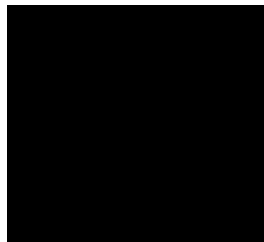
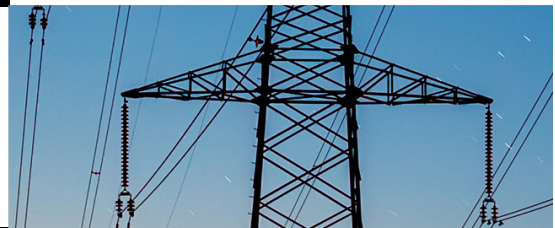
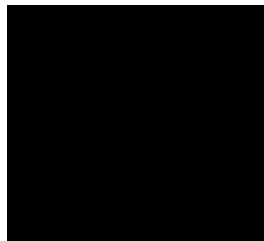


# Flexibility of power grids

Kamil Moskwik

Warsaw 2025



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## Summary

The transformation of the power industry towards renewable energy sources is leading to a significant increase in electricity generation from weather-dependent wind and solar. Unfortunately, the traditional network architecture is ill-suited to properly accommodate high variability of energy supply and the increasing dispersion of generation sources. The bottleneck of the transition is the distribution network, to which over 90% of the new renewable energy sources capacity is connected. Problems with overloads, capacity and availability of connection power are becoming increasingly common. The scale of non-market-based curtailment of RES production by operators is also growing, generating economic losses for investors and the economy and slowing down the pace of decarbonisation.

The traditional method of modernising and expanding the network does not provide a sufficient response to these challenges due to high costs and long implementation periods. In parallel with infrastructural investments, it is essential to implement solutions that increase flexibility, understood as the ability of generation, storage, demand and network assets to dynamically adapt to current conditions in the electricity system.

The strategic importance of flexibility was emphasised in the EU's 2024 electricity market reform. The updated Energy Market Regulation imposes a new obligation on Member States to prepare a report assessing the flexibility needs of the electricity system and to set national flexibility targets. As a following step, the Commission will seek to develop mechanisms for rewarding flexibility in order to increase its level across the EU. Poland has until July 2026 to prepare its FNA report.

At the same time, national frameworks for system flexibility are being developed. Existing cable pooling mechanisms and flexible connection agreements have the potential to significantly increase the utilisation of existing infrastructure. DSOs in Poland are now implementing the first flexibility service markets and dynamic line loading (DLL) pilot projects, but these activities are not coordinated and do not yet apply at the system level.

We note that current measures are insufficient to reduce network transformation costs, increase RES integration and overcome the problems described above. The lack of coordination in the approach to flexibility and the systemic scale of action threatens to delay the achievement of national flexibility targets, thereby slowing down investment in RES and electromobility. Poland needs to prepare a comprehensive flexibility roadmap covering: regulations, the development of the flexibility market, including the designation of responsible parties, network digitalisation, and support for storage facilities and active consumers (DSR).

## Introduction

### Setting free from fossil fuels requires dynamic evolution of the system

Due to the need to become independent from costly fossil fuel imports, the share of renewable energy sources (RES) in European power systems is gradually increasing. The main technologies used are onshore wind farms, offshore wind farms and photovoltaic power plants (PV). The power generated in this way is increasingly supported by battery energy storage systems (BESS).

The operating characteristics of these technologies differ significantly from those of conventional power sources<sup>1</sup>, on which power systems were based in the past. As a result, energy systems are forced to evolve dynamically. This results in several technical challenges, both in the day-to-day operation of power systems and in planning their long-term development.

<sup>1</sup> Conventional power sources include coal-fired thermal capacity (hard coal, lignite), natural gas-fired capacity and nuclear capacity.

### We need flexibility from producers and consumers

In systems based mainly on weather-dependent RES, flexibility will be the foundation and an element of the so-called resource adequacy dimension, necessary to meet energy demand in a cost- and environmentally efficient manner. In other words, the flexibility of electricity producers and consumers will be necessary to effectively balance energy supply and demand in the power system and to ensure the safe operation of the system, while avoiding excessive financial outlays.

### Distribution networks are the bottleneck of the transition

The flexibility of power grids is particularly important at the distribution network level, where over 90% of new photovoltaic and wind sources are connected. Distribution networks also host most of the new consumption points, such as energy storage facilities, electric vehicle chargers and heat pumps. In recent years, the development of weather-dependent RES and the electrification of sectors such as district and individual heating and industry have clearly exposed the existing limitations of distribution networks.

### The decarbonisation of the entire economy is at stake

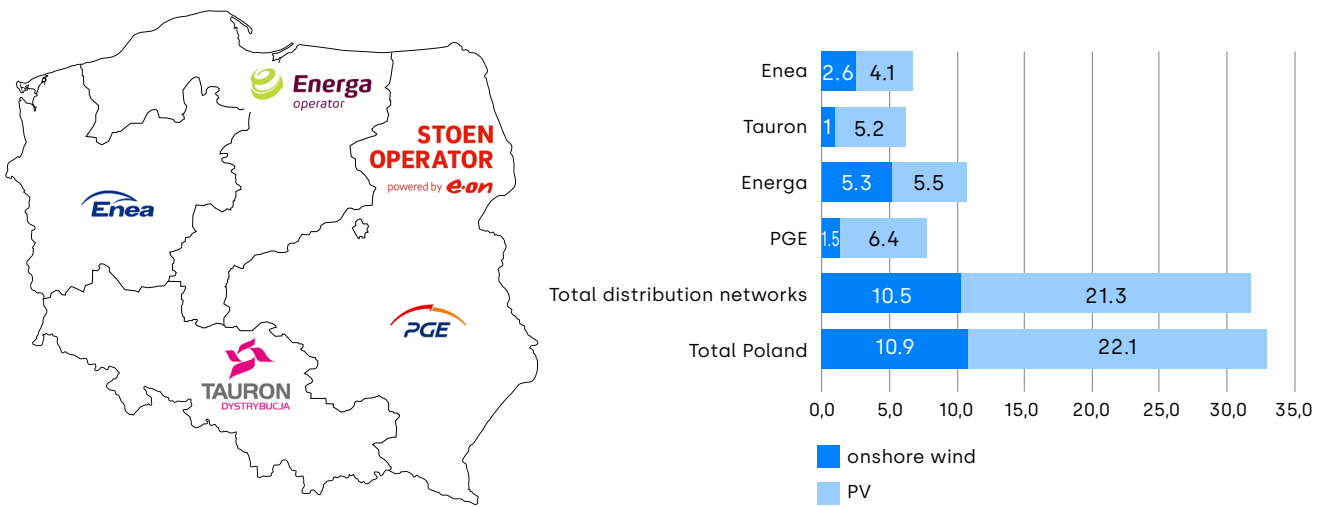
If these challenges are not addressed in time, they could significantly slow down the pace of development of new zero-emission capacity. This, in turn, would not only slow down the transformation of the energy system, but also hinder the development of electromobility, the electrification of district heating and individual heating systems, and the decarbonisation of industry.

### Lack of flexibility means higher costs

In an alternative scenario - without expanding flexibility - the pace of decarbonisation would slow down significantly due to the need to install large amounts of gas-based peaking capacity. This would not only require urgent network expansion (Poland's network infrastructure is underinvested, and the average age of distribution networks is at least 20 years<sup>2</sup>), but also higher energy consumption by consumers. This would naturally result in higher CO<sub>2</sub> emissions and the need to pay increasingly higher fees for that reason. In the long term, the lack of flexibility means an inevitable increase in electricity costs for all consumers.

<sup>2</sup> Based on data from the PTPIREE "Energy. Distribution. Transmission" for report 2024.

**Figure 1. RES capacity within the distribution network in Poland (March 2025)**



Note: According to data from Polskie Sieci Elektroenergetyczne (PSE) for March 2025, the total capacity of onshore wind in Poland was 10.9 GW, and of PV 22.1 GW, of which 10.5 GW and 21.3 GW, respectively, was connected to the distribution network.

Source: own study based on data from PSE, PTPIREE and URE

# 1. Flexibility solutions

The physical implementation of flexibility services is the result of actions taken by flexibility service providers, i.e. producers, storage facilities, consumers or aggregators in the area of active and/or reactive power consumption or generation<sup>3</sup> (with the appropriate volume and response speed), actions to maintain the required levels of inertia, as well as actions related to power flows in the grid.

## 1.1. Technical solutions

### **Flexibility does not have a single source**

The provision of flexibility services can be based on generation resources, storage resources and DSR resources. Large-scale resources such as large energy storage facilities, power plants, combined heat and power plants and flexible industrial consumers will have the greatest flexibility potential per unit. However, flexibility services provided by aggregators that utilise the cumulative flexibility potential of many small consumption and storage assets such as electric vehicles, home storage facilities, domestic heat pumps and office air conditioners, may also play an important role.

Smart grid technologies will be essential for the provision of flexibility services. This term covers a set of devices, algorithms, applications, and information and communication systems that enable the monitoring, coordination and control of resources.

### **Interventional reactive power regulation**

Interventional reactive power regulation (pol. IRB) is a service that supports the management of voltage levels in the distribution network to ensure its proper functioning. It is performed by selected active RES producers at the request of the operator.

### **Interventional active power supply**

Interventional active power supply (pol. IDC) is a DSR service aimed at managing surpluses of generation from renewable energy sources. Under this scheme, consumers have the option of increasing their active power consumption above the contractual power value free of charge during designated hours of the day.

### **Dynamic line rating**

From the point of view of distribution network flexibility, power flows and voltage levels are of key importance, which is why dynamic line rating (DLR) is a special

<sup>3</sup> Increasing or decreasing active power consumption from the grid, increasing or decreasing active power fed into the grid, increasing or decreasing reactive power consumed from the grid, increasing or decreasing the reactive power fed into the grid.

solution in terms of flexibility. The essence of DLR is the use of smart grid technology to monitor current network parameters (conductor temperature, distance from the ground), depending on weather conditions (ambient temperature, wind cooling factor) in order to determine the permissible current load of the line in real time. The DLR approach allows the use of the existing line capacity margin above the static current carrying capacity, determined conservatively (i.e. for extreme weather conditions that occur relatively rarely on an annual basis). At certain times of the day or year, when line operating conditions are safer than the extreme conditions underlying the static current carrying capacity, the DLR approach allows for a significant increase in line capacity without the need for costly and lengthy infrastructure investments related to line expansion.

## 1.2. Regulatory solutions

The development of system and network flexibility is a complex and multidimensional task, which should consist of market, regulatory and technological solutions of a diverse, yet complementary nature. These solutions should be tailored to the local specifics of the system and network in each country or geographical area, and their development should be coordinated and comprehensive, supported by thorough analysis and understanding of the needs of the system in question. Ad hoc and random measures, introduced in a hurry, will not work.

### **Local flexibility markets**

Local flexibility markets are markets in which operators (DSOs, TSOs) and service providers (energy consumers and producers, aggregators) can actively participate in system balancing by offering and purchasing flexibility services. The services offered may include, for example, reducing or increasing electricity generation or consumption.

### **Flexible connection agreements**

A flexible connection agreement is a type of contract that allows connection to the electricity grid in an area with limited capacity. This means, that more energy producers and consumers can use the existing network infrastructure, but until it is upgraded, they agree to temporary restrictions on the volume of energy consumed and fed into the grid, as introduced by the operator.

### **Cable pooling**

Cable pooling is a solution involving the sharing of a connection by several generation units with complementary operating profiles (for example, wind and photovoltaic installations have such complementary energy generation profiles). Individual producers using a shared connection generate electricity and feed it into the grid at different times. This flattens the energy production profile. As a result, cable pooling allows for more efficient use of available connection capacities and transmission capacities, without the need for additional network infrastructure expansion.

### **Locational marginal pricing (LMP)**

Locational marginal pricing (LMP) is a pricing mechanism that can be used to increase the efficiency of network congestion management. In addition to the price

of energy, locational prices take into account the costs of transmission through the networks (valuation of capacity and network congestion), which allows producers and consumers to make flexible decisions in response to signals regarding possible network congestion.

### **Dynamic distribution tariffs**

The idea behind dynamic distribution tariffs is to reflect in real time the situation in the energy system that affects the actual costs of electricity supply (including the costs of network congestion). Under a dynamic tariff, specific time zones are assigned, and variable network charges are set for each zone. Dynamic network charges may be more advantageous for end consumers who have chosen electrification solutions, such as those who heat buildings with electricity (using, for example, heat pumps or electric boilers), own electric vehicles or have electricity storage facilities. You can learn more about dynamic network charges in our report [\*Fixed, variable, or perhaps dynamic? Network charges in the face of energy transition.\*](#)

### **Participation of the producer or consumer in the network expansions costs**

To encourage flexibility in energy consumption and production, regulations concerning the division of grid connection costs between the system operator and the entity connecting to the grid are extremely important. A greater share of grid expansion costs borne by energy producers and consumers translates into a greater incentive to be flexible.

## 2. Development of flexibility of distribution networks in Poland

### 2.1. Legislative measures

#### Polish Grids Bill

The development of the flexibility of power grids in Poland is gaining momentum, as evidenced, among other things, by legislative measures. The so-called "grid bill" (UC84<sup>4</sup>), is currently being adopted. It covers issues such as cable pooling, flexible connection agreements, and mechanisms to increase the availability of connection capacity.

<sup>4</sup> The exact text of the bill in Polish can be found under [this link](#).

**Table 1. Overview of legal solutions regarding grid flexibility in Poland based on draft bill UC84, version dated 17 October 2025**

Solution	Characteristics
Cable pooling	<p>The Act of 17 August 2023 amending the Act on Renewable Energy Sources and certain other acts introduced changes enabling the use of cable pooling. The Act added a provision stating that two or more RES installations belonging to one or more entities may be connected to the power grid with a rated voltage above 1 kV at a single connection point. This provision thus excludes other (non-RES) generation units or storage installations.</p> <p><b>Expected impact:</b> The above restriction on the type of source is removed in the draft UC84 bill of 17 October 2025. The possibility of sharing connections between storage facilities and RES increases flexibility in terms of the scale of new source connections and allows for better management of the currently observed limitations in connection capacity.</p>
A flexible connection agreement and a configurable grid connection	<p>The proposal to introduce a flexible and configurable connection agreement is the core of draft law UC84 of 17 October 2025. A flexible connection agreement allows for connecting a larger number of sources to a network with a limited capacity and includes provisions enabling temporary restrictions on feed-in or consumption. In the case of a configurable connection agreement, the terms of the restrictions may change dynamically over time and be linked to specific network operating parameters (e.g. voltage, load).</p> <p><b>Expected impact:</b> The above solution will allow for more flexible management of the connection process and potentially for connection of a larger number of installations that will have to consider the possibility of production restrictions.</p>

<b>Promotion of flexibility and energy efficiency of households</b>	<p>In order to promote behaviour aimed at rational and economical consumption of electricity, electricity providers and energy companies involved in the transmission or distribution of electricity shall develop and publish codes of good practice on their websites or post information on the promoted behaviours.</p> <p><b>Expected impact:</b> Improved consumer awareness of efficiency and flexibility, translating into desirable behaviours that support system management.</p>
<b>Monitoring the status of investment implementation and expiry of the connection agreement, flexible connection agreement, configurable connection agreement</b>	<p>The draft bill UC84 of 17 October 2025 introduces rules under which:</p> <ul style="list-style-type: none"> <li>▪ an energy company may, at the stage of concluding a connection agreement, re-verify the technical and economic conditions for connection and, if they are found to be lacking, refuse to conclude a connection agreement;</li> <li>▪ connection agreements, flexible connection agreements or configurable connection agreements if will expire not used within a specified timeframe.</li> </ul> <p>This solution is intended to counteract the blocking of connection capacity by investors who are not making progress in the implementation of their investments (zombie projects).</p> <p><b>Expected impact:</b> Increased transparency and control over the connection process, as well as greater discipline on the part of investors, to prevent blocking connection capacity.</p>

Source: own analysis

## 2.2. Actions of distribution system operators in Poland

Over the past few years, Polish DSOs have been gradually developing the flexibility of their own electricity networks. The table below presents an overview of the flexibility measures implemented by Polish DSOs.

**Table 2. Overview of flexibility measures implemented by Polish DSOs**

DSO	Characteristics
<b>PGE Dystrybucja</b>	<ul style="list-style-type: none"> <li>▪ Construction of telecommunication and metering facilities (AMI/LTE450 infrastructure to be intensively implemented from 2023).</li> <li>▪ Pilot project for dynamic line rating based on smart grid solutions<sup>5</sup>, testing the capacity of the power system to load lines above their static current carrying capacity values and 72-hour prediction taking into account actual weather conditions and their impact on lines.</li> <li>▪ Publication of information on connection capacity availability.</li> </ul>
<b>Tauron Distribution</b>	<ul style="list-style-type: none"> <li>▪ Flexibility services market: flexibility certificate (pol. <i>Certyfikat elastyczności</i> – CE), tender processes for suppliers, flexibility demand maps.</li> <li>▪ Introduction of a dynamic tariff for distribution services (G14dynamic); four-zone tariff, in which the duration of each zone of the day: "recommended use", "normal use", "recommended savings" and "required reductions" are defined in the "Energy Compass – <i>Energetyczny Kompas</i>" – an application and website provided by PSE.</li> </ul>

<sup>5</sup> Read more on the [PGE Dystrybucja website](#).

	<ul style="list-style-type: none"> <li>▪ Tauron is working on the implementation of mechanisms such as interventional active power supply (IDC) and interventional reactive power regulation (IRB), which will help to make better use of excess energy from RES and avoid overloads.</li> <li>▪ Publication of information on connection capacity availability.</li> </ul>
<b>Enea Operator</b>	<ul style="list-style-type: none"> <li>▪ IRB – Interventional reactive power regulation<sup>6</sup>. A tool supporting the management of voltage levels in the distribution network for its reliable and proper functioning, implemented by selected active RES energy producers at the request and for remuneration from Enea Operator.</li> <li>▪ IDC – Interventional active power supply for customers A, B, C2. The solution – based on Enea’s weekly forecast of RES generation peaks – allows for a free increase in active power consumption above the contractual power value in periods designated by the Operator, up to the so-called safe power level (max 150%).</li> <li>▪ Publication of information on availability of connection capacity.</li> </ul>
<b>Energa Operator</b>	<ul style="list-style-type: none"> <li>▪ IDC – Interventional active power supply. A service analogous to Enea Operator’s IDC service. Information on periods during which the customer will be able to increase their active power consumption free of charge will be made available at least three days in advance on the Energa-Operator website. The aim of the service is to improve the flexibility of the distribution network, utilise surplus energy from renewable energy sources and increase the security of electricity supply.</li> <li>▪ Publication of information on connection capacity availability.</li> </ul>

<sup>6</sup> For more information, visit the [Enea Operator website](#).

Source: own analysis

The above actions taken by the DSOs indicate the high importance attached to the development of the flexibility of the distribution network in Poland and the increasing transparency of network data. The next desirable step is the large-scale development of solutions in the areas of DLR, flexible connection agreements, cable pooling, aggregation of distributed resources and the use of demand-side flexibility (DSR).

### 2.3. Effective Transformation Charter

#### DSOs discuss the need for system flexibility

The scale and urgency of the need to develop grid flexibility is addressed in the Charter for Effective Transformation of Distribution Grids in the Polish Energy Sector (pol. Karta Efektywnej Transformacji – KET)<sup>7</sup>. KET is a sectoral agreement initiated in October 2021 by the President of the Energy Regulatory Office (URE) and signed in November 2022 by 28 signatories, including the five largest DSOs in Poland. The aim of the Effective Transformation Charter was to diagnose the key needs related to the operation of distribution networks in the context of the growing capacity of RES sources connected to these networks, as well as to identify measures and tools to meet these needs.

<sup>7</sup> The content of the Charter in Polish language can be found [here](#).

According to the KET’s proposals, investments in distribution systems should contribute to the gradual transformation of passive (unidirectional) networks into active (bidirectional) networks. The solutions implemented to increase net-

work flexibility are aimed at enabling the development of the distributed energy resources, active participation of end users in network balancing, and the use of EV charging points and energy storage facilities.

### **Without digitalisation and automation, nothing can be done**

The KET highlights the importance of digitalisation and automation as key factors in developing flexibility on the part of DSOs. Investments in digitalisation and automation are essential for creating an effective flexibility services market and efficient network operation management. A higher level of network digitisation means faster identification and elimination of network failures, shorter power outages and improved electricity quality indicators.

### **We are facing major investments**

The Effective Transformation Charter proposes allocating approximately PLN 20 billion (approximately 15% of the entire investment programme) to grid flexibility.

### **DSOs are changing their perception of network development**

According to one of the largest DSOs<sup>8</sup> in Poland, the two years of KET's existence have changed the way energy companies plan their investments. The traditional approach to network planning (network development and connection of new customers, modernisation of existing assets) has been supplemented by investments in areas such as RES connection, automation, digitalisation and 'smartification'.

In the opinion of the DSO, this is a significant improvement in the approach taken prior to the introduction of the KET, which has become a kind of *modus operandi* for the entire power industry, as it indicates key investment directions.

<sup>8</sup> According to a press release by [Stoen Operator](#).

## 3. Summary and recommendations

### **Distribution networks are the bottleneck of the transition**

The transformation of the power industry is moving towards an increasing share of power and production from weather-dependent RES, supported by energy storage facilities. The vast majority of this capacity is installed within distribution networks, which connection capacities are coming to an end or are even completely exhausted, and which transmission capacities are often approaching the limits of system safety.

### **Greater flexibility means lower expenditure on network expansion**

The nature and observed challenges of the electricity sector transformation in a model based on inverter-based, weather-dependent RES and BESS connected at the distribution network level call for the development of network flexibility as an alternative to complex and capital-intensive network investments. A variety of flexibility-supporting solutions offer the potential for more efficient use of existing grid infrastructure (which will reduce the scale of RES redispatching) and remove barriers to the connection of RES and storage facilities, as well as creating a new market, sources of revenue and jobs in an innovative sector.

### **Smart investments in flexibility mean savings for the whole society**

A lack of acceleration and coordination of actions aimed at increasing system flexibility will result in higher electricity bills for all consumers, as the costs of infrastructure expansion and the construction of additional peak sources based on natural gas will be reflected in the distribution tariff. The growing scale of RES redispatching will have an increasingly negative impact on the profitability of installations.

### **No electrification without flexibility**

Insufficient generation from zero-emission sources, resulting from problems with grid congestion and overloads, will limit the possibilities for electrification of sectors such as transport, district heating and individual heating.

### **Desirable courses of action**

In order to respond to these challenges, from the point of view of grid flexibility, action is needed in the following areas:

- implementation of dynamic line rating systems,
- development of energy storage facilities and demand-side flexibility (including through the aggregation of distributed resources and IDC services),

- development of reactive power management services (IRB services),
- improved management of the grid connection process (minimising the phenomenon of 'zombie' projects, e.g. by enabling TSOs or DSOs to monitor the progress of investments or by organising competitions for connection capacity, increasing the transparency of information on the availability of connection capacity, e.g. by publishing a 'colour map'),
- optimisation of the use of existing connections (cable pooling, flexible and configurable connection agreements).

### **We need coordination of market and regulatory solutions**

At the same time, it should be noted that system and network flexibility is a complex and multidimensional task, which should consist of market, regulatory and technological solutions of a diverse and complementary nature. These solutions should be tailored to the local specifics of the system and network in a given country or geographical area, and their development should be coordinated and comprehensive, supported by thorough analysis and understanding of the needs of the system in question. Ad hoc and random measures, introduced in a hurry, will not work.

### **EU requirements and national efforts**

EU legislation requires Member States to prepare flexibility needs assessments, reports on estimated flexibility needs (FNA reports), and to set national flexibility targets. The deadline for submitting the first FNA reports is July 2026. The development of flexibility in Poland is beginning to gain momentum, which is reflected in the national legislative efforts and in the activities of national DSOs.

### **What's next?**

Considering the potential, but also the possible challenges associated with the more advanced development of the flexibility sector and power grids in Poland, we recommend:

1. For the Ministry of Energy, in cooperation with the TSO and DSOs, to initiate discussions on creating a flexibility roadmap and to take active measures to coordinate the development of this market.
2. For the DSOs to prepare plans for the development of network flexibility and include this topic in their network development plans. ■

## Annex: Flexibility needs assessment methodology

The FNA methodology prepared by ACER specifies guidelines for assessing system flexibility needs.

In accordance with Article 8 of the FNA methodology, the assessment of system flexibility needs in terms of RES integration should indicate how much flexibility resources (taking into account economic and technical rationality) are necessary to minimise the volume of generation reduction from weather-dependent RES (see [section 1.2](#)). The assessment of system flexibility needs in terms of ramping discussed in Article 9 should indicate how much flexibility resources are necessary to respond quickly enough to changes in the residual demand profile (see [section 1.2](#)).

The assessment of system flexibility needs should also take into account the availability of resources to cover random events, such as the loss of a producer, storage facility or network component, or sudden fluctuations in residual demand (Article 10).

The assessment of network flexibility by the DSO, as discussed in Article 11, should take into account the division (granularity) of the network according to voltage levels or be carried out on the basis of the aggregation of individual voltage levels. DSOs should specify in detail the 'upward' and 'downward' network flexibility needs for different scenarios over representative days.

The assessment of network flexibility by DSOs should also take into account:

- local network constraints,
- assessment of the impact on the network of existing and new connections of generation sources, consumption, storage and/or other flexibility resources in specific locations of the distribution network,
- assessment of the degree of "downside" flexibility associated with RES reductions,
- assessment of the degree of unavailability of flexibility resources as a result of the pre-qualification process or temporary restrictions (e.g. due to the provision of frequency balancing services by a given resource),
- assessment of market barriers, regulatory barriers, assessment of incentives and assessment of the impact of digitalisation on network flexibility,
- information on how to obtain flexibility resources, e.g. based on local resources or flexible connection agreements.

In accordance with Article 16 of the amended Energy Market Regulation, DSOs should provide the following indicators characterising network flexibility:

- location of the flexibility need (geographical location, grid voltage level),
- direction of flexibility need ("up", "down"),
- the time interval during which the resource should be available to meet the flexibility need,
- required capacity of the resource and estimated volume of energy associated with the provision of flexibility services,
- frequency of activation of the resource,
- if it is not possible to activate a given resource – a clear justification.

