



## Workshop

**Energy infrastructure  
resilience in response  
to war and other hazards**

23–26 September 2024

Rzeszów, Poland

# Ensuring Operability During Disruptions: Hybrid Energy Systems for Critical infrastructure

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Science for Peace and Security (2024)  
Energy infrastructure resilience in response to war and other hazards  
Advanced Research Workshop (ARW) supported by NATO

**POLAND, Rzeszów, 24.09.2024**



*This workshop  
is supported by:*

The NATO Science for Peace  
and Security Programme

# Part 1 “Operability During Disruptions”

## Ensuring Operability During Disruptions: Hybrid Energy Systems for Critical infrastructure

POLAND, Rzeszów, 24.09.2024

## In this presentation, we will:

- Outline possible disruptions and their causes
- Provide an overview of Ukraine's power system
- Highlight main disruption for Ukraine
- Discuss implications and recommendations for protecting energy autonomy during disruptions

## Disruptions

- Natural Disasters
- Technical Failures
- Operational Challenges
- Economic Factors
- Human Activities



A power outage in Italy on 28 September 2003 affected 56 million people.



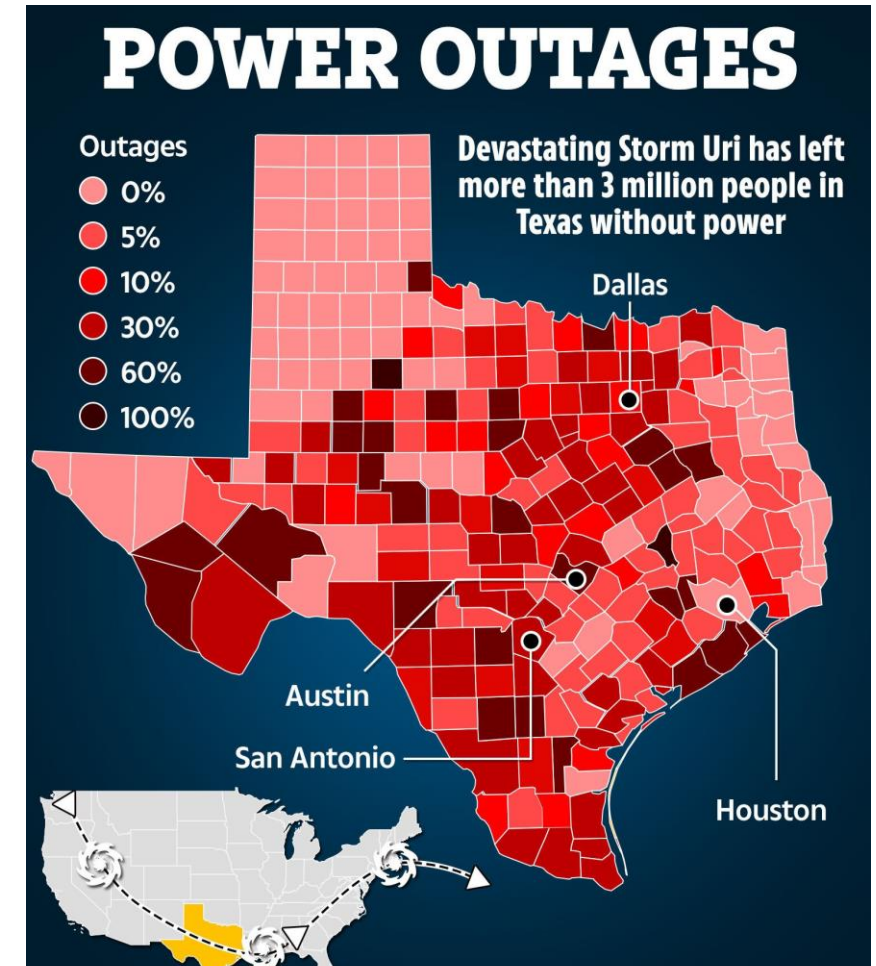
As a result of the **10 largest accidents** related to imbalance in the power system nearly **1.6 billion people** were affected.

# 2021 Texas power crisis

## Main reasons:

- All types of generation technologies failed
- Demand forecasts for severe winter storms were too low
- Planned generator outages were high, but not much higher than assumed in planning scenarios
- Grid conditions deteriorated

**Texas power crisis** in February 2021 brings property damage at \$20.4 billion and took life of 210 people (NOAA, NY Times 2021)



# South Africa

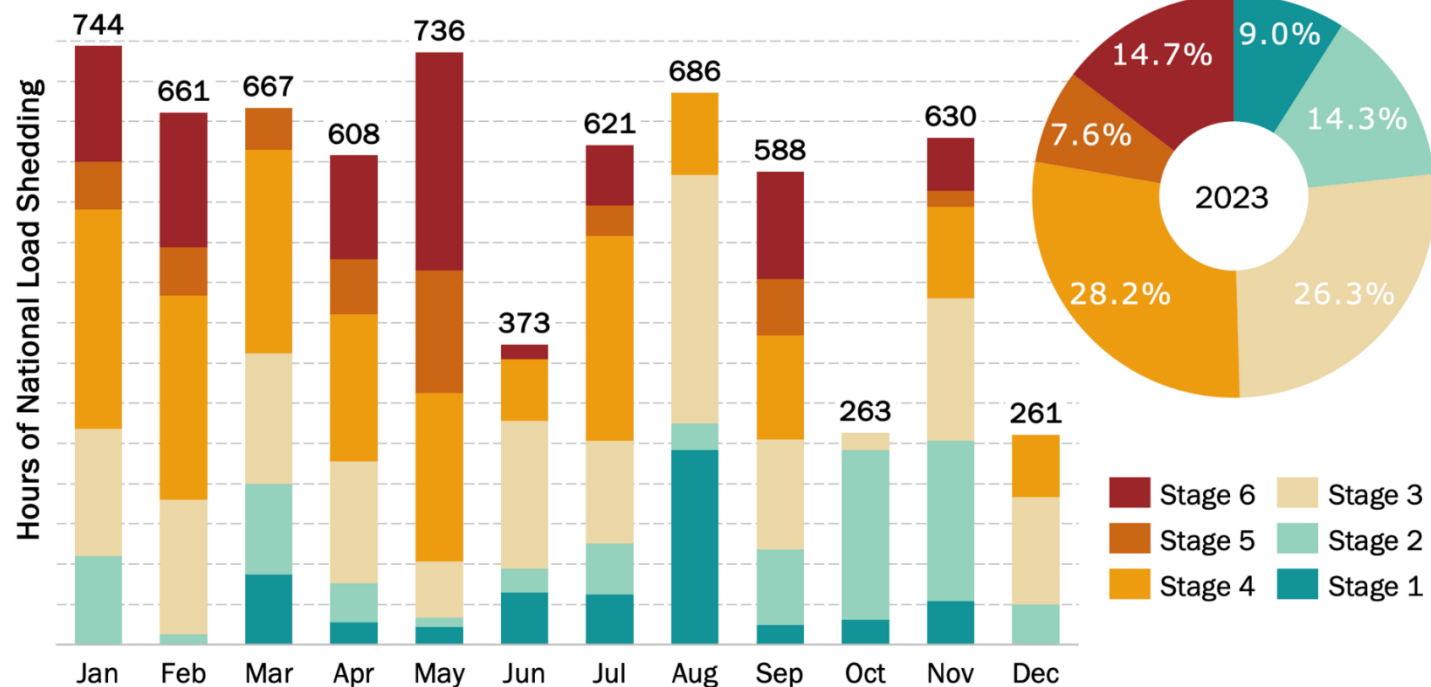


Home News Sport Business Innovation Culture Arts Travel Earth Video Live



South Africans will hope they will no longer have to protest to demand a reliable electricity supply

## Load Shedding Stage Hours



The Centre for Renewable and Sustainable Energy Studies (CRSES) | Stellenbosch University  
 Source: Eskom 2024 | Eskom se Push 2024 | NERSA 2023.

By the end of 2022, South Africans experienced more than 200 days of power cuts, the most in a calendar year to date

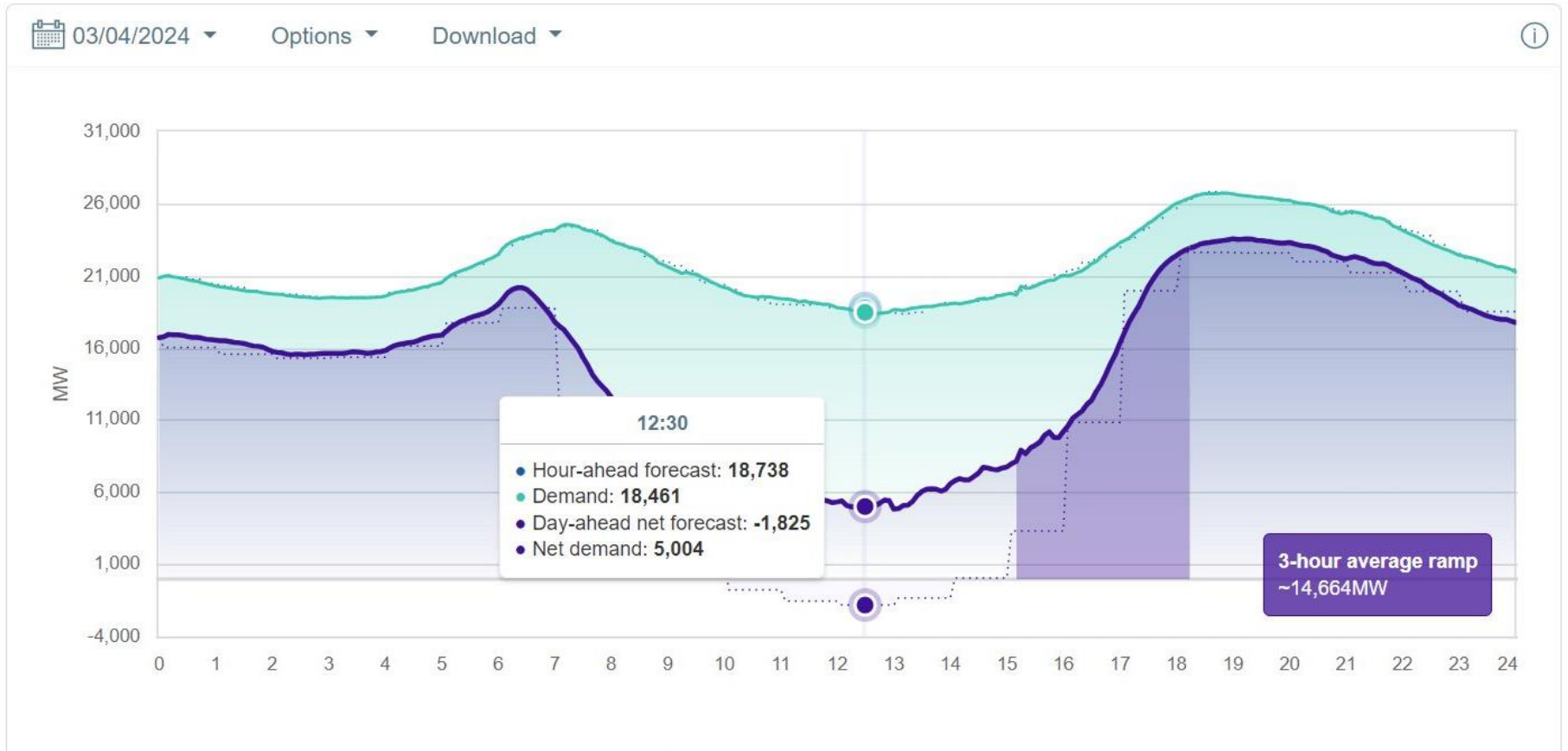
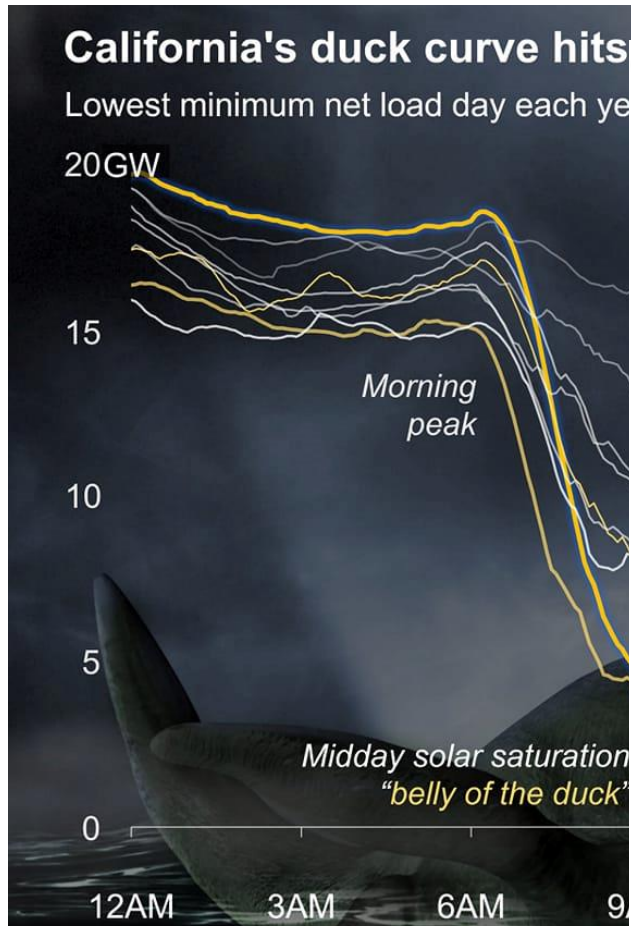
**Vitalii Opryshko**  
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# California duck curve evolution





## Ukraine before and after full-scale invasion

In 2021, electricity generation by Ukrainian power plants totalled 156,575.7 million kWh

The main share in the total output in 2021 was generated by NPPs - 55.1%, TPPs and CHPs - 29.3%, HPPs and PSPs - 6.7%, and RES - 8%. Installed capacity before nearly 55 GW

Installed capacity now almost 20 GW  
(Completely destroyed - 9.2 GW)



## ENTSO-E synchronization

- ENTSO-E and Ukrenergo have been working together since 2017 to achieve such integration.
- Island mode test was launched Feb 24, 2022 (3 hours prior full-scale invasion)
- 16 March 2022 Emergency synchronisation of Ukraine and Moldova with the Continental Europe power system
- April 2022 Observer Member
- 28 November 2023 Completion of the synchronisation project



Volodymyr Kudrytskyi NPC Ukrenergo CEO and Zbyněk Boldiš, President of ENTSO-E during the online conference call welcoming Ukrenergo as new member of ENTSO-E as of 1st January 2024 after Assembly vote (ENTSO-E webpage news)

# Blackouts and Load Shedding

Energy terror started with shelling of Luhanska TPP in Shchastia

(21<sup>st</sup> Feb 2022)

Continues with occupation by russian troops of Zaporizhian NPP (4<sup>th</sup> March 2022)

First attack on energy system 11<sup>th</sup> Sep 2022 – 12 missiles

**23<sup>d</sup> Nov 2022** – 70 missiles Due to infrastructure damage, emergency power outages were introduced across Ukraine, triggering automatic shutdowns at Rivne, South Ukraine, and Khmelnytsky NPPs. Most thermal and hydroelectric power plants were also de-energized.



# Energy infrastructure resilience in response to war and other hazards – Workshop, 23-26 September 2024, Rzeszów, Poland





A man rides a bicycle past an energy infrastructure facility attacked by Russia in Kharkiv, Ukraine, March 22, 2024. AP/Yevhen Ti



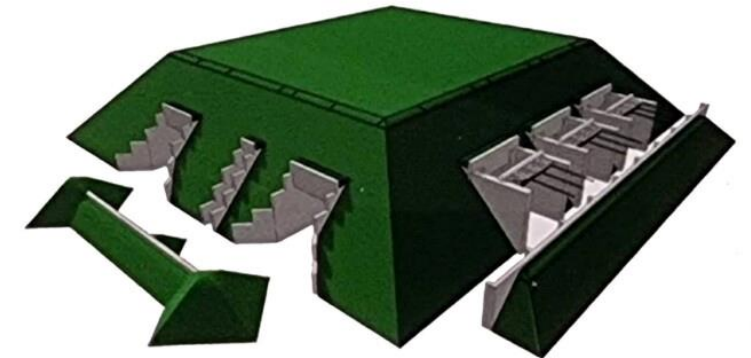
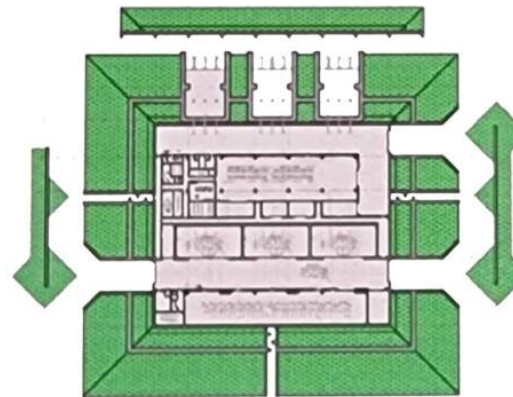
# Defense strategies

What levels of protection have been granted to power facilities

- construction of gabions and big bags,
- protection against drones,
- protection against missiles.



250\*250 m  
500 mln USD only construction price

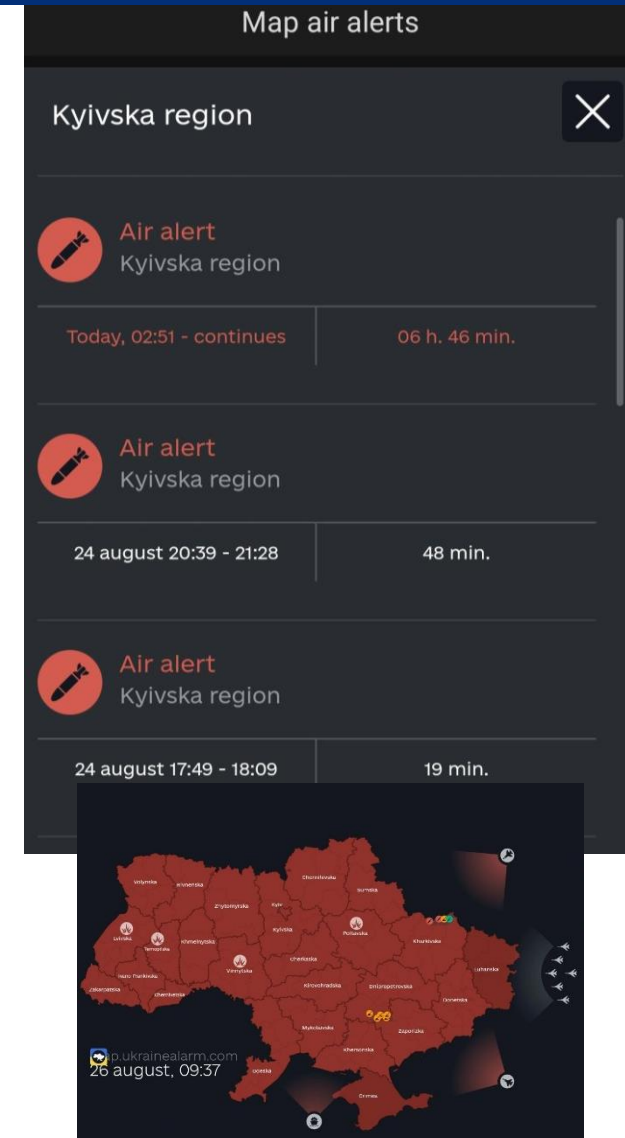
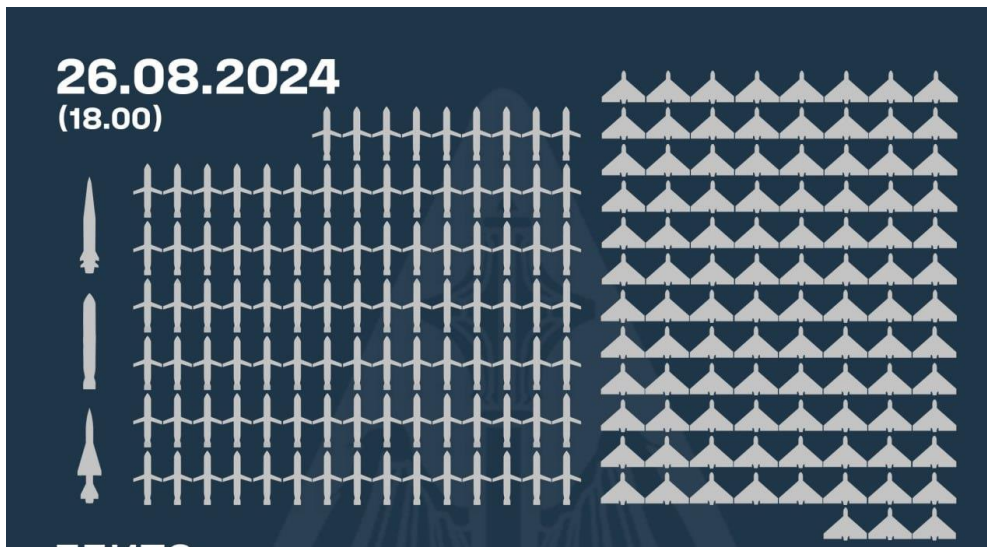


# Latest massive attack 26 Aug

A total of 236 enemy air targets were detected and tracked by the Air Force's: 127 missiles and 109 attack UAVs.

@war\_monitor

A total of 201 air targets were shot down as a result of the air combat.



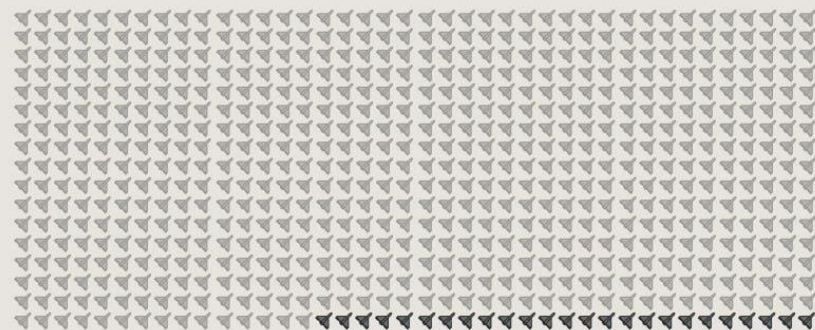
# Зведення по ворожих атаках за серпень 2024

За підрахунками Повітряних Сил та @war\_monitor

БПЛА типу «Шахід»/«Гербера»

655/680

відсоток збиття: 96,32%



Крилатих ракет  
Х-101/55, 3м14 «Калібр»

99/115

відсоток збиття: 86,09%



Балістичних ракет  
9м723 «Іскандер-М» / KN-23

7/45

відсоток збиття: 15,56%



Керованих авіаційних ракет  
Х-59/69

12/48

відсоток збиття: 25%



Аеробалістичних ракет  
комплексу Х-47м2 «Кінджал»

2/9

відсоток збиття: 22,22%



Також було збито з запущених засобів ураження:

Крилатих надзвукових ракет Х-22 (2/7)

Крилатих ракет Р-500 9м728 «Іскандер-К» (1/5)

Протирадіолокаційних ракет Х-31П (0/4)

КР невстановленого типу (3/3)

Загалом було запущено 916 засобів ураження, з них 781 — збито.

Відсоток збиття: 85,26%

# Зведення по ворожих атаках за серпень 2024

За підрахунками @war\_monitor

Планеруючих авіаційних бомб (КАБ)

2687

ФАБ/ОДАБ/ОФАБ/РБК-250/500/1500/2700/3000, УМПБ Д-30СН з  
Універсальним модулем планування та корекції (УМПК)





# Development Strategies

1. National Energy Strategy 2050
2. National Energy and Climate Plan (NECP)
3. The National Renewable Energy Action Plan for the period up to 2030
4. Ukraine Facility

Expectations in terms of installed capacity (total)

	2025	2030
SPPs	8.1 GW	12.2 GW
WPPs	2 GW	6.2 GW
biomass and biogas	463 MW	876 MW
highly maneuver	248 MW	906 MW
BESS	46 MW	656 MW

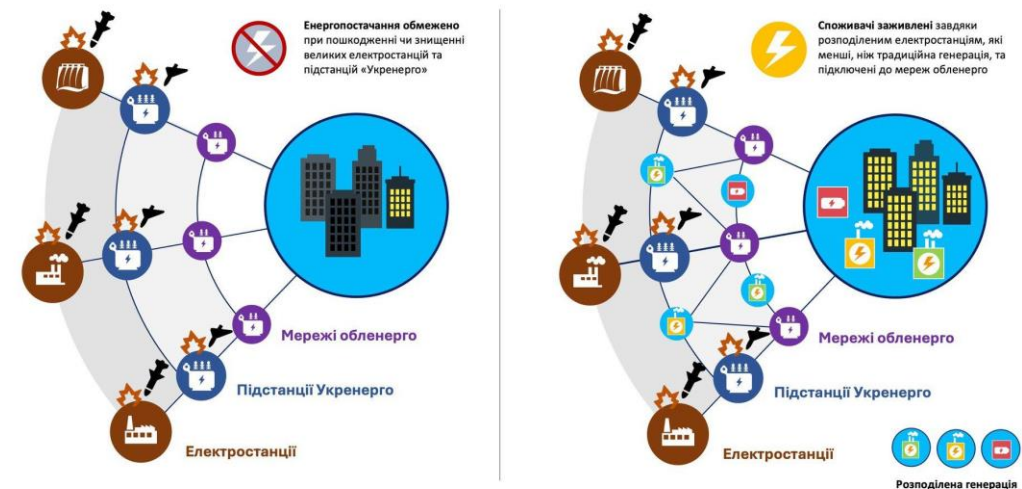
# Main strategies

1. Air defence for critical infrastructure
2. Protect and rebuild what is possible
3. Distributed generation development (legal, economic, tech part)

## ЯК ПРОТИДІЯТИ ЕНЕРГЕТИЧНОМУ ТЕРОРУ РОСІЇ



## ЯК ЗАБЕЗПЕЧИТИ ЕНЕРГОЖИВЛЕННЯМ ТИПОВЕ ВЕЛИКЕ МІСТО УКРАЇНИ



# Part 2 “Low-Power Renewable Energy Communities”

“Ensuring Operability During Disruptions: Hybrid Energy Systems for Critical infrastructure

POLAND, Rzeszów, 25.09.2024