# Moldova Energy Independence and Resilience (MEIR)

***Support in modelling and analysis of Moldova's power system for the integration of renewables and energy storage solutions***

## Modelling and Analysis of Moldova's Power System for the integration of Renewables and Energy Storage Solutions

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***Date: 7 April 2025***

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# Modelling and Analysis of Moldova's Power System for the integration of Renewables and Energy Storage Solutions

## Task 1: Stocktaking and data inputs report

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## ACRONYMS/ABBREVIATIONS

| Acronyms/Abbreviations | Definition |
|---|---|
| BESS | Battery Energy Storage Systems |
| CHP | Combined Heat and Power |
| EnCS | Energy Community Secretariat |
| ENTSO-E | European Network of Transmission System Operators for Electricity |
| ERAA | Electricity Regional Adequacy Assessment |
| EU | European Union |
| HPP | Hydro Power Plant |
| HPS | Hydro Pump Storage |
| IPS | Integrated Power System |
| kW | Kilowatt |
| MESA | Moldova Energy Security Activity |
| MW | Megawatt |
| MWh | Megawatt Hour |
| MoE | Ministry of Energy |
| MGRES | Moldavskaya GRES |
| NECP | National Energy and Climate Plan |
| NTC | Net Transfer Capacity |
| RES | Renewable Energy Resources |
| RoR | Run of River |
| TYNDP | Ten Year Network Development Plan |
| TPP | Thermal Power Plant |
| PV | Photovoltaic |
| RES | Renewable Energy Resource |
| TSO | Transmission System Operator |
| USAID | United States Agency for International Development |
| UPS | Unified Power System |
| WPP | Wind Power Plant |

# 1.0 INTRODUCTION

## 1.1 UNDERSTANDING ENERGY COMMUNITY REQUIREMENTS

### 1.1.1 Background

This report comprises the first deliverable of PN07-2025 service agreement for supporting the Moldovan government in fulfilling certain commitments, stemming from the Letter of Intent signed on 4 February 2025[1] between the Government of the Republic of Moldova and the European Commission. The agreement underscores Moldova's determination to fast-track renewable energy deployment and the integration of energy storage solutions. This initiative is supported by the Energy Community Secretariat, an international organization dedicated to harmonizing the European Union (EU) internal energy market with its neighboring regions, thereby extending European energy market rules and principles to the Energy Community Contracting Parties.

The Letter of Intent foresees the development of an action plan aimed at organizing a series of new renewable energy and energy storage auctions throughout 2025, specifying the allocated capacities for each auction, with a view to fast-track renewable energy deployment by the end of 2026. With the European Commission providing technical support, the Government of Moldova has been tasked with defining the capacity allocations for each auction. As part of this effort and in continuation of the work carried out under the U.S. Agency for International Development (USAID) Moldova Energy Security Activity (MESA), the current assignment will leverage an exhaustive review of existing studies and analyses, including the latest version of the Moldovan National Energy and Climate Plan (NECP) and the draft Ten-Year Network Development Plan (TYNDP), to thoroughly capture the current policy environment and strategic priorities for enhancing energy security and sustainability.

Furthermore, the scope of work under this assignment emphasizes the integration of regional data, drawing on insights from neighbouring Ukraine and Romania, and the leveraging of pertinent information from the European Network of Transmission System Operators for Electricity (ENTSO-E). By combining these diverse data sources, the project seeks to develop a robust understanding of the technical and regulatory challenges facing Moldova's energy sector. This understanding will encompass critical assessments of generation capacity, demand projections and load factors for renewables (for both solar PV and wind), as well as the verification of must-run constraints for thermal power plants. This approach not only ensures alignment with EU energy market principles but also positions Moldova to effectively navigate the complexities of its energy transition.

[1] Letter of Intent between the Government of the Republic of Moldova and the European Commission - European Commission

### 1.1.2 Objectives and scope of the project

The Energy Community Secretariat (EnCS) has appointed Tetra Tech to deliver the project Modelling and Analysis of Moldova's Power System for the Integration of Renewables and Energy Storage Solutions.

The project requires the following services:

- Review and Update Existing Data (**Task 1**): Undertake a critical review of key documents, including the latest NECP and the draft TYNDP, while incorporating regional insights from Ukraine, Romania and ENTSO-E. This review will establish the current policy framework and inform capacity and demand projections.

- Power System Model Update (**Task 2**): Enhance the existing power system model to reflect new data, accurately capture must-run constraints for thermal power plants, and integrate real-time measurements from wind and solar capacities.

- Evaluate Renewable Integration (**Task 3**): Conduct iterative market simulations using PLEXOS software to assess the capacity for additional renewable sources, including solar and wind, while ensuring system stability through controlled spillage thresholds.

- Define Battery Energy Storage Parameters (**Task 4**): Determine the minimum technical specifications required for battery energy storage systems (BESS) to support grid stability and effectively manage renewable variability.

Tetra Tech will develop each task and present it as a separate deliverable. This document represents the first deliverable, addressing **Task 1 – Stocktaking and Data Inputs Report**.

## 2.0 OUR METHODOLOGY AND APPROACH

The objective of this Task 1 report is to comprehensively review and enhance existing input data for Moldova's power system, ensuring alignment with the latest available information. This effort also leverages insights from Romania, Ukraine and ENTSO-E to facilitate a data-driven, regionally aligned analysis.

Several key elements comprised the methodology:

- **Comprehensive Data and Policy Review**: A detailed examination of existing studies, policy frameworks and strategic plans, including the NECP and Moldelectrica's connection offers. The review also incorporated insights from the TYNDP, ensuring consistency with Moldova's long-term energy planning objectives.
- **Regional Market Assessment**: Tetra Tech undertook a broader market analysis by integrating data from neighboring Romania and Ukraine. This included an evaluation of cross-border transfer capacities and system interdependencies, particularly focusing on Moldova's strong electricity connection with Ukraine. Given the impact of the ongoing conflict, we placed specific attention on assessing the extent of damage to Ukraine's generation capacity and the implications for regional energy flows. We modelled the Romanian power system using ENTSO-E Electricity Regional Adequacy Assessment (ERAA) 2024 study input data, aligning with European market standards.

- **Economic and Market Modelling**: We analysed fuel price trends and carbon dioxide ($CO_2$) emission tax forecasts using ENTSO-E reports, including ERAA 2024 and TYNDP 2024 projections. These analyses facilitated the estimation of wholesale electricity prices across relevant ENTSO-E markets, providing insights into cost drivers and economic conditions shaping Moldova's energy landscape.
- **Evaluation of Thermal Power Plant Constraints**: The team conducted a technical review of Moldova's thermal generation fleet, focusing on must-run constraints. This assessment was critical for understanding the operational limitations of conventional generation assets and their role in renewable energy resource (RES) integration.

Notably, the ERAA 2024 data used in this project has been sourced from EnCS. As no publicly available data was accessible at the time of preparing this document, the latest ERAA 2024 input data was used to ensure an accurate representation of Romania's power system in PLEXOS. Furthermore, updated fuel prices and $CO_2$ tax projections impact all three countries, contributing to a more realistic assessment of marginal production costs in future.

To ensure consistency and accuracy in the modelling process, we processed data using statistical and analytical tools to clean, standardize and structure the datasets for seamless integration into the PLEXOS modelling software. This included aligning all time-series data, categorizing relevant parameters and ensuring compatibility with regional datasets. Additionally, the team maintained comprehensive documentation throughout the process to enhance transparency, reproducibility, and traceability of all data modifications and assumptions.

Beyond these objectives, we assessed the quality and reliability of the collected data to identify any gaps or inconsistencies that could impact modelling accuracy. This step is essential for ensuring the robustness and credibility of subsequent analyses. Additionally, we incorporated the latest available data, including recent developments in renewable energy projects, energy storage technologies and policy changes in Moldova, Romania and Ukraine. This process involved direct engagement with local stakeholders and energy authorities to obtain the most up-to-date and relevant information.

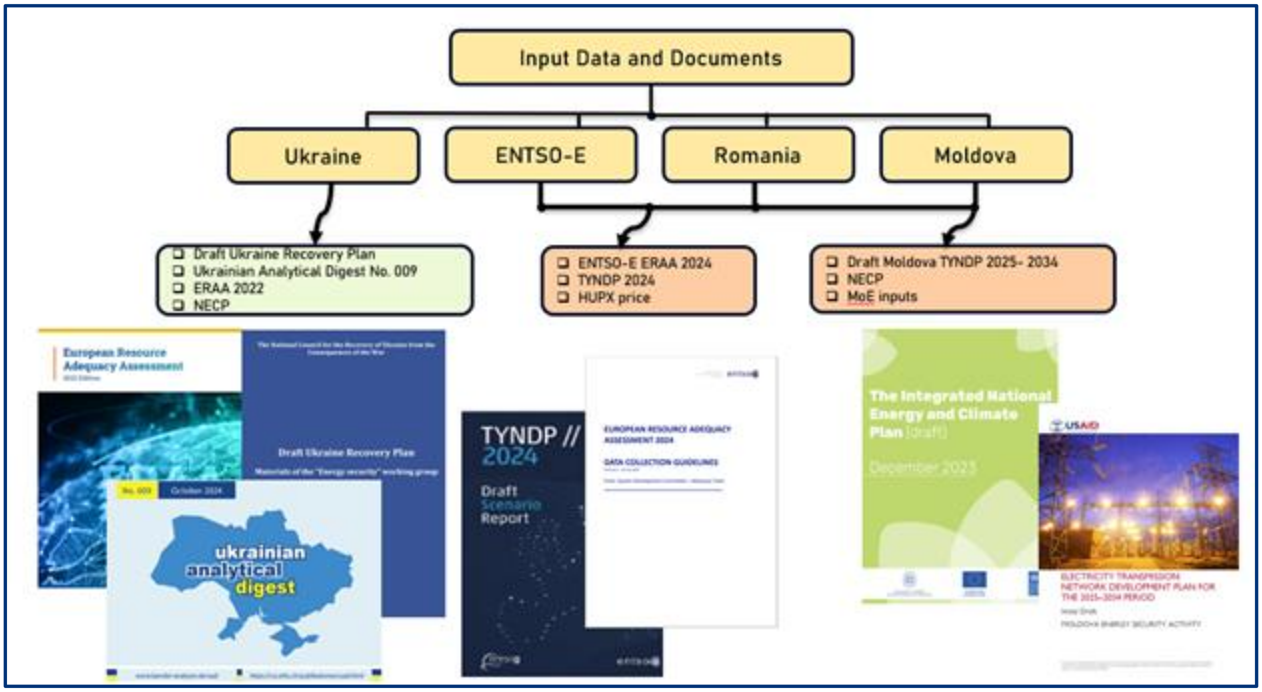


Figure 2-1 Key input documents for the execution of Task 1

## 2.1 REVISION OF EXISTING STUDIES AND POLICIES

As a first step in conducting Task 1, we undertook a systematic analysis of essential studies and policy documents that underpin Moldova's energy strategy. This review examined the latest NECP[2] and the draft TYNDP. Through this process, we gained a detailed understanding of the current policy and regulatory framework, particularly as it pertains to the NECP's renewable energy targets, and identified the strategic priorities and challenges facing Moldova's energy sector.

Importantly, the insights obtained from this analysis serve as critical input data for the PLEXOS model, which will underpin the capacity and demand projections in Task 2. Additionally, regional insights from neighbouring countries were integrated to ensure a comprehensive perspective.

For Ukraine, the review drew on the Recovery Plan,[3] relevant Green Deal documents,[4] ERAA 2022[5] and the latest version of the NECP,[6] offering a clear view of both the current state and future outlook of its power system. For

[2] Moldova National Energy and Climate Plan (draft), December 2023
[3] Draft Ukraine Recovery Plan (Materials for the "Energy Security" working group"), July 2022
[4] Ukrainian Analytical Digest No.009, October 2024
[5] European Resource Adequacy Assessment, 2022 Edition
[6] National Energy and Climate Plan of Ukraine 2025-2030, July 2024

Romania, key documents such as the ENTSO-E ERAA 2024,[7] price profiles from TYNDP 2024,[8] and Hungarian Energy Exchange (HUPX) pricing data[9] were utilized to capture essential trends across the broader ENTSO-E region.

To ensure accurate inputs, information regarding operation of the gas-fired power plant Moldavskaya GRES (MGRES) in Transnistria and the state of cross-border capacities was collected from reliable sources, including the Ministry of Energy (MoE). This integrated approach strengthens our analysis and lays a robust foundation for subsequent modelling and strategic planning. All information used in this process is detailed in the following subchapters, with the results presented in Appendix A.

### 2.1.1 GENERATION CAPACITY AND DEMAND PROJECTIONS

The evaluation of generation capacity and demand projections for Moldova, Ukraine and Romania is essential for identifying the potential for renewable energy integration and understanding regional energy dynamics. The analysis encompasses the existing power generation infrastructure, availability/operational status, and contributions of individual power plants to the national grids, while also examining future demand trajectories based on economic growth, demographic trends and energy efficiency policies.

Additionally, the study incorporates an assessment of solar and wind capacity factors, which were key determinants of renewable energy availability. By evaluating cross-border transfer capacities, the analysis ensures that regional interconnections are accurately represented, providing a foundation for effective capacity planning and market integration.

**Moldova**

For Moldova, capacity and demand projections were derived from the draft NECP, the draft National TYNDP for 2025-2034 period and relevant information from the Ministry of Energy. The assessment includes:

- **Annual demand forecast and hourly load profile:** Derived from the draft of Moldovan TYNDP[3] and adjusted to reflect the 2026–2030 period, ensuring alignment with future planning horizons.
- **Generation capacity assessment:** Analysed based on the installed capacity, operational constraints and anticipated developments in the energy sector.

In the Appendix. The data on installed capacities for solar and wind energy are as of the end of February 2025, which is a reference point for this analysis. Task 3 will include calculations for additional capacity that could be connected to the Moldovan power system in the future.

**Romania**

Romania's capacity and demand projections were sourced from the ENTSO-E ERAA 2024 study, ensuring consistency with European market forecasts. Annual demand forecast and hourly load profile were derived

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[7] European Resource Adequacy assessment, 2024-Preliminary Input data
[8] TYNDP 2024
[9] Hupx Spot Annual Report 2024

from the ERAA 2024 study database, providing a standardized dataset for regional modelling. Expected generation capacity used was also taken from the ERAA 2024 study.

**Ukraine**

The generation capacity and demand projections for Ukraine incorporate data from the Recovery Plan, the NECP, the Green Deal policy framework and ENTSO-E's ERAA 2022. Given the ongoing geopolitical situation, adjustments were made to reflect the impact of occupied and damaged infrastructure on generation capacity and demand. Key considerations included:

**Destroyed and occupied generation capacities:** The assessment of unavailable capacity was based on destruction and occupation percentages provided in the Recovery Plan.

- We use two main figures to illustrate our approach. Figure 2 below illustrates the distribution of operational power generation capacity from the Recovery Plan, detailing installed capacity by technology, percentage of destroyed capacity, capacities in occupied territories and available capacities.

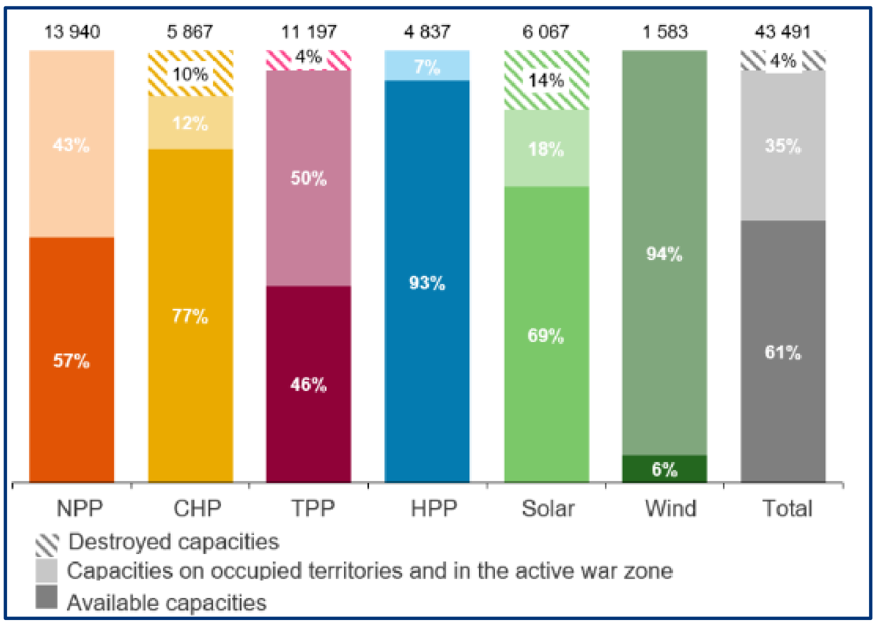


Figure 2-2 Operational status of Ukraine's generation fleet in May 2024

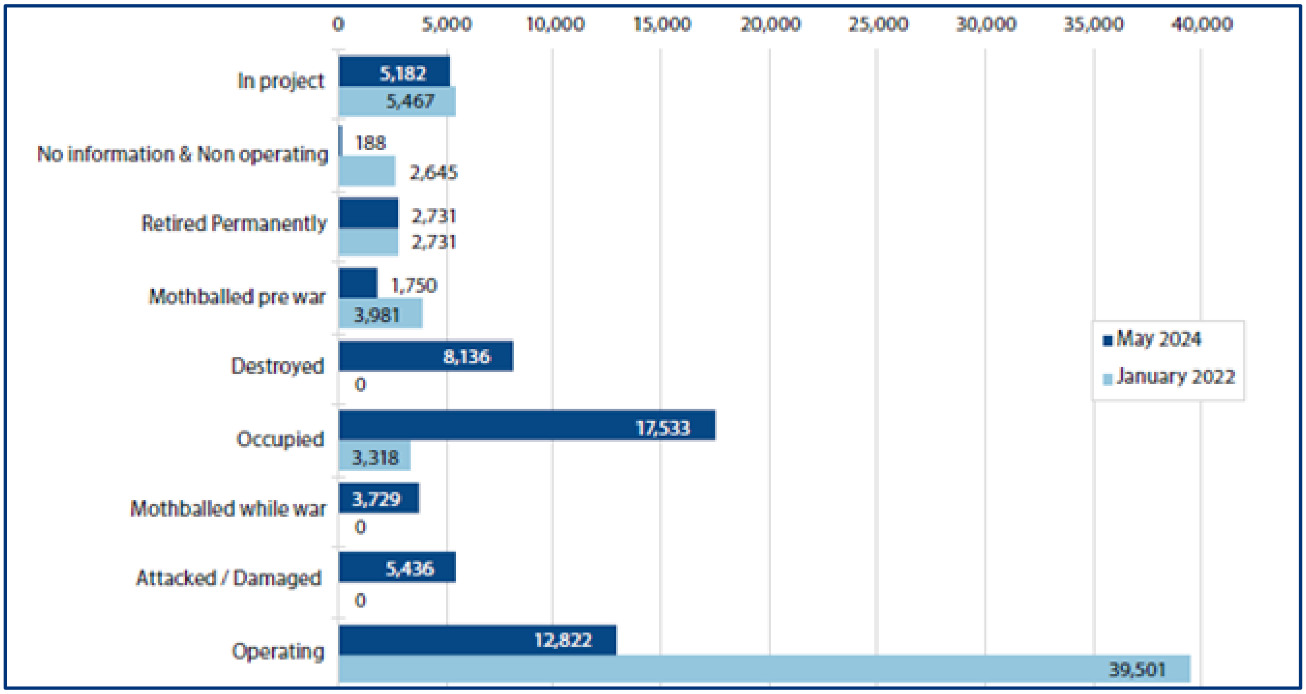


Figure 2-3 Distribution of operational capacity of power generation (MW)

- The percentages of destroyed and occupied capacities from the Recovery Plan (as shown in **Error! Reference source not found.**) were used to recalculate the total unavailable capacity in Ukraine. As the July 2022 edition of the Recovery Plan reported lower values for unavailable capacity, we used more recent data from the Ukrainian Analytic Digest No. 009, published on the Green Deal platform, which provides significantly higher estimates of destruction and occupation. The destroyed and occupied capacities are shown in Figure 2-3.

**Capacity availability by power plant type:** The assessment of capacity availability was based on the planned capacities for thermal power plants (TPP), combined heat and power (CHP) units and hydroelectric power stations (HPS) outlined in the Recovery Plan, as well as for wind power plants (WPP), solar photovoltaics (PV), biomass, biogas, geothermal, and small hydropower plants specified in the Ukrainian NECP. This approach ensured realistic projections of the system's future capabilities. Regarding WPP, PV and HPP, data on installed capacities from the NECP document as of the end of 2021 were used (see Figure 2-4). The unavailable capacity values for these technologies were then recalculated based on the percentages from the Recovery Plan and Green Deal platform information. Finally, the projected capacities for WPP, PV and HPP for the 2026-2030 period (see Figure 2-5), as outlined in the NECP, were adjusted to account for the unavailable capacities.

- **Annual consumption forecast:** Derived from the Recovery Plan and reduced by 35% to account for the impact of occupied territories, following consultant-driven assumptions.
- **Hourly load profile:** Historical consumption patterns from ERAA 2022 were rescaled for future years to reflect projected recovery and system adaptation.

| Electricity generation by source | 2020 | | 2021 | |
|---|---|---|---|---|
| | MW | GW • h | MW | GW • h |
| **Hydropower plants:** | **4 824** | **6 002** | **4 850** | **9 135** |
| capacity over 10MW | 4 708 | 5 793 | 4 730 | 8 868 |
| capacity up to 10 MW | 116 | 209 | 120 | 267 |
| **Geothermal energy** | | | | |
| **Photoelectric plants, including** | **6 872** | **5 969** | **7 586** | **7 581** |
| producers | 6 093 | 5 236 | 6 381 | 6 430 |
| consumers, including energy cooperatives and private households | 779 | 733 | 1 205 | 1 151 |
| **Wind power plants, including** | **1 314** | **3 271** | **1 535** | **3 804** |
| onshore | 1 314 | 3 271 | 1 535 | 3 804 |
| marine (offshore) | | | | |
| **Biomass, including** | **210** | **755** | **274** | **941** |
| solid | 107 | 284 | 150 | 388 |
| biogas | 103 | 471 | 124 | 553 |
| biomethane on installations that use natural gas | | | | |
| **Highly flexible installations with possibility of fast launch** | | | | |
| **Energy storage installations** | | | **1** | |
| **Total (from RES)** | **13,220** | **15,997** | **14,245** | **21,461** |

Figure 2-4 Historical RES and BESS capacity according to the NECP

| Electricity generation by source | 2026 | | 2027 | | 2028 | | 2029 | | 2030 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | MW | GW • h | MW | GW • h | MW | GW • h | MW | GW • h | MW | GW • h |
| **Hydropower plants:** | **4 898** | **7 010** | **4 910** | **7 035** | **4 922** | **7 060** | **4 928** | **7 085** | **4 935** | **7 100** |
| capacity over 10MW | 4 770 | 6 760 | 4 780 | 6 780 | 4 790 | 6 800 | 4 795 | 6 820 | 4 800 | 6 830 |
| capacity up to 10 MW | 128 | 250 | 130 | 255 | 132 | 260 | 133 | 265 | 135 | 270 |
| **Geothermal energy** | **8** | **40** | **12** | **60** | **16** | **80** | **18** | **90** | **20** | **100** |
| **Photoelectric plants, including** | **9 550** | **11,600** | **9 821** | **12,000** | **10,725** | **13,200** | **11 122** | **13,800** | **11,788** | **14,700** |
| producers | 6984 | 8520 | 7 179 | 8 830 | 7 435 | 9 220 | 7 688 | 9 610 | 7 976 | 10,050 |
| consumers, including energy cooperatives and private households | 2567 | 3 080 | 2 642 | 3 170 | 3 289 | 3 980 | 3434 | 4 190 | 3 811 | 4 650 |
| **Wind power plants, including** | **4 120** | **11,200 –** | **4 470** | **12,400 –** | **4 820** | **13,500 –** | **5 120** | **14,500 –** | **5 420** | **15,800 –** |
| onshore | 4120 | 11,200 | 4470 | 12,400 | 4720 | 13 150 | 4 920 | 13,799 | 5 120 | 14,749 |
| marine (offshore) | | | | | 100 | 350 | 200 | 701 | 300 | 1 051 |
| **Biomass, including** | **934** | **3860** | **1074** | **4540** | **1209** | **5200** | **1344** | **5870** | **1448** | **6530** |
| solid | 609 | 2310 | 717 | 2740 | 831 | 3200 | 951 | 3680 | 1030 | 4120 |
| biogas | 324 | 1450 | 357 | 1600 | 378 | 1700 | 393 | 1790 | 418 | 1910 |
| biomethane on installations that use natural gas | | 100 | | 200 | | 300 | | 400 | | 500 |
| **Highly flexible installations with possibility of fast launch** | **850** | | **950** | | **1050** | | **1150** | | **1250** | |
| **Energy storage installations** | **440** | | **490** | | **540** | | **590** | | **640** | |
| **Total (from RES)** | **19,510** | **33,710** | **20,287** | **36,035** | **21,692** | **39,040** | **22,533** | **41,345** | **23,611** | **44,230** |

Figure 2-5 Estimated RES and BESS capacity for period 2026-2030 according to the NECP

### 2.1.2 SOLAR AND WIND CAPACITY FACTORS

Capacity (or load, as it is commonly called) factors quantify the ratio of actual energy output from PV and wind capacities relative to their maximum potential output over a given period. This metric is essential for assessing historical performance and projecting future renewable energy production in Moldova. The solar and wind load factors have been derived using a multisource approach to ensure both accuracy and consistency across borders.

**<u>Moldova</u>**

This dataset utilizes hourly renewable energy generation capacity factors. It covers actual metered data for the largest solar and wind power installations in Moldova. The hourly load factor for solar capacities is derived from measured data in 2024 from the Airini Family plant, which has an installed capacity of 250 kilowatts (kW).

Similarly, the hourly load factor for wind capacities is based on measurements from the S.R.L. Deoner-Exim plant, which has an installed capacity of 1,800 kW. Both datasets, provided by the RES forecasting service, accurately capture the operational performance of existing renewable installations and serve as a critical historical benchmark.

**Romania**

Onshore and offshore wind and solar power plant hourly factors represent the historical availability of the resource (wind and irradiation) needed to produce electricity. These data are crucial to accurately represent the RES generation pattern.

**Ukraine**

The RES capacity factors for Ukraine come from the ENTSO-E ERAA 2022 dataset, as the ERAA 2024 dataset does not include Ukraine. Onshore and offshore wind and solar power plant hourly factors represent the historical availability of the resource (wind and irradiation) needed to produce electricity. These data are crucial to accurately represent the RES generation pattern.

The team used the harmonized load factors to project future renewable energy outputs, which are essential for scenario planning and for guiding strategic energy policy development.

### 2.1.3 CROSS-BORDER CAPACITIES

Cross-border transmission capacities play a crucial role in ensuring the efficient operation of interconnected power systems, facilitating electricity trade, and enhancing regional energy security. These capacities define the maximum allowable power transfer between neighbouring transmission systems while maintaining system stability and reliability. The following sections present an overview of the planned net transfer capacity (NTC) values, the methodology used for their determination, and implications of these values for the regional power network.

**Moldova**

According to the information from the draft National TYNDP 2025-2034, Moldova's power system operated until 2022 as part of the Integrated Power System (IPS)/Unified Power System (UPS), which was not synchronized with the ENTSO-E system of continental Europe. As of February 24, 2022, the power systems of Ukraine and Moldova were disconnected from the IPS/UPS system. On March 16, 2022, the continental European electricity transmission system operators (TSOs) carried out the emergency synchronization of the ENTSO-E European Continental Energy System with the Moldovan and Ukrainian power systems (Figure 2-6).

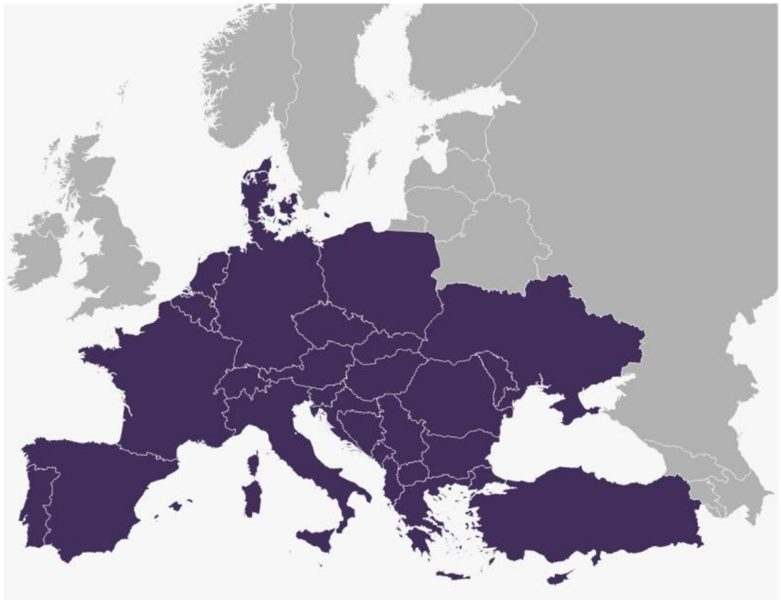

Figure 2-6 Continental Europe synchronous area

Currently, the Moldovan grid experiences limitations in terms of stability and efficiency. ENTSO-E membership would bring about a higher level of operational reliability and efficiency due to stricter compliance with modern grid standards. This includes better frequency control, reduced transmission losses and more robust infrastructure. Being part of ENTSOE would allow Moldova to implement advanced grid technologies and benefit from best practices and cooperative measures with other Member States. Access to the interconnections between Moldova and Ukraine related to the import of electricity from Ukraine is managed by NEK Ukrenergo (the Ukrainian TSO), while access to the interconnections between Moldova and Romania related to imports from Romania is managed by Transelectrica (the Romanian TSO).

The TYNDP considered the current context, including the following specific risks/uncertainties in the energy sector:

- Damage to certain segments of the Ukrainian electricity transmission infrastructure is a risk posed by the war in Ukraine. Such damage, if it occurs, would create considerable risk to ensuring continuous electricity supply to Moldova.
- Moldova is highly dependent on electricity supplied by MGRES, which has an important role in ensuring the stable functioning of the Moldovan electricity system.
- Secure, competitive and reasonably priced (alternative) sources of electricity imports are limited, as imports from Ukraine have been weak following Russia's bombing of its energy infrastructure, and imports of electricity from Romania are limited due to insufficient interconnection with the Romanian electricity system (both technical and commercial risks).

Table 2-1 presents the NTC values for Moldova used in the draft National TYNDP 2025-2034.

**Table 2-1 Net Transfer Capacity (NTC) for Moldova**

| Net Transfer Capacity (NTC) in MW | | | | | | |
|---|---|---|---|---|---|---|
| Direction | Base Scenario | | Moderate Scenario | | Ambitious Scenario | |
| | 2028 | 2033 | 2028 | 2033 | 2028 | 2033 |
| To Romania | 300 | 750 | 300 | 600 | 300 | 750 |
| From Romania | 450 | 750 | 450 | 600 | 450 | 750 |
| To Ukraine | 600 | 600 | 600 | 600 | 600 | 600 |
| From Ukraine | 600 | 600 | 600 | 600 | 600 | 600 |

Based on the aforementioned information and presented data, the MoE has provided the NTC values planned for Moldova's borders with Romania and Ukraine for the purposes of this study. Since these NTC values are lower for the border with Romania compared to the values from the TYNDP, the lower values have been considered for this study to provide a more realistic assessment.

The left and right bank of the Nistru River are modelled as separate nodes connected with transmission capacity that allows only limited power flows (50 MW) from left to right bank during night hours. This ensures that the left bank is supplied solely by generation capacities located in the left bank and allows power flows to the right bank in situations when the load is low and below the minimum stable capacity of one MGRES unit.

**Romania**

We evaluated interconnections with Moldova and Ukraine to capture system interdependencies and cross-border electricity flows. The values for the Romania-Moldova (RO-MD) border were obtained from the MoE, ensuring the use of the most relevant and up-to-date data for this specific interconnection. Meanwhile, the values for Romania's other borders with Hungary, Bulgaria and Serbia were sourced from the ERAA 2024 report, providing a comprehensive and standardized dataset for cross-border electricity transfer analysis.

**Ukraine**

The source for Ukraine's cross-border capacities was the Green Deal Ukraine website. The report used for NTC values is titled 'Six options to boost power transfers from Continental Europe to Ukraine'[10]. Specifically, the values for its borders with Romania (RO), Hungary (HU), Poland (PL) and Slovakia (SK) were considered to ensure consistency with the latest available data and to align with regional energy transition objectives. The NECP provides projected NTC potential values for Ukraine, which will depend on the development of generation capacities as well as the growth in electricity demand. For this reason, the values from this document were used, as they are lower than the values provided in the NECP. For the Ukraine-Moldova (UA-MD) border, data from the MoE were used to ensure the most accurate and up-to-date values for cross-border electricity capacities. The NTC values are shown in the Table 2-9 in Appendix A.

[10] Six options to boost power transfers from Continental Europe to Ukraine, December 2024

### 2.1.4 FUEL PRICES AND EMISSION FORECASTS

The project analysed fuel prices and $CO_2$ emission price forecasts based on publicly available information. This analysis included approximating wholesale electricity prices in the ENTSO-E countries relevant to this study, which provided insights into market conditions and economic viability.

By examining trends in fuel prices, we gained a better understanding of the cost dynamics that influenced energy generation and the transition to renewables. This included assessing the impact of global and regional fuel supply and demand, geopolitical factors, and policy-driven shifts toward cleaner energy sources.

Furthermore, $CO_2$ emission price forecasts were critical for assessing the financial implications of carbon pricing on thermal generation and the overall energy market. These forecasts helped estimate the competitiveness of fossil fuel-based generation compared with low-carbon alternatives, considering potential regulatory changes and market-based mechanisms such as the EU Emissions Trading System (EU ETS).

Additionally, the study evaluated the interaction between fuel and emission prices and the influence on cross-border electricity flows, generation dispatch and long-term investment strategies in the power sector. This comprehensive approach ensured a more accurate representation of future energy market dynamics, supporting informed decision-making for policymakers and industry stakeholders.

For this analysis, data from ENTSO-E ERAA 2024 were used, ensuring alignment with the latest European energy market assessments and scenario-based projections. Fuel prices and $CO_2$ emission taxes, along with variable and start-up costs, are the main input data to calculate the marginal cost of generation for power plants.

### 2.1.5 VERIFICATION OF MUST-RUN CONSTRAINTS

A critical component of this task is the verification of must-run constraints for Moldovan thermal power plants. Understanding these operational limitations is essential for evaluating the role of thermal generation in the context of increasing renewable energy sources. We investigated the technical and regulatory requirements that dictate when and how these plants must operate, particularly in relation to grid stability and reliability. This analysis helps identify potential bottlenecks in the power system and inform strategies for optimizing the integration of renewables. Must-run constraints are mostly related to production of heat energy in winter (CHP 2 and CHP Nord). The proposed must-run constraints for thermal power plants in Moldova have been confirmed by the MoE. Must-run constraints are shown in Table 2-12 and in Table 2-13.

### 2.1.6 OTHER ENTSO-E COUNTRIES

The ENTSO-E perimeter was approximated by the forecasted wholesale hourly electricity price profile for 2030 in Hungary from the ENTSO-E TYNDP 2024 and average wholesale price in Hungary in 2024 gathered from the HUPX website. The NTC values between ENTSO-E and Ukraine and Romania were capped by factors that considered price fluctuations (higher price than average indicates lack of energy in ENTSO-E; lower price than average indicates saturation in ENTSO-E).

## 2.2 CONCLUSION

Task 1 plays a crucial role in ensuring that the modelling and analysis of Moldova’s power system are based on accurate, comprehensive and up-to-date data. This task incorporates insights from Moldova's neighbouring countries, namely Romania and Ukraine, and other ENTSO-E members, providing a broader understanding of regional energy integration dynamics. By leveraging this regional perspective, Task 1 enhances the overall analysis of Moldova's position within the European energy system.

Moldova’s MoE provided the NTC values for Moldova’s interconnections with Romania and Ukraine for the purposes of this study. These values are crucial for system planning, market integration and future infrastructure development, as they incorporate technical, economic and regulatory factors to optimize utilization and address potential constraints and risks. A significant challenge encountered during this task was the alignment of disparate data sources for Ukraine. Data had to be extracted from multiple documents that varied in format and detail, which required careful reconciliation to ensure consistency. Additionally, projecting this information into future years was necessary to fill critical gaps and to provide all the necessary parameters for accurate simulation in PLEXOS.

The findings of this task are thoroughly elaborated in Appendix A and will serve as essential input to the PLEXOS modelling tool. The outcomes will provide a foundation for subsequent modelling efforts, particularly in evaluating the potential for renewable energy development within Moldova’s transmission network. These insights will contribute to the improvement of future energy strategies, supporting decision-making processes aimed at building a sustainable energy future for the country.

# APPENDIX A: INPUT DATA FOR MODELLING

**Table 2-2 Generation capacity – Moldova**

| Available Capacity per unit_PLEXOS (MW) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Moldova | | | | | | | |
| **Unit** | **Zone** | **Fuel Type** | **2026** | **2027** | **2028** | **2029** | **2030** |
| TPP MGRES G4 | left | gas conventional old 1 | 100 | 100 | 100 | 100 | 100 |
| TPP MGRES G5 | left | gas conventional old 1 | 100 | 100 | 100 | 100 | 100 |
| TPP MGRES G7 | left | gas conventional old 1 | 200 | 200 | 200 | 200 | 200 |
| TPP MGRES G8 | left | gas conventional old 1 | 200 | 200 | 200 | 200 | 200 |
| TPP MGRES G9 | left | gas conventional old 1 | 210 | 210 | 210 | 210 | 210 |
| TPP MGRES G10 | left | gas conventional old 1 | 210 | 210 | 210 | 210 | 210 |
| TPP MGRES G11 | left | gas conventional old 1 | 250 | 250 | 250 | 250 | 250 |
| TPP MGRES G12 | left | gas conventional old 1 | 250 | 250 | 250 | 250 | 250 |
| CHP 1 (G1) | right | gas CCGT old 2 | 12 | 12 | 12 | 0 | 0 |
| CHP 1 (G2) | right | gas CCGT old 2 | 12 | 12 | 12 | 0 | 0 |
| CHP 1 (G4) | right | gas CCGT old 2 | 5 | 5 | 5 | 0 | 0 |
| CHP 1 (G5) | right | gas CCGT old 2 | 27 | 27 | 27 | 0 | 0 |
| CHP 1 (G6) | right | gas CCGT present 1 (ICE) | 0 | 0 | 0 | 11 | 11 |
| CHP 1 (G7) | right | gas CCGT present 1 (ICE) | 0 | 0 | 0 | 11 | 11 |
| CHP West G1 | right | gas CCGT present 1 (ICE) | 0 | 0 | 0 | 11 | 11 |
| CHP West G2 | right | gas CCGT present 1 (ICE) | 0 | 0 | 0 | 11 | 11 |
| CHP West G3 | right | gas CCGT present 1 (ICE) | 0 | 0 | 0 | 11 | 11 |
| CHP 2 (G1) | right | gas CCGT old 2 | 98 | 98 | 98 | 98 | 98 |
| CHP 2 (G2) | right | gas CCGT present 1 | 80 | 80 | 80 | 80 | 80 |
| CHP 2 (G3) | right | gas CCGT old 2 | 80 | 80 | 80 | 80 | 80 |
| CHP North G1 | right | gas CCGT old 2 | 12 | 12 | 12 | 12 | 12 |
| CHP North G2 | right | gas CCGT old 2 | 12 | 12 | 12 | 12 | 12 |
| CHP North G3 | right | gas CCGT present 1 | 3.354 | 3.354 | 3.354 | 3.354 | 3.354 |
| CHP North G4 | right | gas CCGT present 1 | 3.354 | 3.354 | 3.354 | 3.354 | 3.354 |
| CHP North G5 | right | gas CCGT present 1 | 3.354 | 3.354 | 3.354 | 3.354 | 3.354 |
| CHP North G6 | right | gas CCGT present 1 | 3.354 | 3.354 | 3.354 | 3.354 | 3.354 |
| New Gas PP* | right | gas CCGT present 1 (ICE) | 0 | 0 | 125 | 125 | 125 |
| **Total Thermal Cap.** | | | **1871** | **1871** | **1996** | **1995** | **1995** |

| Available Capacity per unit_PLEXOS (MW) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Dubasari HPP | left | RoR | 48 | 48 | 48 | 48 | 48 |
| Costesti HPP | right | RoR | 16 | 16 | 16 | 16 | 16 |
| **Total Hydro Cap.** | | | **64** | **64** | **64** | **64** | **64** |
| Wind** | right | wind | 189 | 189 | 189 | 189 | 189 |
| Solar PV** | right | solar | 433 | 433 | 433 | 433 | 433 |
| Waste | | waste | 0 | 0 | 0 | 0 | 30 |
| BioPP | right | biogas | 7 | 7 | 7 | 7 | 10 |
| **Total RES Cap.** | | | **629** | **629** | **629** | **629** | **662** |
| **Total Moldova** | | | **2564** | **2564** | **2689** | **2689** | **2721** |

*This gas PP will be included only in one scenario for 2030
**This represent the recent data on installed capacities end of February (150 MW are from prosumers)

**Table 2-3 Generation capacity – Romania**

| Available generation capacity per type in Romania (MW) | | | | | |
|---|---|---|---|---|---|
| **Country** | **Romania** | | | | |
| **Year** | **2026** | **2027** | **2028** | **2029** | **2030** |
| Nuclear RO00 | 1300 | 650 | 650 | 650 | 1739 |
| Coal RO00 | 130 | 130 | 130 | 130 | 130 |
| Gas conventional RO00 | 2631 | 2631 | 2631 | 2631 | 2631 |
| Gas CCGT new RO00 | 2109 | 3421 | 3421 | 3421 | 3421 |
| **Total Thermal Cap.** | **3672** | **3672** | **6255** | **6255** | **7344** |
| RoR RO00 | 3305 | 3337 | 3337 | 3364 | 3364 |
| Reservoir RO00 | 2391 | 2281 | 2281 | 2403 | 2403 |
| Pump Storage Open Loop RO00 | 810 | 810 | 810 | 810 | 810 |
| **Total Hydro Cap.** | **6352** | **6352** | **6695** | **6695** | **6738** |
| Wind onshore RO00 | 5099 | 5299 | 5499 | 5699 | 5999 |
| Wind offshore RO00 | 0 | 0 | 0 | 0 | 1000 |
| Solar RO00 | 5100 | 5900 | 6700 | 7500 | 8300 |
| Other RES RO00 | 128 | 128 | 130 | 132 | 137 |
| **Total RES Cap.** | **10327** | **11327** | **12329** | **13331** | **15436** |
| **Total Romania** | **23003** | **24586** | **25588** | **26740** | **29934** |

**Table 2-4 BESS capacities – Romania**

| BESS | | | |
|---|---|---|---|
| **Country** | **Romania** | | |
| **Year** | **Installed capacity (MW)** | **Capacity (MWh)** | **Efficiency (%)** |
| 2026 | 270 | 540 | 85 |
| 2027 | 300 | 600 | 85 |

| | | | |
|---|---|---|---|
| 2028 | 330 | 660 | 85 |
| 2029 | 360 | 720 | 85 |
| 2030 | 400 | 800 | 85 |

**Table 2-5 Electrolyser and P2H capacities – Romania**

| Electrolyser & P2H | | |
|---|---|---|
| **Country** | **Romania** | |
| **Year** | **Installed capacity (MW)** | **Efficiency (%)** |
| 2026 | 100 | 80 |
| 2027 | 200 | 80 |
| 2028 | 300 | 80 |
| 2029 | 400 | 80 |
| 2030 | 500 | 80 |

**Table 2-6 Generation capacity – Ukraine**

| Available capacity per type in Ukraine (MW) | | | | | |
|---|---|---|---|---|---|
| **Country** | **Ukraine** | | | | |
| **Year** | **2026** | **2027** | **2028** | **2029** | **2030** |
| Nuclear UA | 7800 | 7800 | 7800 | 7800 | 7800 |
| Coal UA | 2376 | 2376 | 2376 | 2376 | 0 |
| Gas CCGT new UA | 3230 | 3230 | 3230 | 3230 | 6130 |
| Gas new OCGT UA | 600 | 600 | 600 | 600 | 1000 |
| Gas UA | 2608 | 2608 | 2608 | 2608 | 508 |
| Gas CCGT new biogas UA | 290 | 290 | 290 | 290 | 340 |
| **Total Thermal Cap.** | **16904** | **16904** | **16904** | **16904** | **15778** |
| Reservoir UA | 4288 | 4298 | 4308 | 4313 | 4318 |
| Pump Storage UA | 1990 | 1990 | 1990 | 1990 | 1990 |
| Small hydro UA | 128 | 130 | 132 | 133 | 135 |
| **Total Hydro Cap.** | **6406** | **6418** | **6430** | **6436** | **6443** |
| Wind UA | 1990 | 2340 | 2690 | 2990 | 3290 |
| Solar UA | 6079 | 6350 | 7254 | 7651 | 8317 |
| Biogas UA | 324 | 357 | 378 | 393 | 418 |
| Biomass UA | 609 | 717 | 831 | 951 | 1030 |
| Geothermal UA | 8 | 12 | 16 | 18 | 20 |
| **Total RES Cap.** | **9010** | **9776** | **11169** | **12003** | **13075** |
| **Total Ukraine** | **32320** | **33098** | **34503** | **35343** | **35297** |

**Table 2-7 BESS capacities – Ukraine**

| BESS | | | |
|---|---|---|---|
| Country | Ukraine | | |
| Year | Installed capacity (MW) | Capacity (MWh) | Efficiency (%) |
| 2026 | 440 | 440 | 85 |
| 2027 | 490 | 490 | 85 |
| 2028 | 540 | 540 | 85 |
| 2029 | 590 | 590 | 85 |
| 2030 | 640 | 640 | 85 |

**Table 2-8 Demand projections: Annual demand forecast**

| Annual demand forecast (TWh) | | | | |
|---|---|---|---|---|
| Year | Moldova right | Moldova left | Romania | Ukraine |
| 2026 | 4.486 | 1.863 | 54.952 | 101.725 |
| 2027 | 4.56 | 1.917 | 56.298 | 102.05 |
| 2028 | 4.648 | 1.968 | 57.537 | 102.7 |
| 2029 | 4.735 | 2.024 | 58.803 | 103.675 |
| 2030 | 4.822 | 2.081 | 59.979 | 104.65 |

**Table 2-9 Cross-border capacities**

| Moldova | | NTC (MW) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | | 2026 | | 2027 | | 2028 | | 2029 | | 2030 | |
| Country A | Country B | A->B | B->A | A->B | B->A | A->B | B->A | A->B | B->A | A->B | B->A |
| MD | RO | 82 | 255 | 82 | 255 | 500 | 500 | 500 | 500 | 500 | 500 |
| MD | UA | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| **Romania** | | **NTC (MW)** | | | | | | | | | |
| **Year** | | **2026** | | **2027** | | **2028** | | **2029** | | **2030** | |
| **Country A** | **Country B** | **A->B** | **B->A** | **A->B** | **B->A** | **A->B** | **B->A** | **A->B** | **B->A** | **A->B** | **B->A** |
| RO | BG | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 | 2300 |
| RO | HU | 1400 | 1300 | 1400 | 1300 | 1400 | 1300 | 1400 | 1300 | 1400 | 1300 |
| RO | RS | 800 | 800 | 800 | 800 | 1300 | 1300 | 1300 | 1300 | 1300 | 1300 |
| RO | ENTSO-E | 4500 | 4400 | 4500 | 4400 | 5000 | 4900 | 5000 | 4900 | 5000 | 4900 |
| **Ukraine** | | **NTC (MW)** | | | | | | | | | |
| **Year** | | **2026** | | **2027** | | **2028** | | **2029** | | **2030** | |
| **Country A** | **Country B** | **A->B** | **B->A** | **A->B** | **B->A** | **A->B** | **B->A** | **A->B** | **B->A** | **A->B** | **B->A** |
| UA | ENTSO-E | 1492 | 1227 | 1492 | 1227 | 1492 | 1227 | 1492 | 1227 | 1492 | 1359 |
| UA | RO | 198 | 99 | 198 | 99 | 198 | 99 | 198 | 99 | 264 | 264 |

**Table 2-10 Fuel prices and emission factors per technology**

| | Fuel Price (€/GJ) | | | | | Emission factor (kg/GJ) |
|---|---|---|---|---|---|---|
| **Technology** | **2026** | **2027** | **2028** | **2029** | **2030** | **CO2** |
| Hard coal | 2.84 | 2.72 | 2.59 | 2.47 | 2.34 | 94 |
| Gas | 7.32 | 7.05 | 6.77 | 6.5 | 6.22 | 57 |
| Light oil | 15.13 | 15.43 | 15.73 | 16.03 | 16.33 | 78 |
| Heavy oil | 12.41 | 12.65 | 12.90 | 13.15 | 13.39 | 78 |
| Oil shale | 1.88 | 1.95 | 2.02 | 2.09 | 2.16 | 100 |
| Lignite | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 101 |
| Nuclear | 1.95 | 1.95 | 1.95 | 1.95 | 1.95 | 0 |
| Hydrogen | 22.74 | 22.46 | 22.18 | 22.82 | 23.47 | 0 |

**Table 2-11 CO2 emission price forecasts**

| CO2 Price (€/t$CO_2$) | | | | |
|---|---|---|---|---|
| **2026** | **2027** | **2028** | **2029** | **2030** |
| 72.68 | 88.6 | 104.52 | 120.44 | 136.36 |

**Table 2-12 Must-run constraints for generator units in Moldova (2026-2028)**

| Must-run constraints for generator units in Moldova (2026-2028) | | |
|---|---|---|
| **Number** | **Name** | **Note** |
| 1 | TPP MGRES G4 | Used just to supply load of the left bank |
| 2 | TPP MGRES G5 | |
| 3 | TPP MGRES G7 | |
| 4 | TPP MGRES G8 | |
| 5 | TPP MGRES G9 | |
| 6 | TPP MGRES G10 | |
| 7 | TPP MGRES G11 | |
| 8 | TPP MGRES G12 | |
| 9 | CHP 1 (G1) | Not operational during whole year |
| 10 | CHP 1 (G2) | Not operational during whole year |
| 11 | CHP 1 (G4) | Not operational during whole year |
| 12 | CHP 1 (G5) | Not operational during whole year |
| 13 | CHP 2 (G1) | Must run from December till February (90%), in March and November 50%. Not operational in period April-October |
| 14 | CHP 2 (G2) | Must run from December till February (90%), in March and November 50%. Not operational in period April-October |
| 15 | CHP 2 (G3) | Must run during Jan and Feb (50 MW). Not operational in period March-December. |
| 16 | CHP North G1 | Must run from December till February (90%), in March and November 40%. Not operational in period April-October |
| 17 | CHP North G2 | Must run from December till February (90%), in March and November 40%. Not operational in period April-October |
| 18 | CHP North G3 | Must run during winter hours. Not operational in period April-September |
| 19 | CHP North G4 | Must run during winter hours. Not operational in period April-September |
| 20 | CHP North G5 | Must run during winter hours. Not operational in period April-September |
| 21 | CHP North G6 | Must run during winter hours. Not operational in period April-September |

**Table 2-13 Must-run constraints for generator units in Moldova (2029-2030)**

| Must-run constraints for generator units in Moldova (2029-2030) | | |
|---|---|---|
| **Number** | **Name** | **Note** |
| 1 | TPP MGRES G4 | Used just to supply load of the left bank |
| 2 | TPP MGRES G5 | |
| 3 | TPP MGRES G7 | |
| 4 | TPP MGRES G8 | |
| 5 | TPP MGRES G9 | |
| 6 | TPP MGRES G10 | |
| 7 | TPP MGRES G11 | |
| 8 | TPP MGRES G12 | |
| 9 | CHP 1 (G6) | Must run for the whole year |
| 10 | CHP 1 (G7) | Must run for the whole year |
| 11 | CHP West G1 | Must run for the whole year |
| 12 | CHP West G2 | Must run for the whole year |
| 13 | CHP West G3 | Must run during winter hours. Available according to market condition in period April-September |
| 14 | CHP 2 (G1) | Must run during winter hours (80.24 MW). Not operational in period April-September |
| 15 | CHP 2 (G2) | Must run during winter hours (65.2 MW). Not operational in period April-September |
| 16 | CHP 2 (G3) | Must run during Jan and Feb (50 MW)<br>Not operational in period March-December. |
| 17 | CHP North G1 | Must run from December till February (90%), in March and November 40%. Not operational in period April-October |
| 18 | CHP North G2 | Must run from December till February (90%), in March and November 40%. Not operational in period April-October |
| 19 | CHP North G3 | Must run during winter hours. Not operational in period April-September |
| 20 | CHP North G4 | Must run during winter hours. Not operational in period April-September |
| 21 | CHP North G5 | Must run during winter hours. Not operational in period April-September |
| 22 | CHP North G6 | Must run during winter hours. Not operational in period April-September |
| 23 | New Gas PP* | Available throughout the year based on market conditions |
| * This gas PP will be included only in one scenario for 2030 | | |