

# MODELLING THE ELECTRICITY DEFICIT IN UKRAINE AND POTENTIAL POLICY RESPONSES

FOR THE PERIOD JUNE 2024 – MAY 2025

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## AIMS OF THE STUDY

**Analyse potential load shedding over the next 12 months and discuss the impact of possible mitigation strategies:**

1. Make European/G7+ policymakers and the public more aware of the scale of the current deficit and thus urge them to take further measures in the fields of security and, above all, energy.
2. Highlight that solutions are available, give a sense of the order of magnitude of the capacities needed and stimulate a discussion on prioritisation.
3. Contribute to the discussion on how to minimise the impact of blackouts on the Ukrainian population, in particular for the winter of 2024/25.



## DISCLAIMER

For data security reasons, we only provide results at lower temporal and technical resolution.

A more comprehensive annex will be provided bilaterally to legitimately interested parties upon request. Please contact the authors for further information.

**For further analyses, you can find a more detailed report at**

<https://greendealukraina.org/products/analytical-reports/modelling-the-electricity-deficit-in-ukraine-and-potential-policy-responses-for-the-period-june-2024-may-2025>

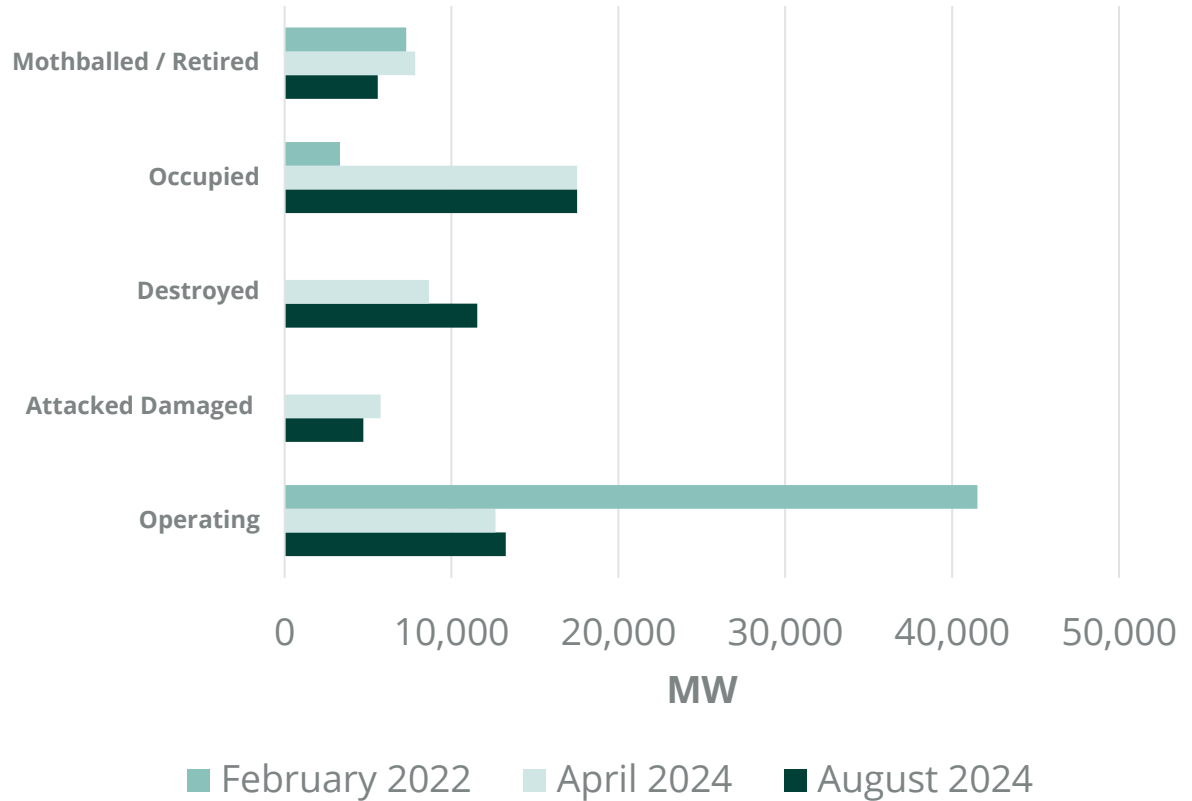


## CAPACITY COMPARISON 2022 VS. 2024

**Occupied:** ~ 18,000 MW

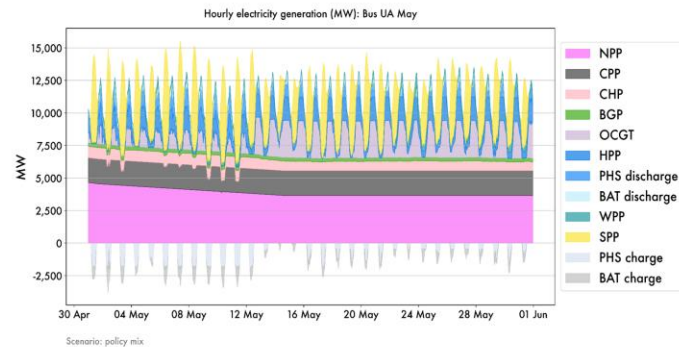
**Destroyed:** ~ 8,000 MW

**Attacked/damaged:** ~ 5,500 MW



## Tool used: Python for Power System Analysis (PyPSA)

- One of prominent electricity system model (e.g., used by Entso-E)
- **Open-source Python module** for analysing and simulating energy/electricity systems under various technical and economic conditions
- Optimisation (LP/MIP) based on **system-cost minimisation** under a multitude of constraints
- Concrete representation of an electricity system and consists of a specified grid topology, including the following components: **buses, generators, loads, lines, links, and storage units.**



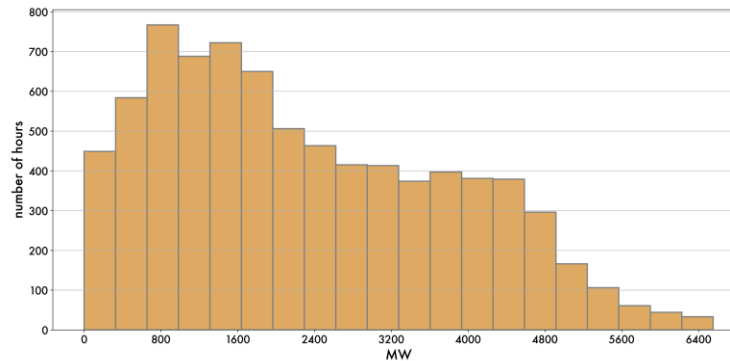
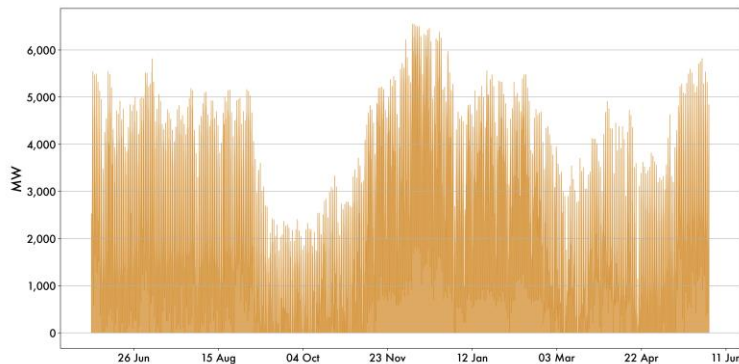
Example: Optimal dispatch



## SCENARIO: BASELINE

**Key assumption:** installed capacity consists of the confirmed, still-operating generators, no repairs and no additional policy

Load shedding of **18.3 TWh**  
– 18 % of annual demand



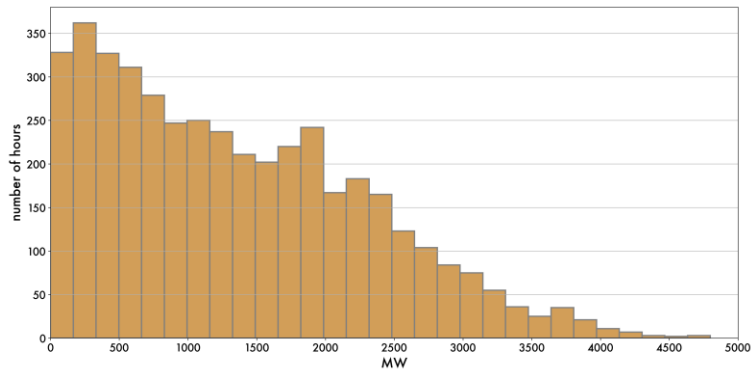
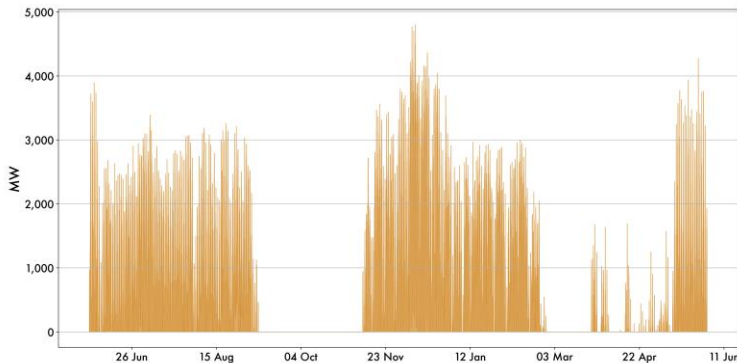
**7900 hours** with at least some load shedding  
– 90 % of the time



## SCENARIO: LIMITED REPAIRS

**Key assumption:** installed capacity consists of the confirmed, still-operating generators and 50 % repairs of attacked and (partially) damaged capacities

Load shedding of **5.8 TWh** –  
6 % of annual demand



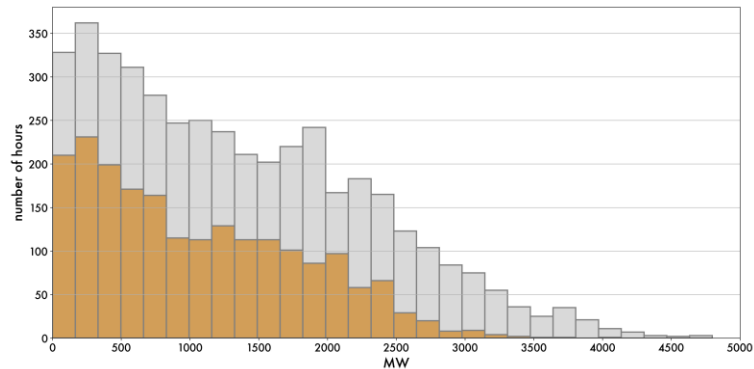
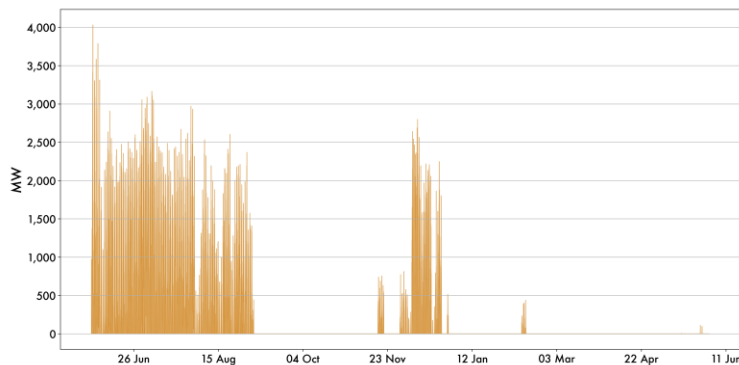
**4314 hours** with at least some load shedding  
– 49 % of the time



## SCENARIO: 1.5 GW ADDITIONAL OCGT

**Key assumption:** installations as in the scenario “limited repairs” + 1.5 GW OCGT

Load shedding of **2.1 TWh** –  
2 % of annual demand



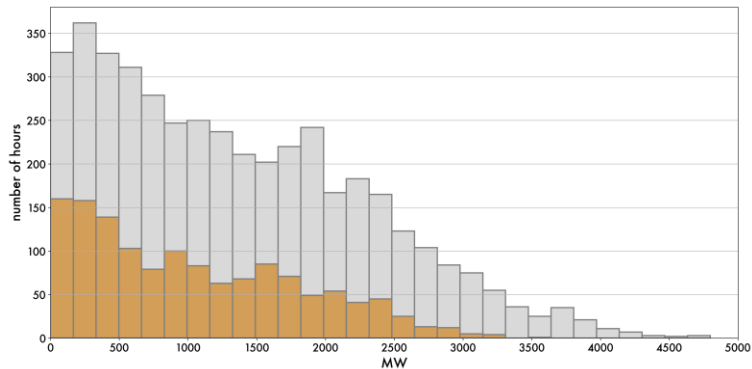
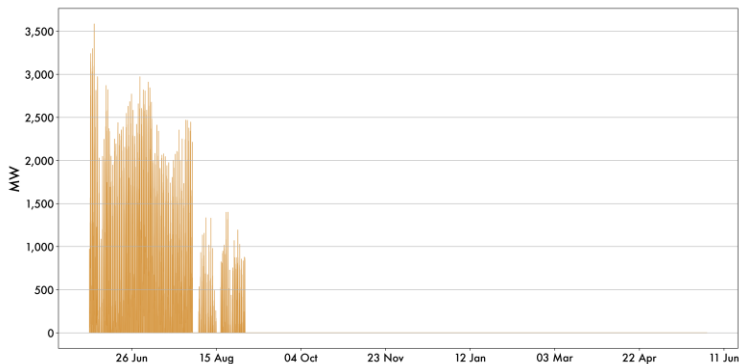
**2041 hours** with at least some load shedding  
– 23 % of the time



## SCENARIO: 3 GW ADDITIONAL OCGT

**Key assumption:** installations as in the scenario “limited repairs” + 3 GW OCGT

Load shedding of **1.4 TWh** –  
1 % of annual demand



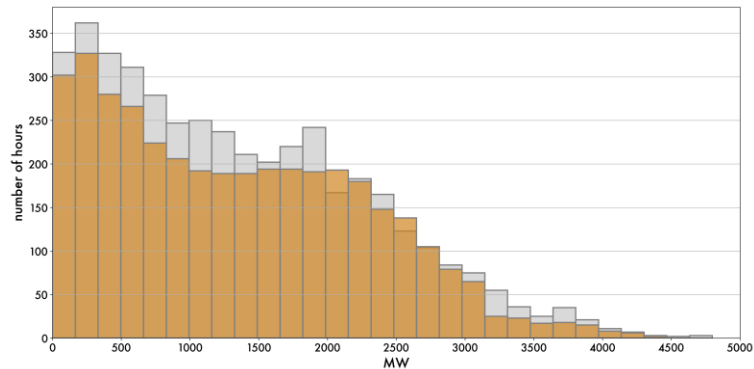
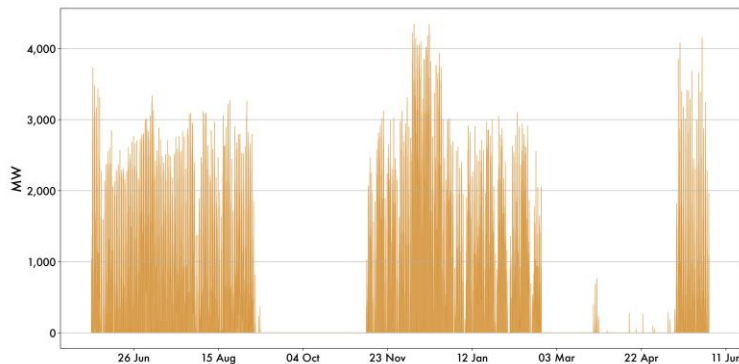
**1357 hours** with at least some load shedding  
– 15 % of the time



## SCENARIO: 1 GW ADDITIONAL WIND

**Key assumption:** installations as in the scenario “limited repairs” + 1 GW wind

Load shedding of **5.1 TWh** –  
5 % of annual demand



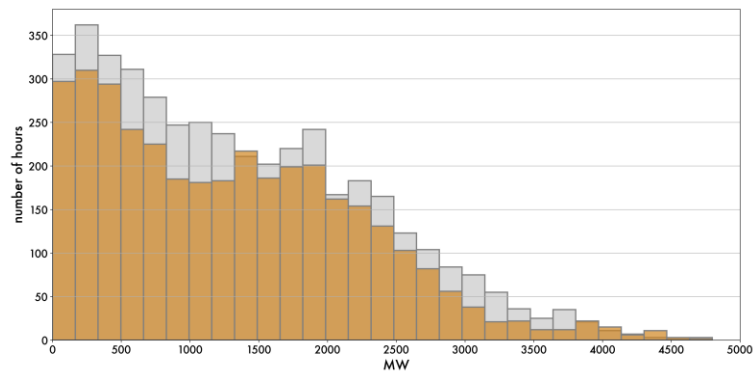
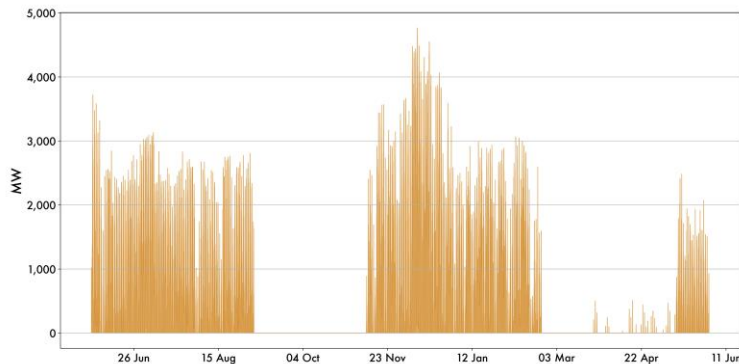
**3774 hours** with at least some load shedding  
– 43 % of the time



## SCENARIO: 5 GW ADDITIONAL PV

**Key assumption:** installations as in the scenario “limited repairs” + 5 GW PV

Load shedding of **4.7 TWh** –  
5 % of annual demand



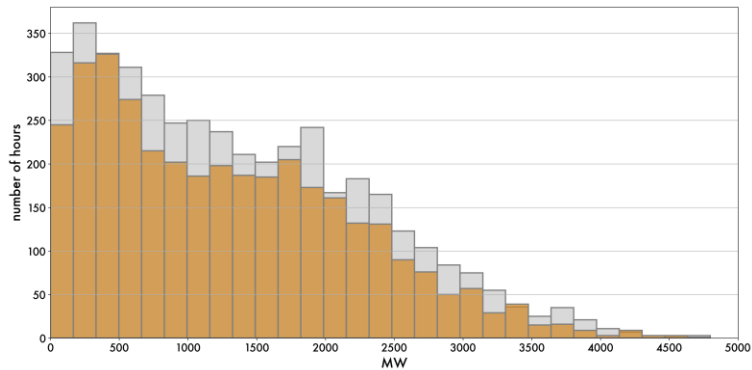
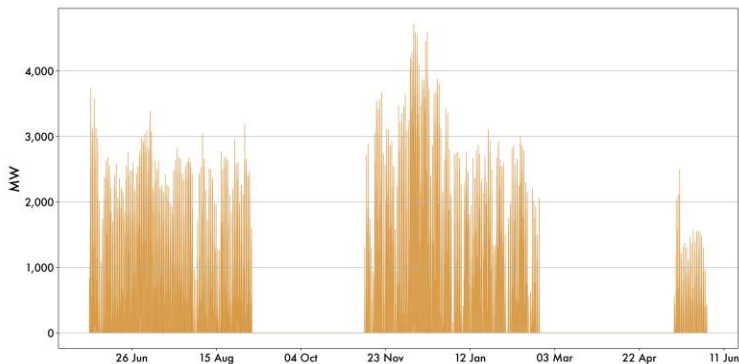
**3572 hours** with at least some load shedding  
– 41 % of the time



## SCENARIO: 5 GW ADDITIONAL PV & 2.5 GW ADDITIONAL BATTERIES

**Key assumption:** installations as in the scenario “limited repairs” + 5 GW PV & 2.5 GW batteries

Load shedding of **4.6 TWh** –  
5 % of annual demand



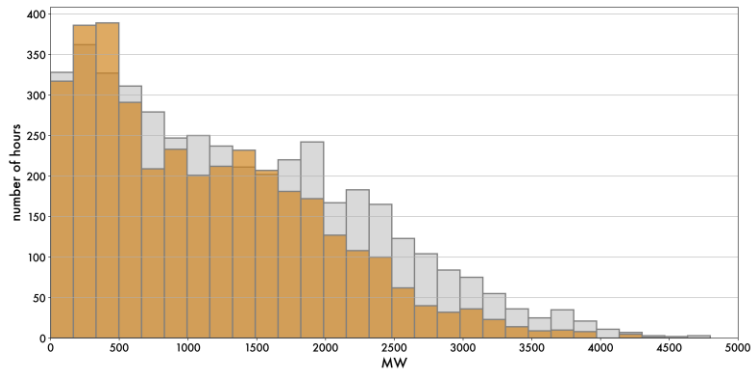
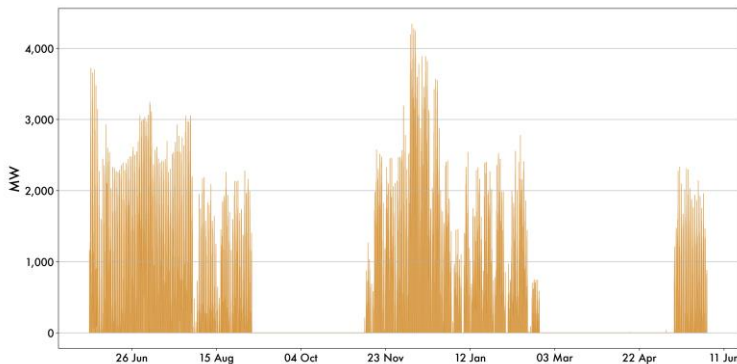
**3535 hours** with at least some load shedding  
– 40 % of the time



## SCENARIO: 0.5 GW ADDITIONAL IMPORTS

**Key assumption:** installations as in the scenario "limited repairs" + 0.5 GW imports

Load shedding of **4 TWh** –  
4 % of annual demand



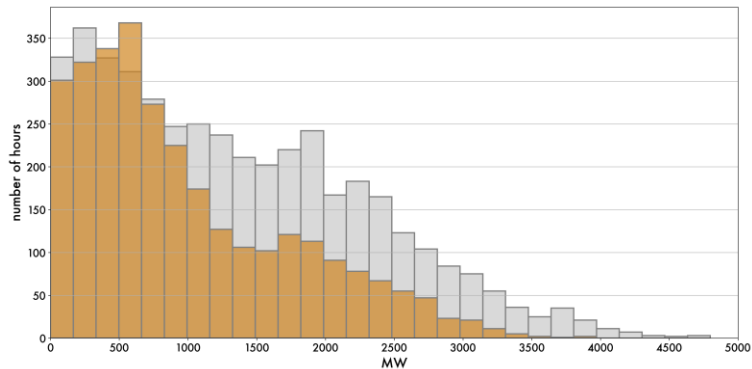
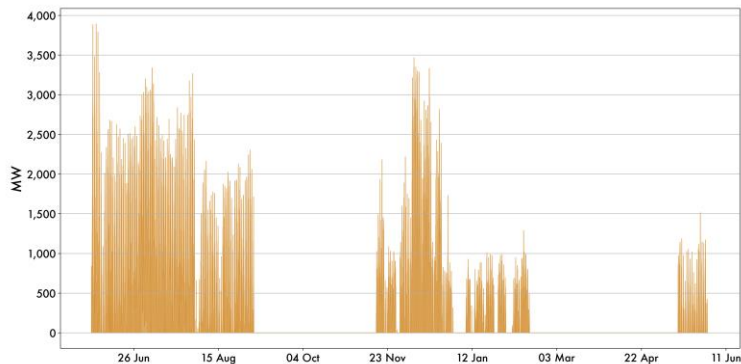
**3603 hours** with at least some load shedding  
– 41 % of the time



## SCENARIO: 1 GW ADDITIONAL IMPORTS

**Key assumption:** installations as in the scenario “limited repairs” + 1 GW imports

Load shedding of **2.9 TWh** –  
3 % of annual demand



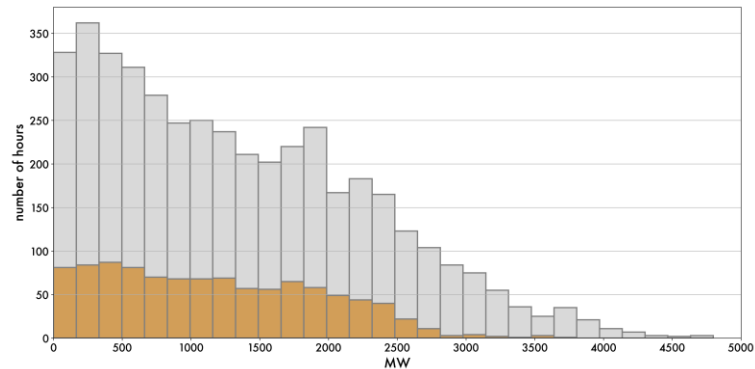
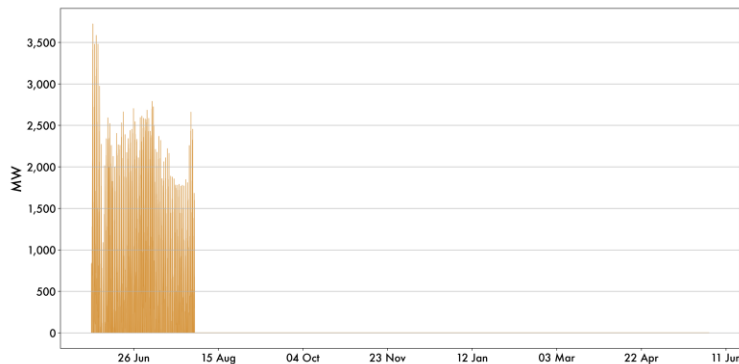
**2971 hours** with at least some load shedding –  
34 % of the time



## SCENARIO: ALL-OF-THE-ABOVE

**Key assumption:** installations as in the scenario “limited repairs” + 1.5 GW OCGT, 1 GW wind, 5 GW PV & 2.5 GW batteries and 1 GW imports

Load shedding of **1.4 TWh** –  
1 % of annual demand

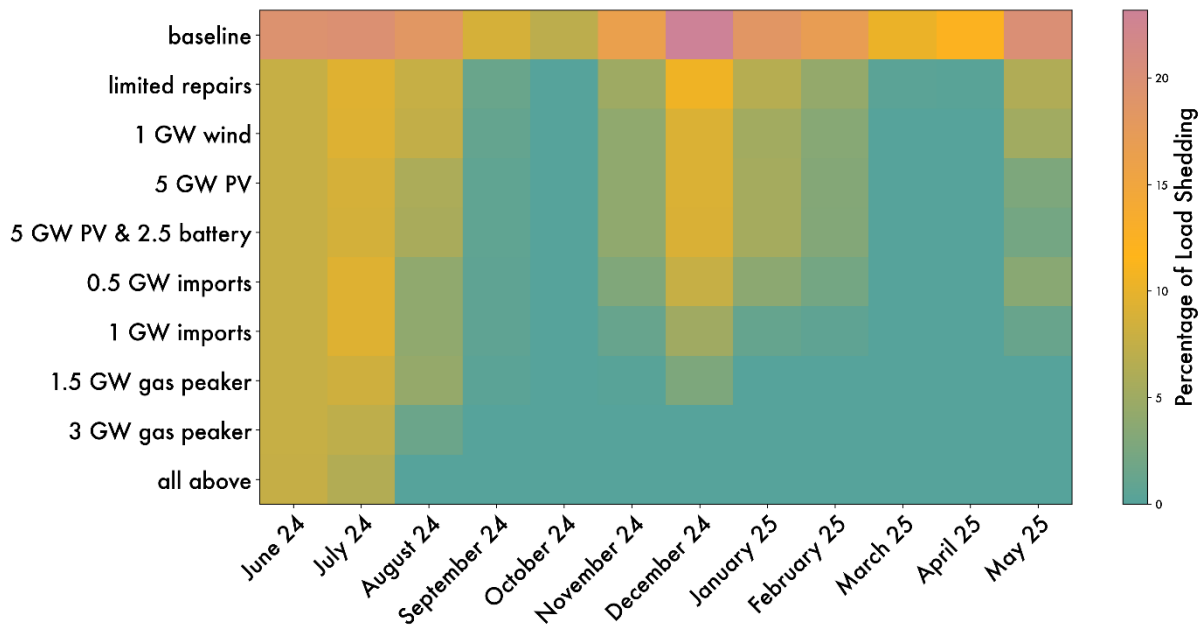


**980 hours** with at least some load shedding –  
11 % of the time



## SCENARIO COMPARISON

Monthly load shedding as a percentage of net demand by scenario





## KEY MESSAGES

If the damaged power plants remain unrepaired, some Ukrainians could face electricity shortages for up to 90 percent of the winter hours, leaving one-fifth of the overall electricity demand unmet.

The cornerstone of securing Ukraine's power supply next winter lies in **strengthening its air defence systems.**

**Repairing partly damaged power plants:** This can quickly and cost-effectively restore significant capacity. Therefore, ensuring the timely delivery of necessary parts into the country is critical.

**Deploying small gas generation units:** These units, ranging from container-sized to full-scale gas turbines, can bolster a decentralized and resilient system without heavy investment in fossil assets. However, their deployment hinges on the availability of gas and gas infrastructure.

**Enhancing electricity imports from the EU:** This requires regulatory adjustments and specific investments.

**Investing in renewables and batteries:** These technologies offer long-term benefits beyond the immediate crisis. Second-hand wind turbines can generate power during winter, while solar panels can maintain electricity supply during summer nuclear plant refuelling.

## POLICY DISCUSSION

Rapid implementation of supply improvements requires significant resources and effective coordination. To achieve this, we suggest to discuss:

- The creation of an '**energy situation room**' to improve information sharing and coordination of Ukraine's energy resilience strategy
  - > well-staffed secretariate with access to timely data from key actors; and tools
  - > high-level political involvement (like NSDC) to determine solutions and responsibilities
  - > need-to-know data sharing with partners/stakeholders
- A mechanism to **empower municipalities** to invest in targeted solutions
  - > municipalities might lease needed energy installations from private developers, with International financial institutions underwriting such leasing contracts
- A mechanism to **empower private actors** to invest in systemic solutions
  - > a joint trust fund that guarantees a minimum level of market revenue for private investors in technologies compatible with decarbonization



## SELECTION OF SOURCES FOR GENERATOR STATUS

Global Energy Monitor - <https://globalenergymonitor.org/projects/>, [https://www.gem.wiki/Main\\_Page](https://www.gem.wiki/Main_Page)

Ukrainian Energy - <https://ua-energy.org/en>

Censor.net - <https://censor.net/en>

Interfax-Ukraine - <https://en.interfax.com.ua/>

Forbes Ukraine - <https://forbes.ua/>

Free Radio Ukraine - <https://freeradio.com.ua/>

Reuters - <https://www.reuters.com/>

Babel - <https://babel.ua/en>

The New Voice of Ukraine - <https://nv.ua/>

Ukrinform - <https://www.ukrinform.net/>

Suspilne Media - <https://suspilne.media/>

World Nuclear Association - <https://world-nuclear.org/information-library/country-profiles/countries-t-z/ukraine>



## CONTACT

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[www.GreenDealUkraine.org](http://www.GreenDealUkraine.org)

## Mathematical representation (sample)

- Objective:
 
$$\min C = \sum_{n,s} c_{n,s} \bar{g}_{n,s} + \sum_{n,s} c_{n,s} \bar{h}_{n,s} + \sum_l c_l F_l$$

$$+ \sum_t w_t \left[ \sum_{n,s} o_{n,s,t} g_{n,s,t} + \sum_{n,s} o_{n,s,t} h_{n,s,t} \right] + \sum_t [suc_{n,s,t} + sdc_{n,s,t}]$$
- Nodal balance:
 
$$\sum_s g_{n,s,t} + \sum_s h_{n,s,t} - \sum_s f_{n,s,t} - \sum_l K_{nl} f_{l,t} = \sum_s d_{n,s,t} \quad \leftrightarrow \quad w_t \lambda_{n,t}$$
- Generator constraints:
 
$$\tilde{g}_{n,s,t} * \bar{g}_{n,s} \leq g_{n,s,t} \leq \bar{g}_{n,s,t} * \bar{g}_{n,s}$$
- Storage constraints (uptake):
 
$$0 \leq f_{n,s,t} \leq \bar{h}_{n,s}$$

## Network components

Component	Description
Network	Container for all components and functions which act upon the whole network
Bus	Electrically fundamental node where x-port objects attach
Generator	Power generator
Load	Electricity consumption (n-hourly snapshots) at a given bus
Line	Electrical lines connecting buses, represent conventional alternating current (AC) or direct current (DC) transmission lines.
Link	Controllable, directed connections between buses, with the possibility for both unidirectional and bidirectional flows
Storage Unit	Storage unit with fixed nominal-energy-to-nominal-power ratio.



## 10 SCENARIOS OF OUTAGES AND POTENTIAL POLICY RESPONSES

**Baseline:** Available capacity is restricted to only the generators in the *operating* category. Imports are set to the commercial maximum agreed with ENTSO-E of 1.7 GW. No new generators are installed.

**Limited Repairs:** Available capacity consists of all generators in the *operating* category, plus 50% of the capacities of generators in the *attacked-damaged* category. Imports are set to the commercial maximum of 1.7 GW. No new generators are installed.

**1.5 GW additional OCGT:** Available capacity as described in the "Limited Repairs" scenario, plus an additional 1.5 GW of newly installed OCGT capacity, distributed across nodes in proportion to demand.

**3 GW additional OCGT:** Available capacity as described in the "Limited Repairs" scenario, plus an additional 3 GW of newly installed OCGT capacity, distributed across nodes in proportion to demand.

**1 GW additional wind:** Available capacity as described in the "Limited Repairs" scenario, plus an additional 1 GW of newly installed wind onshore capacity. Distributed based on pre-existing shares of wind.

**5 GW additional PV:** Available capacity as described in the "Limited Repairs" scenario, plus an additional 5 GW of newly installed photovoltaic (solar) capacity, distributed across nodes based on shares of pre-existing PV.



## 10 SCENARIOS OF OUTAGES AND POTENTIAL POLICY RESPONSES

**5 GW additional PV and 2.5 GW additional batteries:** Available capacity as described in the “Limited Repairs” scenario, plus an additional 5 GW of newly installed PV capacity and 2.5 GW of newly installed battery capacity.

**0.5 GW additional imports:** Available capacity as described in the “Limited Repairs” scenario. Import capacity from Poland is increased by 0.5 GW and added to node “UA\_1” (the region bordering EU countries). No new generators are installed.

**1 GW additional imports:** Available capacity as described in the “Limited Repairs” scenario. Import capacity from Poland and Hungary is increased by a total of 1 GW and added to node “UA\_1” (the region bordering EU countries). No new generators are installed.

**All-of-the-above** (3 GW additional OCGT and 5 GW additional PV and 2.5 GW additional batteries and 1 GW additional imports): This scenario includes all individual measures and checks whether a mix makes it possible to completely avoid load shedding.



## THE FOLLOWING KEY ASSUMPTIONS HOLD FOR ALL SCENARIOS:

**Demand:** net demand of around 100 TWh for the period June 2024 – May 2025, i.e., a decline of around 20% compared to 2021, *under consideration of sectoral shares, GDP losses, migration, and the loss of territory due to occupation by RUS*

**Hydro:** water flow is equivalent to 8.5 TWh generation pre-war potential.

**Wind/PV capacity factors :** 2013 weather year

**Nuclear maintenance:** outages follows the same schedule as 2023/24

**Capacity status of generators:** based on latest publicly available information as of June 5th and verified in bilateral exchanges with Ukrainian experts in Kyiv.

**Fossil and nuclear power plants:** (TPP & NPP): no unit commitment considered, no maintenance outages

**Import/Export:** Imports modelled endogenously, no consideration of potential exports

**Reserves:** no consideration of reserve requirements

**New capacities:** will be gradually put into operation by 30 September, after which no new capacities area added.