installations to the grid in locations where there is more capacity available and to optimise the balancing of electricity grids (generation of power in alternating periods).
The authors of the Report also highlight the need to create legal conditions for the use of direct line solutions as a necessary and expected solution (especially by the energy-intensive industry) to boost the competitiveness of the Polish economy on the international level.

Based on data from the ERO, in the years (2020 and 2021) alone, the largest DSOs issued a total of 5,037 refusals to grant connection conditions, for a total capacity of more than 20 GW. In order to address the problem of refusals to connect new generating units, which has been particularly evident in recent years, experts suggest introducing financial incentives for DSOs to reduce the number of refusals.
The creation of an incentive mechanism is intended to provide a more rational assessment of connection capacities to and stimulate investment in the development of electricity infrastructure.

One of the experts' recommendations is to introduce mechanisms to curtail RES generation both in the event of a global balance surplus and local surpluses causing periodic overloading of lines or exceeding permitted voltage levels.

It is also recommended that the criteria for connection to the medium-voltage grid are modified and made more flexible, making use of the adjustability of RES installations; however, the DSOs should not be allowed to do this on their own. An important method to improve the functioning of the Polish grid connection system is also the improvement of the operating conditions of the low-voltage grid, which is permanently loaded with more than one million prosumer installations. It is advisable to limit the number of switching operations for household installations and to introduce monitoring systems in the local low-voltage networks to identify the relevant areas of intervention.

The intensification of activities towards Poland's energy transformation and the achievement of the assumed targets for the share of renewable energy sources in our country's energy mix create the need to change the way existing network infrastructure is used, in order to make it more efficient.
Urgent and well-considered action is required with regard to grid connections, without burdening end consumers with the costs of network expansion.
The Report contains specific proposals for solutions, ready and recommended for implementation.