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INTRODUCTION

The full-scale military aggression by the Russian Federation launched on February 24, 2022, has a significant negative impact on the Ukrainian energy sector. Due to their economic, humanitarian and geopolitical importance, energy infrastructure facilities were among the primary targets for the Russian army.

At the beginning of 2022, the Ukrainian energy sector was one of the most developed in Europe. Ukraine had one of the largest electricity generation capacities in Europe (~60 GW), was among the top-3 natural gas producers (~20 bcm), and had the largest underground gas storage in Europe (32 bcm).

August 24, 2022 marked the 31st anniversary of Ukraine’s declaration of independence from the Soviet Union and the six-month anniversary of Russia's full-scale invasion. During half a year of the war, Russia occupied or damaged about 35% of the country’s installed power capacity, thousands of km of electric, gas and heat networks, thousands of transformers, compressor stations and heating points. The oil refining industry was destroyed. Electricity and natural gas consumption decreased by 30-35%. The 2022-2023 heating season in affected regions is at high risk. As of August 22, 2022, the estimated damages to the Ukrainian energy sector were at least $1.8 bln1.

The damage assessment report was developed by the Task Force comprised of representatives of Ukrainian authorities and the Energy Charter Secretariat, established under the project, “Cooperation for Restoring the Ukrainian Energy Infrastructure”, and in cooperation with other Ukrainian and international organisations. The general objective of the project is to assist the Government of Ukraine in the cost-effective restoration of energy infrastructure, taking into account the clean energy transition while ensuring energy security. The project is funded by the European Commission and implemented by the Energy Charter Secretariat.

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1 Kyiv School of Economics
POWER SECTOR

Nuclear energy

Nuclear energy provides a reliable base load and covers more than half of the electricity production in Ukraine (55.5% in 2021). There are four nuclear power plants (NPPs) in Ukraine with a total installed capacity of 13.8 GW (15 reactors in total, incl. 13 reactors with a capacity of 1,000 MW and two reactors with a capacity of 415 MW and 420 MW, respectively).

Zaporizka NPP (ZNPP), the largest nuclear power plant in Europe and the fifth largest in the world\(^2\), has been occupied by the Russian military forces since early March 2022. The installed power capacity of the plant is 6,000 MW which is 43% of Ukraine's total nuclear power installed capacity. Before the Russian large-scale military invasion of Ukraine, the plant covered about 25% of electricity production in Ukraine. As of today, the Russian forces declared that they are working on disconnecting the plant from the Ukrainian power system. The main goal of the disconnection is to meet the power needs of occupied territories, especially the occupied Crimea peninsula, using the electricity generated by ZNPP. The plant is being regularly shelled by the Russian army and allegedly used as an ammunition warehouse, posing a significant threat to nuclear safety. In the event of an accident at ZNPP, the evacuation of at least half a million people will be required.

Thermal energy

At the beginning of 2022, there were 12 thermal power plants (TPPs) in Ukraine with a total installed power capacity of 21.5 GW (excluding the plants located in the territories temporarily occupied by Russia before February 24, 2022). Most TPPs are using coal as a primary fuel. In 2021 the of TPPs' share in electricity production was 23.8 %.

\(^2\) Top ten nuclear power plants by capacity, POWER TECHNOLOGY
Since 2014, two TPPs with an installed capacity of 3.3 GW have been located in the occupied Donbas region. After February 24, 2022, Russian military forces occupied three TPPs (Zaporizka TPP, Luhanska TPP, Vyglehirsa TPP) with a total installed capacity of 7.7 GW. As of today, 44% of the total thermal capacities in Ukraine are under occupation. Four TPPs with an installed capacity of 5.6 GW are located close to the areas of active hostilities and under the constant threat of occupation. The operation of two plants is also suspended due to the damages to the railway tracks that used to be the primary mean for coal supply.

*Vyglehirsa TPP under shelling, Donetsk region*

Source: Suspilne.media

**Combined heat and power**

At the beginning of 2022, the total installed power capacity of combined heat and power plants (CHPs) was 6.1 GW (excluding the plants located in the territories temporarily occupied by Russia before February 24, 2022). Most CHPs are using natural gas as a primary fuel. In 2021 the share of CHPs and cogeneration units in electricity production was 5.5%.

As of today, around 10% of CHPs installed capacity is under occupation. Four CHPs (Severodonetska CHP, Kremenchutksa CHP, Chernihivska CHP, Okhtyrkska CHP) with an installed capacity of 0.7 GW, or about 11% of total CHPs installed capacity, were completely destroyed as a result of Russian attacks. Given that the destroyed CHPs were the primary suppliers of thermal energy, the 2022/2023 heating season in the affected regions is at high risk.

**Large Hydropower**

At the beginning of 2022, there were ten large hydropower plants (HPPs) with a total installed power capacity of about 4.7 GW (101 units in total) and three pumped storage plants (PSPs) with an installed capacity of 1.5 GW (11 units ranging from 33 MW to 324 MW per unit). Hydropower plays a crucial role in the functioning of the Ukrainian power system, as HPPs and PSPs are the main providers of auxiliary services to meet the peak demand of the power system and balance intermittent Renewable Energy Source (RES) capacities. PSPs also contribute to flattening the night “gaps” of electricity consumption. In 2021 the share of HPPs and PSPs in electricity production was 5.8% and 0.8%, respectively.
Since the first day of the war, Kakhovska HPP (343.2 MW) has been occupied by the Russian army. Two units of the plant were damaged and only three out of six units are currently operating, which is about 30-40% of the installed capacity of Kakhovska HPP.

**Renewable energy (excluding large HPP)**

Ukraine has the highest technical RES potential among other countries in Southeast Europe - 874 GW³, including solar - 83 GW, onshore wind - 438 GW, and offshore wind - 250 GW. Due to high RES potential and efficient support mechanisms, the renewable energy sector in Ukraine has been developing rapidly and the share of RES in electricity production increased from 1.8% in 2018 to 8.2% in 2021. At the beginning of 2022, the total installed RES capacity (all grid-connected) reached 9.5 GW (excluding 0.6 GW of RES capacities located in the territories temporarily occupied by Russia before February 24, 2022). About $12 bln was invested in the Ukrainian RES sector during 2009-2021.

**Solar**

The PV sector had the highest growth rate among other renewable energy sources in Ukraine during 2019-2021. At the beginning of 2022, the total installed PV capacity (excluding the plants located in the territories temporarily occupied by Russia before February 24, 2022) reached 7.6 GW or 80% of the total RES installed capacity in Ukraine (incl. 45 thousand prosumer installations with a total capacity of 1.2 GW). In 2021, Ukraine was ranked 7th in Europe for the development of solar generation.⁴

Currently, about 18% of Ukrainian PV capacities are under occupation. About 6% of total installed solar capacity has been destroyed or damaged.

*A solar power plant after a missile attack, Kharkiv region*

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³ Atlas of RES potential in Ukraine, Renewable energy institute of Ukraine
⁴ Renewable Energy Statistics 2022, IRENA
**Wind**

At the beginning of 2022, Ukraine’s total installed capacity of wind power plants (all onshore) was 1.6 GW (excluding the plants located in the territories temporarily occupied by Russia before February 24, 2022). Almost all wind power plants in Ukraine were built in the southern regions nearby the Azov and Black seas coasts, where natural conditions for wind power plants are the most favorable.

Currently, the south of Ukraine, where the highest wind potential is available, is occupied by Russian Federation. Thus, approximately 80 % of wind generation capacities are located in the occupied territories. There are at least six wind turbines known to be damaged or destroyed as a result of the hostilities by the Russian army (about 1 % of the total installed wind capacity).

*Damaged wind power turbine, Kherson region*

**Bioenergy**

At the beginning of 2022, the total installed capacity of bioenergy electricity facilities was 273.9 MW (excluding the plants located in the territories temporarily occupied by Russia before February 24, 2022), including biomass – 149.8 MW (21 power plants) and biogas (59 power plants) – 124.1 MW. In 2021 the share of bioenergy in electricity production was 0.6%.

As of today, 9.6 MW (3.5%) of bioenergy facilities are under occupation. It is known that at least four plants were shelled and damaged. One of them, a solid waste landfill biogas station in the Chernihiv region with a 1.1 MW installed capacity, was completely destroyed in March 2022.
Small hydro (<10MW)

At the beginning of 2022, there were 177 small hydropower plants (SHPPs) in Ukraine with an installed capacity of 120 MW (excluding the plants located in the territories temporarily occupied by Russia before February 24, 2022). In 2021 the share of SHPPs in electricity production was 0.1 %.

As of today, 5.1 MW, or 4% of the total installed capacity of SHPPs are under occupation.

Storage

In 2021, the first pilot energy storage facility with an installed capacity of 1 MW was built at the Zaporizka TTP, and at least 212 MW of storage capacities were at different stages of development.

Nowadays, the only electricity storage facility in Ukraine is under occupation, and the implementation of all planned projects has been temporarily suspended.

Transmission system

The Ukrainian electricity transmission system includes 23,600 km of overhead lines and 141 substations with a voltage 110–750 kV operated by the Ukrainian transmission system operator (TSO) NEC "Ukrenergo". On 16 March 2022, Ukrainian Power Grid successfully synchronised with the Continental European Grid. (ENTSO-E) in response to Russia's invasion of Ukraine. On June 30, 2022, Ukraine started commercial electricity export to the ENTSO-E countries (currently about 500 MW per hour). The maximum available capacity of interconnectors with the ENTSO-E countries is ~2,300 MW per hour.

Nowadays, more than 30 overhead lines and more than ten substations with a voltage 220–750 kV are either damaged or disconnected due to continuous shelling and hostilities.

Distribution networks

The electricity distribution systems in Ukraine include more than 800 thousand km of overhead and cable lines with 0.4 - 150 kV voltage and about 200 thousand 6-150 kV transformer substations operated by 32 distribution system operators (DSOs).

As of today, more than 1,200 overhead lines (6–150 kV) and more than 7.7 thousand transformers (6-150 kV) are damaged or disconnected due to continuous shelling and hostilities.
**Demand and supply**

At the beginning of 2022, there were 17.7 mln electricity consumers in Ukraine, including 17.2 mln households and 0.5 mln commercial customers.

As a result of hostilities, electricity demand decreased by 30-35% compared to 2021. The consumption pattern also changed due to the shutdown of industrial enterprises and the massive displacement of consumers from Eastern to Western Ukraine. It is foreseen that the total electricity generation in 2022 will be 25% less than the “pre-war” forecast due to Russian military aggression. Since February 24, 2022, more than 7.2 mln consumers have been cut off from power supply. Currently, the electricity supply has already been restored to more than 6.6 mln consumers. As of August 24, 2022, about 792 settlements in Ukraine remained without electricity (completely or partially), covering about 605 thousand consumers.

**NATURAL GAS SECTOR**

**Natural gas production**

Ukraine has the third-largest proven natural gas reserves in Europe (up to ~719 bcm). The largest reserves are located in Poltava, Kharkiv, Lviv regions, as well as on the shelf of the Black and Azov Seas. In 2021, there were about 560 issued licenses and 25 large companies operating in the oil and gas exploration and production sector, including three state-owned and 22 companies with Ukrainian and foreign investments. Over the last 20 years, the volume of natural gas production in Ukraine was about 20 bcm/year (~ 55 mcm/day). Ukraine’s main gas production regions (excluding the territories temporarily occupied by Russia before February 24, 2022) are Poltava and Kharkiv regions (~90% of total production).

After February 24, 2022, about 20% of the country’s natural gas reserves are under Russian occupation. More than 150 gas production facilities, primarily located in the Kharkiv region, were suspended because of hostilities. Therefore, the average daily production decreased by almost 11% (~ 49 mcm/day). The information on damages to natural gas production facilities is restricted.

**Underground gas storage**

Ukrainian underground natural gas storages (UGS) are the largest in Europe and 3rd in the world after the US and Russia. There are 13 UGS facilities in Ukraine with a total working gas storage capacity of 31.95 bcm/y (including two UGS with a total capacity of 1.4 bcm/y located in regions temporarily occupied by Russia before February 24, 2022), with maximum gas injection and withdrawal capacity of above 250 and 260 mcm/day, respectively. Most UGS capacities are located in Western Ukraine (25.32 bcm/y or 79%).

After February 24, 2022, the operation of one UGS in the East (0.42 bcm/y) was suspended due to hostilities, and one UGS in the central part of Ukraine (capacity 0.31 bcm/y) was damaged. Thus, about 8% of UGS capacities remain unavailable, including 5.7% (1.82 bcm/y) in the temporarily occupied territories and 2.3% are damaged.

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5 Extractive Industries transparency Initiative: Report of Ukraine, 2020, EY
6 Underground gas storage in the world - 2018 Status, CEDIGAZ INSIGHTS
The Ukrainian natural gas transmission system (GTS) is one of the most developed in Europe, with a total length of more than 38,000 km and interconnections with the following EU member states Poland, Slovakia, Hungary and Romania. The total capacity of the GTS: “entry” points is 281 bcm/year (770 mcm/day) and “exit” points – 146 bcm/year (400 mcm/day). 41.6 bcm of Russian natural gas transited via Ukraine GTS to Europe in 2021.

From May 2022, the volume of transit of Russian gas through Ukraine to EU consumers decreased by approximately 30% due to the interruption of gas transit through the "Sokhranivka" gas metering station (GMS) located on the territory temporarily occupied by Russia. As a result, in May-August 2022, the gas transit through Ukraine's territory decreased to 40-42 mcm/day or to 37-38.5% of the capacity contracted by Gazprom (109 mcm/day). About 200 km of gas pipelines and equipment are known to be damaged due to Russian hostilities. Despite the damages, the Ukrainian TSO expressed its readiness to increase transit volumes to the EU via GMS "Sudzha" (capacity 77-244 mcm/day), while Gazprom reduced transit volumes.

Gas distribution networks

There are about 290,000 km of gas distribution networks operated by 45 gas distribution system operators (DSOs) in Ukraine.

Since February 24, 2022, approximately 7,000 km of distribution networks in Eastern and Southern Ukraine have been destroyed or damaged (approximately 10% of the distribution networks in Eastern and Southern Ukraine). More than 5,000 gas distribution control units were either suspended or damaged.

Demand and supply

At the beginning of 2022, there were 12.6 mln of natural gas consumers in Ukraine, including 12.5 mln households and 0.1 mln commercial customers.

As a result of the hostilities and damaged infrastructure, natural gas consumption decreased by more than 30% compared to daily consumption in 2021. As of August 24, 2022, about 234.9 thousand households are left without the gas supply (2% of the total). Due to damages, consumers of the Donetsk region are almost entirely disconnected from the gas supply. DSO companies regularly restore gas supplies where possible, but regular attacks by Russian troops lead to new damages and destructions.
OIL & PETROLEUM PRODUCTS

Oil production

Ukraine’s oil reserves are estimated at approximately 85 mln tons. More than 51% of the total reserves are concentrated in the North and Central regions, 36% in the Western and 13% in Southern Ukraine. Oil and gas condensate production in 2021 amounted to 2.4 mln tons (6.66 thousand tons/day). In 2021, there were 25 large companies operating in the oil and condensate exploration and production sector, including two state-owned (that produced about 80% of total oil production) and more than 20 companies with Ukrainian and foreign investments (up to 20% of total oil production).

After February 24, 2022, more than 10% of the country’s oil reserves are located in temporarily occupied territories. The volume of oil production in areas close to active hostilities and under the constant threat of occupation has decreased significantly. The information on damages to oil production facilities is restricted.

Oil transmission system

In 2021, the oil transmission system of Ukraine included 19 oil pipelines with a diameter of up to 1,220 mm, a total length of 3,506.6 km and 176 pumping stations. The total capacity of the tank park was 1,083 thousand m³. The total capacity of the oil transmission system at the “entry” points was 114 mln tons/year, at the “exit” points - 56.3 mln tons/year in 2021. The system transmitted oil from Ukrainian oil fields and seaports, i.e. imported by sea transport (including for the needs of the refinery of Belarus), as well as transited Russian oil through the “Druzhba” oil pipeline (to Slovakia, the Czech Republic, and Hungary). In 2021, the Ukrainian oil transmission system transported 15.7 mln tons, including 12.7 mln tons - of transit of Russia’s oil and 3.0 mln tons – to local refineries.

After February 24, 2022, a significant amount of principal and auxiliary equipment was damaged at three oil transmission facilities, including three cases of damage to cable communication systems. It is estimated that the volume of oil transit and transportation will be significantly reduced due to destroyed oil transmission facilities and Ukrainian refineries and the reduction/suspension of transit to Belarus in 2022.

Oil refinery and gas processing

In 2021, there were six refineries and one gas processing plant in Ukraine, with a total designed oil processing capacity of over 50 mln t/year. Still, the actual production capacity was about 7.5 mln t/year and was mainly based on the capacities of two plants: Kremenchuk Refinery (up to 7 mln t/year) and Shebelynka Gas Processing Plant (about 0.5 mln t/year). The two plants covered about 25% of the needs of the Ukrainian demand for oil products, which was 12.35 mln t in 2021.

After February 24, 2022, the work of the Shebelynka GPP was suspended due to Russian hostilities and the plant was later damaged by a missile attack. Multiple missile attacks destroyed the Kremenchuk Refinery (in total, Russia shot 27 missiles at Kremenchuk city) and damaged the facilities of Odesa and Lysychansk Refineries (the Rosneft oil company owns the latter). As a result, the Ukrainian oil refinery industry has been destroyed and the country is almost 100% dependent on imported petroleum products.

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7 Extractive Industries transparency Initiative: Report of Ukraine, 2020, EY
8 Note: Starting from 2014, only two out of six oil refinery and gas processing plants remained active in Ukraine, mainly due to changes in the structure of the owners as well as aging refinery equipment.
Consequences of the shelling of the Kremenchuk Oil Refinery, Poltava region

Oil products storage (oil depots)
Since oil product storage capacities were among the primary targets for Russian military forces, the information about the total number of oil depots and "pre-war" status is restricted.
Since February 24, 2022, more than 27 oil depots have been destroyed or significantly damaged in almost all regions of Ukraine.

Fuel stations
In 2021, there were more than 7,500 fuel stations, including petroleum, natural gas and electricity charging stations in Ukraine. The vast majority of stations belong to private companies.
It is impossible to accurately estimate the number of fuel stations damaged or destroyed due to occupation and ongoing hostilities.
COAL

**Coal production**

Ukraine is a coal-rich country with the largest coal reserves in Europe\(^9\). According to various estimates, the total proven coal reserves equal to 38 bln tons (including the coal reserves located in the territories temporarily occupied by Russia before February 24, 2022). About 92.4% of total coal reserves are located in the Donetsk coal basin (Donbas). In 2021, Ukraine produced about 29 mln tons of hard coal. For comparison, the average production of coal before Russia occupied the territories of Donbas in 2014 was 80 mln tons per year.

As of today, about 63% of the country’s coal deposits are temporarily occupied by Russia.

**Coal mines**

There were 151 coal mines in operation in 2013 (before Russia temporarily occupied the Donbas region in 2014) and only 47 coal mines in 2021 (before the full-scale invasion of the Russian Federation of Ukraine on February 24, 2022).

As of today, 95 mines are located in the Ukrainian territories temporarily occupied by Russia, including 28 privately owned and 67 state-owned mines. According to the publicly available data, at least six coal mines are flooded, threatening an ecological disaster in the region.

* ![Flooded coal mine, Donetsk region](source: Depositphotos)

**URANIUM (mines and refinery)**

There are three uranium mines and uranium refinery capacities in Ukraine located in Dnipropetrovsk and Kirovograd regions. In 2021, the domestic mining, processing of uranium ores and nuclear fuel production covered about 40% of the country’s needs. In 2021, Ukraine commissioned the centralised storage of used nuclear fuel in the exclusion zone of the Chornobyl NPP. The life cycle of the storage is at least 100 years.

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\(^9\) [Coal reserves - Country rankings, The global economy](https://www.globalenergy.org/en/)
The exclusion zone of the Chornobyl NPP was under occupation from February 24, 2022, to March 31, 2022. As a result of the occupation, the Russian military forces looted and destroyed the newest Central Analytical Laboratory in Chornobyl, a unique complex with powerful analytical capabilities that could provide services related to radioactive waste management (from conditioning to disposal, as well as at the stage of research and development of technologies).

**AMMONIA**

Ukraine’s ammonia pipeline is the fifth largest in the world. Ammonia is transferred from the Russian chemical enterprise in Tolyatti to the Odessa Port Plant in Yuzhny city. The length of the pipeline is 2,417 km, of which 1,021 km pass through the territory of Ukraine. The capacity of the ammonia pipeline is up to 2.5 mln tons per year.

Even if there is no supply of ammonia from the territory of Russia, the pipeline has the potential to be used to transport ammonia converted from “green” hydrogen.

On February 24, 2022, the first day of the Russian invasion of Ukraine, the transit of ammonia through the pipeline was stopped. On May 30, 2022, the Russian military forces damaged the ammonia pipeline branch located in the Bakhmut district of Donetsk region.

*Ammonia leak after pipeline damage, Bakhmut district of Donetsk region*

**LITHIUM**

According to preliminary estimates, Ukraine’s overall lithium resource potential is relatively high (approximately 500,000 tons of lithium oxide)\(^\text{10}\). This ultra-light metal is a critical element for the future of the Ukrainian power system as it is widely used to make power batteries, including energy storage and electric vehicles. There are two explored deposits and two pre-explored areas of lithium ores in Ukraine.

As of today, at least two lithium deposits are located in the territories temporarily occupied by Russia (Zaporizhzhia and Donetsk regions).

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\(^{10}\) PROSPECTS OF DEVELOPMENT OF LITHIUM RESOURCE BASE IN UKRAINE
DISTRICT HEATING

Thermal energy is mainly produced by CHPs (described above) and heat-only boilers (HOBs) in Ukraine. In 2021, there were ~19,025 HOBs in Ukraine from which the thermal energy was transported by 1,9 mln km of pipelines and distributed through 5,523 central heating points. The energy balance in the district heating sector consists of gas and coal, which together make up 90%, and about 10% of bioenergy.

As of today, a minimum of 329 HOBs, 222 km of pipelines and 99 central heating points have been destroyed or damaged. Since the local district heating infrastructure has been severely damaged due to Russian hostilities, there will be no heating season in some regions of Ukraine. For that reason, Ukraine is evacuating civilians from the Donetsk region. Likely, Ukraine will also need to evacuate civilians from some parts of Zaporizhzhia, Kherson and Kharkiv regions to avoid a humanitarian crisis in these territories during the winter.

*Heat pipeline after shelling, Kharkiv*

Source: Day.kyiv.ua