



Analytical Report
**Ukrainian Renewable
Energy Sector**

BDO in Ukraine



Analytical Report on the Ukrainian Renewable Energy Sector by BDO in Ukraine presents a thorough exploration of Ukraine's renewable energy landscape, highlighting its importance during war time, challenges, and further potential.

From the first days of the war, the Russian aggressor has been massively shelling not only Ukrainian cities and villages, but also trying to destroy critical energy infrastructure. Significant part of installed renewable capacity remained on occupied territory which may decrease such post-war capacity by up to 60% due to destruction or stealing (75% of wind and more than 20% of solar generation according to Minister of Energy Herman Halushchenko).

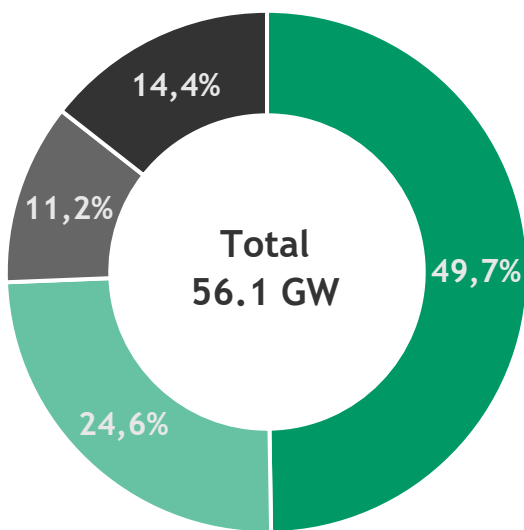
In this report BDO in Ukraine's experts have prepared a general overview of the Ukrainian renewable and low-carbon energy market and provided key predictions for its further development.



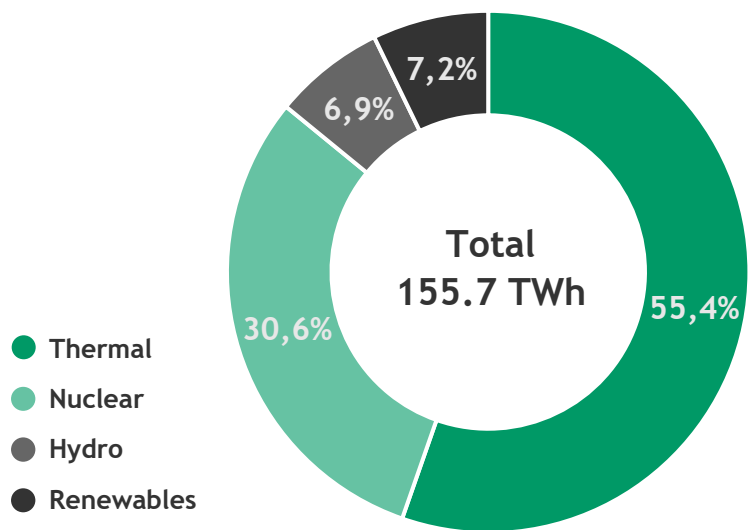
Ukrainian energy-generating industry and renewable capacities

As of the beginning of 2022, the Ukrainian energy industry was one of the most powerful in Europe: the total installed capacity of the UES of Ukraine as of the end of 2021 was 56.1 GW (production in 2021 - 155.7 TWh of electricity, **70% of generation - from low-carbon and renewable sources**).

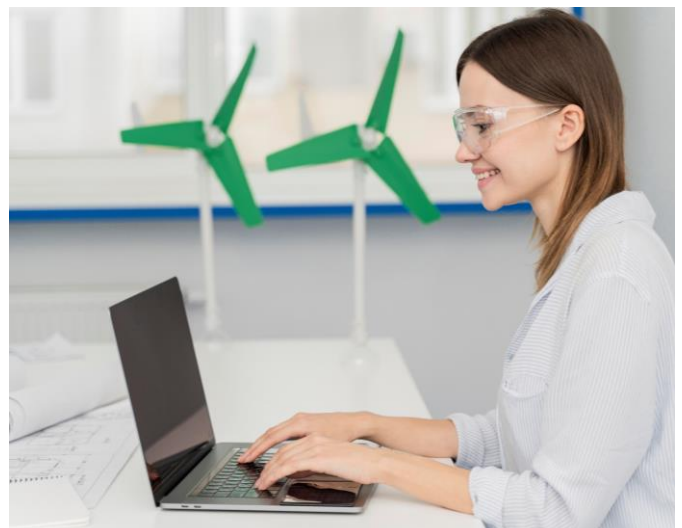
The structure of installed capacities, GW (2021)



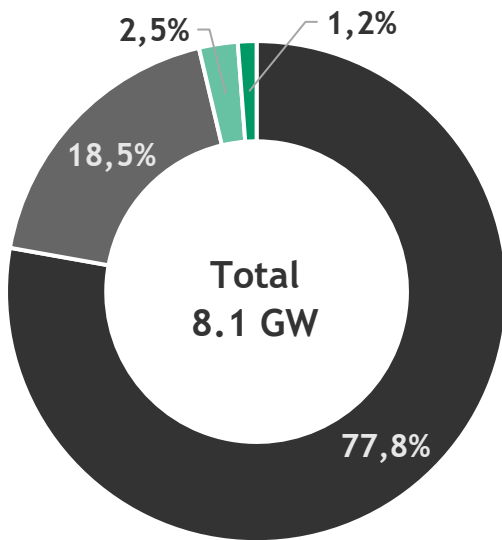
Generation by sources, TWh (2021)



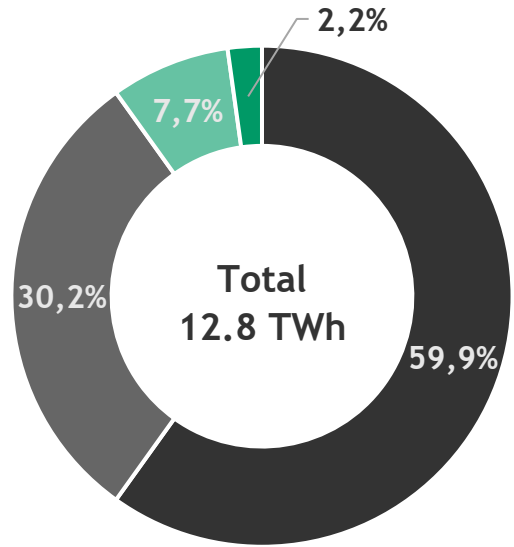
- ▶ Nuclear generation (50% of generation) was represented by 4 NPPs (Zaporizhskaya, Rivnenska, Khmelnytska, South Ukrainian), 15 units with total capacity of 13.8 GW;
- ▶ The installed capacity of hydroelectric power plants was 6.3 GW (6.1 GW - 9 stations on the Dnipro and Dniester rivers, which are part of PrJSC "Ukrhydroenergo", client of BDO in Ukraine);
- ▶ The renewable energy sector accounted for 8.1 GW of installed capacity, of which: 5.1 GW were solar power plants; 1.5 GW - wind power plants; 1.2 GW - private solar power plants; 0.2 GW - bioelectric plant; 0.1 GW - small hydroelectric power plants.



The structure of installed renewable capacity, GW (2021)



Renewable generation structure, TWh (2021)

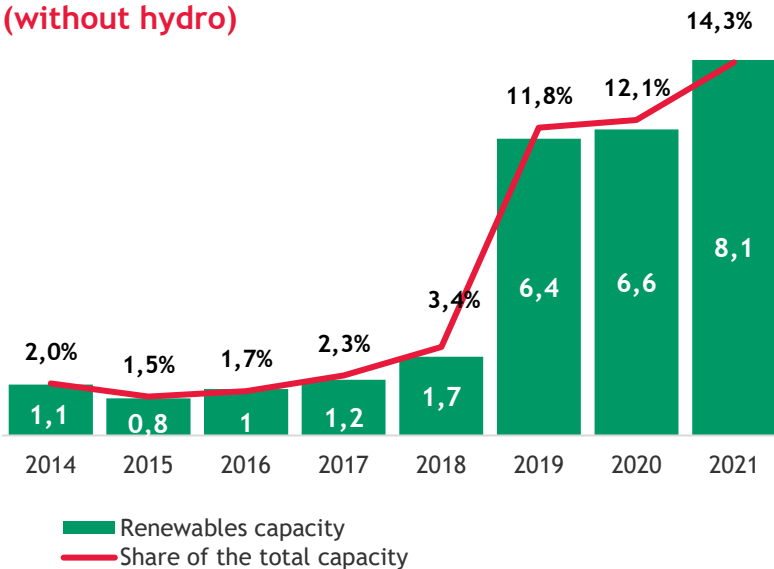


- Solar
- Wind
- Bioenergy
- Small hydro

A **significant increase in the installed renewables capacity** during 2019-2021 (from 1.7 GW in 2018 to 8.1 GW in 2022) was associated with the introduction of one of highest green tariffs in Europe (1Q2019) tied to EUR (as of 2022, the average in Ukraine was 9 UAH/kWh, while in the EU it was about 4.15 UAH/kWh). The rapid development of renewable generation created a significant burden on the budget, so in 2020 there was a **retrospective reduction of the tariff** and the accumulation of payment arrears. In addition, there were real problems with the balancing of the power grid, when TPPs had to be partially used as manoeuvrable capacities.



Dynamics of renewable installed capacity and share in total installed capacity (without hydro)



Despite the rapid development, the share of energy production from renewables (including hydro) in Ukraine is relatively low (**14%**): as of 2021, **39.7%** of electricity was generated from renewables in **Germany**, **20.7%** in the **USA**, **17.1%** in **Poland**, average in the world - **28.4%**.

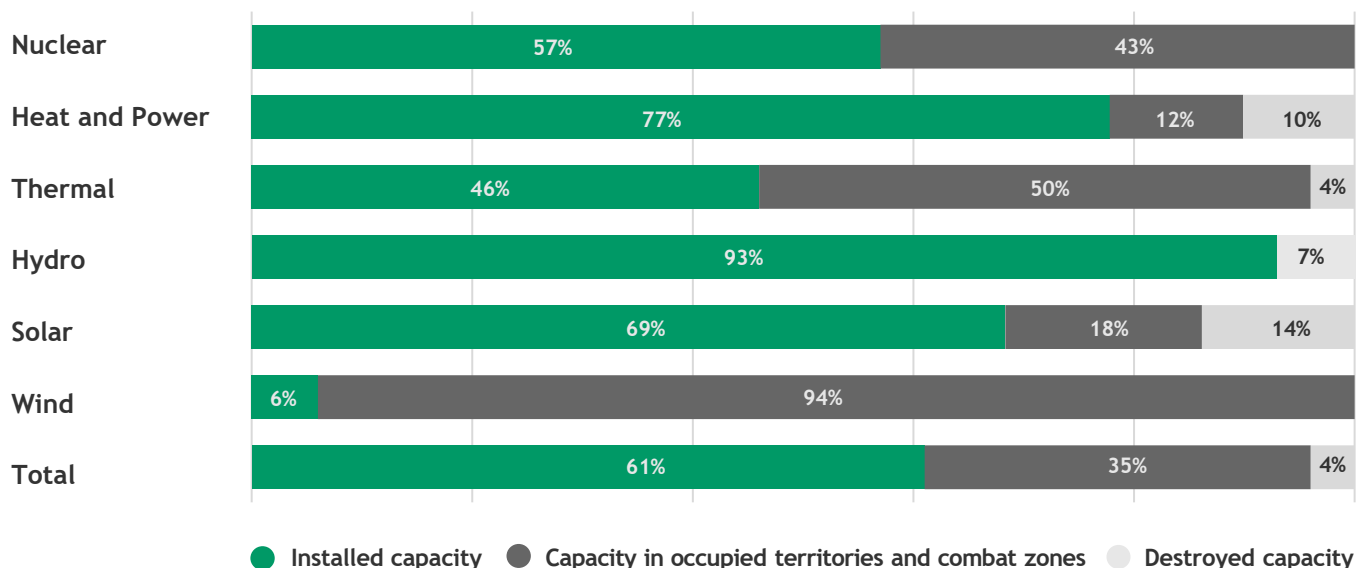
The impact of war



About **4%** of the generating capacity was destroyed during the military actions as of July 2022, another **35%** of the installed capacity is located on the occupied territories (including Europe's largest

Zaporizhzhya NPP). In addition, on June 6, 2023, Russian troops blew up and destroyed the Kakhovka HPP dam, creating an environmental and humanitarian disaster.

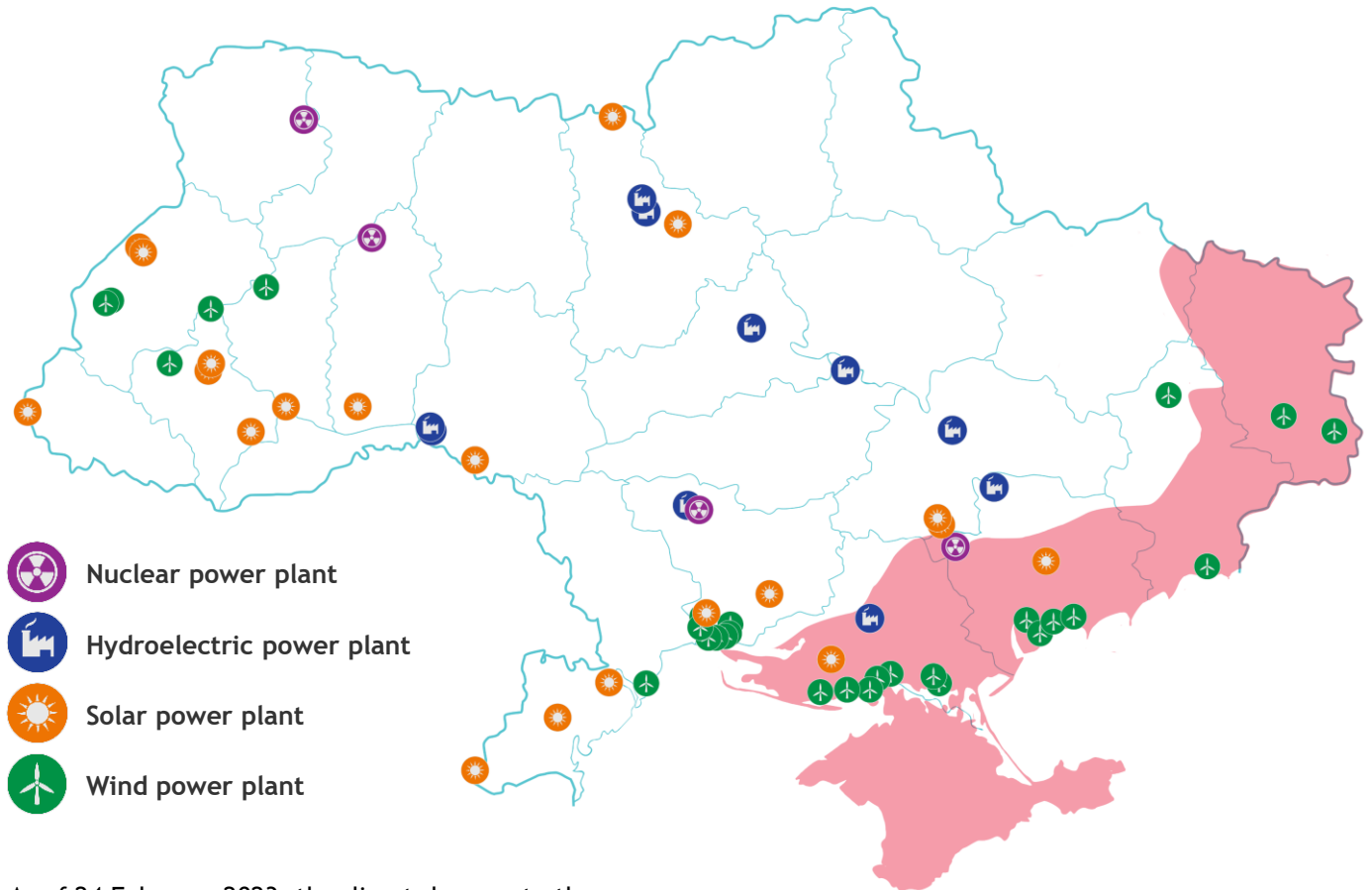
Distribution of operating capacity of generation facilities by status, July 2022 (with update on Kakhovka dam)



Most renewable capacities currently installed in the country are concentrated in the southern and southeastern regions of Ukraine. According to various experts' estimates, as of August 2022,

30-40% of renewable power plants in these regions, or about 1.1-1.5 GW of installed capacity, have already been affected.

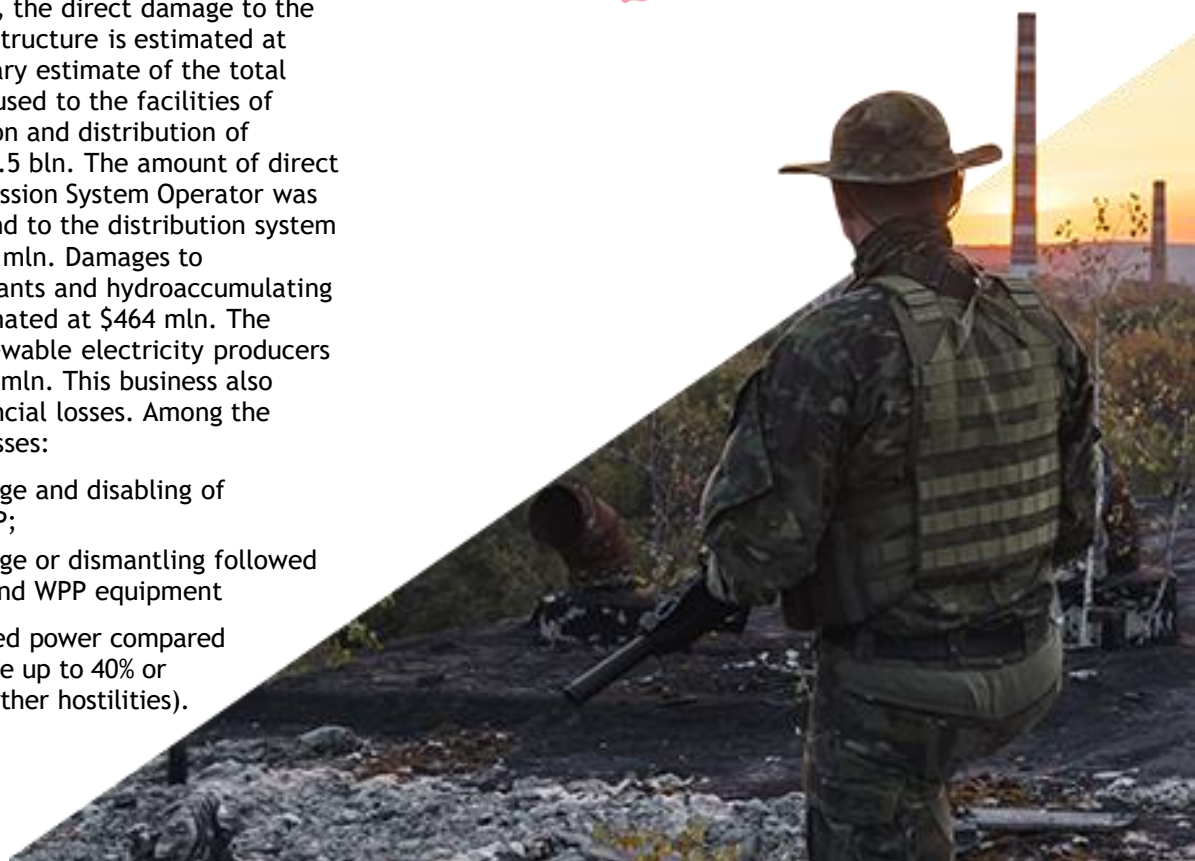
Distribution of the largest renewable and low-carbon energy facilities, August 2023



As of 24 February 2023, the direct damage to the Ukrainian energy infrastructure is estimated at \$8.1 bln. The preliminary estimate of the total amount of damages caused to the facilities of production, transmission and distribution of electricity is almost \$6.5 bln. The amount of direct damage to the Transmission System Operator was estimated at \$2 bln, and to the distribution system operators at over \$350 mln. Damages to hydroelectric power plants and hydroaccumulating power plants was estimated at \$464 mln. The direct damages to renewable electricity producers was estimated at \$220 mln. This business also suffers significant financial losses. Among the expected additional losses:

- ▶ Intentional damage and disabling of Zaporizhzhya NPP;
- ▶ Intentional damage or dismantling followed by theft of SPP and WPP equipment

The total loss of installed power compared to pre-war values can be up to 40% or more (depending on further hostilities).



Restoration and development of energy sector

The main challenges for Ukraine in renewable energy industry are **the reconstruction of destroyed or stolen capacities** and the restoration, diversification of the energy infrastructure (substations, power lines, etc.).

Among the announced plans is the **development of nuclear generation** (including projects with Westinghouse): in 2023-25 launch of 2+ GW of new units construction at the Khmelnytskyi NPP is planned. Ukraine has already negotiated with the Bulgarian state energy company NEK potential sale of equipment from the unfinished Belene NPP worth at least EUR 600 mln (source of funding - US contribution in the form of aid or sale a minority stake in the Khmelnytska NPP to Bulgaria). Also, at the beginning of June 2022 Energoatom signed agreements on the supply of nuclear fuel for all the country's nuclear power plants with Westinghouse Electric Company (until 2005, only Russian fuel was used, by the beginning of 2022 American fuel was used in 6 units out of 15).

The technology of **small modular reactors** is quite promising, which, due to compactness and reliability, will bring power generation closer to consumers, in order to reduce the risks of the delivery infrastructure (taking into account the experience of attacks on energy infrastructure by Russia). Westinghouse intends to begin construction of the first AP300 small modular reactor in Ukraine, but certification of the technology will take until at least 2028.

The development of **large hydropower** involves the construction of the Kakhovskaya HPP-2, the commissioning of the 4th hydrounit at the Dniester HPP, the 3rd hydrounit at Tashlitskaya, the implementation of the third stage of construction at the Dniester HPP, and the modernization of a number of existing capacities.

The recovery and development of renewables will require significant private investments, but there is a basis for them: according to the World Bank,

Ukraine has one of **the best technical potentials for the development of offshore wind energy** in the Black Sea among all the countries of the Black Sea region. The theoretical technical potential of offshore wind energy in the Black Sea and in the shallow waters of Ukraine is 250 GW, while the total theoretical potential of all Black Sea countries is 435 GW. In addition, the moderate continental climate and the presence of a sufficient number of sunshine hours contribute to **the high efficiency of solar panels**, which can be translated into high production capacity of solar power plants.



Export development

In 2017, Ukraine signed an agreement with the EU on synchronization with European power grid and in 2022 Ukraine disconnected from the ex-USSR energy systems of Russia and Belarus and in a few weeks joined the unified energy system of continental Europe ENTSO-E (the process took place at an unprecedented speed during the beginning of the invasion of Russia in February-March 2022). Connection to ENTSO-E allowed to export energy to Europe from the end of June 2022.

By 2032, it is planned to expand the capacity of ENTSO-E to 6 GW.

Ukraine has the potential to become an energy resource centre for Europe, as the EU faces a

permanent shortage of energy due to a reduction in the export of cheap energy resources from Russia, the transition to green energy (unstable energy from the sun and wind), a lack of own production and storage capacities, an overall increase in demand.

The main development potential is the export of energy from renewable and nuclear power plants. There is a discussion on NPP energy already underway: the European Commission issued a proposal to count the use of nuclear energy to "green" energy (subject to compliance with certain conditions). This initiative was supported by France and a group of Central and Eastern European countries (opposing by Germany and a group of Western European countries).

Cyber risks and performed attacks

Except a threat of military-related attacks, cyberattacks on Ukrainian power grid were among most dangerous ones as in case of full implementation potential harm to infrastructure could have been significant.

Attacks were planned as a complex of actions in order to intercept the control over infrastructure and switch it to non-standard mode with high probability of permanent damage ⇨

It is likely, that attacks aimed to demonstrate capabilities as potential harm could have been significant: fast switching on and off on substation could destroy the infrastructure.

After participation in investigation USA changed its legislation for critical infrastructure (manual mechanical switches).

Dec, 2015 - Prykarpattya-oblenergo (30 substations disabled / 230 ths people exposure)

Chernivtsioblenergo, Kyivoblenergo - first in the world proved cyberattack over power grid

Dec, 2016 - Kyivoblenergo, part of Kyiv and Kyiv region w/o electricity supply for more than an hour

Phishing to reach local network

Interception the control over on/off switch on substations

Disabling IT infrastructure elements (RTU, modems and so on)

KillDisk on workstations and servers

Attack on call centers to prevent assistance to clients

Final thoughts

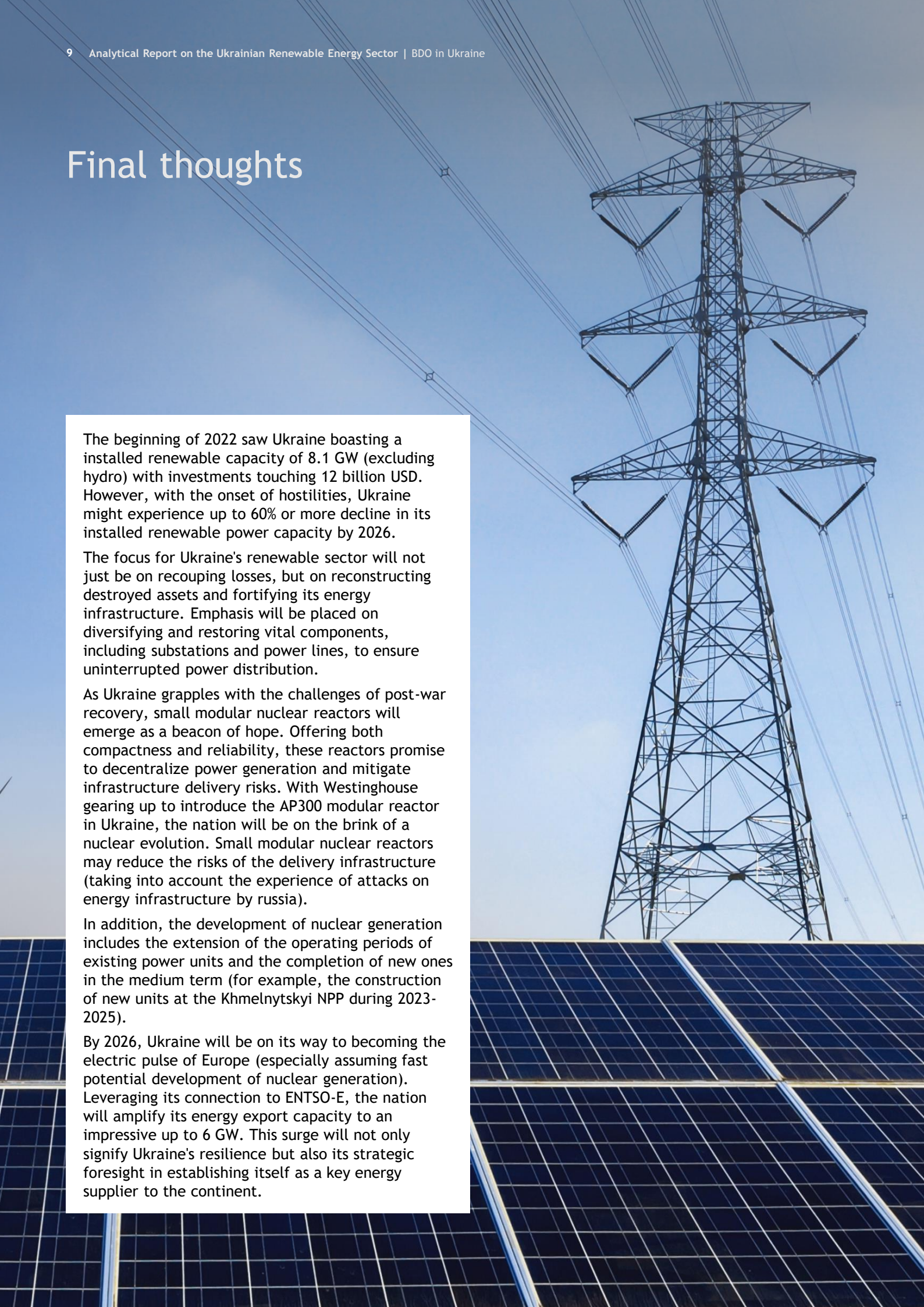
The beginning of 2022 saw Ukraine boasting a installed renewable capacity of 8.1 GW (excluding hydro) with investments touching 12 billion USD. However, with the onset of hostilities, Ukraine might experience up to 60% or more decline in its installed renewable power capacity by 2026.

The focus for Ukraine's renewable sector will not just be on recouping losses, but on reconstructing destroyed assets and fortifying its energy infrastructure. Emphasis will be placed on diversifying and restoring vital components, including substations and power lines, to ensure uninterrupted power distribution.

As Ukraine grapples with the challenges of post-war recovery, small modular nuclear reactors will emerge as a beacon of hope. Offering both compactness and reliability, these reactors promise to decentralize power generation and mitigate infrastructure delivery risks. With Westinghouse gearing up to introduce the AP300 modular reactor in Ukraine, the nation will be on the brink of a nuclear evolution. Small modular nuclear reactors may reduce the risks of the delivery infrastructure (taking into account the experience of attacks on energy infrastructure by Russia).

In addition, the development of nuclear generation includes the extension of the operating periods of existing power units and the completion of new ones in the medium term (for example, the construction of new units at the Khmelnytskyi NPP during 2023-2025).

By 2026, Ukraine will be on its way to becoming the electric pulse of Europe (especially assuming fast potential development of nuclear generation). Leveraging its connection to ENTSO-E, the nation will amplify its energy export capacity to an impressive up to 6 GW. This surge will not only signify Ukraine's resilience but also its strategic foresight in establishing itself as a key energy supplier to the continent.



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