EPSO-G
Naujoji energetika

Litgrid

Flexibility needs assessment report

2026

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Content

Terms

Acronym/Term	Meaning
FNA	Flexibility Needs Assessment
FNA methodology	ACER Decision No. 05/2025 on the data type and format, and on the methodology for analyzing flexibility needs of transmission and distribution system operators
FCR	Frequency containment reserves active-power reserves that can be used to maintain system frequency when the imbalance appears
mFRR	Manually activated Frequency Restoration Reserve
aFRR	Automatically activated Frequency Restoration Reserve
RES	Renewable energy sources
Flexibility	The electrical power system's ability to respond to uncertainty of generation, demand and network availability
Demand	Total instant electricity power consumption in transmission and distribution systems, including network losses
Downward flexibility needs	Needs whose solution requires either decreasing injection into the network or increasing demand from the network;
Upward flexibility needs	Needs whose solution requires either increasing injection into the network or decreasing demand from the network
Target year	A year for which data and analysis are provided within the framework of the FNA methodology
Uncovered flexibility needs	The additional flexibility needs identified by the FNA methodology, not expected to be met by new or existing resources based on ERAA or NRAA inputs
D-1	Day-ahead
DE	Intraday
LTrSc	Slower transformation scenario
ENTSO-E	The association of European electricity transmission system operators
ERAA	European Resource Adequacy Assessment
MTU	Market time unit
LITGRID	Lithuanian electricity transmission system operator
ESO	Distribution system operator
EBGL	The Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing the electricity balancing guidelines
EU	European Union
P2X	Power-to-X technologies converting electricity into another energy carrier or product (e.g., hydrogen)
KHAE	Kruonis pumped storage hydropower plant
FRR	Frequency Restoration Reserve
SO GL	System Operation Guidelines
HVDC	High Voltage Direct Current
FRCE	Frequency Restoration Control Error
BESS	Battery energy storage system
DSO	Distribution system operator
TSO	Transmission system operator
VE	Wind power plant

SE	Solar power plant
VERT	National Energy Regulatory Council
EMD	Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity
EEĮ	Law on electricity of the Republic of Lithuania
DNDP	Distribution Network Development Plan
DSO Entity	Distribution system operators' association
GV	Generating Consumers (i.e. prosumers)

1. Executive Summary

1.1. Context

The purpose of the flexibility needs analysis is to determine how much and what type of flexibility is required for the Lithuanian electricity system to adapt to the variability of generation and demand arising from the variable generation of renewable energy sources.

The performance of the Flexibility Needs Analysis (FNA) is defined by Article 19e of the EMD

1.2. Scope of assessment and scenarios

ACER-approved FNA methodology identifies two main types of flexibility:

- System flexibility — determines the volumes required to adapt to generation and demand variability arising from the generation of renewable energy sources.
- Network flexibility — determines the volumes required to address operational parameter deviations and congestion issues.

The FNA methodology also includes responses to the ACER questionnaire on flexibility barriers and digitalization.

The TSO assessment additionally incorporates specific flexibility needs intended to further detail the flexibility requirements of the Lithuanian energy system. The full list of assessed items is provided in Fig. 1.

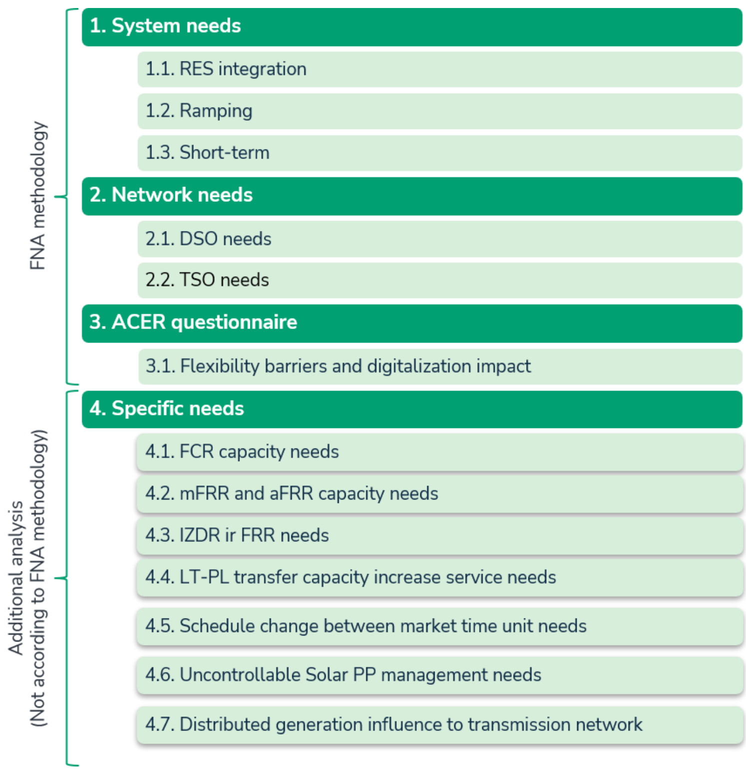

Figure 1 Scope of the assessment of flexibility needs

Flexibility needs are assessed under two scenarios:

- National Strategy Scenario (hereinafter - NacSc), whose assumptions are based on the state's strategic planning documents in force.
- Slower Transformation Scenario (LTrSc), developed considering market development conditions and the latest surveys

Each scenario is evaluated in two regimes:

- Basic – all technical resources that can be used to ensure flexibility are assessed.
- Realistic – reliably available cross-border capacities are assessed according to balancing market rules; the use of P2X technologies for covering flexibility needs is not foreseen

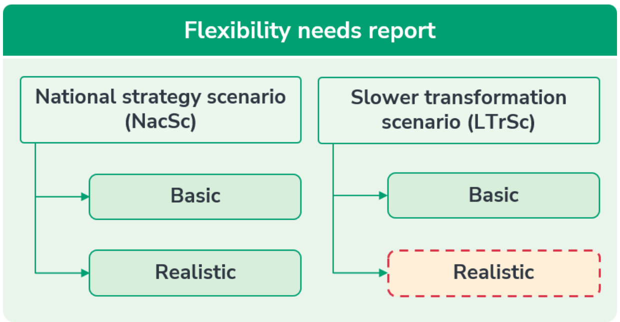

Figure 2 Scenarios used in the assessment

The Slower Transformation Scenario best reflects the development trends of the Lithuanian power system; therefore, the conclusions of the analysis will be provided based on the results of the **LTrSc realistic regime**.

1.3. Data used in the analysis

In the case of a Slower Transformation Scenario, it is assumed that the implementation pace of RES projects slows down, resulting in lower RES volumes in the Lithuanian power system compared to the NacSc scenario. This trend remains consistent throughout all analyzed years.

In the Slower Transformation Scenario, a higher level of cross-border capacity utilization is observed. The change arises from the differing Lithuania–Poland and Lithuania–Latvia capacity possibilities across the scenarios. In the LTrSc scenario, the Lithuania–Poland cross-border capacity is assessed considering Litgrid's concept for increasing the Lithuania–Poland interconnection capacity, while the Lithuania–Latvia cross-border exchange volumes are assessed based on the most up-to-date information related to infrastructure development. In the realistic regime, for both LTrSc and NacSc, the available cross-border capacities are assessed according to balancing market rules.

The amount of flexible resources remains similar in both LTrSc and NacSc. A difference becomes visible when the volumes are reduced to the values defined in the realistic regime assumptions. In the realistic regime, P2X technologies are assumed not to be used for flexibility.

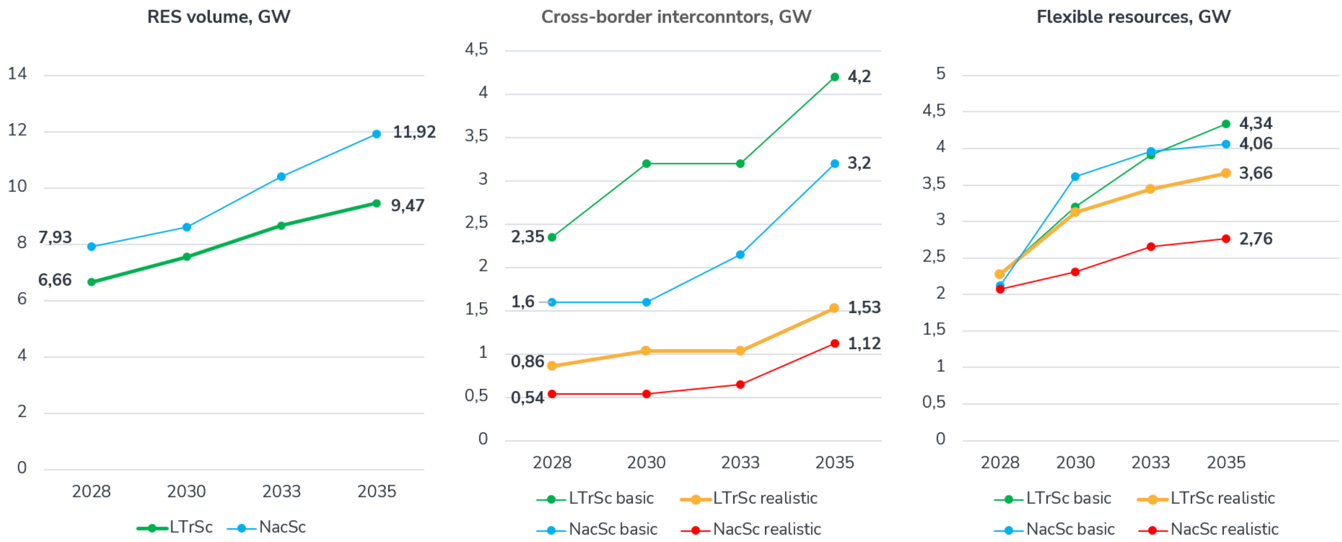

Figure 3 Key indicators by scenario

1.4. Summary of flexibility needs

Flexibility needs are divided into three components:

- System needs
- Network needs
- Specific needs

System needs are determined by assessing the needs of RES integration, Ramping, and Short-term flexibility. Minding that same flexibility measures are applicable to different flexibility needs the maximum value is equal to the system needs. System needs also include mFRR and aFRR capacities, schedule change between MTU and uncontrolled solar needs, however they do not affect the final system needs but elaborates the short-term flexibility needs.

In line with the FNA methodological guidelines, the maximum value identified from the transmission network and distribution network flexibility assessment is used to determine network needs. The assessment of distribution generation influence to transmission networks needs provides additional details to the distribution network needs evaluation, but it does not affect the result.

Specific needs are determined by summing all identified needs that fall under this category. These include the requirements for isolated operation reserve services, fast active power response services, FCR needs, and the service requirements related to increasing the cross-border capacity of the Lithuania–Poland interconnection.

The principle for summing flexibility resource needs is presented in the figure below.

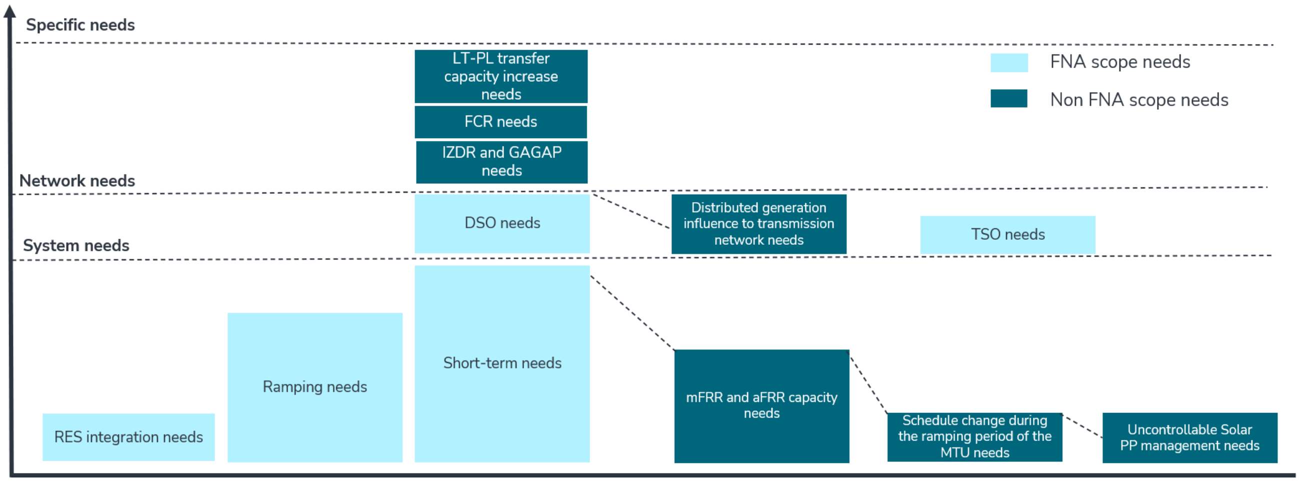

Figure 4 Principle of assessing flexibility needs

When assessing the input data within the Slower Transformation Scenario, an additional upward flexibility need was identified. The additional flexibility need remains at approximately 1 GW in all analyzed years. These additional flexibility needs can be covered by technological solutions with limited energy capacity.

No additional downward flexibility needs were identified in any of the analyzed scenarios. The resources foreseen in the LTrSc scenario are sufficient to cover all downward flexibility requirements.

table 1 Additional flexibility needs in the LTrSc realistic regime

Type	Year	2028		2030		2033		2035	
		Power, MW	Capacity, MWh	Power, MW	Capacity, MWh	Power, MW	Capacity, MWh	Power, MW	Capacity, MWh
System needs	Short-term	429	982	484	1789	415	1414	536	848
Network needs	DSO needs	30	-	42	-	77	-	108	-
Specific needs	FCR	14	28	18	36	23	46	25	50
	IZDR	200	200	200	200	0	0	0	0
	GAGAP	154	154	154	154	354	354	354	354
	LT-PL	146	146	146	146	0	0	0	0
	Total	**973**	**1519**	**1044**	**2325**	**869**	**1814**	**1023**	**1252**

The total amount of flexible resources required to cover flexibility needs, including additional flexibility needs, is shown in the graph below. The analysis identifies an increase in flexible resource volumes from 4.36 GW to 7.13 GW in 2035.

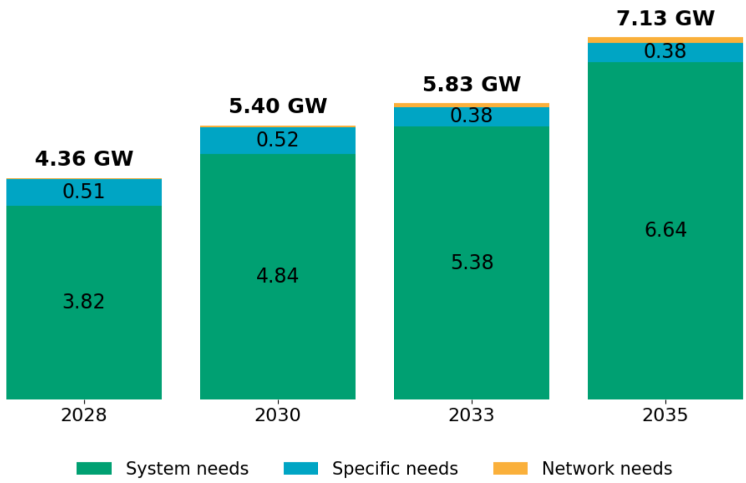

Figure 5 Flexibility resource needs

1.5. Development of flexible resources

Flexible resources such as demand-side response, RES (for downward flexibility), BESS, P2X technologies and cross-border exchanges can be used to cover flexibility needs. In Lithuania, BESS projects are currently developing the fastest, and their installation volumes allow identifying the potential of flexible resources to meet system flexibility requirements. According to the available data, it is identified by the end of 2028. 3.12 GW of storage systems will be installed in the Lithuanian electricity system. When assessing the additional forecasted by LTrSc and identified in the analysis flexibility needs, the expected demand for BESS is 2.23 GW. Considering the expected connection indication of the developers, all flexibility needs will be covered by newly installed battery energy storage systems, although they may also be met by other technological solutions

In the period between 2030 and 2035, after assessing the planned deployment volumes of the battery energy storage system according to the protocols of intent, it is predicted that all flexibility needs will be covered.

The summary is presented in the graph below.

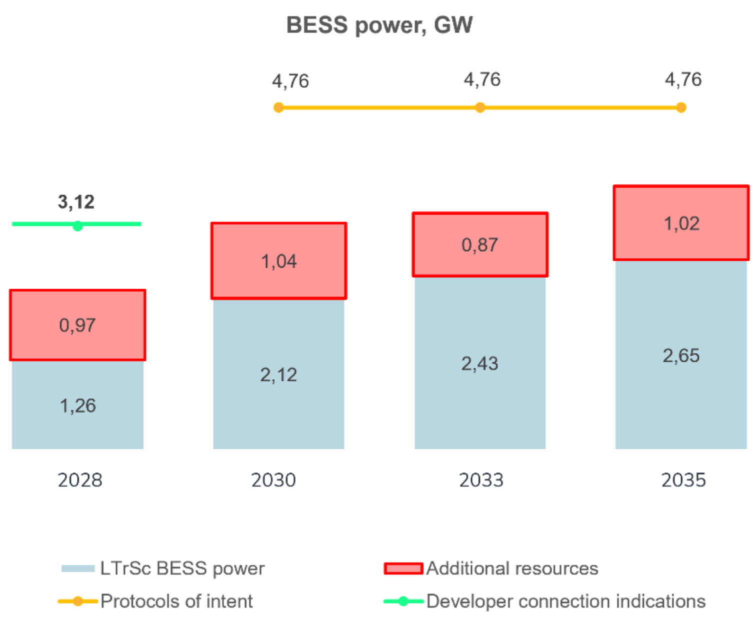

Figure 6 Forecasted capacity of BESS and flexibility needs determined in the flexibility assessment

2. Summary

The interpretation of the results presents the operators' assessment based on the identified flexibility needs. The interpretation is provided only for the Slower Transformation Scenario under the Realistic regime. It is assumed that the LTrSc input data used in the calculations best reflect the development of the Lithuanian energy system, therefore, the conclusions should be based on the results of this scenario. The decision was made based on the fact that the Slower Transformation Scenario reflects market participant survey results and development trends, which represented the most accurate information available at the time of the report's preparation. Furthermore, its realistic assumptions enable the assessment of existing electricity market mechanisms and the expected applicability of flexibility measures for ensuring power system flexibility.

Slower Transformation Scenario – Realistic Regime

RES integration assessment

Downward needs

The results show that additional RES curtailment does not exceed the 5% limit in any of the analyzed years. This indicates that even with rapidly increasing RES capacities, most of the renewable generation is successfully integrated into the power system. However, it also highlights a growing need for additional flexibility resources to avoid curtailment in the future.

In all analyzed years, the highest curtailment volumes occur between 09:00 and 15:00, with the peak around midday. This distribution reflects the generation profile of solar and indicates that excess-generation challenges are primarily associated with daytime hours when solar generation is at its highest. During evening and night hours, curtailment levels decrease significantly, meaning that the main flexibility need is concentrated during the daytime.

RES curtailment mainly arises under excess-generation conditions when high RES generation coincides with limited system capability to absorb additional energy.

Considering that curtailment levels under the Realistic regime do not exceed 5%, no additional flexibility needs are required from this perspective.

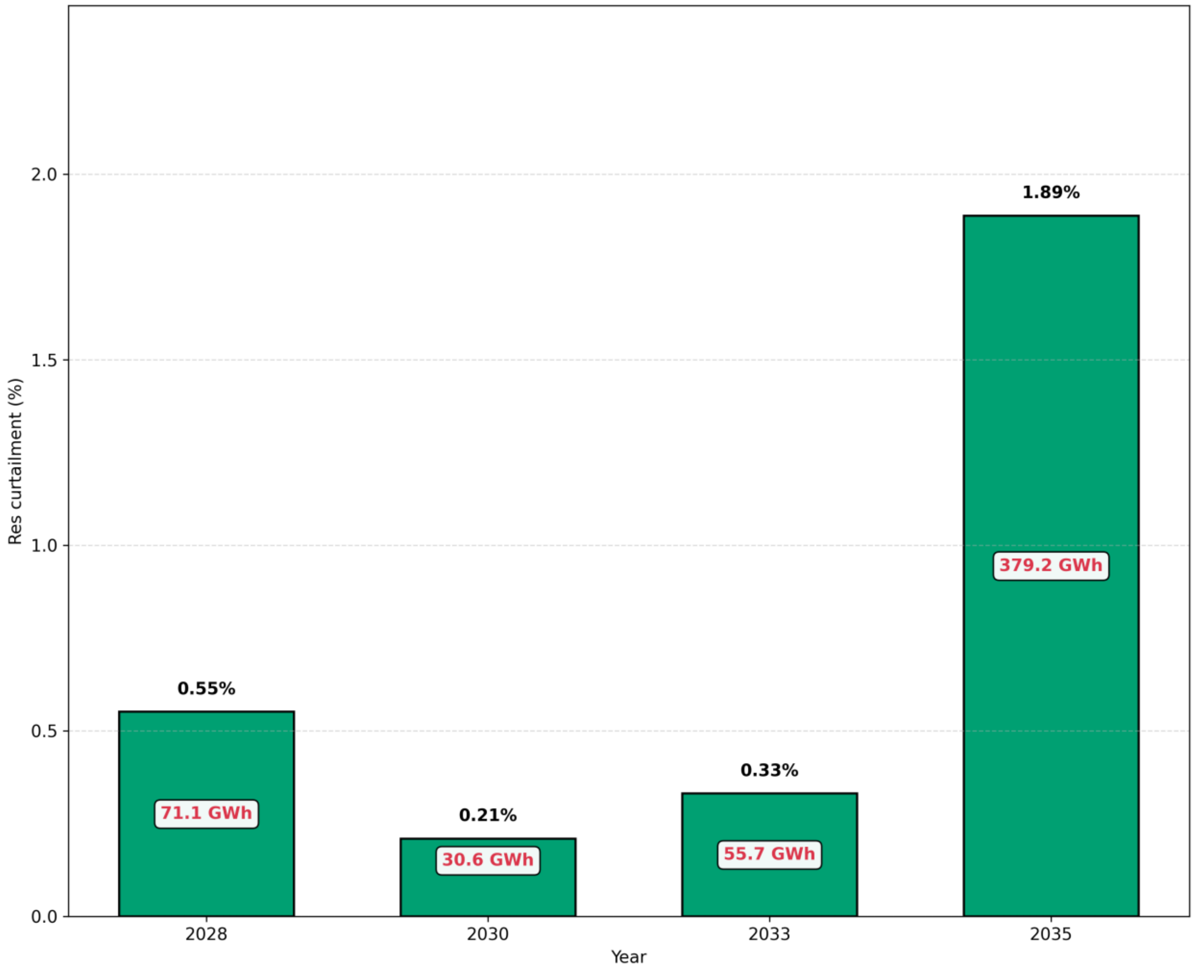

Figure 7 RES integration

Upward needs

Upward flexibility needs resulting from excess RES generation have no physical meaning and therefore are not assessed.

Ramping needs assessment

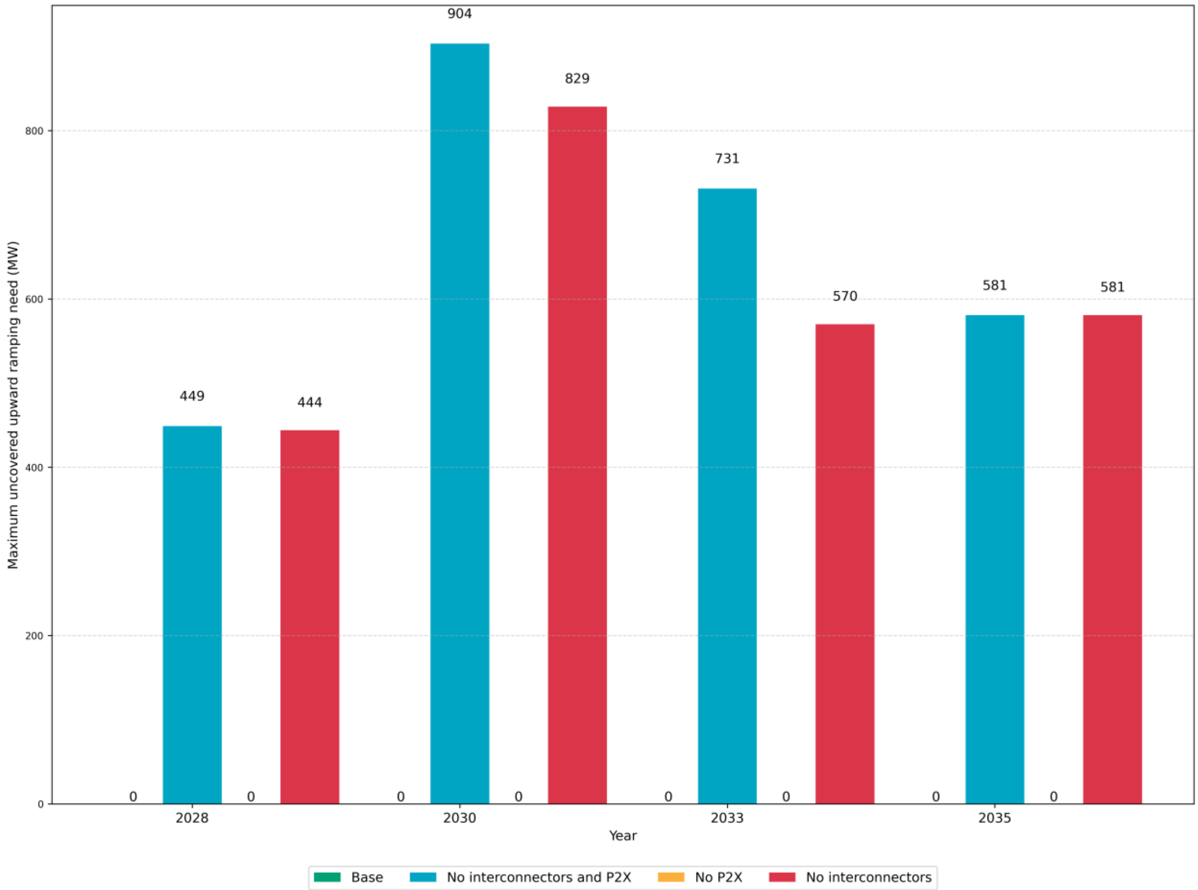

Figure 8 Ramping needs assessment

Downward needs

This indicator describes the system's ability to reduce generation or increase consumption during periods when residual load becomes negative and excess generation forms in the system. The results show that in all analyzed scenarios and time periods, no uncovered downward ramping need was identified — the maximum values in all cases remain equal to 0 MW.

From this perspective, no additional flexibility need is identified.

Upward needs

This indicator shows the magnitude of the maximum power deficit that occurs when the system's available upward flexibility capacity is insufficient to cover a sudden increase in residual load. The Realistic regime in this context is defined as the calculation performed without P2X technologies. No uncovered upward ramping needs were identified. The results identify that the main factor determining the emergence of ramping needs is the unavailability of cross-border connections.

The Realistic regime assessment did not identify any additional flexibility needs.

Short-term flexibility

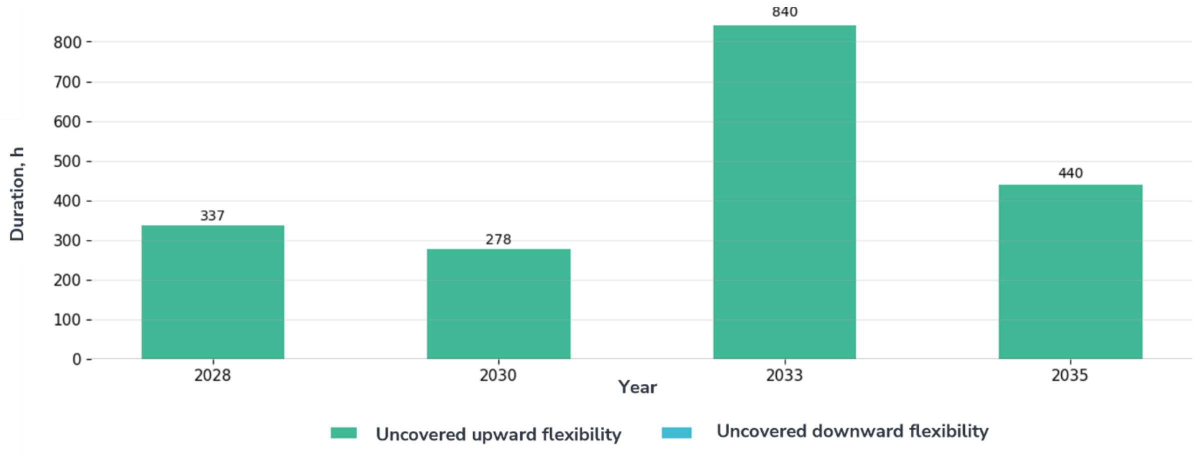

Figure 9 Number of hours with uncovered flexibility needs

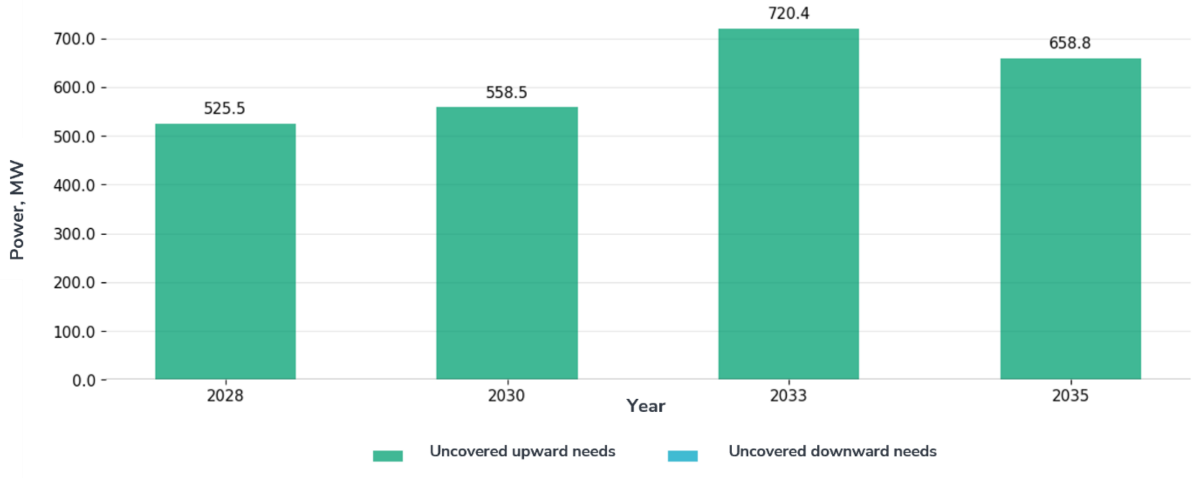

Figure 10 Maximum amount of uncovered flexibility

Downward needs

In the Realistic regime, no additional flexibility resources are required. The flexibility resources defined in the scenario are sufficient to ensure system flexibility in all cases. The analysis shows that downward flexibility needs can be successfully met using RES units, where reducing their generation volumes provides the necessary flexibility.

Upward needs

The analysis identified an additional flexibility need under the Realistic regime. Considering the limited cross-border capacity and the restricted utilization of P2X technologies, the volume of flexible resources is not sufficient to cover the flexibility needs. According to the TSO's assessment, the amount of flexible resources required to meet the additional flexibility needs is classified into two categories:

- The resource volume covers energy resources capable of covering demand for less than 4 hours, such as battery energy storage systems (Short-term resource).
- The resource volume with energy capable of covering demand for more than 4 hours, such as existing gas generation (Long-term resource).

table 2 Additional flexibility needs for short-term flexibility

Year	2028	2030	2033	2035
Additional short-term resource, MW	429,00	484,00	415,00	536,00

Capacity of additional short-term resource, MWh	982,00	1789,00	1414,00	848,00
Long-term resource, MW	256,00	124,00	22,00	241,00

The analysis shows that ensuring system flexibility requires both short-term and long-term resources. Short-term resources can be provided by any type of technical solution capable of supplying energy resources for a limited period. If deviations prolonged for a longer period, short-term resources can no longer ensure the flexibility of the system, therefore long-term resources are necessary to replace them. According to TSO assessments, the entire identified amount of long-term resources can be covered by existing power plants that are already connected to the transmission network.

Use of balancing reserves to cover short-term flexibility needs

Article 16(8) of the FNA methodology identifies the requirement to assess the possibility of meeting additional flexibility needs using FRR capacity, as defined in accordance with Article 157 of the SO GL.

The volume of FRR capacity required to cover a single contingency event in the system is already included in the assessment scope. Therefore, any additional flexibility need identified must be covered by resources that are not part of the FRR capacity volume.

Distribution network flexibility needs

Downward needs

Downward flexibility needs are driven by newly connected solar power plants with an installed and allowed generation capacity of up to 100 kW.

The data shows an increase in downward flexibility needs from 167 MW in 2028 to 181 MW in 2030. In subsequent years (2033–2035), there is no significant annual growth in flexibility needs. This is influenced by growing consumption on the grid, a declining number of newly connected power plants, and an increasing number of newly connected power plants with an allowed generation capacity of 1 kW.

Upward needs

Upward flexibility needs are driven by growth in consumption among residential and commercial customers. Based on the modeling results, a significant increase in grid loads is projected due to the electrification of residential customers. Home EV charging and the expansion of heat pumps drive upward flexibility needs in the distribution network, which will reach 30 MW in 2028 and increase to 108 MW by 2035.

table 3 Assessment of DSO flexibility needs

Year	2028	2030	2033	2035
DSO downward flexibility needs (MW)	167	181	182	181
DSO upward flexibility needs (MW)	30	42	77	108

Curtailment of RES connected to the DSO was not assessed.

Transmission system flexibility needs

Considering Article 12 of the FNA methodology provisions the flexibility needs of the transmission network were not assessed.

Additional needs

FCR capacity volume needs

A steady increase in FCR requirements is observed in the Lithuanian power system, driven by growing demand and generation, together with the rising share of RES integration. In 2028, the FCR requirement reaches 14 MW, in 2030, it increases to 18 MW, in 2033, it rises further to 23 MW and in the final assessed year, the FCR requirement is estimated at 25 MW.

mFRR and aFRR capacity volume needs

mFRR and aFRR downward needs

From the mFRR perspective, a continuous increase in maximum downward needs is observed. In 2028, the need is identified as 632 MW, in 2030, it rises to 666 MW, in 2033, it reaches 710 MW and by 2035, it increases further to 773 MW.

Downward aFRR needs remained stable throughout the analyzed period at 68 MW.

mFRR upward needs

Unlike the downward trend of mFRR, the upward trend of needs are not increasing. Demand remains the same throughout the analyzed period, with a value of 633 MW in 2028-2035.

aFRR upward needs remained stable at 67 MW throughout the analyzed period.

Fast frequency response reserves

Synchronous operation of Lithuanian power system is established with only via LitPol Link connection, thus fast frequency response reserves needs are necessary for the safe operation of the Lithuanian electricity system. The established volumes of isolated operating reserve services and fast frequency response reserves volumes are necessary to ensure reliable and operationally managed isolated operating mode. The services are necessary to strengthen the technical resilience of the system, ensure national energy security and reliability of supply to end users.

table 4 Fast frequency response reserves

Year	2028	2030	2033	2035
Isolated operation reserve service volume	200	200	0	0
Fast frequency response reserves volume	154	154	354	354
Total	354	354	354	354

The implementation of the Harmony Link 220 kV interconnection project between Lithuania and Poland requires a solution to the rapid response service needs.

LT-PL transfer capacity increase service needs

Until the new 220 kV double-circuit line between Lithuania and Poland — Harmony Link – is commissioned, the potential of cross-border capacity is 500 MW. To utilize the full potential of this interconnection, a Lithuania–Poland capacity-increase service is required.

The service enables the full use of the Lithuania–Poland cross-border capacity up to the stability limit. The assessment determined that the need for this service is up to 146 MW. Volumes may vary depending on the ordered of Fast frequency response reserves volume.

The decision on implementation must be made considering the experience gained from the application of the Fast frequency response services.

Schedule change during the ramping period of the market time unit needs

During the assessment, imbalance volumes were identified resulting from the change in active power settings of devices of different technologies corresponding to the market plan. Sensitivity is checked by changing the ramping period for RES, BESS and P2X technologies at 10min, 5min, 1min and instant change intervals. Conventional generation technologies are ramping in line with their technical capabilities.

Key indicators assessed:

- Probability of imbalance
- Instantaneous imbalance size
- Energy imbalance size
- Impact on aFRR capacity

A summary of the results is provided below:

table 5 Schedule change during the ramping period of the market time unit needs

2028				
Ramping period	**10 min**	**5 min**	**1 min**	**0 s**
Probability of imbalance, %	0,58	1,75	4,05	4,53
Instantaneous demand downwards, MW	-519	-570	-652	-683
Instantaneous demand upwards, MW	528	570	704	728
Imbalance deviation upwards, MWh	-28	-32	-42	-44
Imbalance deviation downwards, MWh	25	30	39	41
aFRR additional need upward	0	-15	-30	-34
aFRR additional need downwards	0	15	31	35
2030				
Ramping period	**10 min**	**5 min**	**1 min**	**0 s**
Probability of imbalance, %	0,27	2,13	6,70	7,72
Instantaneous demand downwards, MW	-557	-625	-937	-1003
Instantaneous demand upwards, MW	558	623	931	972
Imbalance deviation upwards, MWh	-28	-37	-53	-56
Imbalance deviation downwards, MWh	26	35	49	52
aFRR additional need upward	0	-34	-70	-77
aFRR additional need downwards	0	34	70	77
2033				
Ramping period	**10 min**	**5 min**	**1 min**	**0 s**
Probability of imbalance, %	0,09	0,52	4,36	5,27
Instantaneous demand downwards, MW	-399	-581	-932	-1005

Instantaneous demand upwards, MW	392	576	914	990
Imbalance deviation upwards, MWh	-14	-31	-51	-55
Imbalance deviation downwards, MWh	15	29	46	51
aFRR additional need upward	0	-45	-93	-102
aFRR additional need downwards	0	46	95	104
2035				
Ramping period	**10 min**	**5 min**	**1 min**	**0 s**
Probability of imbalance, %	0,39	1,20	5,31	6,15
Instantaneous demand downwards, MW	-472	-645	-978	-1058
Instantaneous demand upwards, MW	419	609	957	1036
Imbalance deviation upwards, MWh	-20	-37	-59	-56
Imbalance deviation downwards, MWh	15	32	54	58
aFRR additional need upward	0	-49	-102	-113
aFRR additional need downwards	0	48	100	110

Uncontrollable Solar power plants generation needs

The indicator identifies the system flexibility needs required to cover the electricity generated by uncontrolled solar power plants.

The analysis identifies that, if only considering demand possibilities, all generated solar energy from uncontrollable power plants will not be consumed and the flexibility resources will be needed to manage generation.

A summary of the results is provided in the table below.

table 6 Uncontrollable Solar PP needs

	2028	2030	2033	2035
Uncontrolled SE surplus per year, %	9,42	8,75	6,10	7,03
Avg. hours, h	5,73	5,50	3,60	4,18
Flexible resource need, MW	1345	1518	1662	2089
Flexible resource capacity, MWh	8071	9109	6647	10443
Excess energy, GWh	390	406	272	405

The assessment results indicate a market potential to utilize excess generation from uncontrolled solar power plants through flexibility resources. When surplus energy cannot be absorbed in the local market, it is either exported or stored. In cases where the available flexibility resources to manage excess electricity are insufficient, the TSO, together with the distribution network operator, is developing a technical solution that would allow the disconnection of uncontrolled solar generation power plants and reduce and manage the surplus of electricity generated in the Lithuanian power system.

Distributed generation influence to transmission network

Due to the increasing integration of renewable energy sources (RES) in the distribution network, reverse power flows are forming in the transmission network. These flows may cause overloads in capacity zones. Based on this information, an assessment is carried out to verify whether the technical capacity of the zone will be exceeded. In the event of a capacity overrun, the excess energy is calculated, which constitutes the scope of the flexibility requirement. The assessment results are presented in the table below.

table 7 Distributed generation influence to transmission network

Year	2028		2030		2033		2035	
	Power, MW	Capacity, MWh	Power, MW	Capacity, MWh	Power, MW	Capacity, MWh	Power, MW	Capacity, MWh
Distributed generation flexibility	104	327	166	574	167	575	166	561

Summary of additional needs in Slower transformation scenario realistic regime

Interpretation of summary volumes

Flexibility needs are divided into three components:

- System needs
- Network needs
- Specific needs

System needs are determined using additional flexibility values obtained from assessing RES integration, ramping and short-term flexibility needs. The highest identified value is considered as the system need. system needs also include mFRR and aFRR capacity, Schedule change during the ramping period of the market time unit and uncontrollable Solar PP needs, which do not affect the final system needs, but detail short-term flexibility needs.

Network needs are determined using the maximum value identified from transmission and distribution network flexibility assessments. The Distributed generation influence to transmission network assessment provides additional detail for the distribution network evaluation but does not affect the final network need value.

Specific needs are calculated by summing all identified needs that fall under this category. They include isolated operation reserve service needs, Fast frequency response reserve's needs, FCR needs, and Lithuania–Poland cross-border capacity-increase service needs.

The principle for summing additional flexibility needs is presented in the table below.

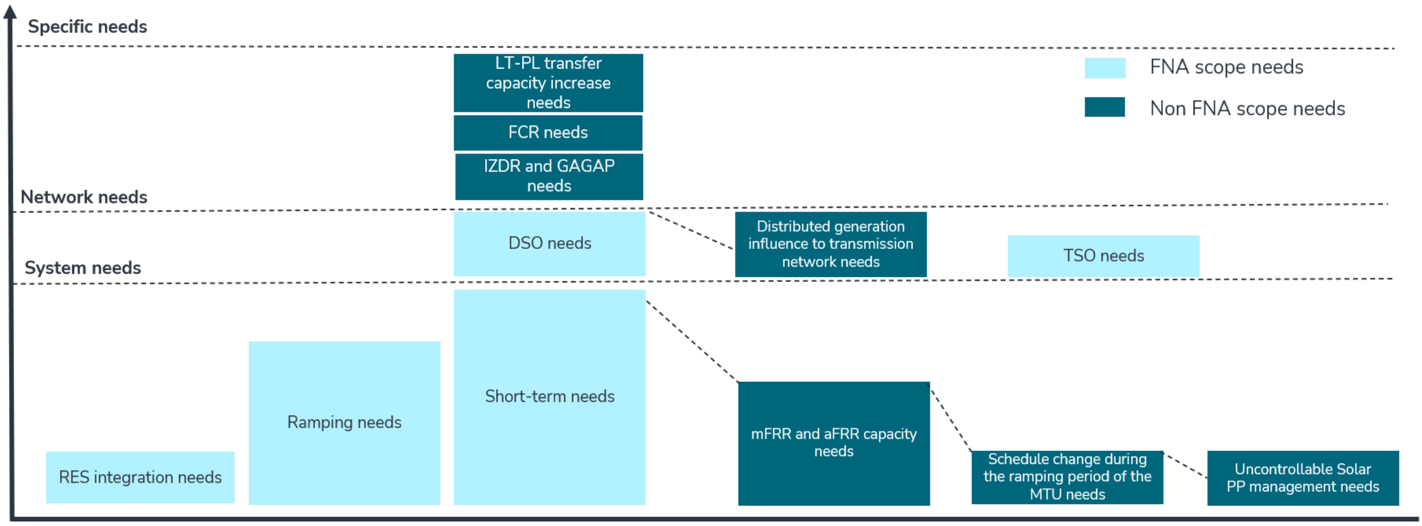

Figure 11 Principle of assessing flexibility needs

When assessing the input data within the Slower Transformation Scenario, an additional flexibility need was identified, which can be covered by technological solutions with limited energy resources.

table 8 Upward flexibility needs assessment summary

Type	Year	2028		2030		2033		2035	
		Power, MW	Capacity, MWh	Power, MW	Capacity, MWh	Power, MW	Capacity, MWh	Power, MW	Capacity, MWh
System needs	Short-term	429	982	484	1789	415	1414	536	848
Network needs	DSO needs	30	-	42	-	77	-	108	-
Specific Needs	FCR	14	28	18	36	23	46	25	50
	IZDR	200	200	200	200	0	0	0	0
	GAGAP	154	154	154	154	354	354	354	354
	LT-PL	146	146	146	146	0	0	0	0
	Total	**973**	**1519**	**1044**	**2325**	**869**	**1814**	**1023**	**1252**

All downward flexibility needs are covered without additional flexibility needs.

2.1. Key indicators according to the FNA methodology

The main results defined in the FNA methodology are presented in Appendix 1.

2.2. Flexibilities barriers, regulatory recommendations and actions

The barrier and digitalization assessment shows that Lithuania's legal and regulatory framework generally enables market participants to operate in flexibility markets, although several important gaps remain. First, certain definitions in the Electricity Sector Law — particularly those related to flexibility services, aggregation, and active consumer rights — create a lack of legal clarity that may, in practice, limit the opportunities for new and smaller market participants.

The wide deployment of smart meters enables participation in flexibility markets and allows customers to choose among various dynamic and time-varying tariff plans currently offered by both electricity suppliers and network operators. However, the application of dynamic network tariffs remains limited. The TSO has already initiated preparatory work to enable dynamic tariff selection from 2027, while the DSO is currently conducting analysis for the development of such a tariff plan.

In the area of balancing services, the identified barriers (minimum 1 MW bid size, FCR symmetry requirement) are aligned with European standards, and there are currently no plans to revise these requirements.

In the area of congestion management, market-based service procurement mechanisms are currently not applied at either the TSO or DSO level, but both operators have effective alternative means for congestion management. To further empower market participants, it is worth considering additional incentives for network operators to purchase these services. Currently, both network operators have relatively little incentive to consider flexibility services as an alternative to network reconstructions. Under Lithuanian regulation, the DSO may procure flexibility resources for this purpose, but the associated costs can only be recovered through OPEX. Meanwhile, the TSO lacks a clearly defined mechanism for evaluating congestion-management resources as an alternative to network expansion.

Also, to promote the development of flexibility services markets, it would be useful to review the operating conditions of the pilot energy innovation environment, in particular by expanding the possibility of applying exceptions not only for by-laws, but also for legal acts at the level of laws, thus creating broader opportunities for pilot projects.

3. Introduction

3.1. Purpose and scope of the flexibility report

The objective of the Flexibility Needs Analysis is to determine how much and what type of flexibility is required for the Lithuanian power system to adapt to generation and demand variability arising from the generation of renewable energy sources.

According to Article 4 of the FNA methodology, within four months of ACER's approval of the methodology, each Member State's transmission system operator (TSO) and distribution system operator (DSO), together with the national regulatory authority, must agree on the scope of the flexibility needs assessment. The scope was agreed between ESO AB, LITGRID AB, and the National Energy Regulatory Council on 19 December 2025. The agreed assessment scope is presented below.

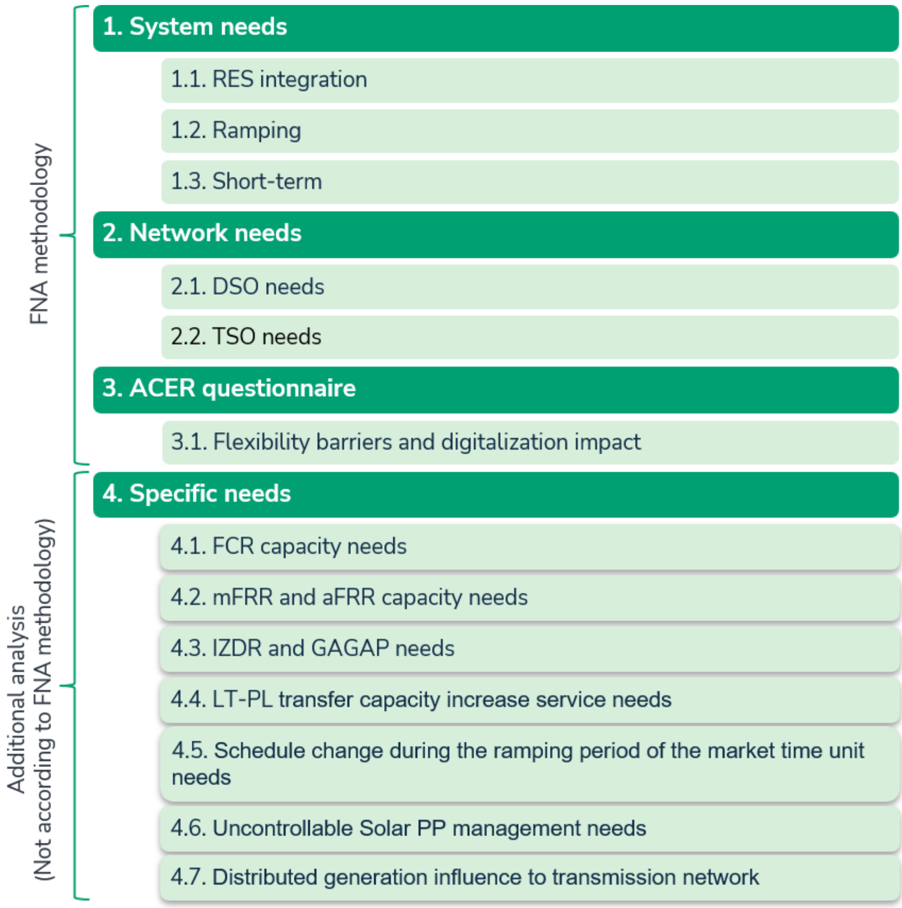

Figure 12 Scope of the assessment of flexibility needs

3.2. Legal and regulatory context

The analysis is based on the legal framework of the European Union and the Republic of Lithuania, which consists of:

- Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity, Article 19e (hereinafter - EMD)
- EEĮ
- FNA methodology

3.3. Institutions participating in the FNA report

The roles of the responsible institutions in preparing the report are clearly defined in the EEĮ. Lithuania has one electricity transmission system operator, one distribution system operator, and three small distribution network operators. In line with part 2(a) of Section 3 of the FNA methodology, the flexibility assessment must be based on the Distribution Network Development Plan (DNDP), which in Lithuania only ESO is obliged to prepare. Therefore, only ESO DNDP is considered in the assessment of the flexibility of the distribution network.

table 9 Institutions preparing the report on flexibility needs

No.	Article	Responsibilities	Institution
1	Article 9(3) point 51(2) of the EEĮ	• Approve the report on the expected flexibility needs at national level. • Publish a report on expected national level flexibility needs.	VERT
2	Article 31(1) point 36 of the EEĮ Article 3(1) of the FNA Methodology	• Perform an analysis of the system and transmission network flexibility needs • Prepare a flexibility needs report. • Provide flexibility needs report and data to VERT. • Consult with the DTO.	Litgrid
3	Article 39(1) point 13 of the EEĮ Article 3(1) and Article 3(2) of the FNA Methodology	• Perform analysis of the distribution network flexibility needs. • Prepare and submit flexibility needs report and data to the TSO. • Consult with the TSO.	ESO

All responsible parties are involved in preparing the Flexibility Needs Report. Coordination between the operators takes place in bi-weekly meetings. Coordination between VERT and the operators is carried out through dedicated coordination meetings and during the presentation of interim results. Meanwhile, coordination between the transmission system operator and ENTSO-E was conducted through regular weekly meetings. The main actions and timelines are presented in the table below.

table 10 Key steps and deadlines for assessing flexibility needs

No.	Act	Deadline/Regularity	Responsible
1	Coordination meetings between TSO and ENTSO-E	Held regularly, once a week	ENTSO-E
2	Coordination meetings between DSO and DSO Entity	Held regularly, once a month	DSO Entity

3	Coordination meetings between DSO and TSO	Held regularly, once every two weeks	LITGRID
4	Coordination with the VERT according to Article 4.1 of the FNA methodology	Agreed on 2025-12-19	LITGRID
5	Presentation of interim results to the VERT	2026-02-25	LITGRID
6	Presentation of interim results to the VERT	2026-04-28	LITGRID/ESO
7	Submission of the report to the VERT	2026-06-30	LITGRID/ESO
8	Presentation of final results to VERT	2026-07-10	LITGRID
9	Reporting to ACER	2026-07-25	VERT

4. Description of the assumptions for assessing flexibility

This section describes the key assumptions for the flexibility assessment:

- Scenarios used to assess flexibility needs
- RES integration target
- Other assumptions

4.1. Scenarios used to assess flexibility needs

4.1.1. Scenarios used to determine system needs

Taking into account Section 7, Clause 1 of the FNA methodology, the assessment is carried out using the data of the 2025 European Resource Adequacy Assessment (ERAA) which is based on valid state strategic planning documents, information obtained during the annual survey of electricity producers about the perspective plans of power plants, data on the connection projects of generating capacities implemented by the Company, and signed protocols of intent with the developers of generating capacities. An additional scenario is included, built using the ERAA 2025 model but with input data updated according to the Slower Transformation Scenario (LTrSc). The Slower Transformation Scenario was developed during the preparation of Lithuania's 400–110 kV transmission network Ten-Year Development Plan (TYNDP).

Both the ERAA scenario and the LTrSc scenario are assessed under two regimes:

- Basic regime — assuming that all flexibility resources are available and can be used to ensure system flexibility.
- Realistic regime — in line with the provisions of Section 13 of the FNA methodology, assuming that part of the flexibility resources are not available. In the realistic mode, only part of the cross-border capacity can be used for flexibility, and the utilization of P2X technologies is restricted in the calculations.

A graphical overview of the flexibility-needs assessment scenarios is provided in Figure 14. The data used for ERAA and LTrSc are presented in Section 5 of this document.

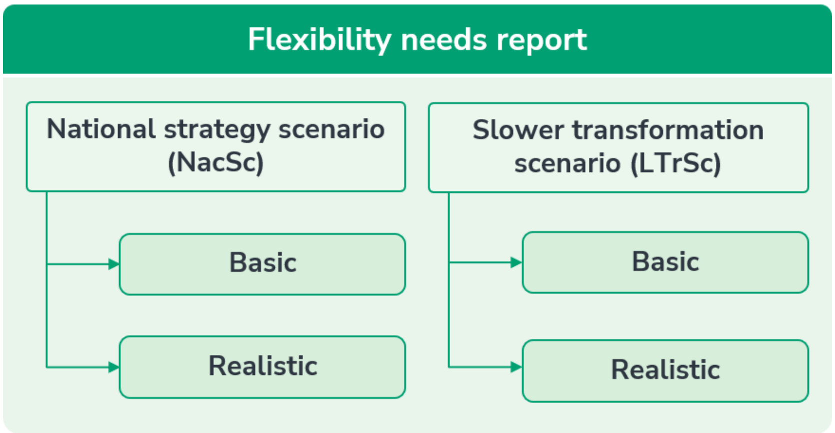

Figure 13 Scenarios used in the assessment of flexibility needs

4.1.2. Scenarios used to determine network needs

4.1.2.1. Transmission network scenarios

In accordance with the provisions of Article 12 of the FNA methodology, the transmission system operator has decided not to assess transmission-system flexibility needs.

4.2. RES generation curtailment target value (%)

Since Lithuania's National Energy and Climate Plan (NECP) does not specify a concrete target value for permissible RES curtailment, this study applies an indicative RES-curtailment target level of 5%. This target value was established by the transmission system operator and agreed with the National Energy Regulatory Council (VERT) to ensure a consistent and transparent basis for assessing RES integration. This indicator was selected regarding international practice and with the aim of ensuring an economically justified balance between RES integration, power-system flexibility, and the required investments in the grid and flexibility resources. Eliminating RES curtailment entirely would require disproportionately large investments; therefore, the 5% curtailment level is used in this study as a practical RES-integration benchmark. It enables an assessment of whether planned system-development resources and flexibility resources are sufficient to ensure a high level of RES integration while maintaining economically efficient power-system development.

4.3. Profile of flexible resources

The scope of flexible resources that participate in the determination of flexibility needs is presented in Chapter 5 of this report.

4.4. Other assumptions

4.4.1. Economic assumptions

The flexibility-needs assessment uses the generator portfolio from the ERAA model. The generation capacities included in the model are based on the Economic Viability Assessment, which determines whether specific generation units remain economically viable to operate in the target years, considering projected market conditions, revenues, and operational costs.

Following this principle, the set of power plants and other generation resources used in this report is not formed using additional national assumptions. Instead, it relies on the Europe-wide Economic Viability Assessment, which is an integral part of ERAA scenario development. This approach ensures that the flexibility-needs analysis is carried out using an economically justified generator portfolio aligned with the planning assumptions of the European power system.

4.4.1.1. Distribution network scenarios

The publicly available document is the ESO Investment Plan for 2024–2033. The DSO flexibility-needs assessment was carried out without using the dataset from this specific plan. This decision was made due to insufficient data relevance. The published 2024–2033 plan does not contain basic-scenario data for the target year 2035, which are required under the FNA methodology. For modelling purposes, the basic-scenario data from the forthcoming ESO Ten-Year Investment Plan for 2026–2035 were used instead. This ensures that the calculations comply with the objectives of the National Energy and Climate Plan (NECP) and with the requirements of Article 6 of the FNA methodology regarding target-year coverage.

The 2024-2033 investment plan foresees the need to flexibly manage network load and generation to postpone physical network reconstructions and use existing capacities more efficiently.

4.4.2. Assumptions for storage tank charge level control

When assessing the contribution of BESS and KHAE to covering short-term flexibility needs in the FNA, it is assumed that storage units operate according to the generation and charging schedules provided in the ERAA or LTrSc scenarios, and their operating mode is not adjusted during the calculation of ensuring short-term flexibility needs. Only the additional flexibility available from the current operating point is calculated, taking into account maximum discharge power, maximum charging power, energy capacity, and the remaining energy stored in the unit. The charging efficiency of BESS is assumed to be 0.92, and for PHES – 0.75, while discharge losses are not assessed separately. The stored energy at each time step is constrained by the physical limits of the calculated energy capacity; therefore, the available power is additionally limited by the amount of stored energy or free capacity.

For the assessment of the impact of additional flexibility resources on reducing RES curtailment, a technologically neutral flexibility-resource model was applied. The model is defined by power, energy capacity, the energy-to-power ratio, and efficiency. The following parameters were used in the assessment:

Evaluated flexibility resource capacities:

- ***From 500 MW to 6000 MW.***

Estimated energy storage durations:

- ***2 hours,***
- ***4 hours,***
- ***8 hours,***
- ***20 hours,***
- ***50 hours,***
- ***100 hours,***
- ***200 hours,***

The corresponding energy capacity, depending on the selected combination of power and duration, ranges from **1 GWh to 1200 GWh.**

Roundtrip efficiency:

- 92% – 2 hours,
- 90% – 4 hours,
- 88% – 8 hours,
- 85% – 20 hours,
- 75% – 100 hours,
- 70% – 200 hours,

4.4.3. Use of FRR capacity for flexibility

It is assumed that the instantaneous active-power change caused by a unit incident is already accounted for in the FRR-capacity determination process as the reference incident. According to the FRR-capacity determination logic, both upward and downward FRR volumes must be no smaller than the corresponding incident that may occur due to the disconnection of a single electricity-generation module, consumption unit, HVDC link, or AC line within the LFC block Therefore, in the FNA calculation this need is not assessed as an additional short-term flexibility requirement, in order to avoid double-counting the same need. KHAE resources may be used both to ensure FRR volumes and to provide system flexibility; however, the requirement to compensate the unit incident is considered already included in the FRR-capacity determination logic.

5. Method

In the flexibility-needs assessment, a post-processing method was applied, meaning that the analysis was carried out using already-calculated ERAA model results. This method does not modify the primary optimization outputs of the ERAA model; instead, additional flexibility indicators are computed based on the model's derived data. During the analysis, generator production schedules, RES generation, demand, cross-border electricity flows, the operation of energy storage systems, and other model outputs were evaluated. From these results, the flexibility needs and flexibility indicators defined in the FNA methodology were calculated.

5.1. Data sources

5.1.1. Data used to determine system requirements

The flexibility-needs assessment is carried out using the data defined in Section 6 of the FNA methodology, i.e. the ENTSO-E European Resource Adequacy Assessment (ERAA) dataset, which includes:

a) Hourly generation by different technologies
b) Hourly cross-border flows
c) Hourly electricity demand
d) Power changes within the MTU, considering ramping constraints
e) Cross-border transmission capacities for different periods
f) Installed battery-storage power and energy capacity by year
g) Electrolysers capacity by year

Using ERAA data ensures alignment with European adequacy standards and guarantees that the report provides clear and practical insights for determining flexibility needs.

To evaluate a more likely development pathway, an additional flexibility-needs assessment was performed using the Slower Transformation Scenario (LTrSc), which is based on the ERAA model.

The LTrSc scenario was developed considering the 2025 market-development outlook, the latest market-participant surveys, historical trends, and newly assessed assumptions regarding the development pace of various energy-system projects. This scenario is more conservative with respect to the energy transition and reflects more advanced projects currently being developed in the market.

The table below presents the ERAA 2025 and LTrSc input data and the differences in key indicators.

table 11 Input data for ERAA and LTrSc scenarios.

	2028		2030		2033		2035	
	ERAA 2025	LTrSc 2025	ERAA 2025	LTrSc 2025	ERAA 2025	LTrSc 2025	ERAA 2025	LTrSc 2025

LT->PL, MW	150	500	700	1200	700	1200	700	1200
PL->LT, MW	150	353	700	1200	700	1200	700	1200
LT-SE4, MW	700	700	700	700	700	700	700	700
LT->LV, MW	1134	1250	1134	1250	1134	1250	2200	2250
LV->LT, MW	750	1300	750	1300	750	1300	1750	2300
BESS power, MW	1060	1260	1300	2115	1650	2428	1750	2652
BESS capacity, MWh	3427,7	2903	4205,7	5083,25	4885,7	5881,4	5175,7	6452,6
Demand, TWh	15,439	14,5	17,737	17,1	19,741	19,2	20,873	20,7
P2X power, MW	50	5	1300	75	1300	475	1300	675
Offshore wind farm power, MW	0	0	0	0	700	0	1400	700
Onshore wind farm power, MW	4015	3386	4215	3882	5100	4520	5520	4530
Solar power plant parks power, MW	2369	937	2500	1227	2940	1600	3300	1600
Small solar power plants power, MW	1550	2343	1600	2446	1660	2550	1700	2640

To assess short-term flexibility needs, this report also uses historical data from 2024-2025, which includes:

a) Hourly demand forecasting error;
b) Hourly solar generation forecasting error;
c) Hourly wind generation forecasting error.

5.1.2. Data used for network needs

The DSO flexibility-needs assessment under the National Strategy Scenario (NacSc) was carried out using the basic-scenario input data from ESO's Ten-Year Investment Plan for 2026–2035 (hereinafter – 10MIP). At the time of report preparation, this investment plan had not yet been formally approved. The decision was made not to use the data from ESO's 2024–2033 Ten-Year Investment Plan due to outdated information and the absence of basic-scenario data for the target year 2035.

The selected basic scenario is aligned with the objectives of the National Energy and Climate Action Plan (NECAP).

For the Slower Transformation Scenario (LTrSc), the TSO's ERAA 2025 data was used.

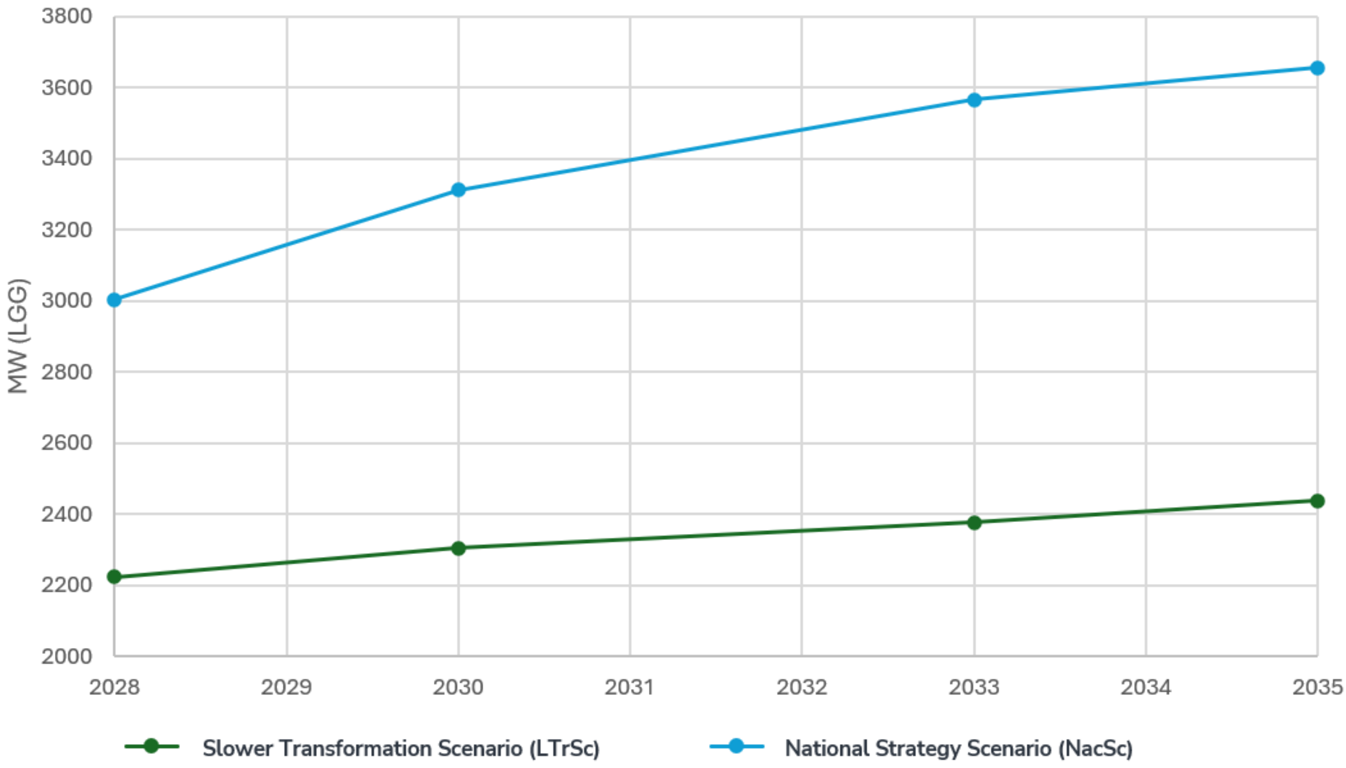

Figure 14 Solar power plant development scenarios for 2026–2035, permitted generation capacity (MW)

The following data, assumptions, and sources were used in addition to the core FNA methodology inputs:

- Adjusted NacSc input data for the Slower Transformation Scenario (LTrSc).
- Smart-meter consumption profiles: hourly actual active-power consumption data for 2025, covering residential and commercial customers.
- Customer classification: data on object types (apartments, houses) and their historical organic growth (sample of 1.39 million objects for 2023–2025).
- Customer survey: survey of 500 residential customers on installed equipment (heat pumps, EV charging) and installation dates.
- European Heat Pump Association (EPHA) data for Lithuania.
- Profiling of commercial facility loads based on 2025 facility electricity data (hourly electricity consumption data):
    - Offices and retail: this type is characterized by standard daytime operating hours, with a pronounced drop in consumption during weekends;
    - Continuous industry: facilities whose consumption remains stable around the clock;
    - Morning Shift / Manufacturing: peak consumption in the morning;
    - Evening Entertainment: activity increases in the evening;
    - Inactive facilities: consumption not recorded in 2025
- Historical weather data: 10-year continuous dataset (2015–2024) from four meteorological stations (Vilnius, Ukmerge, Varena, Kaunas).
- Climate parameters: hourly outdoor temperature used for baseline-load standardization and heat-pump demand modelling.
- Climate parameters: hourly outdoor temperature used for baseline-load standardization and heat-pump demand modelling.
- Data linking:
    - Historical database linking objects to specific 110 kV transformers and substations.
    - Data on the connection of ESO transformer substations to Litgrid zones.

- Geographical classification of objects:
    - *High-rise buildings*
    - *Low-Rise Buildings*
    - *Industry*
    - *Countryside*
    - *Vacation homes*
- Infrastructure technical limits:
    - Technical capacity of transformer substations in MW ensuring N-1 reliability;
    - Litgrid issued limits for solar generation (technical profile of SE production and safe generation limits).

5.1.3. Data used to determine specific needs

5.1.3.1. Distributed generation influence to transmission network needs

The analysis of distributed generation influence to transmission network was carried out using data from several sources:

- Distribution-network flows in bandwidths zones — provided by the distribution system operator.
- Historical RES generation data of transmission-grid users in bandwidths zones — obtained from the transmission system operator's data repository.
- Annual solar and wind generation data used to determine generation profiles — sourced from the transmission system operator's data repository.
- TSO AEIC data on planned connections in capacity zones — used together with solar and wind generation profiles to simulate future RES-plant generation.
- TSO AEIC data on bandwidths zone transmission limits.
- Safe-generation boundary values between transmission and distribution grids — determined based on the provisions of the transmission-distribution interface agreement between the transmission system operator and the distribution system operator.

5.1.3.2. FCR, mFRR and aFRR needs

For the calculation of aFRR and mFRR needs, historical imbalance data and the projected future changes in installed RES-generation capacities are required.

For determining FCR needs, two years of historical generation and demand data are used (excluding demand from storage units).

5.1.3.3. Fast frequency response reserves needs

To determine the need for fast-response services, historical data from the Lithuanian power system were used, including:

- The maximum demand in the Lithuanian power system.
- The generation profile of units operating in the Lithuanian electricity system.
- The amount of rotating mass present in the system, determined based on the generation profile data.

5.1.3.4. Schedule change during the ramping period of the market time unit needs

The same data as defined in section 5.1.1. are used.

5.1.3.5. Uncontrollable Solar PP management needs

To determine the management needs of uncontrolled solar generation, the following were used:

a) The same data as defined in section 5.1.1. is used;
b) ESO forecast of installed capacities of solar power plants of generating consumers.

5.2. Target year

In accordance with Articles 4 and 6 of the FNA methodology, the flexibility assessment must be carried out for at least two target years: one corresponding to EU policy target years defined in EMD 19e(4)(b)(iii), and another covering the common target years used in ERAA and in the distribution-network development plan. LITGRID and ESO agreed to perform modelling and analysis for all four ERAA-defined target years, namely 2028, 2030, 2033, and 2035.

5.3. Calculation principles

Based on the residual-load distribution analysis, the selected weather scenario WS01 is classified within the group of unfavorable climate years. Among the 36 historical weather years analyzed, this scenario ranks 10th in terms of the highest residual load, corresponding to the 26th percentile. This means that 74% of historical years exhibited lower residual load than the WS01 scenario. Due to its relatively high residual load, WS01 reflects more tense power-system adequacy conditions and enables an assessment of system performance under unfavorable meteorological circumstances.

Within the scope of this analysis, the WS01 scenario was chosen to ensure a sufficiently conservative system-reliability assessment. Since the scenario exhibits higher residual load than most historical years, its application allows evaluating system adequacy and the effectiveness of flexibility resources under conditions where balancing needs are greater and adequacy risks are higher. This approach provides a basis for verifying whether the planned flexibility resources are sufficient not only under average conditions but also under more challenging operational circumstances, thus ensuring a more reliable assessment of their contribution to system adequacy and security of supply.

The analysis was carried out using the results of the ERAA study. A separate mathematical model for flexibility assessment was not developed.

5.3.1. Use of cross-border lines

In accordance with the provisions of the EMD and the FNA methodology, cross-border flexibility exchanges are included in the scope of the analysis. The residual quantity after the electricity market is assessed to cover flexibility needs. The reduction of cross-border capacities considering electricity market liquidity problems in response to FNA methodology 9(3)(c) and 10(3)(c) is not covered by the scope of the analysis.

All assumptions related to cross-border capacity curtailments are defined in Section 5.3.5.

5.3.2. Evaluation principles of forecast deviations

In accordance with Article 10(1)(b) of the FNA methodology, the historical forecasting-error data are grouped as follows:

- Seasonality: 1) Cold season (winter): October–March; 2) Warm season (summer): April–September.
- Time-of-day distribution: 1) Daytime: 06:00 – 18:00; 2) Night-time: 18:00 – 06:00.

This grouping approach enables the assessment of different load and generation distributions throughout the day.

Historical forecasting-error data were also extrapolated to the target years, considering projected electricity-demand growth and changes in installed RES-generation capacities, as required by Article 10(1)(a) of the FNA methodology.

The TSO performed an additional assessment of RES curtailment based on the assumption that, for ensuring short-term flexibility needs, technologies with higher marginal generation cost are curtailed first.

This means that flexibility needs in the market are primarily met by units not belonging to the RES group (conventional generation, storage, P2X).

Under this assumption, RES units would reduce generation in the following order:

- Offshore wind power plants;
- Onshore wind power plants;
- Solar power plant.

Article 10(7) of the FNA methodology requires the TSO to assess prequalification constraints. Based on historical TSO data, it was determined that different RES technologies exhibit different proportional ability to respond to flexibility needs, due to prequalification requirements and/or technical limitations of the units.:

table 12 RES quantities are used for flexibility

Category	The part that can provide short-term flexibility needs, %
Onshore and offshore wind power plant	51 %
Solar power plant parks	83,2 %
Small solar power plants (rooftop)	0*

*Small solar power plants are considered as facilities unable to meet short-term flexibility needs.

5.3.3. Assumptions when performing distribution network calculations in accordance with Article 11 of the FNA methodology

In accordance with Article 1(a) of the FNA methodology, annual temporal granularity was selected for assessing flexibility needs for the period 2028–2035. Mathematical modelling is performed with hourly resolution (8 760 hours per year), while the final DSO flexibility-needs results are aggregated into annual values for each target year.

In accordance with Article 1(b), spatial granularity covers the entire territory served by ESO (the whole Lithuanian bidding zone). Each customer is mathematically linked to a specific physical network location through a topological-tracking algorithm, which enables the identification of flexibility needs at individual 110 kV transformer substations.

In accordance with Article 1(c), voltage granularity is set at the 110 kV level of the distribution network. The analysis focuses on 110 kV transformer substations (TS).

In accordance with Article 2, the dataset selected for detailing upward and downward DSO flexibility needs consists of the local maximum power values (MW) and the total annual energy values (MWh) for each target year.

The conversion of input data into time-resolved series is performed using the Disaggregated Component-Based Framework, implemented through ESO's digital-twin mathematical model. This process transforms static annual forecast indicators into dynamic 8 760-hour time series for each of more than 200 network transformer substations.

1. Creating base load profiles.

Customer load is not treated as a single aggregated profile. Instead, for each transformer substation, distinct load-profile types are simulated, and normalized hourly weighting coefficients are created for the following load-profile groups:

Household customer load: Based on 2025 smart meter data, separate profiles are formed for the object types "apartment" and "house".

Commercial customer load: Objects are classified into 5 behavior types based on their load profiles, each of which is assigned a unique hourly weight factor.

Solar power generation: Hourly generation profiles for residential, commercial generating users and producers for 2025.

Heat pump profile: Generated by evaluating the outdoor temperature in detail through a linear regression equation that determines how much kW load increases as temperature drops.

Electric vehicle charging profile: The „Eraser" algorithm is used, which mathematically subtracts the known base load of the house and solar generation from the total consumption, thus refining the charging curve.

2. Standardization by weather.

A Random Forest regression model is applied. The model is trained using actual consumption data and calendar features for 2025 and then fed 10 years of historical meteorological information (2015-2024) to generate an hourly profile for a "standard year".

3. Load growth modeling.

The growth potential of different load types for the 2026–2035 period was modelled using specific algorithms that account for macroeconomic trends, historical development patterns, and technological progress.

Residential customer load: 2025 smart meter data (filtered out for generating consumers) was used to form the base "apartment" and "house" profiles. A growth rate of 0.52% in electricity consumption was used in the simulations, which was calculated by analyzing the historical changes in electricity consumption of 1.39 million stable consumers. The development of new facilities is allocated to transformers according to their historical growth rate, calculated using linear regression and the 10MIP basic scenario forecast.

Commercial customer load: Properties are classified into behavior types, each of which is assigned a different annual growth rate: 1.5% for offices and retail, 1.0% for entertainment, and 0.0% for industry (assuming that growth is offset by efficiency). An additional 5% annual probability is considered that properties currently without electricity will switch to electricity. The 10MIP basic scenario forecast data is used.

Solar-PV generation growth. For residential prosumers, growth potential is calculated using 10MIP basic-scenario data, applying an average 7.0 kW permitted generation capacity per new object. For commercial prosumers and producers, growth up to 2027 follows the reserved-capacity list with a 70% realization probability, after which modelling transitions to macroeconomic trends. Growth at transformer substations is constrained by the "Cap and Freeze" mechanism, applied when transmission-grid solar-profile limits are reached (Litgrid-issued solar generation profile for the ESO network).

Heat-pump load growth. Growth is modelled as a linear increase in the absolute number of units, based on 10MIP basic-scenario data. Spatial distribution is determined using the "Adoption DNA" matrix, which assigns installation probability according to location type (e.g., countryside vs. high-rise zones).

EV-charging load growth. EV penetration is modelled as linear growth following 10MIP basic-scenario data. Growth potential for each transformer substation is allocated using a Spatial Density Transfer algorithm, identifying EV "hot spots" across five network zones.

From the total demand in MW, the total generation in MW is subtracted. This makes it possible to see not only consumption loads but also reverse power flow into Litgrid when solar generation is present in the network.

When performing calculations, the DSO did not identify and calculate the share of downward flexibility demand that falls specifically on RES (renewable energy sources) generation curtailment, compared to the total downward flexibility demand.

Information on expected contractual arrangements (e.g. local services, flexible connection contracts or other commercial arrangements) was not calculated in the technical load modelling for 2028–2035.

Data on the unavailability of flexibility

Data on unavailable flexibility due to grid prequalification or temporary restrictions were not assessed. According to Article 13(2)(a)(ii) of the FNA methodology, operators may ignore this impact if historical data is not available or is zero.

Since the flexibility market in Lithuania is at the initial stage, historical data on these restrictions has not been accumulated.

5.3.4. Results fine-tuning

In accordance with Article 14, paragraph 3 of the FNA methodology, it was determined that:

a. Refinement due to transmission-system needs (in line with Article 12 of the FNA methodology) no refinement was performed for transmission-system needs. The total annual amount of restrictions is below 10% of the RES-curtailment volume assessed under Article 8 of the FNA methodology; therefore, refinement under this aspect is not required.
b. The refinement of the results due to the needs of the distribution network considering Article 11 of the FNA methodology is less than 10% of the RES restrictions assessed in accordance with Article 8 of the FNA methodology, therefore the adjustment of the results in this aspect is not performed.
c. The results were adjusted for the unavailability of facilities in accordance with the guidelines of Article 13 of the FNA methodology. Given that the unavailability of flexible resources was greater than 10% of the installed capacity, in this aspect, the results were adjusted (sensitivity). The data used in the sensitivity scenarios are presented below.

Cross-border line capacities used in assessing short-term flexibility:

Short-term flexibility needs arise in real time due to deviations from scheduled volumes caused by forecast-errors in RES generation and electricity demand. The operator assumes that these deviations cannot be reliably predicted in advance, meaning that the resources available to manage them are limited. For this reason, result refinement is performed.

In accordance EBGL Article 41(2) defines the volumes that may be used for balancing purposes Based on EBGL, and as reflected in the Baltic CCR cross-border balancing-capacity market-based allocation methodology, approved by VERT in December 2024, the following volumes may be used for balancing exchanges:

- 50% of the capacity of the Lithuania-Latvia interconnection;
- 20% of the capacity of the Lithuania-Poland interconnection;
- 20% of the capacity of the Lithuania-Sweden interconnection;

Assessing that there is a constant risk of starting work in isolated mode in the Lithuanian electricity system, in extreme cases it is accepted (assumptions are used only for ramping need):

- 0% of the capacity of the Lithuania-Latvia interconnection;
- 0% of the capacity of the Lithuania-Poland interconnection;

- 0% of the capacity of the Lithuania-Sweden interconnection;

The utilization of cross-border capacities in short-term flexibility has a significant impact on the final results, therefore the results are adjusted on this basis.

Using P2X technology:

P2X technologies are included in the system modelling, but their contribution to the assessment of flexibility needs is not included in the sensitivity assessment. This assumption aims to determine how uncovered flexibility needs would change if P2X capacity were not available for flexibility provision.

5.4. Additional analysis

During the analysis of flexibility needs, additional flexibility needs were identified that are related to the specifics of the operation of the Lithuanian electricity system.

5.4.1. FCR capacity needs

5.4.1.1. Issues

In the flexibility assessment, FCR services should be considered as an additional flexibility requirement, as they are intended to manage instantaneous imbalances. SO GL Article 153 provides that FCR is used to maintain system frequency in the event of an imbalance.

5.4.1.2. Methodology

The FCR requirement is determined according to the methodology established for the synchronous area. The FCR volume is calculated as a symmetric MW value for the entire synchronous area and is then allocated to individual LFC blocks based on the amount of generation and demand within each block. The Continental Europe TSO methodology applies a probabilistic model aimed at selecting the minimum FCR volume such that the probability of FCR insufficiency does not exceed once in 20 years. The calculation considers the main sources of frequency disturbances: flexibility deviations between market time units, long-term frequency deviations, and the disconnection of significant units such as generators or HVDC links.

Assumptions for long-term assessment:

- The analysis is performed using 2026 data as a base for all remaining years.
- Demand and generation profile in Continental European networks remains the same. A change is observed only in Lithuania's demand and consumption profile.

5.4.2. mFRR and aFRR capacity needs

5.4.2.1. Issues

Short-term flexibility needs arise due to forecast-errors in RES generation and electricity demand. Unforeseen equipment outages are also included in short-term flexibility needs; today these events are covered by frequency response reserves (mFRR and aFRR). When assessing flexibility needs, the transmission system operator additionally considers long-term aFRR and mFRR volumes in order to provide a detailed breakdown of short-term flexibility needs.

5.4.2.2. Methodology

The assessment is carried out in accordance with the guidelines set out in Article 157 of SOGL, as well as the provisions of the Baltic FRR-capacity determination methodology approved by VERT.

5.4.3. Fast frequency response reserves

5.4.3.1. Issues

The Lithuanian power system has an atypical architecture, characterized by large-capacity units and a weak cross-border connection linking Lithuania to the rest of the synchronous area. Loss of this weak interconnection would result in isolated-operation conditions. Because the system is not inherently designed to operate in island mode, the loss of external links significantly reduces system inertia, flexibility, and the ability to safely manage sudden power imbalances. The system is dominated by high-power electrical devices, which is why the disconnection of even one significant component can have a significant impact on the deviation of the system stability parameters.

In the absence of cross-border connections, i.e., when operating in isolated mode, these structural features become critical: there is no possibility to use the inertia of neighboring systems, emergency flows or balancing energy exchange with neighboring systems, operational parameters must be ensured solely by national resources. At the same time, as the share of synchronous generation decreases and the number of devices based on power electronics increases, the impact of disruptions on the system is increasing, and traditional resources become insufficient.

The Lithuanian power system must be prepared for isolated operation. Insufficient preparation for operation in isolated mode poses a direct risk not only to the integrity of the system itself, but also for end-users of electricity from automatic load disconnection to blackout. To solve this problem, specialized, pre-guaranteed and quickly activated resources are necessary, which would compensate for the absence of cross-border power lines during isolated operation.

5.4.3.2. What are fast frequency response reserves?

In Lithuania, two fast-response reserves are in place: the isolated-operation reserve service and the fast frequency response service (GAGAP). Both services are critical for power-system security and are designed to ensure that the national power system can operate stably in isolated mode, i.e., without synchronous cross-border interconnections. The purpose of these reserves is to guarantee pre-secured, readily available capacities capable of rapidly responding to the potential disconnection of large-capacity generation sources or demand, and provide immediate active power response, allowing frequency stabilization and avoiding blackout.

These reserves can be provided only by electricity-storage units due to their fast-response capability.

5.4.3.3. Method of determining volumes

The volumes are determined in accordance with the Procedure for Trading in Non-Frequency-Related Ancillary Services, approved by the National Energy Regulatory Council on 15 June 2026 by Resolution No. O3-731 “On the Approval of the Procedure for Trading in Non-Frequency-Related Ancillary Services”. Since the procedure defines reserve-volume determination only for the upcoming year, additional assumptions are introduced for the 2028–2035 assessment period:

- Maximum market time unit (MTU) consumption is evaluated.
- The potential generation profile of the Lithuanian power system required to cover demand is assessed.

Together with the data defined in Section 5, the analysis uses the mathematical model of the Lithuanian power system, which enables the assessment of the impact of a single-unit outage on frequency stability under isolated-operation conditions. The assessment is carried out by checking the following conditions:

- the frequency change rate must not exceed 1 Hz/s;
- in the event of a generator disconnection, the frequency must not drop below 49,2 Hz;
- in the event of a consumer device disconnection, the frequency must not rise above 50,8 Hz.

The needs for fast frequency response reserves are determined by assessing the disconnection of the largest single generation and consumption equipment. The response of the electricity system is compared with the specified conditions. If the conditions are not met, the impact of the storage facility on the Lithuanian EES is additionally modeled and by gradually increasing the capacity of the storage facility, the minimum capacity of the storage facility is determined, which ensures the disconnection of the largest single event (generation and demand), while satisfying all the established conditions, this value is considered the demand for the isolated working reserve service. The determined volume is divided into two parts. For the volume of the Lithuanian isolated operation reserve – the entire quantity that can be provided by the designated electricity storage system operator, the remaining quantity – for the fast frequency response service.

5.4.4. LT-PL transfer capacity increase service needs

5.4.4.1. Issues

On 9 February 2025, the Baltic power system began synchronous operation with the Continental Europe network. Synchronous operation between the Baltic States and Continental Europe is currently established through a single double-circuit 400 kV overhead line between Alytus and Elk. To ensure safe and stable operation of the power system, cross-border capacity on the Lithuania–Poland interconnection is restricted. Assessments show that until the new 220 kV double-circuit line between Lithuania and Poland (Harmony Link) emerged, the potential cross-border transfer capacity is 500 MW.

The aim of the service is to exploit the full potential of the cross-border by using flexible resources, increasing the system's capabilities to stabilize frequency and increase trade between Lithuania and Poland.

5.4.4.2. Method of determining volumes

The maximum service volume is defined by the capacity potential, i.e. 500 MW. The volume is reduced by fast frequency response service. Other flexibility resources are not fast enough to stabilize the frequency and influence the Lithuanian-Polish interconnection, therefore they are not included in the assessment.

$$PDPP = PP - IZDR - GAGAP$$

Here:

PDPP – Lithuanian-Polish interconnection capacity increase service requirements

PP – Cross-border capacity potential

IZDR – Isolated operating reserve service needs

GAGAP – fast frequency response service needs

5.4.5. Schedule change between the market time unit needs

5.4.5.1. Issues

During active-power schedule changes between market time units (MTUs), the technical capabilities of generation and demand units are not the same. Their power ramps occur at different speeds, and planned values are reached at different moments. As a result, an imbalance forms in the system during the period in which active power is transitioning toward the scheduled value. The extent of the imbalance directly depends on the profile of the devices performing the active power change according to the market plans. The principle is defined in the graph below.

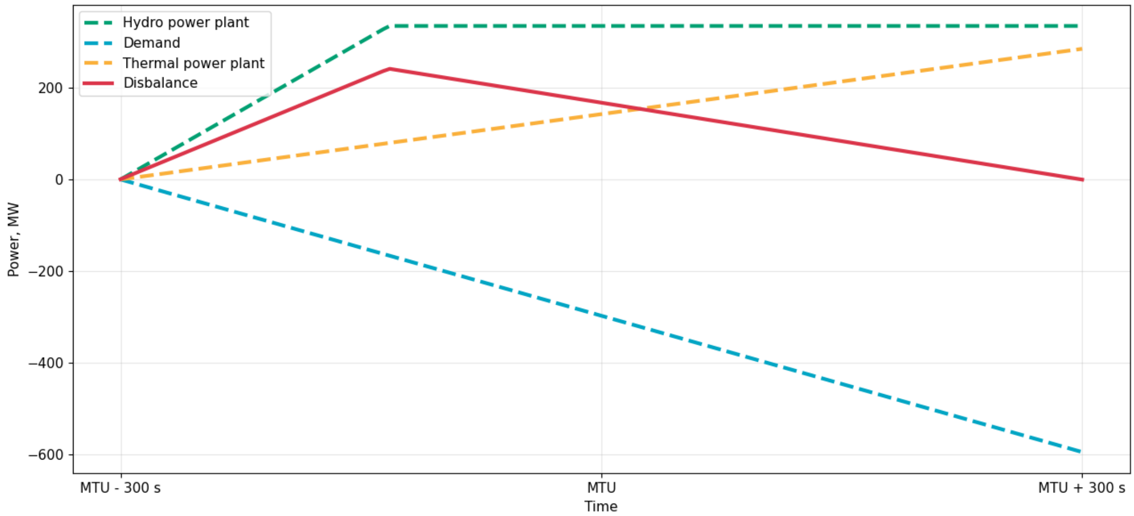

Figure 15 Different power changes in devices and the resulting imbalance

5.4.5.2. Methodology

The assessment is carried out using the data provided in section 5.1. Deviations resulting from changes in active power are assessed for each MTU individually, considering changes in active power of generating sources and demand sources and technological capabilities. Changes to the power change between MTUs can only be made during the designated period, i.e. 5 minutes before the scheduled MTU start and 5 minutes after the scheduled MTU start. Total 10 minutes.

table 13 Technological capabilities for changing active power

Nr.	Device/Technology	Power ramp rate, MW/min	Comment
1	Battery energy storage system	a) 10 % Pn/min b) 20 % Pn/min c) 100 % Pn/min d) Instant change	Several scenarios are used in the scope of the assessment
2	RES	No restrictions	The change is carried out throughout the MTU, continuously
3	P2X	a) 10 % Pn/min b) 20 % Pn/min c) 100 % Pn/min d) Instant change	Several scenarios are used in the scope of the assessment
4	Conventional generation sources	According to technical capabilities	
5	Demand	The change is made within 10 minutes	

Here: Pn – Installed power

5.4.5.3. Assessment of imbalance formation due to plan changes between MTUs

Having 10min power ramping periods for all resources, they are divided into two parts Ramp1 and Ramp2 and according to the above scheme, add up:

a. MTU_x Ramp2 values and
b. MTU_x Ramp1 values,

new 10-minute periods are created, from which the imbalance value is estimated for each MTU:

$$P_{RAMP} = \frac{\sum BP \cdot 4}{3600},$$

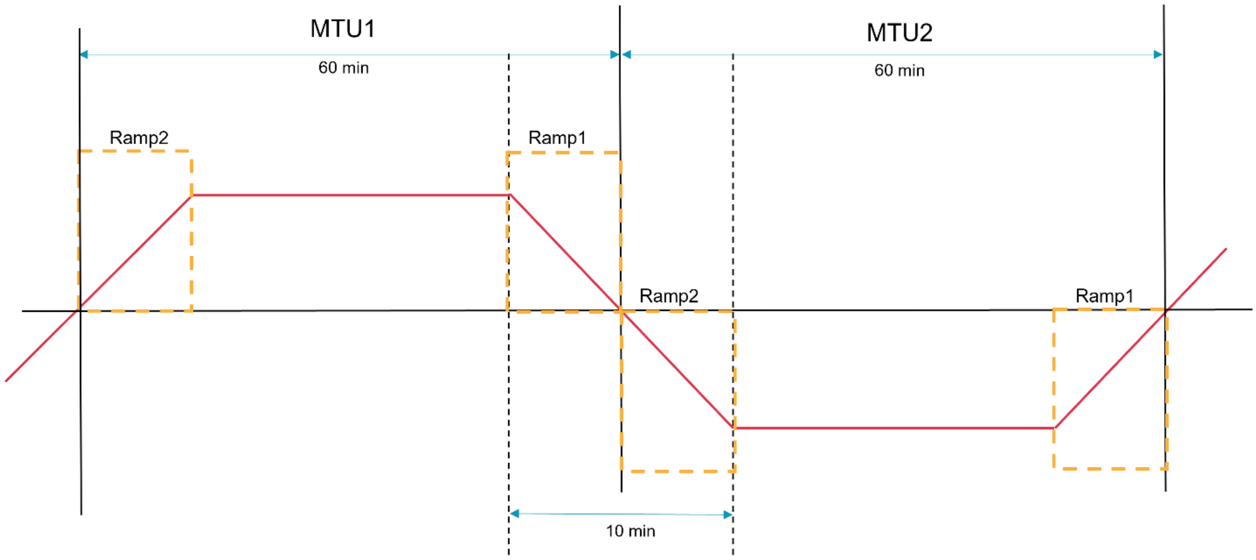

Figure 16 Explanation of the power exchange between MTU and the imbalance calculation

here:

P_{RAMP}- imbalance,

BP – total power change through the resource.

Then the 1st and 99th percentiles are determined, which represent the largest possible surplus and deficit imbalances, respectively.

5.4.5.4. Assessment of additional aFRR needs

After assessing the extent of the imbalance, data manipulation is performed to prepare the data for the assessment of additional aFRR needs. During the manipulation, the data sample is changed from 10 min to 15 min, repeating the last sample value for data expansion, assuming that there is no additional imbalance during the period after the plan change. The manipulation is performed to apply the same principles for aFRR assessment as applied in the FRR volume determination methodology. It is assumed that with a 10 min change in active power between MTUs, there is no additional aFRR requirement. The additional aFRR requirement for a shorter-term technology power change is estimated as the difference between the 10 min change and the faster change.

Additional upward volumes are set:

$$aFRR_{up} = \left(P_{NB_{1min}} - P_{NB_{15min}}\right)_{1\text{th}}$$

Additional downward volumes are set:

$$aFRR_{down} = \left(P_{NB_{1min}} - P_{NB_{15min}}\right)_{99\text{th}}$$

Here:

P_{NB1min} – Imbalance 1minute average data

$P_{NB15min}$ – Imbalance 15 minutes average data

5.4.6. Uncontrollable Solar PP management needs

5.4.6.1. Issues

Surplus of uncontrolled solar generation poses not only a risk of system imbalance, but also a security risk, because this energy is obtained from generating consumers whose devices cannot be controlled or shut down when needed. As the proportion of this type of generation increases, the Lithuanian electricity system needs to have flexible resources to manage excess generation. The problem of uncontrolled solar generation surplus is represented in the graph below.

5.4.6.2. Methodology

The data used to determine the needs are described in Chapter 5.

The need is determined by assessing the possible demand potential of the system over the year, which is determined by:

$$PP = P_{load} - BG$$

Here:

PP – Demand potential

P_{load} – System demand determined for each time moment based on input data.

BG – Must-run generation. The amount of generation that is constantly operating in the Lithuanian electricity system regardless of market conditions. The assessment assumes a constant value of 259 MW.

Demand potential, a value indicating the maximum amount of uncontrolled solar generation that the Lithuanian electricity system can consume without additional flexibility resources.

The solar power generation profile is adjusted based on the ESO forecast of installed capacity of solar power plants of generating consumers. The forecast values are presented in the table below.

table 14 Forecasted installed capacity of uncontrolled solar power plants

Year	2028	2030	2033	2035
Installed capacity of generating consumers, MW	2017.3	2217.3	2517.3	2717.3

The generation surplus is calculated as the difference between the uncontrolled solar generation and the demand potential. From the determined generation surplus, the following is determined:

- annual surplus energy, GWh;
- annual surplus generation duration, %;
- average duration of one surplus event, h;
- flexibility demand power (calculated as the 99th percentile value of the surplus), MW;
- flexibility demand capacity (calculated as the 99th percentile value of the surplus multiplied by the average event duration), MWh.

The principle is presented in the graph below.

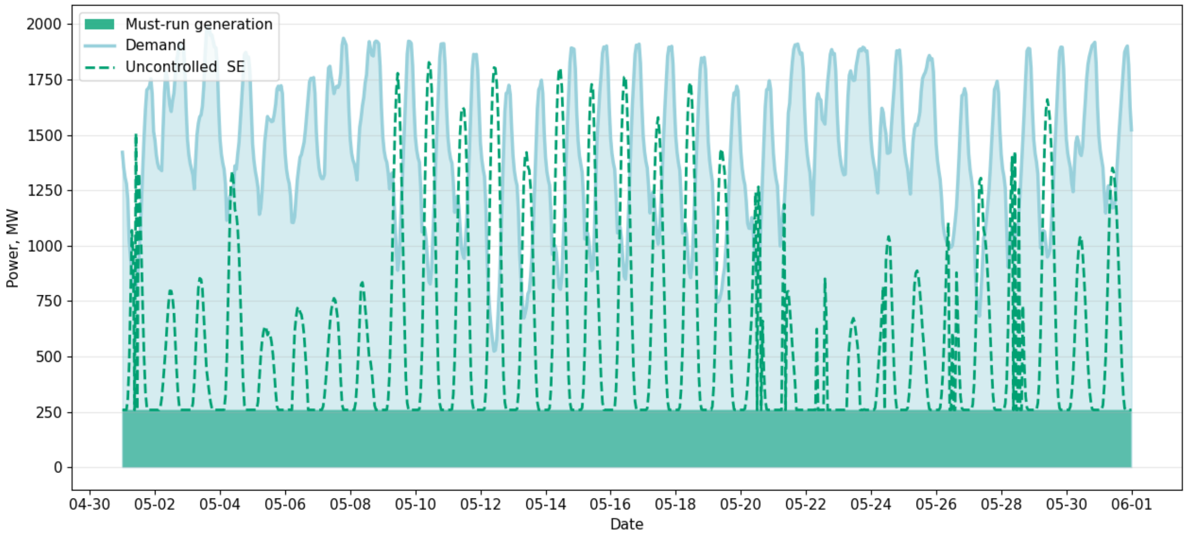

Figure 17 Uncontrolled SE generation and consumption in 2028

These indicators allow us what scale of flexibility resource will be needed to manage the risks posed by uncontrolled solar generation and ensure reliable system operation as the proportion of uncontrolled RES increases.

5.4.7. Distributed generation influence to transmission network

5.4.7.1. Issues

The increasing integration of renewable energy sources (RES) in the distribution network is leading to reverse power flows into the transmission network. This can cause overloads in capacity zones. Capacity zone - related transmission network substations and the lines connected to these substations issues are identified in the electricity transmission network.

5.4.7.2. Data and calculation principles

The analysis is performed in the following bandwidth zones:

table 15 Bandwidth areas where analysis is performed

Bandwidth zone no.	Description
3	Klaipėda- Pagėgiai
4	Bitėnai-Pagėgiai-Jurbarkas
5	Jurbarkas-Kybartai-Kapsai
13	Šiauliai-Radviliškis-Šeduva-Panevėžys; Berčiūnai
26	Jonava-Ukmergė I, II
28	Utena-Rašė I, II - Suginčiai-Molėtai-Paberžė-Širvintos-Neris
32	IAE-Dūkštas-Kazitiškis-Padysnis-Didžiasalis
35	Kaunas-Biruliškės-Rumšiškės-KHAE; Kaišiadorys I; Palemonas
36	KHAE-Žasliai; Kaišiadorys II; KHAE-LE-Žasliai; Žasliai-Vievis-VE3; Kruonis
40	Kapsai-Bukta-Šeštokai-Lazdijai-Alytus; Kvietiškis
41	Alytus-Seirijai-Leipalingis-Druskininkai-Merkinė-Varėna-Matuizos-Valkninkai-Rūdiškės-Trakai-Šventininkai-Vilnius; Vidzgiris
59	Griškonys-Šilas-Bakšiai-Alytus

These areas were selected because the distribution network operator has already suspended connections in these areas. Also, in some of them, significant reverse flows from the distribution to the transmission network are already being recorded.

All scenarios assess the generation of existing transmission network users in the capacity zone and simulate the generation of future network users. The calculations also use the total transformer power flow in the capacity zone provided by the ESO.

Based on this data, it is checked whether the technical capacity of the capacity zone will not be exceeded. In case of capacity exceedance, the excess energy is calculated, which constitutes the scope of the flexibility demand.

5.4.7.3. Assessment of the flexibility needs

The need for flexibility is assessed when the distribution network does not exceed the safe generation limit (SGR) set for it in the bandwidth zone.– the calculated flexibility need is for the transmission network

5.4.7.4. Assessment of the storage resource needs

The installed power and capacity requirements of battery energy storage system required to absorb excess energy in the bandwidth zone are assessed. The assessment is carried out in terms of two parameters:

- • **Power:** the installed power is determined to ensure the absorption of the 99th percentile excess power peak in the bandwidth zone.
- **Capacity:** Determines the 99th percentile of energy from all excess events in the bandwidth zone.

Then checked whether a storage device characterized by these parameters could absorb the 98th percentile of all excess energy in the bandwidth zone If this criterion is not met - the capacity is increased by 1 MW until the storage unit absorbs 98 percent of all excess energy in the bandwidth zone.

The need to increase the capacity arises from the fact that even if the 99th percentile of all excesses is absorbed separately, it is impossible to absorb 99 percent of all excess energy in the bandwidth zone in normal operation: the storage device must be discharged to absorb the next excess.

6. Results of the assessment of flexibility needs

6.1. ERAA 2025 evaluation scenario

6.1.1. RES integration needs

In accordance with parts 2, 4 and 6 of Article 8 of the ACER FNA methodology, the annual RES-curtailment volumes were assessed for each target year (see figure below). The results show that in 2028 RES curtailment amounted to 334,5 GWh, while in 2030 it decreased to 7,8 GWh. The main reason for the decrease is the additional installation of 1250 MW of electrolysis capacity, which increased the system's ability to absorb excess RES generation. In 2033, RES curtailment increased again to 124,7 GWh due to the integration of the first offshore wind farm, and in 2035 it reached 1276,3 GWh, mainly because of the connection of the second offshore wind farm to the power system.

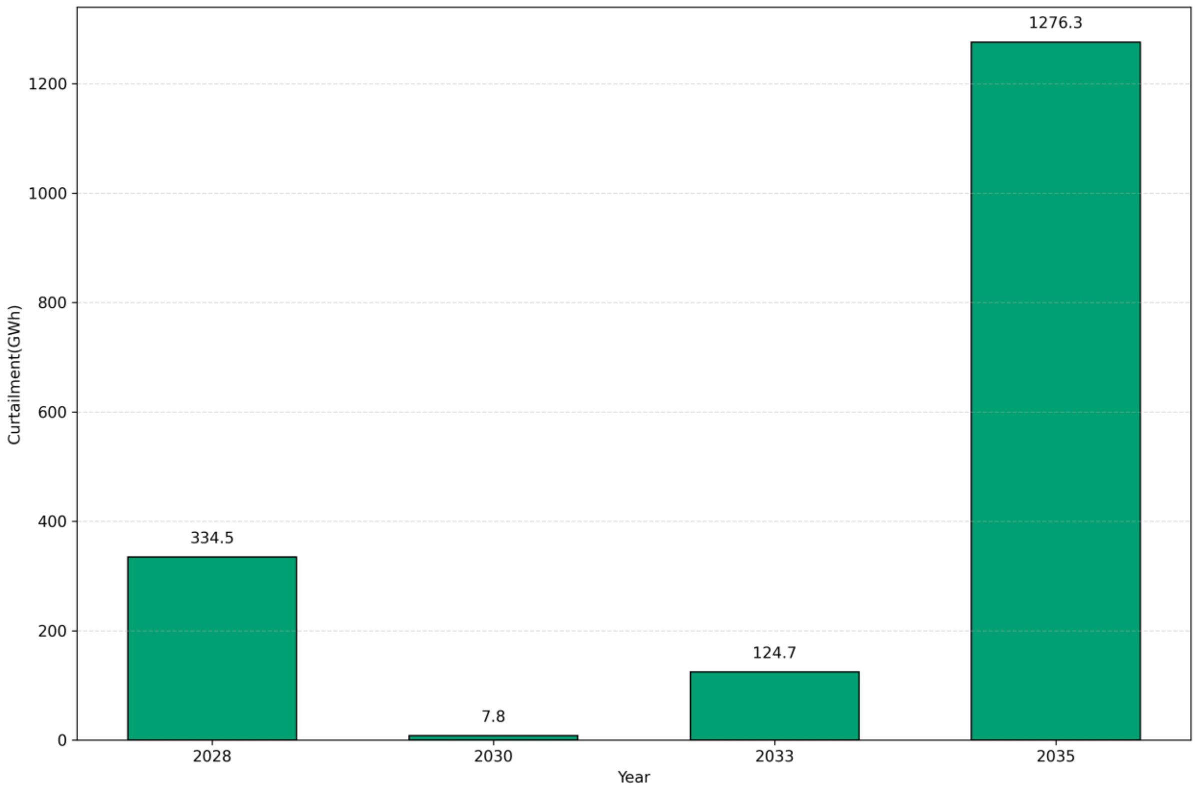

Figure 18 Annual RES generation curtailment by target year

In accordance with part 4 of Article 8 of the ACER FNA methodology, the duration characteristics of RES-curtailment events were assessed using the average, 95th percentile, and maximum event duration (see figure below). The results show that, as RES integration increases, curtailment episodes become not only more frequent but also longer. In 2035, the maximum duration of a single curtailment event reaches 81 hours, while the 95th-percentile value amounts to 37,6 hours, indicating prolonged periods of surplus RES generation within the system.

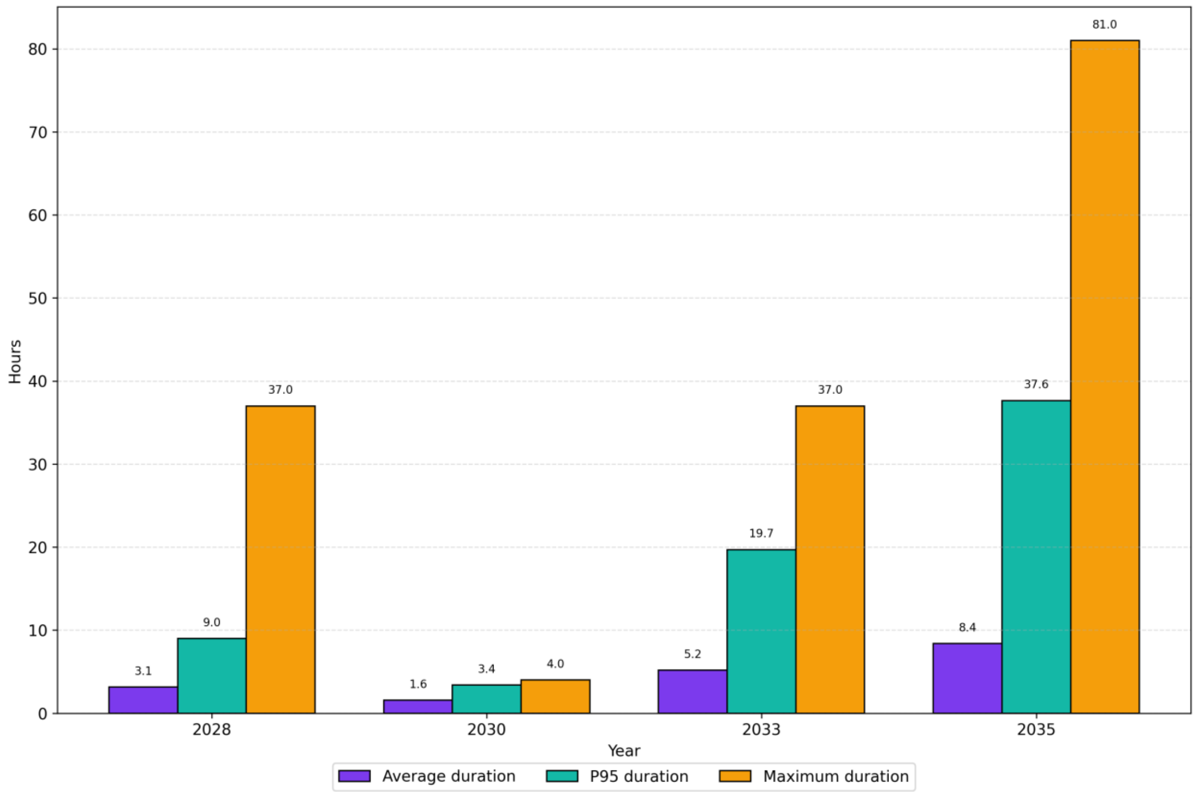

Figure 19 RES generation curtailment indicators by target year

In accordance with part 4(c) of Article 8 of the FNA methodology, RES-curtailment was analyzed by hour of day (see figure below). The results show that the largest RES-curtailment volumes occur during daytime hours, mostly between 9 am and 2 pm. This indicates a strong influence of solar power plant generation on curtailment formation, particularly in 2035, when the average curtailment level during peak hours exceeds 240 MWh per interval.

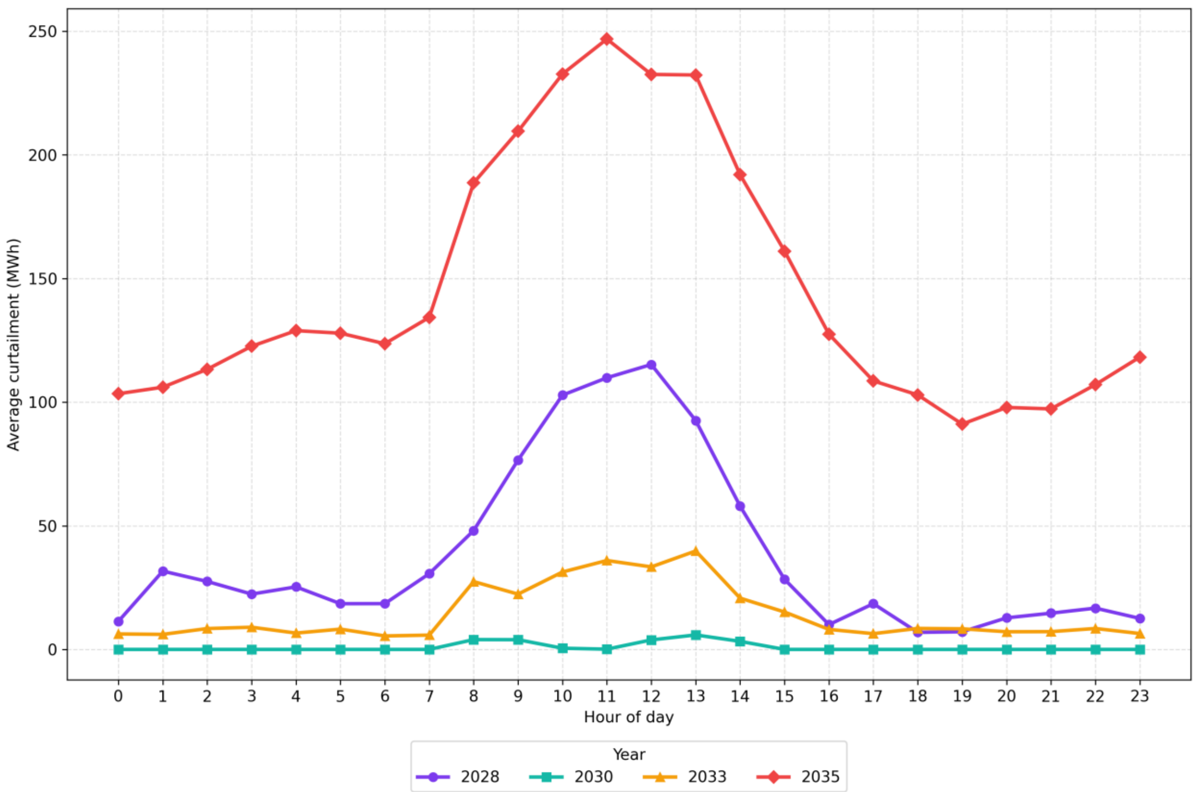

Figure 20 Average RES generation curtailment by hour of day

In accordance with part 4(c) of Article 8 of the FNA methodology, RES-curtailment was analyzed across monthly and hour-of-day dimensions. The resulting average curtailment heatmaps allow identifying periods during which the power system experiences the highest levels of surplus RES generation (see Figures 22–25). The results show that RES constraints are mainly concentrated during daytime hours and during the spring and autumn periods, when the generation level exceeds domestic demand and cross-border capacities for export are maximally utilized. The highest intensity of RES curtailment is observed in 2035, especially in October, during the daytime

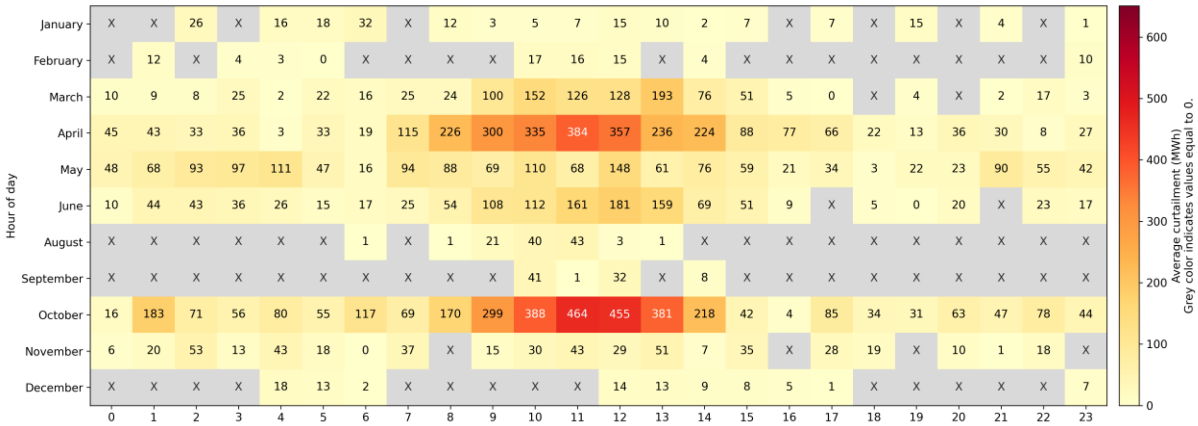

Figure 21 Average generation curtailment heatmap by month and hour (2028)

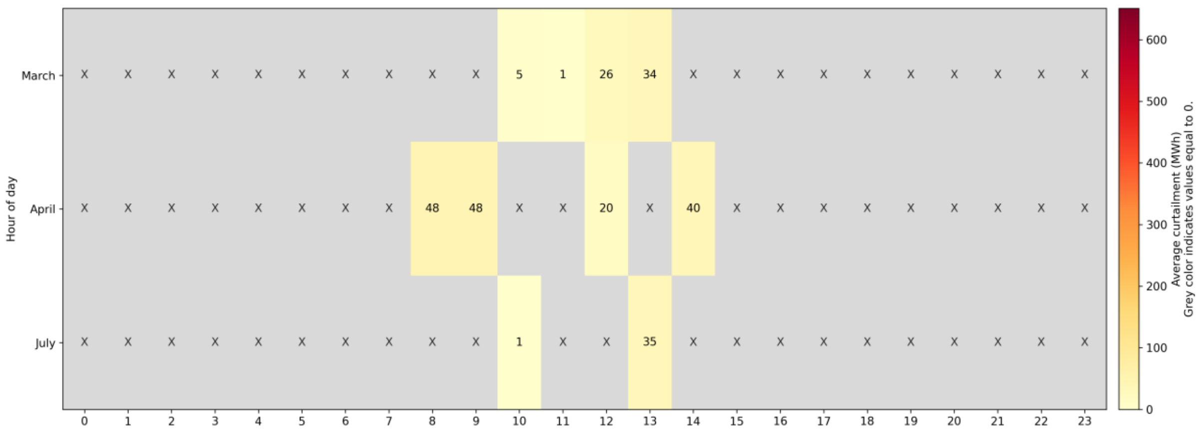

Figure 22 Average generation curtailment heatmap by month and hour (2030)

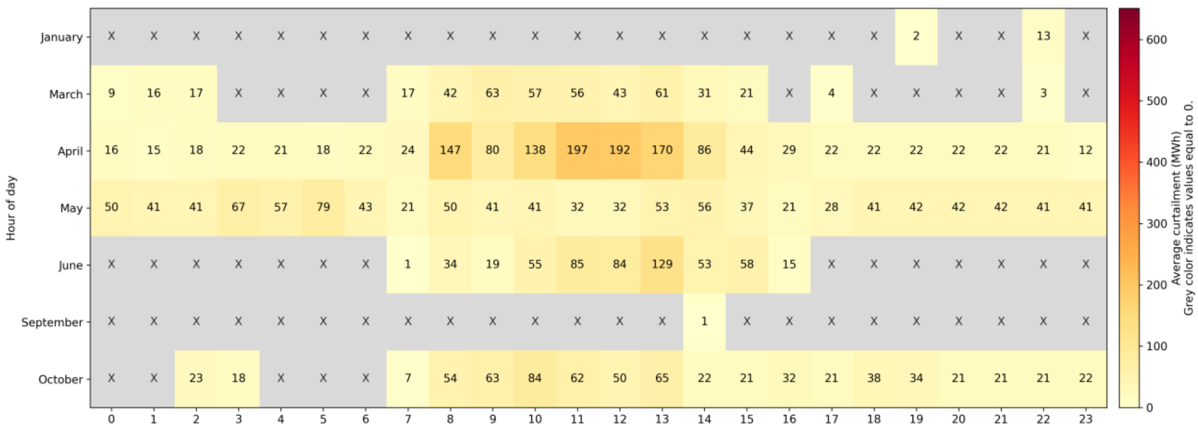

Figure 23 Average generation curtailment heatmap by month and hour (2033)

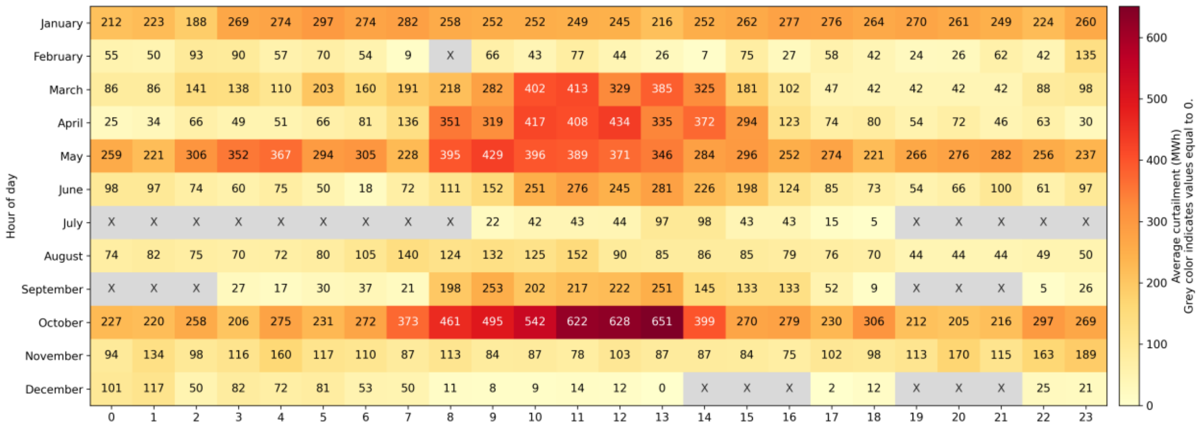

Figure 24 Average generation curtailment heatmap by month and hour (2035)

In accordance with part 4 of Article 8 of the FNA methodology, a correlation analysis was performed between RES-curtailment volumes and different system parameters (see figure below).The results show that the strongest positive correlation is observed between RES curtailment and wind generation as well as total actual RES generation, a negative correlation is identified with the residual-load indicator. This confirms that RES constraints are mainly formed under conditions of excess generation when low residual load levels indicate a limited ability of the system to absorb additional RES production. The most pronounced dependencies are observed in 2035.

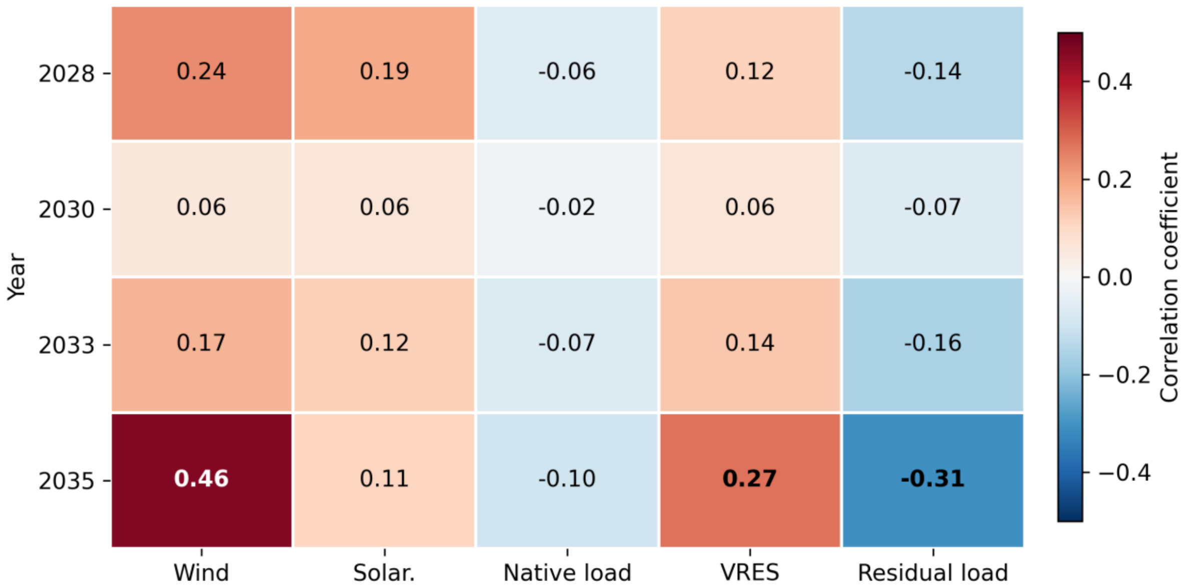

Figure 25 Correlation of RES production restrictions with different parameters

In accordance with part 5 of Article 8 of the FNA methodology, the variability of residual load was assessed across hourly, daily, and seasonal dimensions (see figure below):

- The hourly indicator shows the deviations of residual load from the same day's average;
- The daily indicator reflects the deviations of daily values from the weekly average;
- The seasonal indicator shows the deviations of monthly values from the annual average.

The results show that the largest part of the variability in residual load is accounted for by hourly changes, with the annual sum of absolute deviations consistently increasing from 5154 GWh in 2028 to 7143 GWh in 2035. The daily variability indicator increases from 210 GWh to 340 GWh during the same period, while the seasonal variability remains small – around 1,5–2,9 GWh. This shows that as the share of RES generation increases, the greatest impact on the system flexibility demand appears in short-term (hourly) residual load variation and long-term seasonal changes remain relatively small.

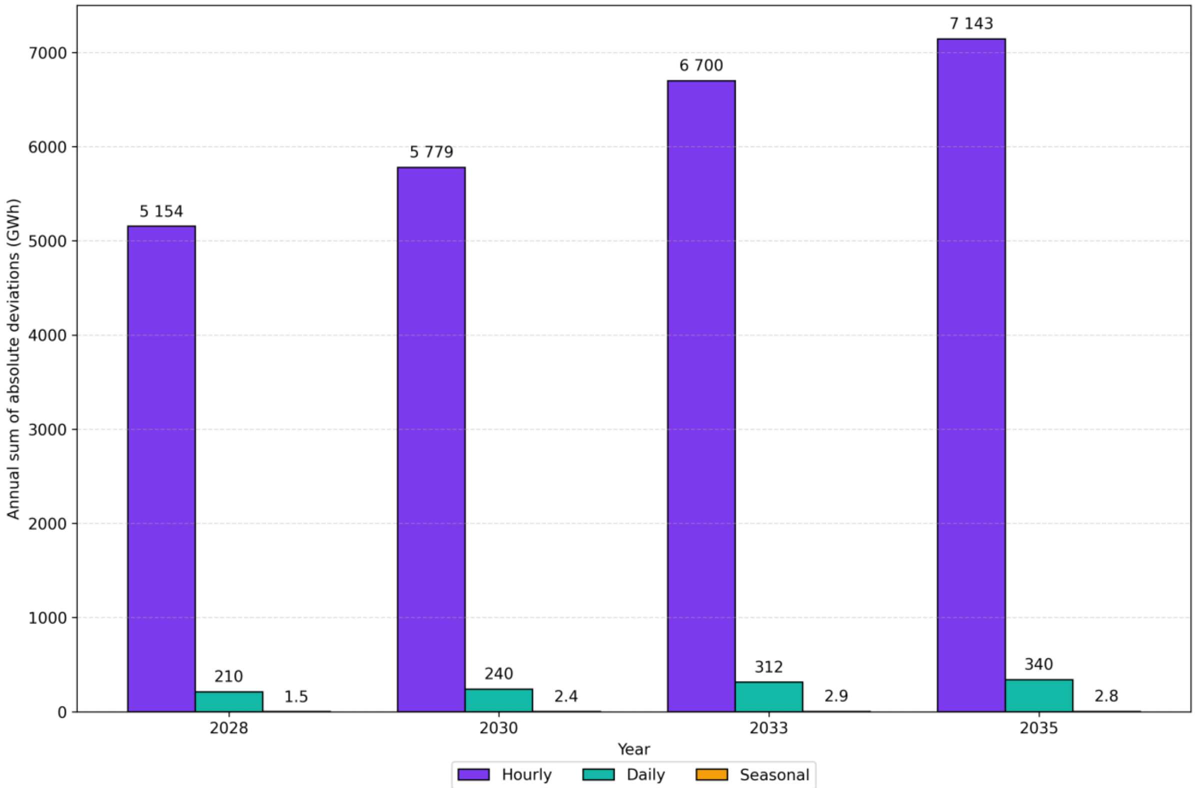

Figure 26 Residual load variation indicators by target year

In accordance with part 5 of Article 8 of the FNA methodology, the normalized residual-load variability indicators were additionally assessed (see figure below). Unlike the case of annual aggregates, this analysis shows the average absolute deviation in each examined interval. The results show that, for all sections, the residual variability of uncovered demand increases with the scale of RES integration. The largest growth is observed in hourly and daily indicators - in 2035, the average hourly residual uncovered load deviation reaches about 815 MW, and the daily one - about 930 MW. This indicates a growing need for short-term system balancing and flexibility in conditions of large RES generation.

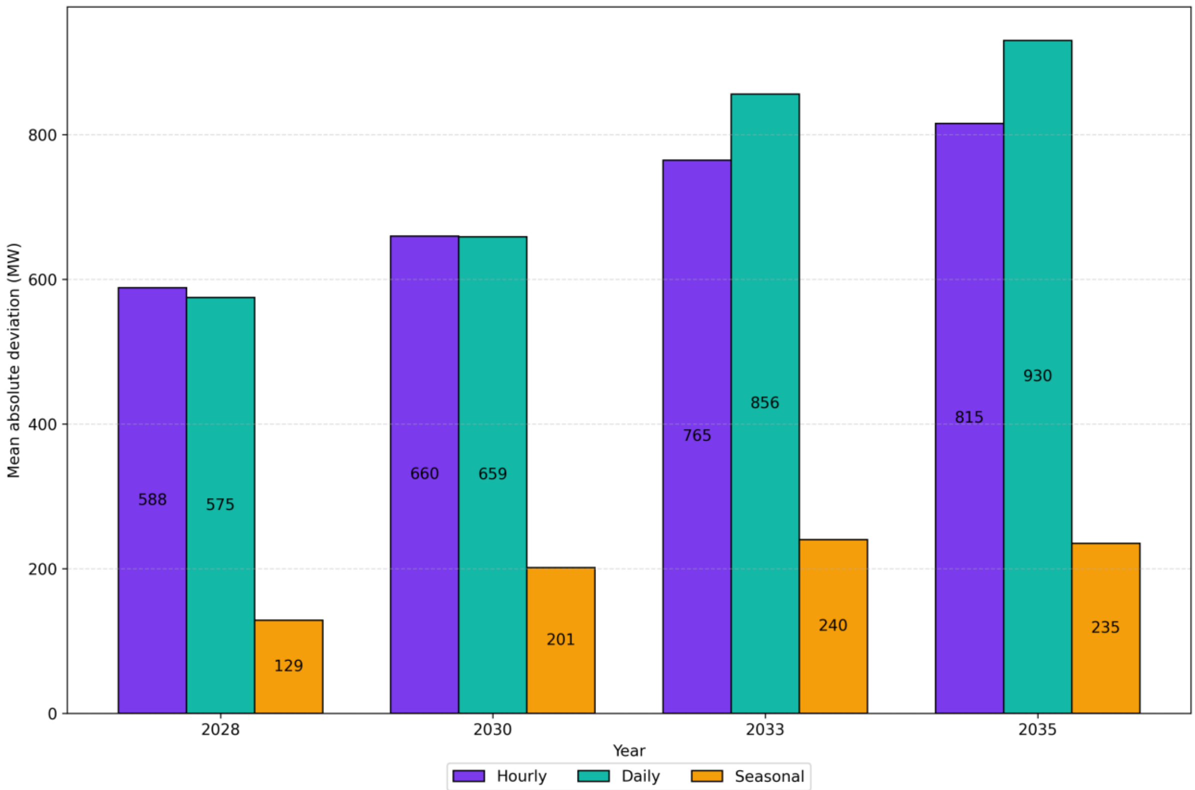

Figure 27 Normalized residual uncovered load variability indicators

In accordance with part 4 of Article 8 of the FNA methodology, the distribution of RES-curtailment event energy across individual curtailment periods was assessed (see Figure 29). The results show that, as RES integration increases, not only do total curtailment volumes grow, but the size of individual curtailment events also increases. Particularly pronounced changes are observed in 2035, when individual long-term RES curtailment episodes are formed, with the total amount of curtailed generation exceeding 150 GWh. This indicates prolonged periods of excess generation when domestic demand and export opportunities are not sufficient to absorb additional RES generation.

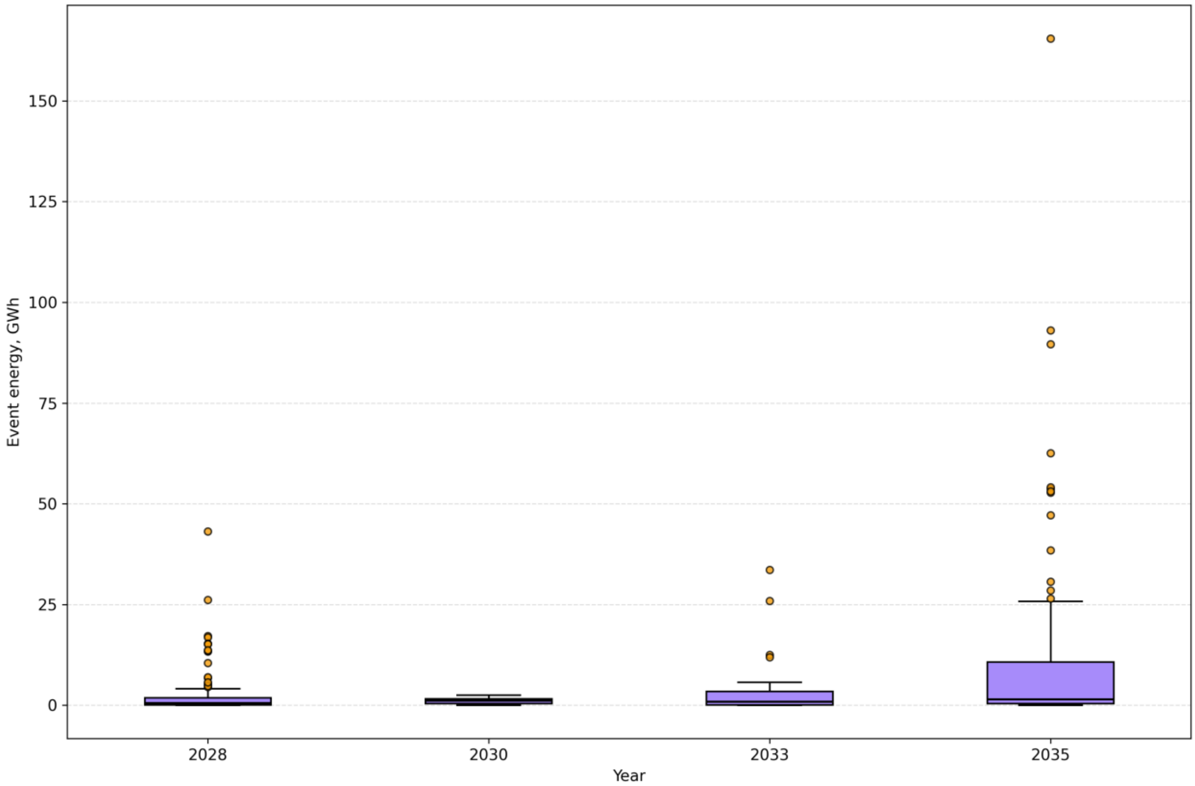

Figure 28 Energy distribution of RES curtailment events by target year

In accordance with parts 6–9 of Article 8 of the FNA methodology, the share of RES curtailment relative to total RES generation was assessed for each target year. The results show that the highest RES-curtailment level is observed in 2035, when curtailed generation accounts for 4,78 % of total RES output. In contrast, the curtailment level in 2030 remains extremely low—only 0,05 %—but gradually increases following the integration of the first and second offshore wind farms. This indicates a growing need for system flexibility to ensure efficient RES integration in future periods. According to the methodology, the RES-curtailment level should not exceed the national RES-integration target threshold, which—based on discussions with VERT—is set at 5 %. In this assessment, none of the target years exceed this value.

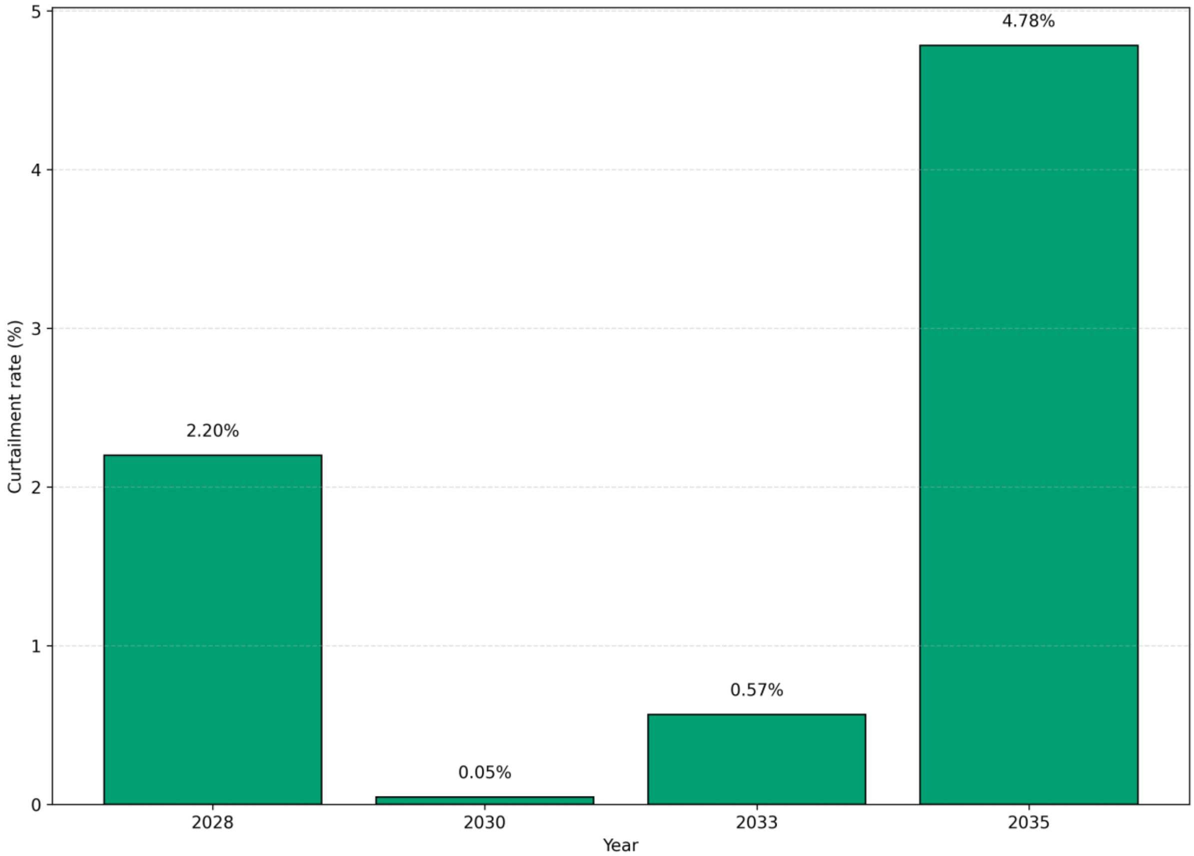

Figure 29 Part of RES curtailment in total RES generation in target year

In accordance with part 4 of Article 8 of the FNA methodology, the structure of RES curtailment by generation technology was assessed (see Figure 31). The results show that in 2028 the largest share of the curtailment will be onshore wind farms – 49,2 %, and TSO and DSO solar power plants respectively consists of 28,1 % and 22,8 From 2033 onwards, the structure of the curtailment changes fundamentally – offshore wind farms become the dominant limited technology, with a part of 73,6% in 2033 and increasing to 82,1% in 2035.

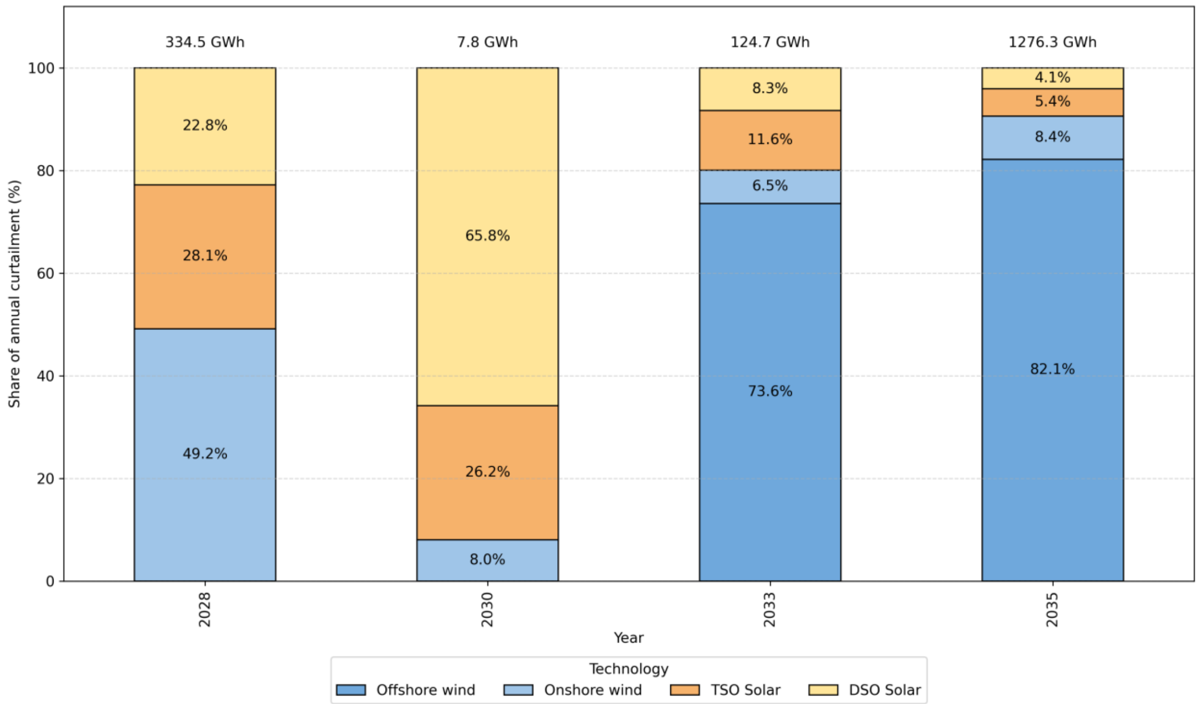

Figure 30 RES curtailment level by technology

6.1.1.1. Assessment of the impact of additional flexibility resources on reducing RES curtailment

In accordance with parts 10–12 of Article 8 of the FNA methodology, the impact of additional flexibility resources on reducing RES curtailment was assessed.

During modelling, flexibility resources were charged exclusively from curtailed RES generation, while the stored energy was discharged during periods of positive residual load. This modelling approach makes it possible to determine how much RES curtailment remains after integrating flexibility resources and to identify the most effective combinations of power and duration for each target year.

Based on parts 10-12 of Article 8 of the FNA methodology, the residual curtailment of RES generation after the integration of additional flexibility resources was estimated (for combinations of different powers and energy capacities). The results show that the effectiveness of RES-curtailment reduction depends strongly not only on the power rating of the flexibility resources but also on their storage duration (see Figures 32–35).

In 2028 and 2033, a significant reduction in RES curtailment is achieved by increasing both capacity and storage duration, and in some scenarios, RES curtailment is eliminated. Meanwhile, in 2030, due to the extremely low initial RES curtailment, even relatively small flexibility resources allow for the practically complete elimination of generation curtailment.

The highest flexibility needs are identified in 2035, when short-duration flexibility resources remain insufficient even at high power ratings. The results show that achieving a meaningful reduction in RES curtailment in 2035 requires long-duration energy-storage solutions, as increasing power alone does not provide adequate capability to absorb extended periods of surplus RES generation.

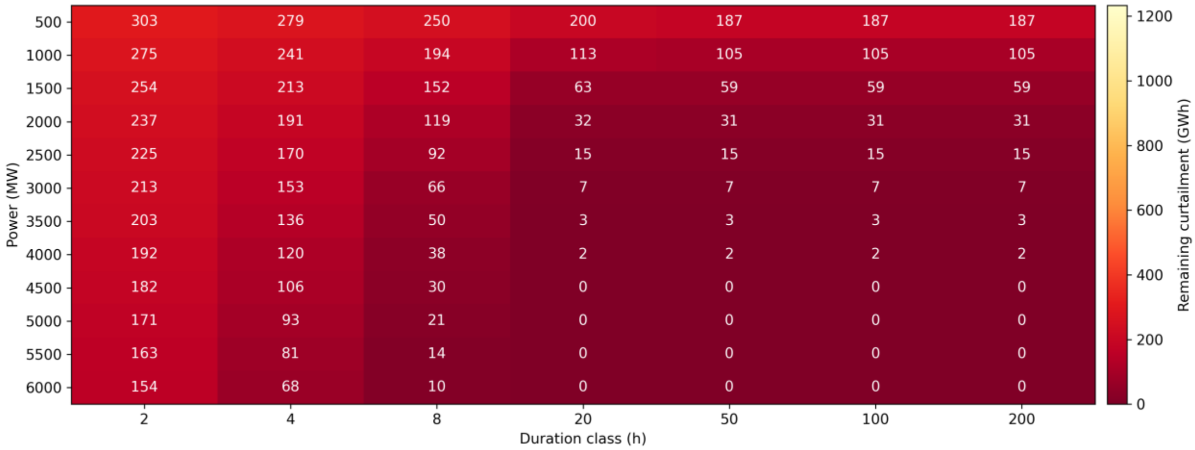

Figure 31 Residual generation curtailment amount after the inclusion of additional flexibility resources (2028)

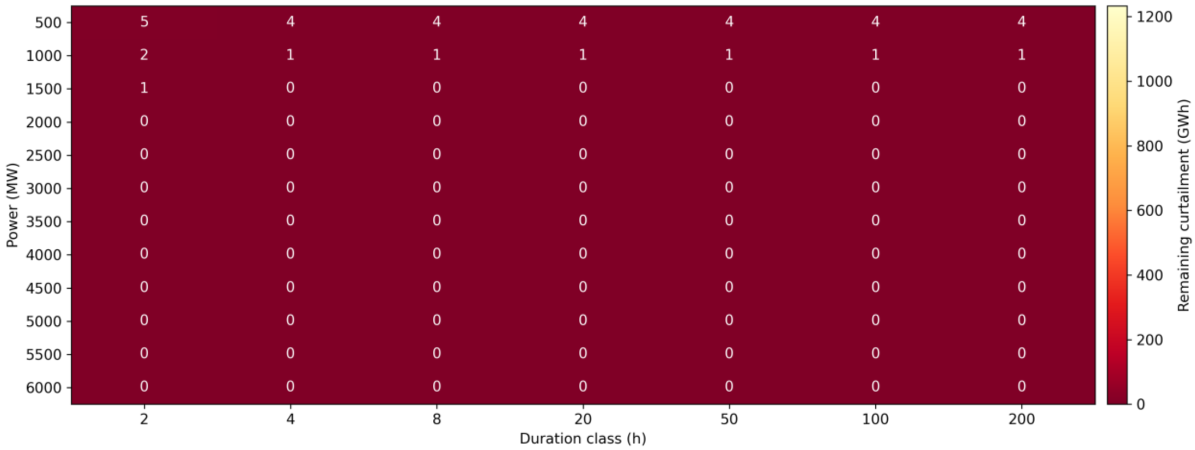

Figure 32 Residual generation curtailment amount after the inclusion of additional flexibility resources (2030)

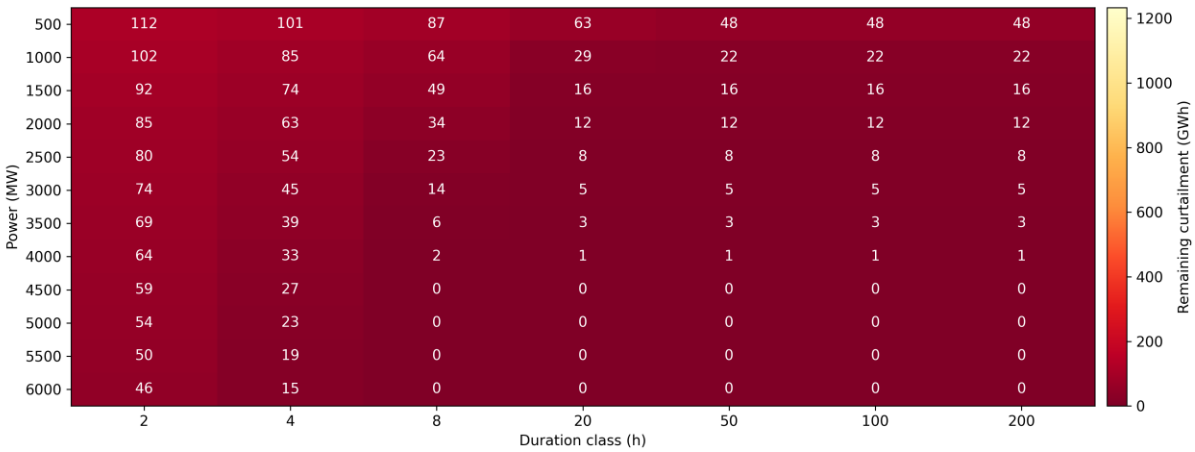

Figure 33 Residual generation curtailment amount after the inclusion of additional flexibility resources (2033)

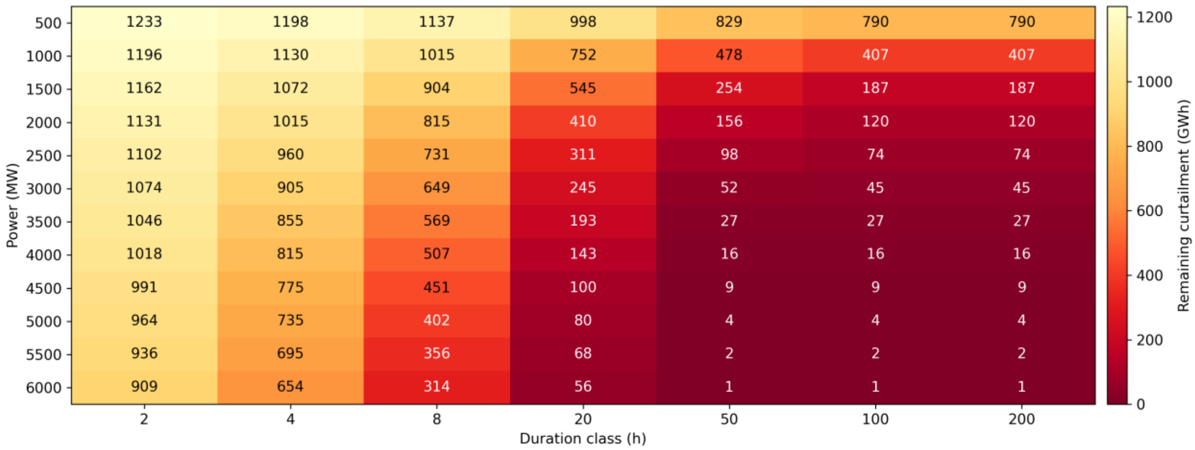

Figure 34 Residual generation curtailment amount after the inclusion of additional flexibility resources (2035)

In accordance with parts 10–12 of Article 8 of the FNA methodology, the potential for reducing RES curtailment was additionally assessed as a function of flexibility-resource power and energy-storage duration. Figures 36–39 present the amount of curtailment reduction relative to the baseline RES-curtailment level for each target year.

The results show that shorter-term flexibility resources (2–4 h) are most effective in reducing short-term RES generation surpluses, but their effectiveness decreases significantly with increasing overall RES curtailment in the system. Meanwhile, longer-term flexibility resources (20–200 h) allow for the absorption of prolonged periods of excess generation and achieve a significantly greater reduction in RES curtailment.

In 2028, the baseline level of RES curtailment is almost fully eliminated when using flexibility resources with a storage duration of ≥20 hours and power levels above approximately 2000–2500 MW. In 2030, due to the extremely low initial curtailment level, complete elimination of RES curtailment is achieved even with relatively small flexibility capacities.

In 2033, the situation remains broadly similar to 2028, but larger combinations of power and energy-storage capacity are required to achieve full elimination of RES curtailment. Meanwhile, in 2035, a fundamentally different system behavior was observed – short-duration flexibility resources become insufficient even at high power levels, and a meaningful reduction in RES curtailment is achieved only through long-duration energy-storage solutions. This indicates that, with the increasing part of offshore wind generation, the system begins to experience not short-term but prolonged periods of surplus RES generation, which can only be effectively managed using flexibility resources with large energy capacities.

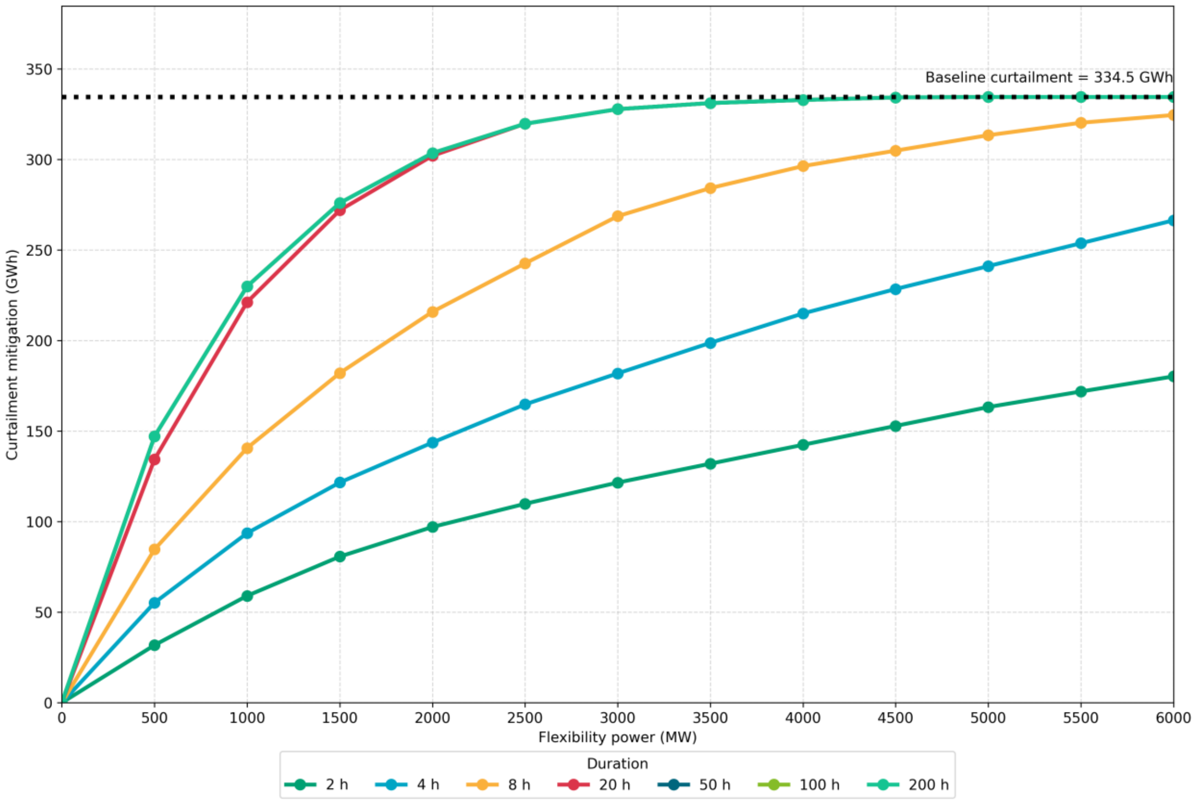

Figure 35 Removal of RES curtailment and flexible generation (2028)

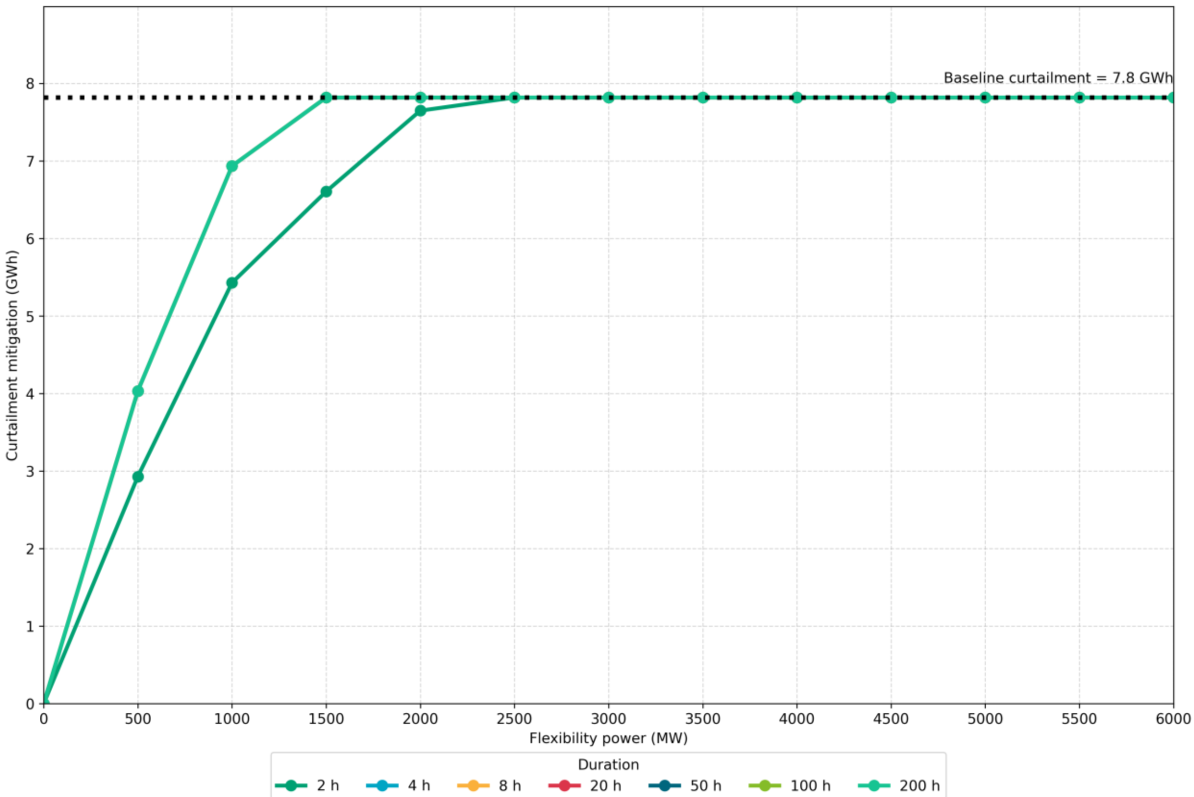

Figure 36 Removal of RES curtailment and flexible generation (2030)

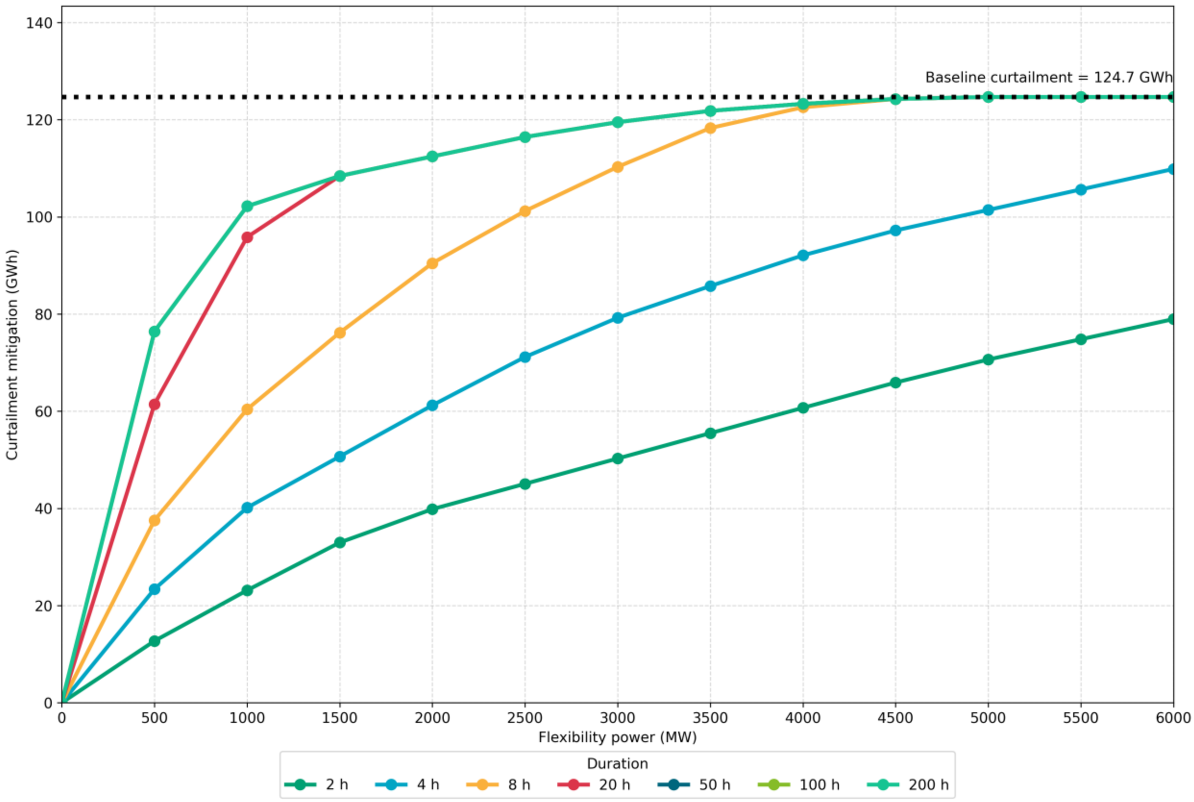

Figure 37 Removal of RES curtailment and flexible generation (2033)

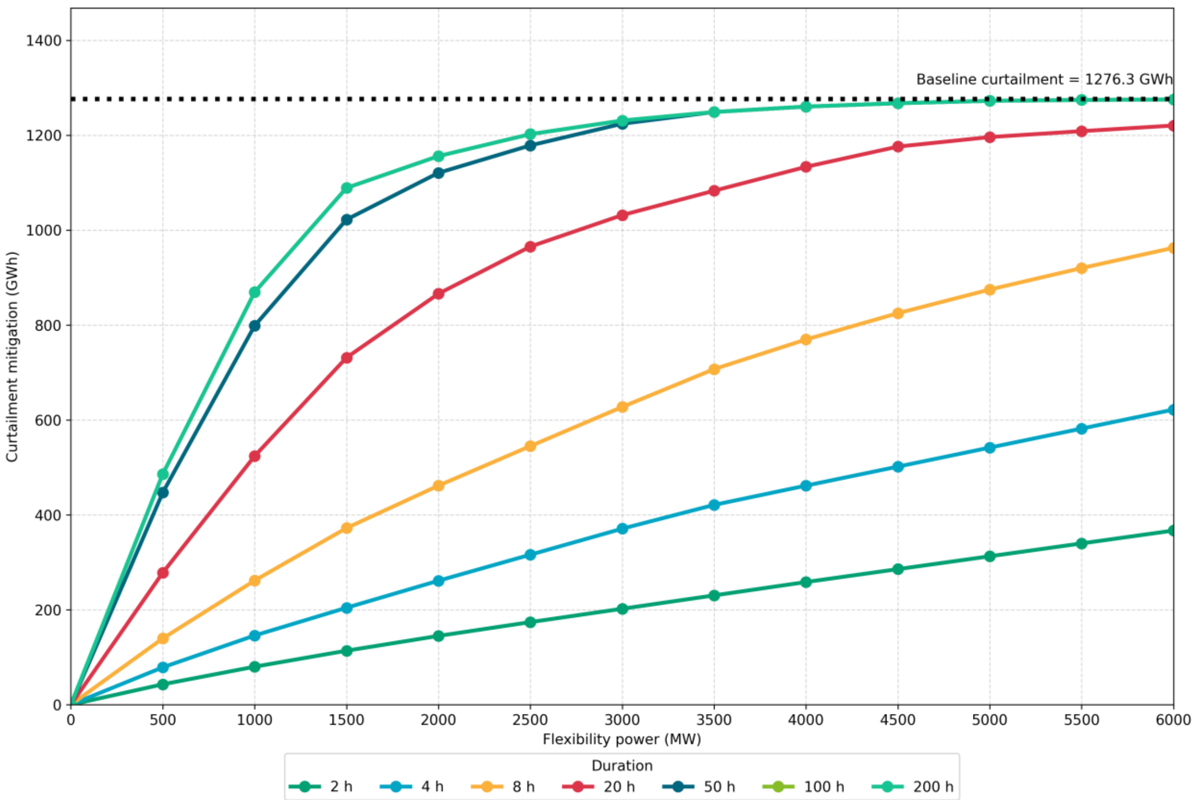

Figure 38 Removal of RES curtailment and flexible generation (2035)

In accordance with Article 8(3) of the ACER FNA methodology, short-term flexibility curtailments were additionally assessed in addition to the basic RES curtailment, which may lead to additional RES generation curtailments.. The results show that this additional curtailment component remains relatively small in all analyzed years compared with the baseline RES-curtailment volume: 11,9 GWh in 2028, 13,8 GWh in 2030, 18,9 GWh in 2033, and only 0,7 GWh in 2035.

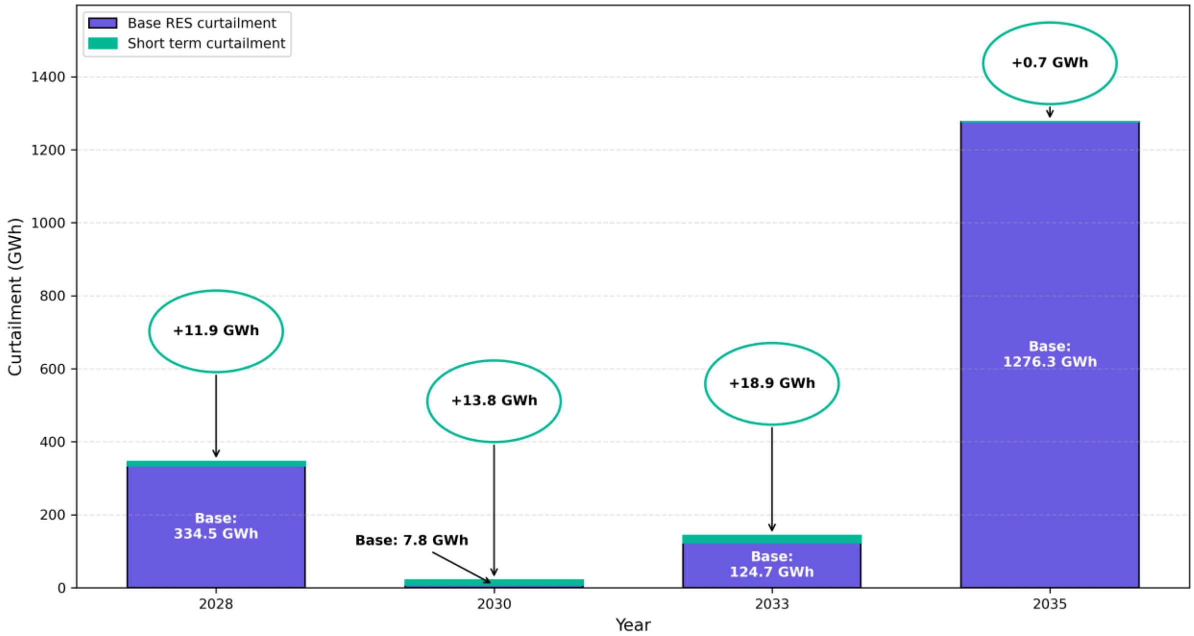

Figure 39 Basic and additional short-term flexibility RES curtailment

After adjusting the RES-curtailment level to account for the impact of short-term flexibility constraints, no substantial change in the indicator is observed in most target years. The largest relative change occurs in 2030, where the curtailment level increases from 0,05 % to 0,13 %, although the absolute value remains exceedingly small.

In 2028, the indicator increases from 2,20 % to 2,28 %; in 2033, from 0,57 % to 0,65 %; and in 2035, it remains effectively unchanged at 4,78 %. These results confirm that the influence of short-term flexibility constraints on the overall RES-curtailment level is limited.

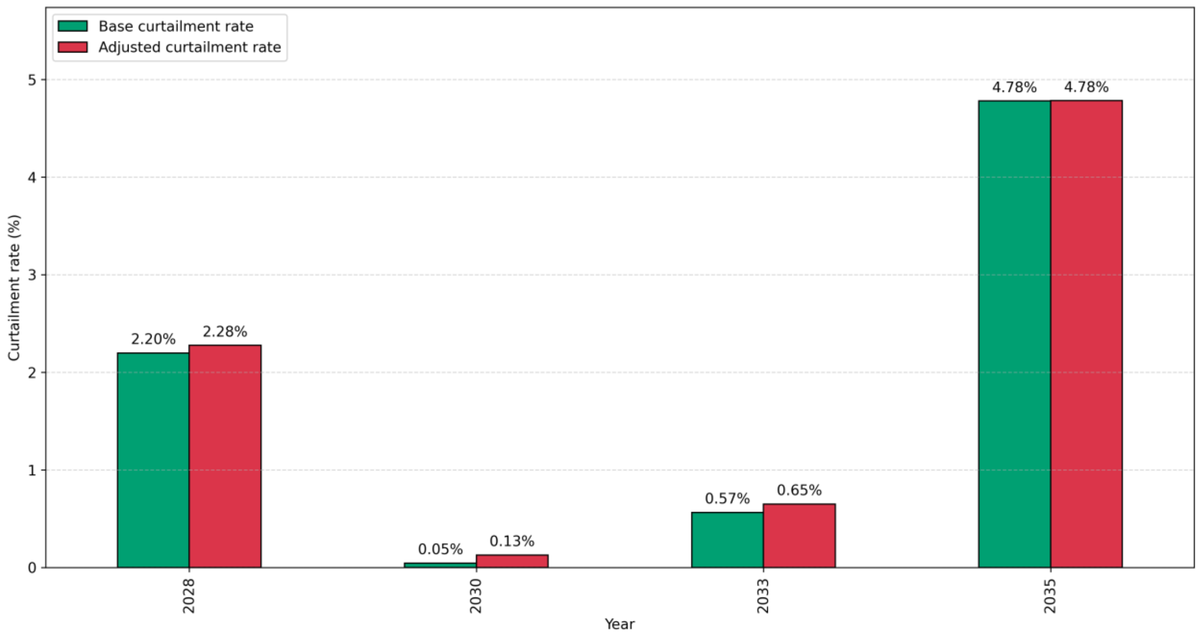

Figure 40 Basic and adjusted RES curtailment levels by target year

6.1.2. Ramping needs

6.1.2.1. Ramping needs assessment methodology

In accordance with Article 9 of the FNA methodology, a ramping-needs assessment was carried out by analyzing changes in residual load between consecutive market time units for each target year (see figures below).

Residual load was calculated by subtracting RES generation—offshore wind, onshore wind, PSO solar and DSO solar power plant and hydropower—from total demand. Positive changes in residual load were attributed to upward ramping needs, while negative changes were assigned to downward ramping needs..

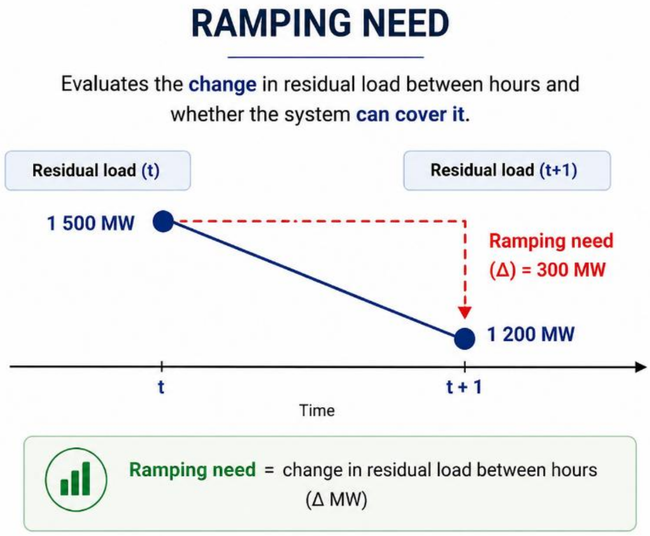

Figure 41 Example of ramping needs assessment methodology

To evaluate the system's ability to cover these ramping requirements, upward and downward ramping capabilities were calculated based on the technical constraints of all major flexibility sources. The assessment included thermal generation units, RES-curtailment capabilities, KHAE in both generation and pumping modes, BESS, electrolysers, and cross-border interconnectors.

Uncovered ramping needs were computed as the difference between the residual-load change and the available ramping capability in the corresponding direction. If system flexibility was sufficient, the uncovered ramping need was set to zero. A sensitivity analysis was additionally performed for four scenarios:

- Basic scenario;
- Scenario without interconnectors and without electrolysers;
- Scenario without interconnectors but with electrolysers;
- Scenario without electrolysers.

This approach made it possible to assess the contribution of cross-border interconnectors and flexible electrolysers operation to covering ramping needs.

6.1.2.2. Results of ramping needs

In accordance with part 2 of Article 9 of the ACER FNA methodology, the average system capability to cover upward ramping needs was assessed across different scenarios and target years. This indicator reflects the average annual flexibility capacity of the system to increase generation or reduce demand during periods when the residual load increases.

The results show that in the basic scenario, upward ramping capability increases from 2994 MW in 2028 to 5690 MW in 2035 (see figure below), reflecting the growing system-flexibility requirement driven by higher RES integration. The lowest capabilities are observed in the scenario without interconnectors and without P2X technologies, where upward capability reaches only 1705 MW in 2035. This demonstrates that cross-border interconnectors and P2X technologies constitute a significant share of the system's total upward flexibility capability.

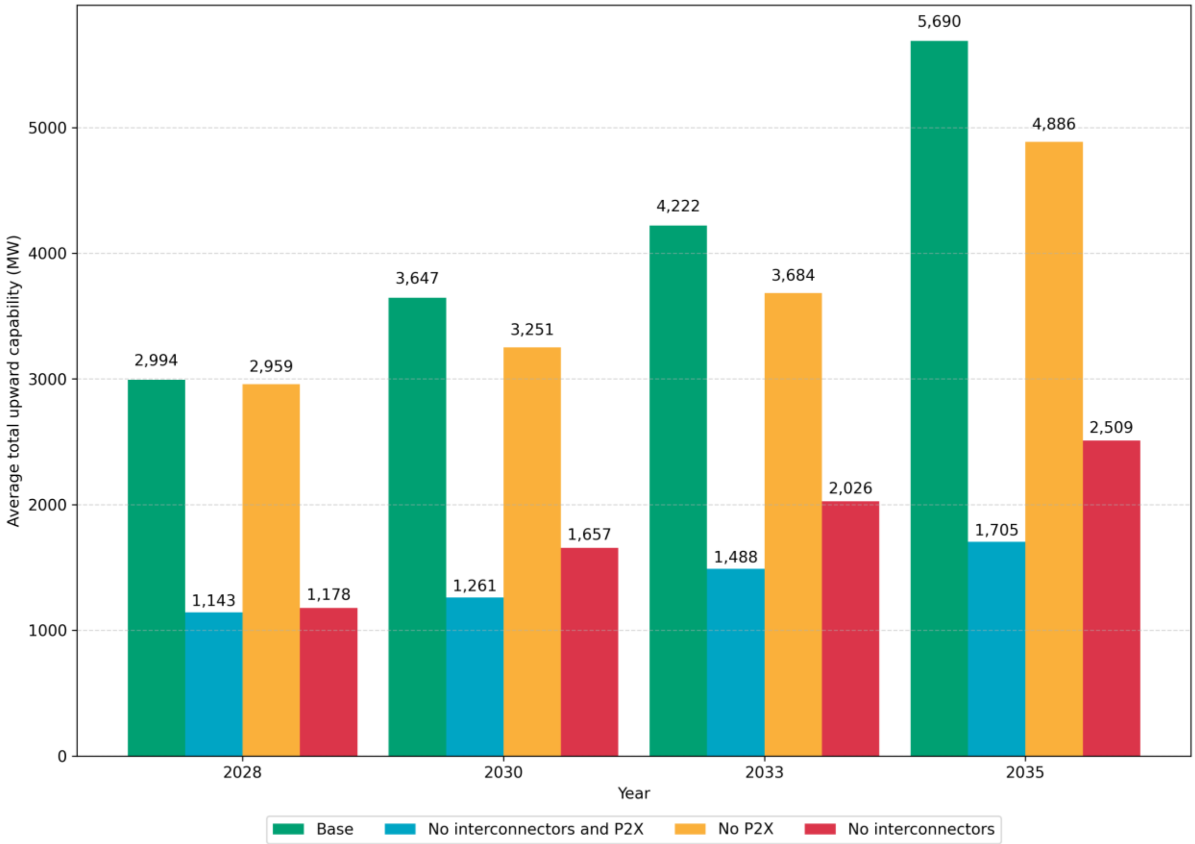

Figure 42 Average annual upward ramping capability by scenario and target year (MW)

In accordance with part 3 of Article 9 of the FNA methodology, the average system capability to cover downward ramping needs was assessed. This indicator reflects the system's ability to reduce generation or increase demand during periods when residual load becomes negative, indicating surplus RES generation. The results show that downward ramping capability remains significantly higher than upward capability in all analyzed years (see Fig. 44). In the basic scenario, downward capability increases from 5602 MW in 2028 to 9367 MW in 2035, highlighting the growing need to manage extended surplus RES-generation periods under high wind and solar conditions. The lowest values are again observed in the scenario without interconnectors and P2X technologies, confirming the importance of these resources for ensuring adequate system flexibility.

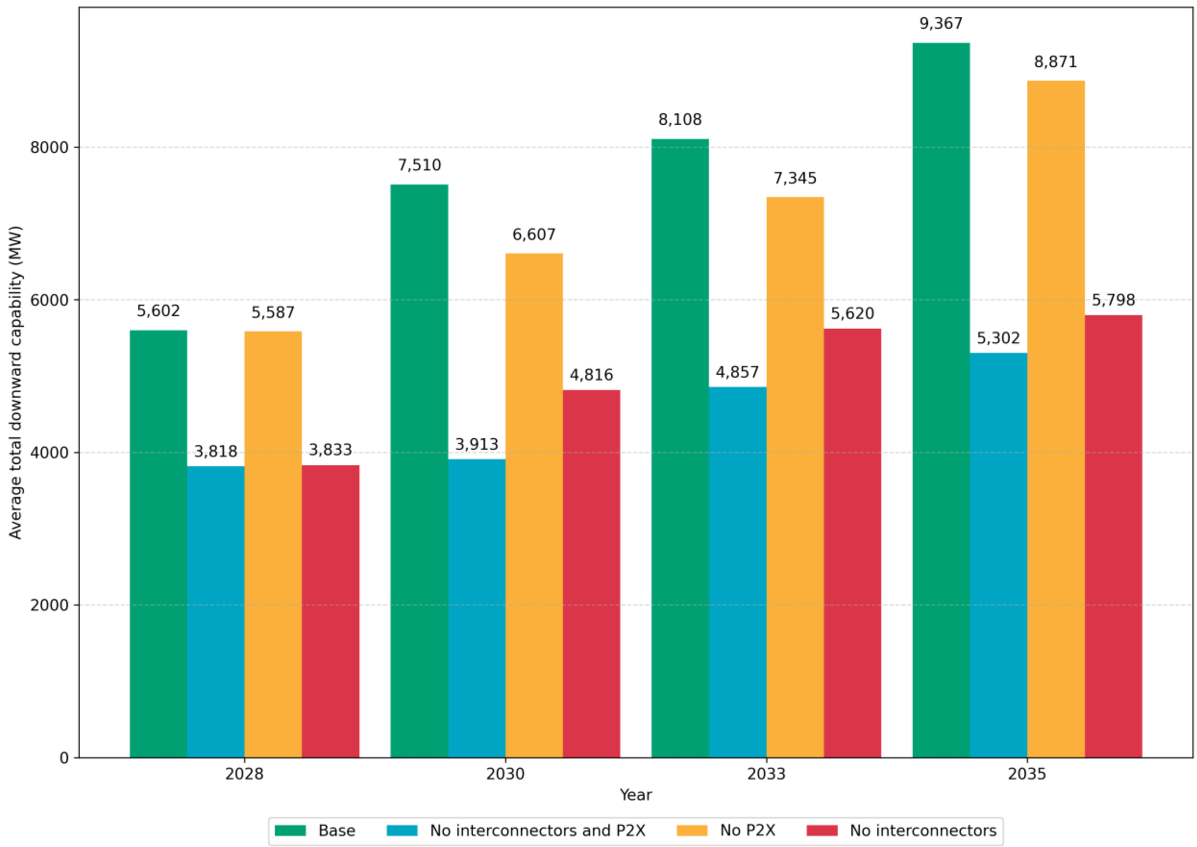

Figure 43 Average annual downward ramping capability by scenario and target year (MW)

In accordance with part 4 of Article 9 of the FNA methodology, the maximum uncovered upward ramping need was evaluated for each scenario and target year. This indicator shows the largest power deficit that occurs when the system's available upward ramping capability is insufficient to cover a sudden increase in residual load.

The results show (see figure below) that in both the basic scenario and the scenario without electrolysers, no uncovered upward ramping need is observed. Meanwhile scenarios without cross-border interconnectors exhibit a significant uncovered upward ramping needs: in the scenario without interconnectors and without P2X, the uncovered upward need reaches 673 MW in 2028 and increases to 826 MW in 2035, in the scenario without interconnectors but with P2X, the uncovered need ranges from 623 MW in 2028 to 542 MW in 2035. This confirms that cross-border interconnectors are a critical factor in covering the largest upward ramping needs.

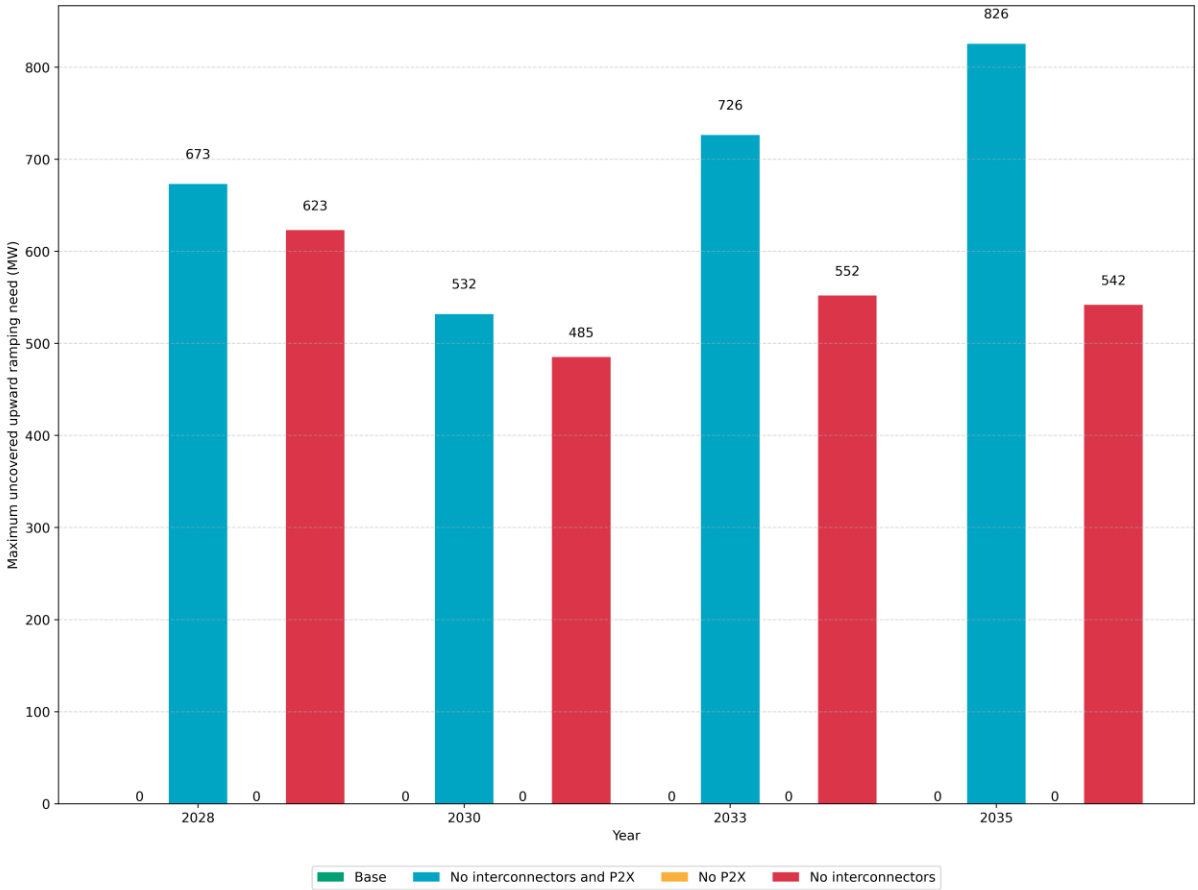

Figure 44 Maximum uncovered upward ramping need by target year and scenario (MW)

In accordance with part 5 of Article 9 of the FNA methodology, the maximum uncovered downward ramping need was assessed across all scenarios and target years. The results show (see figure below) that no uncovered downward ramping need occurs in any of the analyzed scenarios or years — the maximum value remains 0 MW throughout. This indicates that, in all modelled periods, the system had sufficient downward flexibility to manage decreases in residual load, either by reducing generation or increasing demand when surplus RES generation emerged.

Figure 45 Maximum uncovered downward ramping needs by target year and scenario (MW)

According to part 2 of Article 9 of the FNA methodology, the distribution of uncovered upward ramping needs was assessed across different scenarios and target years. The results show (see Figs. 47–54) that most uncovered upward ramping events remain relatively small, although flexibility shortages do occur during certain periods.

The largest uncovered upward ramping needs are observed in the scenarios without cross-border interconnectors and without P2X technologies, particularly during the 2033–2035 period. For example, in 2035 the maximum uncovered upward ramping need reaches 826 MW in the scenario without interconnectors and P2X, but decreases to 542 MW in the scenario where P2X technologies are retained.

Meanwhile, the average values of uncovered upward ramping needs remain similar across scenarios. This indicates that P2X technologies and cross-border interconnectors primarily help reduce rare but system-critical flexibility shortage events under conditions of high RES generation.

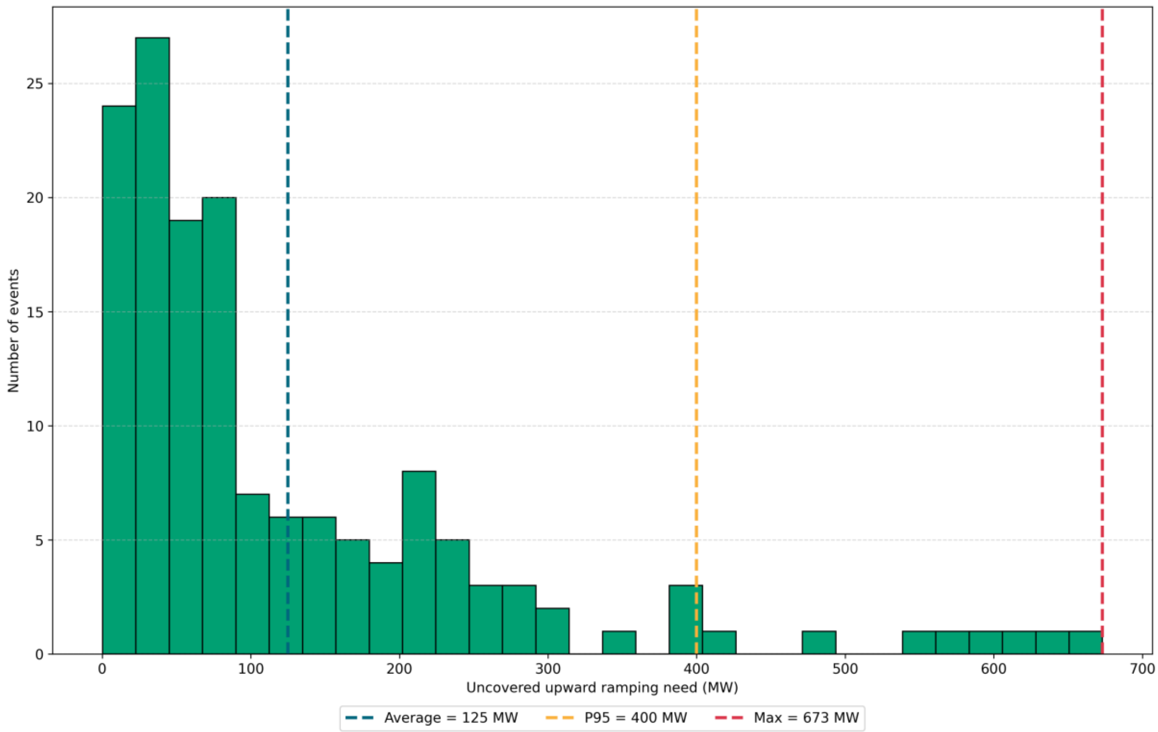

Figure 46 Distribution of uncovered upward ramping needs in the scenario without interconnectors and P2X [2028]

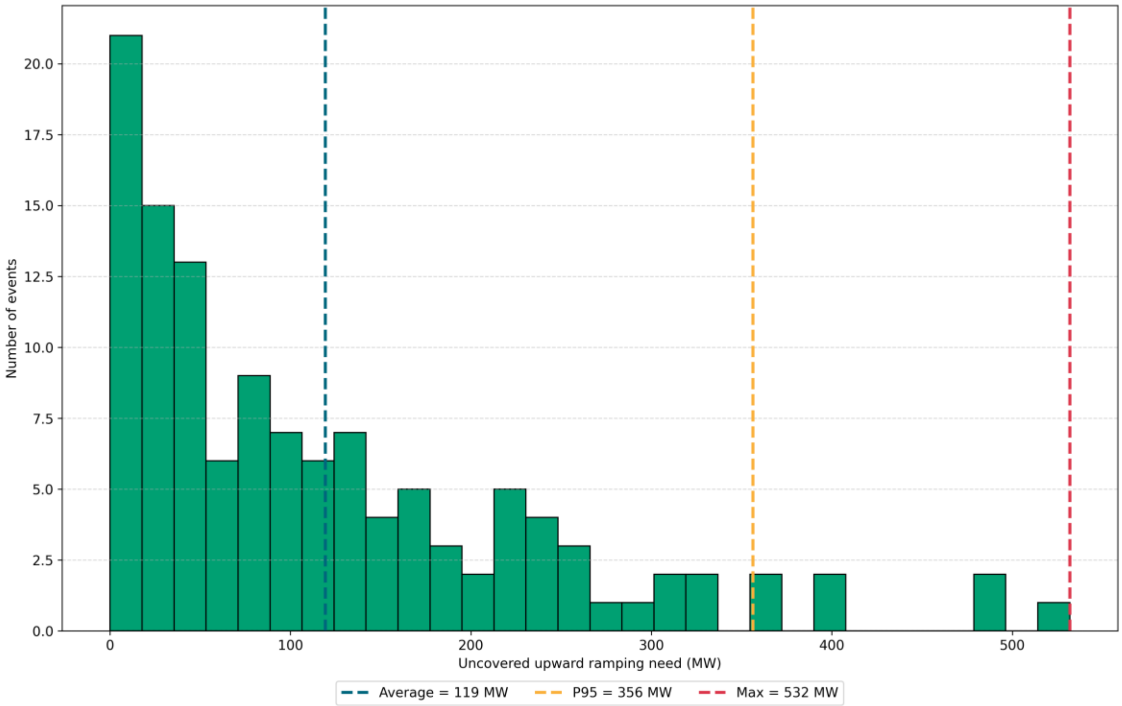

Figure 47 Distribution of uncovered upward ramping needs in the scenario without interconnectors and P2X [2030]

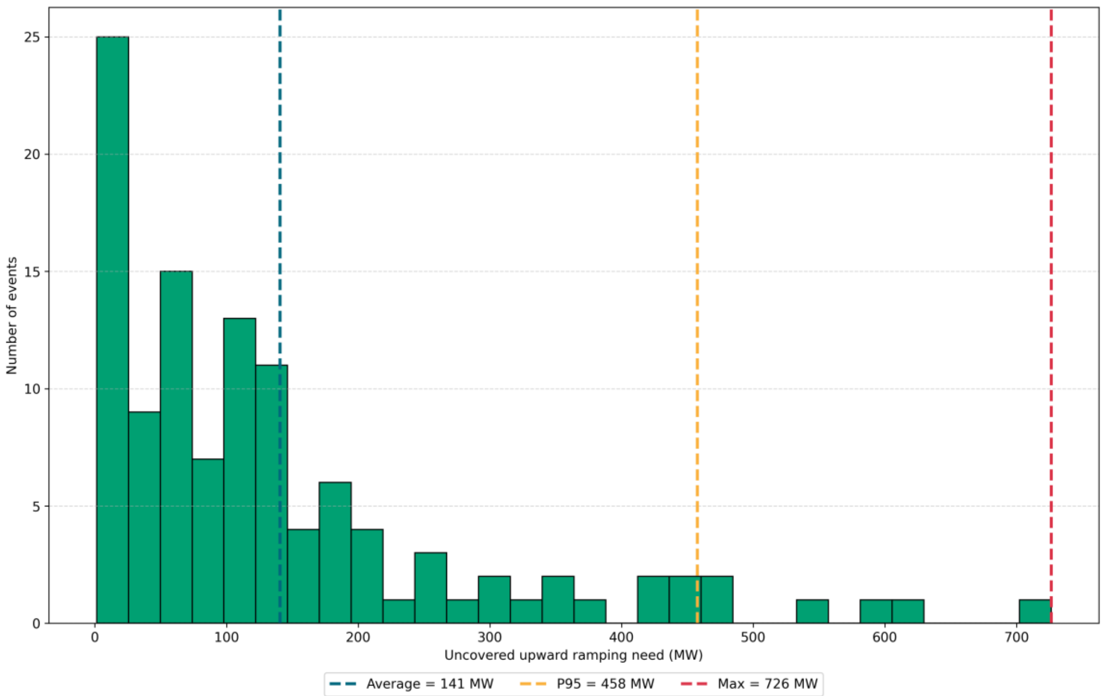

Figure 48 Distribution of uncovered upward ramping needs in the scenario without interconnectors and P2X [2033]

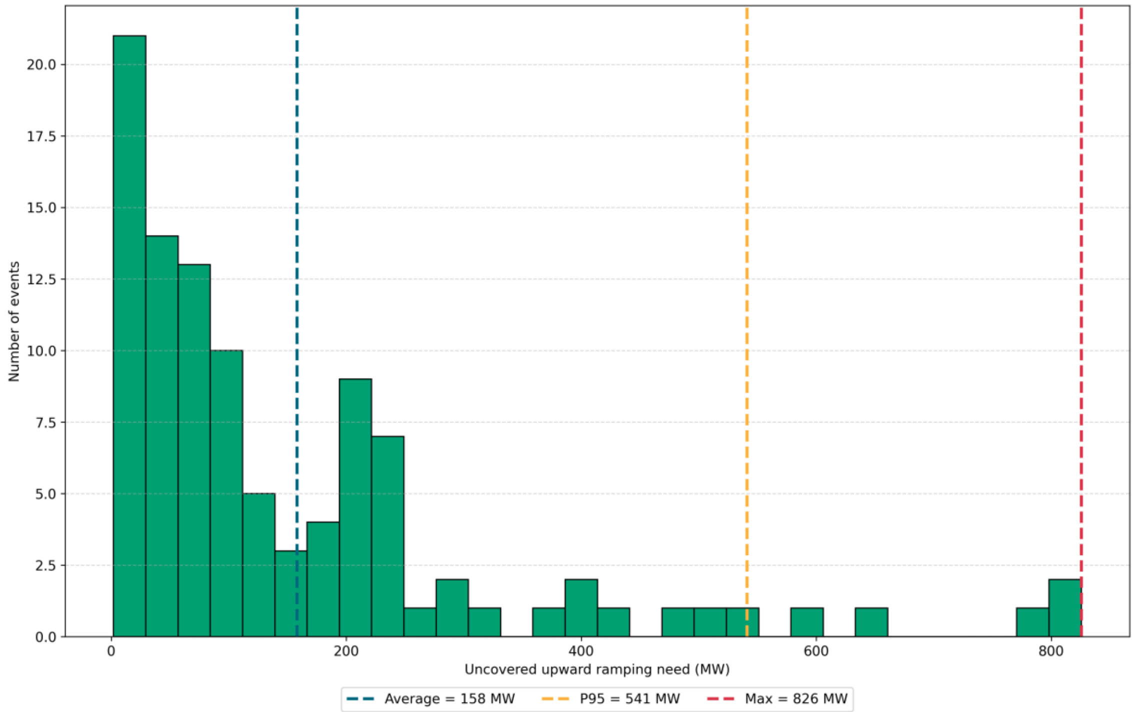

Figure 49 Distribution of uncovered upward ramping needs in the scenario without interconnectors and P2X [2035]

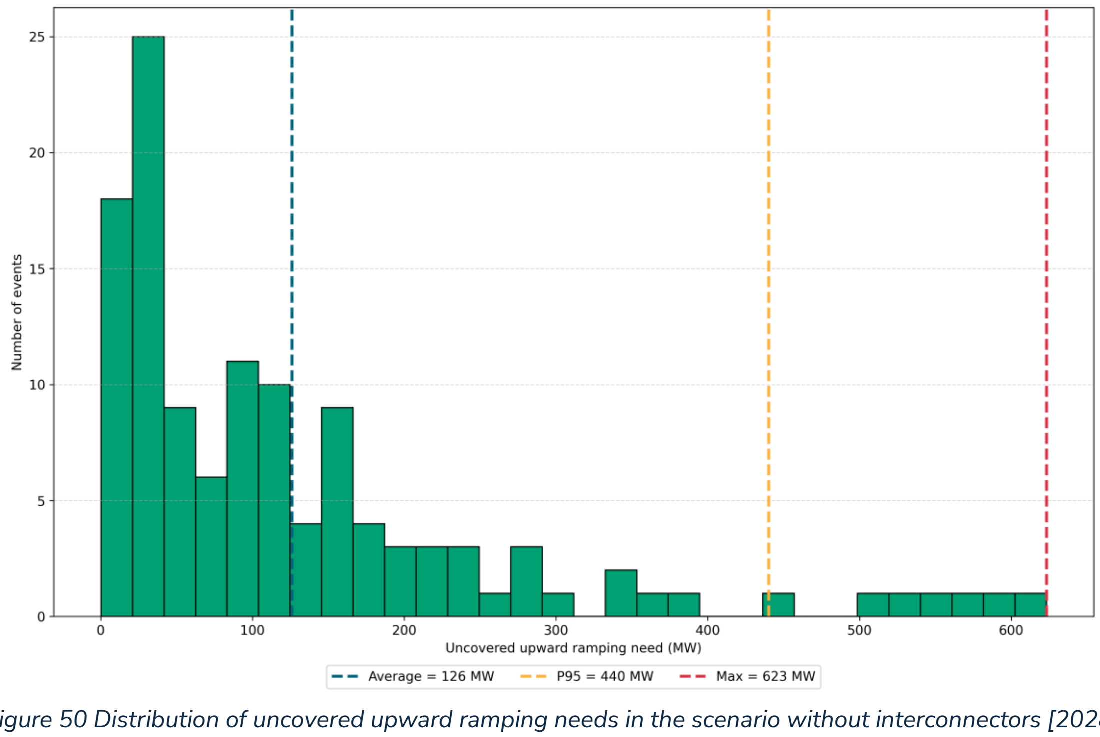

Figure 50 Distribution of uncovered upward ramping needs in the scenario without interconnectors [2028]

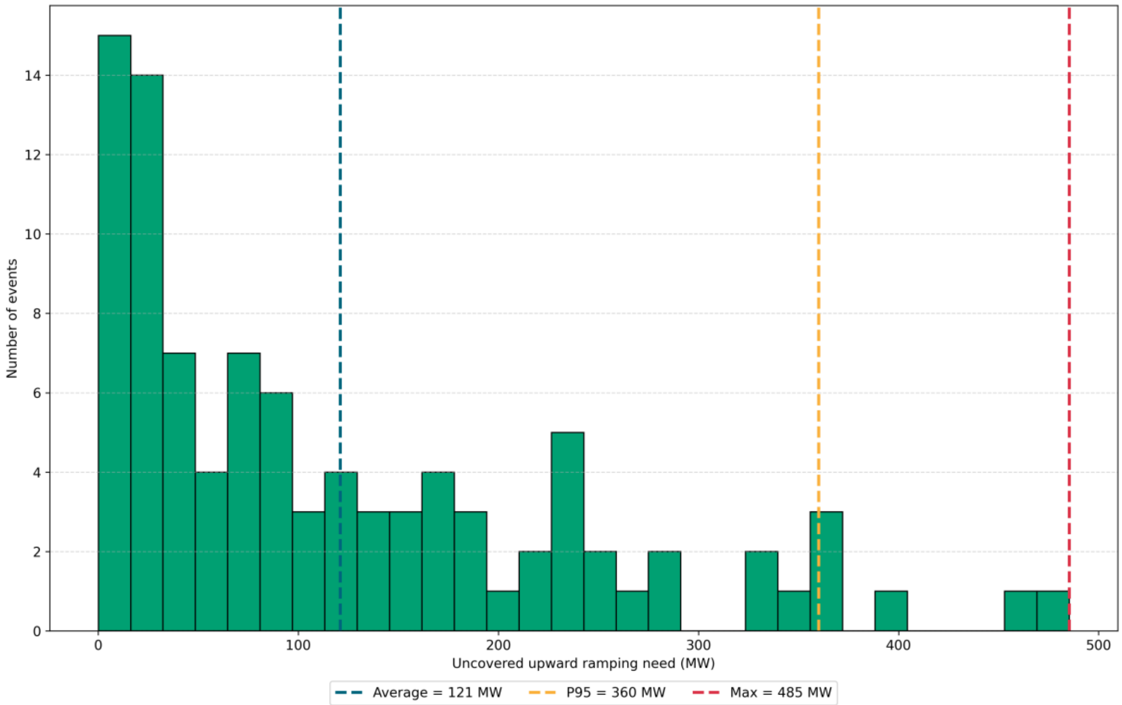

Figure 51 Distribution of uncovered upward ramping needs in the scenario without interconnectors [2030]

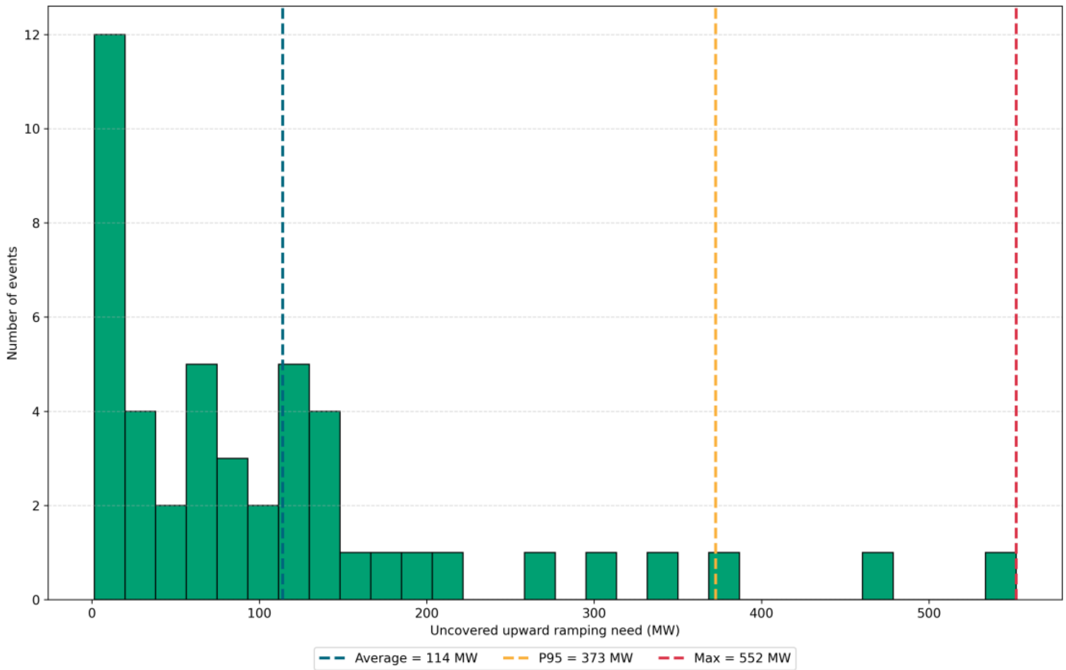

Figure 52 Distribution of uncovered upward ramping needs in the scenario without interconnectors [2033]

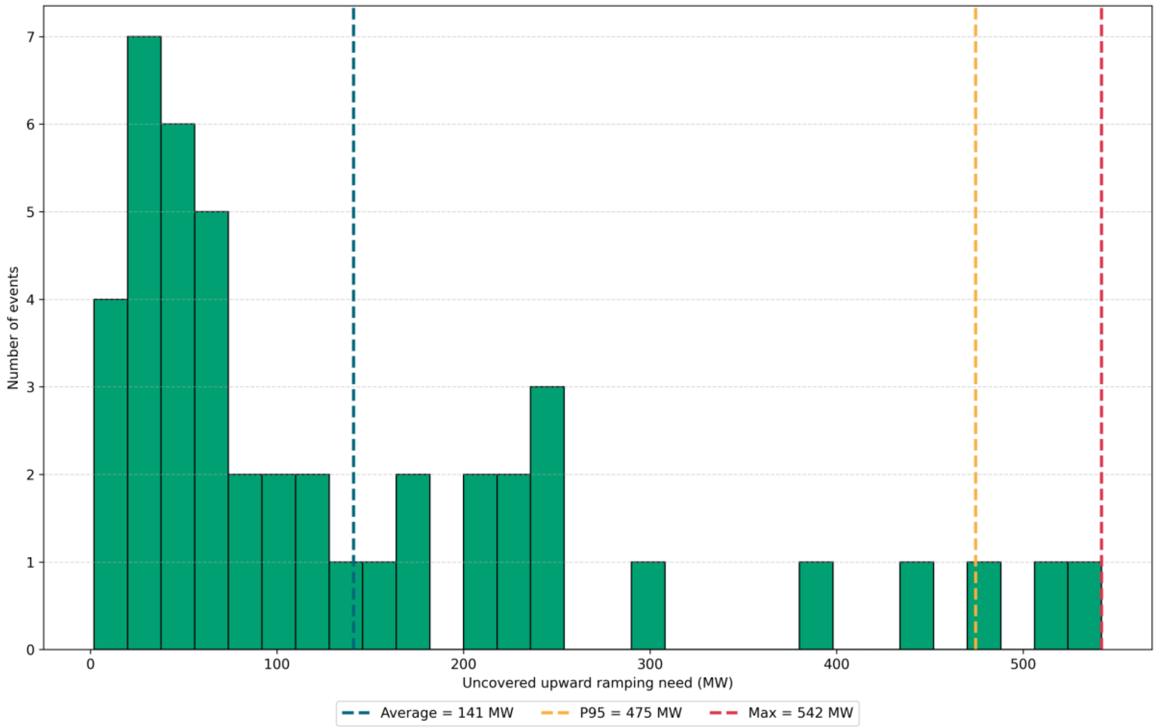

Figure 53 Distribution of uncovered upward ramping needs in the scenario without interconnectors [2035]

6.1.3. Short-term flexibility needs analysis

6.1.3.1. Short-term flexibility needs (10 str. (1))

Short-term flexibility needs describe the power system's ability to respond to differences between day-ahead forecasts of electricity demand and RES generation and the system's actual operation. Short-term flexibility needs, defined as the 0.1st and 99.9th percentiles of the forecasting-error distribution, are specified in Article 10(1) of the FNA methodology.

According to Section 5 of this report and the method described in part 1 of Article 10 of the FNA methodology, the received short-term flexibility needs are presented in Fig. 55

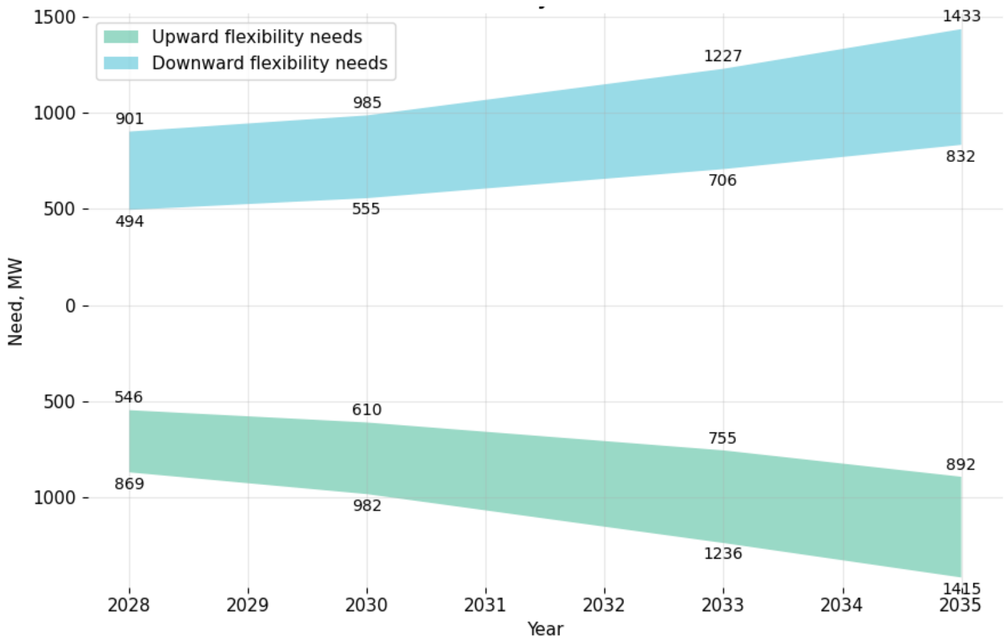

Figure 54 Short-term flexibility need 2028-2035

Figure 55 shows a clear trend in flexibility needs in both directions over the 2028–2035 period. This indicates that short-term flexibility requirements increase as installed RES capacity and electricity consumption grow. Upward flexibility needs range from 546 to 869 MW in 2028 and rise to 892–1415 MW in 2035. Downward flexibility needs reach 494–901 MW in 2028 and increase to 832–1433 MW in 2035. The overall trend also shows that the interval between minimum and maximum values widens over time.

6.1.3.2. Short-term flexibility capacities (Art. 10(2, 3))

Short-term available flexibility (capacity) is identified as the residual amount of power remaining after D-1 market clearing that can meet the flexibility need, considering the technical constraints of generation, storage, and network elements. The calculation of short-term flexibility capacity is described in parts 2–3 of Article 10 of the FNA methodology. This residual power represents the flexibility available in the system that can be used to manage deviations, considering the current operational state of system assets. The residual power calculated under this provision does not reflect the overall short-term flexibility condition of the system — even if average flexibility appears sufficient relative to needs, the system may not be flexible at all times.

As specified in part 2(a) of Article 10 of the FNA methodology, downward flexibility can additionally be ensured by curtailing RES generation. The additional curtailment of RES resources is analyzed in Section 5 of this report.

table 16 Short-term flexibility resources

Technology	Average downward flexibility	Average upward flexibility
	2028	
LT–PL	52,85	247,15
LT–LV	920,48	963,52
LT–SE	794,87	605,13
P2X	35,04	14,96
BESS	916,09	606,83
KHAE	955,75	475,4
Thermal power plants	12,35	0,38
Offshore Wind Power Plants	0	0
Onshore Wind Power Plants	641,15	0
DSO solar power plants	0	0
TSO solar power plants	195,9	0
Other RES	31,68	0,14
	2030	
LT–PL	462,04	937,96
LT–LV	1256,01	627,99
LT–SE	975,91	424,09
P2X	396,36	903,64
BESS	1016,57	847,64
KHAE	821,46	332,3
Thermal power plants	20,29	0,55
Offshore Wind Power Plants	0	0
Onshore Wind Power Plants	733,7	0
DSO solar power plants	0	0
TSO solar power plants	215,51	0
Other RES	33,06	0
	2033	

LT–PL	587,54	812,46
LT–LV	1051,84	832,16
LT–SE	848,55	551,45
P2X	537,31	762,69
BESS	1266,06	1079,67
KHAE	820,79	330,78
Thermal power plants	20,6	0,32
Offshore Wind Power Plants	179,2	0
Onshore Wind Power Plants	828,32	0
DSO solar power plants	0	0
TSO solar power plants	252,29	0
Other RES	32,98	0,01
	2035	
LT–PL	461,57	938,43
LT–LV	2276,06	1673,94
LT–SE	831,23	568,77
P2X	804,36	495,64
BESS	1327,82	1106,74
KHAE	893,48	368,09
Thermal power plants	13,45	0,14
Offshore Wind Power Plants	307,9	0
Onshore Wind Power Plants	890,76	0
DSO solar power plants	0	0
TSO solar power plants	278,22	0
Other RES	32,43	0,04

During the analyzed 2028–2035 period, the short-term flexibility potential in the system increases, but its structure remains across flexibility directions and technologies. Downward flexibility potential is mainly provided by cross-border interconnectors, storage units, KHAE, and RES curtailment capabilities — particularly onshore wind, TSO-connected solar, and, from 2033 onwards, offshore wind. upward flexibility potential is primarily associated with cross-border interconnectors, demand-side response units, and KHAE. The values presented in the table should be interpreted as the calculated potential flexibility available after D-1 market clearing, rather than as capacity guaranteed to be available at the moment of need. The actual utilization of this potential in specific periods depends on the technical constraints of generation, storage, and network elements, asset availability, market outcomes, and the system operating state. Therefore, even with sufficient average flexibility potential, short-term flexibility shortages may still occur during certain hours.

6.1.3.3. Analysis of uncovered short-term flexibility needs (Art. 10(4))

The analysis of uncovered short-term flexibility needs makes it possible to assess not only the existence of flexibility capacities, but also their magnitude, interaction with the energy market, and temporal distribution.

According to Article 10(6) of the FNA methodology, the analysis of uncovered flexibility needs must be carried out across the following dimensions:

1) Average power per uncovered-need event (MW);
2) Distribution of uncovered-need power;

3) Total expected amount of uncovered energy (MWh);
4) Expected number of hours with uncovered needs;
5) Time distribution of uncovered needs;
6) Distribution of uncovered energy (MWh);
7) Correlation with system conditions.

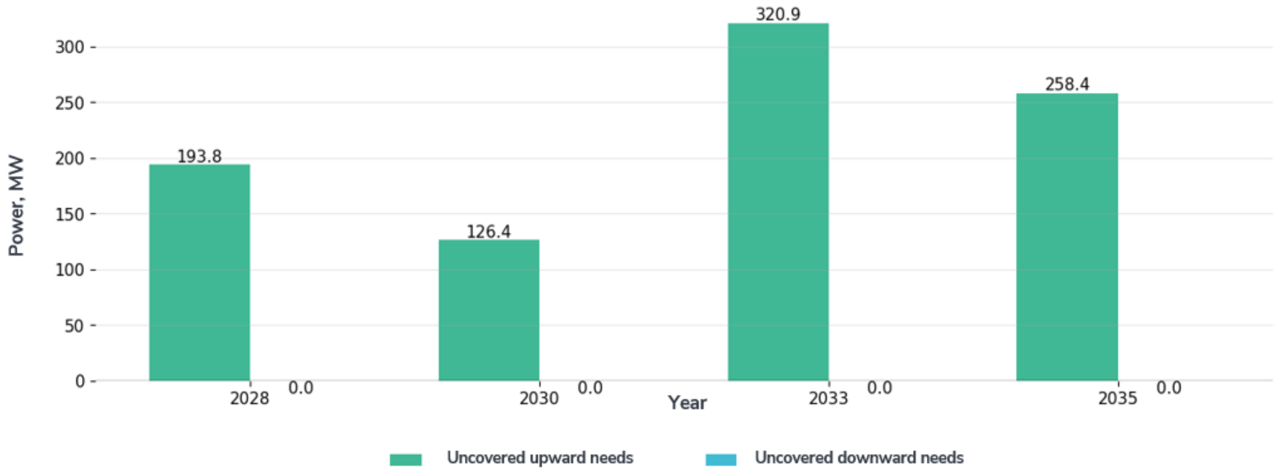

Figure 55 Average uncovered power during an event in which short-term flexibility is insufficient

The graph in Fig. 56 indicates that in all analyzed years, uncovered short-term flexibility needs arise only in the upward direction. The highest average uncovered power per event is observed in 2033, reaching 320,9 MW, while the lowest value appears in 2030 at 126,4 MW. The difference between 2028, 2030, and 2033 can be explained by the input data: the volume of flexible resources (BESS, P2X and cross-border capacities) increased proportionally more than the drivers of short-term flexibility needs (load and RES generation). Between 2028 and 2030, installed BESS and P2X capacity increased by 1,49 GW, whereas installed RES capacity grew by only 0,38 GW. The opposite situation emerges when comparing 2030 and 2033: RES capacity increases by 2,09 GW, while the amount of flexibility resources grows by just 0,9 GW..

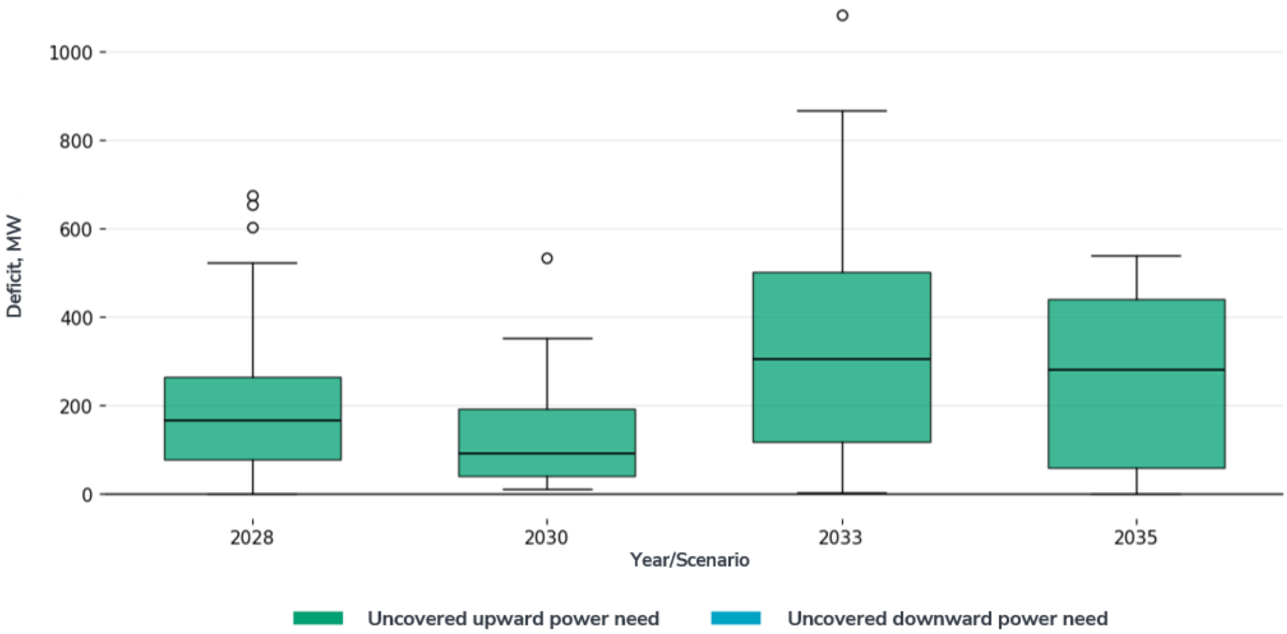

Figure 56 Distribution of uncovered-need power

The graph in Fig. 57 illustrates the distribution of uncovered short-term upward flexibility needs across the analyzed years. It is evident that in 2030 the magnitudes of uncovered needs are the smallest and are more concentrated in the lower range, indicating a comparatively limited short-term flexibility deficit. In contrast, 2033 exhibits the widest spread of values and the highest individual deficit events, exceeding 1000 MW. This difference can be explained by the fact that between 2030 and 2033 the growth of installed RES capacity is significantly faster than the expansion of additional flexibility resources. As forecasting errors and unexpected residual-load variations increase, the available flexibility becomes insufficient to cover all upward short-term flexibility needs. In 2035 the distribution remains relatively broad, but extreme deficit events become less frequent, likely due to continued growth in flexible resources and only moderate changes in RES generation and demand.

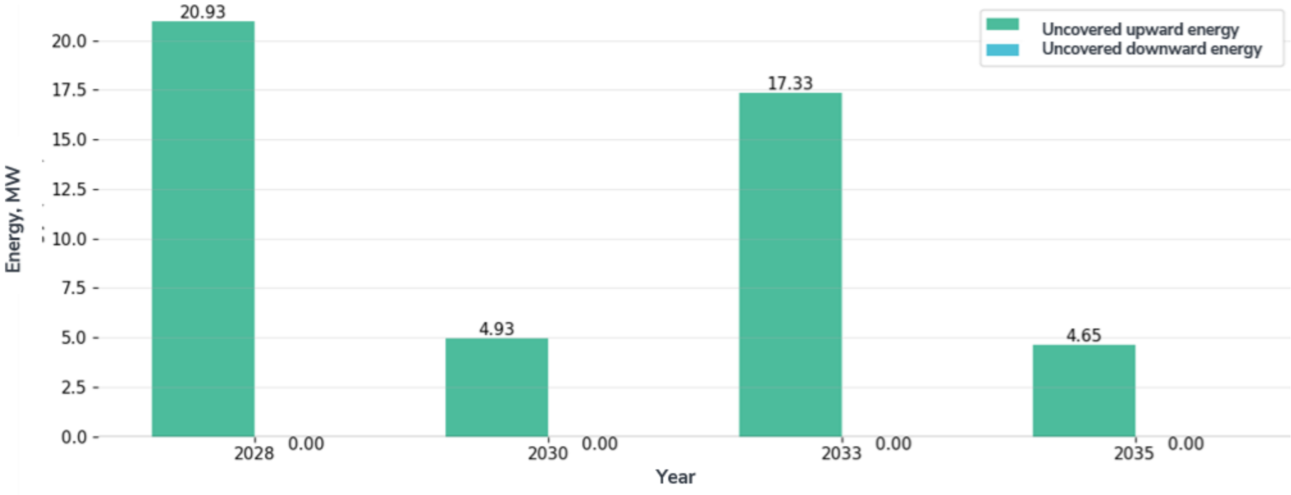

Figure 57 Total expected amount of uncovered short-term flexibility energy

The graph in Fig. 58 presents the total expected amount of uncovered energy resulting from insufficient short-term flexibility. The largest volume of uncovered energy is observed in 2028, reaching 20,93 GWh, while in 2033 it remains significant at 17,33 GWh. In contrast, the uncovered energy in 2030 and 2035 is substantially lower — 4,93 GWh and 4,65 GWh respectively. This outcome indicates that the magnitude of uncovered power alone does not determine the total amount of uncovered energy; the frequency and duration of events are equally important. The high uncovered energy volume in 2028 can be attributed to the still-limited availability of flexible resources in the system, whereas the increase in 2033 is linked to the rapid growth of installed RES capacity, which outpaces the expansion of additional flexibility resources.

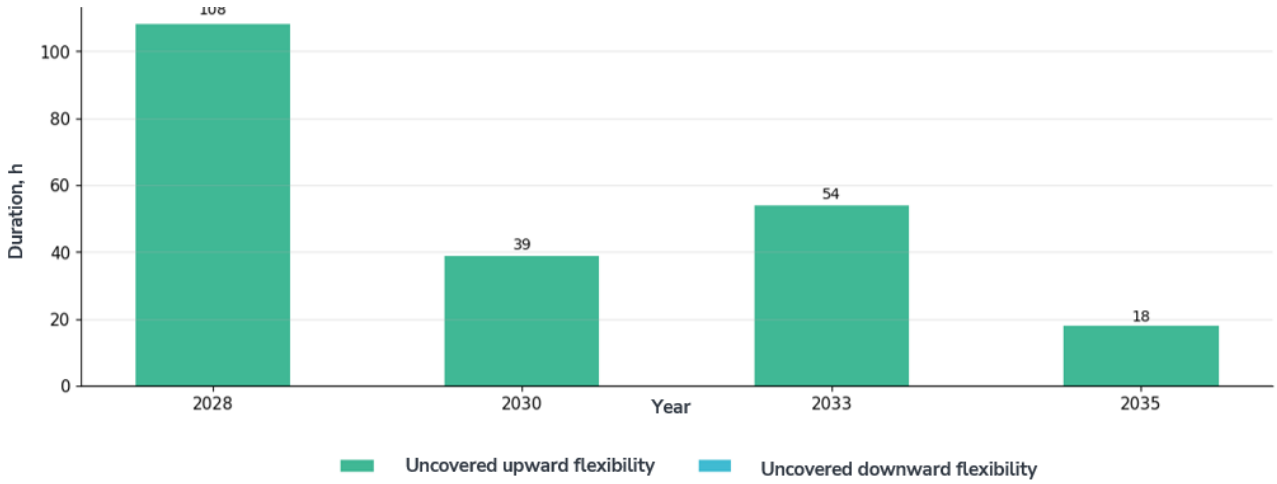

Figure 58 Expected number of hours with uncovered short-term flexibility needs per year

The graph in Fig. 59 presents the number of hours during which uncovered short-term flexibility needs occurred. The highest number of hours is recorded in 2028 — 108 h — while the lowest appears in 2035 at 18 h. In 2030 this indicator decreases to 39 h, but in 2033 it rises again to 54 h. This dynamic reflects changes in the input data: between 2028 and 2030 the expansion of flexibility resources outpaces the growth of RES and demand, resulting in fewer hours with uncovered needs. In contrast, between 2030 and 2033 the increase in installed RES capacity becomes more rapid, leading to higher short-term flexibility requirements and more frequent intervals in which part of these needs remain uncovered.

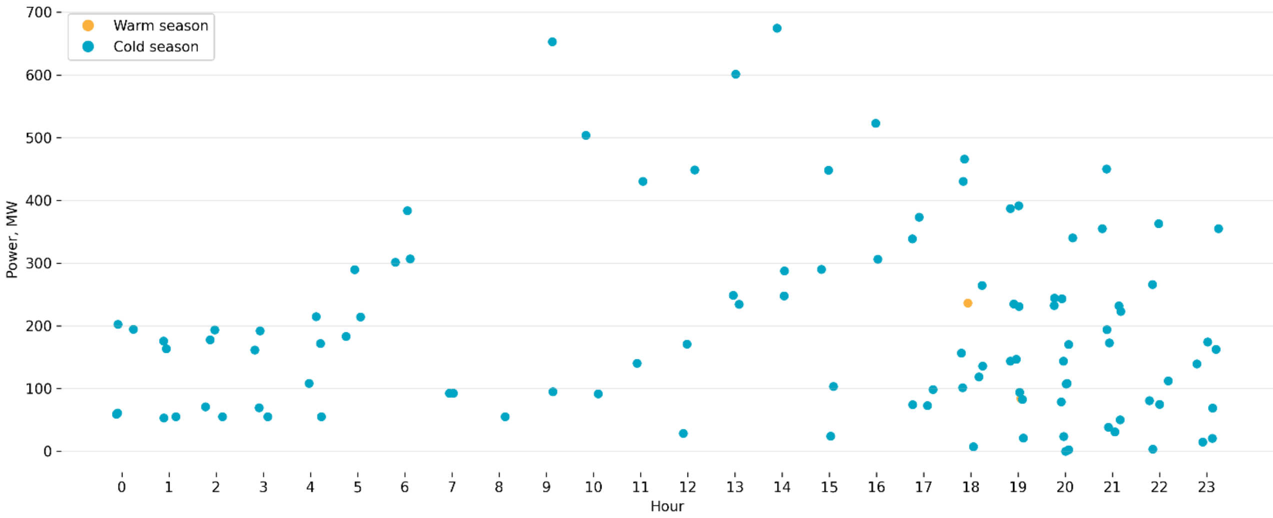

Figure 59 Distribution of uncovered needs by hour in 2028

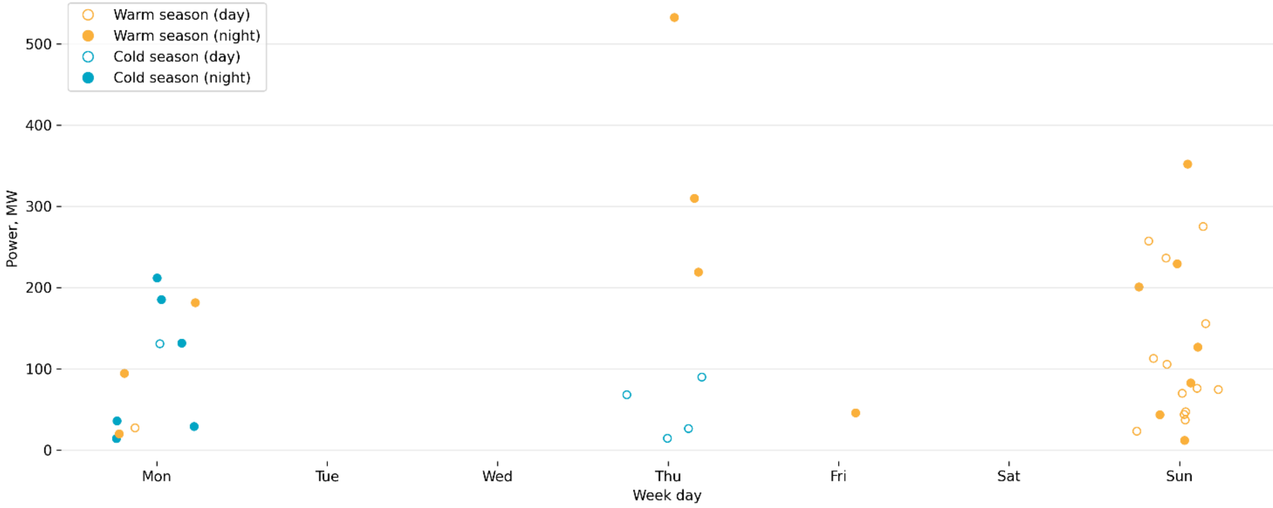

Figure 60 Distribution of uncovered needs by hour in 2030

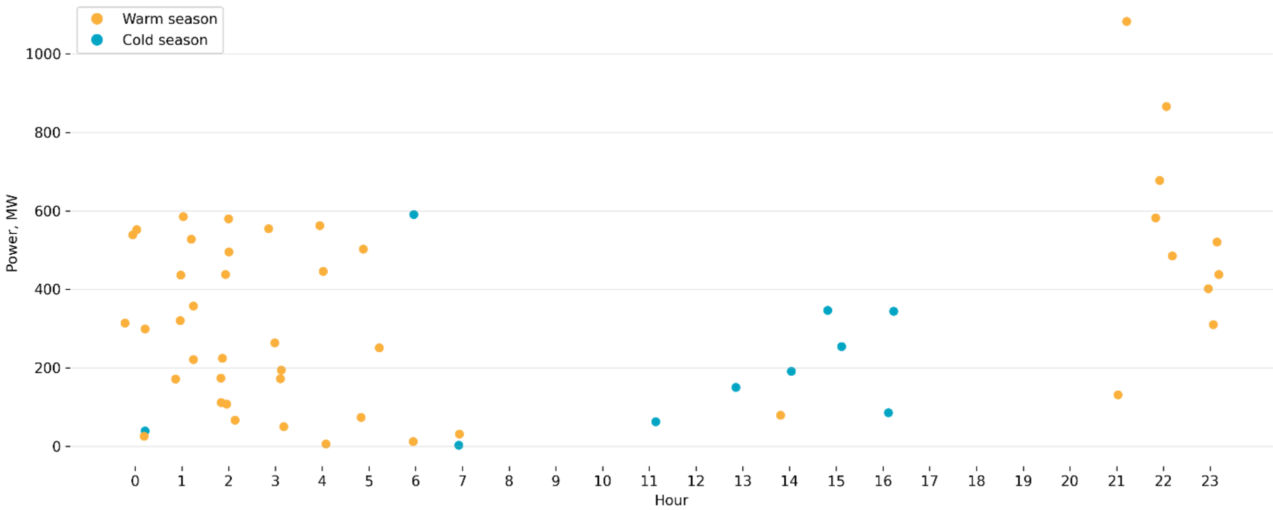

Figure 61 Distribution of uncovered needs by hour in 2033

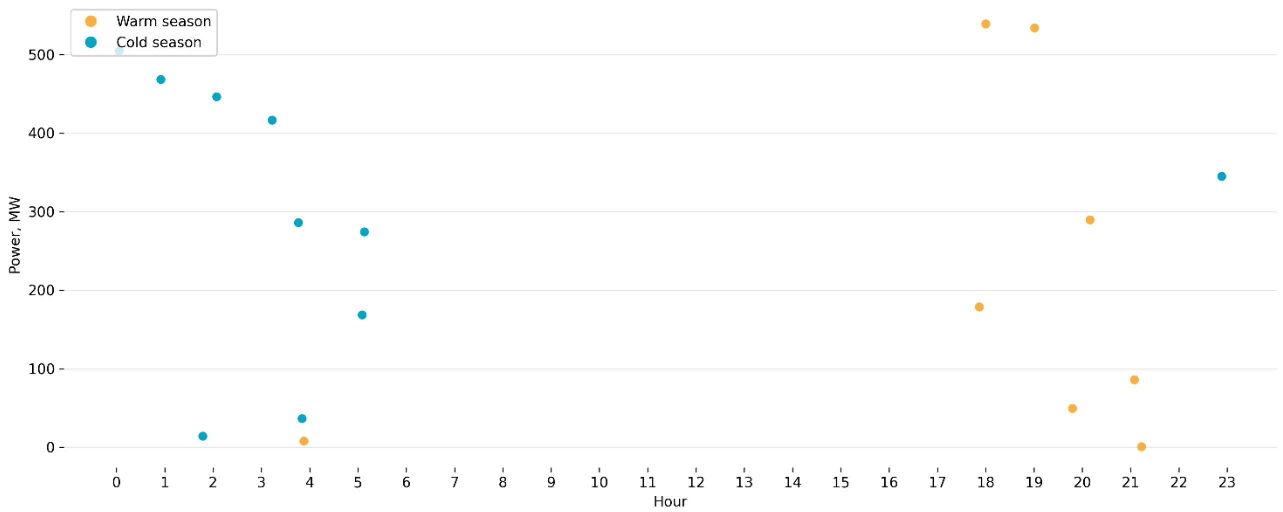

Figure 62 Distribution of uncovered needs by hour in 2035

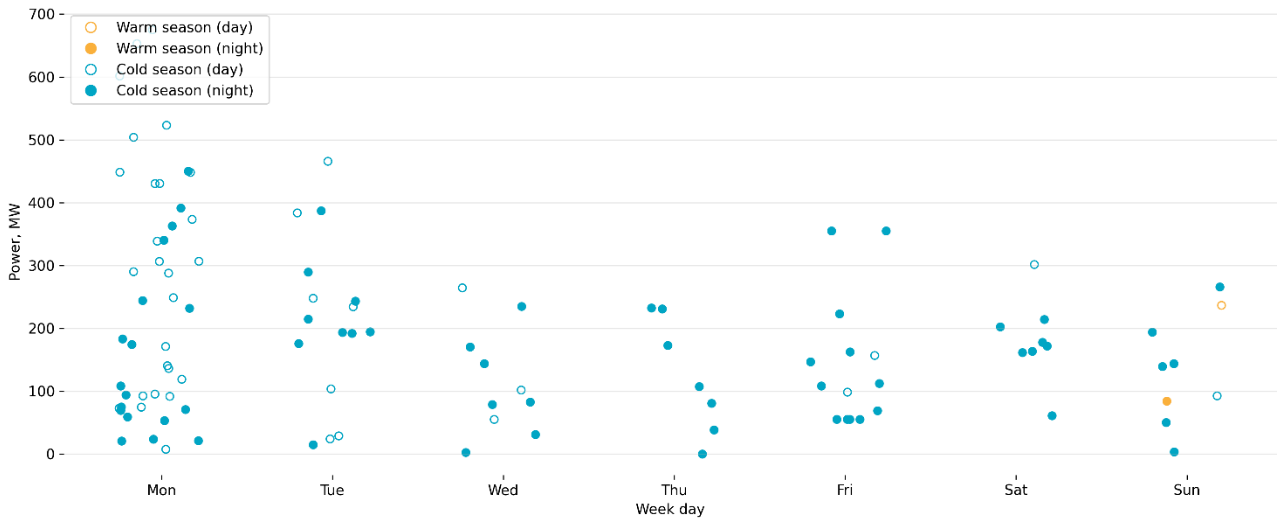

Figure 63 Distribution of uncovered needs by weekdays in 2028

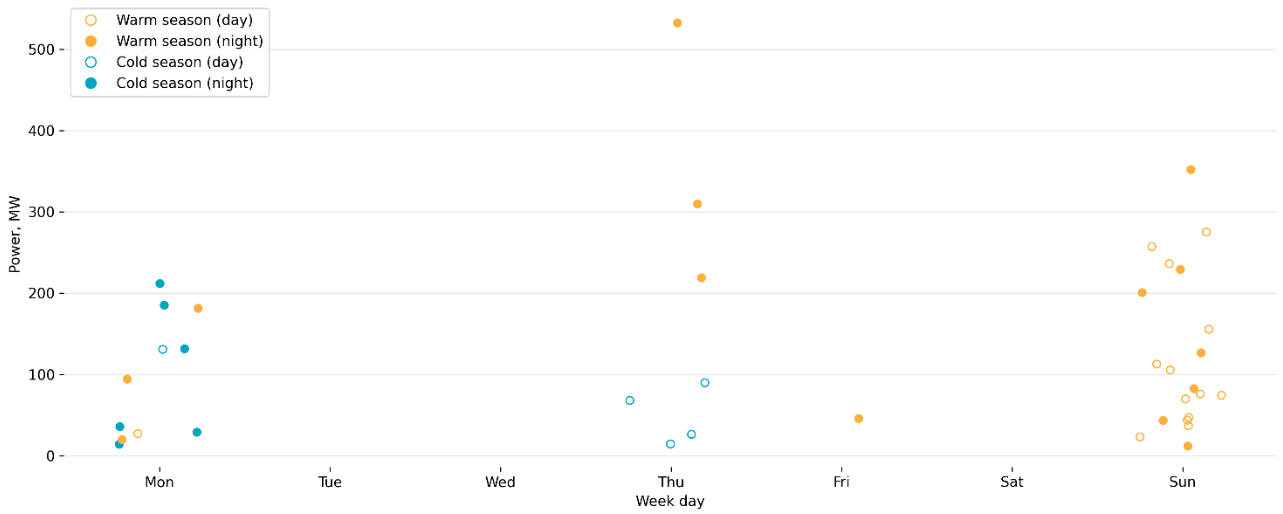

Figure 64 Distribution of uncovered needs by weekdays in 2030

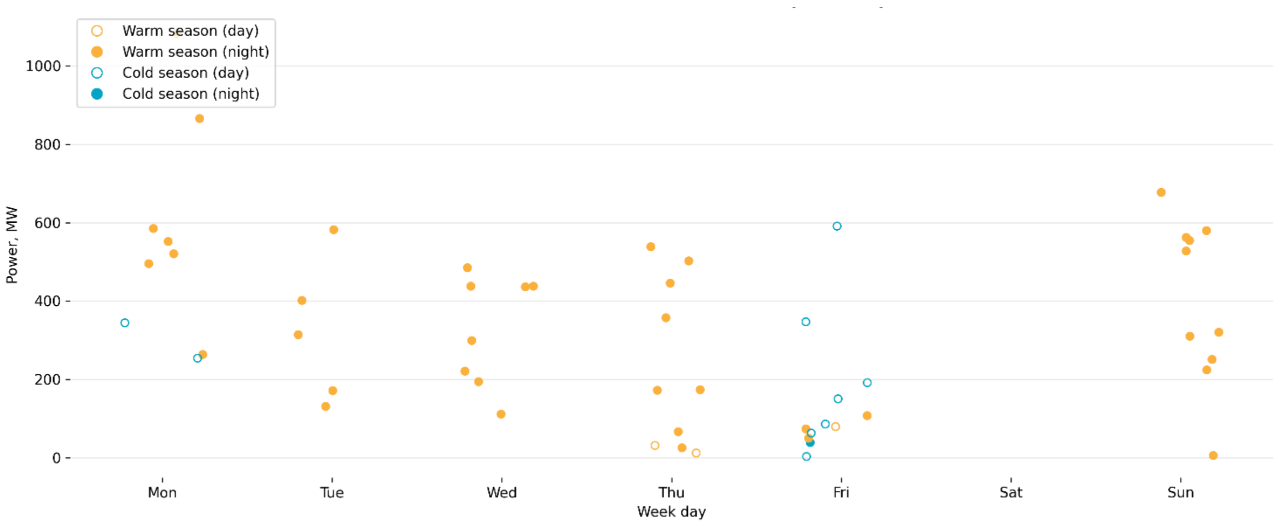

Figure 65 Distribution of uncovered needs by weekdays in 2033

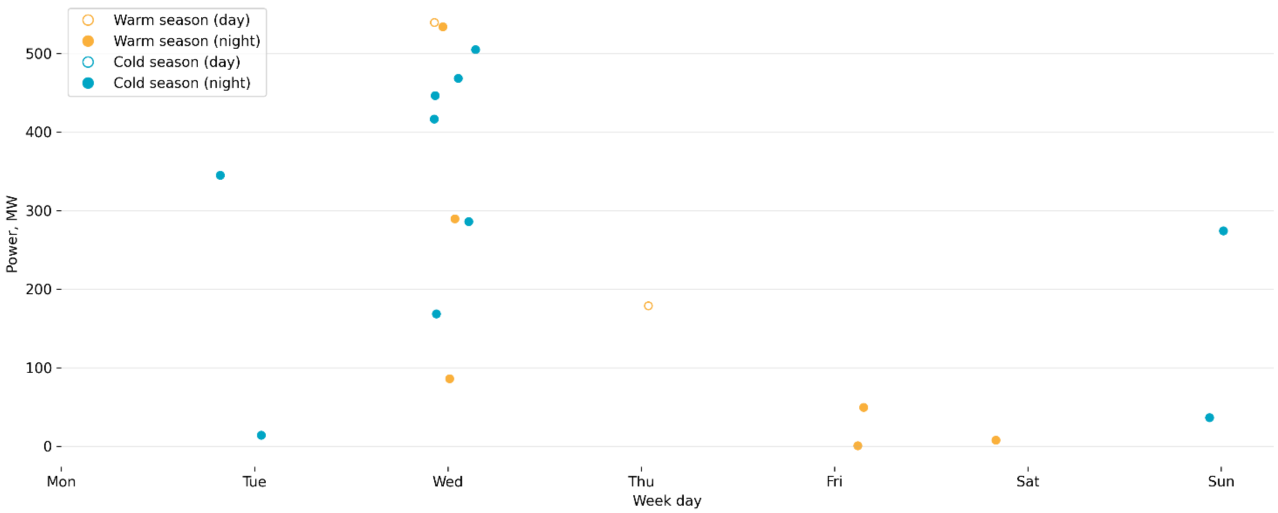

Figure 66 Distribution of uncovered needs by weekdays in 2035

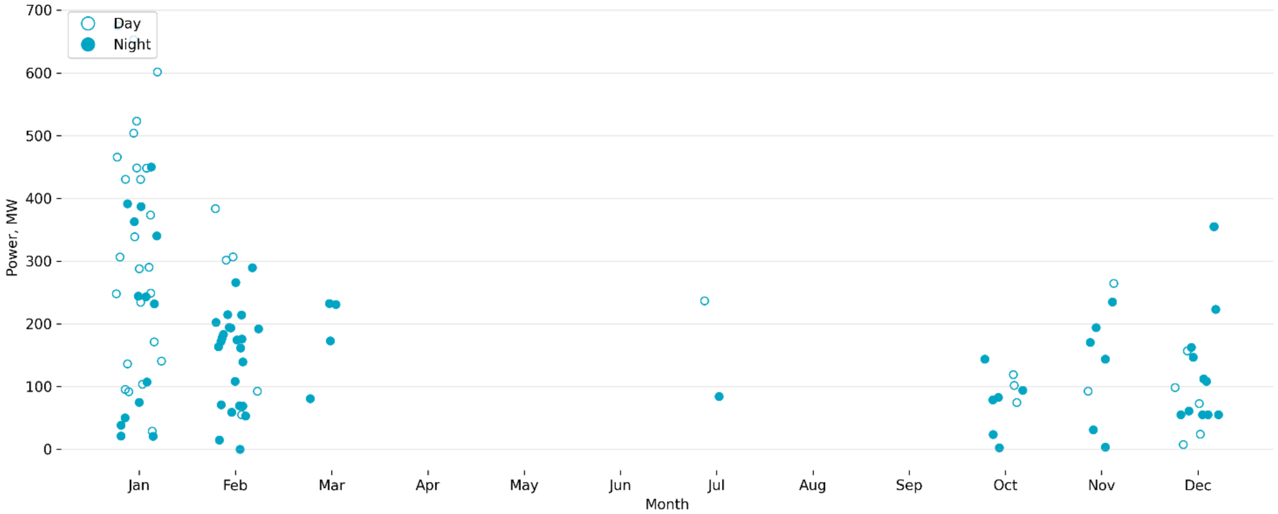

Figure 67 Distribution of uncovered needs by month in 2028

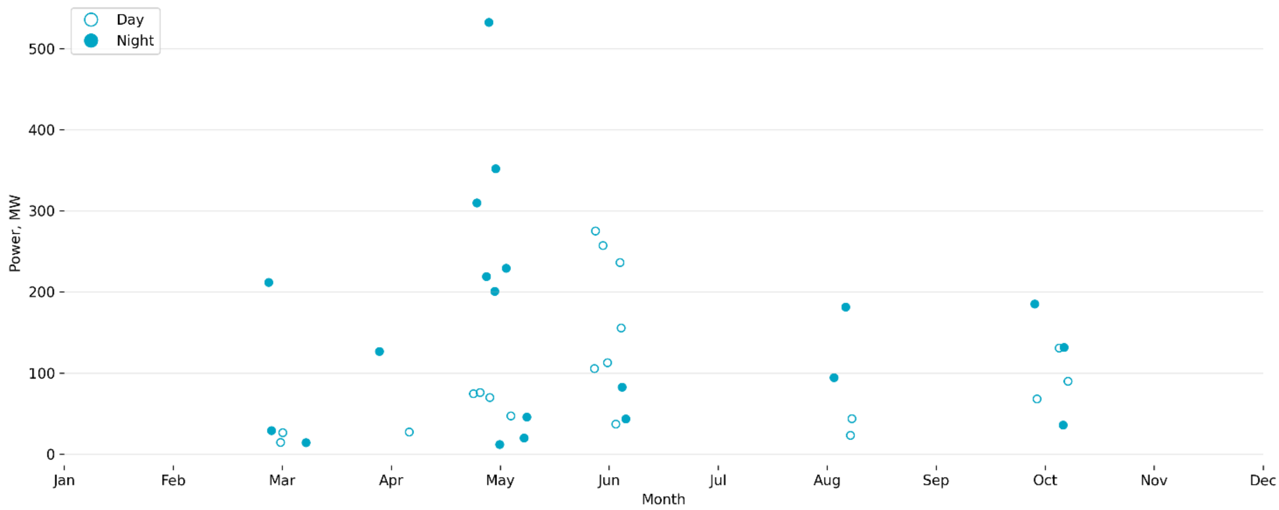

Figure 68 Distribution of uncovered needs by month in 2030

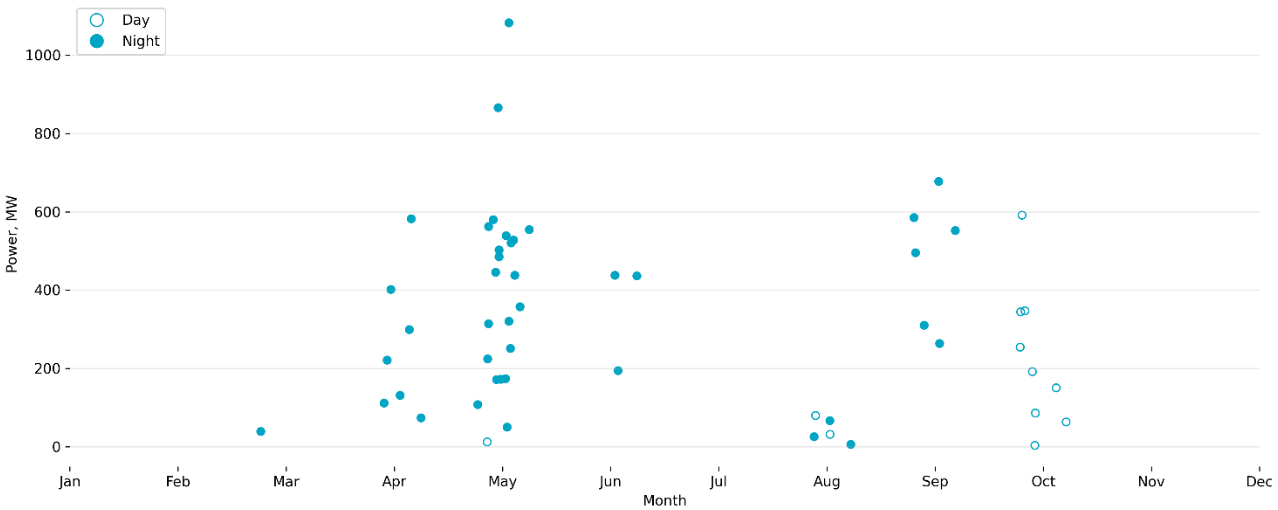

Figure 69 Distribution of uncovered needs by month in 2033

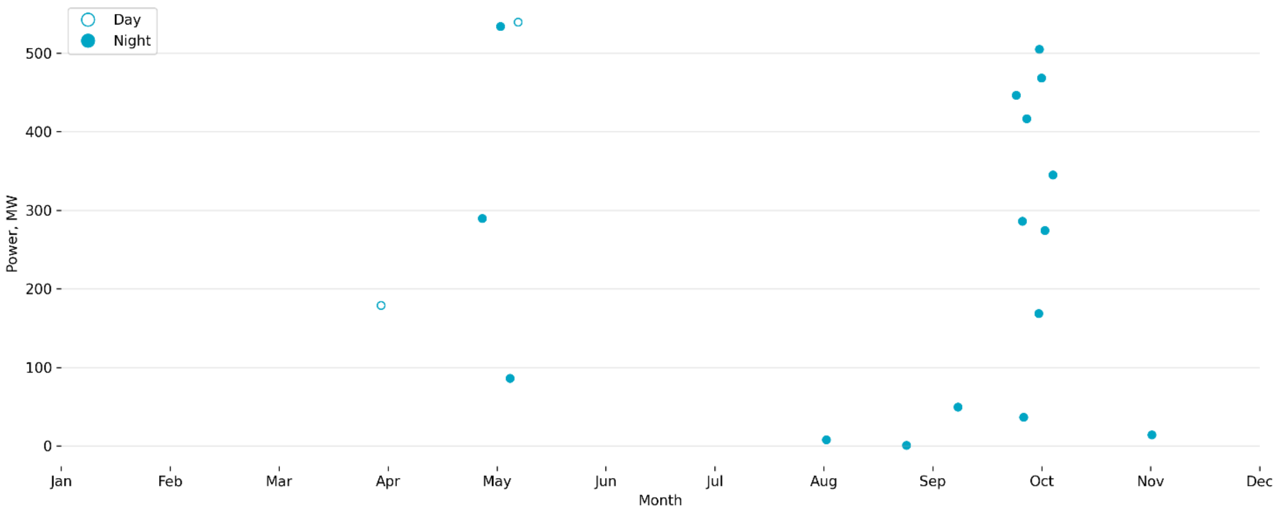

Figure 70 Distribution of uncovered needs by month in 2035

In 2028, uncovered needs arise mainly during the cold season. They appear across various hours of the day, but higher-magnitude events are more common during daytime and evening periods. Among weekdays, Monday stands out most clearly, while in terms of months, January, February, and parts of late autumn / winter dominate. This indicates that in 2028 the flexibility deficit is more linked to cold-season system conditions.

In 2030, there are fewer needs, but their format changes - a larger part of the unmet needs is seen in the warm season. The most prominent episodes occur in the early morning, daytime, and evening hours. Among weekdays, Sunday stands out, while in terms of months, May, June, and September dominate. This indicates that the flexibility deficit increasingly relates to RES generation variability and warm-season balancing conditions.

In 2033, the largest uncovered flexibility needs are recorded, with individual events exceeding 1 GW. In terms of hourly distribution, the most prominent periods are night and early morning as well as the evening hours, particularly around 21:00–23:00. Monthly patterns show a strong concentration in May, with additional occurrences in April, September, and October. This indicates that in 2033 the short-term flexibility deficit becomes the most pronounced both in magnitude and in its temporal spread.

In 2035, the number of uncovered flexibility events decreases, however, individual episodes remain significant. Two main groups can be observed: cold-season needs occurring during early-morning hours, and warm-season needs emerging in the evening. In terms of monthly distribution, most events appear in May and September. This suggests that in 2035 the issue becomes less frequent but does not disappear entirely.

In general, Fig. 60 - Fig. 71 show that in 2028, uncovered needs are more typical of the winter period, in 2030–2033 they move to the warm and transitional seasons. In 2035, the situation improves, but separate events of greater power remain.

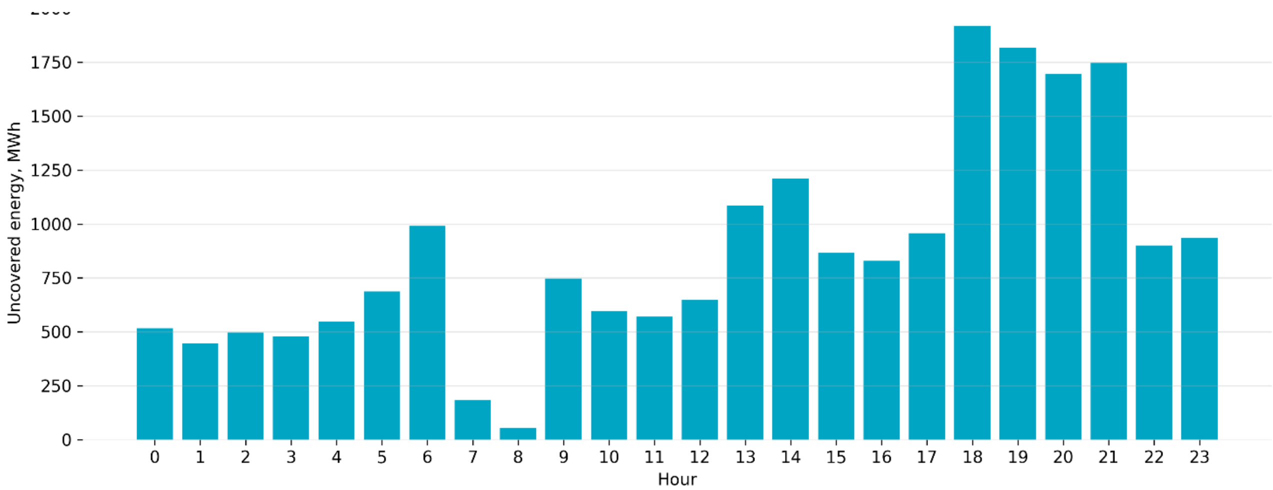

Figure 71 Distribution of uncovered energy by hour in 2028

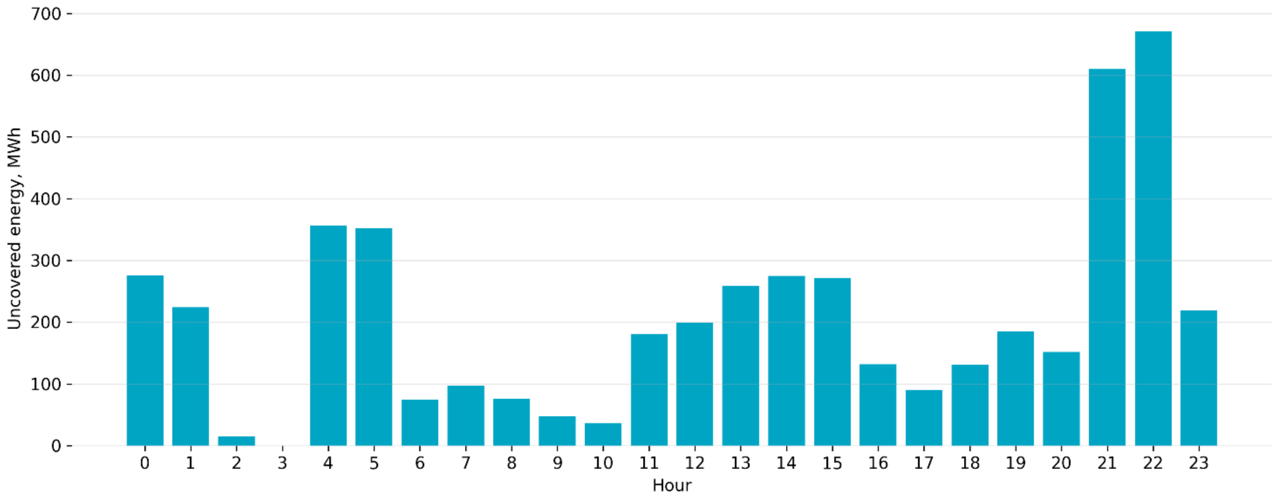

Figure 72 Distribution of uncovered energy by hour in 2030

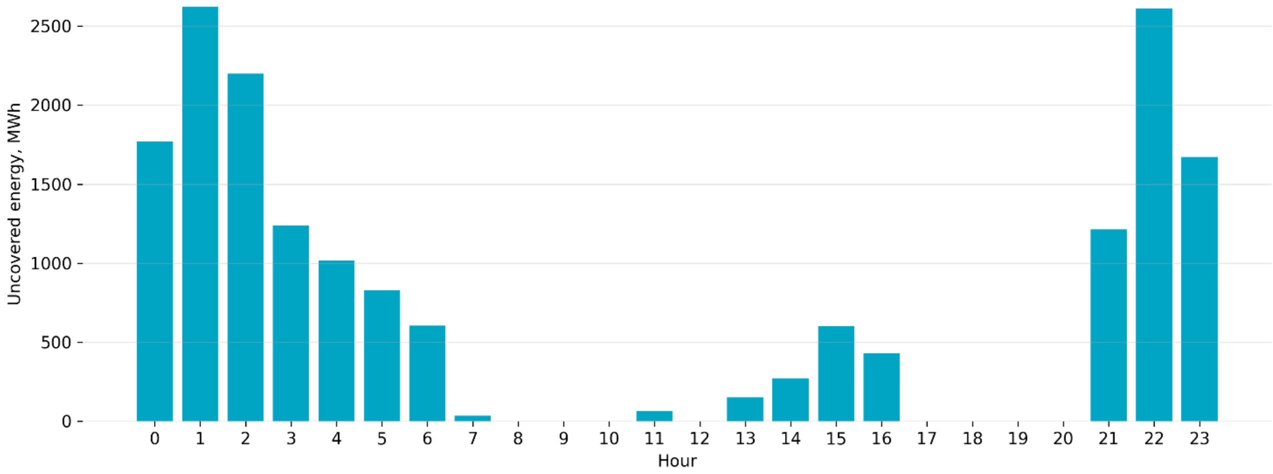

Figure 73 Distribution of uncovered energy by hour in 2033

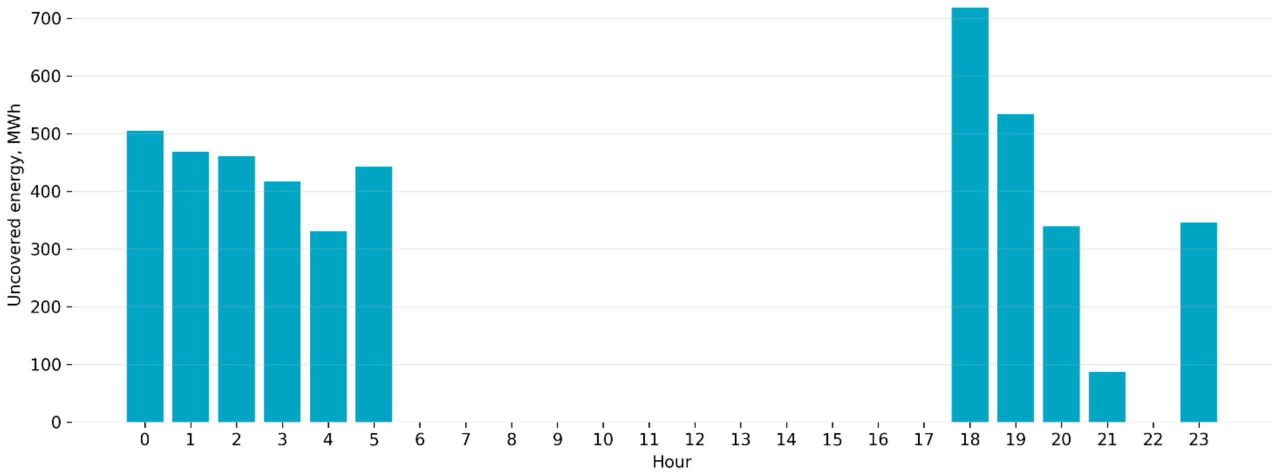

Figure 74 Distribution of uncovered energy by hour in 2035.

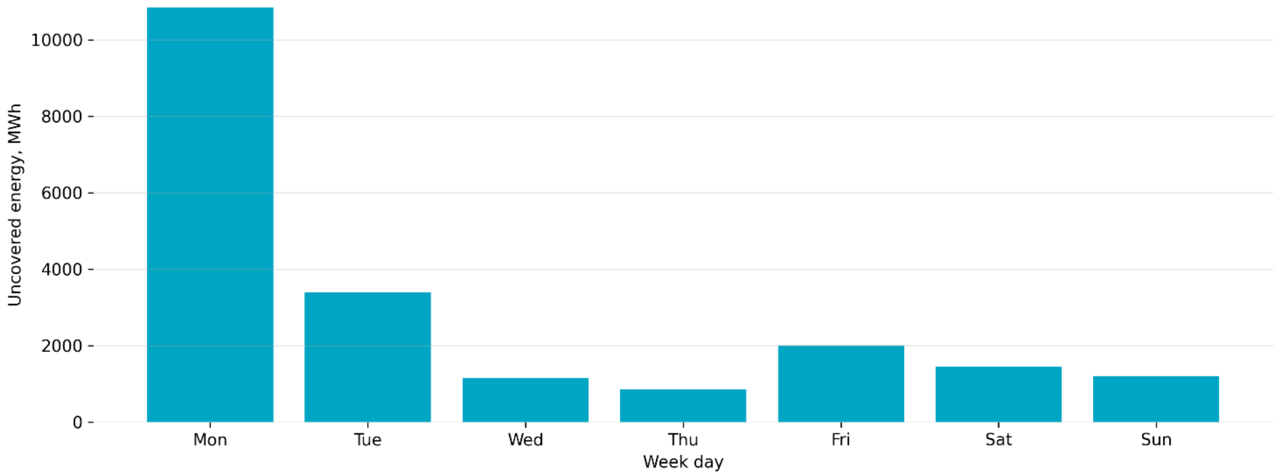

Figure 75 Distribution of uncovered energy by weekdays in 2028

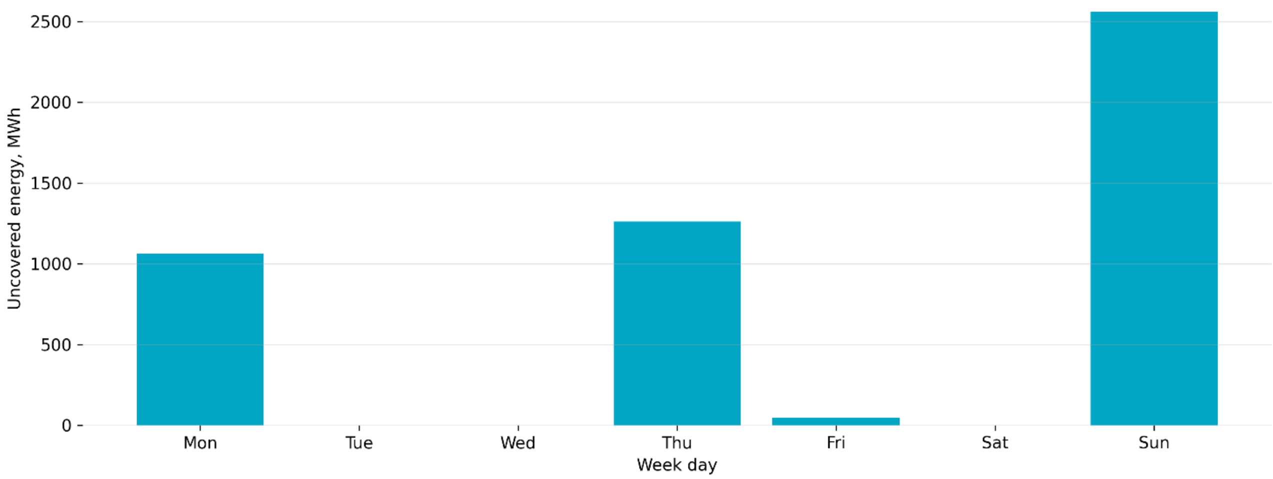

Figure 76 Distribution of uncovered energy by weekdays in 2030

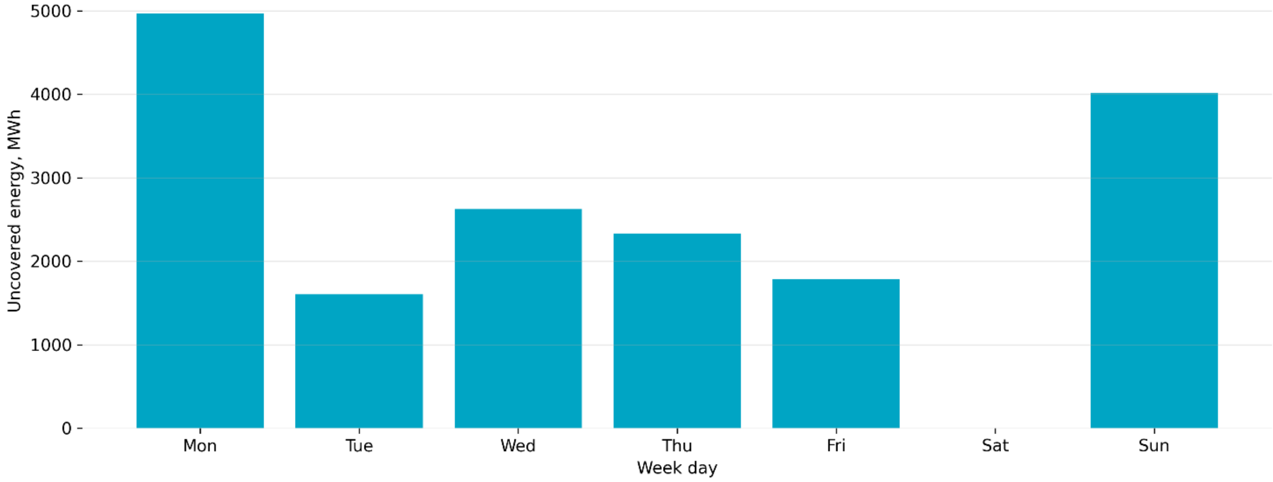

Figure 77 Distribution of uncovered energy by weekdays in 2033

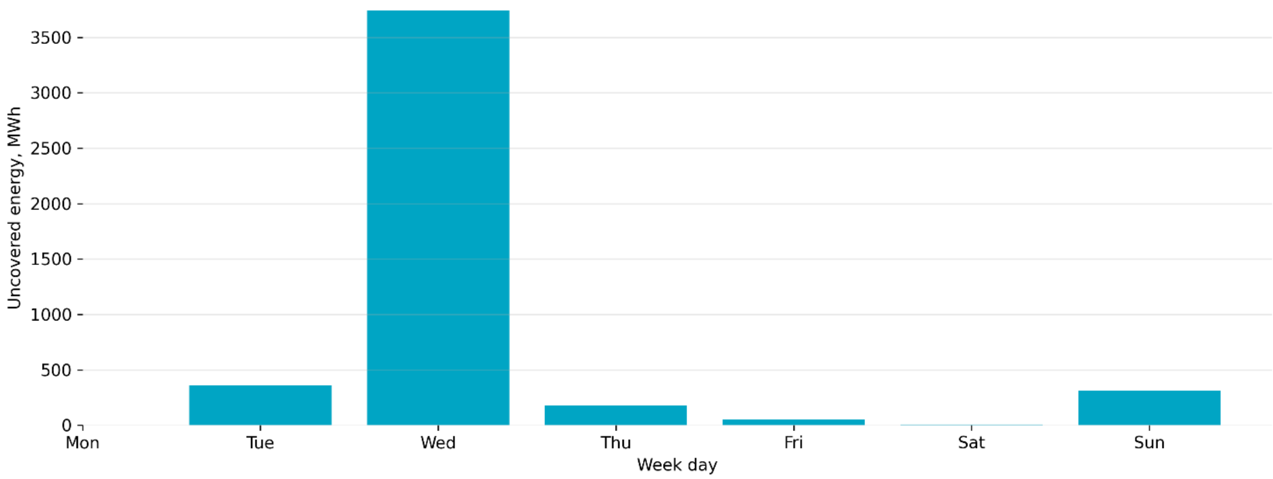

Figure 78 Distribution of uncovered energy by weekdays in 2035

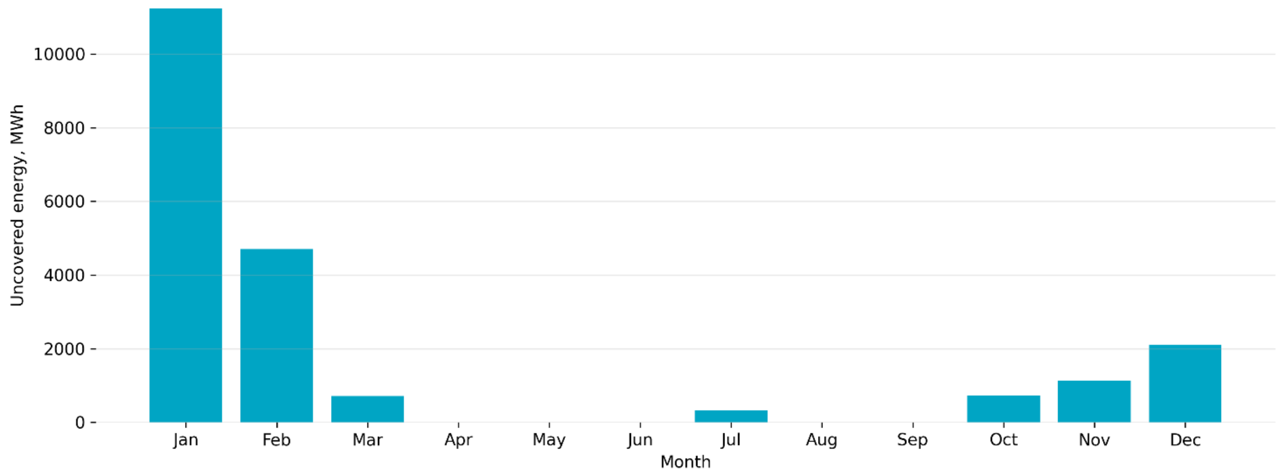

Figure 79 Distribution of uncovered energy by month in 2028

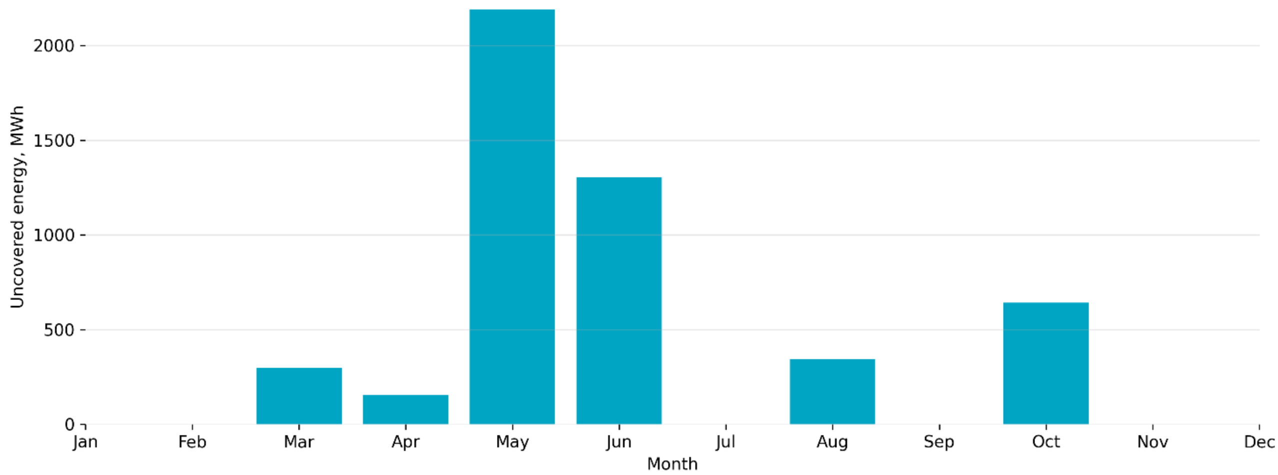

Figure 80 Distribution of uncovered energy by month in 2030

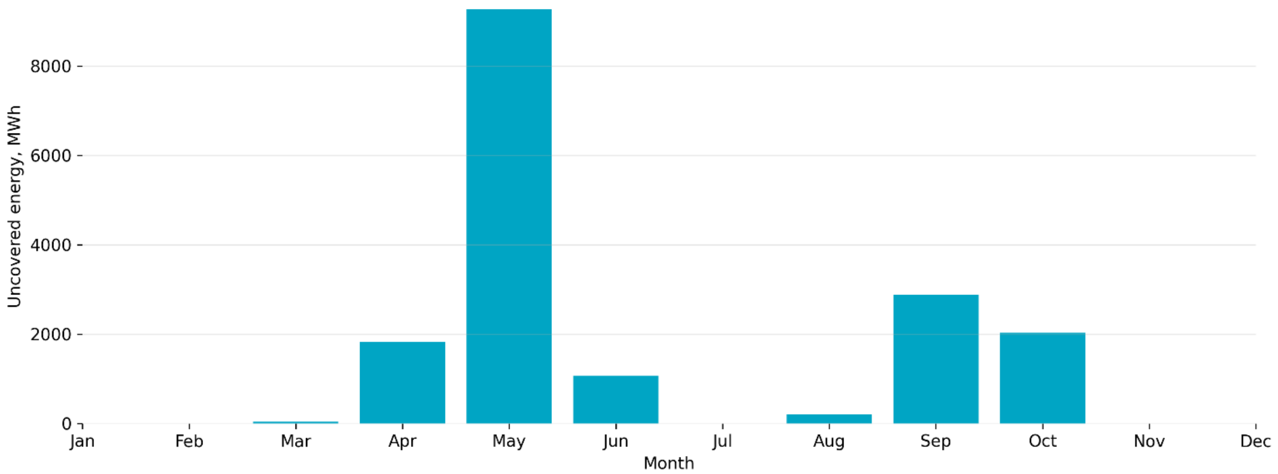

Figure 81 Distribution of uncovered energy by month in 2033

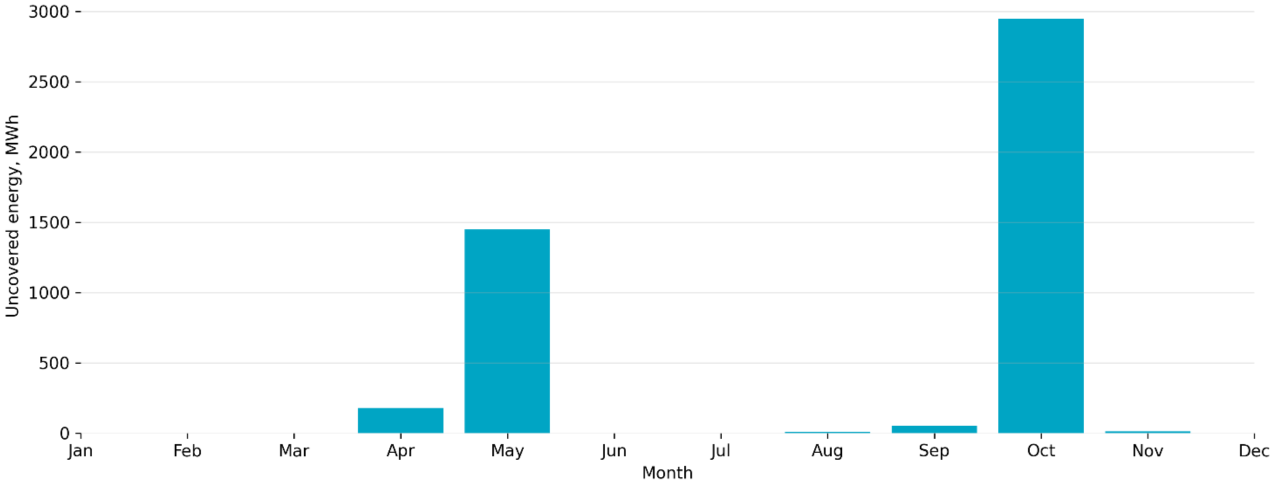

Figure 82 Distribution of uncovered energy by month in 2035

2028 m. uncovered energy is distributed broadly throughout the day, but the highest concentration appears in the evening hours, especially around 18–21. Monday stands out clearly in the weekly pattern, accounting for the largest share of uncovered energy. In the monthly distribution, January and February dominate, with smaller amounts also visible in late-autumn and winter months. This indicates that in 2028 the main flexibility deficit is linked to cold-season conditions.

In 2030 the total amount of uncovered energy is lower than in 2028, but its structure changes. By hour, the largest energy volumes accumulate in the evening, around 21–22, with additional morning and daytime episodes also visible. In the weekly pattern, Sunday stands out most clearly, followed by Thursday and Monday. In the monthly distribution, the highest uncovered energy appears in May and June, indicating that in 2030 the need shifts more strongly toward the warm and transitional season.

In 2033, the year is the most critical in terms of uncovered energy magnitude. The largest amounts appear during night and early-morning hours, especially between 0–2, as well as in the evening around 21–23. In the weekly pattern, Monday and Sunday accumulate the most energy, with significant volumes also observed on Wednesday and Thursday. In the monthly distribution, May clearly dominates, with notable amounts also occurring in September, October, and April.

In 2035 the amount of uncovered energy decreases, but clear concentration zones remain. By hour, the energy accumulates in two main periods — at night / early morning and in the evening around 18–20. In the weekly pattern, almost all uncovered energy falls on Wednesday, while other days show much smaller amounts. In the monthly distribution, October and May dominate. This indicates that in 2035 the issue becomes more episodic, yet can still be significant during certain periods.

Overall, it can be stated that in 2028 uncovered energy is mainly associated with winter months, in 2030 it shifts more toward the spring and early-summer period, in 2033 it reaches its largest scale and widest spread, and in 2035 it decreases but remains concentrated in specific months and hours. The key periods from the system-flexibility perspective are evening hours, night / early-morning intervals, and certain months — particularly January–February in 2028, May in 2030–2033, and October in 2035.

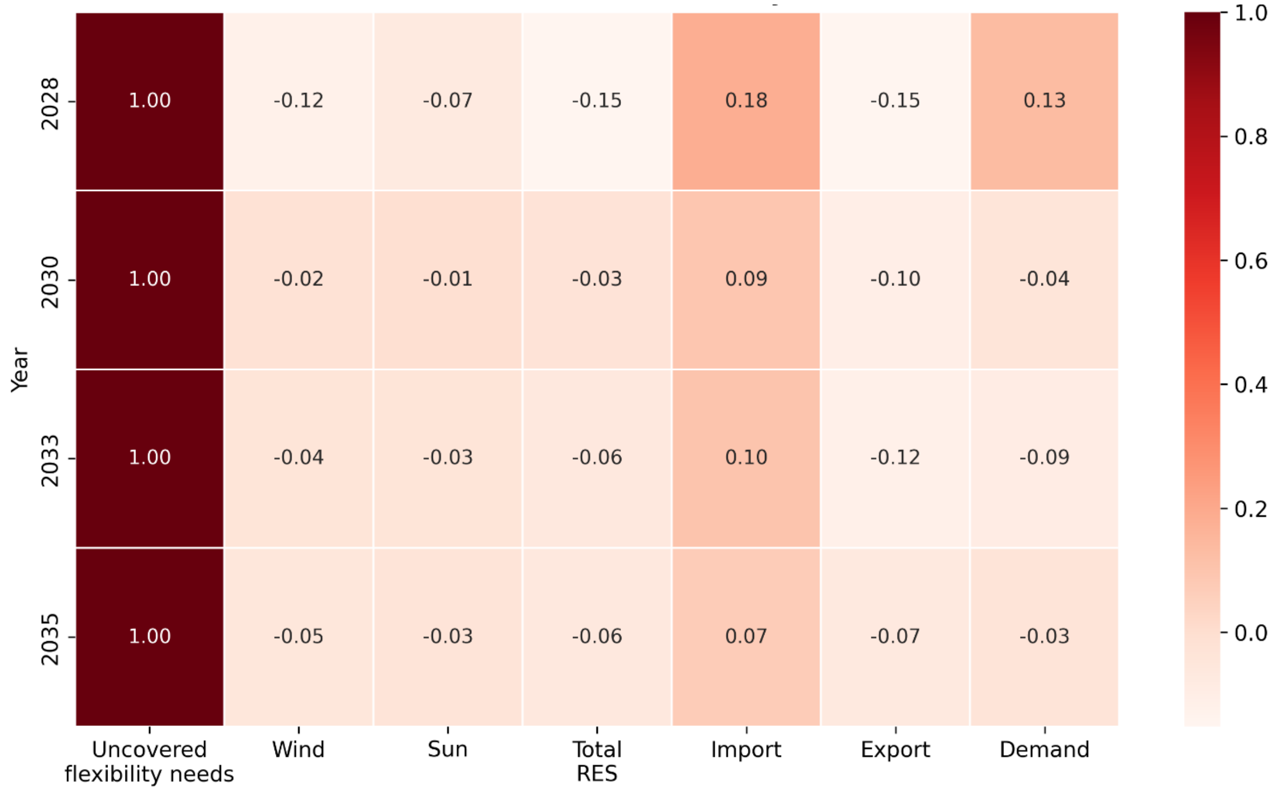

Figure 83 Correlation of uncovered short-term flexibility needs with different system states

The chart shows that the relationship between uncovered short-term flexibility needs and individual system-state indicators is very weak, as most correlation coefficients in Figure 84 are close to zero. Wind, solar, and total RES generation indicators do not exhibit a clear dependence on uncovered needs. A slightly more noticeable, though still weak, positive relationship appears with imports, especially in 2028. This indicates that uncovered needs are not explained by any single indicator but rather arise from the overall system state and the coincidence of several factors during specific hours.

6.1.3.4. Use of renewable energy sources to meet short-term flexibility needs (Article 10(5))

Article 10(2)(a) of the FNA methodology stipulates that short-term flexibility needs may be covered by additionally curtailing RES generation

The summarized results for the additionally curtailed RES volume are presented in Figure 85.

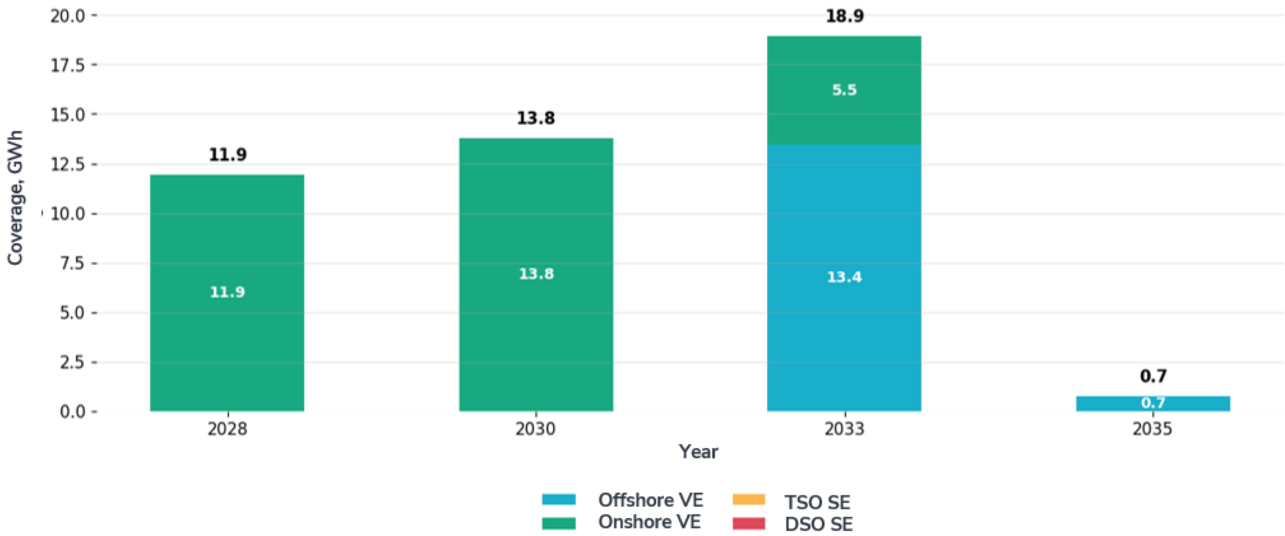

Figure 84 Additionally curtailed RES volume for covering short-term flexibility needs

According to the data shown in Figure 85, the downward flexibility capability of wind power plants alone is sufficient to fully cover all downward flexibility needs. Article 10(5) of the FNA methodology provides that additionally curtailed RES generation must be assessed in accordance with Article 8(3) of the methodology.

6.1.3.5. Realistic regime analysis (10 str. (7))

According to Article 10(8) of the FNA methodology, a realistic regime is constructed in which, after accounting for network constraints and the unavailability of flexibility resources, the available short-term flexibility through cross-border flows is reduced.

The realistic regime adjusts the short-term flexibility values of available capacity, as provided for in Article 10, paragraph 8 of the FNA methodology, and requires the recalculation of parts 2-6 of Article 10 of the FNA methodology. The results of the realistic regime assessment are presented below.

The change in flexibility provision is introduced only in cross-border capacities and P2X, therefore only the tables representing these capacities are provided below.

table 17 Flexibility resource used in the assessment

Technology	Average downward flexibility	Average upward flexibility
	2028	
LT–PL	10,57	49,43
LT–LV	460,24	481,76
LT–SE	158,97	121,03
P2X	0	0
	2030	
LT–PL	92,41	187,59
LT–LV	628,01	313,99
LT–SE	195,18	84,82
P2X	0	0
	2033	
LT–PL	117,51	162,49
LT–LV	525,92	416,08
LT–SE	169,71	110,29
P2X	0	0

2035		
LT–PL	92,31	187,69
LT–LV	1138,03	836,97
LT–SE	166,25	113,75
P2X	0	0

As can be seen in the charts presented below, in all analyzed years the size of cross-border capacities decreases in proportion to the assumptions defined for the realistic regime. The short-term flexibility capability of P2X decreases to 0 MW in every analyzed year.

Applying the different capacity assumptions, an analogous analysis is carried out as required under Article 10(4) of the methodology, using the realistic regime assumptions.

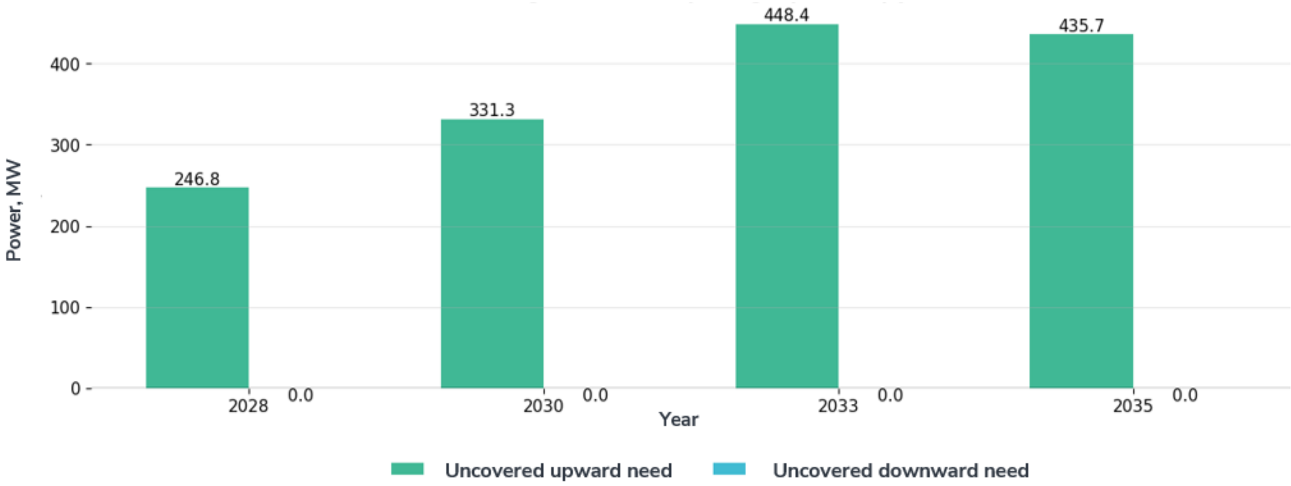

Figure 85 Average uncovered power per event with insufficient short-term flexibility in the realistic regime

The chart in Figure 86 shows that, in the realistic regime—as in the basic regime—uncovered short-term flexibility needs occur only in the upward direction, while no uncovered downward needs appear in any of the analyzed years. The average power per uncovered-need event increases from 246,8 MW in 2028 to 331,3 MW in 2030, reaches its highest value of 448,4 MW in 2033, and then decreases slightly to 435,7 MW in 2035, although it remains significantly higher than in 2028–2030.

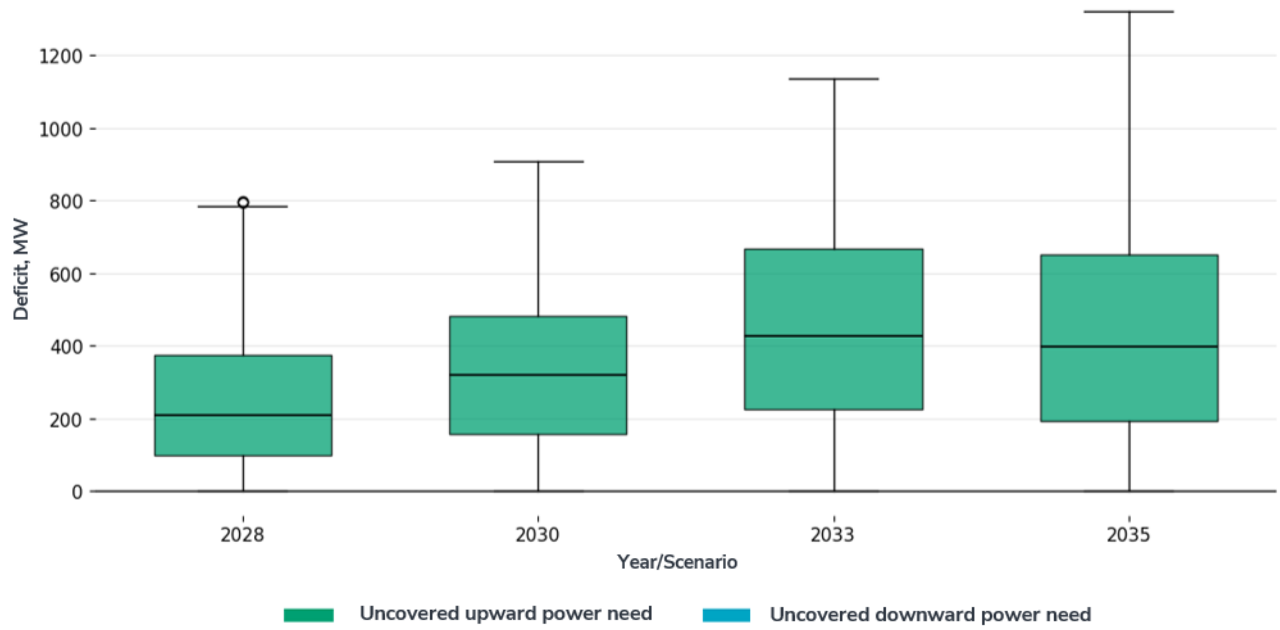

Figure 86 Uncovered-need power distribution in the realistic regime

The chart in Figure 87 shows that, in later years, uncovered upward needs become larger and more dispersed. In 2028, most values are concentrated in the lower range, whereas in 2033–2035 more high-magnitude events appear, exceeding around 1 GW. This indicates that not only the average size of an uncovered need increases, but also the risk of more extreme short-term flexibility deficit events.

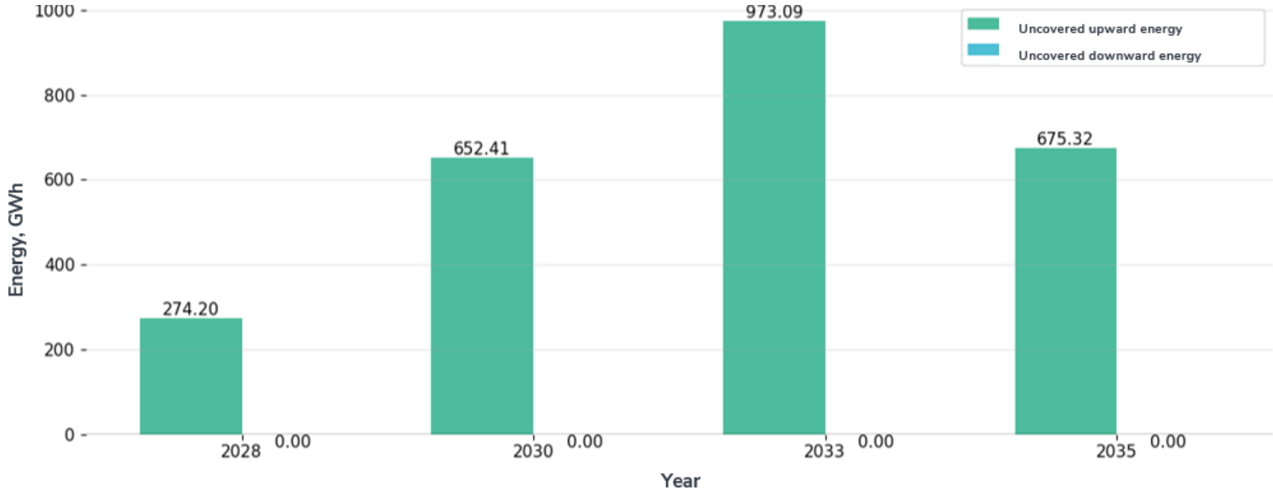

Figure 87 Total expected uncovered energy for short-term flexibility in the realistic regime

The chart in Figure 88 shows that, in the realistic regime, uncovered energy arises only upward, with no uncovered downward energy in any of the analyzed years. The amount of uncovered energy increases from 274,20 GWh in 2028 to 652,41 GWh in 2030, reaching its maximum in 2033 at 973,09 GWh. In 2035, the value decreases to 675,32 GWh, yet remains higher than in 2028. This indicates that the short-term deficit of upward flexibility remains relevant, and the total amount of uncovered energy is determined not only by the deficit power, but also by the frequency and duration of events.

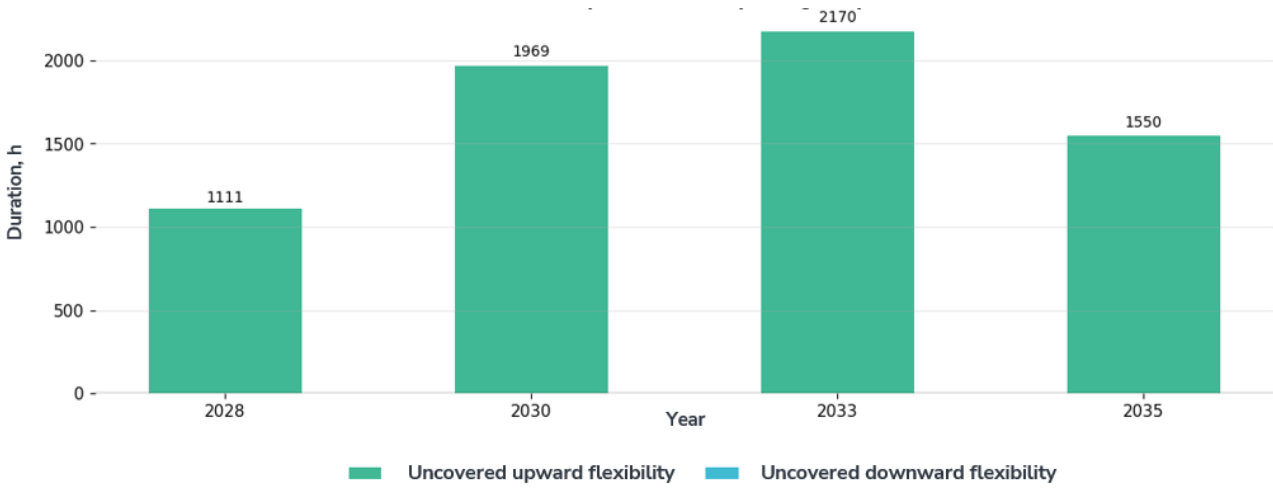

Figure 88 Expected number of uncovered hours per year in the realistic regime

The chart in Figure 89 shows that hours with uncovered short-term flexibility needs arise only in the upward. Their number increases from 1111 hours in 2028 to 1 969 hours in 2030, reaching a maximum of 2170 hours in 2033. In 2035, the indicator decreases to 1550 hours, yet remains higher than in 2028. This indicates that upward flexibility shortages occur more frequently in later years, although the situation improves in 2035 compared to 2033.

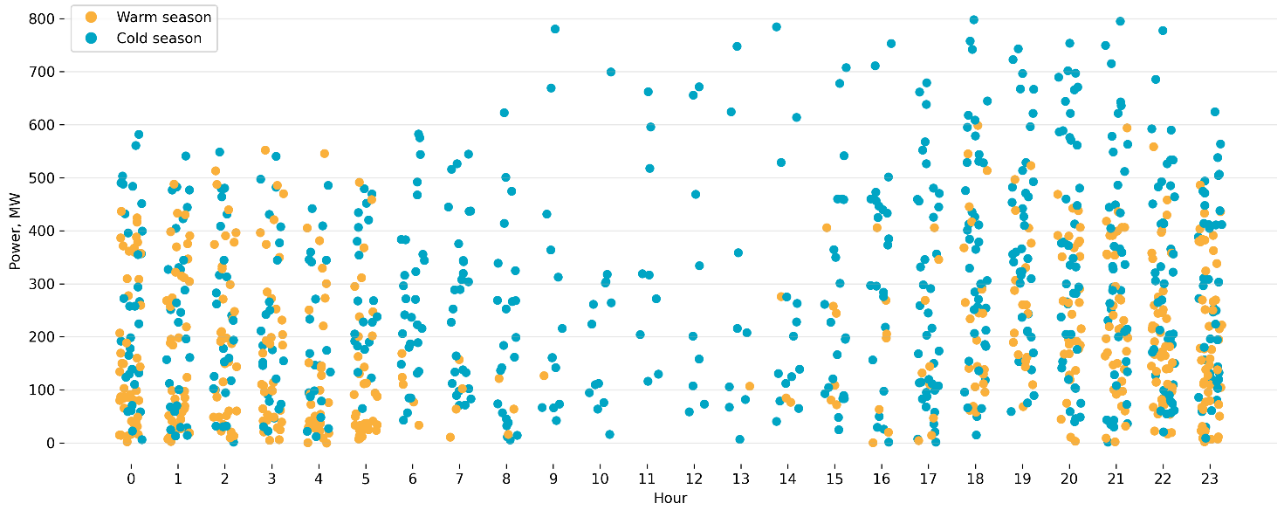

Figure 89 Distribution of uncovered needs by hour in 2028 in the realistic regime

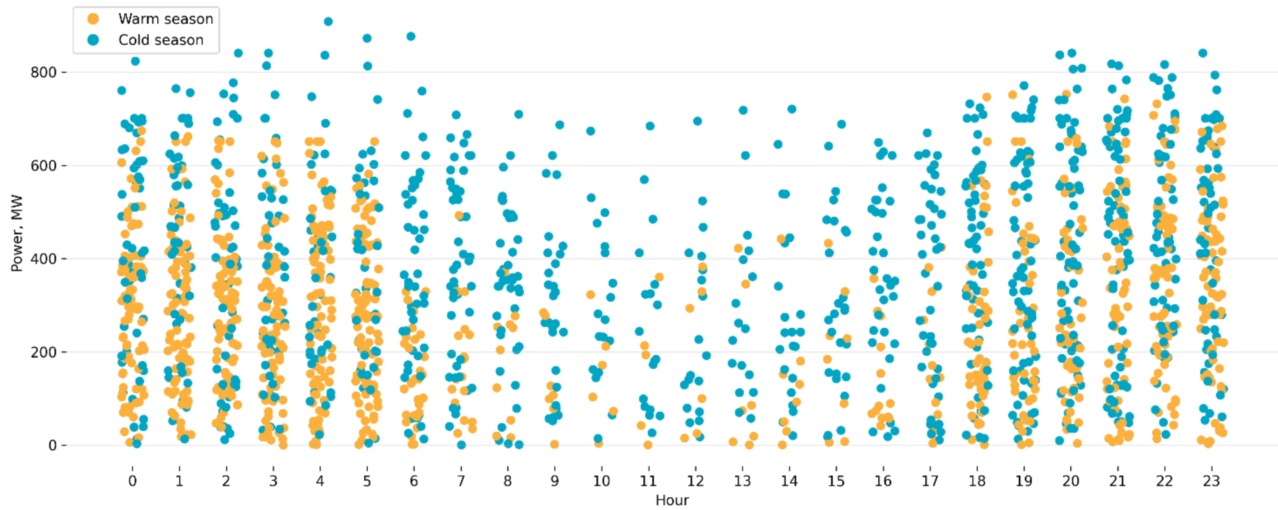

Figure 90 Distribution of uncovered needs by hour in 2030 in the realistic regime

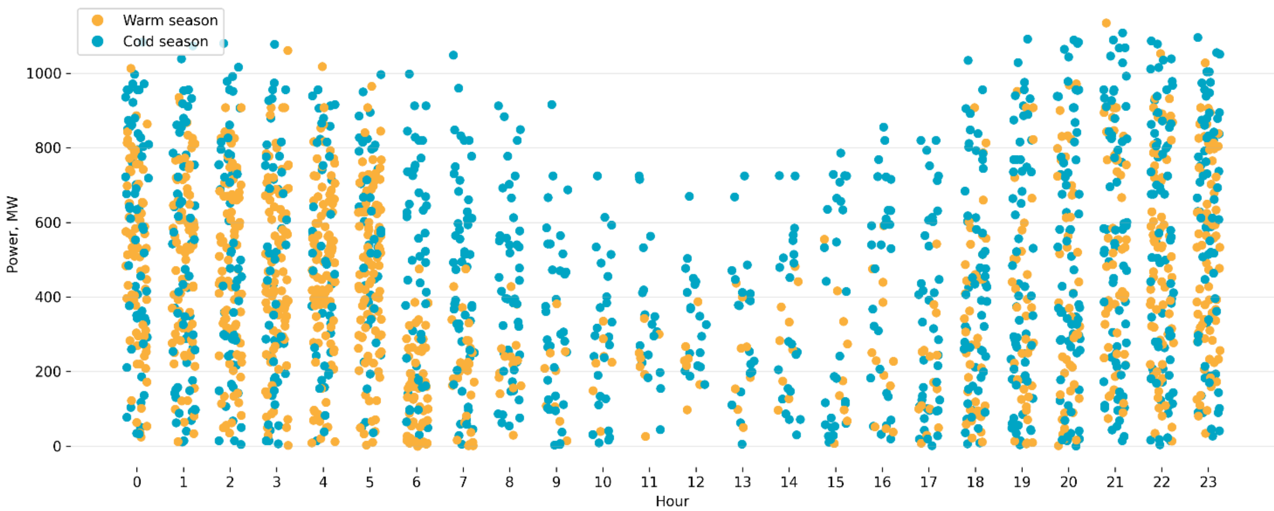

Figure 91 Distribution of uncovered needs by hour in 2033 in the realistic regime

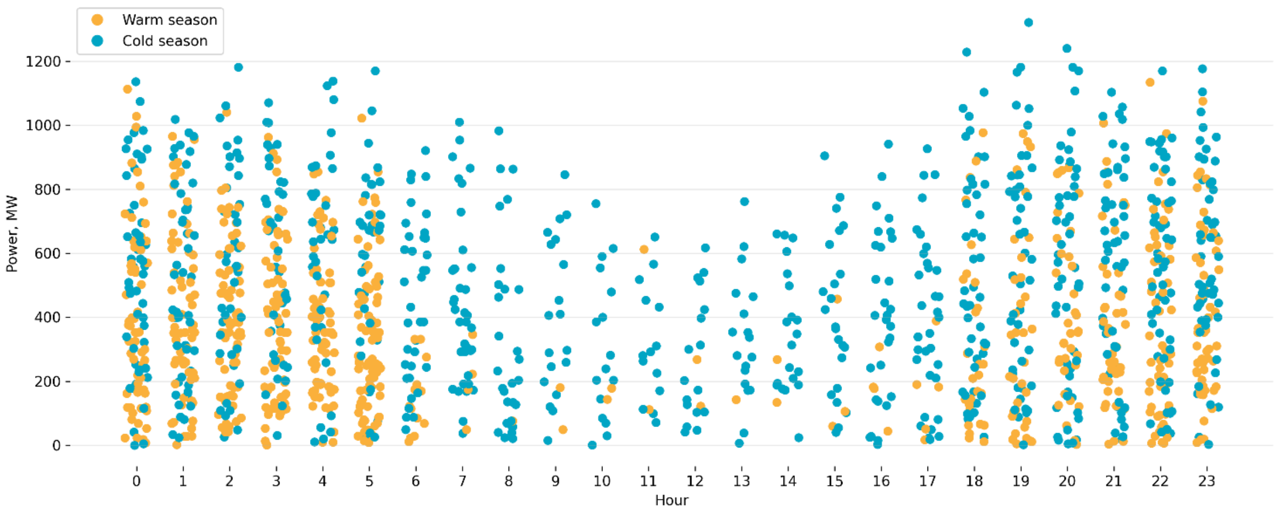

Figure 92 Distribution of uncovered needs by hour in 2035 in the realistic regime

Figure 93 Distribution of uncovered needs by weekdays in 2028 in the realistic regime

Figure 94 Distribution of uncovered needs by weekdays in 2030 in the realistic regime

Figure 95 Distribution of uncovered needs by weekdays in 2033 in the realistic regime

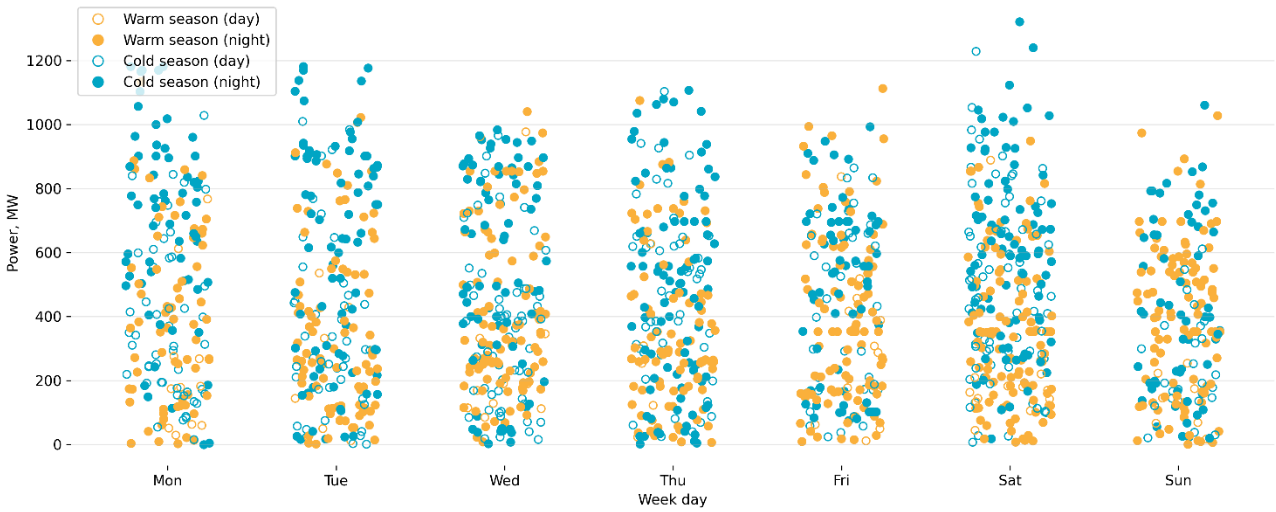

Figure 96 Distribution of uncovered needs by weekdays in 2035 in the realistic regime

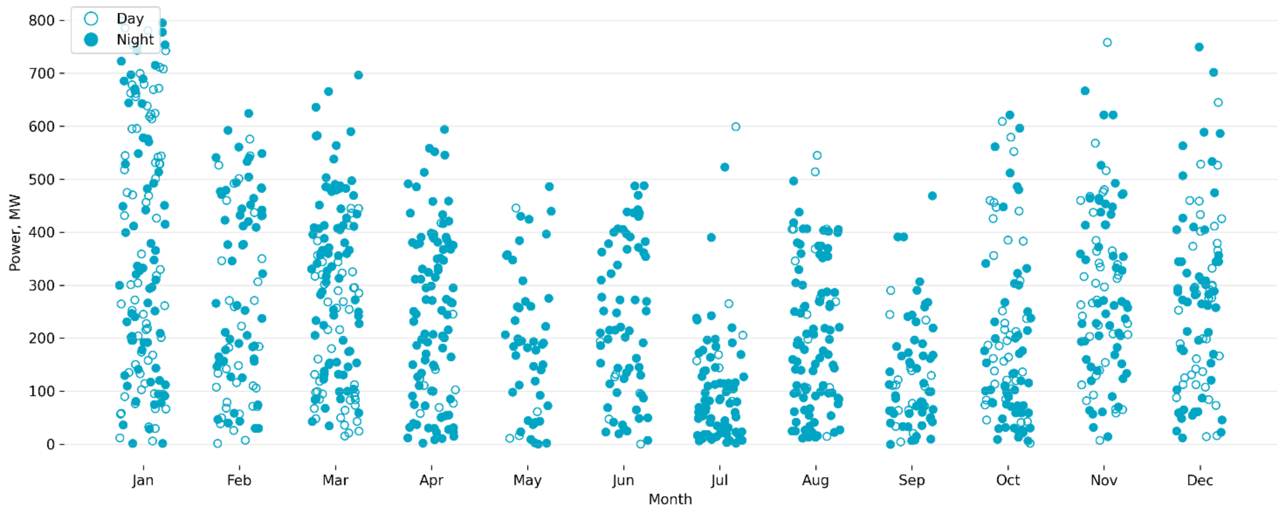

Figure 97 Distribution of uncovered needs by month in 2028 in the realistic regime

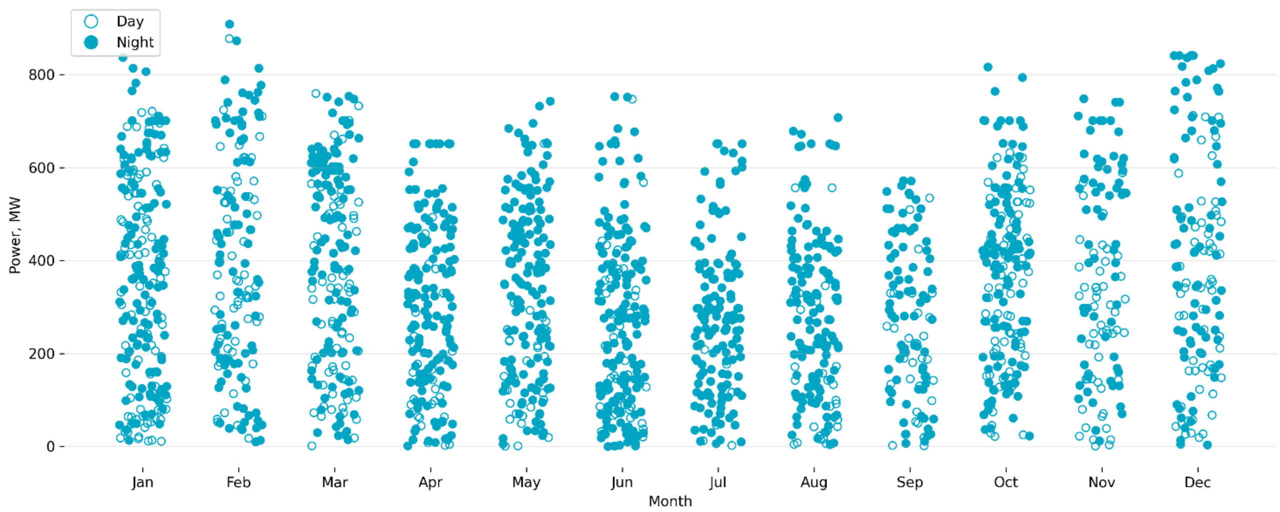

Figure 98 Distribution of uncovered needs by month in 2030 in the realistic regime

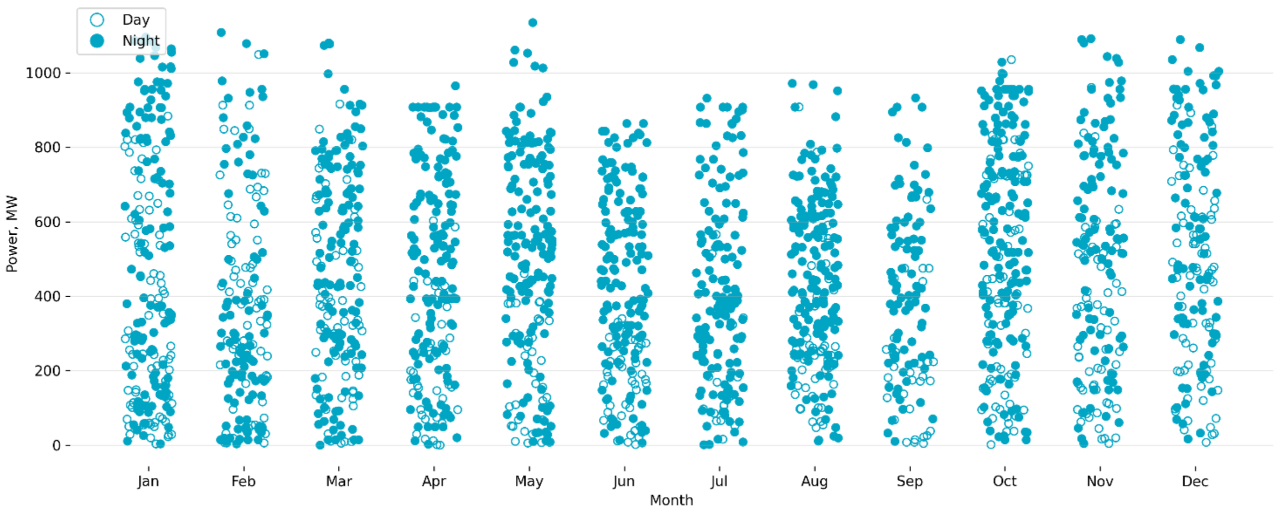

Figure 99 Distribution of uncovered needs by month in 2033 in the realistic regime

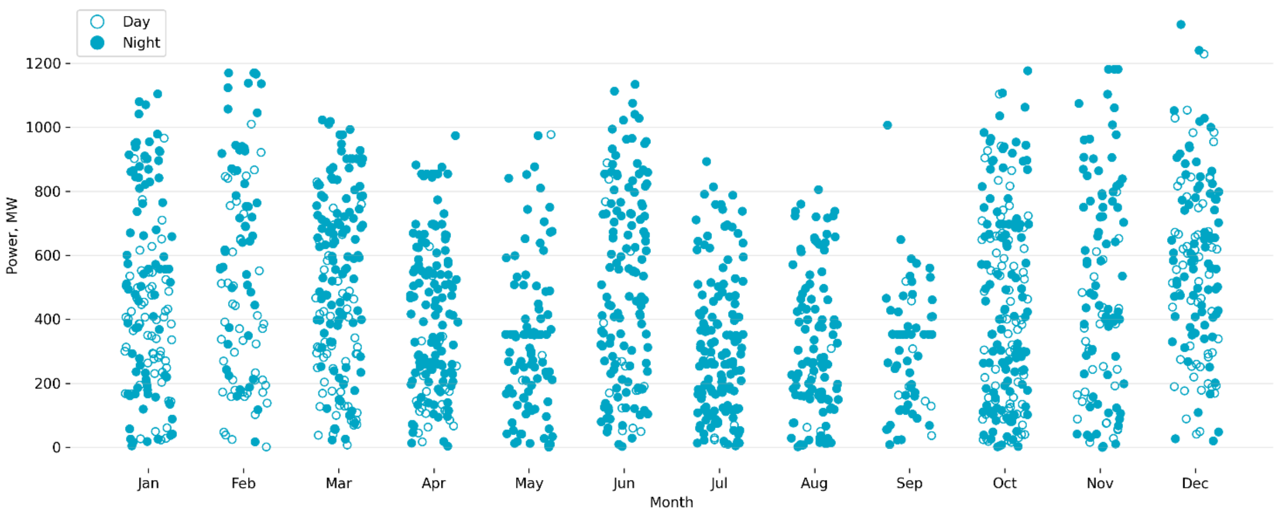

Figure 100 Distribution of uncovered needs by month in 2035 in the realistic regime

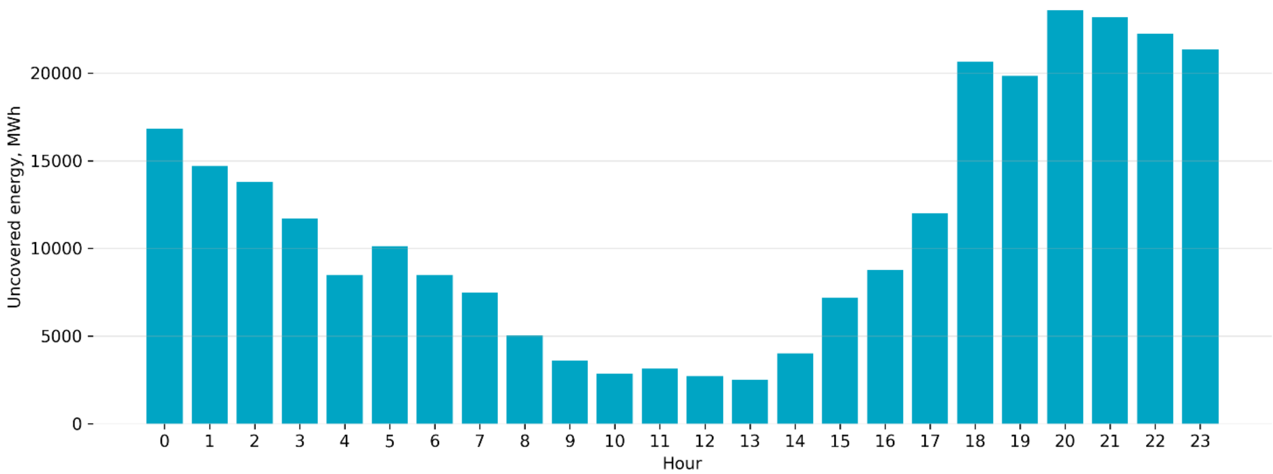

Figure 101 Distribution of uncovered energy by hour in 2028 in the realistic regime

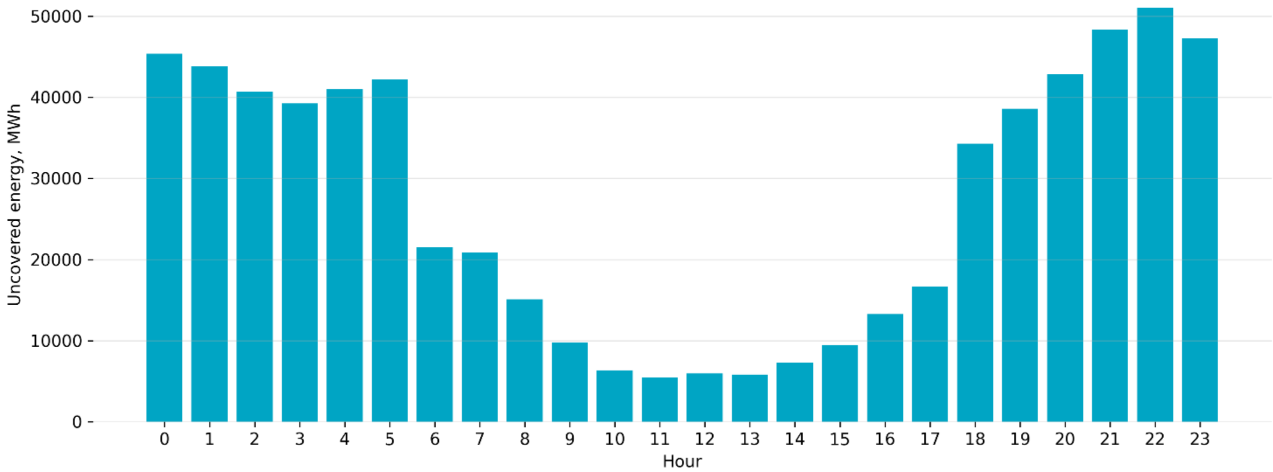

Figure 102 Distribution of uncovered energy by hour in 2030 in the realistic regime

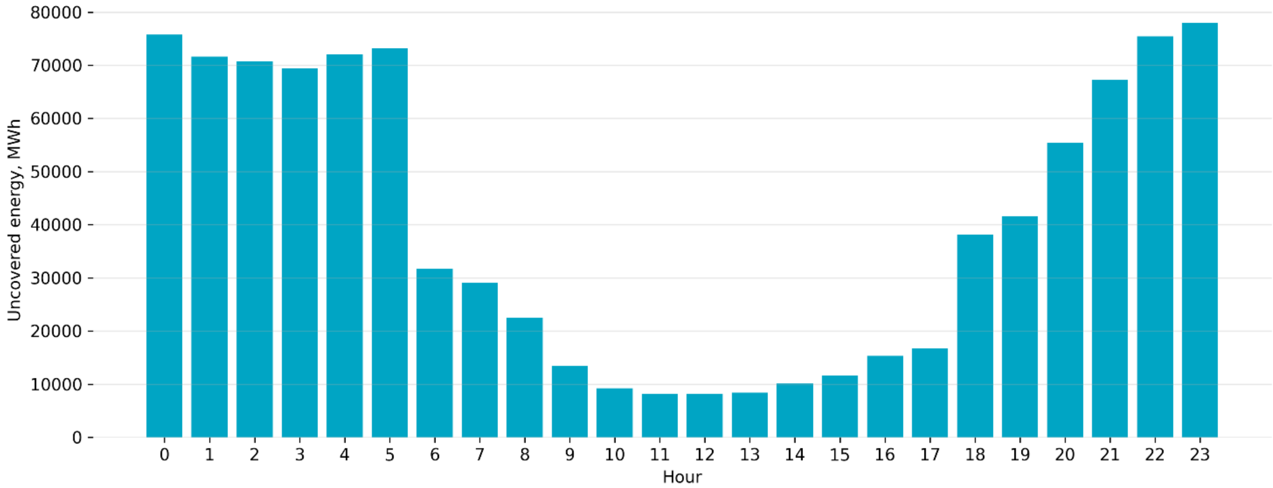

Figure 103 Distribution of uncovered energy by hour in 2033 in the realistic regime

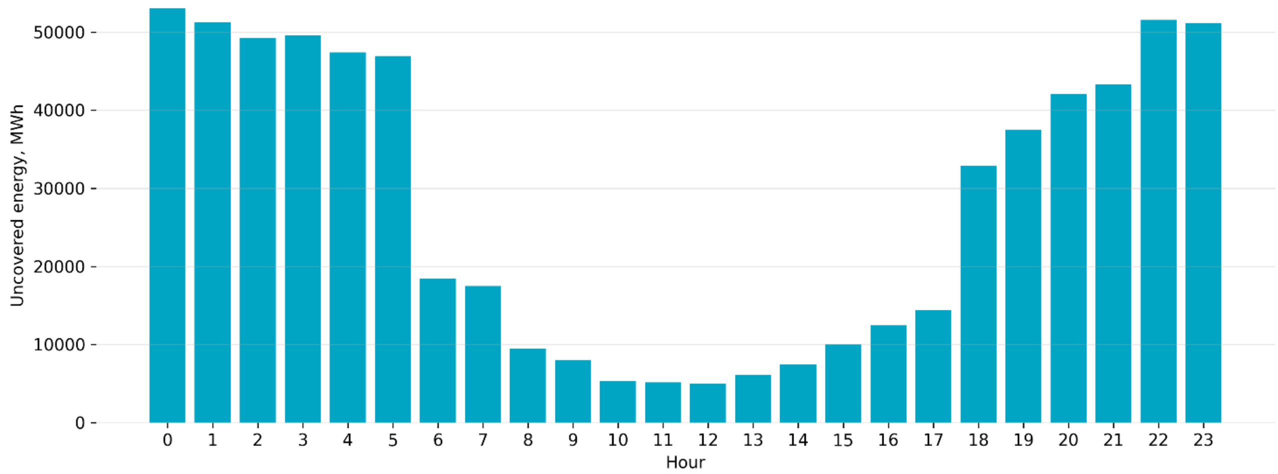

Figure 104 Distribution of uncovered energy by hour in 2035 in the realistic regime

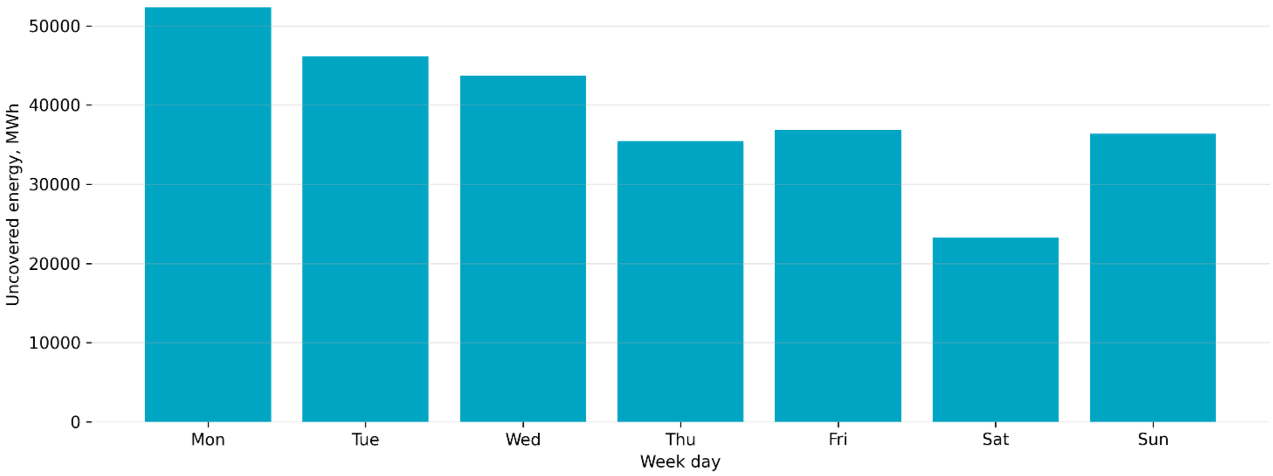

Figure 105 Distribution of uncovered energy by weekdays in 2028 in the realistic regime

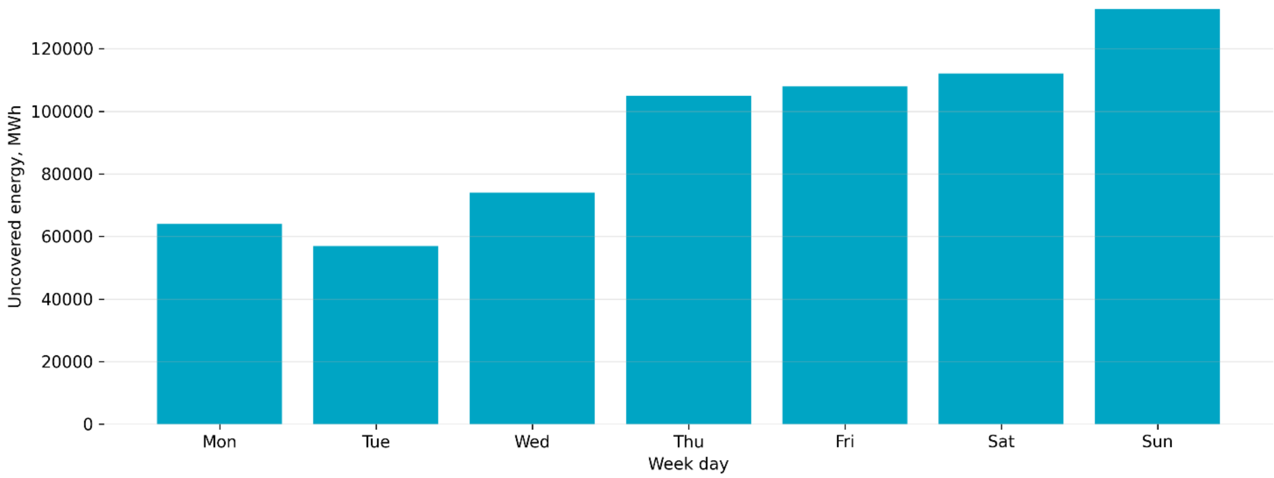

Figure 106 Distribution of uncovered energy by weekdays in 2030 in the realistic regime

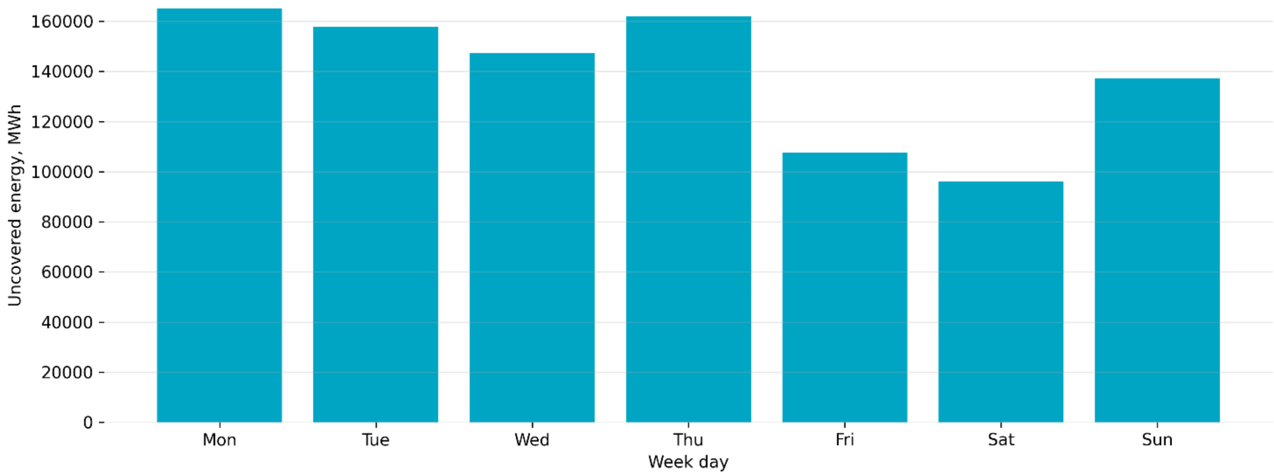

Figure 107 Distribution of uncovered energy by weekdays in 2033 in the realistic regime

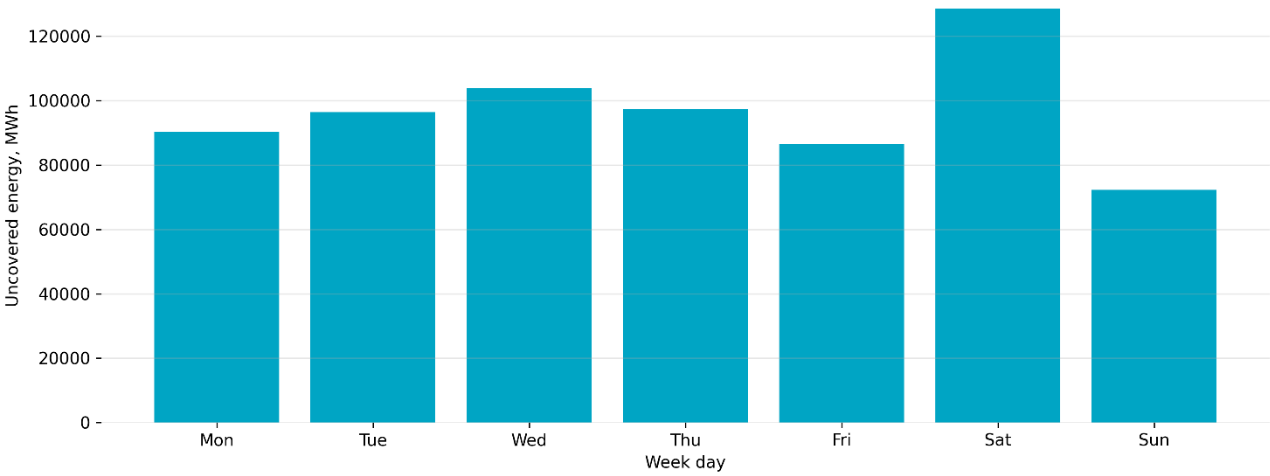

Figure 108 Distribution of uncovered energy by weekdays in 2035 in the realistic regime

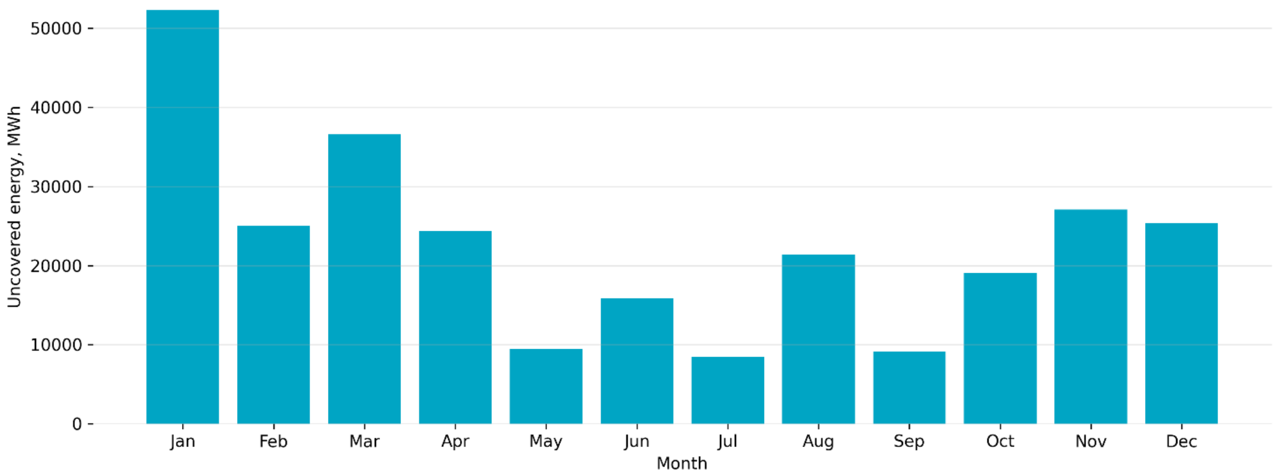

Figure 109 Distribution of uncovered energy by months in 2028 in the realistic regime

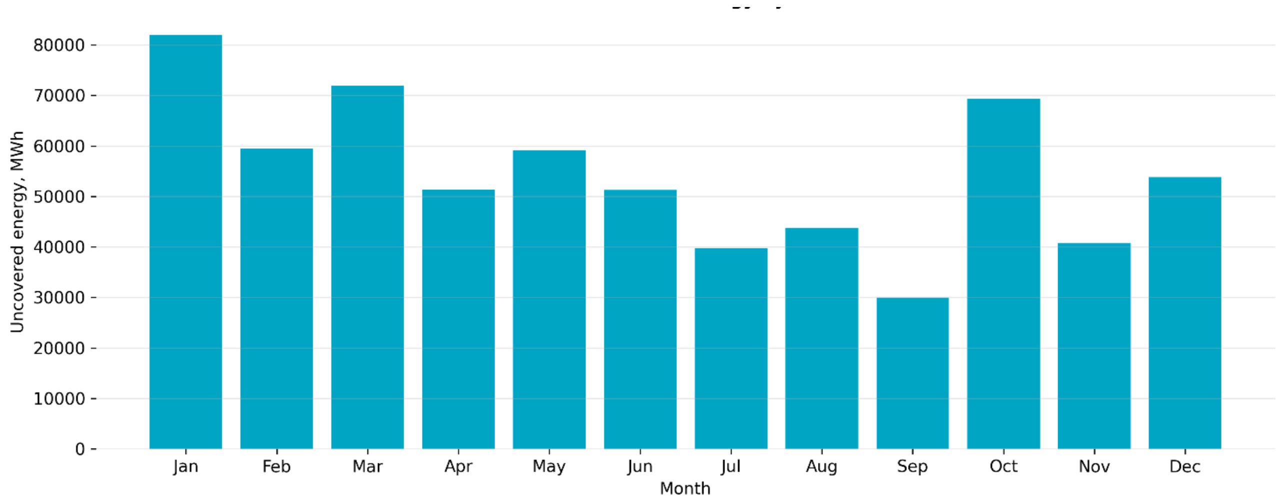

Figure 110 Distribution of uncovered energy by months in 2030 in the realistic regime

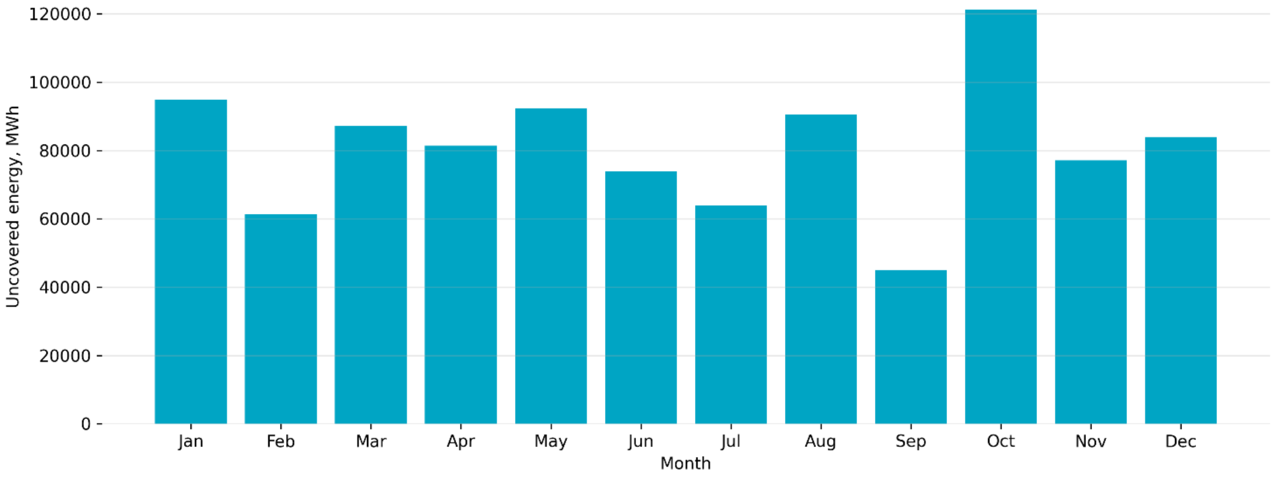

Figure 111 Distribution of uncovered energy by months in 2033 in the realistic regime

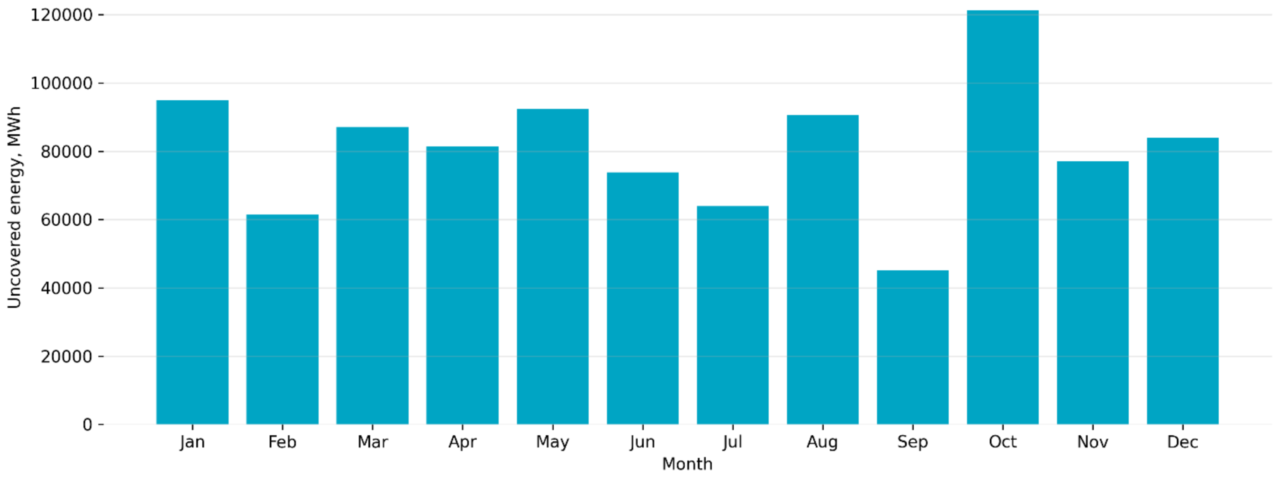

Figure 112 Distribution of uncovered energy by months in 2034 in the realistic regime

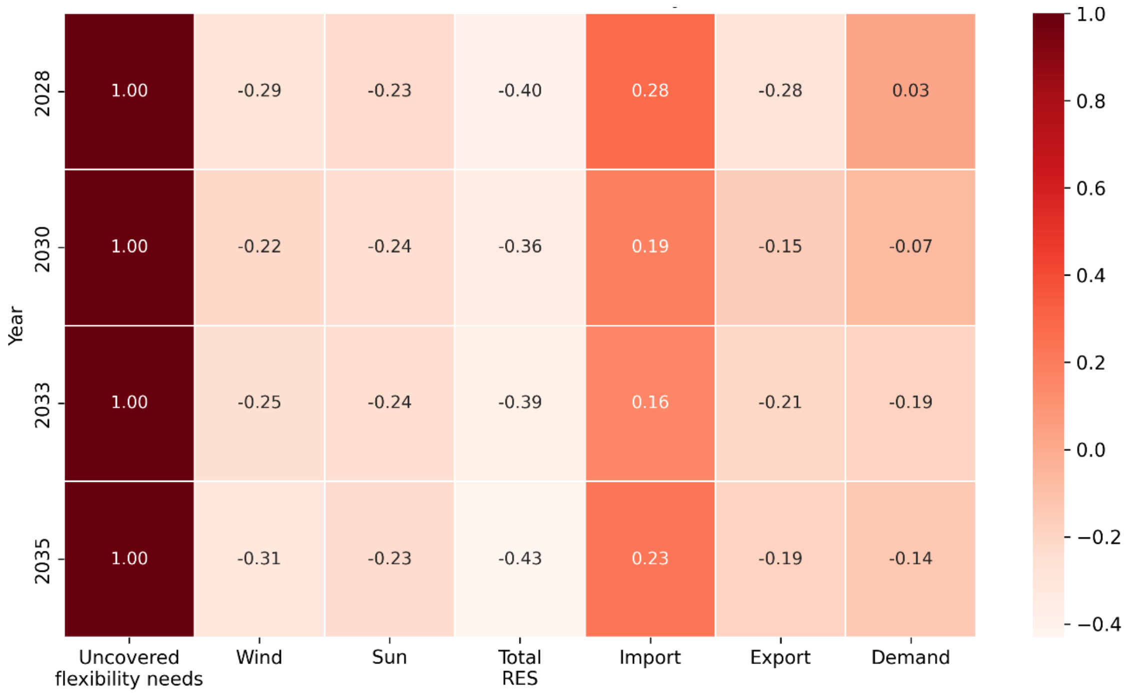

Figure 113 Correlation between uncovered short-term flexibility needs and different system-state indicators in the realistic regime

6.2. Slower Transformation Scenario

6.2.1. RES integration needs

Based on parts 2, 4 and 6 of Article 8 of the ACER FNA methodology, the annual RES curtailment volumes were assessed for each target year (see Figure 115).

The results show that additional RES curtailment amounted to 70,2 GWh in 2028, decreased to 30,3 GWh in 2030, and increased again to 55,6 GWh in 2033. The highest value was recorded in 2035, when curtailment reached 379,2 GWh. This trend is linked to the commissioning of the offshore wind farm in 2035.

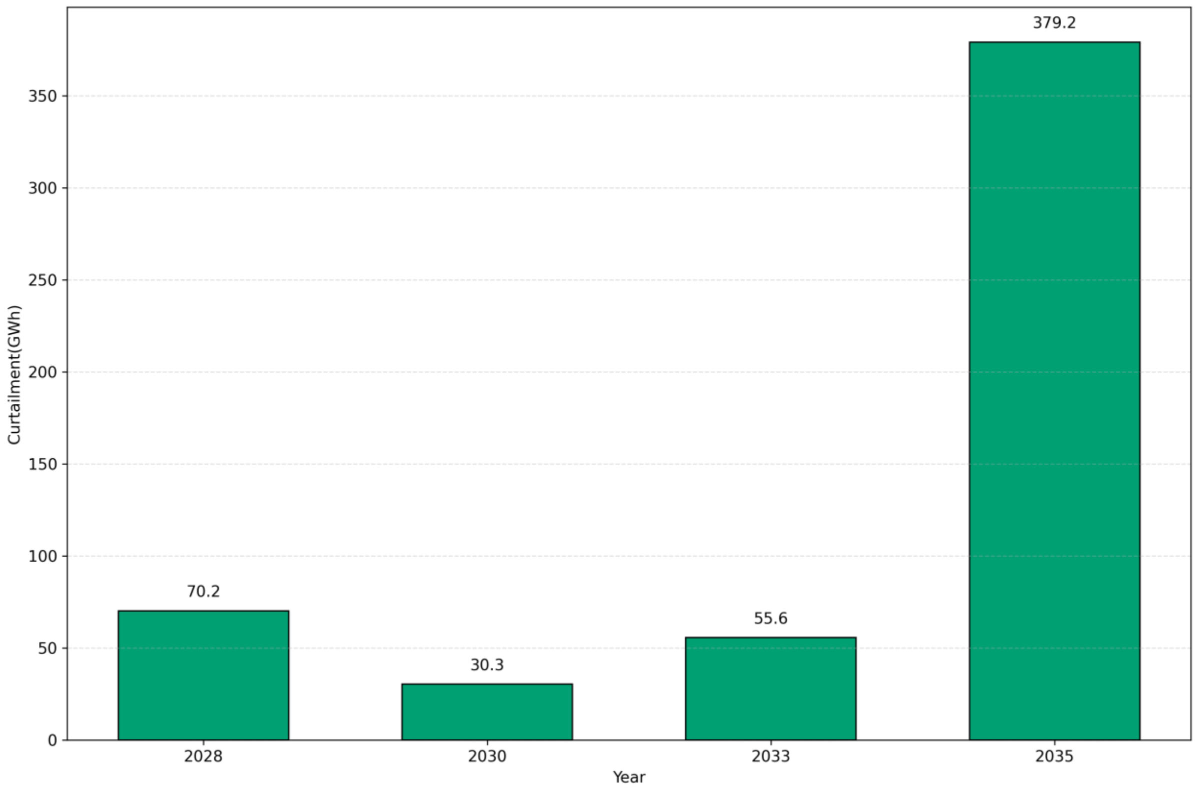

Figure 114 Annual RES curtailment by target year

Based on part 4 of Article 8 of the FNA methodology, the duration characteristics of RES curtailment events were assessed, including the average duration, the 95th percentile, and the maximum duration (see figure below).

The analysis shows that most RES curtailment events are relatively short. The average duration across the analyzed years ranged from 2,0 to 7,4 hours, while the 95th-percentile values varied between 4,4 and 15,0 hours. However, maximum duration indicators reveal isolated long-term episodes of restriction. n 2035, the longest curtailment event lasted 81 hours, whereas in earlier years the maximum values did not exceed 20 hours. This indicates that, going forward, the system faces not only more frequent but also longer periods of excess RES generation that existing flexibility resources can no longer fully absorb.

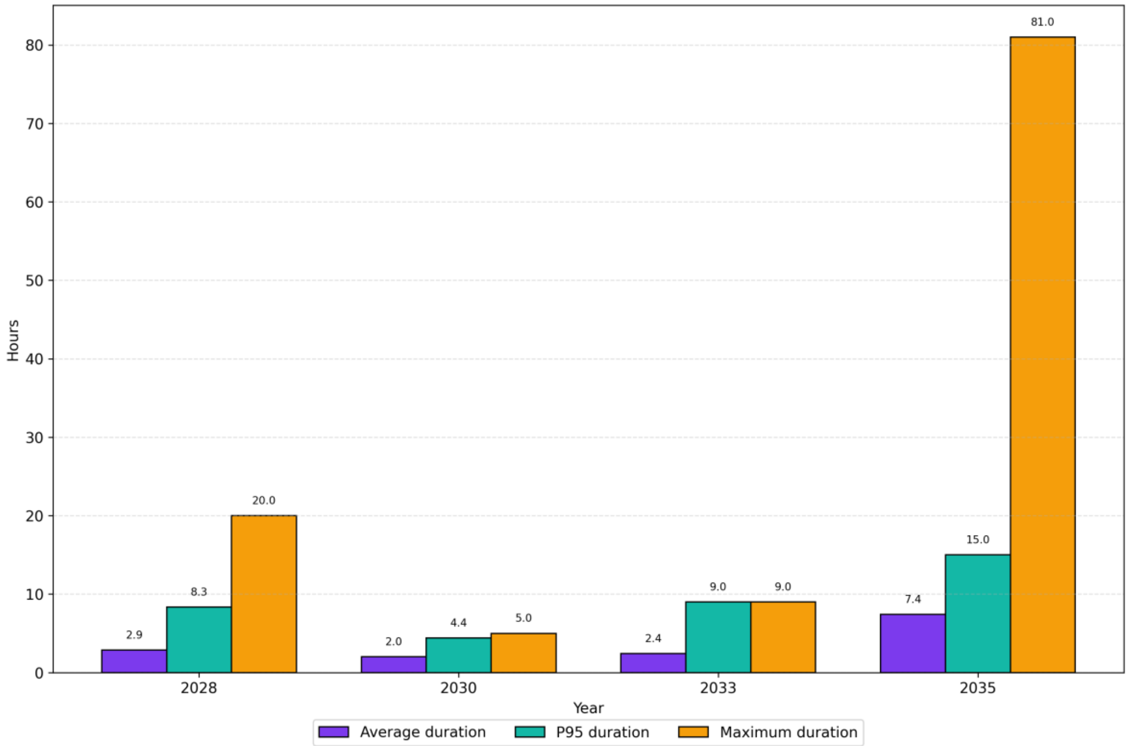

Figure 115 RES generation curtailment indicators by target year

Based on part 4(c) of Article 8 of the FNA methodology, an hourly RES-curtailment analysis was carried out (see figure below). The results show a clear concentration of RES curtailment during daytime hours. In all analyzed years, the highest curtailment volumes occur between 09:00 and 15:00, with a peak around midday. The strongest effect is observed in 2035, when the average curtailment at around 12:00 exceeds 100 MWh. This distribution reflects the solar generation profile and indicates that excess-generation issues are primarily linked to daytime periods when solar output is at its highest. During evening and night hours, curtailment levels decrease significantly, meaning that the main flexibility need is concentrated during daytime.

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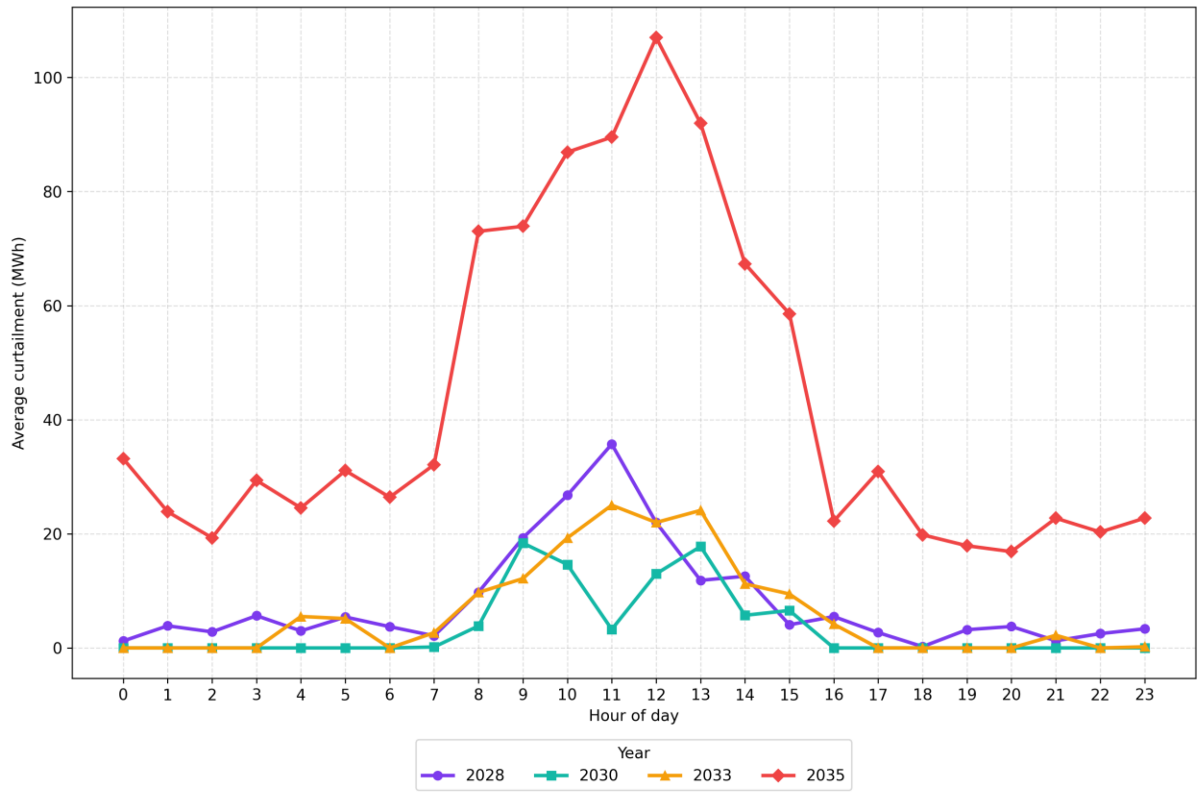

Figure 116 Average RES curtailment by hour of day

Based on part 4(c) of Article 8 of the FNA methodology, an analysis of RES curtailment was carried out across monthly and hourly dimensions. The results show (see figure below) that in all analyzed target years RES curtailment is mainly concentrated in spring months, particularly March–June, when solar power generation is already significant, but the demand for electricity remains relatively small. The highest curtailment levels occur during daytime hours, most often between 09:00 and 15:00, with a pronounced peak around midday. In 2028–2033, the curtailment events remain relatively localized in terms of both time and seasonality, but in 2035 their distribution becomes significantly broader – curtailment are fixed from January to October and cover most of the day. his indicates that as RES capacity grows, especially with the integration of additional offshore wind parks, the problem of excess generation is no longer a problem of isolated periods, but a systemic phenomenon that occurs for a larger part of the year. The highest average curtailment intensity is recorded in April 2035 between 11:00 and 13:00, when hourly average curtailment values exceed 300 MWh, confirming that the main RES-integration challenge is associated with midday periods and high solar-generation hours.

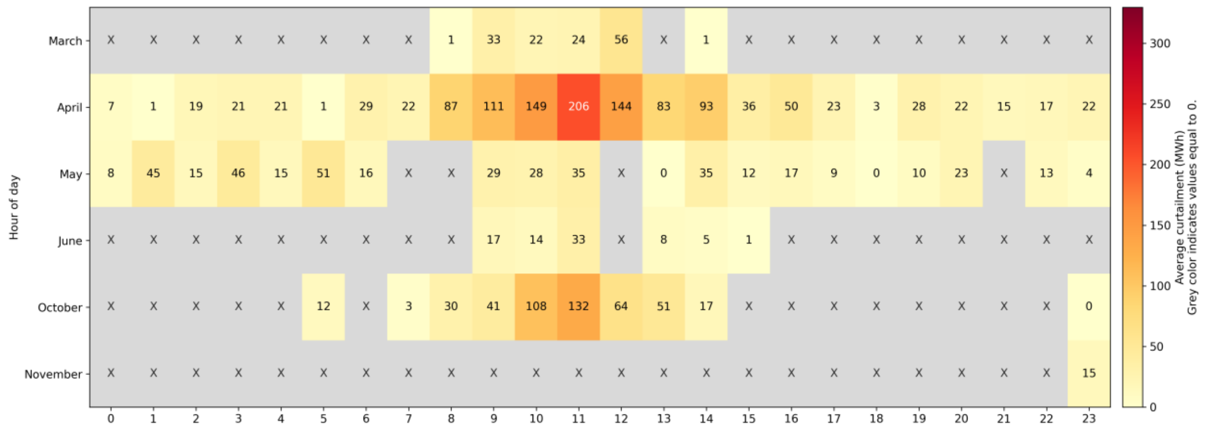

Figure 117 Average generation curtailment heatmap by month and hour (2028)

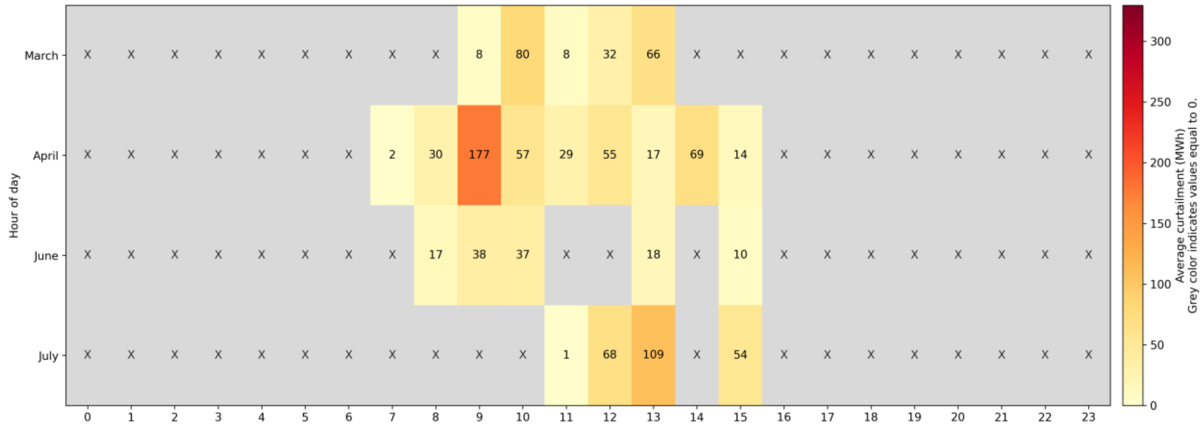

Figure 118 Average generation curtailment heatmap by month and hour (2030)

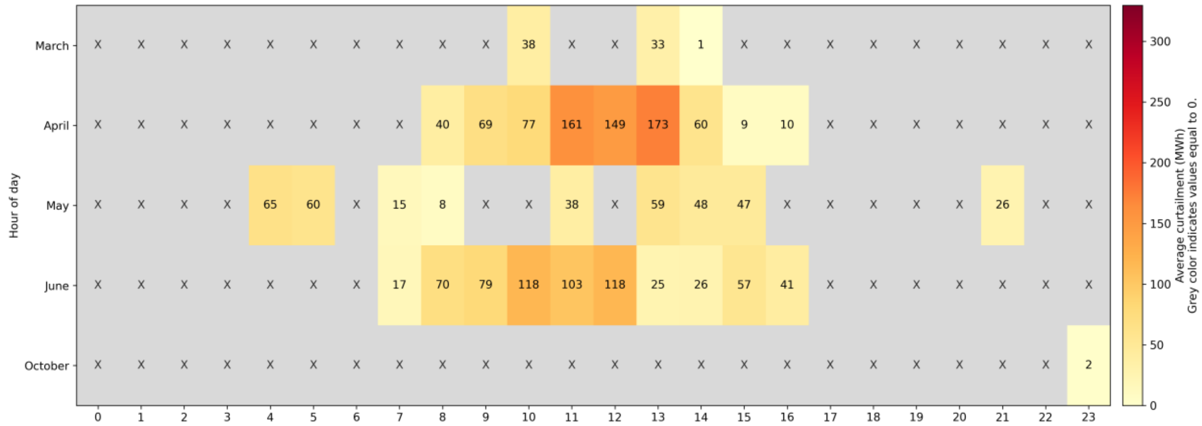

Figure 119 Average generation curtailment heatmap by month and hour (2033)

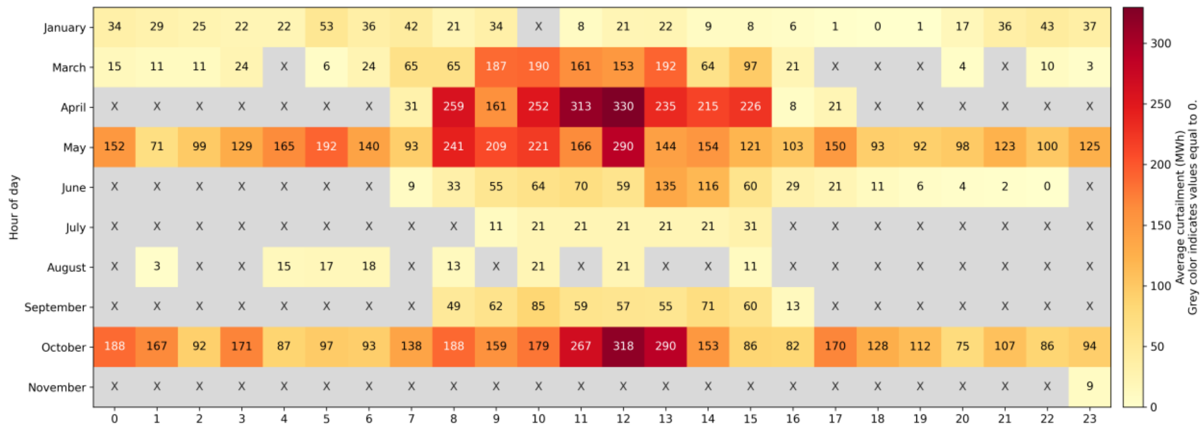

Figure 120 Average generation curtailment heatmap by month and hour (2035)

Based on part 4 of Article 8 of the FNA methodology, a correlation analysis of RES curtailment with different parameters was carried out (see Figure 122).

The results show that the strongest positive correlation is observed between RES curtailment and wind and solar generation, while a negative correlation is found with the residual load indicator. This confirms that RES curtailment mainly formed under excess-generation conditions when high RES output coincides with limited system capability to absorb additional energy. Meanwhile, the correlation with electricity demand remains weak, indicating that demand variations are not a primary driver of RES curtailment. The most pronounced dependencies are observed in 2035, when the highest correlation coefficients are recorded between RES curtailment and wind generation as well as total RES output.

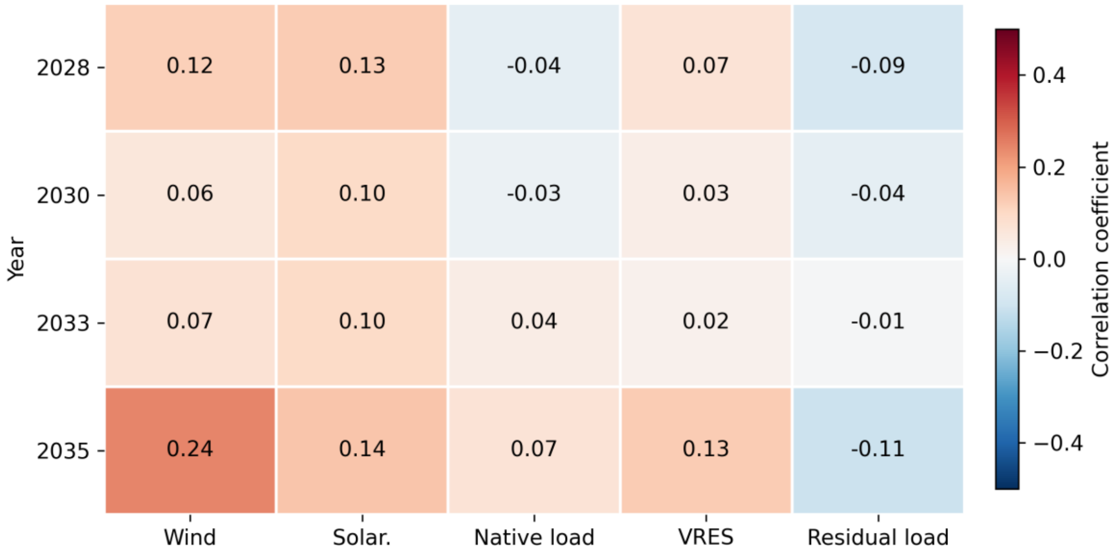

Figure 121 Correlation of RES production restrictions with different parameters

Based on part 5 of Article 8 of the FNA methodology, residual-load variability was evaluated across hourly, daily and seasonal dimensions (see Figure 123):

- Hourly indicator — shows residual-load deviations from the same-day average;
- Daily indicator — reflects daily values' deviations from the weekly average;
- Seasonal indicator — shows monthly values' deviations from the annual average..

The results show that hourly variations have the greatest impact on residual-load variability in all analyzed years, with their absolute annual sum increasing from 4,438 GWh in 2028 to 5,440 GWh in 2035. In contrast, the daily variability indicator grows more moderately — from 184 GWh to 248 GWh — while seasonal variability remains relatively small, ranging between 1,7 and 3,0 GWh. These findings indicate that the main system-balancing challenges arise from short-term, hour-scale residual-load changes, whereas longer-term variations account for a much smaller share of total variability. A consistent increase in all variability indicators up to 2035 is also observed, reflecting the growing influence of RES generation on power-system operation and rising flexibility needs for maintaining balance..

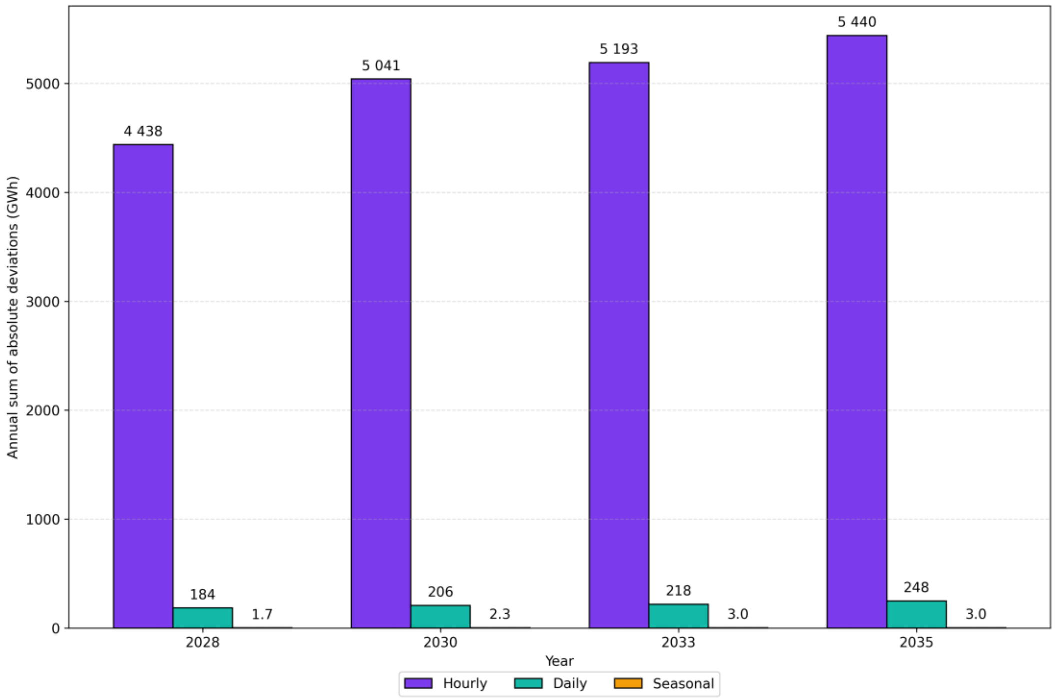

Figure 122 Residual load variation indicators by target year

Based on part 5 of Article 8 of the FNA methodology, the normalized residual-load variability indicators were additionally evaluated (see Figure 124).

The results show that the normalized values of all three variability components increase as the level of RES integration in the power system grows. The hourly variability indicator rises from 507 MW in 2028 to 621 MW in 2035, while the largest increase is observed in the daily-variability segment, where the indicator grows from 505 MW to 679 MW. Meanwhile, seasonal variability increases from 141 MW to 251 MW but remains significantly lower than hourly and daily fluctuations. The results indicate that in the future power system the greatest flexibility needs will be driven not only by short-term hourly changes but also by increasingly pronounced daily residual-load variations. The most pronounced change is observed in 2035, when the daily variability indicator exceeds the hourly one for the first time, indicating the growing importance of longer-lasting generation and demand imbalances for system balancing.

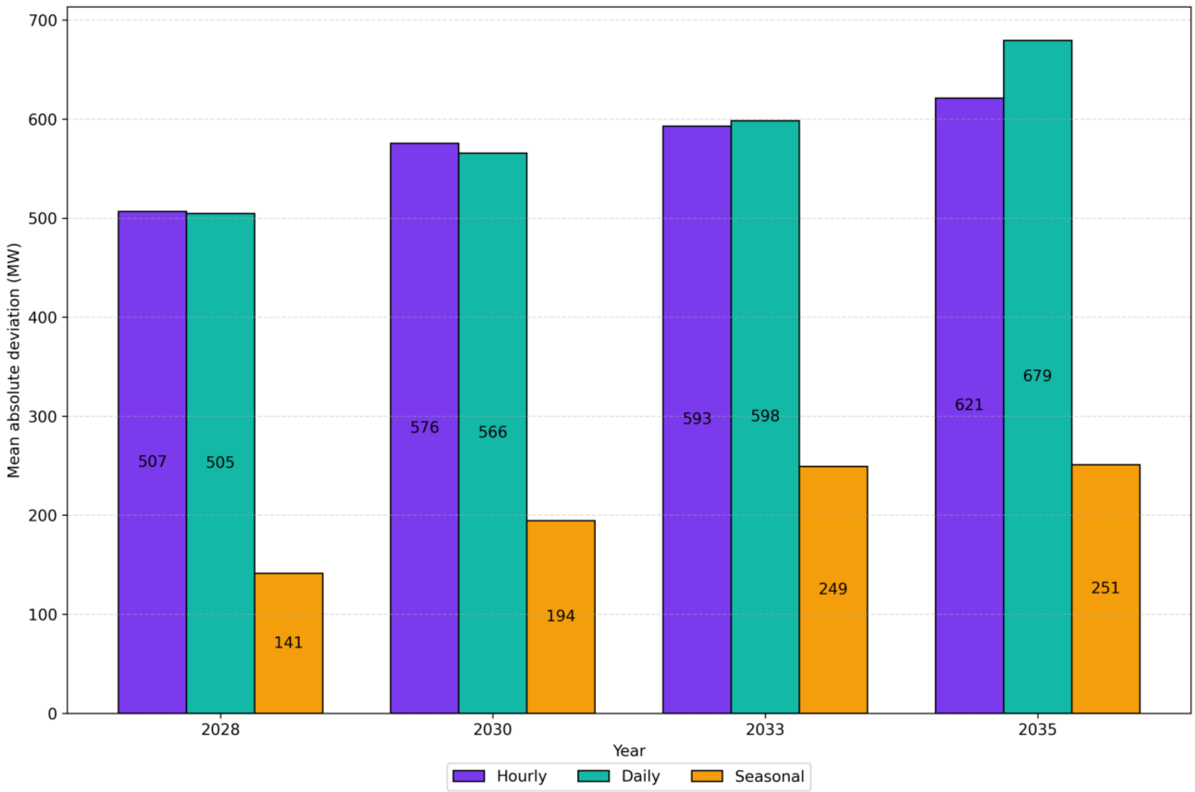

Figure 123 Normalized residual uncovered load variability indicators

Based on part 4 of Article 8 of the FNA methodology, the distribution of RES-curtailment event energy across individual curtailment periods was evaluated (see Figure 125).

The results show that most RES-curtailment events involve relatively small energy volumes, with a strongly asymmetric distribution shaped by a few large-scale events. In 2028–2033, the majority of curtailment periods remain below a few GWh, although isolated cases reach around 20–30 GWh. In contrast, the 2035 distribution becomes substantially wider — both the typical event size and the magnitude of exceptional events increase. The largest curtailment period in 2035 exceeds 80 GWh, indicating that the future system will face not only more frequent but also significantly larger excess-generation episodes. This means that growing RES deployment and increasing generation concentration raise the risk of isolated yet highly impactful curtailment events that substantially influence the total annual curtailment volume.

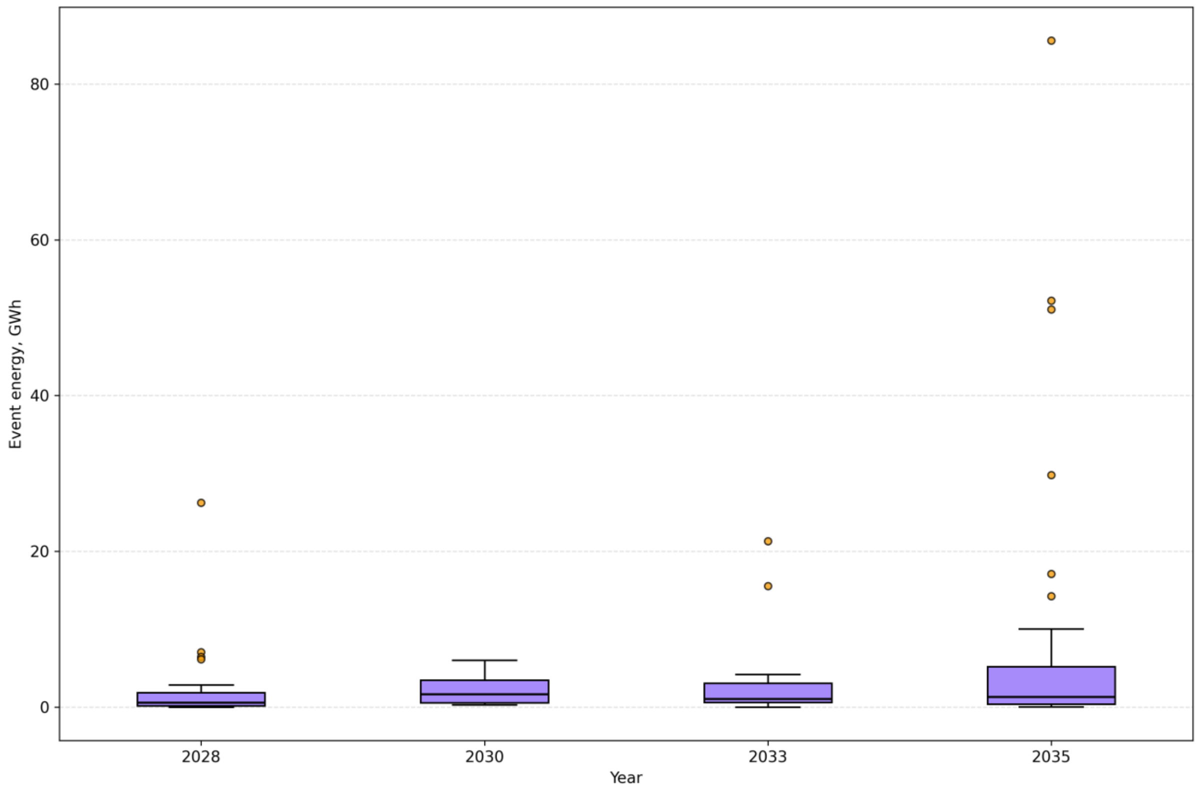

Figure 124 Energy distribution of RES curtailment events by target year

Based on parts 6–9 of Article 8 of the FNA methodology, the share of RES curtailment relative to total RES generation was evaluated for each target year (see Figure 126).

The results show that the level of RES curtailment remains relatively low in all analyzed years, not exceeding 2 % of total annual RES generation. The smallest curtailment share is observed in 2030, at 0,21 %, reflecting the positive impact of additional BESS capacities on system flexibility and the ability to absorb excess RES production. In subsequent years, the curtailment level increases — reaching 0,33 % in 2033 and rising to 1,89 % in 2035. Although absolute curtailment volumes become significant in 2035, their relative share of total RES generation remains modest. This indicates that even with rapidly growing RES capacities, the majority of renewable energy is successfully integrated into the power system, while the increasing curtailment trend highlights the growing need for additional flexibility resources to avoid curtailment in the future.

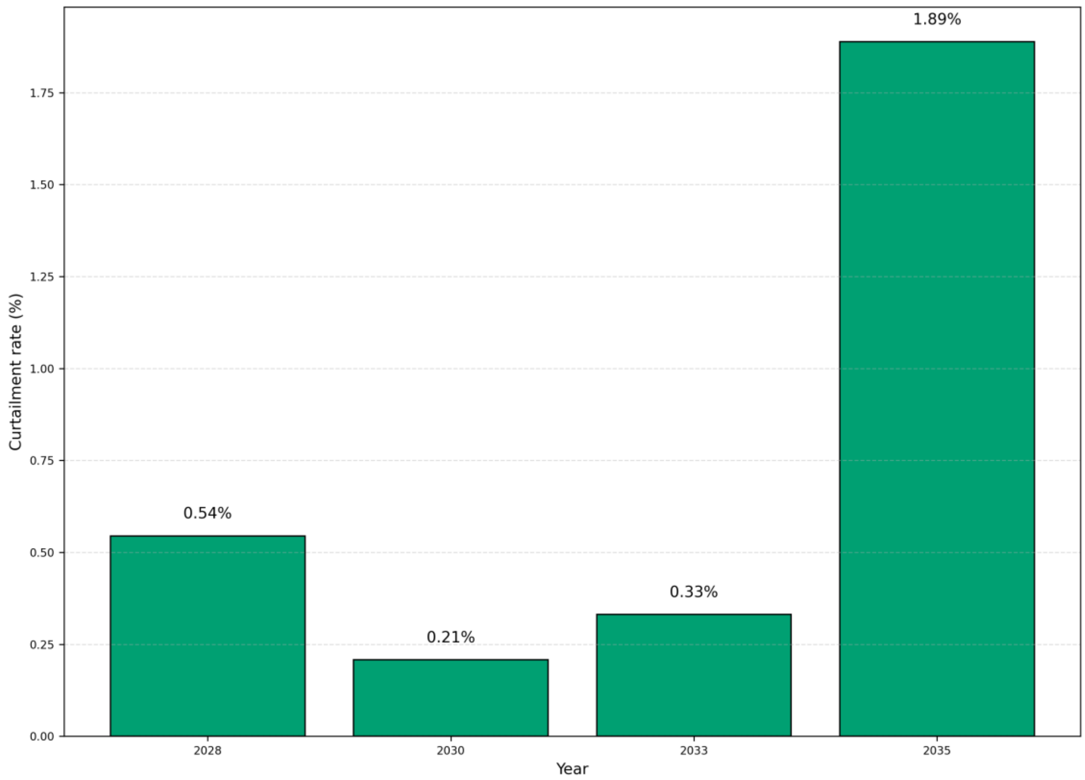

Figure 125 Part of RES curtailment in total RES generation in target year

Based on part 4 of Article 8 of the FNA methodology, the structure of RES curtailment by generation technologies was evaluated (see Figure 127).

The results show that in 2028–2033 the structure of RES curtailment was dominated by onshore wind and solar power plants generation. In 2028, the largest share of curtailment was attributed to onshore wind (39,9 %), while the remaining part was distributed relatively evenly between TSO solar power plants (27,1 %) and DSO solar power plants (33,0 %). In 2030, the contribution of onshore wind and TSO solar power plants became nearly identical (30,3 % and 30,4 % respectively), with DSO solar power plants forming the largest share (39,3 %). In 2033, the importance of onshore wind increased again, reaching 42,8 % of total curtailment.

The results show a fundamental structural change in 2035, when the integration of the offshore wind park causes its curtailment part to rise to 61,6 % of all RES curtailment. At the same time, the part of onshore wind drops to 19,6 %, while the contribution of TSO and DSO solar power plants decreases to 8,9 % and 10,0 % respectively. Considering that total annual RES curtailment increases to 379,2 GWh in 2035, it can be concluded that offshore wind generation becomes the primary driver of curtailment growth, and its integration significantly reshapes the overall curtailment structure in the Lithuanian region..

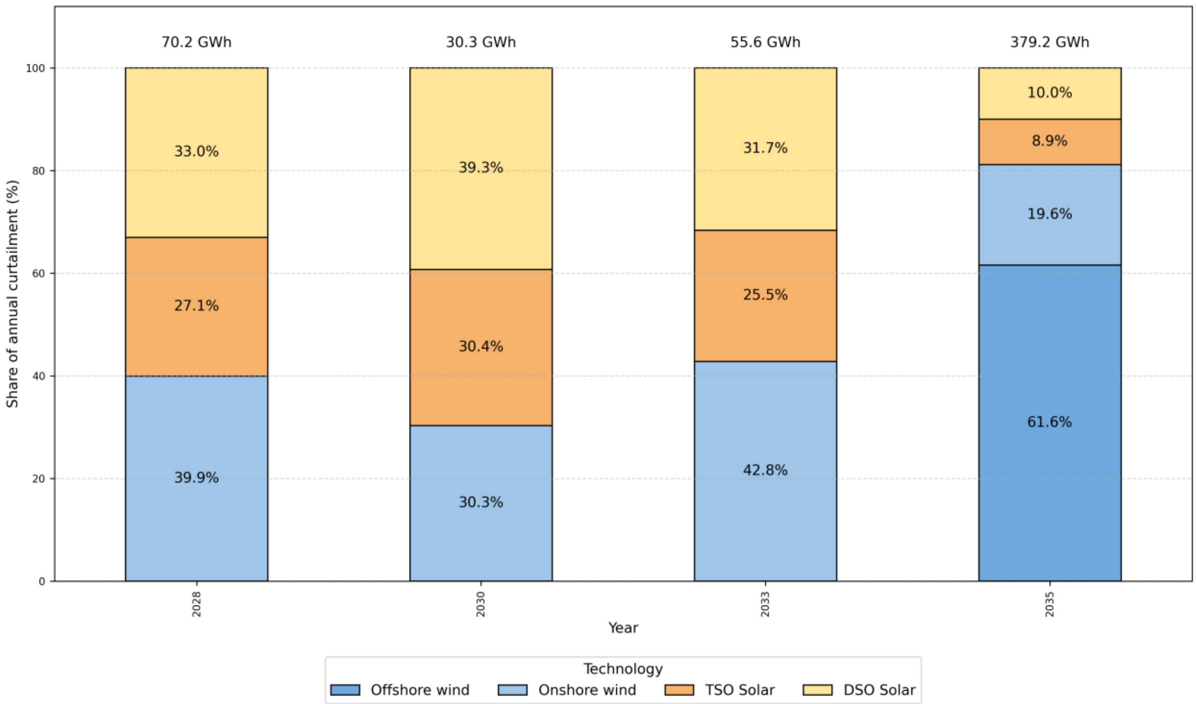

Figure 126 RES curtailment level by technology

6.2.1.1. Assessment of the impact of additional flexibility resources on reducing RES curtailment

Based on parts 10–12 of Article 8 of the FNA methodology, the impact of additional flexibility resources on reducing RES curtailment was evaluated. During the modelling, flexibility resources were charged exclusively from curtailed RES generation, while the stored energy was discharged during periods of positive residual load. This approach allowed assessing how much RES curtailment remains in the system after integrating additional flexibility resources and identifying the most effective combinations of power and duration for each target year

Based on parts 10–12 of Article 8 of the FNA methodology, the remaining RES curtailment after integrating additional flexibility resources was evaluated by analyzing different combinations of power and energy-storage capacity (see Figures 128–131). The results show that the effectiveness of RES-curtailment reduction depends on both the power of flexibility resources and the duration of energy storage. In the 2028, 2030 and 2033 scenarios, initial curtailment levels amount to 58 GWh, 25 GWh and 48 GWh respectively, yet increasing power and storage capacity allows RES curtailment to be fully eliminated. The highest flexibility need is observed in 2035, when initial RES curtailment reaches 350 GWh per year. Nevertheless, the results indicate that even in this scenario, sufficiently high-power and long-duration flexibility resources can reduce residual RES curtailment to 0 GWh. This confirms that additional flexibility resources can significantly contribute to increasing RES integration across all analyzed target years.

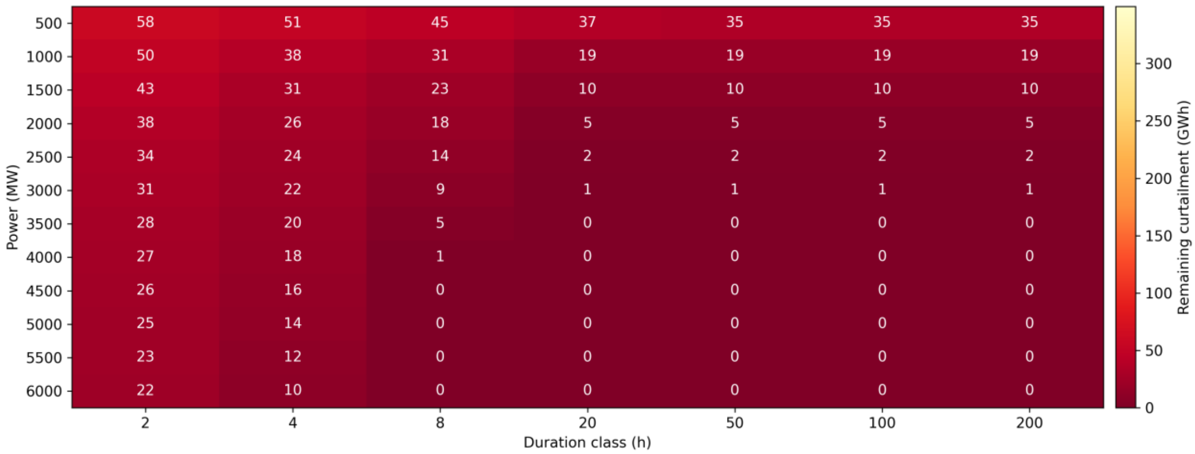

Figure 127 Residual generation curtailment amount after the inclusion of additional flexibility resources (2028)

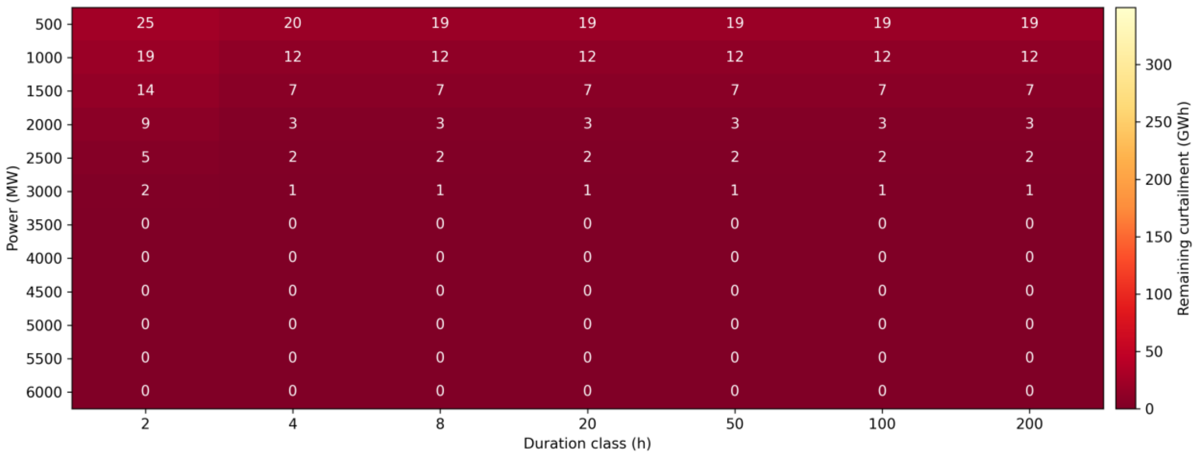

Figure 128 Residual generation curtailment amount after the inclusion of additional flexibility resources (2030)

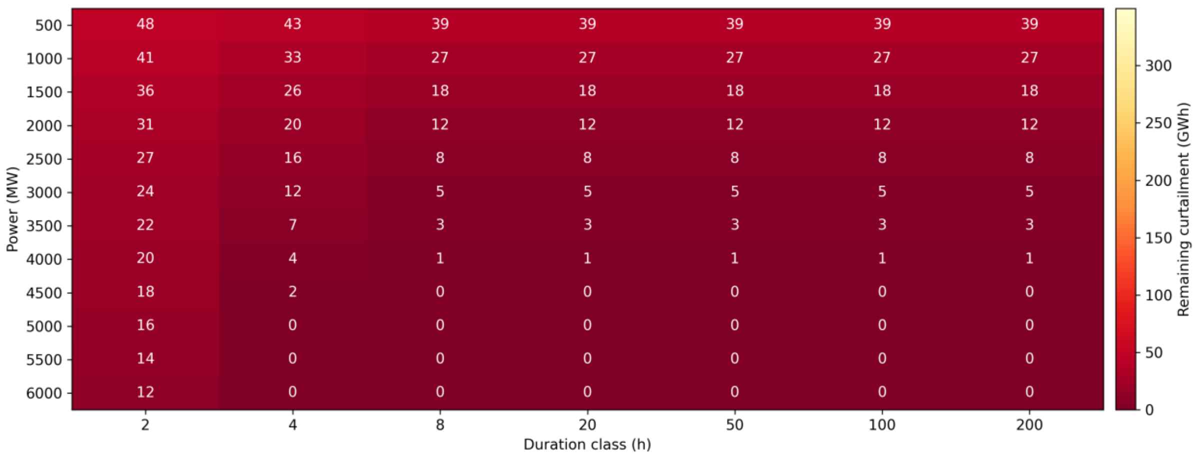

Figure 129 Residual generation curtailment amount after the inclusion of additional flexibility resources (2033)

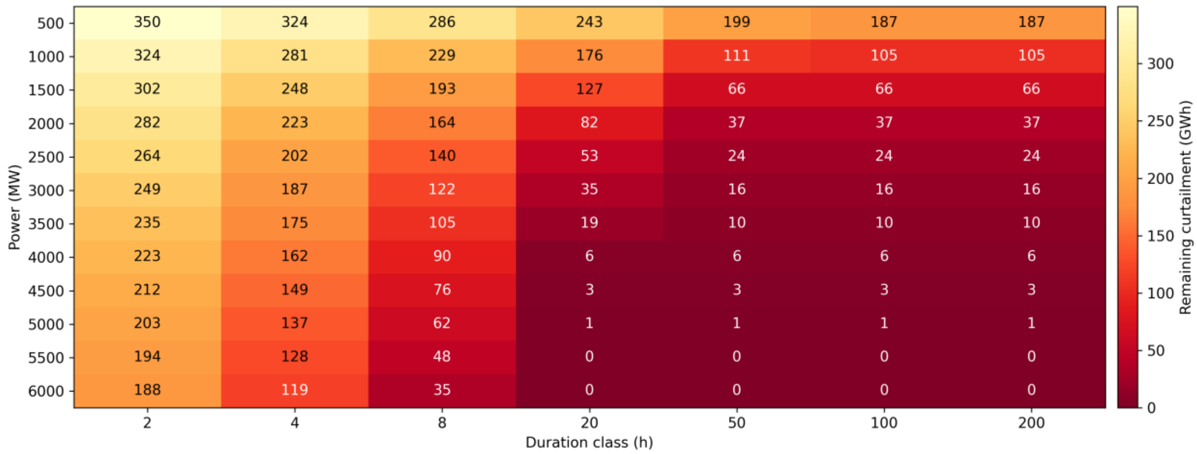

Figure 130 Residual generation curtailment amount after the inclusion of additional flexibility resources (2035)

Based on parts 10–12 of Article 8 of the FNA methodology, the potential for reducing RES curtailment was additionally evaluated as a function of flexibility-resource power and energy-storage duration. The figures (see Figures 132–135) present the magnitude of RES-curtailment reduction relative to the baseline curtailment level for each target year. The results show that the potential for reducing RES curtailment increases with both higher flexibility-resource power and longer energy-storage duration. Short-duration flexibility options (2–4 h) effectively reduce short-term RES-generation surpluses, but their potential becomes limited as overall curtailment volumes grow. In contrast, long-duration flexibility resources (20–200 h) can absorb extended periods of excess generation and achieve near-complete elimination of RES curtailment.

In 2028, the baseline RES-curtailment level of 70,2 GWh is almost fully eliminated when using flexibility resources with durations of at least 8 hours and power ratings of approximately 4000–4500 MW. In 2030, due to the relatively small initial curtailment (30,3 GWh), the entire curtailment volume can be removed with significantly lower flexibility capacities. In 2033, a similar pattern to 2028 is observed, although achieving full curtailment elimination requires larger combinations of power and energy-storage capacity.

The highest flexibility need is observed in 2035, when the baseline RES-curtailment level reaches 379,2 GWh. In this case, short-duration flexibility resources remain insufficient even at high power ratings, and a meaningful reduction in curtailment is achieved only with long-duration (20–200 h) energy-storage solutions. For example, 2-hour flexibility resources — even at 6000 MW of power — reduce only about half of the baseline curtailment, whereas 50–200 hour storage durations enable near-complete elimination of the 379,2 GWh curtailment. This demonstrates that as offshore-wind generation increases in the system, the dominant requirement shifts from power capacity to energy capacity, which is essential for absorbing prolonged periods of surplus generation..

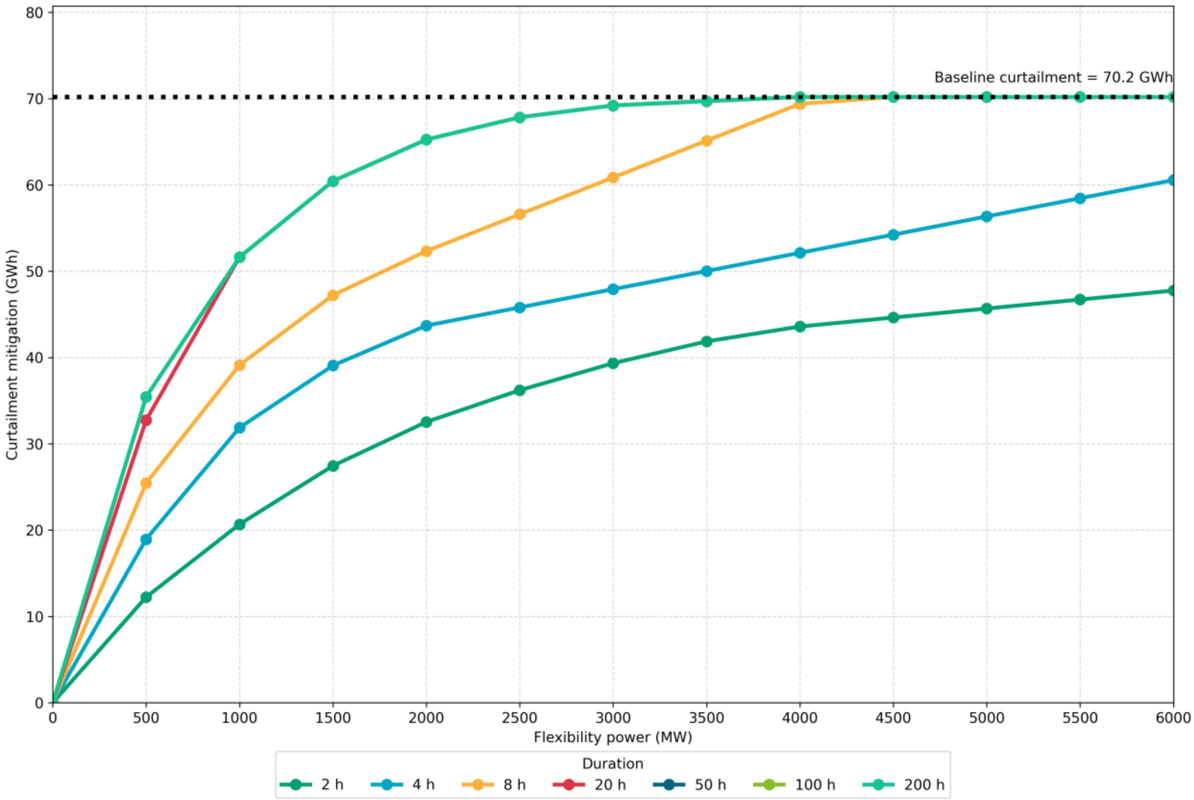

Figure 131 Removal of RES curtailment and flexible generation (2028)

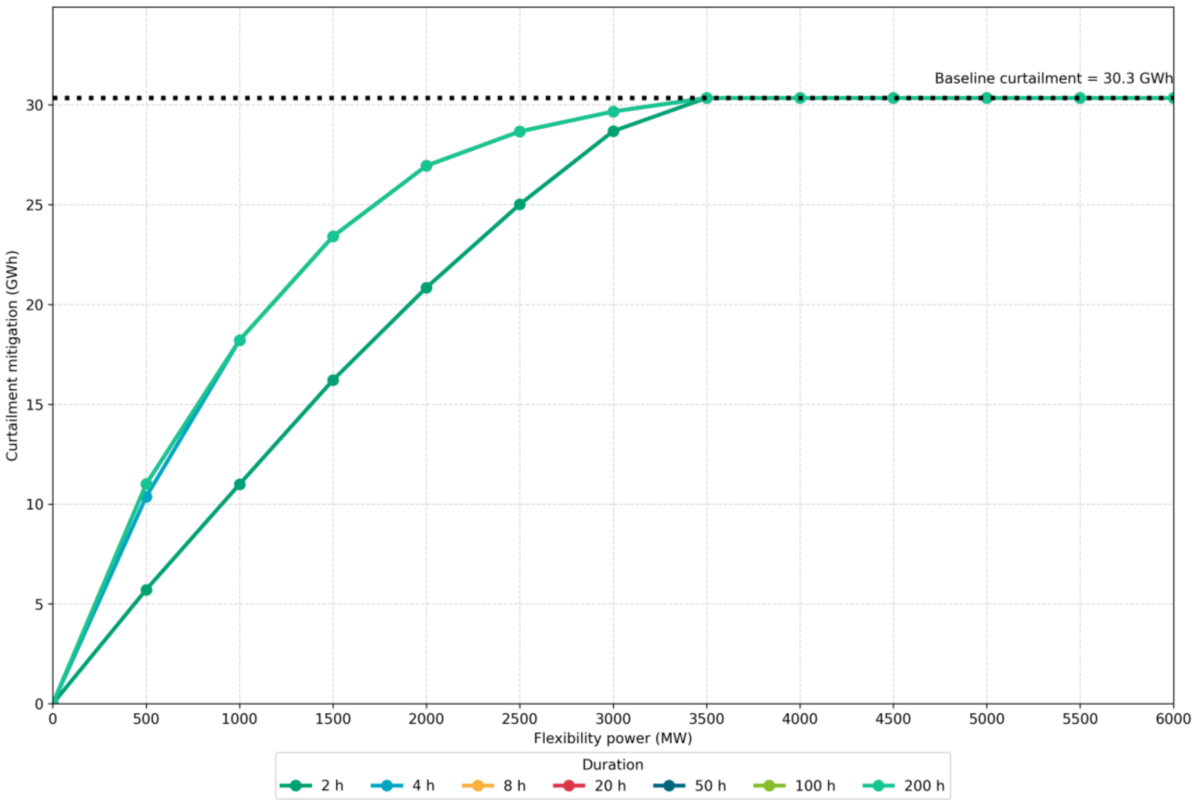

Figure 132 Removal of RES curtailment and flexible generation (2030)

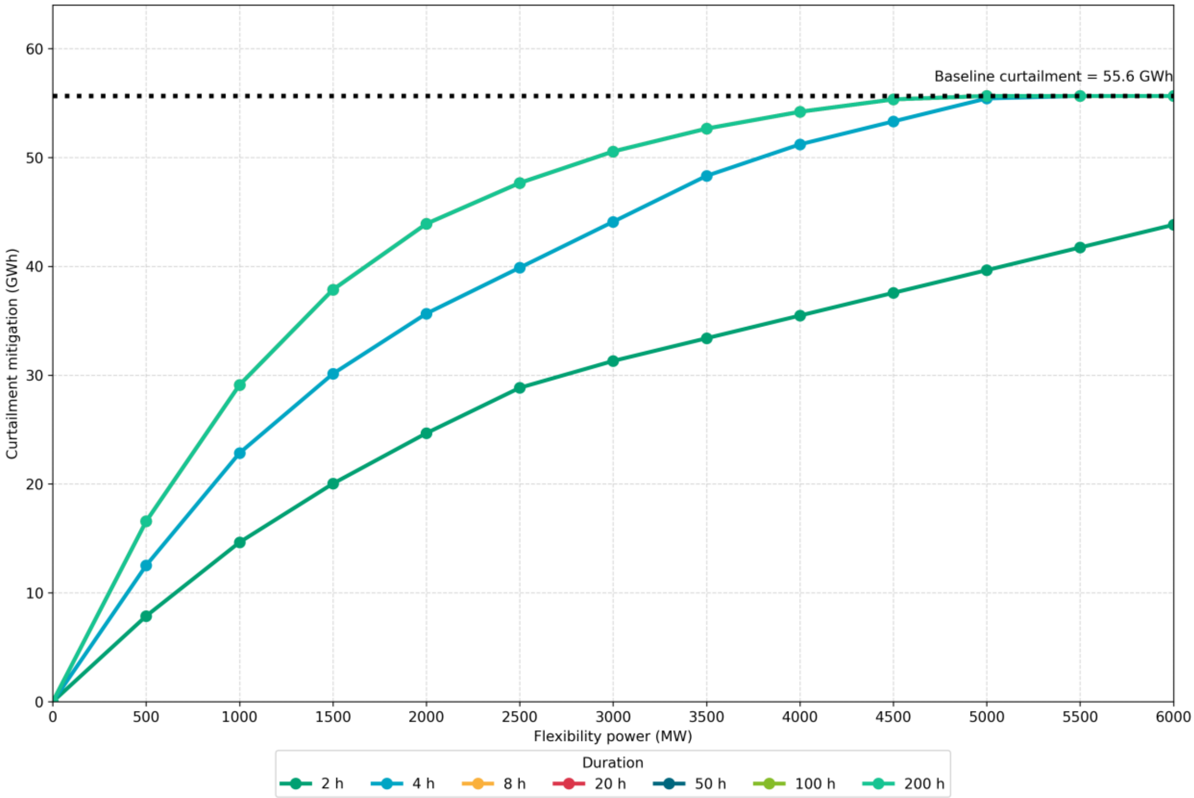

Figure 133 Removal of RES curtailment and flexible generation (2033)

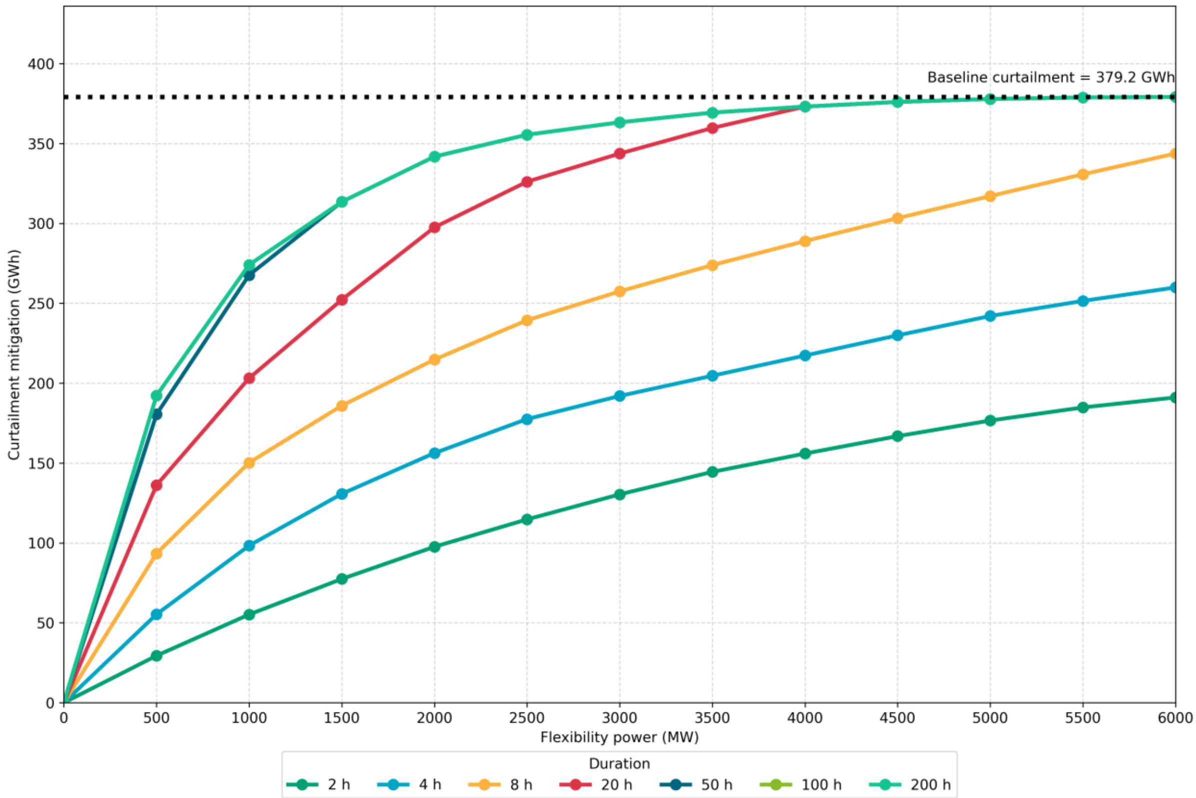

Figure 134 A Removal of RES curtailment and flexible generation (2035)

Based on part 3 of Article 8 of the FNA methodology, short-term flexibility constraints were assessed in addition to the baseline RES-curtailment levels (see Figure 136). The results show that the additional RES curtailment in all target years is small, ranging from 0,0 to 0,9 GWh. The largest impact is observed in 2028 (0,9 GWh), while in 2030 and 2033 the additional curtailment amounts to only 0,3 GWh and 0,1 GWh respectively. In 2035, practically no additional RES curtailment is identified. This indicates that the influence of short-term flexibility constraints on overall RES-curtailment levels in the analyzed scenarios is negligible.

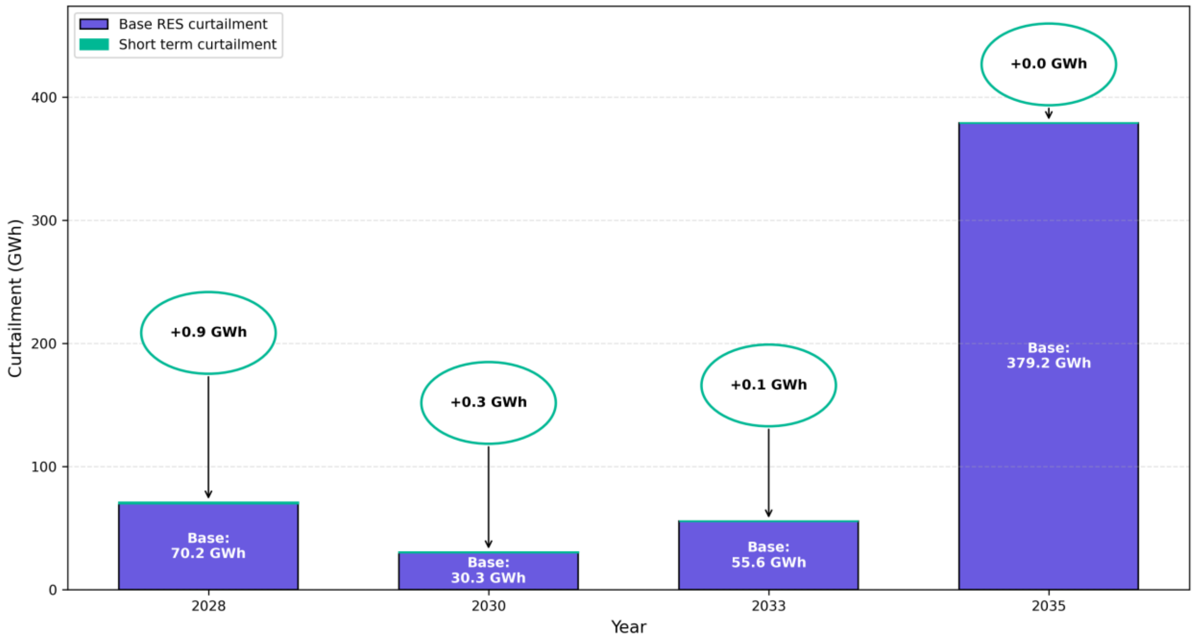

Figure 135 Basic and additional short-term flexibility RES curtailment

The adjusted results show that incorporating the impact of short-term flexibility constraints leads to no meaningful changes in overall RES-curtailment levels (see figure below). In 2028, the curtailment level increases only marginally—from 0,54 % to 0,55 %—while in 2030, 2033 and 2035 the indicators remain practically unchanged at 0,21 %, 0,33 % and 1,89 % respectively. These findings confirm that the influence of short-term flexibility limitations on total RES curtailment in the analyzed scenarios is negligible

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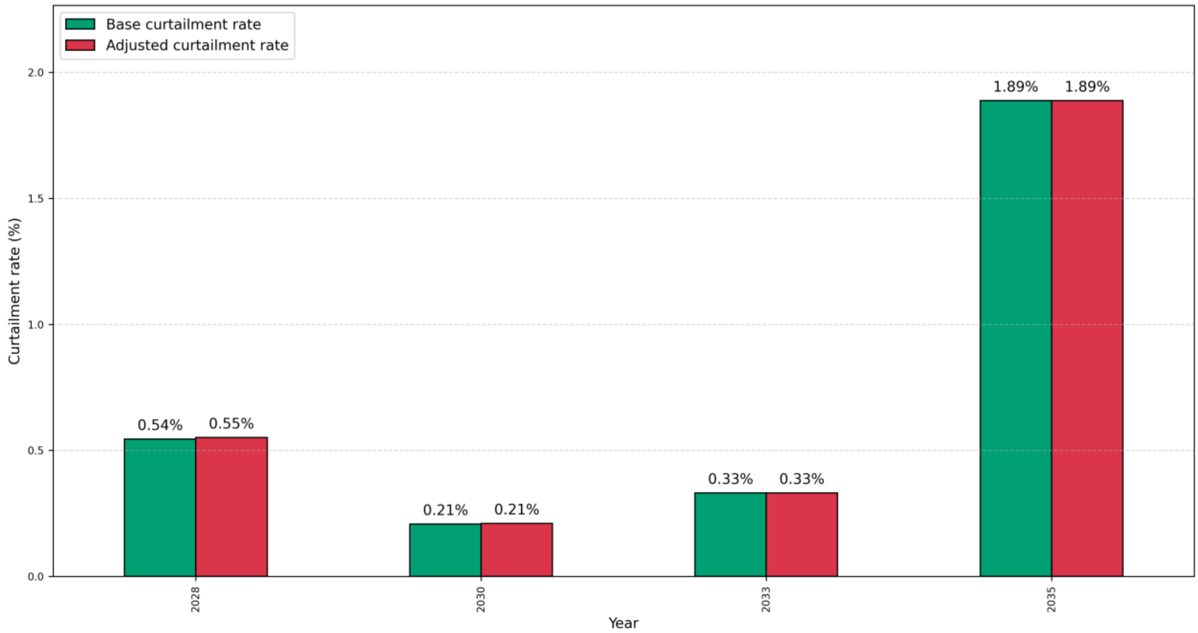


Figure 136 Basic and adjusted RES curtailment levels by target year

6.2.2. Ramping needs

6.2.2.1. Ramping needs assessment methodology

In accordance with Article 9 of the FNA methodology, a ramping-needs assessment was carried out by analyzing changes in residual load between consecutive market time units for each target year (see figures below).

Residual load was calculated by subtracting RES generation—offshore wind, onshore wind, PSO solar and DSO solar power plant and hydropower—from total demand. Positive changes in residual load were attributed to upward ramping needs, while negative changes were assigned to downward ramping needs..

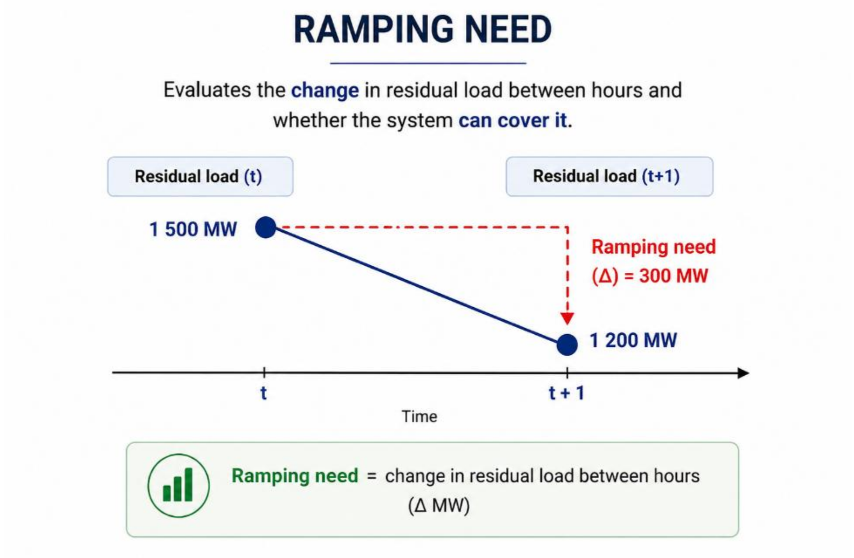


Figure 137 Example of ramping needs assessment methodology

To evaluate the system's ability to cover these ramping requirements, upward and downward ramping capabilities were calculated based on the technical constraints of all major flexibility sources. The assessment included thermal generation units, RES-curtailment capabilities, KHAE in both generation and pumping modes, BESS, electrolysers, and cross-border interconnectors.

Uncovered ramping needs were computed as the difference between the residual-load change and the available ramping capability in the corresponding direction. If system flexibility was sufficient, the uncovered ramping need was set to zero. A sensitivity analysis was additionally performed for four scenarios:

- Basic scenario;
- Scenario without interconnectors and without electrolysers;
- Scenario without interconnectors but with electrolysers;
- Scenario without electrolysers.

This approach made it possible to assess the contribution of cross-border interconnectors and flexible electrolysers operation to covering ramping needs.

6.2.2.2. Results of ramping needs

According to part 2 of Article 9 of the FNA methodology, the average system capability to cover upward ramping needs was evaluated across different scenarios and target years. This indicator reflects the system's average annual flexibility to increase generation or reduce demand during periods when the residual load is rising.

The results show (Figure 139) that in the basic scenario the average coverage of upward ramping needs increases steadily from 3656 MW in 2028 to 6556 MW in 2035. The strongest contributors to system flexibility are cross-border interconnectors and electrolysers. In the "No interconnectors & no P2X" scenario, the indicator drops by more than half, reaching only 2155 MW in 2035, while in the "No interconnectors" scenario it amounts to 2537 MW. In contrast, the "No P2X" scenario remains close to the basic, differing by only 1–6 %, which indicates that electrolysers have a relatively small impact on the average coverage of upward ramping needs. Overall, the results confirm that the primary factor enhancing system flexibility is the availability of cross-border interconnectors, and their absence significantly reduces the system's ability to respond to rapid increases in residual load.

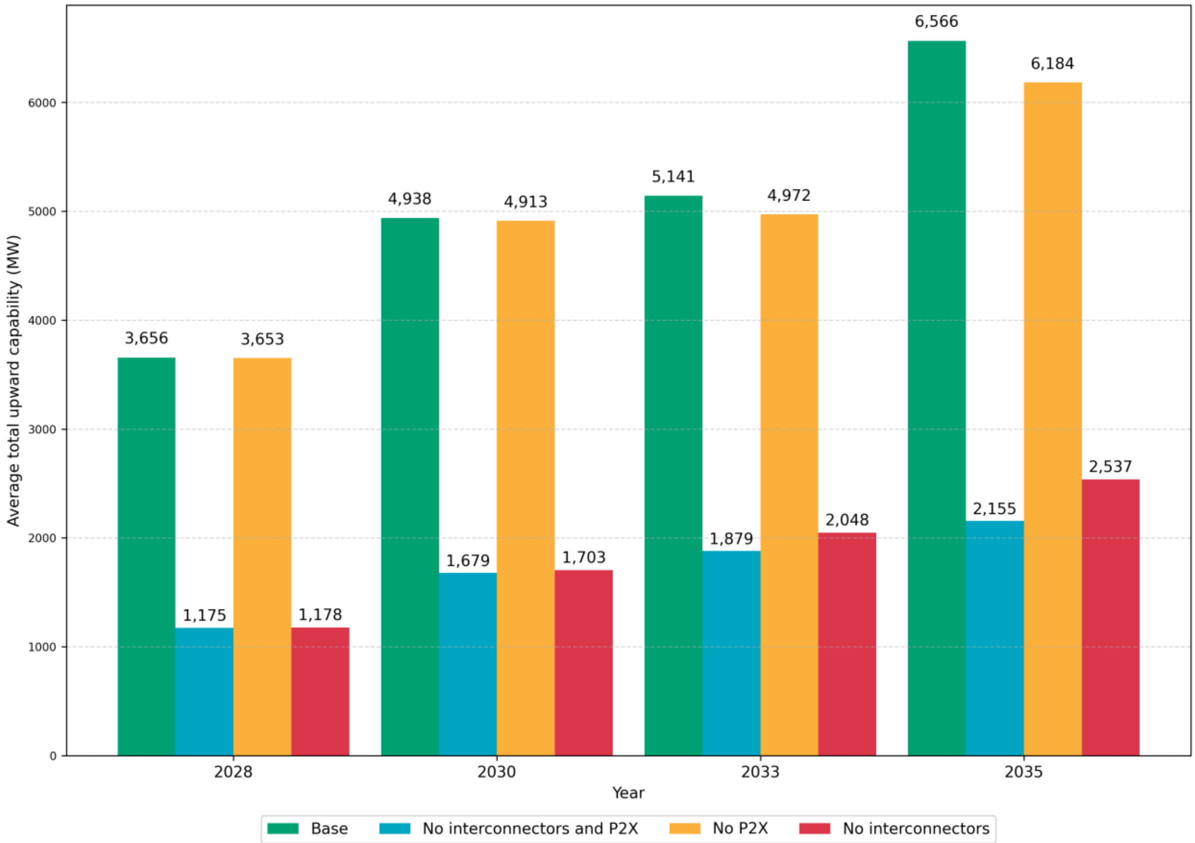


Figure 138 Average annual upward ramping capability by scenario and target year (MW)

According to part 3 of Article 9 of the FNA methodology, the average system capability to cover downward ramping needs was evaluated. This indicator reflects the system's ability to reduce generation or increase demand during periods when the residual load becomes negative and surplus generation forms in the system.

The results (Figure 140) show that in the basic scenario the average coverage of downward ramping needs increases steadily from 5856 MW in 2028 to 9912 MW in 2035. As with upward ramping needs, cross-border interconnectors are the dominant factor shaping system flexibility. In the "No interconnectors & no P2X" and "No interconnectors" scenarios, the system's ability to absorb surplus generation decreases by approximately 40–45 %, reaching 5298 MW and 5591 MW respectively in 2035. In contrast, the "No P2X" scenario remains remarkably close to the basic, with differences of only a few percent across all target years. These results indicate that the system's capability to manage periods of surplus generation is primarily driven by the availability of cross-border interconnectors, while the impact of electrolysers on average downward ramping coverage is relatively small..

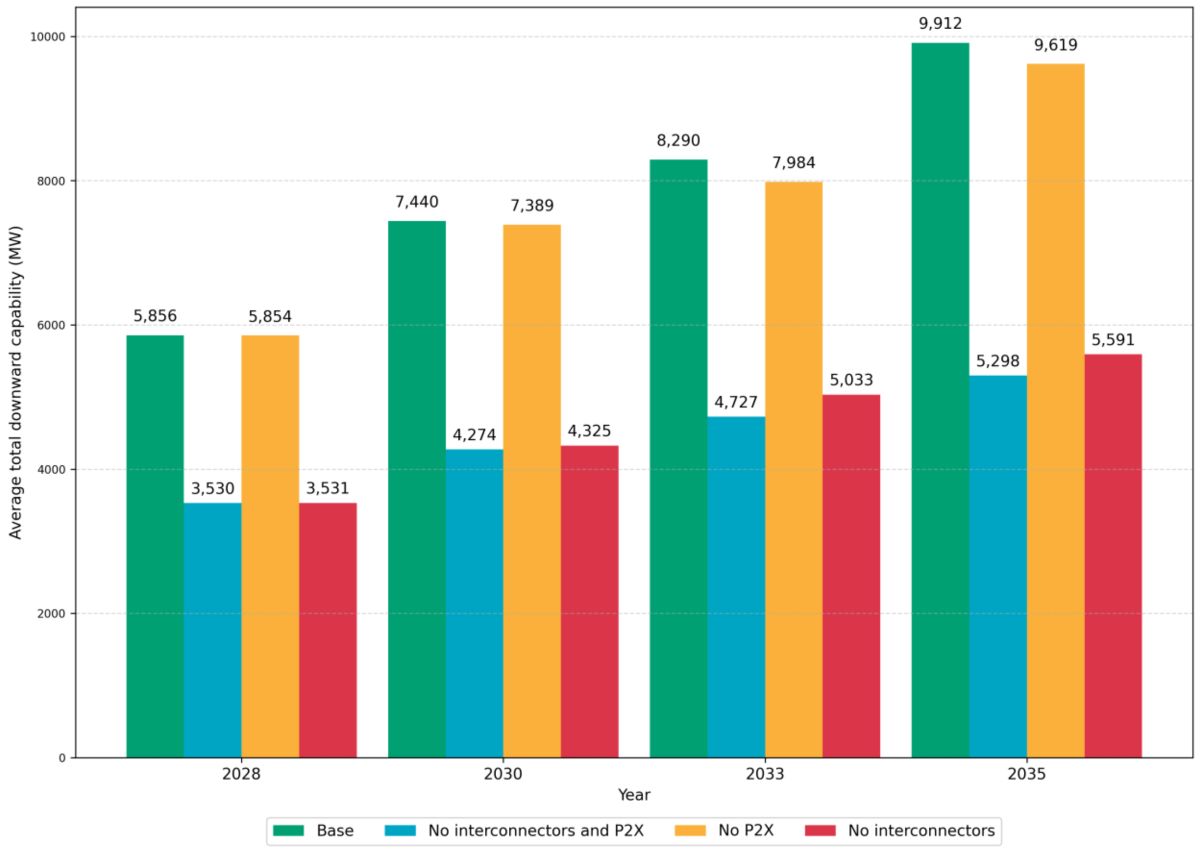


Figure 139 Average annual downward ramping capability by scenario and target year (MW)

According to part 4 of Article 9 of the FNA methodology, the maximum uncovered upward ramping need was evaluated across different scenarios and target years. This indicator shows the largest power deficit that occurs when the system's available upward-flexibility capability is insufficient to cover a sudden increase in residual load.

The results (see Figure 141) show that in the basic scenario the maximum uncovered upward ramping need is equal to 0 MW in all target years, indicating that the system has sufficient upward-flexibility reserves even during the most challenging hours. In contrast, scenarios with limited cross-border connections create significant uncovered needs. The highest value is observed in 2030 in the "No interconnectors & no P2X" scenario, where the maximum uncovered need reaches 904 MW, while in the "No interconnectors" scenario it amounts to 829 MW. In 2028, 2033 and 2035 the uncovered needs range from 444 MW to 731 MW. No uncovered upward ramping needs are identified in the "No P2X" scenario, confirming that the primary driver behind these shortages is the unavailability of cross-border interconnectors.

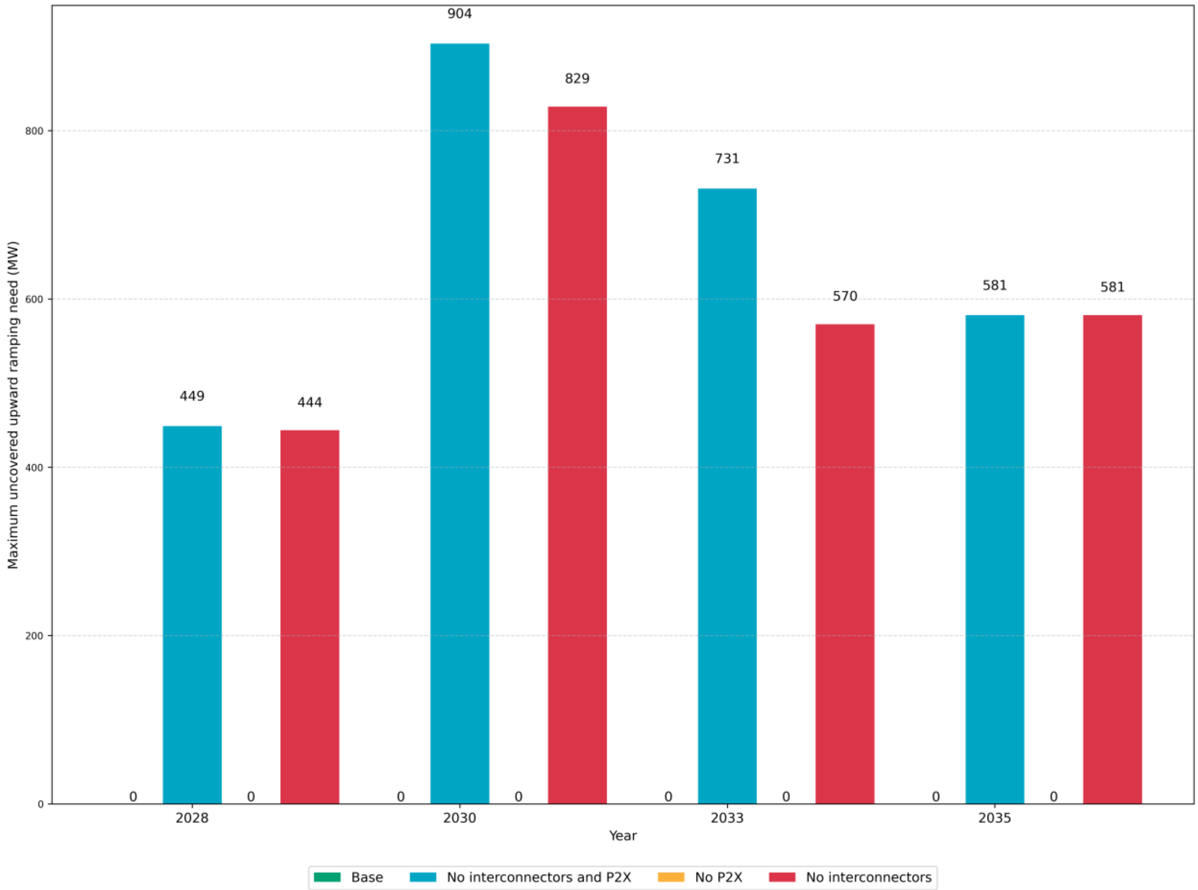


Figure 140 Maximum uncovered upward ramping need by target year and scenario

According to part 5 of Article 9 of the FNA methodology, the maximum uncovered downward ramping need was evaluated across different scenarios and target years. The results show that in all analyzed scenarios and target years no uncovered downward ramping needs were identified — in every case, the maximum value remains equal to 0 MW (see Figure 142).

This indicates that throughout all modelled periods the system had sufficient flexibility capacity to reduce generation or increase demand during moments of declining residual load.

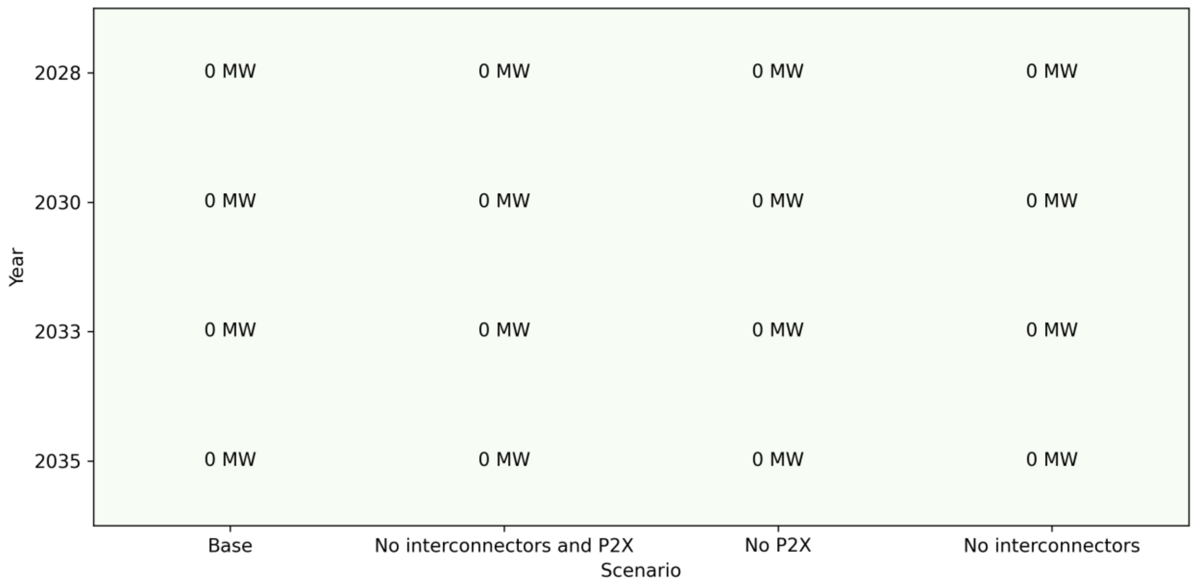


Figure 141 Maximum uncovered downward ramping needs by target year and scenario (MW)

According to part 2 of Article 9 of the FNA methodology, the distribution of uncovered upward ramping needs was evaluated across different scenarios and target years. The results (see figure below) show that most uncovered upward ramping events remain relatively small, yet certain periods exhibit substantial flexibility shortages. In the “No interconnectors & no P2X” scenario, the average uncovered need ranges from 87 MW in 2028 to 128 MW in 2033, while the largest recorded deficits span from 449 MW to 904 MW. The highest risk is observed in 2030, when the maximum uncovered need reaches 904 MW. In the “No interconnectors” scenario, average values are similar (88–138 MW), and maximum deficits range from 444 MW to 829 MW. In both scenarios, the distributions are strongly asymmetric – most events are concentrated in the lower range, but occasionally there are large, uncovered needs that significantly increase the maximum rates. This shows that the unavailability of cross-border connections primarily increases the risk of extreme flexibility shortage situations, and the additional lack of P2X capacity further amplifies this effect.

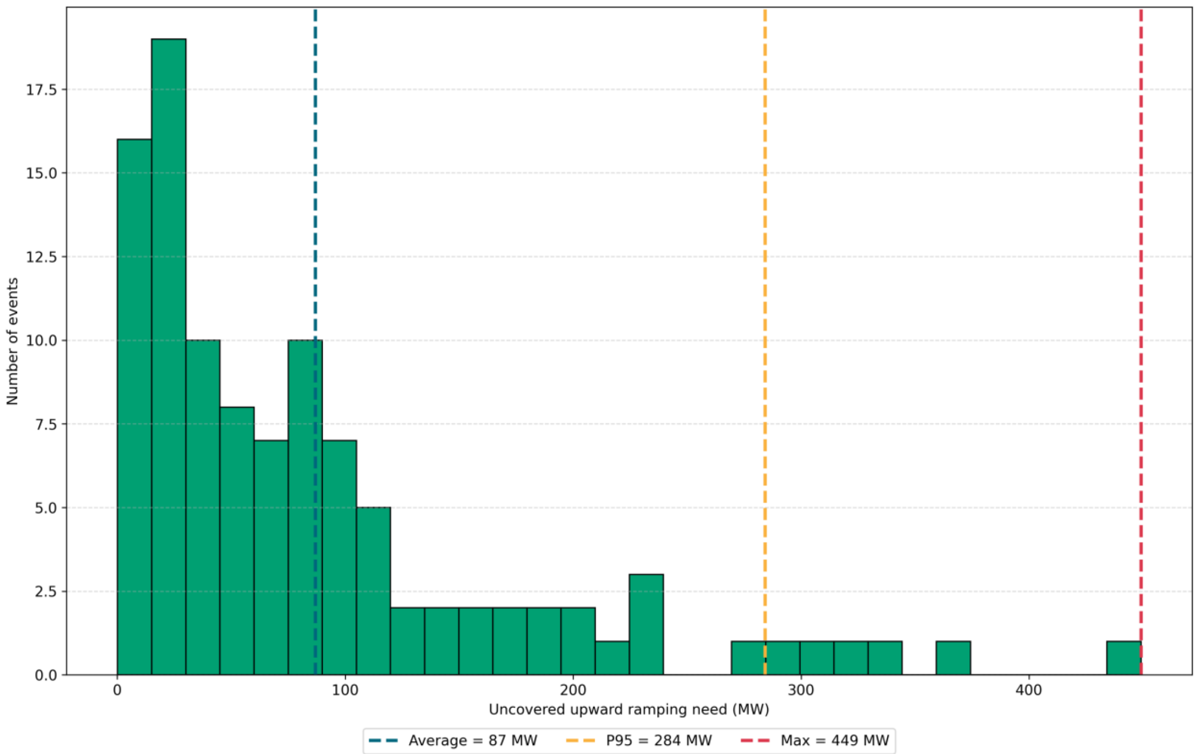


Figure 142 Distribution of uncovered upward ramping needs in the scenario without interconnectors and P2X [2028]

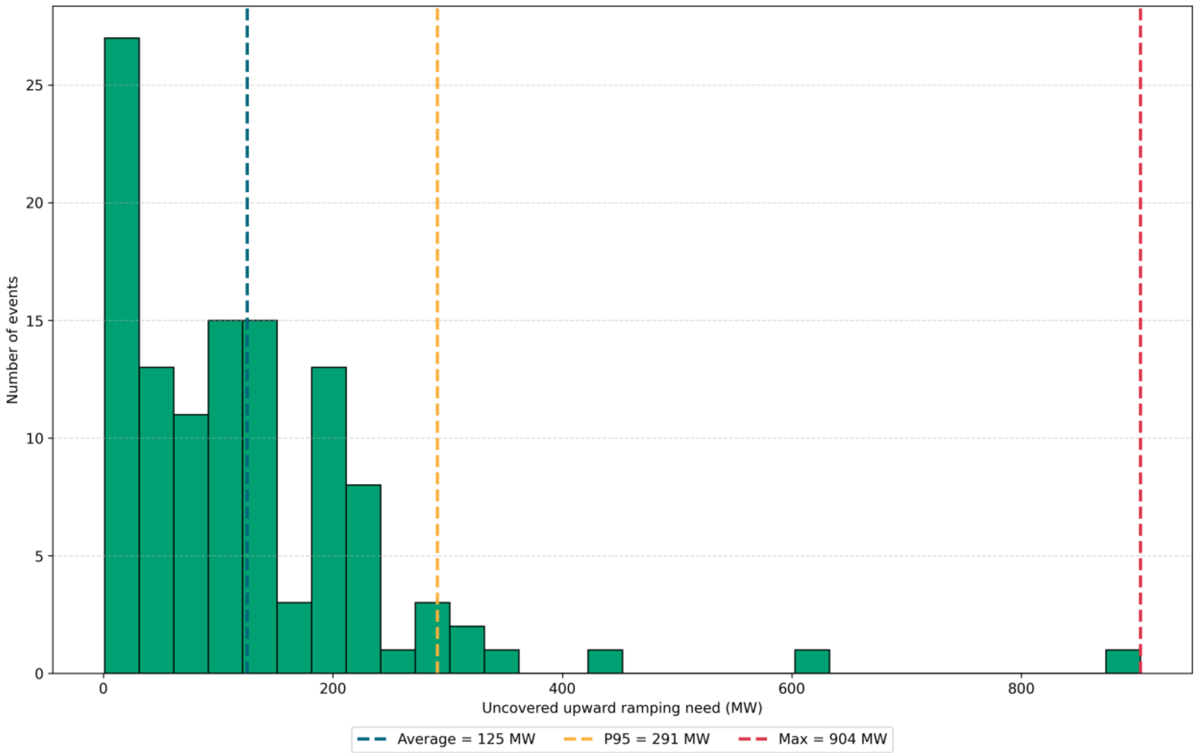


Figure 143 Distribution of uncovered upward ramping needs in the scenario without interconnectors and P2X [2030]

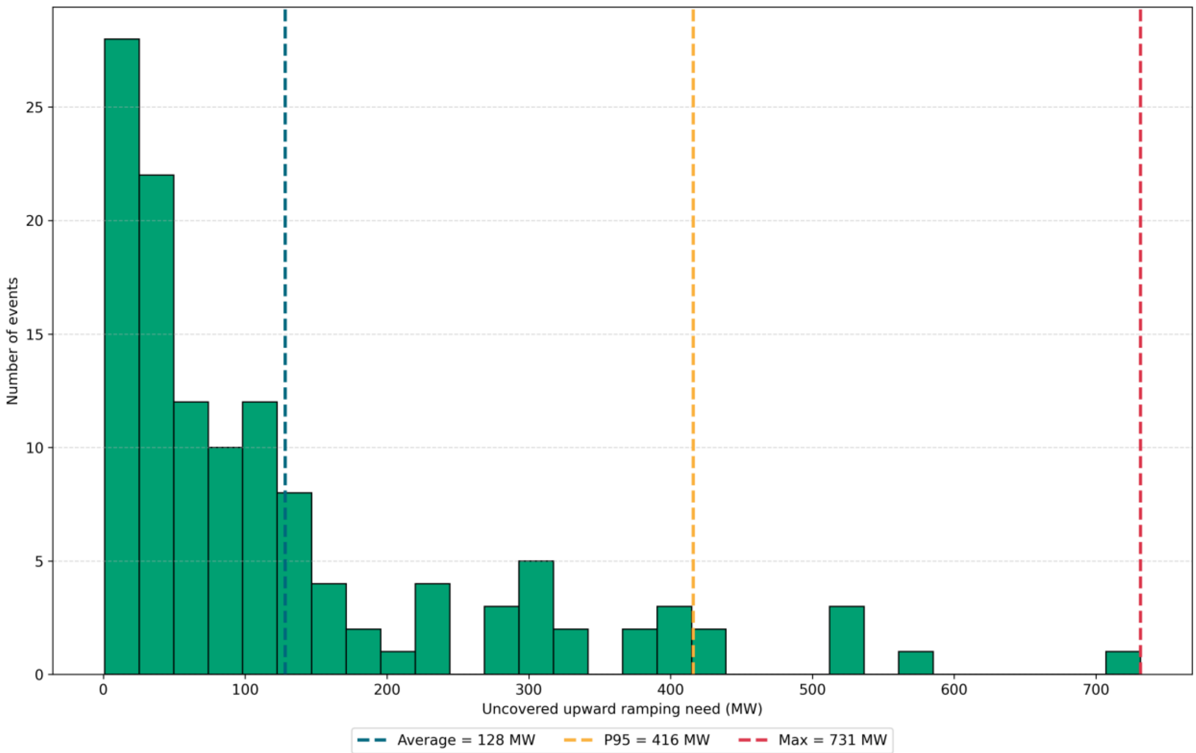


Figure 144 Distribution of uncovered upward ramping needs in the scenario without interconnectors and P2X [2033]

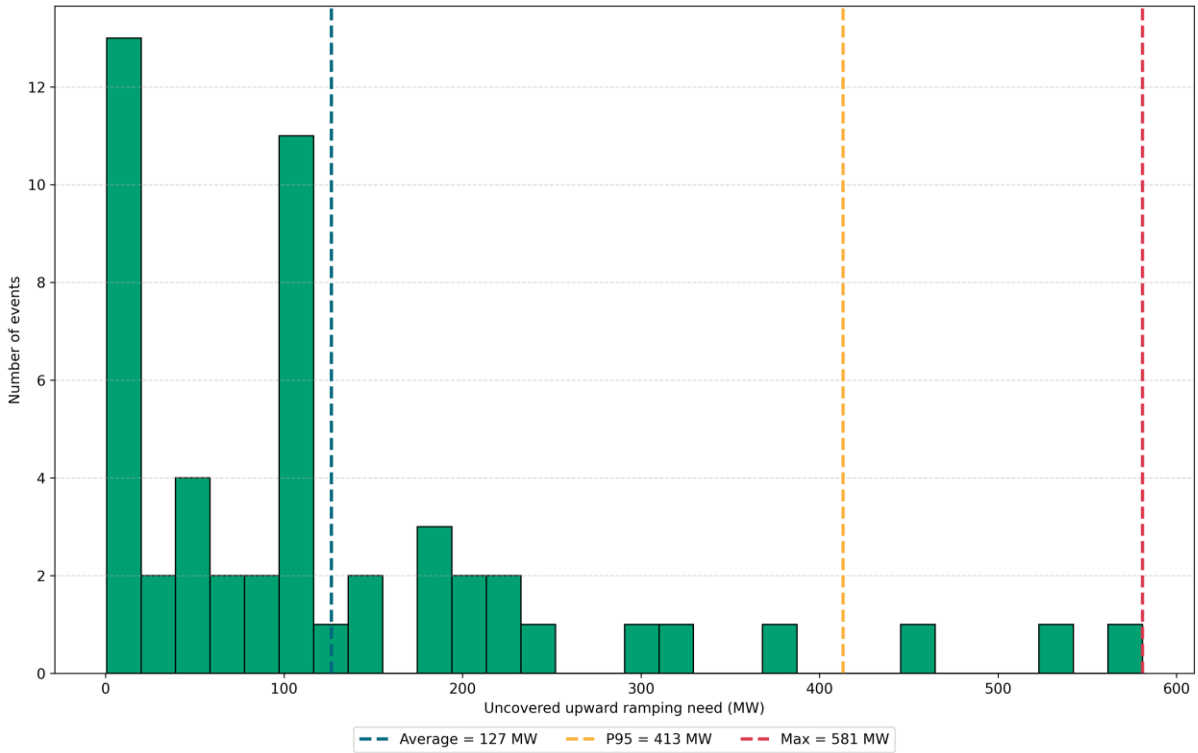


Figure 145 Distribution of uncovered upward ramping needs in the scenario without interconnectors and P2X [2035]

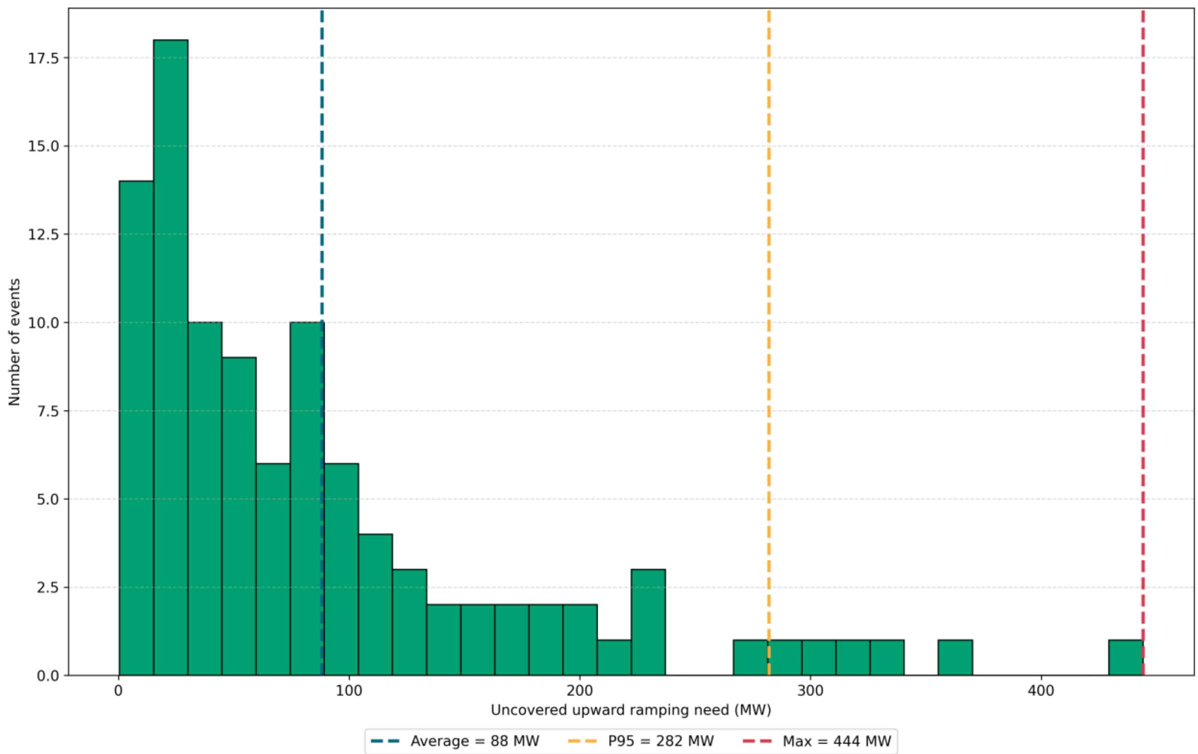


Figure 146 Distribution of uncovered upward ramping needs in the scenario without interconnectors [2028]

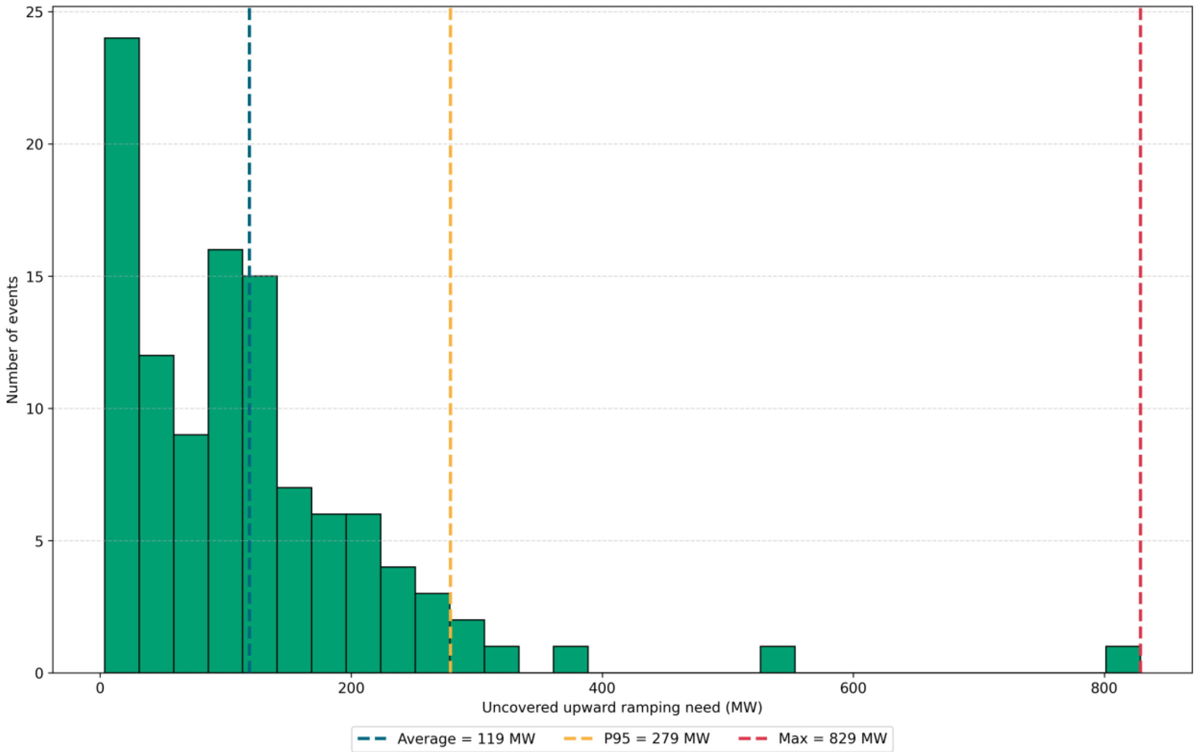


Figure 147 Distribution of uncovered upward ramping needs in the scenario without interconnectors [2030]

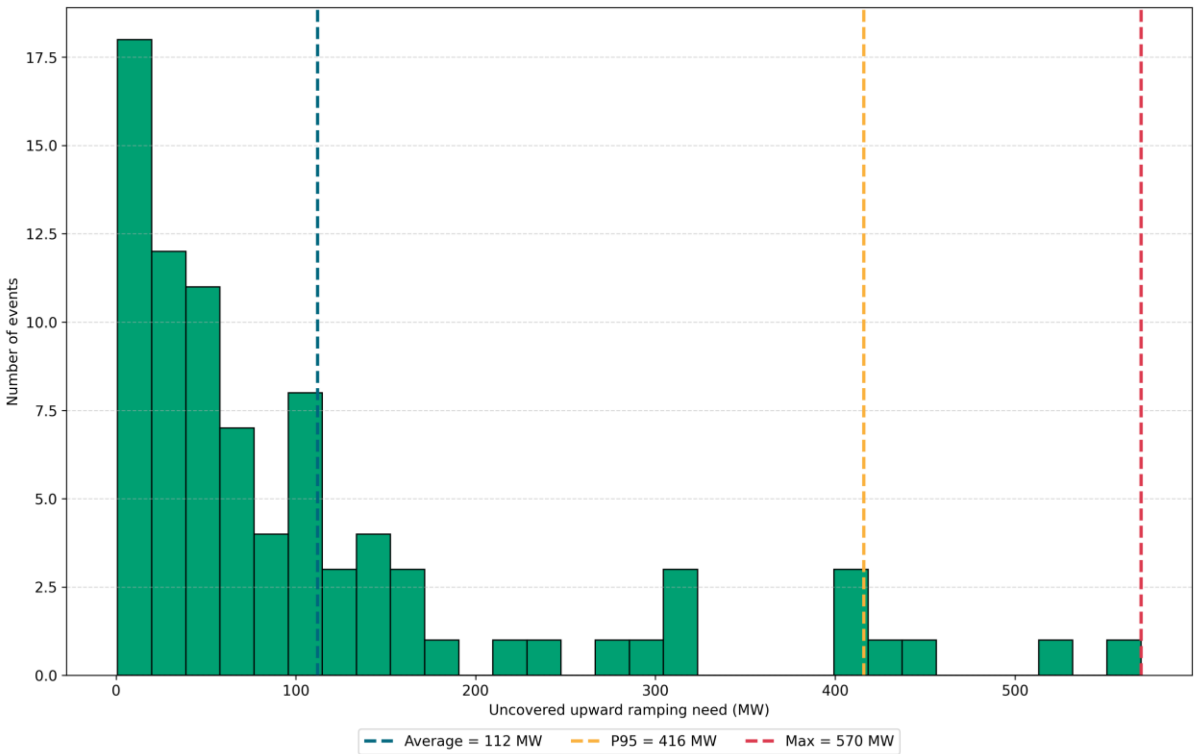


Figure 148 Distribution of uncovered upward ramping needs in the scenario without interconnectors [2033]

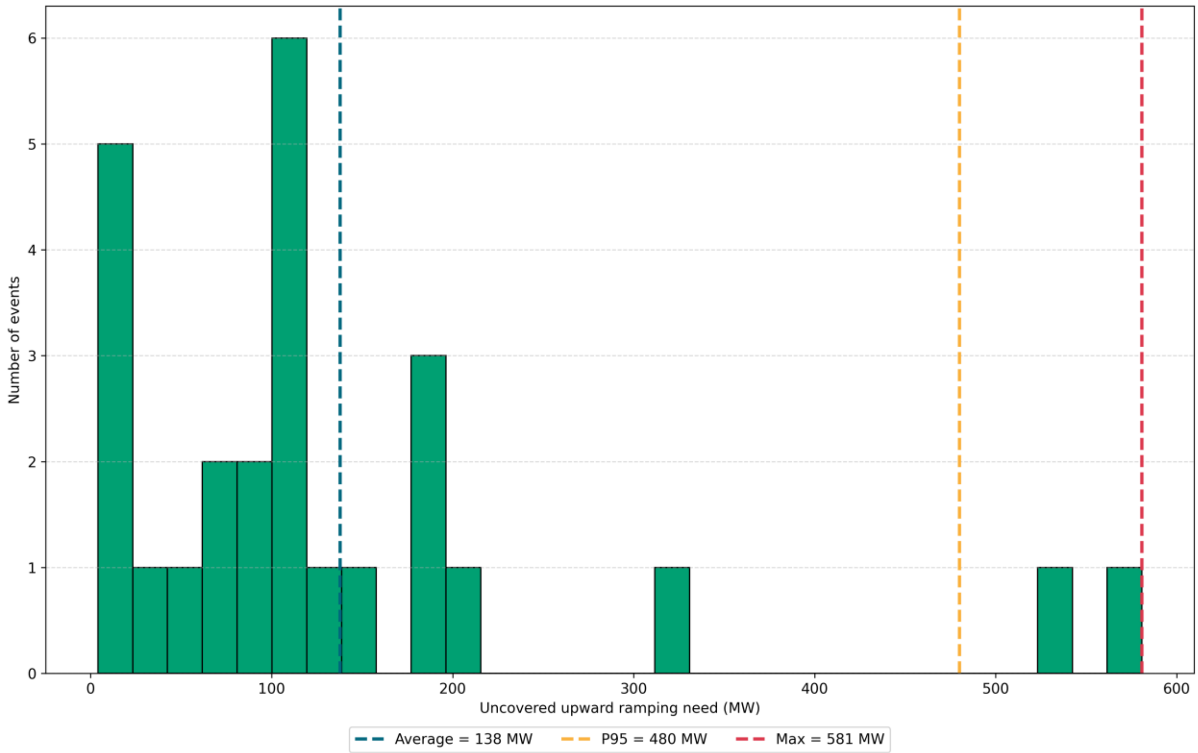


Figure 149 Distribution of uncovered upward ramping needs in the scenario without interconnectors [2035]

6.2.3. Short-term flexibility analysis

6.2.3.1. Short-term flexibility needs (10 str. (1))

Short-term flexibility needs describe the power system's ability to respond to differences between day-ahead forecasts of electricity demand and RES generation and the system's actual operation. Short-term flexibility needs, defined as the 0.1st and 99.9th percentiles of the forecasting-error distribution, are specified in Article 10(1) of the FNA methodology.

The short-term flexibility needs obtained using the method described in Section 5 and part 1 of Article 10 of the FNA methodology are presented in the figure below.

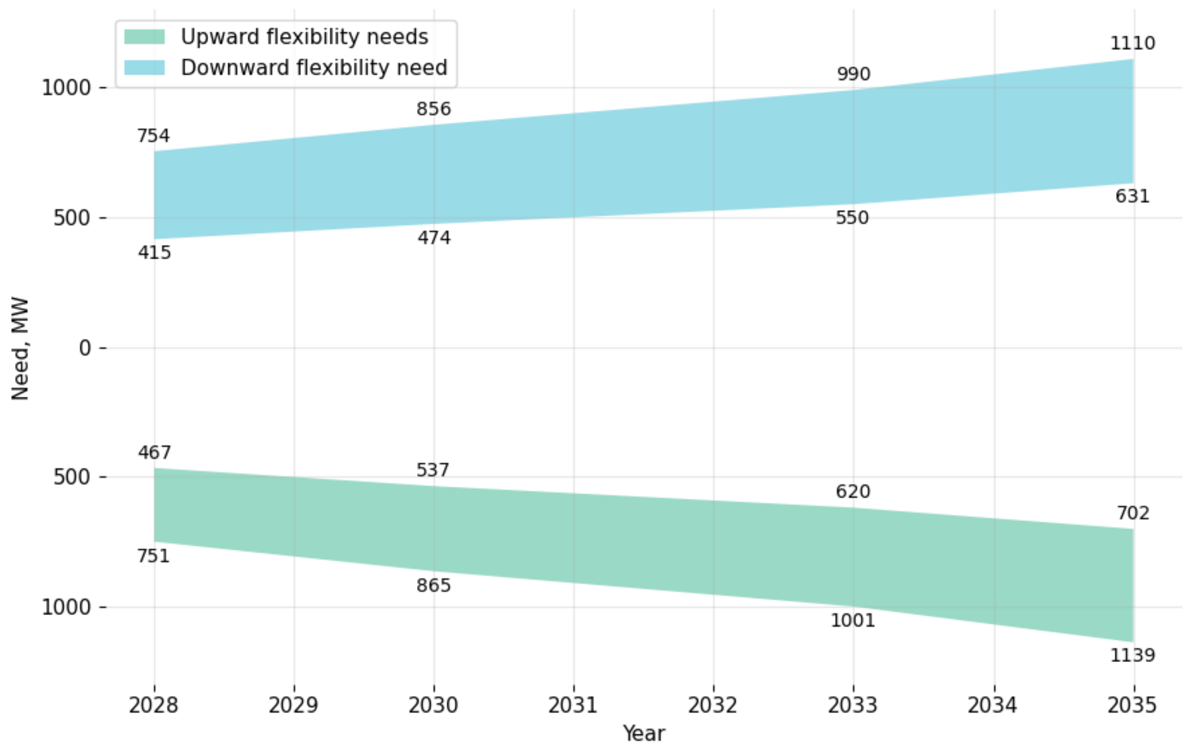


Figure 150 Short-term flexibility need 2028-2035

In the figure above, a clear trend in short-term flexibility needs in both directions is observed for 2028–2035. This means that as RES installed capacity and electricity consumption increase, short-term flexibility needs also grow. Upward flexibility needs range from 467 to 751 MW in 2028 and rise to 702–1139 MW in 2035. Downward flexibility needs amount to 415–754 MW in 2028 and increase to 631–1110 MW in 2035. The overall trend also shows that the interval between minimum and maximum needs expands over time.

6.2.3.2. Short-term flexibility capacities (10 str. (2, 3))

Short-term available flexibility (capacity) is identified as the residual amount of power remaining after D-1 market clearing that can meet the flexibility need, considering the technical constraints of generation, storage, and network elements. The calculation of short-term flexibility capacity is described in parts 2–3 of Article 10 of the FNA methodology. This residual power represents the flexibility available in the system that can be used to manage deviations, considering the current operational state of system assets. The residual power calculated under this provision does not reflect the overall short-term flexibility condition of the system — even if average flexibility appears sufficient relative to needs, the system may not be flexible at all times.
As specified in part 2(a) of Article 10 of the FNA methodology, downward flexibility can be ensured by additionally curtailing RES generation.

table 18 Short-term flexibility resources

Technology	Average downward flexibility	Average upward flexibility
	2028	
LT–PL	175,08	677,92
LT–LV	1203,86	1346,14
LT–SE	945,7	454,3
P2X	3,17	1,83
BESS	1024,47	590,26
KHAE	966,65	449,66
Thermal power plants	12,02	0,27

Offshore Wind Power Plants	0	0
Onshore Wind Power Plants	547,09	0
DSO solar power plants	0	0
TSO solar power plants	79,2	0
Other RES	32,79	0,03
	2030	
LT–PL	762,41	1637,59
LT–LV	1415,79	1134,21
LT–SE	936,87	463,13
P2X	24,56	50,44
BESS	1045,52	845,27
KHAE	325,03	381,62
Thermal power plants	20,44	0,56
Offshore Wind Power Plants	0	0
Onshore Wind Power Plants	630,27	0
DSO solar power plants	0	0
TSO solar power plants	104,99	0
Other RES	33,02	0,01
	2033	
LT–PL	1125,21	1274,79
LT–LV	1244,34	1305,66
LT–SE	887,03	512,97
P2X	168,92	306,08
BESS	1292,69	1060,34
KHAE	941,59	181,86
Thermal power plants	20,88	0,41
Offshore Wind Power Plants	0	0
Onshore Wind Power Plants	733,09	0
DSO solar power plants	0	0
TSO solar power plants	136,7	0
Other RES	32,97	0,01
	2035	
LT–PL	927,69	1472,31
LT–LV	2467,49	2082,51
LT–SE	925,69	474,31
P2X	381,63	293,37
BESS	1334,14	1131,77
KHAE	940,42	177,01
Thermal power plants	14,95	0,1
Offshore Wind Power Plants	170,93	0
Onshore Wind Power Plants	731,77	0
DSO solar power plants	0	0
TSO solar power plants	134,85	0
Other RES	32,65	0,04

During the analyzed period 2028–2035, the system's short-term flexibility potential increases, but its structure remains across flexibility directions and technologies. Downward flexibility potential is mainly provided by cross-border interconnectors, storage units, KHAE and RES curtailment capabilities, particularly onshore wind, TSO solar and from 2033 onwards also offshore wind. The potential for upward flexibility is mainly associated with inter-system connections, BESS and KHAE. The values presented in the table should be interpreted as the calculated potential flexibility available after D-1 market clearing, rather than as capacity guaranteed to be available at the moment of need. The actual utilization of this potential in specific periods depends on technical constraints of generation, storage and network elements, asset availability, market outcomes, and the system operating state. Therefore, even when average flexibility potential is sufficient, short-term flexibility shortages may still occur during certain hours.

6.2.3.3. Analysis of uncovered short-term flexibility needs (10 str. (4))

The analysis of uncovered short-term flexibility needs makes it possible to assess not only the existence of flexibility capacities, but also their magnitude, interaction with the energy market, and temporal distribution.

According to Article 10(6) of the FNA methodology, the analysis of uncovered flexibility needs must be carried out across the following dimensions:

1) Average power per uncovered-need event (MW);
2) Distribution of uncovered-need power;
3) Total expected amount of uncovered energy (MWh);
4) Expected number of hours with uncovered needs;
5) Time distribution of uncovered needs;
6) Distribution of uncovered energy (MWh);
7) Correlation with system conditions.

After performing the basic assessment of the LTrSc scenario, no uncovered short-term flexibility needs were identified, therefore, no further analysis is carried out.

6.2.3.4. Use of renewable energy sources to meet short-term flexibility needs (10 str. (5))

Article 10(2)(a) of the FNA methodology stipulates that short-term flexibility needs may be covered by additionally curtailing RES generation

The summarized results for the additionally curtailed RES volume are presented in Figure 152.

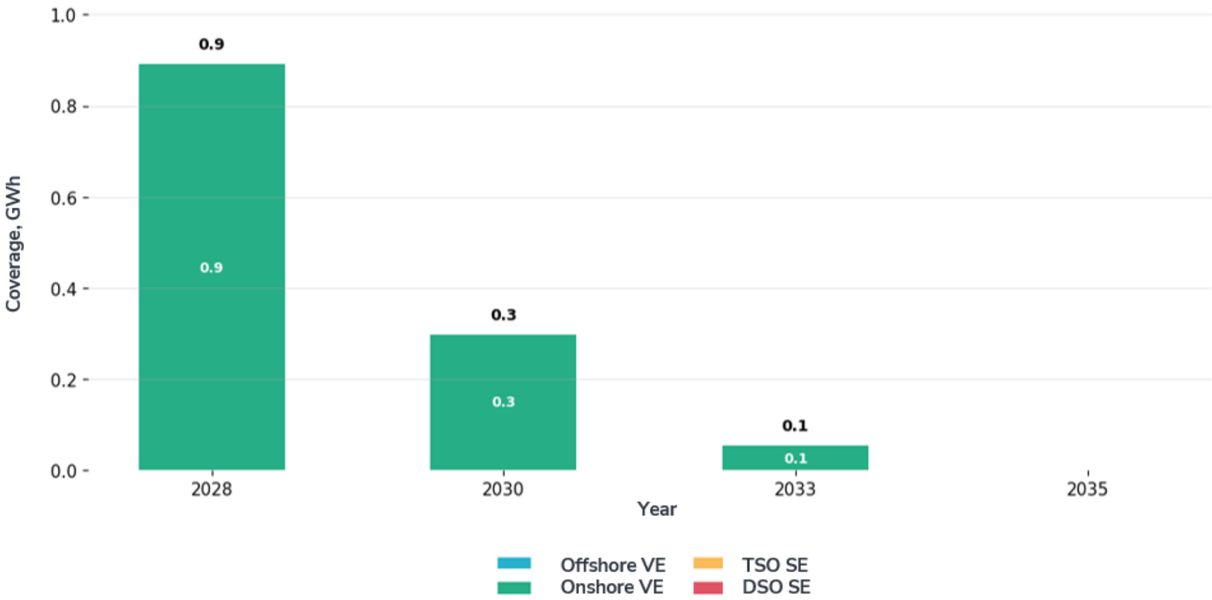


Figure 151 Additionally curtailed RES volume for covering short-term flexibility needs

Based on the illustrated data, we see that the existing downward flexibility capability of wind power plants alone is sufficient to fully cover all downward flexibility needs. Part 5 of Article 10 of the FNA methodology stipulates that any additionally curtailed RES generation must be assessed in accordance with part 3 of Article 8 of the methodology.

6.2.3.5. Realistic regime analysis (10 str. (7))

According to Article 10(8) of the FNA methodology, a realistic regime is constructed in which, after accounting for network constraints and the unavailability of flexibility resources, the available short-term flexibility through cross-border flows is reduced.

The realistic regime adjusts the short-term flexibility values of available capacity, as provided for in Article 10, paragraph 8 of the FNA methodology, and requires the recalculation of parts 2-6 of Article 10 of the FNA methodology. The results of the realistic regime assessment are presented below.

The change in flexibility provision is introduced only in cross-border capacities and P2X, therefore only the tables representing these capacities are provided below.

table 19 Flexibility resource used in the assessment

Technology	Average downward	Average upward
	2028	
LT–PL	35,02	164,98
LT–LV	601,93	673,07
LT–SE	189,14	90,86
P2X	0	0
	2030	
LT–PL	152,48	327,52
LT–LV	707,9	567,1
LT–SE	187,37	92,63
P2X	0	0
	2033	
LT–PL	225,04	254,96
LT–LV	622,17	652,83
LT–SE	177,41	102,59
P2X	0	0
	2035	
LT–PL	185,54	294,46
LT–LV	1233,75	1041,25
LT–SE	185,14	94,86
P2X	0	0

As can be seen in the charts presented below, in all analyzed years the size of cross-border capacities decreases in proportion to the assumptions defined for the realistic regime. The short-term flexibility capability of P2X decreases to 0 MW in every analyzed year.

Applying the different capacity assumptions, an analogous analysis is carried out as required under Article 10(4) of the methodology, using the realistic regime assumptions.

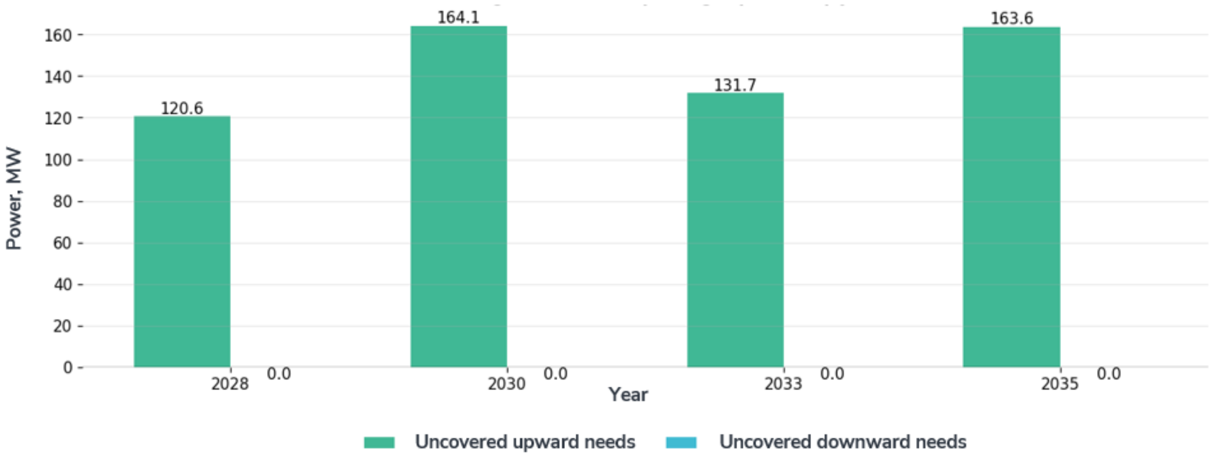


Figure 152 Average uncovered power per event with insufficient short-term flexibility in the realistic regime

The figure 153 shown that, in the realistic case, uncovered short-term flexibility needs arise only in the upward, while no uncovered downward needs are observed in any of the analyzed years. The average power of a single uncovered need event reaches 120,6 MW in 2028, increases to 164,1 MW in 2030, then decreases to 131,7 MW in 2033. In 2035, the value rises again to 163,6 MW, nearly returning to the 2030 level.

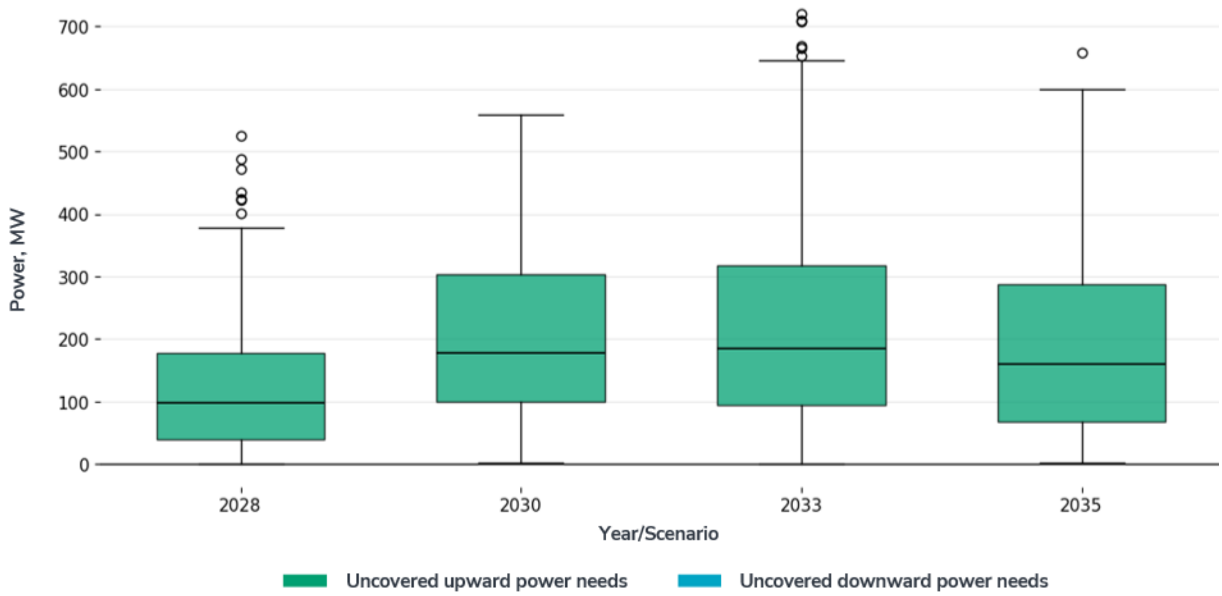


Figure 153 Uncovered-need power distribution in the realistic regime

The figure 154 shows that the distribution of uncovered upward needs in 2028 is the smallest, while in later years the values increase and become more dispersed. In 2030, both the median and the interquartile range grow; in 2033, the widest spread is observed along with the highest outliers exceeding 700 MW; and in 2035, the distribution decreases slightly but still remains larger than in 2028. The outliers show that in certain periods significantly higher short-term flexibility shortages may occur compared to typical values. No uncovered downward needs are present.

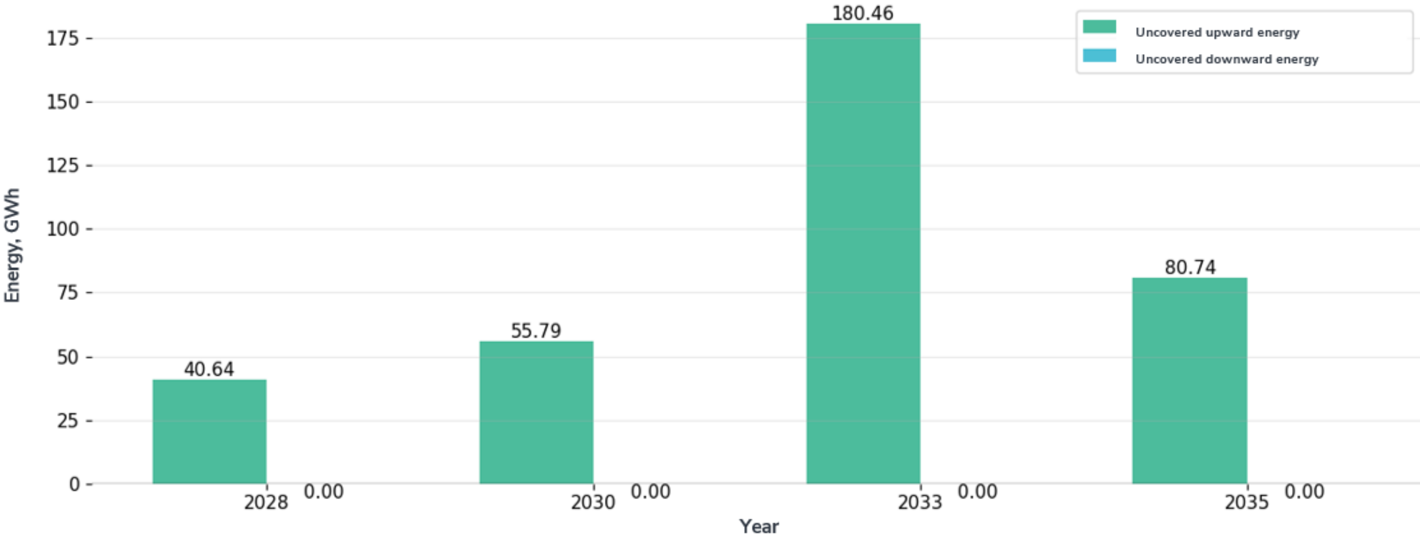


Figure 154 Total expected uncovered energy for short-term flexibility in the realistic regime

Figure 155 indicates that uncovered energy arises only upward, while no uncovered downward energy is observed. The amount of uncovered energy increases from 40.64 GWh in 2028 to 55.79 GWh in 2030 and reaches its highest value of 180.46 GWh in 2033. In 2035, the value decreases to 80.74 GWh, but still remains higher than in 2028–2030. This shows that the largest short-term upward flexibility deficit occurs in 2033.

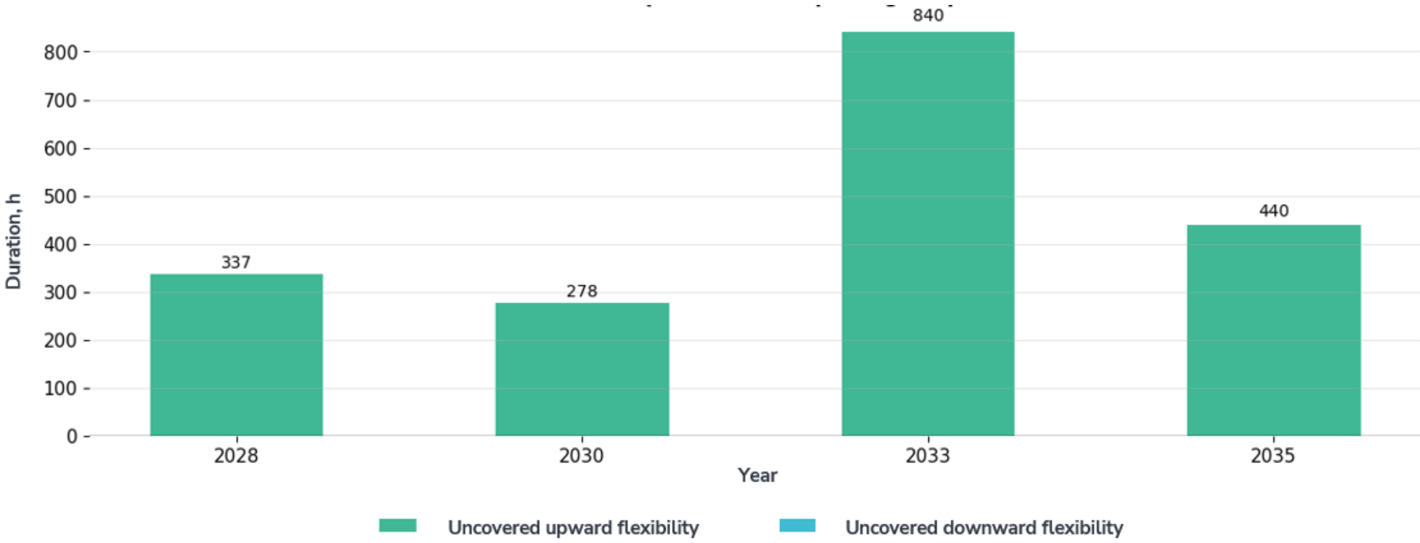


Figure 155 Expected number of uncovered hours per year in the realistic regime

The figure shown in Fig. 156 indicates that hours with uncovered short-term flexibility needs arise only in the upward. Their number reaches 337 hours in 2028, decreases to 278 hours in 2030, and then climbs to its maximum of 840 hours in 2033. In 2035, the indicator falls to 440 hours, but still remains higher than in 2028–2030. This shows that upward-direction flexibility shortages are most pronounced in 2033, while in 2035 the situation improves, though the issue does not fully disappear.

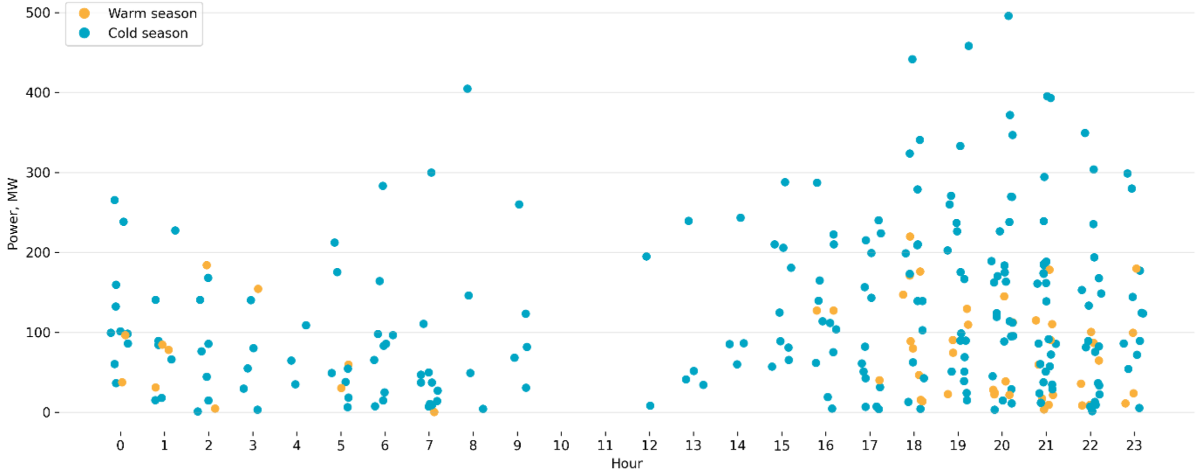


Figure 156 Distribution of uncovered needs by hour in 2028 in the realistic regime

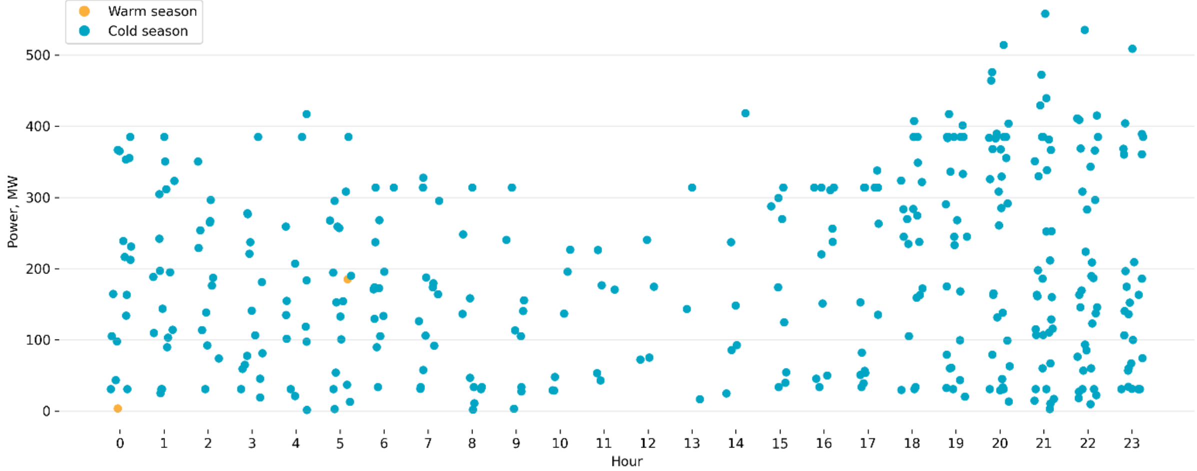


Figure 157 Distribution of uncovered needs by hour in 2030 in the realistic regime

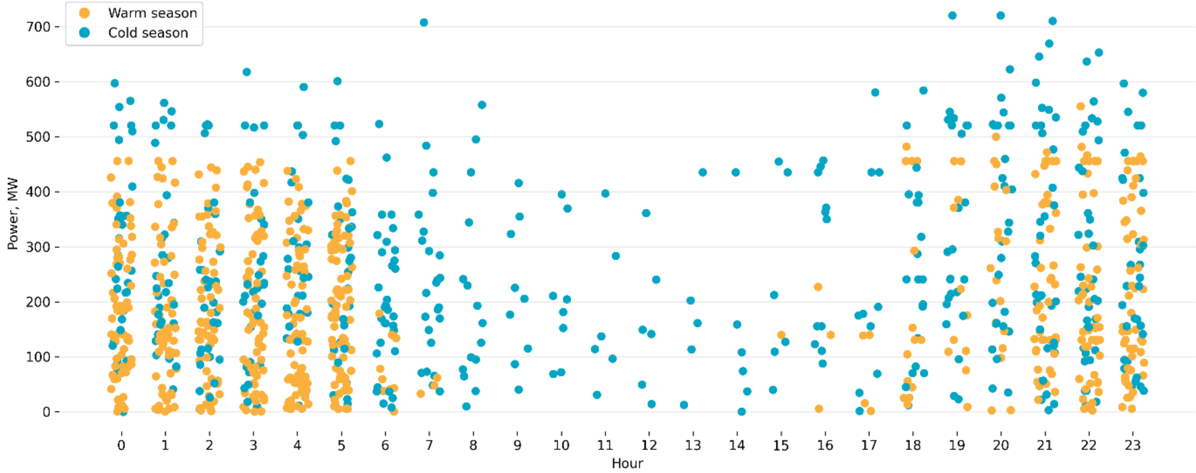


Figure 158 Distribution of uncovered needs by hour in 2033 in the realistic regime

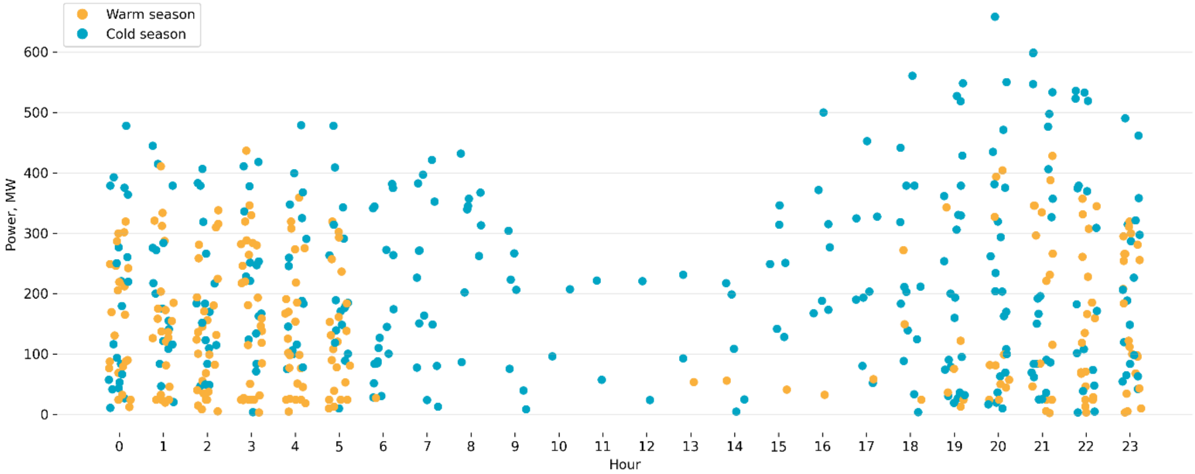


Figure 159 Distribution of uncovered needs by hour in 2035 in the realistic regime

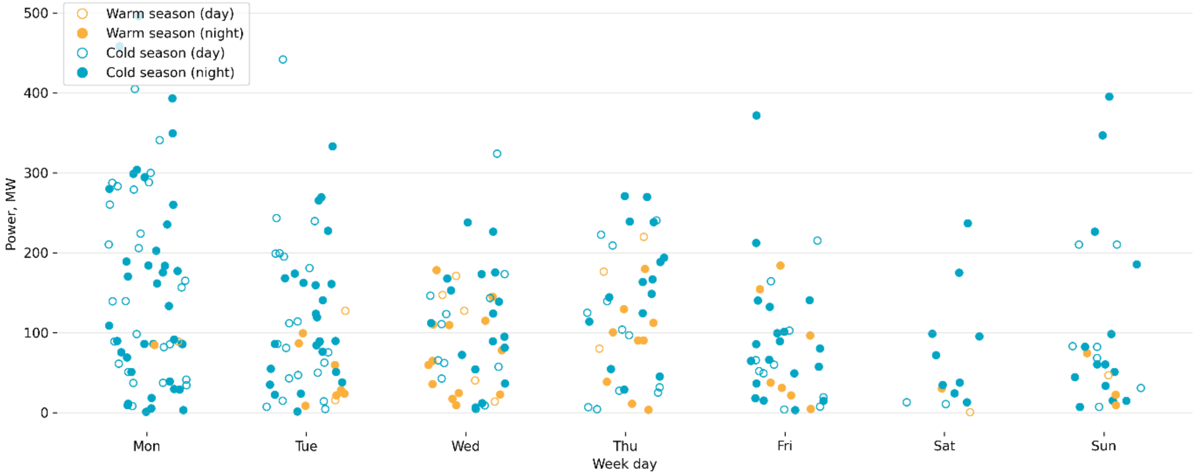


Figure 160 Distribution of uncovered needs by weekdays in 2028 in the realistic regime

Figure 161 Distribution of uncovered needs by weekdays in 2030 in the realistic regime

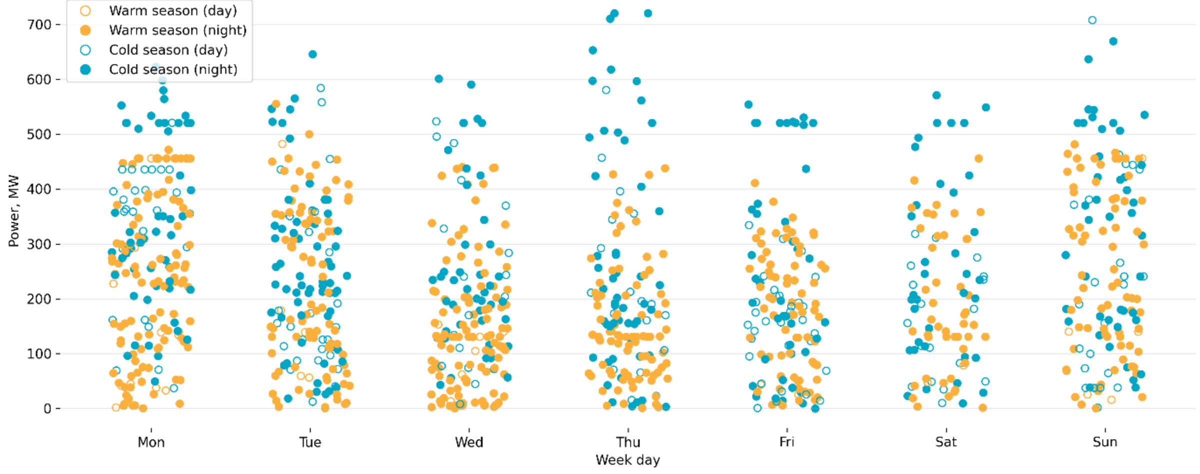


Figure 162 Distribution of uncovered needs by weekdays in 2033 in the realistic regime

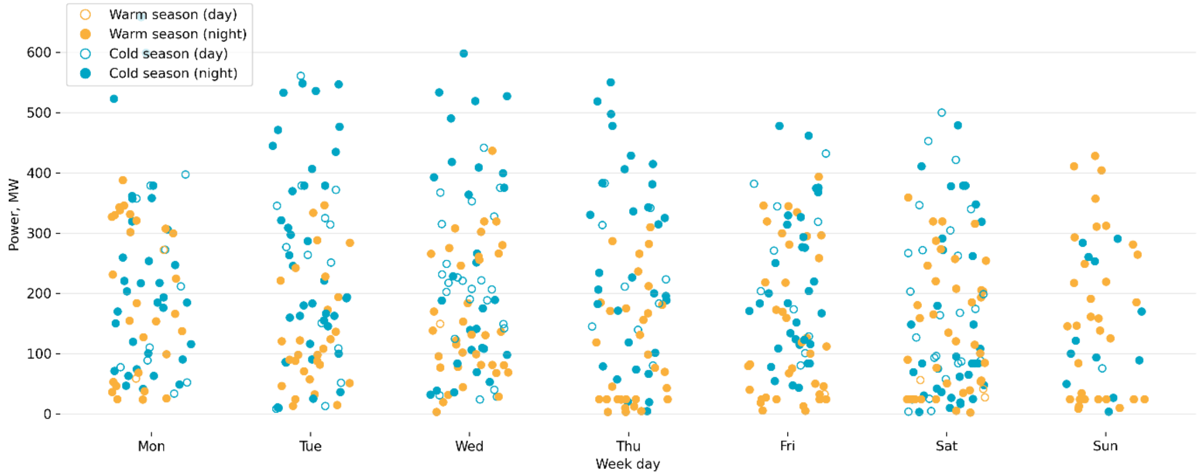


Figure 163 Distribution of uncovered needs by weekdays in 2035 in the realistic regime

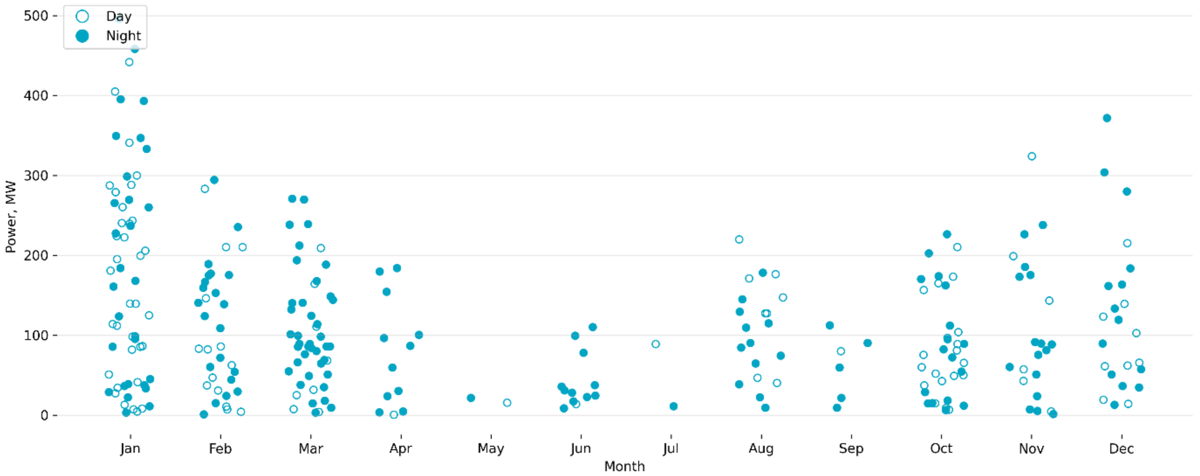


Figure 164 Distribution of uncovered needs by month in 2028 in the realistic regime

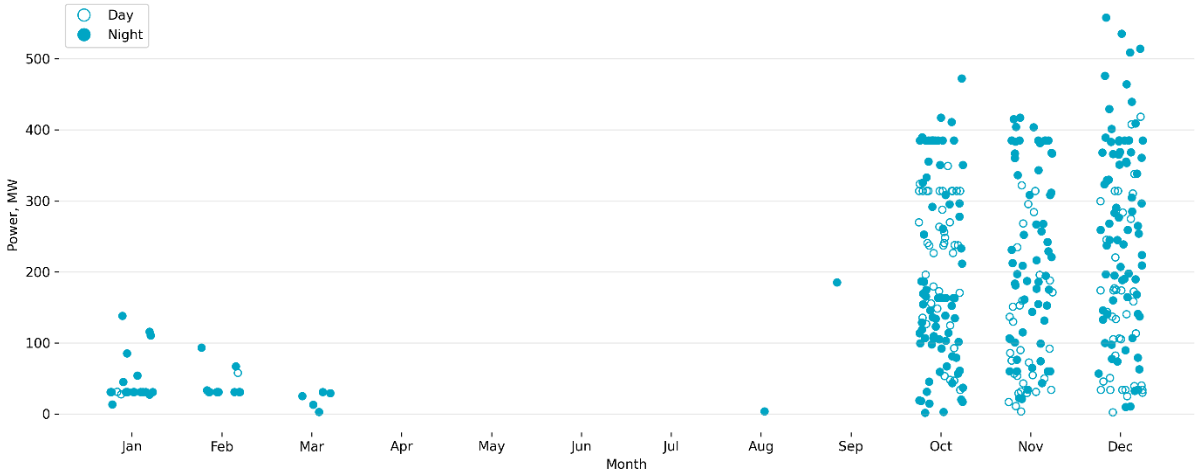


Figure 165 Distribution of uncovered needs by month in 2030 in the realistic regime

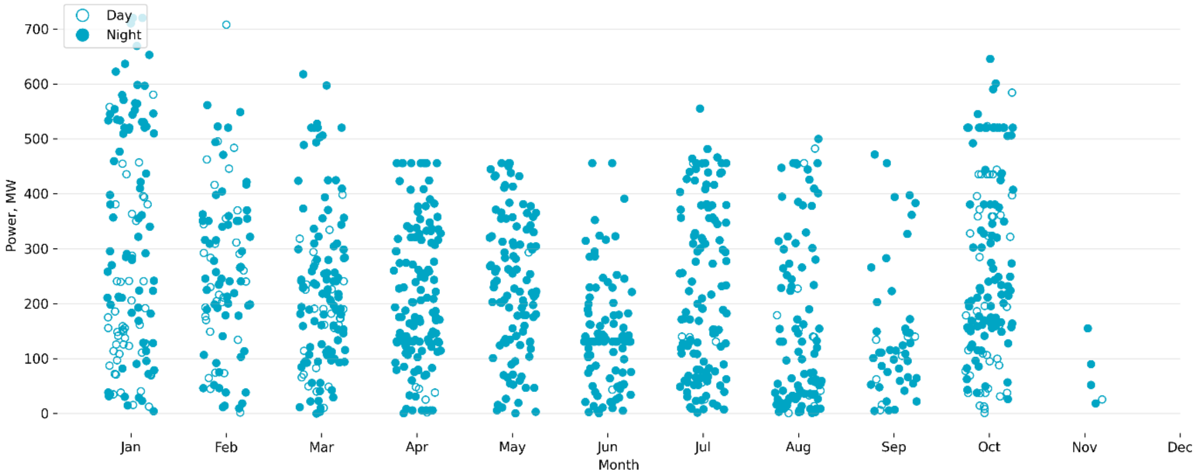


Figure 166 Distribution of uncovered needs by month in 2033 in the realistic regime

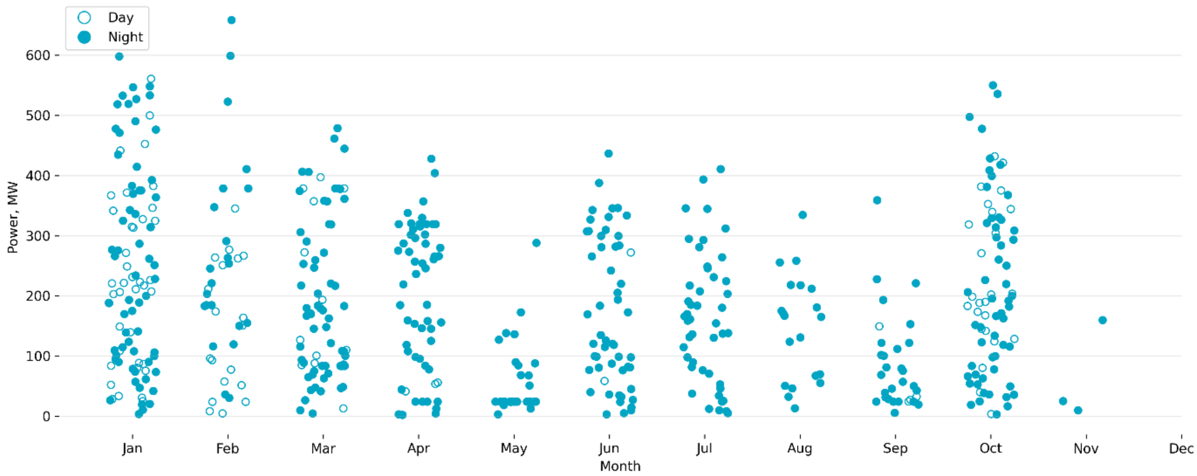


Figure 167 Distribution of uncovered needs by month in 2035 in the realistic regime

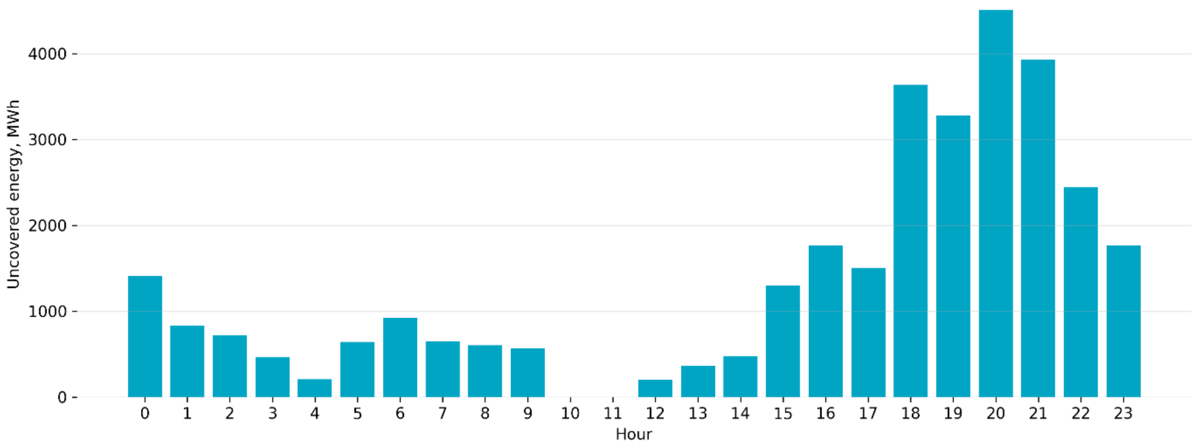


Figure 168 Distribution of uncovered energy by hour in 2028 in the realistic regime

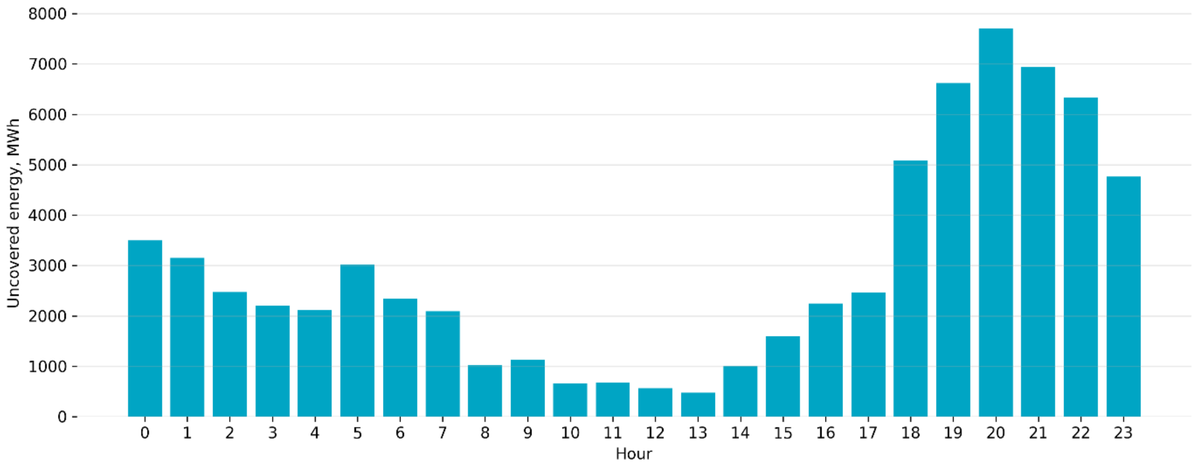


Figure 169 Distribution of uncovered energy by hour in 2030 in the realistic regime

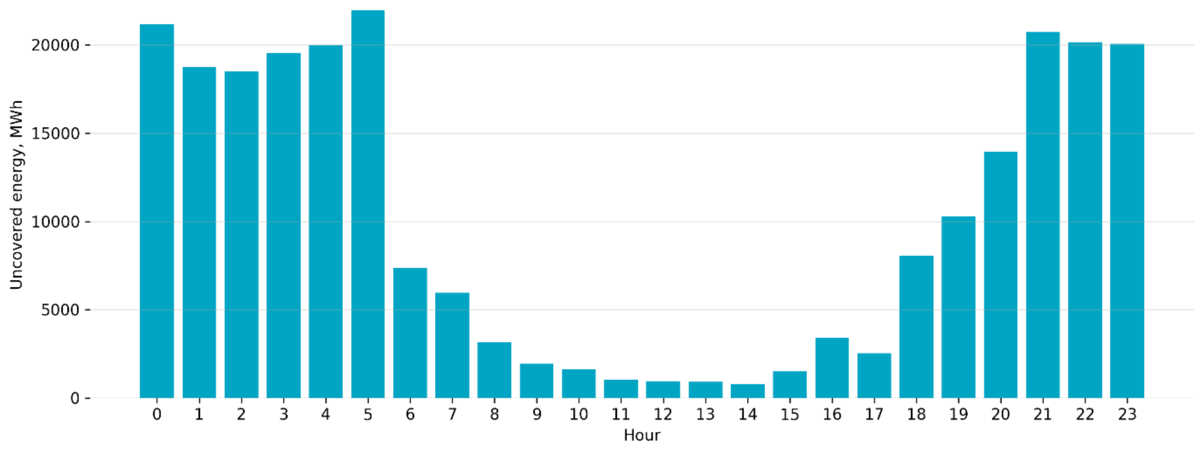


Figure 170 Distribution of uncovered energy by hour in 2033 in the realistic regime

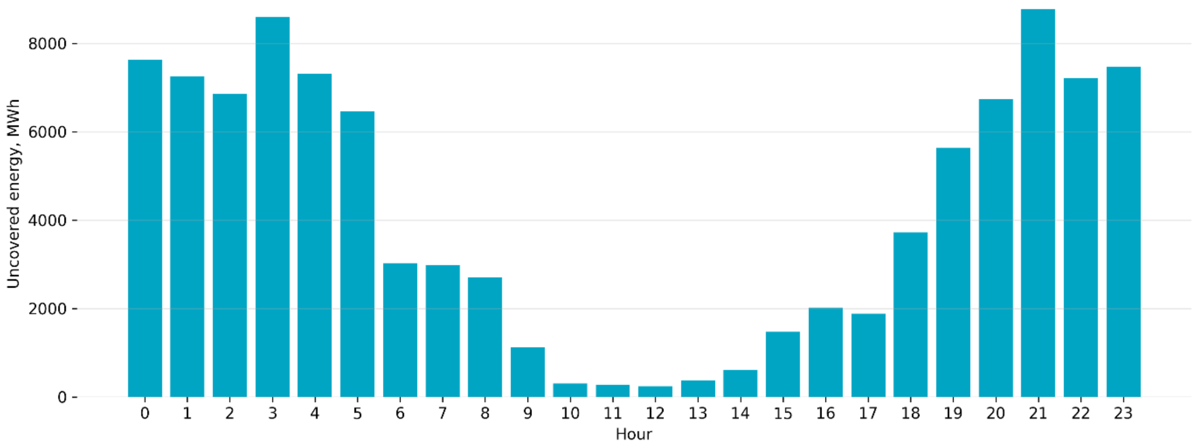


Figure 171 Distribution of uncovered energy by hour in 2035 in the realistic regime

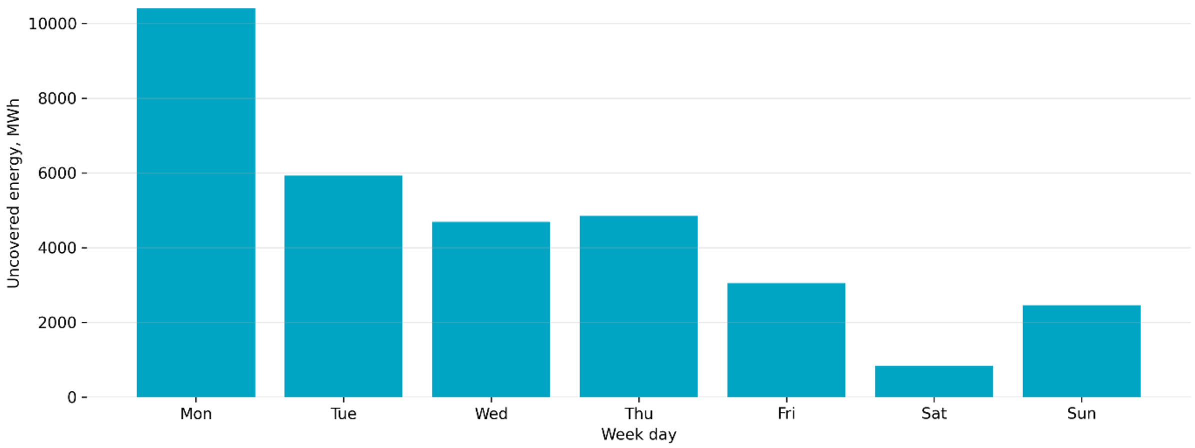


Figure 172 Distribution of uncovered energy by weekdays in 2028 in the realistic regime

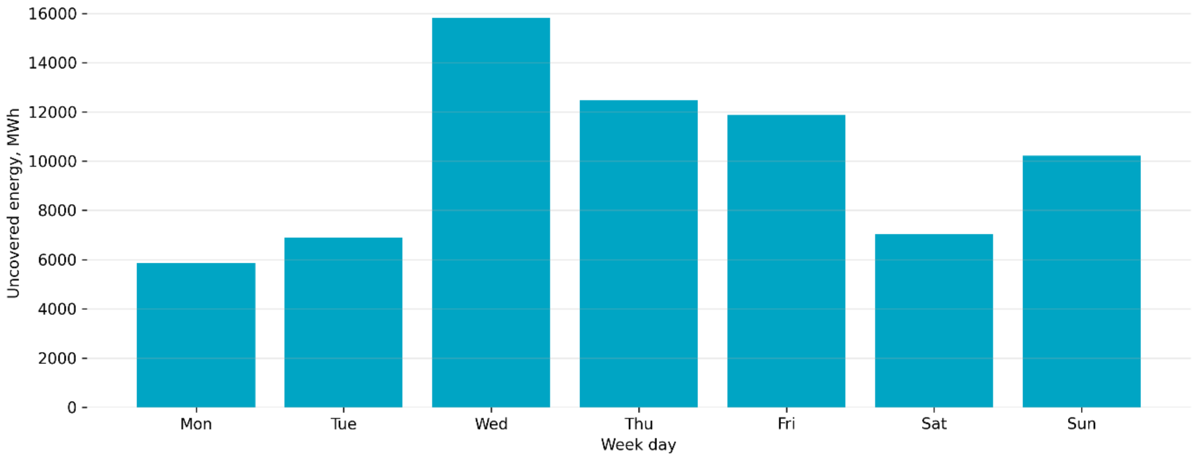


Figure 173 Distribution of uncovered energy by weekdays in 2030 in the realistic regime

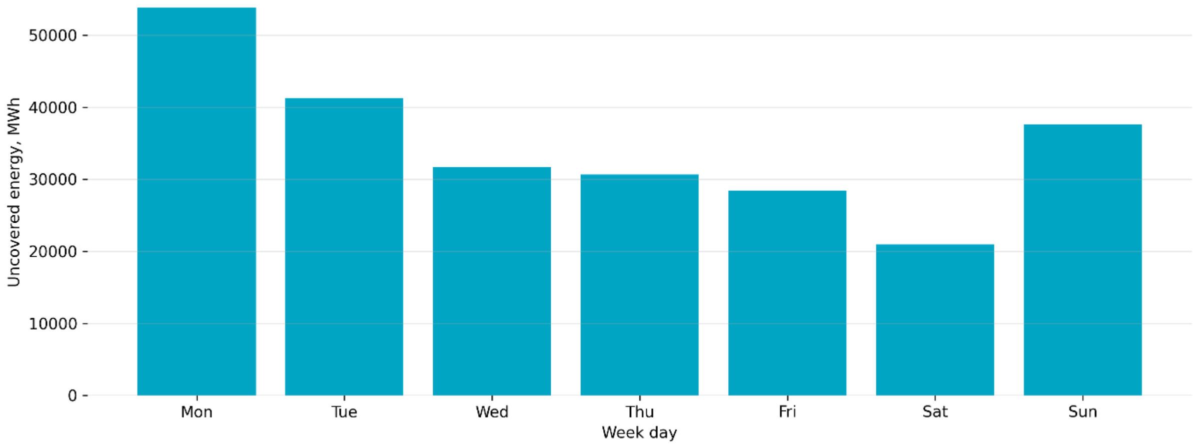


Figure 174 Distribution of uncovered energy by weekdays in 2033 in the realistic regime

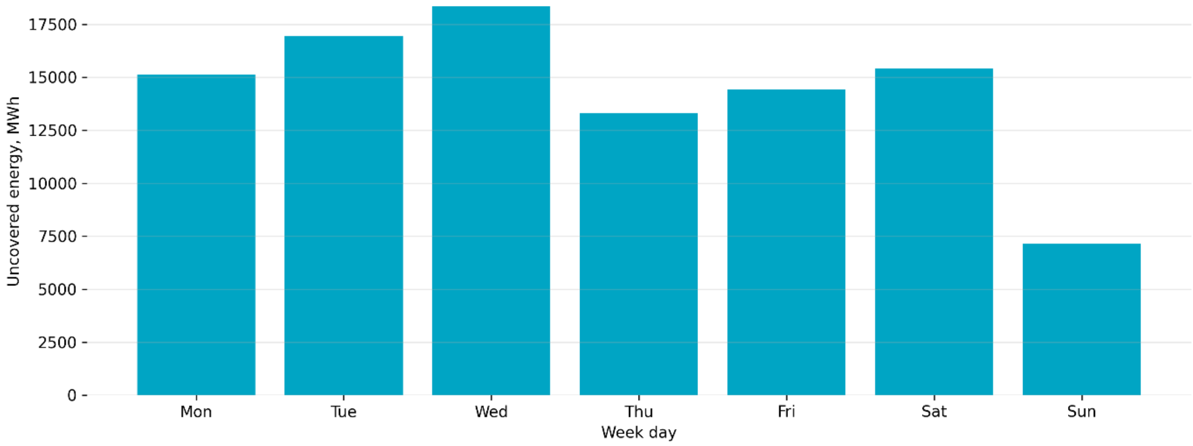


Figure 175 Distribution of uncovered energy by weekdays in 2035 in the realistic regime

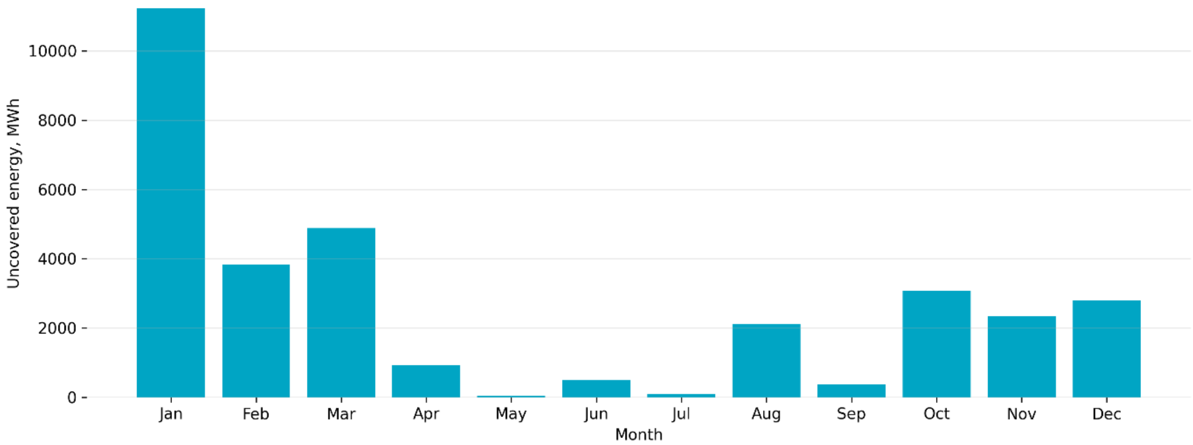


Figure 176 Distribution of uncovered energy by months in 2028 in the realistic regime

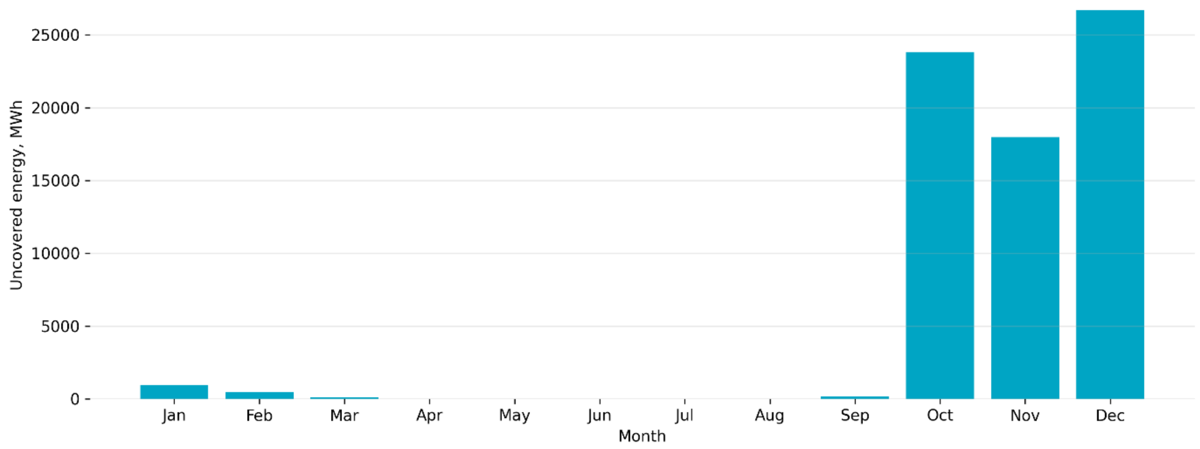


Figure 177 Distribution of uncovered energy by months in 2030 in the realistic regime

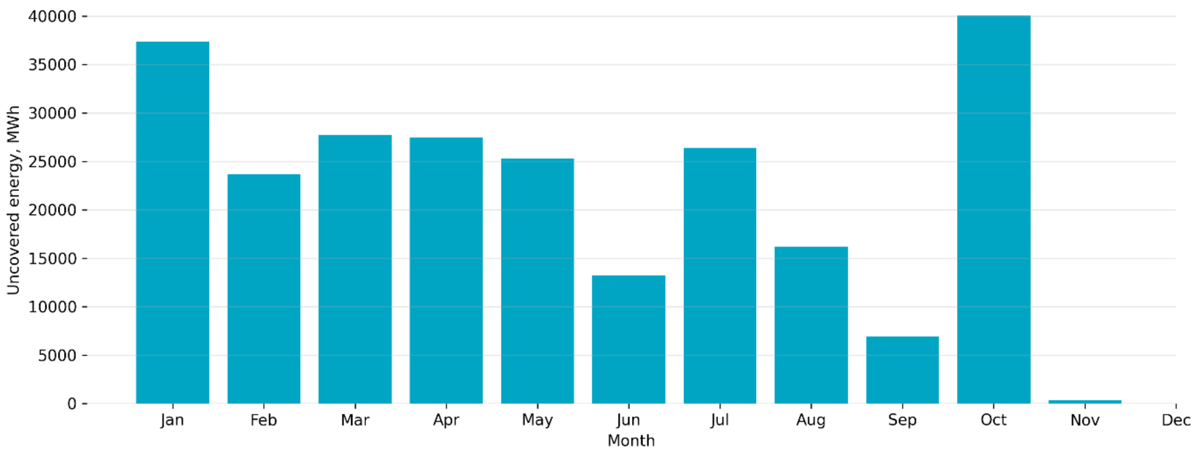


Figure 178 Distribution of uncovered energy by months in 2033 in the realistic regime

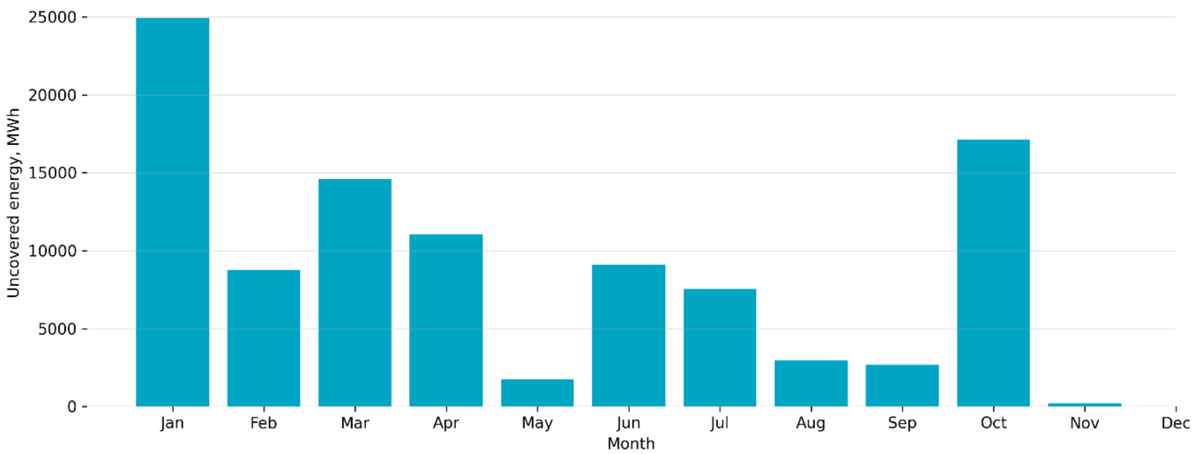


Figure 179 Distribution of uncovered energy by months in 2035 in the realistic regime

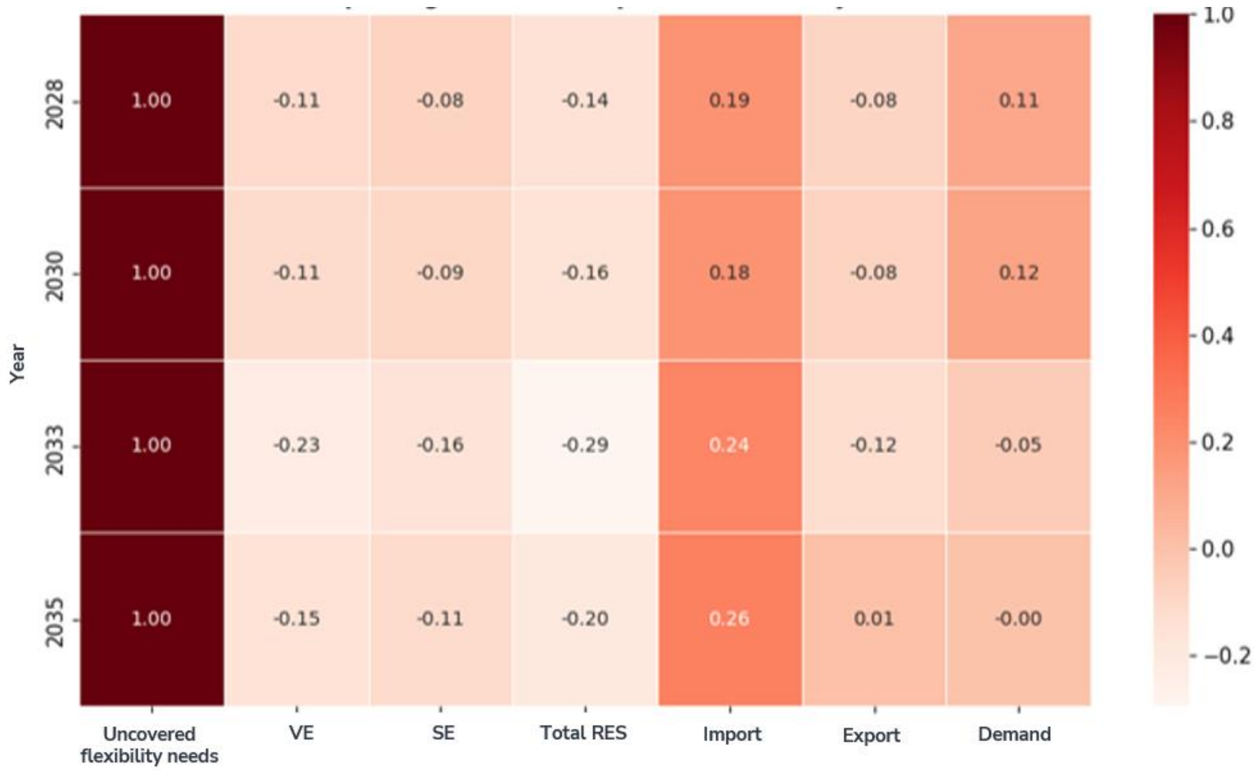


Figure 180 Correlation between uncovered short-term flexibility needs and different system-state indicators in the realistic regime

6.3. Assessment of distribution network flexibility

DSO flexibility needs were assessed under two scenarios:

- 1st scenario – National Strategy Scenario, based on the DSO's Ten-Year Investment Plan for 2026–2035;
- 2nd scenario – Slower Development Scenario (LTrSc).

The downward flexibility need of the distribution network is calculated as the difference between the technical solar power plant profile capacity limit issued by the transmission system operator in the grid zone and the safe generation limit (SGL) in the grid zone. This difference is equated to downward flexibility needs, as shown in Figure 182.

Under the specified scenarios, solar power plant (PV) connections are carried out to the technical PV profile capacity limit issued by the TSO. Once the PV profile limit is reached in individual grid zones, connecting solar power plants with an allowed generation capacity greater than 1 kW is not possible.

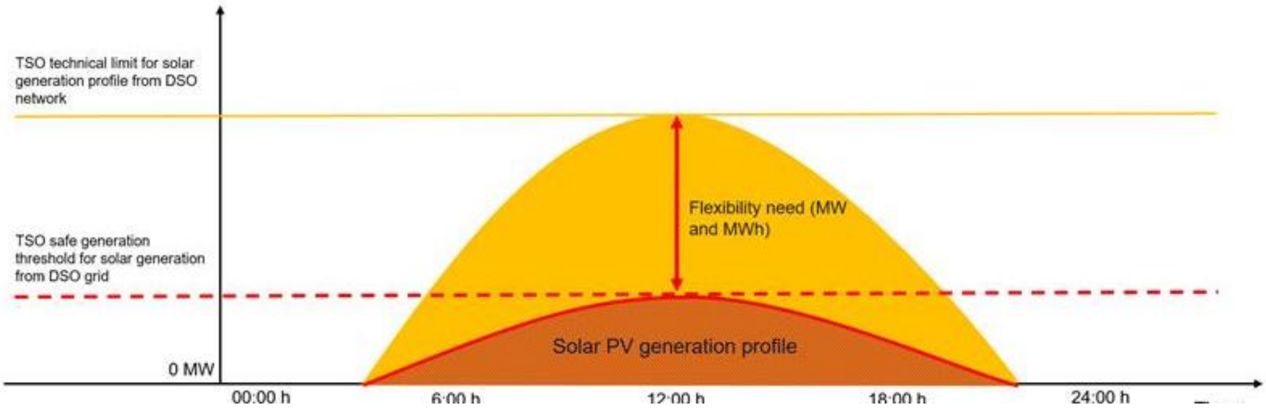


Figure 181 Principle for calculating the DSO flexibility need with solar generation

DSO upward flexibility needs are evaluated considering the rated power of 110 kV transformer substations under N-1 contingency mode (evaluating the rated power available at the substation following the outage of a single power transformer). In cases where the capacities of two power transformers at a substation differ, the lower transformer rating is used in the evaluation.

If the N-1 rated power of the transformer substations is exceeded, the connection of new household consumers continues.

In the period from 2028 to 2035, under the calculated scenarios, an upward flexibility need emerges, increasing from 30 MW in 2028 to 108 MW in 2035.

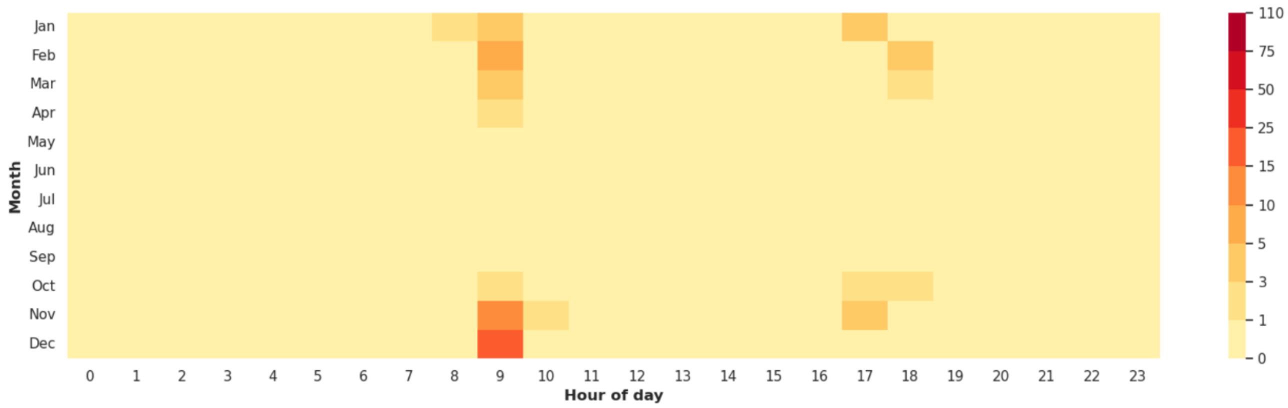


Figure 182 Temporal distribution matrix of upward flexibility needs in 2028

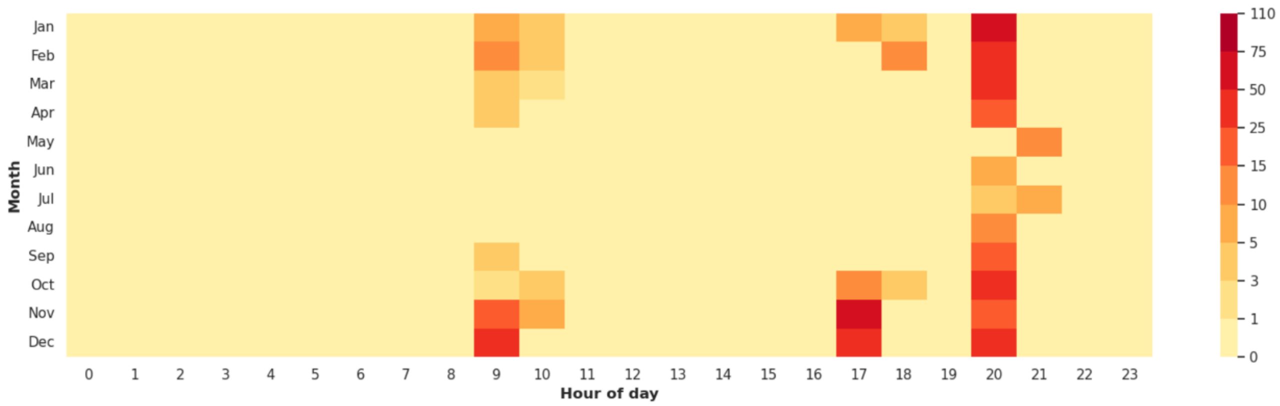


Figure 183 Temporal distribution matrix of upward flexibility needs in 2035

Based on the data in Figures 183 and 184, upward flexibility needs emerge during the hours of 09:00–10:00, 17:00–18:00, and 20:00–21:00.

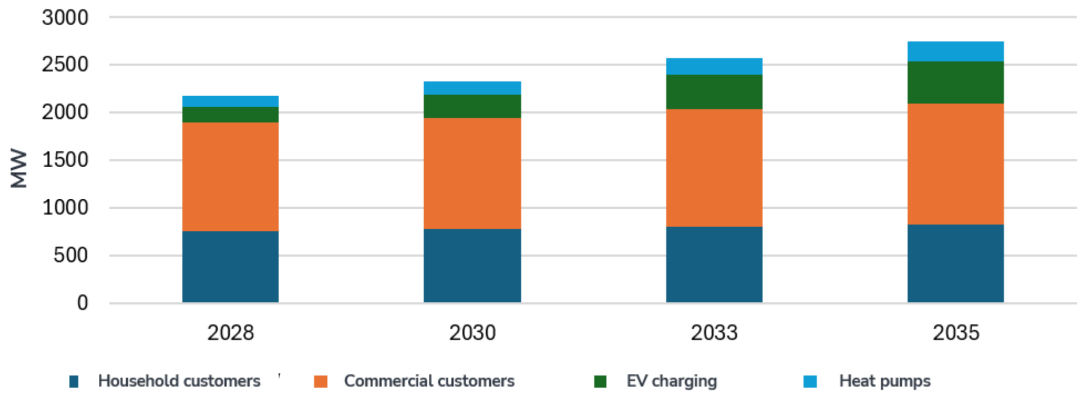


Figure 184 ESO network peak-load forecast

Based on the data in Figure 185, we can see that a significant increase in the actual grid load within the ESO network is driven by EV charging and heat pumps.
The EV charging load on the grid increases from 162 MW in 2028 to 438 MW in 2035. Similarly, the grid load from heat pumps grows from 120 MW to 205 MW in 2035.

table 20 DSO flexibility needs upward and downward across different scenarios

Scenario	Direction of the need for flexibility	2028		2030		2033		2035	
		MW	MWh	MW	MWh	MW	MWh	MW	MWh
Scenario 1	Up	30	13756	42	22131	77	44735	108	69576
	Down	343	69207	410	76557	455	76895	458	73023
Scenario 2	Up	30	13756	42	22131	77	44735	108	69576
	Down	167	26975	181	27340	182	23758	181	21339

6.4. Assessment of transmission network flexibility

In accordance with the provisions of Section 12 of the FNA methodology, flexibility assessment in the transmission network is not performed. According to the TSO, current constraints are minor, meaning that a long-term assessment would have a high margin of error. The analysis will be carried out in the next flexibility-needs assessment cycle.

7. Additional analysis

7.1. FCR capacity needs

A steady increase in FCR needs is observed in the Lithuanian power system, driven by growing demand and generation together with the rising share of RES integration. In 2028, the FCR requirement reaches 14 MW; in 2030, it increases to 18 MW; in 2033, it rises further to 23 MW; and in the final assessed year, the FCR requirement is estimated at 25 MW.

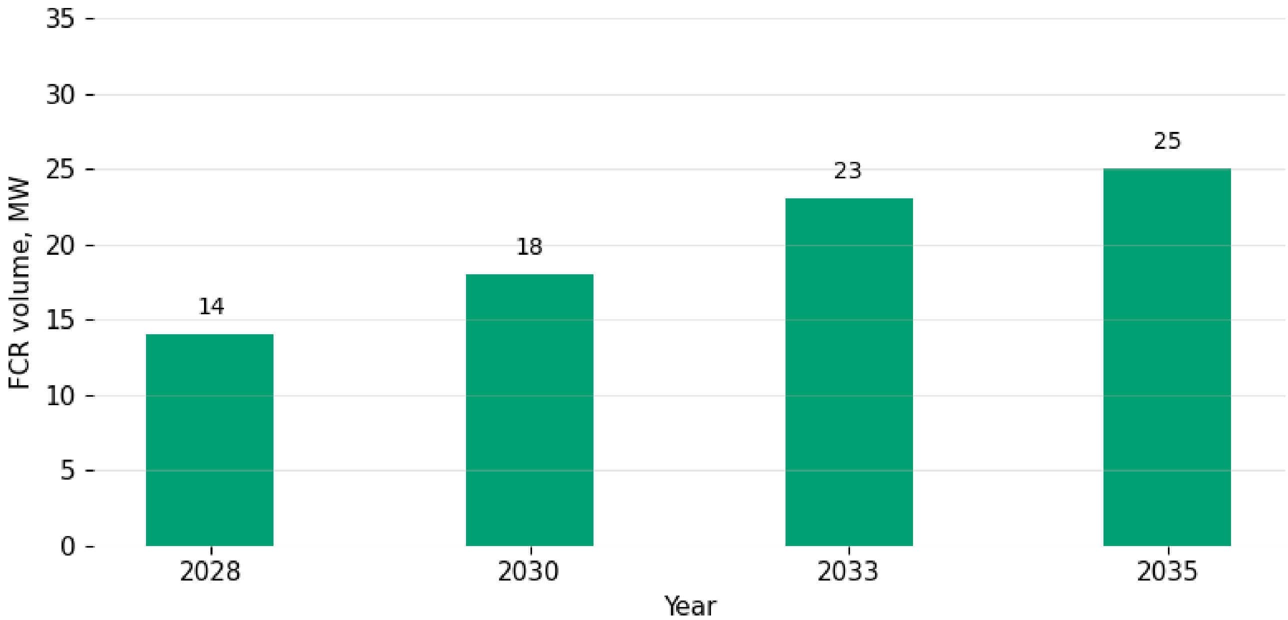


Figure 185 FCR needs assessment

7.2. mFRR and aFRR capacity needs

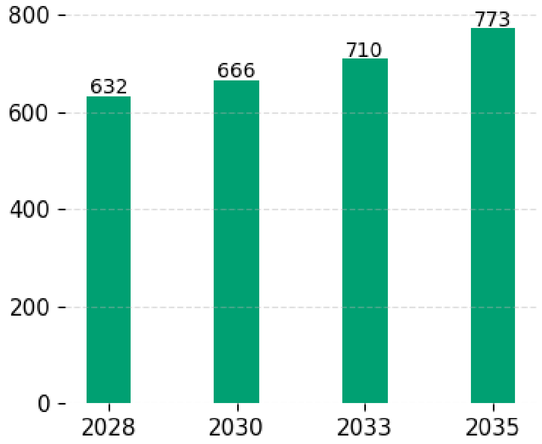
The flexibility assessment defined the long-term mFRR and aFRR capacity needs of the Lithuanian power system

mFRR downward needs

From the mFRR perspective, a continuous increase in maximum downward needs is observed. In 2028, the requirement is identified as 632 MW; in 2030 it rises to 666 MW; in 2033 it reaches 710 MW; and by 2035 it grows further to 773 MW.

mFRR upward needs

Unlike the downward mFRR needs, the upward mFRR requirement does not show a growing trend. Throughout the entire 2028–2035 assessment period, the upward need remains constant at 633 MW,



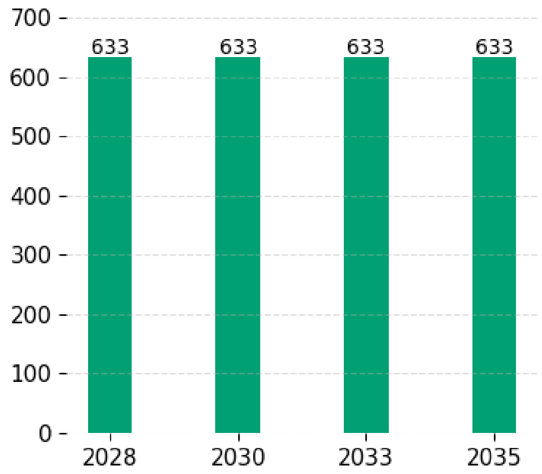


Figure 186 mFRR capacity needs in 2028-2035.

aFRR needs

Throughout the entire assessment period, aFRR needs remain stable. Downward requirements stay at 68 MW, while upward requirements remain at 67 MW.

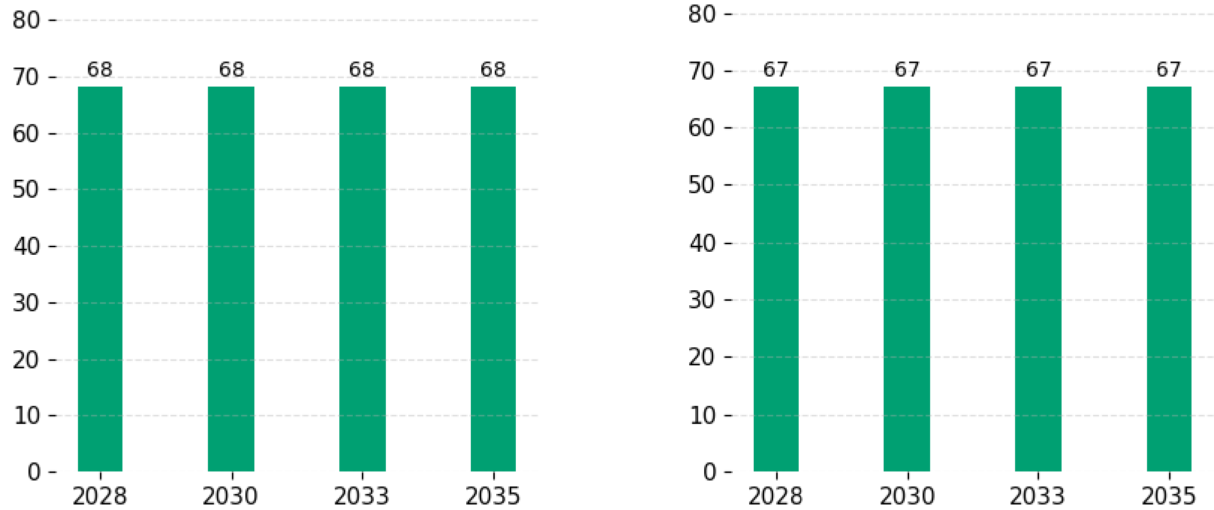


Figure 187 aFRR capacity needs in 2028-2035.

7.3. Fast frequency response reserves needs

The analysis identified flexibility needs for Fast frequency response reserves, which are required to ensure the secure operation of the power system in isolated-operation conditions.

The same volumes were set for all analyzed periods – 354 MW.

- **Isolated-operation reserve service**

The isolated-operation reserve service is an ancillary service regulated by legal acts, used by the transmission system operator used in preparation for isolated operation of the power system and to maintain secure system operation during such conditions.

The Law on the Synchronized Operation of the Electricity System with the Continental European Networks, Article 6(1)(4), provides that the isolated-operation service must be purchased from a designated storage system operator:

During the implementation of the power-system synchronization project, and until the date of entry into force of the Government resolution referred to in paragraph 5 of this Article, the designated storage system operator is obliged to provide the transmission system operator with the isolated-operation reserve service, enable the performance of the transmission system operator's technological-loss reduction function, and provide other ancillary services necessary for ensuring power-system security that are not related to frequency regulation, where such services are required to achieve the objectives of this Act, if the transmission system operator is unable to procure these services from electricity-market participants..

The service is purchased from the designated energy storage system operator, UAB *Energy Cells*, which operates battery-storage facilities with a total installed power of 200 MW and an energy capacity of 200 MWh.

In accordance with Article 48(1)(3) of EEĮ, the isolated-operation service may be provided exclusively by the designated energy storage system operator, UAB *Energy Cells*. Other market participants are not permitted to provide this service.

„3. The owner of an energy-storage facility has the right to provide all electricity-storage services that have demand in the electricity market and that can be delivered using the energy-storage facilities under its control, except for the isolated-operation reserve service provided to the transmission system operator."

The provision of the service ensures part of the capacity required for stable isolated operation of the electricity system.

- **Fast frequency response reserves**

The isolated-operation reserve does not cover the full capacity required to ensure preparation for isolated system operation, therefore, an additional service — the Fast frequency response reserves— is assessed. From a technical part of view, the same technical requirements apply to the fast frequency response reserves as to the isolated operation reserve service.

Considering the total demand for fast frequency response reserves and isolated operation reserve volumes, the fast frequency response reserves volumes are directly dependent on the isolated operation reserve service volumes.

- **Fast frequency response reserves needs**

Synchronous operation of Lithuanian power system is established with only via LitPol Link connection, thus fast frequency response reserves needs are necessary for the safe operation of the Lithuanian electricity system. The established volumes of isolated operating reserve services and fast frequency response reserves volumes are necessary to ensure reliable and operationally managed isolated operating mode. The services are necessary to strengthen the technical resilience of the system, ensure national energy security and reliability of supply to end users.
Before the implementation of the 220 kV inter-system line between Lithuania and Poland "Harmony Link" ,it is planned to assess the further need for a fast frequency response reserve resource to ensure system flexibility.

table 21 Fast frequency response reserve needs

Year	2028	2030	2033	2035
Isolated operation reserve volume	200	200	0	0
Fast frequency response reserve volume	154	154	354	354
Total	354	354*	354*	354*

* Decision on the necessity of the resource after the commissioning of the Harmony Link interconnector.

7.4. LT-PL transfer capacity increase service needs

Until the new 220 kV double-circuit line between Lithuania and Poland — Harmony Link – is commissioned, the potential of cross-border capacity is 500 MW. To utilize the full potential of this interconnection, a Lithuania–Poland capacity-increase service is required.
The service enables the full use of the Lithuania–Poland cross-border capacity up to the stability limit. The assessment determined that the need for this service is up to 146 MW. Volumes may vary depending on the ordered of Fast frequency response reserves volume.

The decision on implementation must be made considering the experience gained from the application of the Fast frequency response products.

7.5. Schedule change during the ramping period of the market time unit needs

7.5.1. ERAA2025 scenario

During the analysis, the impact of active-power schedule changes between market time units was assessed, assuming that devices of different technologies adjust their active-power setpoints according to the data provided in Table 5. Sensitivity is checked by changing the ramping period for RES, BESS and P2X technologies at 10min, 5min, 1min and instant change intervals, each of which results in different upward and downward imbalance volumes (the results are presented in the table below).

When assessing different ramping periods, the risk that the imbalance volume exceeds the short-term limits permitted in the synchronous area ranges from 0.31 % to 6.7 % per year.

In critical cases in 2028, with a 10-minute power-change period, the imbalance deviation may reach 25 MWh of surplus or 33 MWh of deficit. Shortening the power-change period to 5 minutes increases the imbalance, which may reach up to 30 MWh or 37 MWh of surplus and deficit respectively. A 1 minute power-change period further worsens the situation, creating an imbalance of up to 37 MWh of surplus or 44 MWh of deficit. The most severe case occurs with an instantaneous power change, where the imbalance may reach up to 39 MWh of surplus or up to 45 MWh of deficit at the moment of the change.

In 2030, with a 10-minute power-change duration, the possible imbalance deviations reach about 28 MWh of surplus or up to 30 MWh of deficit. Shortening the power-change period to 5 minutes further increases the imbalance — in extreme cases up to 32 MWh of surplus or up to 35 MWh of deficit. Reducing the change duration to 1 minute may result in an imbalance of 40 MWh of surplus or 46 MWh of deficit. The largest deviations occur in the case of an instantaneous power change, where the imbalance may rise to 42 MWh of surplus or up to 48 MWh of deficit.

In 2033, if the power change occurs over 10 minutes, the possible deviations reach up to 28 MWh of surplus or up to 31 MWh of deficit. Shortening the change duration to 5 minutes increases the imbalance, which may reach up to 33 MWh of surplus or 36 MWh of deficit. Even faster power changes, with the duration reduced to 1 minute, result in imbalance deviations of up to 43 MWh of surplus or 47 MWh of deficit. The most extreme situation occurs during an instantaneous power change, when the imbalance deviation may rise to 46 MWh of surplus or up to 49 MWh of deficit.

In critical cases in 2035, with a 10-minute power-change period, the imbalance deviation may reach 36 MWh of surplus or 48 MWh of deficit. Shortening the power-change period to 5 minutes increases the imbalance, which may reach up to 42 MWh or 56 MWh of surplus and deficit respectively. A 1-minute power-change period further worsens the situation, creating an imbalance of up to 53 MWh of surplus or 64 MWh of deficit. The most severe case occurs with an instantaneous power change, where the imbalance may reach up to 56 MWh of surplus or up to 66 MWh of deficit at the moment of the change..

The table presents the additional upward and downward aFRR needs arising from different power-change periods between market time units, showing that shorter power-change periods and larger imbalance volumes create an additional need for aFRR capacity in the market. The additional aFRR capacity needs:

- In 2028, it increases to 37 MW for upward aFRR and 30 MW for downward aFRR.
- In 2030, the need increases to 56 MW for both upward and downward aFRR.
- In 2033, it rises further to 71 MW for both upward and downward aFRR.
- In 2035, the additional need reaches up to 80 MW for upward aFRR and 77 MW for downward aFRR.

table 22 Schedule change during the ramping period of the market time unit needs

2028				
Power-change period	**10 min**	**5 min**	**1 min**	**0 s**
Risk that the imbalance will exceed permitted limits, %	1,35	2,32	4,28	4,82

Instantaneous downward need, MW	-536	-574	-658	-670
Instantaneous upward need, MW	522	556	661	668
Imbalance deviation upward, MWh	-33	-37	-44	-45
Imbalance deviation downward, MWh	25	30	37	39
Additional upward aFRR need	0	-18	-33	-37
Additional downward aFRR need	0	13	26	30
2030				
Power-change period	**10 min**	**5 min**	**1 min**	**0 s**
Risk that the imbalance will exceed permitted limits, %	0,49	1,71	4,33	4,79
Instantaneous downward need, MW	-554	-616	-788	-814
Instantaneous upward need, MW	557	615	803	818
Imbalance deviation upward, MWh	-30	-35	-46	-48
Imbalance deviation downward, MWh	28	32	40	42
Additional upward aFRR need	0	-26	-51	-56
Additional downward aFRR need	0	26	51	56
2033				
Power-change period	**10 min**	**5 min**	**1 min**	**0 s**
Risk that the imbalance will exceed permitted limits, %	0,31	0,97	3,10	3,76
Instantaneous downward need, MW	-570	-636	-805	-835
Instantaneous upward need, MW	567	631	814	847
Imbalance deviation upward, MWh	-31	-36	-47	-49
Imbalance deviation downward, MWh	28	33	43	46
Additional upward aFRR need	0	-32	-64	-71
Additional downward aFRR need	0	32	64	71
2035				
Power-change period	**10 min**	**5 min**	**1 min**	**0 s**
Risk that the imbalance will exceed permitted limits, %	2,11	3,11	5,88	6,67
Instantaneous downward need, MW	-733	-806	-946	-956
Instantaneous upward need, MW	625	714	888	905
Imbalance deviation upward, MWh	-48	-56	-64	-66
Imbalance deviation downward, MWh	36	42	53	56
Additional upward aFRR need	0	-38	-72	-80
Additional downward aFRR need	0	33	68	77

7.5.2. LTrSc scenario

The analysis of schedule changes between MTUs in the Slower Transformation Scenario shows that instantaneous power changes and the resulting imbalance remain significant in all analyzed years, although the magnitude varies depending on the development of system units (the results are presented in the table below). In the Slower Scenario, flexibility needs are higher than in the ERAA2025 Scenario, and the imbalance risk ranges from 0,1 % to 7,7 % of the time

In 2028, in critical cases, with a 10 minute power-change period, the imbalance deviation may reach 25 MWh of surplus or 28 MWh of deficit. Shortening the power-change period to 5 minutes increases the imbalance, which may reach up to 30 MWh or 32 MWh of surplus and deficit respectively. A 1 minute power-change period further worsens the situation, creating an imbalance of up to 39 MWh of surplus or 42 MWh of deficit. The most severe case occurs with an instantaneous power change, where the imbalance may reach up to 41 MWh of surplus or up to 44 MWh of deficit at the moment of the change

In 2030, with a 10 minute power-change duration, the possible imbalance deviations reach about 26 MWh of surplus or up to 28 MWh of deficit. Shortening the power-change period to 5 minutes further increases the imbalance — in extreme cases up to 35 MWh of surplus or up to 37 MWh of deficit. Reducing the change duration to 1 minute may result in an imbalance of 49 MWh of surplus or 53 MWh of deficit. The largest deviations occur in the case of an instantaneous power change, where the imbalance may rise to 52 MWh of surplus or up to 56 MWh of deficit.

In 2033, if the power change takes 10 minutes, the possible deviations reach up to 15 MWh of surplus or up to 14 MWh of deficit. Shortening the change duration to 5 minutes increases the imbalance, which may reach up to 29 MWh of surplus or 31 MWh of deficit. Even faster power changes, with the duration reduced to 1 minute, result in imbalance deviations of up to 46 MWh of surplus or 51 MWh of deficit. The most extreme situation occurs during an instantaneous power change, when the imbalance deviation may rise to 51 MWh of surplus or up to 55 MWh of deficit.

In 2035, in critical cases, with a 10 minute power-change period, the imbalance deviation may reach 15 MWh of surplus or 20 MWh of deficit. Shortening the power-change period to 5 minutes increases the imbalance, which may reach up to 32 MWh of surplus or 37 MWh of deficit. A 1 minute power-change period further worsens the situation, creating an imbalance of up to 54 MWh of surplus or 59 MWh of deficit. The most severe case occurs with an instantaneous power change, where the imbalance may reach up to 58 MWh of surplus or up to 56 MWh of deficit at the moment of the change.

The table presents the additional upward and downward aFRR needs arising from different power-change periods between market time units, showing that shorter power-change periods and larger imbalance volumes create an additional need for aFRR capacity in the market. The aFRR energy volume is defined by the imbalance magnitudes described at the beginning of the section. The additional aFRR capacity need:

- In 2028, it increases to 34 MW for upward aFRR and 35 MW for downward aFRR.
- In 2030, the need increases to 77 MW for both upward and downward aFRR.
- In 2033, it rises further to 102 MW for upward aFRR and 104 MW for downward aFRR.
- In 2035, the additional need reaches up to 113 MW for upward aFRR and 110 MW for downward aFRR.

table 23 Slower scenario schedule change during the ramping period of the market time unit needs

2028				
Power-change period	**10 min**	**5 min**	**1 min**	**0 s**
Risk that the imbalance will exceed permitted limits, %	0,58	1,75	4,05	4,53
Instantaneous downward need, MW	-519	-570	-652	-683
Instantaneous upward need, MW	528	570	704	728
Imbalance deviation upward, MWh	-28	-32	-42	-44
Imbalance deviation downward, MWh	25	30	39	41
Additional upward aFRR need	0	-15	-30	-34
Additional downward aFRR need	0	15	31	35
2030				
Power-change period	**10 min**	**5 min**	**1 min**	**0 s**
Risk that the imbalance will exceed permitted limits, %	0,27	2,13	6,70	7,72
Instantaneous downward need, MW	-557	-625	-937	-1003
Instantaneous upward need, MW	558	623	931	972
Imbalance deviation upward, MWh	-28	-37	-53	-56
Imbalance deviation downward, MWh	26	35	49	52
Additional upward aFRR need	0	-34	-70	-77
Additional downward aFRR need	0	34	70	77
2033				
Power-change period	**10 min**	**5 min**	**1 min**	**0 s**

Risk that the imbalance will exceed permitted limits, %	0,09	0,52	4,36	5,27
Instantaneous downward need, MW	-399	-581	-932	-1005
Instantaneous upward need, MW	392	576	914	990
Imbalance deviation upward, MWh	-14	-31	-51	-55
Imbalance deviation downward, MWh	15	29	46	51
Additional upward aFRR need	0	-45	-93	-102
Additional downward aFRR need	0	46	95	104
2035				
Power-change period	**10 min**	**5 min**	**1 min**	**0 s**
Risk that the imbalance will exceed permitted limits, %	0,39	1,20	5,31	6,15
Instantaneous downward need, MW	-472	-645	-978	-1058
Instantaneous upward need, MW	419	609	957	1036
Imbalance deviation upward, MWh	-20	-37	-59	-56
Imbalance deviation downward, MWh	15	32	54	58
Additional upward aFRR need	0	-49	-102	-113
Additional downward aFRR need	0	48	100	110

7.6. Uncontrollable Solar PP management needs

7.6.1. ERAA2025 scenario

The analysis of uncontrolled solar generation in 2028–2035 shows a clear and steady increase (results are provided in the table below). Situations in which solar power plant generation exceeds electricity demand plus must-run generation — creating uncontrolled surplus — occur during 8.18 % of annual hours in 2028, increasing to 10.14 % in 2035. The intermediate years, 2030 and 2033, also show a consistent upward trend (8.37 % and 9.55 % respectively). The figure below illustrates that the largest share of high-surplus situations is expected from April to July. During winter months, surplus is almost non-existent due to low solar output. Comparing the analyzed years, a steady increase in surplus is visible, driven by the expansion of permitted solar generation capacity.

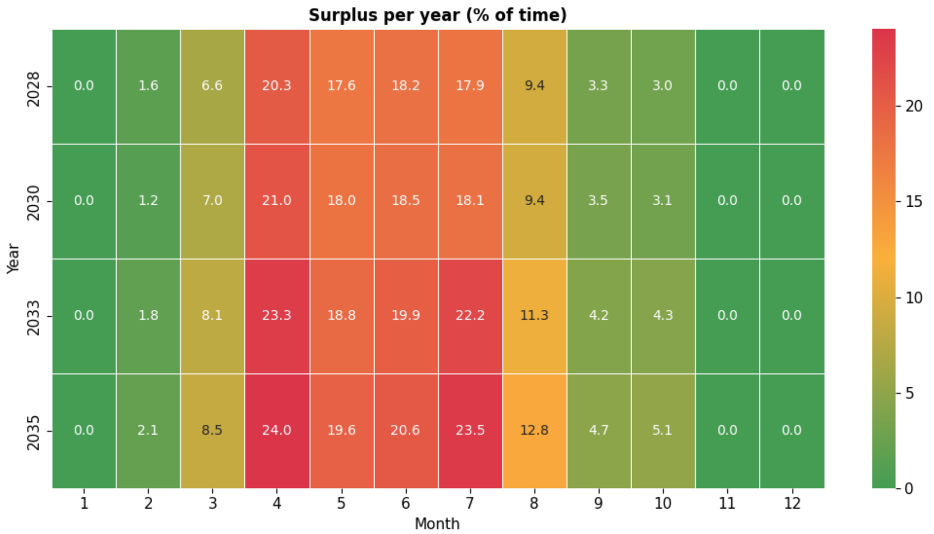


Figure 188 Uncontrolled SE generated energy exceeding consumption, time %

Although the average duration of a surplus event increases only slightly — from 5.56 hours in 2028, to 5.58 hours in 2030, 6.04 hours in 2033, and 6.15 hours in 2035 — however, the amount of unused energy almost doubles:

- 2028 - 322 GWh,
- 2030 - 377 GWh,
- 2033 - 535 GWh,
- and in 2035 reaches 639 GWh.

Flexibility need indicates the amount of power capacity required to absorb surplus solar generation. This need increases from 1268 MW to 1971 MW over 2028–2035 (reaching 1437 MW in 2030 and 1751 MW in 2033) and is linked to installed solar capacity, as both installed capacity and flexibility need grow by approximately ~700 MW during the analyzed period.

table 24 Uncontrollable Solar PP management needs- NacSc

	NacSc			
	2028	**2030**	**2033**	**2035**
Must-run generation	259	259	259	259
Uncontrollable SE, MW	2017	2217	2517	2717
Uncontrollable SE surplus per year %	8,18	8,37	9,55	10,14
Average event duration, h	5,56	5,58	6,04	6,15
Flexibility resources need, MW	1268	1437	1751	1971
Flexible resource energy capacity, MWh	7605	8624	12256	13797
Energy, GWh	322,474	377,084	534,626	638,525

7.6.2. LTrSc scenario

In the Slower Scenario, installed solar generation power remains unchanged, yet a larger share of generated energy is consumed, resulting in fewer hours per year with surplus energy. Solar generation surplus occurs during 9.42 % of annual hours in 2028 and decreases to 7.03 % in 2035. The intermediate years — 2030 and 2033 — show a consistent decline as well (8.75 % and 6.10 % respectively). The figure below illustrates how surplus-generation events are distributed across months. Most surplus situations occur from April to July, when solar output is high. During winter months, surplus is almost non-existent due to low solar generation. Comparing the analyzed years, a clear downward trend in surplus is visible, driven by higher consumption of available solar energy

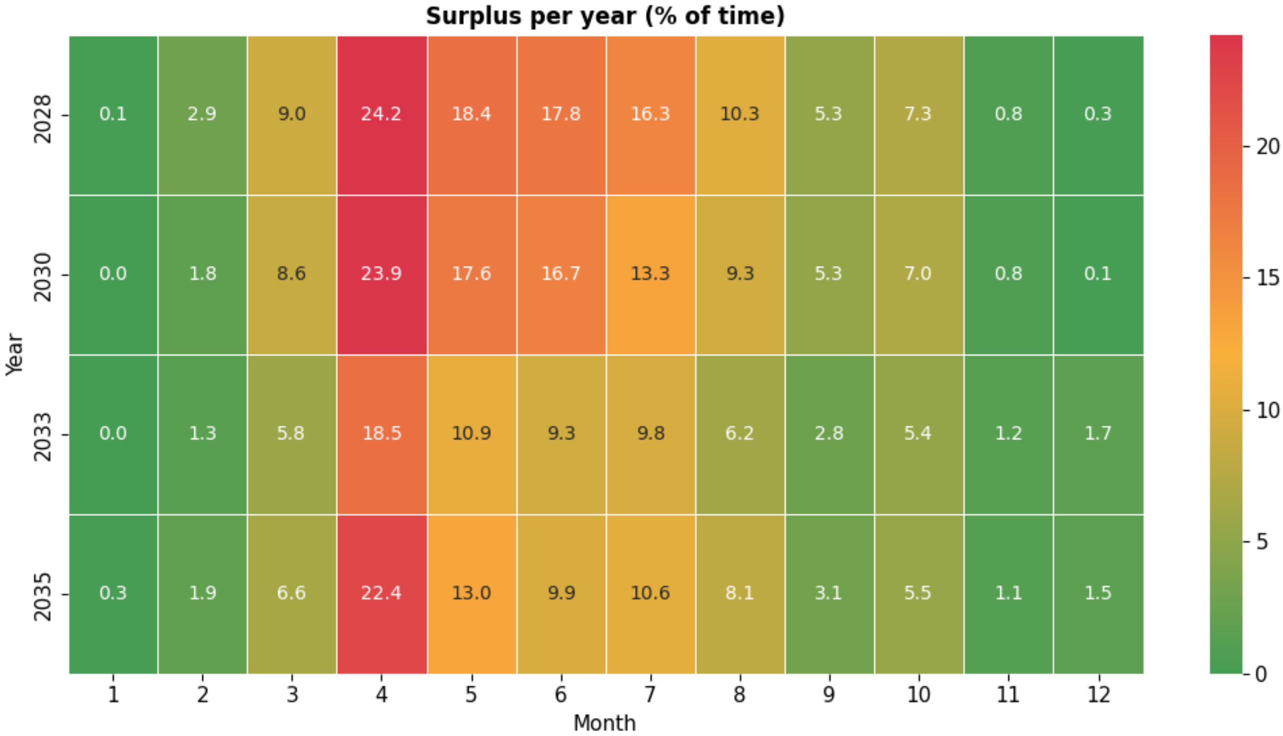


Figure 189 Uncontrolled SE generated energy exceeding consumption, time %

The average duration of surplus events in 2028 is similar — 5.73 hours — but in later years it becomes slightly shorter: 5.5 hours in 2030, 3.6 hours in 2033, and then increases again to 4.18 hours in 2035. The amount of unused energy is:

- 2028 - 391 GWh,
- 2030 - 407 GWh,
- 2033 - 272 GWh,
- and in 2035 - 405 GWh.

Flexibility need increases from 1345 MW to 2089 MW over 2028–2035, reaching 1662 MW in 2030 and 2089 MW in 2033.

table 25 Uncontrollable Solar PP management needs - LTrSc

	LTrSc			
	2028	**2030**	**2033**	**2035**
Must-run generation	259	259	259	259
Uncontrollable SE surplus per year %	9,42	8,75	6,10	7,03
Average event duration, h	5,73	5,50	3,60	4,18
Flexibility resources need, MW	1345	1518	1662	2089
Flexible resource energy capacity, MWh	8071	9109	6647	10443
Energy, GWh	390,594	406,567	272,443	405,053

7.7. Distributed generation influence to transmission network

7.7.1. Flexibility needs

In the flexibility-needs assessment, it is assumed that reverse power flow from the distribution network within the transmission-grid capacity zone does not exceed the Safe Generation Range (SGR). Under this assumption, the resulting value represents the transmission-grid flexibility need. NacSc corresponds to Scenario 1, while LTrSc corresponds to Scenario 2. The respective indicators are presented in the figure below.

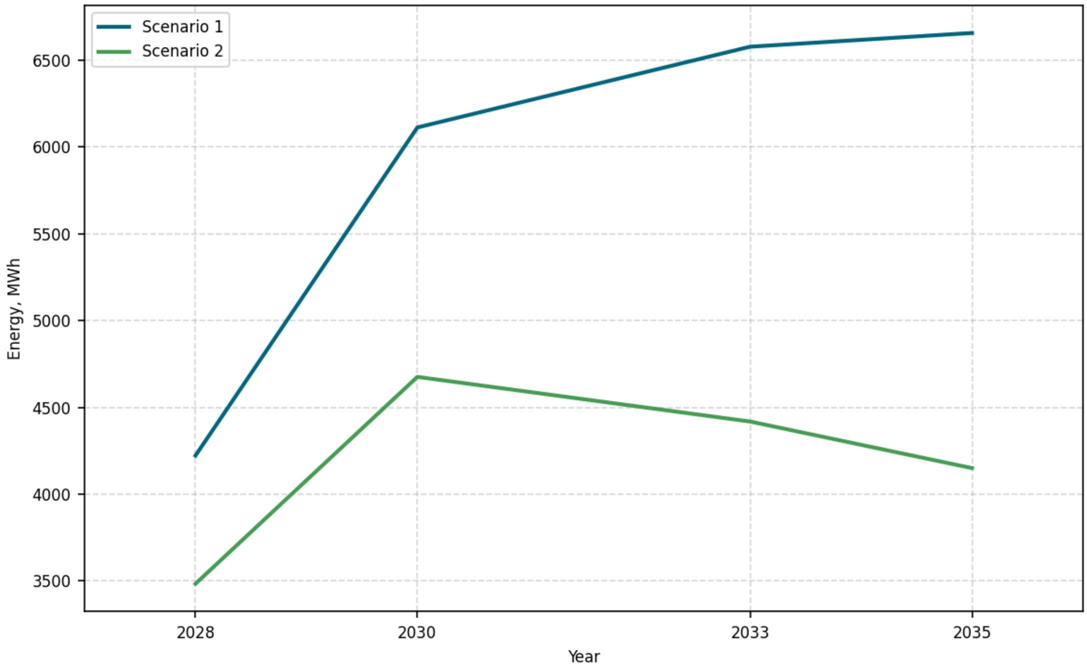


Figure 190 Flexibility need when the distribution-network backflow does not exceed the SGR

The chart displays the data provided in the table below. In Scenario 1, values range from 4 222 MWh in 2028 to 6 655 MWh in 2035. Under Scenario 2, the need increases from 3 484 MWh in 2028 to 4 675 MWh in 2030, and later decreases to 4 150 MWh in 2035.

26 table. Flexibility need when the distribution-network backflow does not exceed the SGR.

Scenario	2028	2030	2033	2035
1 scenario, MWh	4 222	6 111	6 576	6 655
2 scenario, MWh	3 484	4 675	4 418	4 150

If flexibility need were simply curtailed, the curtailment expressed as a percentage of all energy delivered to the transmission grid over the year is shown in the figure below.

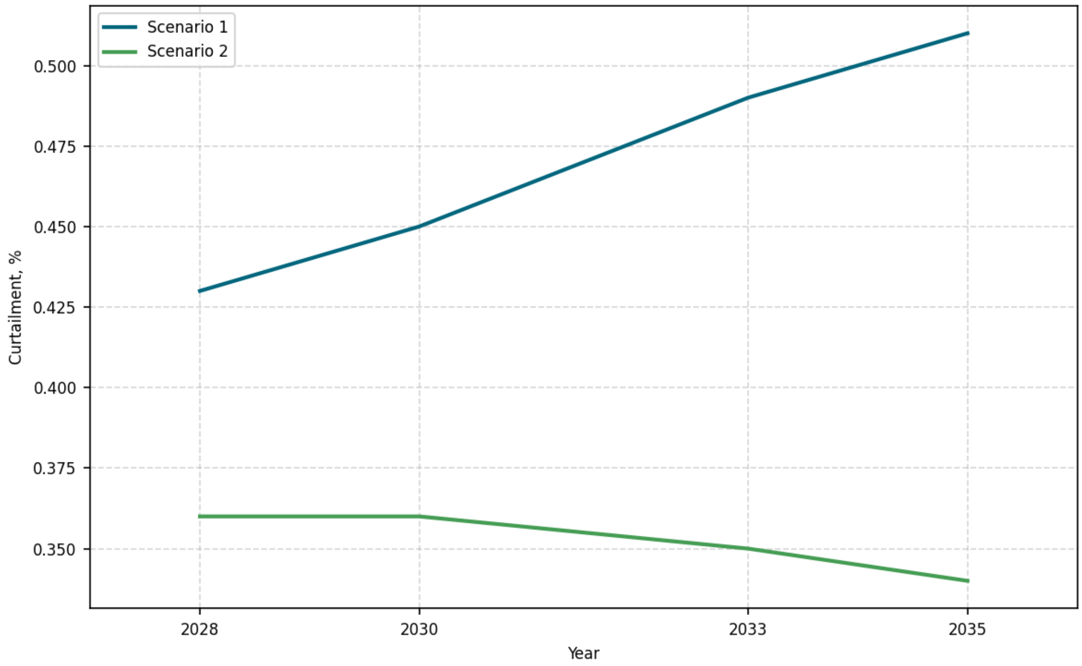


Figure 191 Curtailment as a percentage of the total energy supplied to the transmission network per year, when ST does not exceed SGR

The chart displays the data provided in the table below; in Scenario 1, values range from 0.43 % to 0.51 %.

27 table Curtailment as a percentage of the total energy supplied to the transmission network per year, when ST does not exceed SGR

Scenario	2028	2030	2033	2035
1 scenario, %	0,43	0,45	0,49	0,51
2 scenario, %	0,36	0,36	0,35	0,34

7.7.2. Storage units for flexibility needs

The storage-unit power and capacity values presented below are selected based on the surplus analysis performed for each capacity zone.
The storage-unit power is selected as the 99th percentile of surplus power peaks. This means that the storage unit would be capable of absorbing 99 percent of all occurring power exceedances.
The initial storage-unit capacity is selected as the 99th percentile of surplus-energy volumes. However, this percentile-based capacity alone is not sufficient to absorb the entire surplus energy under normal operating conditions. This is because the storage unit operates cyclically – it must absorb energy and then discharge before it can absorb the next surplus event. For this reason, the initial capacity is increased in 1 MWh increments until the storage unit is able to absorb 98 percent of all surplus energy within the specific capacity zone.
The required total storage power is presented in the figure below.

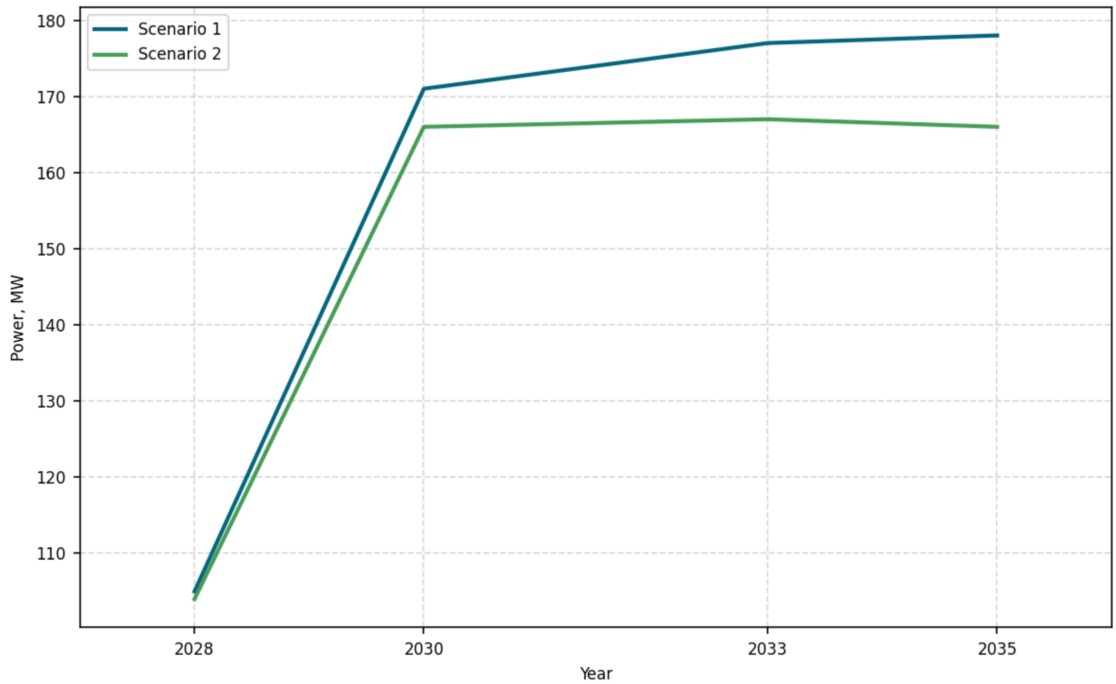


Figure 192 Total storage power when distribution-network backflow does not exceed the SGR

The chart displays the data provided in the table below. Under Scenario 1, values range from 105 MW to 178 MW. Under Scenario 2, storage power increases from 104 MW in 2028 to 167 MW in 2033, and reaches 166 MW in 2035.

The required total storage capacity is presented in the figure below.

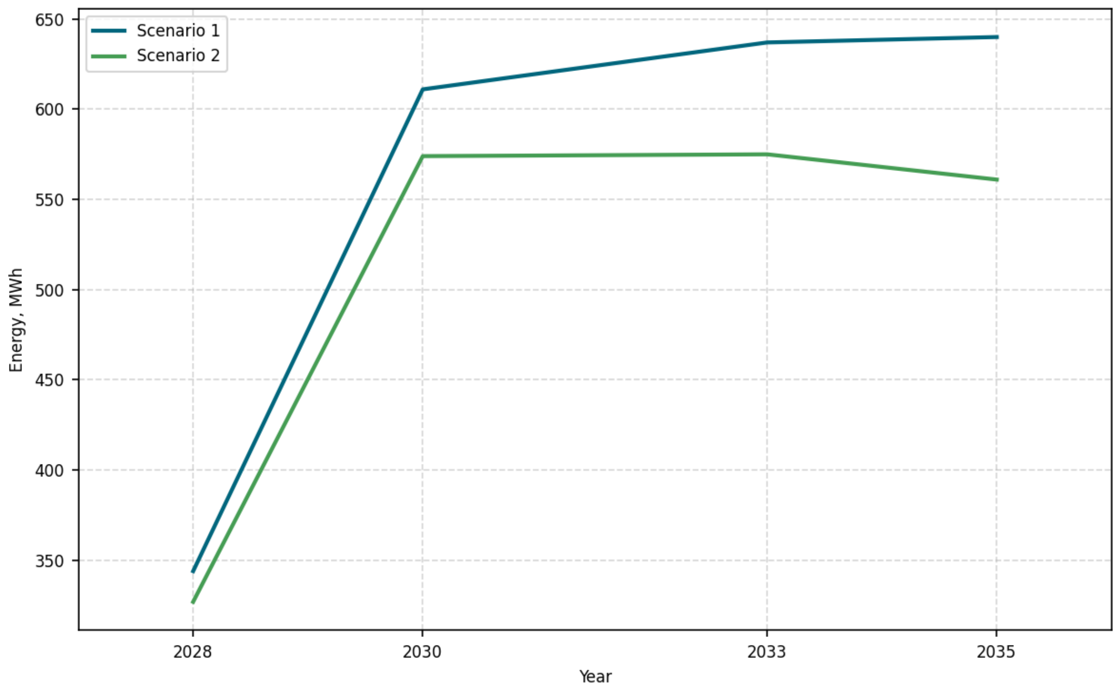


Figure 193 Total storage capacity when distribution-network backflow does not exceed the SGR

The chart displays the data provided in the table below. Under Scenario 2, values range from 344 MWh in 2028 to 640 MWh in 2035. Under Scenario 4, storage capacity increases from 327 MWh in 2028 to 575 MWh in 2033, and reaches 561 MWh in 2035.

28 table. Total storage power and capacity when distribution-network backflow does not exceed the SGR

Year	2028		2030		2033		2035	
	Power, MW	Capacity, MWh	Power, MW	Capacity, MWh	Power, MW	Capacity, MWh	Power, MW	Capacity, MWh
1 scenario	105	344	171	611	177	637	178	640
2 scenario	104	327	166	574	167	575	166	561

The amount of energy that storage units with these parameters can accumulate is shown in the figure below.

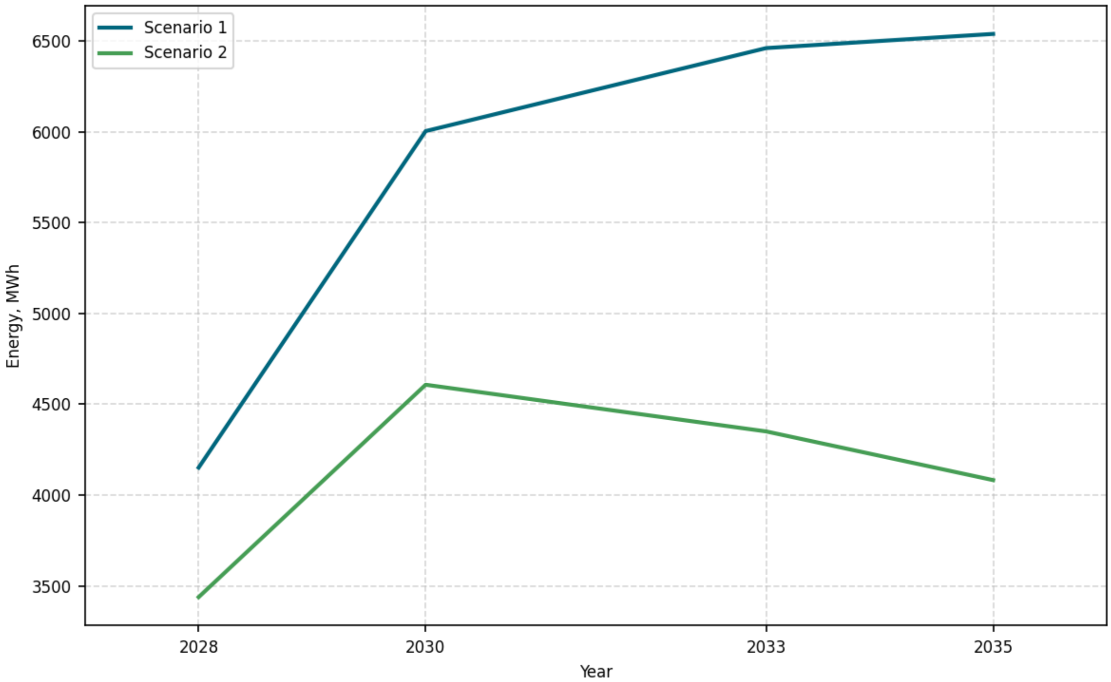


Figure 194 Energy accumulated by storage units when distribution-network backflow does not exceed the SGR

The chart displays the data provided in the table below. Under Scenario 1, values increase from 4 151 MWh to 6 538 MWh. Under Scenario 2, the amount of accumulated energy grows from 3 438 MWh in 2028 to 4 607 MWh in 2030, then decreases to 4 082 MWh in 2035

29 table. Energy accumulated by storage units when distribution-network backflow does not exceed the SGR

Scenario	2028	2030	2033	2035
1 scenario, MWh	4 151	6 003	6 460	6 538
2 scenario, MWh	3 438	4 607	4 350	4 082

The amount of energy not accumulated by storage units indicates how much energy remains unabsorbed due to their technical limitations. This reflects the remaining need for flexibility after the accumulators. These data are presented in the figure below.

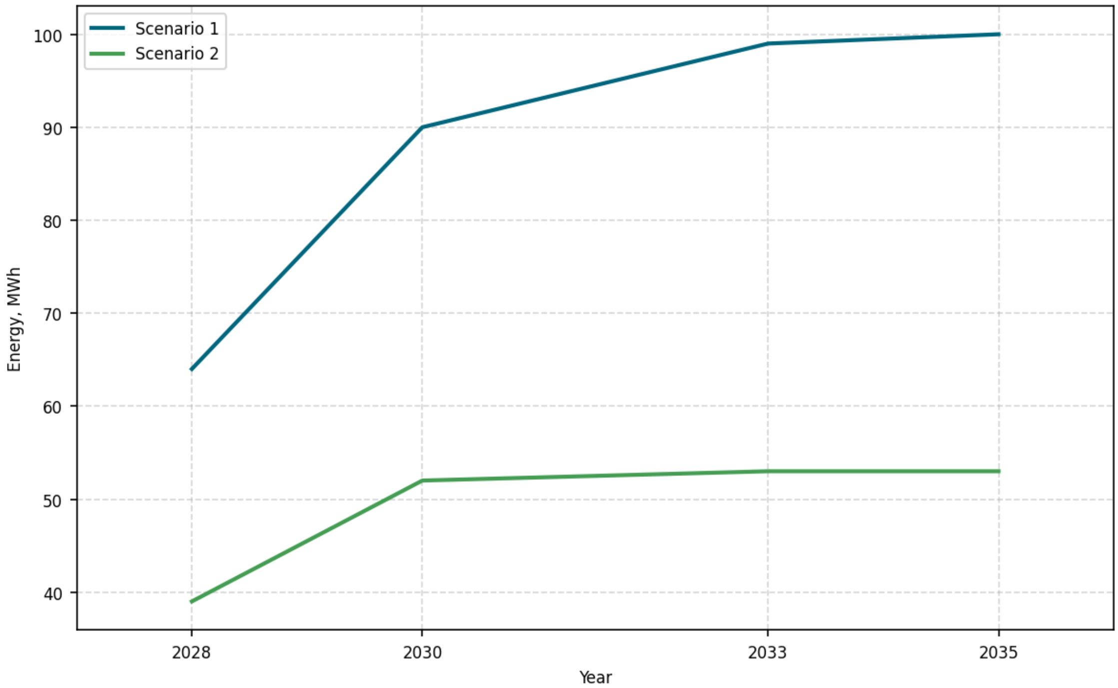


Figure 195 Flexibility requirement after accumulators when distribution-network backflow does not exceed the SGR

The chart displays the data provided in the table below. Under Scenario 1, the residual flexibility need increases from 64 MWh to 100 MWh. Under Scenario 4, the need grows from 39 MWh in 2028 to 53 MWh in 2030 and remains stable through 2035.

30 table. Flexibility requirement after accumulators when distribution-network backflow does not exceed the SGR

Scenario	2028	2030	2033	2035
1 scenario, MWh	64	90	99	100
2 scenario, MWh	39	52	53	53

The limitation under the accumulators percentage shows the remaining limitation after considering the contribution of the accumulators. This data is presented in the figure below.

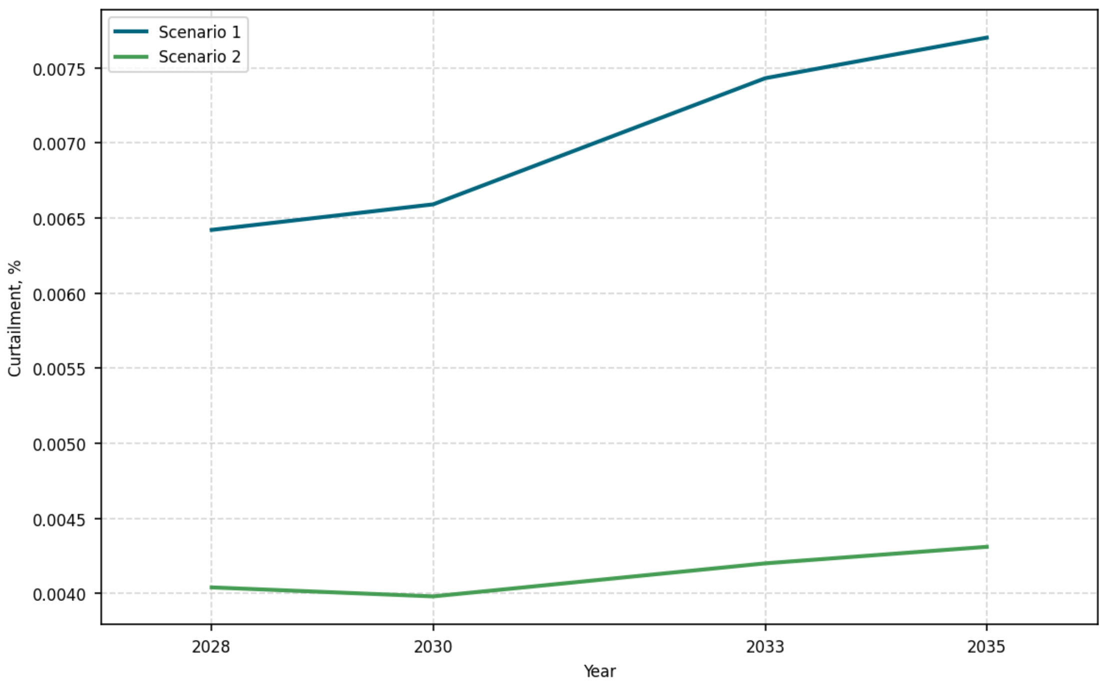


Figure 196 Limitation as a percentage of the total energy supplied to the transmission network per year after storage, when distribution-network backflow does not exceed the SGR

The chart displays the data provided in the table below. Under Scenario 1, post-storage curtailment values range from 0.006 % in 2028 to 0.008 % in 2035. Under Scenario 2, curtailment remains the most stable at 0.004 % throughout the entire analyzed period.

31 table. Limitation as a percentage of the total energy supplied to the transmission network per year after storage, when distribution-network backflow does not exceed the SGR

Scenario	2028	2030	2033	2035
1 scenario, %	0,006	0,007	0,007	0,008
2 scenario, %	0,004	0,004	0,004	0,004

7.7.3. Conclusions

When assessing transmission-grid flexibility (with the distribution grid resolving its own flexibility issues and not exceeding the safe generation limit), the highest flexibility need under Scenario 1 occurs in 2035 and reaches 6 655 MWh. Without flexibility resources, curtailing this amount of energy would correspond to 0.51 % of all energy delivered to the transmission grid over the year in the analyzed capacity zones. With storage units installed—total power 178 MW and total capacity 640 MWh—the flexibility need would decrease to 100 MWh (0.008 %).

Under the Slower Transformation Scenario 2, the highest flexibility need occurs in 2030 and reaches 4 675 MWh, which corresponds to 0.36 % of all energy delivered to the transmission grid over the year. With storage units installed—total power 166 MW and total capacity 574 MWh—the flexibility need would decrease to 52 MWh (0.004 %).

8. Results fine-tuning

8.1. Additional calculations performed in accordance with Section 16 of the FNA methodology

According to Article 16 of the FNA methodology, the required additional calculations were performed and used to formulate flexibility conclusions. The calculation results are provided in Annex 2.

8.2. Principles for assessing the amount of flexible resources required to cover flexibility needs

Flexibility needs are grouped into three main categories:

- System needs;
- Network needs;
- Specific needs.

System needs include the requirements related to the entire electricity system's ability to adapt to changes in generation and demand. This category includes RES integration needs, ramping needs and short-term flexibility needs. These needs indicate the additional flexibility volumes that may be required to ensure system balance when consumption changes, RES generation fluctuates, or short-term deviations arise between forecasted and actual system conditions. To determine the amount of system flexibility resources, the minimum volume of resources required to ensure system flexibility is identified. The largest value among RES integration needs, ramping needs and short-term flexibility needs is taken as the system need.

Short-term flexibility needs are further detailed by the required volumes of mFRR and aFRR capacities, plan change between MTU and uncontrolled solar needs variability. However, these elements are not directly added to the final system-need value. They serve only to refine the understanding of short-term flexibility dynamics rather than to increase the quantified system need.

Network needs include needs related to the ability of the electricity network to transmit and distribute electricity when technical capacity limits or operational parameter deviations occur in certain parts of the network. This category includes the needs of the transmission system operator and the needs of the distribution system operator. The network needs are also detailed by the assessment of distributed generation influence to transmission network needs, which allows to assess situations where generation from the distribution network affects the transmission network, but this component is not directly added to the final value of the network need. The higher value is determined from the transmission system needs and the distribution system needs are evaluated as the network needs value..

Specific needs include individual technical, service-related, or infrastructure-related requirements that are not directly assigned to general system-level or network-level flexibility needs. This category includes the needs for isolated-operation reserve services, fast frequency response reserves, FCR needs, and the needs related to increasing the Lithuania–Poland interconnection capacity. These needs are assessed separately because they relate to specific system functions, reliability requirements, or infrastructure development needs. Unlike system or network needs, specific needs may exist in parallel, so their total value is determined by summing all components assigned to this category.

The total flexibility need is evaluated considering that the same portfolio of flexibility resources can be used to cover multiple need categories. Therefore, system, network, and specific needs are not directly summed together. It is considered that covering systemic flexibility needs forms a sufficient base of flexibility resources, which, under appropriate technical and territorial conditions, can also be used to meet network or specific needs.

A graph detailing the determination of flexible resources is shown in Fig. 198.

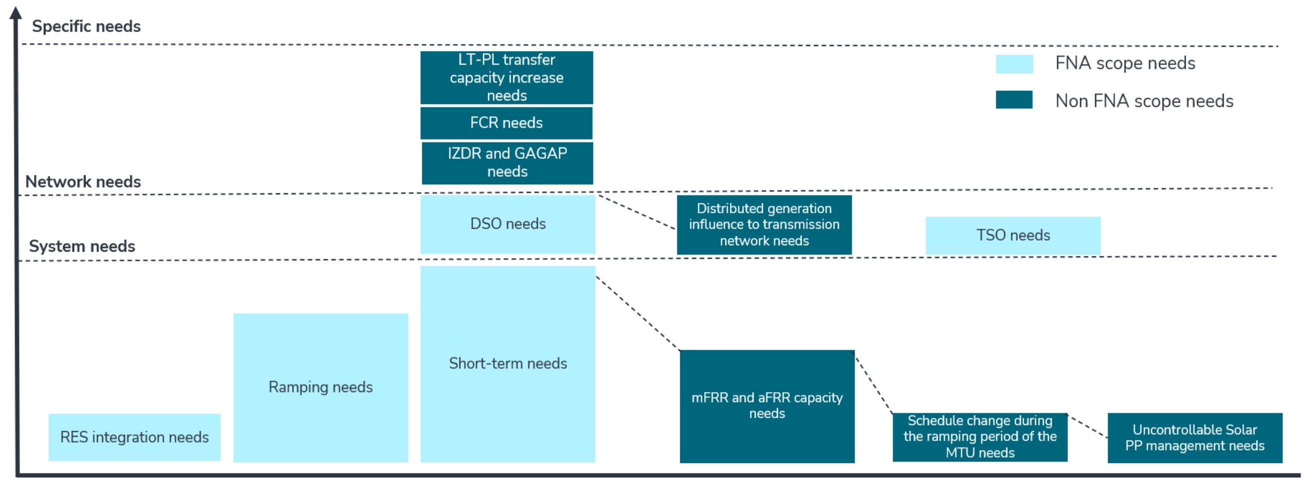


Figure 197 Principle of assessing flexibility needs

Additional needs:

Based on additional indicative calculations carried out in accordance with Article 16 of the FNA methodology and on supplementary assumptions, an interpretation was made of the volumes of flexible resources required to cover system flexibility needs.

Short-term flexibility needs define system requirements across all analyzed scenarios, as their magnitude is identified as the largest. In assessing short-term flexibility coverage needs, the calculation is divided into two components:

1) Short-term flexibility can be covered by limited-energy sources (for example BESS);
2) Short-term flexibility is covered by unlimited-energy sources (e.g., conventional generation).

Additional needs are divided into two components, considering the magnitude of uncovered flexibility events in terms of energy. Considering market trends, limited-energy capacity resources such as BESS are typically installed with energy capacity enabling operation at rated power for up to 4 hours. The calculations show that some events are longer in terms of energy, and covering them with limited-energy sources would not be rational; therefore, a linear regression model is applied to determine the need for unlimited-capacity generation. Using this principle, the required limited-capacity generation is also assessed.

Additional network needs in all scenarios are defined by the results calculated by the DSO.

8.3. Assessment of the National Strategy Scenario

8.3.1. Basic regime

In the National Strategy Scenario under the basic regime, the need for flexible units to cover system flexibility is presented in the tables below. No additional downward needs were identified. The amount of flexible resources required downward changes from 4671 MW in 2028 and increases steadily to 7144 MW in 2035. This growth is driven by rising system flexibility needs.

table 32 Downward flexible resource need– NacSc basic regime

	2028		2030		2033		2035	
	Need	Uncovered	Need	Uncovered	Need	Uncovered	Need	Uncovered

System flexibility, MW	3814	0	5187	0	6005	0	6307	0
Network flexibility, MW	343	0	410	0	455	0	458	0
Specific flexibility, MW	514	0	518	0	377	0	379	0
Total	4671	0	6115	0	6837	0	7144	0

In the basic scenario, the amount of flexible resources required upward ranges from 4,939 MW to 8,407 MW. The analysis identified an additional flexibility need. The values are presented in the table below.

table 33 Upward flexible resource need– NacSc basic regime

	2028		2030		2033		2035	
	Need	Uncovered	Need	Uncovered	Need	Uncovered	Need	Uncovered
System flexibility, MW	4395	466	5743	533	7193	591	7920	540
Network flexibility, MW	30	30	42	42	77	77	108	108
Specific flexibility, MW	514	514	518	518	377	377	379	379
Total	4939	1010	6303	1093	7647	1045	8407	1027

The table below provides a detailed breakdown defining the resources required to cover flexibility needs.

table 34 Additional flexibility needs

	Metai	2028	2030	2033	2035	Comment
To cover system flexibility	Additional short-term resources, MW	466	533	591	540	
	Additional short-term resources capacity, MW	1096	1108	1070	1450	
To cover network flexibility	Additional short-term resources, MW	30	42	77	108	
	Additional short-term resources capacity, MW					
To cover specific flexibility	Additional short-term resources, MW	514	518	377	379	

	Additional short-term resources capacity, MW	528	536	400	404	
Total, MW		1010	1093	1045	1027	
To cover system flexibility	Long-term resources, MW	209	0	492	170	Covered by existing flexible power plants

Both short-term and long-term additional flexibility needs were identified. Since long-term resources were required during periods when conventional generation units were not operating, it is assumed that the entire long-term flexibility need is covered by conventional power plants. Therefore, these data are not included further in the assessment of additional needs..

Short-term flexibility needs can be covered by resources of any technological type. To simplify the presentation of results, additional needs are shown together with the battery energy storage capacities included in the scenario. The results are provided in the table below.

table 35 Additional needs are evaluated from the perspective of BESS

	Year	2028	2030	2033	2035
BESS	Additional short-term resources, MW	1010	1093	1045	1027
	Existing BESS power in the assessment, MW	1060	1300	1650	1750
	Total power, MW	**2070**	**2393**	**2695**	**2777**
	Additional short-term resources capacity, MW	1624	1644	1470	1854
	Existing BESS capacity in the assessment, MW	3428	4206	4886	5176
	Total capacity, MWh	**5052**	**5850**	**6356**	**7030**

8.3.2. Realistic regime

Based on the principles described in this section, the assessment of flexibility resources under the National Strategy Scenario in the realistic regime is presented below.

table 36 Downward flexibility need – NacSc realistic regime

	2028	2030	2033	2035

	Need	Uncovered	Need	Uncovered	Need	Uncovered	Need	Uncovered
System flexibility, MW	3814	0	5187	0	6005	0	6307	0
Network flexibility, MW	343	0	410	0	455	0	458	0
Specific flexibility, MW	514	0	518	0	377	0	379	0
Total	4671	0	6115	0	6837	0	7144	0

table 37 Upward flexibility need – NacSc realistic regime

	2028		2030		2033		2035	
	Need	Uncovered	Need	Uncovered	Need	Uncovered	Need	Uncovered
System flexibility, MW	4395	571	5743	701	7193	913	7920	912
Network flexibility, MW	30	30	42	42	77	77	108	108
Specific flexibility, MW	514	514	518	518	377	377	379	379
Total	4939	1115	6303	1261	7647	1367	8407	1399

table 38 Additional flexibility needs

	Metai	2028	2030	2033	2035	Comment
To cover system flexibility	Additional short-term resources, MW	571	701	913	912	
	Additional short-term resources capacity, MW	1427	1936	2340	2703	
To cover network flexibility	Additional short-term resources, MW	30	42	77	108	
	Additional short-term resources capacity, MW					

To cover specific flexibility	Additional short-term resources, MW	514	518	377	379	
	Additional short-term resources capacity, MW	528	536	400	404	
Total		1115	1261	1367	1399	
To cover system flexibility	Long-term resources, MW	519	579	720	708	Covered by existing flexible power plants

According to the transmission system operator's assessment, all identified long-term flexibility resources can be covered by existing flexible power plants and are therefore not included in the total volume of additional resources.

table 39 Additional needs are evaluated from the perspective of BESS

	Year	2028	2030	2033	2035
BESS	Additional short-term resources, MW	1115	1261	1367	1399
	Existing BESS power in the assessment, MW	1060	1300	1650	1750
	Total power, MW	**2175**	**2561**	**3017**	**3149**
	Additional short-term resources capacity, MW	1955	2472	2740	3107
	Existing BESS capacity in the assessment, MW	3428	4206	4886	5176
	Total capacity, MWh	**5383**	**6678**	**7626**	**8283**

8.4. Assessment of the Slower Transformation Scenario

8.4.1. Basic regime

Based on the principles described in this section, the assessment of flexibility resources under the Slower Transformation Scenario in the basic regime is presented below.

table 40 Downward flexibility need – LTrSc basic regime

	2028	2030	2033	2035

	Need	Uncovered	Need	Uncovered	Need	Uncovered	Need	Uncovered
System flexibility, MW	3830	0	4983	0	5099	0	5835	0
Network flexibility, MW	167	0	181	0	182	0	181	0
Specific flexibility, MW	514	0	518	0	377	0	379	0
Total	4511	0	5682	0	5658	0	6395	0

table 41 Upward flexibility need – LTrSc basic regime

	2028		**2030**		**2033**		**2035**	
	Need	Uncovered	Need	Uncovered	Need	Uncovered	Need	Uncovered
System flexibility, MW	3821	0	4838	0	5380	0	6644	0
Network flexibility, MW	30	0	42	0	77	0	108	0
Specific flexibility, MW	514	0	518	0	377	0	379	0
Total	4364	0	5398	0	5834	0	7131	0

table 42 Additional needs are evaluated from the perspective of BESS

	Year	**2028**	**2030**	**2033**	**2035**
BESS	Additional short-term resources, MW	0	0	0	0
	Existing BESS power in the assessment, MW	1260	2115	2428	2652
	Total power, MW	**899**	**1163**	**1199**	**1296**
	Additional short-term resources capacity, MW	0	0	0	0
	Existing BESS capacity in the assessment, MW	2903	5083	5881	6452

	Total capacity, MWh	2071	2795	2904	3153

* The table shows that the BESS capacity identifies the minimum amount of flexible resources required to cover flexibility needs. This value is lower than the capacity defined in the scenario..

8.4.2. Realistic regime

Based on the principles described in this section, the assessment of flexibility resources under the Slower Transformation Scenario in the realistic regime is presented below

table 43 Downward flexibility need – LTrSc realistic regime

	2028		2030		2033		2035	
	Need	Uncovered	Need	Uncovered	Need	Uncovered	Need	Uncovered
System flexibility, MW	3830	0	4983	0	5099	0	5835	0
Network flexibility, MW	167	0	181	0	182	0	181	0
Specific flexibility, MW	514	0	518	0	377	0	379	0
Total	4511	0	5682	0	5658	0	6395	0

table 44 Upward flexibility need – LTrSc realistic regime

	2028		2030		2033		2035	
	Need	Uncovered	Need	Uncovered	Need	Uncovered	Need	Uncovered
System flexibility, MW	3821	429	4838	484	5380	415	6644	536
Network flexibility, MW	30	30	42	42	77	77	108	108
Specific flexibility, MW	514	514	518	518	377	377	379	379
Total	4364	973	5398	1044	5834	869	7131	1023

table 45 Additional flexibility needs

Metai	2028	2030	2033	2035	Comment

To cover system flexibility	Additional short-term resources, MW	429,00	484,00	415,00	536,00	
	Additional short-term resources capacity, MW	982,00	1789,00	1414,00	848,00	
To cover network flexibility	Additional short-term resources, MW	30	42	77	108	
	Additional short-term resources capacity, MW					
To cover specific flexibility	Additional short-term resources, MW	514	518	377	379	
	Additional short-term resources capacity, MW	528	536	400	404	
Total			1044	869	1023	
To cover system flexibility	Long-term resources, MW	256,00	124,00	22,00	241,00	Covered by existing flexible power plants

According to the transmission system operator's assessment, all identified long-term flexibility resources can be covered by existing flexible power plants and are therefore not included in the total volume of additional resources.

table 46 Additional needs are evaluated from the perspective of BESS

	Metai	**2028**	**2030**	**2033**	**2035**
BESS	Additional short-term resources, MW	973	1044	869	1023
	Existing BESS power in the assessment, MW	1260	2115	2428	2652
	Total power, MW	**2233**	**3159**	**3297**	**3675**
	Additional short-term resources capacity, MW	1510	2325	1814	1252
	Existing BESS capacity in the assessment, MW	2903	5083	5881	6452

	Total capacity, MWh	4413	7408	7695	7704

9. Flexibility barriers and digitalization impact

This section summarizes the conclusions of the flexibility barriers and digitalization impact analysis. The analysis was carried out in accordance with points (c) and (d) of Article 19e(2) of the EMD and Article 15 of the FNA methodology, which require Member States to assess existing legal, regulatory and administrative barriers that hinder the participation of flexibility resources in energy markets.

A detailed analysis was prepared on the basis of the recommendations published by ACER on 19 March 2026 regarding the assessment of existing barriers. These recommendations provided the methodological foundation for a consistent and comparable identification and evaluation of barriers. The full description of the analysis, including detailed assessments and justifications, is presented in the annex to this report. This section summarizes only the key results and main conclusions relevant for further planning and decision-making.

9.1. Barriers, reduction resources and incentives

Lack of an appropriate legal framework ensuring market access for new and small market participants

EEĮ and the Law on Renewable Energy define the main roles and responsibilities in the sector. These laws, together with accompanying secondary legislation, regulate the rights of active consumers, aggregators, energy communities, and storage facility owners. In principle, all these market participants have the right to participate in all market segments; however, certain provisions of Lithuanian legislation require further clarification and refinement..

Assessment of concentration regulation: in the Lithuanian Electricity Sector Act, the definition of concentration—translated from Directive (EU) 2019/944—appears as “demand concentration”. This translation creates ambiguity: it is unclear whether concentration covers only consumption or also generation. Although the definition further specifies that electricity generation may be controlled, it remains uncertain whether concentration applies only to sites that have both consumption and generation, or whether standalone generation units may also participate. In addition, the term “consumer load” used in the directive is translated as “unsupplied electricity,” which gives the impression that concentration may cover only consumption reduction, but not consumption increase.

Regarding the ability of different market participants to participate directly in market segments: EEĮ and the Law on Renewable Energy grant storage facility owners, citizen energy communities, and renewable energy communities the right to participate in energy markets. Since the specific markets in which they may operate are not listed in the legislation, it can be assumed that all market segments are open to them.

Regarding active consumers, the Law on Electricity provides that they may sell the electricity they generate themselves, but the law does not specify whether they may do so directly. At present in Lithuania, active consumers do not participate directly in wholesale markets in practice – the electricity they generate is sold to their electricity supplier under a contractual arrangement. Regarding the ability to participate in providing services to system operators: The law states that these consumers may participate in flexibility services; however, in the Law on Electricity, flexibility services are defined as services procured only by the distribution system operator (while services procured by the transmission system operator are defined as balancing services and non-frequency-related ancillary services). Therefore, a direct interpretation of the law would imply that active consumers cannot participate in services provided by the transmission system operator In practice, this possibility is granted to them; however, to ensure legal clarity, the relevant definitions in the law should be refined

Lack of resources and incentives that promote the provision of flexibility

Lithuania has a high level of smart metering deployment: All 100% of customers connected to the transmission grid have smart meters installed, and in the distribution grid smart metering coverage reaches 68% of household customers and 96% of commercial customers. Customers equipped with smart meters can monitor their consumption and generation data through the operators' online portals. Customers connected to the distribution grid can access real-time data by installing a P1 interface, while third parties can access customer information via the DataHub portal.

All electricity suppliers serving more than 200,000 customers offer a variety of pricing plans – fixed, multi-time-zone, or dynamic plans linked to wholesale market prices. However, there are currently no specific data on how these plans are distributed among customers, meaning it is not possible to assess their uptake or distribution across the customer base.

Users of the distribution network can choose between a fixed tariff, a two-time-zone tariff, or a four-time-zone tariff (the latter available only to household customers). The TSO currently applies a fixed network tariff, but from 2027 it plans to introduce a dynamic network tariff linked to the wholesale electricity price. It should be noted that feeding electricity into the grid is not subject to charges in either the distribution or transmission network. In addition, electricity storage facilities connected to the transmission grid are exempt from paying the transmission tariff for the electricity they consume.

In summary, one key barrier is identified in this category – the limited application of dynamic tariffs. However, this situation is expected to change in the near term: the TSO has concrete plans to introduce a dynamic tariff, and the DSO is currently assessing and analyzing the possibilities for its implementation.

Restrictive requirements for providing balancing services

The TSO procures balancing capacity and energy exclusively through market-based mechanisms. All balancing products are subject to prequalification: reserve-providing groups are permitted to deliver FCR, aFRR and mFRR services. Any combination of electricity generation, demand and storage units located within the same reserve-providing group may participate in balancing services. The average duration of the prequalification procedure for service providers is approximately four weeks from the approval of the application.

Two potential barriers have been identified: the minimum bid size (1 MW) and the symmetry requirement for FCR services. However, there are no plans to change these requirements. Smaller-capacity units can participate in balancing services through concentration, and the 1 MW threshold corresponds to the standard applied across European countries – lowering it only in Lithuania would be impractical, as such bids would not be able to compete in the common market. Similarly, the symmetry principle for FCR services is widely applied throughout Europe, meaning that changing it at the national level would not be justified.

Restrictive requirements for providing congestion-management services

At present, neither the TSO nor the DSO procure congestion-management services through market-based mechanisms.

The TSO are solving congestion problems through other means: These include changes in network topology and restrictions on generation and consumption. In practice, generation curtailment is applied most frequently, and only to those units that directly influence the specific congestion. The main reason why market-based services are not used is linked to Lithuania's current connection policy: renewable energy sources may be connected to the transmission grid up to 300% of the capacity available at the same connection point, shared between wind, solar and storage technologies. For example, with 100 MW of available capacity, up to 100 MW of wind, 100 MW of solar, and 100 MW of storage can be connected at the same point. This policy enables the connection of more units, but it also means that connected facilities may be subject to curtailment.

The DSO has defined a congestion-management service, but in practice it is not applied, as no need for such services has been identified so far. In addition, the distribution system operator is currently implementing a flexible connection scheme, which will allow customers to receive a lower, time-varying capacity until network reinforcement works are completed. A variable-capacity connection mechanism has also been introduced, under which storage units exceeding 1 MW may opt for a variable-capacity mode and manage their consumption and generation based on real-time substation load data.

In summary, both the TSO and the DSO have effective congestion-management resources in place, primarily grounded in connection-policy instruments. However, market-based congestion-management services are currently not procured in Lithuania, meaning it is worth considering resources that would encourage system operators to purchase such services.

Complex, lengthy and discriminatory administrative requirements

Based on ACER guidelines, the assessment of administrative requirements did not reveal any significant barriers. Devices connecting to both the transmission and distribution grids can complete all necessary procedures online, most of them are carried out in parallel, and each step has clearly defined deadlines.

Nevertheless, two additional potential barriers have been identified:

Balancing-service providers must obtain permits and licenses from the National Energy Regulatory Council before qualification tests. The duration of this process can represent a significant share of the overall preparation time, and for foreign participants unfamiliar with Lithuanian administrative procedures, it may pose additional challenges.

Another potential barrier relates to the procurement of flexibility services. Although DSO do not currently provide flexibility services, if they did, the procurement would be carried out through the national public procurement system. This platform ensures transparency, but is not suitable for frequent or small-scale procurement - complex registration and documentation procedures can discourage smaller participants and create a practical barrier to market entry even in cases where the technical requirements are not restrictive.

Lack of regulatory incentives for system operators to consider alternatives for network expansion

Lithuanian legal regulation does not provide equal conditions for TSO and DSO to purchase flexibility services..

Under the EEĮ, flexibility services can only be purchased by DSO - they can be used for congestion management as an alternative to network reconstruction, and this option must be assessed in the distribution network operator's 10-year network development plan. Meanwhile, TSO can purchase balancing services and additional services not related to frequency regulation. Although the law obliges the transmission system operator to reduce capacity constraints on the network, no clear market mechanism has been established to achieve this goal.. Both TSO and DSO costs for the aforementioned services can be included in network tariffs.

In addition to financial incentives, Lithuania operates a Pilot Energy Innovation Environment, which provides an opportunity to test innovative products and services under the supervision of the National Energy Regulatory Council. However, this environment has significant limitations: exemptions can only apply to sub-statutory legislation, which narrows the scope of innovations that can be tested.. In the event of an unsuccessful pilot, the associated costs may not be included in the tariff, which may result in network operators avoiding using this scheme due to financial risks.. An additional burden arises from the need to coordinate all pilot-phase activities with the National Energy Regulatory Council throughout the entire testing period, which introduces administrative complexity.

9.2. Digitalization

In Lithuania, most electricity consumers have smart meters with 15-minute accuracy, which ensure accurate measurement and accounting of services.. However, access to data is delayed in certain cases: at both the TSO and DSO levels, consumers receive metering data by default the next day.. TSO customers can receive real-time data by directly integrating into TSO systems. Meanwhile, DSO customer data can be accessed by third parties via the DataHub portal, but if customers want to receive real-time data they must install P1 interfaces.. Digital tools for network monitoring and flexibility forecasting, especially at the DSO level, are still being developed, and limited monitoring of low and medium voltage networks makes it difficult to identify flexibility needs.

In terms of service procurement, TSO procure balancing services through a single digital platform (LMMS), but other non-frequency regulation services are still procured through auctions without specialized platforms. DSO would procure flexibility services through a central procurement portal, which ensures transparency but requires manual procedures.

Currently, Lithuania lacks a unified platform that would provide both network operators with information about flexibility service providers and their qualifications.

10. The expected development of flexible resources

Developer connection indications provide the most up-to-date view of developer activity in constructing battery energy storage systems. Based on the available data, it is identified that by the end of 2028, 3,12 GW of storage systems will be installed in Lithuania's power system. Considering the additional flexibility need projected under the LTrSc scenario and identified in the analysis, a 2,23 GW BESS requirement is expected. Given the current developer connection indications, all flexibility needs will be covered by newly built battery energy storage systems.

In the period between 2030 and 2035, considering the battery energy storage system capacities planned for installation under letters of intent, it is projected that all flexibility needs will be fully covered.

The summary is presented in the graph below.

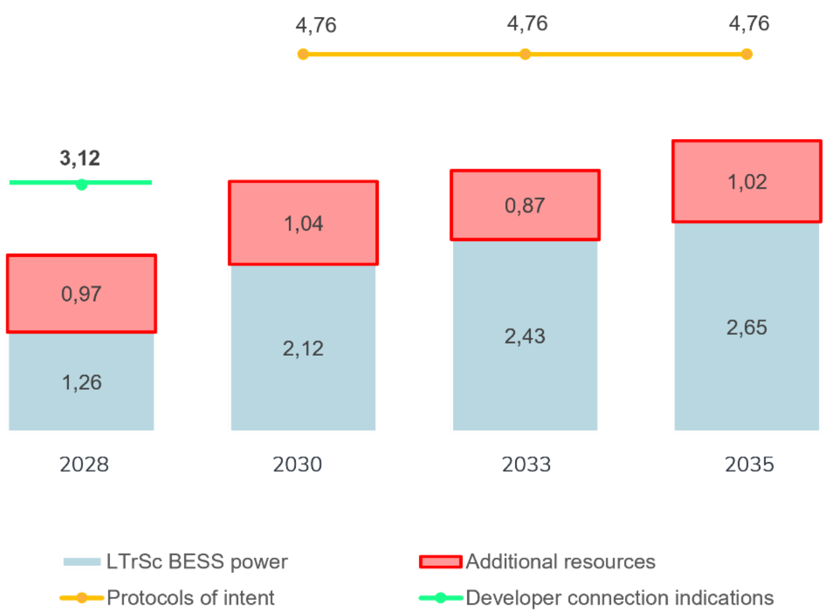


Figure 198 Projected BESS capacity and the flexibility need identified in the flexibility assessment

11. Conclusions

11.1. Main results of the analysis

- Based on the assessment data, a significant increase in demand is observed in the distribution network due to heating electrification and electric vehicle charging. Upward flexibility needs arise between 17:00 and 20:00, varies between 30 and 108 MW.
- Downward flexibility needs are formed downwards by solar power plants up to 100 kW, between 11:00 and 14:00. The demand for flexibility varies between 167 and 182 MW.
- No additional flexibility needs related to RES curtailment were identified. The share of RES curtailment in total RES generation in the target year does not reach 2% (limit <5%).
- The assessment of ramping needs showed that in all analyzed scenarios and periods, no downward uncovered need was identified – maximum values in every case remained at 0 MW. This indicates that throughout all modelled periods, the system had sufficient flexibility capacity to reduce generation or increase consumption during moments of declining residual demand
- The assessment of ramping needs in the upward show that in the basic scenario, the maximum uncovered upward need is 0 MW in all target years, meaning the system has sufficient flexibility reserves even during the most challenging hours. No flexibility needs were identified
- In the basic regime, no short-term flexibility needs were identified in either the upward or downward direction
- Short-term downward flexibility needs were not identified under the realistic regime. The system's flexibility, ensured through the ability to reduce RES generation, is sufficient to maintain operational balance
- Short-term flexibility analysis identified additional upward-direction needs under the realistic regime. Reduced cross-border capacity and limited P2X utilization reveal cases where the system lacks sufficient flexibility. The following additional flexibility volumes are required to ensure adequate system flexibility:

table 47 Short-term flexibility needs

Year	2028	2030	2033	2035
Additional short-term resources, MW	429,00	484,00	415,00	536,00
Additional short-term resources capacity, MWh	982,00	1789,00	1414,00	848,00
Long-term resources, MW	256,00	124,00	22,00	241,00

- A long-duration flexibility need (>4 h) was identified, ranging from 22 MW to 256 MW, which can be fully covered by the existing flexible gas-fired power plants.
- The analysis of uncontrolled solar generation management needs showed that, when considering consumption alone, not all of the energy produced by non-dispatchable solar units can be absorbed; additional flexibility resources will be required . The analysis results indicate a market potential to utilize surplus generation from uncontrolled solar PP plants through flexibility resources. If the energy is not absorbed in the local market, it is exported. In the critical scenario, if no resources are available to manage the surplus energy, curtailment of prosumers would be carried out. The potential amount of surplus energy is:

table 48 The energy surplus generated by uncontrollable Solar PP

	LTrSc			
	2028	2030	2033	2035

Surplus energy, GWh	390	406	272	405

- The analysis identified an additional amount of flexible resources, considering the needs for FCR, isolated-operation reserve service, fast frequency response service, and the Lithuania–Poland cross-border capacity-increase service
- he total amount of additional resources required to ensure system flexibility under the Slower Transformation Scenario in the realistic regime is defined in the table below:

table 49 Additional resource needs LTrSc realistic regime

Type	Year	2028		2030		2033		2035	
		Power, MW	Capacity, MWh	Power, MW	Capacity, MWh	Power, MW	Capacity, MWh	Power, MW	Capacity, MWh
System needs	Short-term	429	982	484	1789	415	1414	536	848
Network needs	DSO needs	30	-	42	-	77	-	108	-
Specific needs	FCR	14	28	18	36	23	46	25	50
	IZDR	200	200	200	200	0	0	0	0
	GAGAP	154	154	154	154	354	354	354	354
	LT-PL	146	146	146	146	0	0	0	0
	Total	**973**	**1519**	**1044**	**2325**	**869**	**1814**	**1023**	**1252**

- Considering the developers' activity in deploying battery energy storage systems, it is highly likely that all additional flexibility needs will be covered.

11.2. Summary of additional flexibility needs identified by the FNA

A summary of the results is provided in Annex 1.

11.3. Next steps

Following the results obtained in the report, the Transmission System Operator and the Distribution Network Operator will implement the flexibility-market development plan. The purpose of the plan is to define the necessary flexibility services in the Lithuanian power system to ensure RES integration and system flexibility. The preparation of the plan will be closely coordinated with all market participants. A public consultation with market participants is planned to start by the end of 2026 Q4.

The report results will also be used to provide recommendations on non-fossil fuel targets. The non-fossil fuel targets are approved in accordance with the provisions of the EMD network code

It is planned that the results of this report will be included in future network development plan