

Ukrainian energy sector evaluation and damage assessment - XI

(as of June 24, 2023)

**Cooperation for Restoring the
Ukrainian Energy
Infrastructure project**

Task Force

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INTRODUCTION

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

The first Ukrainian energy sector evaluation and damage assessment report was published on August 24, 2022, on the six-month anniversary of Russia's full-scale invasion¹. Since then, the Task Force regularly provided the international community with reliable information on key energy sector damages on a monthly basis². This is the eleventh edition of the document that provides a concise overview of key attacks and damages inflicted on the Ukrainian energy infrastructure from May 25 to June 24, 2023.

Russia occupied, damaged or destroyed about 50% of the country's installed power capacity, thousands of km of electric, gas and heat networks, transformers, compressor stations, heat-only boilers and other infrastructure facilities. The oil refining industry was destroyed. Electricity and natural gas consumption decreased by 30-35% compared to 2021.

According to the latest analysis as of April 2023, the direct losses of the Ukrainian energy sector, including utilities and district heating sectors, were estimated at **\$11 bln** by the Kyiv School of Economics³ and **\$10.6 bln** by the World Bank⁴. It is expected that the actual damages may be higher, as there is no complete information on energy facilities located in the temporarily occupied territories, and considering the current restrictions on publishing detailed information on the damages caused to the country's energy infrastructure facilities.

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 Task Force, "Ukrainian energy sector evaluation and damage assessment – I (as of August 24, 2022)", 2022,

https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/20220829_UA_sectoral_evaluation_and_damage_assessment_final.pdf

² Task Force, "Ukrainian energy sector evaluation and damage assessment – II – IX:

https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2022_09_30_UA_sectoral_evaluation_and_damage_assessment_Version_II.pdf

https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2022_10_24_UA_sectoral_evaluation_and_damage_assessment_Version_III.pdf

https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2022_11_24_UA_sectoral_evaluation_and_damage_assessment_Version_IV.pdf

https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2022_12_20_UA_sectoral_evaluation_and_damage_assessment_Version_V.pdf

https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2023_01_24_UA_sectoral_evaluation_and_damage_assessment_Version_VI.pdf

https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2023_02_27_UA_sectoral_evaluation_and_damage_assessment_Version_VII.pdf

https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2023_03_28_UA_sectoral_evaluation_and_damage_assessment_Version_VIII.pdf

https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2023_04_27_UA_sectoral_evaluation_and_damage_assessment_Version_IX.pdf

https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2023_05_24_UA_sectoral_evaluation_and_damage_assessment_Version_X_final.pdf

³ \$147.5 billion — the total amount of damages caused to Ukraine's infrastructure due to the war, as of April 2023, <https://kse.ua/about-the-school/news/147-5-billion-the-total-amount-of-damages-caused-to-ukraine-s-infrastructure-due-to-the-war-as-of-april-2023/>

⁴ Rapid Damage and Needs Assessment, February 2022 – February 2023,

<https://documents1.worldbank.org/curated/en/099184503212328877/pdf/P1801740d1177f03c0ab180057556615497.pdf>

KEY CHANGES IN THE UKRAINIAN ENERGY SECTOR

(May 25 – June 24, 2023)

During the 16th month of the war, Russia intensified its massive attacks. However, due to constant changes in Russia's tactics aiming to inflict maximum damages on critical energy infrastructure facilities and the increased effectiveness of the Ukrainian defense forces intercepting up to 90% of Russia's missiles and drones, it was no longer possible to draw a clear line between attacks targeting energy objects and other facilities.

June 2023 was marked by the largest man-made disaster since the accident that occurred Chornobyl Nuclear Power Plant in April 1986. On June 6, 2023, the Russian military forces blew up the Kakhovska hydropower plant (HPP) and the Nova Kakhovka dam. The man-made flood destroyed entire villages, released at least 150 tonnes of machine oil, destroyed farmlands, deprived tens of thousands of people of their access to electricity and clean water, and caused massive environmental damage.

Satellite images of the Nova Kakhovka dam before (June 5, left) and after the explosion (June 7, right)



Source: Maxar Technologies/Reuters, [CNN](#)

The information below provides a concise overview of key damages inflicted on the Ukrainian energy infrastructure from May 25 to June 24, 2023.

On May 25, 2023, Russian military forces launched a massive attack on the whole territory of Ukraine using drones. The power grid in the Chernivtsi region was damaged.

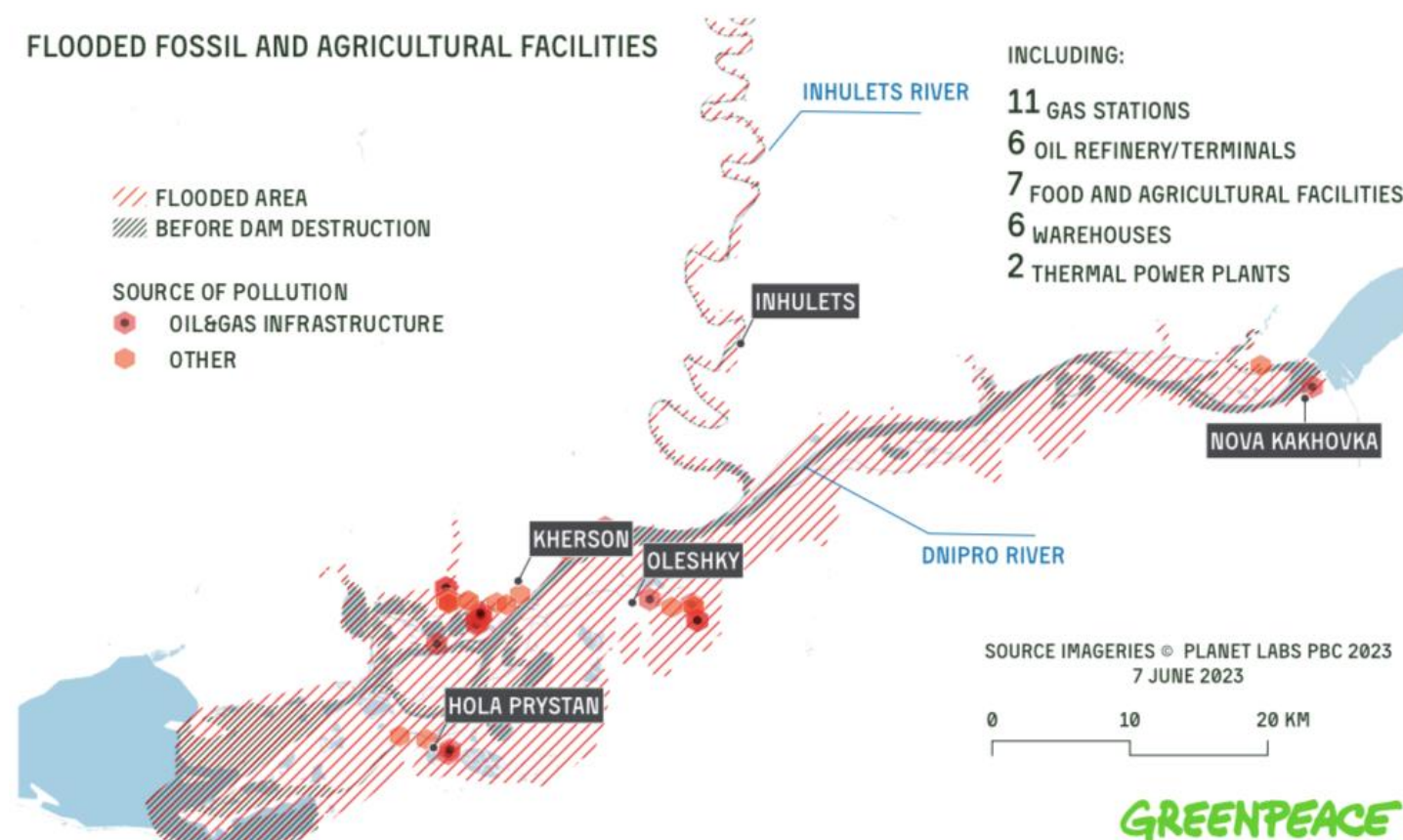
On May 30, 2023, the Ukrainian energy system was desynchronized due to an emergency related to the massive attack. In total, almost 2 million consumers were cut off from the electricity supply in many regions. All Ukrainian

HPP and pumped storage plants (PSPs) were working at full capacity to maintain the frequency and balance of the power system.

On June 2, 2023, Russia launched another massive attack on Kyiv and the Kyiv region. As a result, multiple power lines were damaged.

On June 6, 2023, the Russian military forces blew up the Kakhovka hydropower station (HPP) and the Nova Kakhovka dam. As a result of the dam destruction, 129 substations, two thermal power plants and 17 oil and gas infrastructure facilities in the Kherson region were flooded. In total, more than 20,000 consumers were disconnected from the electricity supply in the Kherson region. In addition, two solar power plants were flooded in the Mykolaiv region.

Impact of the Nova Kakhovka dam destruction



Source: [Greenpeace](https://www.greenpeace.org/ukraine/en/press-releases/2023/06/07/kakhovka-dam-destroyed/)

On the same day, Russia launched another massive missile attack on the entire territory of the country. As a result of the attack, the power grid in Kyiv and the Kyiv region was damaged.

On June 9, 2023, the Russian military forces launched another massive attack using missiles and drones on multiple Ukrainian regions. Two gas production facilities and the transmission network in the Zhytomyr region were damaged. One of the natural gas transmission system facilities in the Zaporizhzhia region was also damaged as a result of artillery shellings.

On June 10, 2023, Russia launched another massive attack on the territory of Ukraine using missiles and drones. A gas production facility was damaged. The supply of natural gas from this facility to the transmission network was temporarily stopped.

On June 13, 2023, Russia launched another attack on the territory of Ukraine using missiles and drones. The multiple elements of the power transmission network facilities were damaged. More than 9,000 people were disconnected from the electricity supply. Three coal mines in Kryvyi Rih remained without electricity and the miners were trapped underground until the power supply was restored.

On June 20, 2023, the power grid in the Kyiv region was damaged during a drone attack.

On June 20, 2023, Russia launched another missile and drone attack on the territory of Ukraine. As a result of the attack, the power grid in Kyiv was damaged. About 4,800 consumers were disconnected from the power supply.

Besides the massive missile and drone attacks, the Russian military forces continued to attack energy infrastructure facilities with artillery which caused power supply outages in the frontline regions almost every day. Despite Russia's tactic of targeting the personnel of the energy companies performing emergency repairs described in the previous reports, the power supply in most regions was effectively restored within the same day.

In June 2023, the Ukrainian power system had several challenges related to the large deficit of electricity generation. Firstly, the destruction of the Nova Kakhovka dam by Russia on 6 June 2023 resulted in the reduction of power generation by all HPPs. Hydropower plants had to operate at minimum capacities in order to reduce the water level in the Kakhovske reservoir and reduce flooding in the Kherson and Mykolaiv regions. Secondly, the consumption of electricity during the peak hours increased because of hot weather conditions and consequently the use of air conditioners. Therefore, Ukrainian power companies were forced to resort to emergency measures and use electricity imports from European countries to cover the deficit.

In June 2023, Ukrainian authorities and energy companies continued the preparation for the next heating season. In particular, companies increased the natural gas injection into underground gas storage facilities. The Ministry of Energy of Ukraine, together with energy sector companies, developed an optimized schedule for power plant repairs to maximize generating capacity of the energy system before the beginning of the 2023-2024 heating season. Therefore, June 2023 was also marked by the most extensive repair campaign of the energy infrastructure over the last 30 years.

DAMAGES AND LOSSES OF THE ENERGY INFRASTRUCTURE

The full-scale military aggression by the Russian Federation caused significant damage to the Ukrainian energy sector. As of June, 2023, there were three up-to-date key studies estimating damages and losses in the Ukrainian energy sector:

- Report on the direct damage to the infrastructure from the destruction caused by Russia's military aggression against Ukraine a year after the start of the full-scale invasion, as of March 2023, by the Kyiv School of Economics (KSE)⁵, including the updated analysis as of April 2023⁶.
- Rapid Damage and Needs Assessment (RDNA), February 2022 – February 2023, as of March 2023, by the World Bank⁷.
- Ukraine Energy Damage Assessment Report prepared by the United Nations Development Programme (UNDP) and the World Bank⁸.

According to the KSE's assessment, the damages to the Ukrainian energy sector, were at least **\$11 bln**, including **\$8.3 bln** in the energy sector and **\$2.7 bln** in the utility infrastructure (including the district heating, water supply and drainage, and household waste management facilities).

According to RDNA, damage to the energy sector of Ukraine is estimated at **\$10.6 billion**, including **\$6.5 billion** damage in the power sector only. The total needs for recovery and reconstruction of the energy sector are estimated at **\$47 billion**.

According to UNDP and the World Bank, damage to power, gas, and heating infrastructure and coal mining is **above \$10 billion**.

In addition to the inflicted damages, the Russian Federation also took control of Ukraine's mineral deposits worth at least **\$12.4 trillion**. Ukraine has lost 63% of coal deposits, 11% of oil deposits, 20% of natural gas deposits, 42% of metal deposits and 33% of deposits of rare earth elements and other critical minerals, including lithium.⁹

It should also be noted that the actual damages and losses most likely will be higher as there is no complete information on Ukrainian facilities located in the temporarily occupied territories and no publicly available information on the detailed damages caused to the country's energy infrastructure facilities.

⁵ Report on the direct damage to the infrastructure from the destruction caused by Russia's military aggression against Ukraine a year after the start of the full-scale invasion, https://kse.ua/wp-content/uploads/2023/03/UKR_Feb23_FINAL_Damages-Report.pdf

⁶ \$147.5 billion — the total amount of damages caused to Ukraine's infrastructure due to the war, as of April 2023, <https://kse.ua/about-the-school/news/147-5-billion-the-total-amount-of-damages-caused-to-ukraine-s-infrastructure-due-to-the-war-as-of-april-2023/>

⁷ Rapid Damage and Needs Assessment, February 2022 – February 2023, <https://documents1.worldbank.org/curated/en/099184503212328877/pdf/P1801740d1177f03c0ab180057556615497.pdf>

⁸ Ukraine Energy Damage Assessment Report, <https://www.undp.org/ukraine/publications/ukraine-energy-damage-assessment>

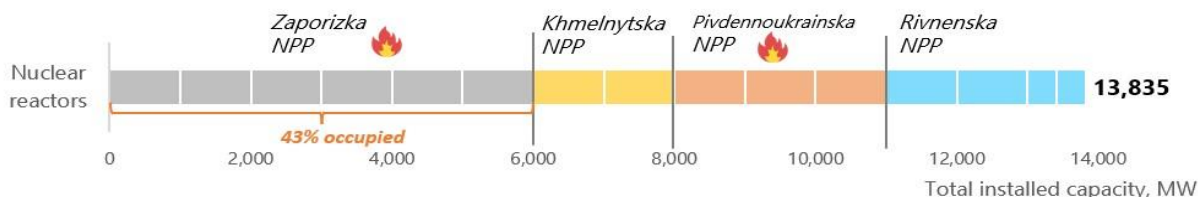
⁹ In the Ukraine war, a battle for the nation's mineral and energy wealth, <https://www.washingtonpost.com/world/2022/08/10/ukraine-russia-energy-mineral-wealth/>

GENERAL SITUATION

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 operating NPPs in Ukraine with a total installed capacity of 13,835 MW (15 reactors in total, including 13 reactors with a capacity of 1,000 MW and two reactors with a capacity of 415 MW and 420 MW, respectively).



Source: Energy Charter Secretariat (ECS) based on publicly available data

Zaporizka NPP (ZNPP), the largest nuclear power plant in Europe and the fifth largest in the world (Power Technology, 2019)¹⁰, 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. Since September 11, 2022, the operation at ZNPP was suspended. Pivdennoukrainska NPP was shelled. Khmelnytska NPP and Rivnenska NPP were also affected due to attacks on transmission system infrastructure.

State Company (SC) Energoatom, the operator of all Ukrainian NPP's, conducted a preliminary analysis of the damages inflicted by the Russian military forces on the ZNPP. According to the analysis, the estimated value of destroyed and damaged assets as of March 2023 was about \$0,8 bln. The final amount of losses and damages inflicted by Russia on the ZNPP will be determined after the liberation of the plant.

In May 2023, Russia continued increasing their military presence at the ZNPP and created defensive positions constructed from sandbags on reactor buildings (see photo above). According to IAEA, the Russian military forces stored military equipment, weapons and explosives materials in the turbine hall of reactor #4¹¹

In May 2023, the Russian Federation also imposed draconian measures on the staff, increased pressure and threats on the plant's employees and forbade the workers to communicate with each other¹². As of mid-May 2023, only 2,500 ZNPP workers were still operating the Plant¹³. In contrast, there were about 11,000 employees at the ZNPP before the beginning of the war¹⁴. The duress under which NPP staff are having to operate is an imminent threat to the safe operation of the Ukrainian NPPs. Operating under such stress exacerbates the impact of human error and hinders the safe operation of the Ukrainian NPPs¹⁵.

In June 2023, Russia continue to increase its military presence on ZNPP and put pressure on the plant's employees.

¹⁰ "Top ten nuclear power plants by capacity", Power Technology, 2019, <https://www.power-technology.com/analysis/feature-largest-nuclear-power-plants-world/>

¹¹ Russian occupants located military equipment and explosives in the turbine room of ZNPP Unit 4, [Russian occupants located military equipment and explosives in the turbine room of ZNPP Unit 4 | State Nuclear Regulatory Inspectorate of Ukraine \(snriu.gov.ua\)](https://snriu.gov.ua/)

¹² At ZNPP, control over nuclear workers has strengthened: staff is forbidden to even communicate with each other, <https://www.energoatom.com.ua/app-eng/eng-1605231.html>

¹³ Ibid.

¹⁴ <https://interfax.com.ua/news/general/884989.html>

¹⁵ Dangerous Targets: Civilian Nuclear Infrastructure and the War in Ukraine. Preliminary Lessons for Safety and Security in War Zones, <https://static.rusi.org/398-SR-Dangerous-Targets-web-final.pdf>

According to the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU), the so-called Russian "administration" of the plant resorted to the dismantling or theft of important elements of the nuclear safety system (i.e. computer equipment, sensors etc.), destroyed the automatic emergency response system and blocked the information transfer from the Automated System for Radiation Monitoring.

The destruction of the Nova Kakhovka dam on June 6, 2023, led to a significant reduction in the level of the reservoir used to supply cooling water to the ZNPP. According to the Ministry of Defence of Ukraine, the Russian military forces also planned explosives at the cooling pond of the ZNPP. An insufficient level of cooling water and the potential destruction of the cooling pond by Russia added new ominous risks related to the safe operation of the ZNPP.

According to Energoatom, after the liberation of the Zaporizhzhia NPP and the satellite city of Energodar, it would take at least two months to defuse the explosive devices installed by the Russian military Forces, check the condition of equipment related to the safe operation of the plant, facilities and the surrounding area.

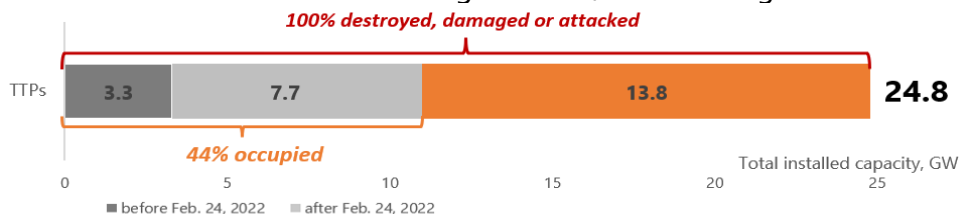
Thermal energy

At the beginning of 2022, there were 12 TPPs in Ukraine with a total installed power capacity of 21.5 gigawatts (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 TPPs' share in electricity production was 23.8%. 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, and Vuglehirska TPP) with a total installed capacity of 7.7 GW. As of April, 2023, Ukraine lost about 78% of its thermal power capacities.

All TPP's under Ukrainian control before February 24, 2022 were either destroyed or damaged (see figure below). The majority of TTP's were attacked more than one time. Almost twenty TPP power units remain damaged due to constant attacks.

DTEK Energy, the largest operator of TPPs in Ukraine, estimated damages from Russia's attacks on these plants at \$160 million. In total, the facilities of the company were attacked 30 times and more than one thousand pieces of equipment were damaged. The TTPs of the state-owned company "Centrenergo" were targeted during 13 out of 15 massive missile attacks and were hit 32 times during the 2022/2023 heating season.



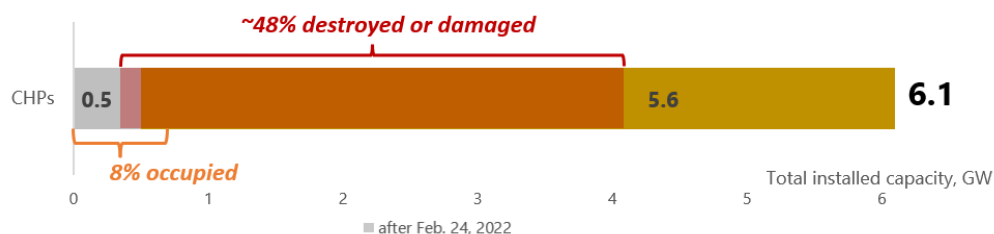
Source: ECS based on publicly available data

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 8% of the installed capacity from CHPs is under occupation, while at least 48% of installed capacities (including 2/3 capacities of CHPs used for balancing the power system) are either destroyed or damaged as a result of Russian attacks (see figure below).

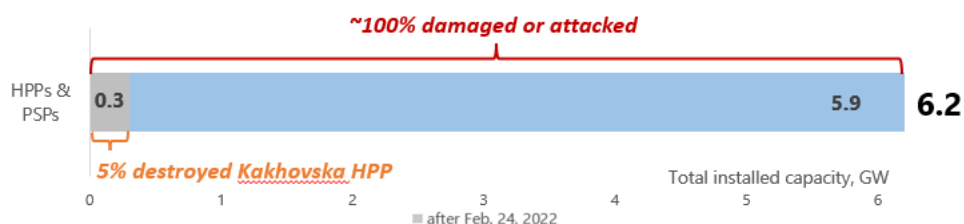
According to preliminary estimates, during the period of the full-scale invasion, five CHP located near the frontline were completely destroyed, while eight CHPPs in Kharkiv, Sumy, Mykolaiv, and Kyiv regions were damaged.



Source: ECS based on publicly available data

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). Three pumped storage plants (PSPs) with an installed capacity of 1.5 GW (11 units ranging from 33 MW to 324 MW per unit) (see Annex 1 for more details). 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 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. All of the Ukrainian hydropower facilities were either damaged or attacked.



Source: ECS based on publicly available data

During the 2022/2023 heating season, there were more than 30 missile hits on hydropower facilities. According to Ukrhydroenergo in total company lost 2,000 MW of generating capacity during the war. As of April 2023, the company restored 500 MW and another 1,500 MW remained damaged or destroyed. As of April 2023, powerlines connecting the HPPs to the grid, including reserve ones, were able to transmit only 50-70% of the installed capacity of operating plants due to the inflicted damages and required urgent restoration.

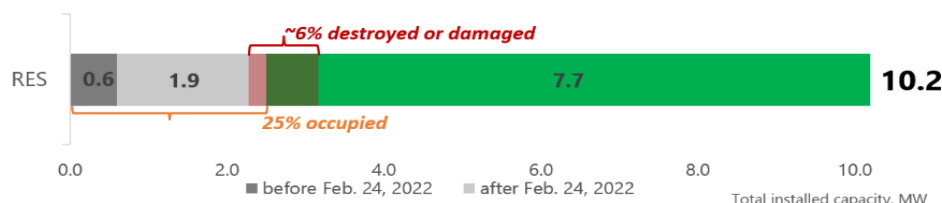
On June 6, 2023, Russia destroyed the Kakhovska HPP. According to a preliminary assessment, the estimated amount of losses due to the destruction of the Kakhovska HPP is about \$1,5 billion. The power plant is destroyed and cannot be restored. According to Ukrhydroenergo, it will take a minimum of 6 years to dismantle the destroyed plant and build a new one.

Renewable energy (excluding large HPP)

Ukraine has the highest technical RES potential among other countries in Southeast Europe - 874 GW¹⁶, including solar - 83 GW, onshore wind - 438 GW, and offshore wind - 250 GW. Due to its high RES potential and efficient support mechanisms, Ukraine's renewable energy sector has been developing rapidly, with the share of RES in electricity production increasing 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.

¹⁶ "Renewable energy sources of Ukraine", National Academy of Sciences of Ukraine, 2022, <https://www.ive.org.ua/wp-content/uploads/atlas.pdf>

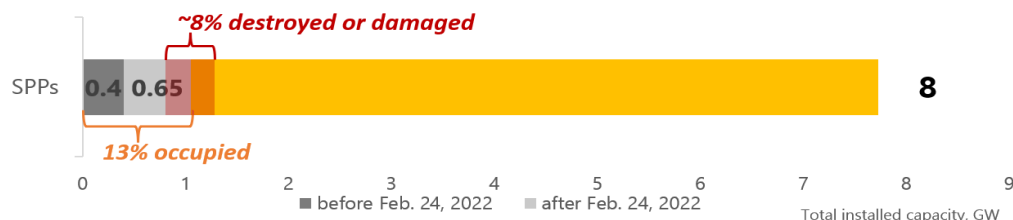
As of today, 2.5 GW (25%) of RES facilities are under occupation. About 6% of the total installed RES capacity has been destroyed or damaged.



Source: ECS based on publicly available data

Solar

The photovoltaic (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 0.4 GW 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 (including 45,000 prosumer installations with a total capacity of 1.2 GW). In 2021, Ukraine was ranked 7th in Europe for the development of solar generation (IRENA, 2022).¹⁷



Source: ECS based on publicly available data

As outlined in one of the previous reports, after the liberation of territories temporarily occupied by the Russian Federation at the end of 2022, RES facilities were gradually put into operation. For example, the results of the preliminary inspection indicate that about 20% of the solar panels at the liberated Tryfonivska SPP with an installed capacity of 10 MW were damaged.

On June 6, 2023, the Russian military forces blew up the Kakhovska HPP that led to the flooding of two solar power plants in the Mykolaiv region. Currently, about 13% of Ukrainian PV capacities are under occupation. About 8% of the total installed solar capacity has been destroyed or damaged, including hundreds of prosumer installations.

Wind

At the beginning of 2022, Ukraine's total installed capacity of wind power plants (all onshore) was 1.6 GW (excluding 0.2 GW 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 (Kherson and Zaporizhzhia regions), where natural conditions for wind power plants are the most favourable.

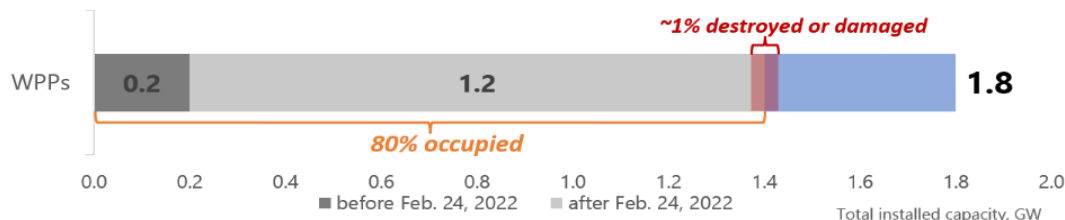
Currently, the Russian Federation occupies the south of Ukraine, where the highest wind potential is available. Thus, approximately 80 % of wind generation capacities are located in the occupied territories. As of today, at least 10 wind turbines are known to be damaged or destroyed as a result of the hostilities by the Russian army (about 1 % of the total installed wind capacity).

According to preliminary estimates of the Ministry of Energy and the Ukrainian Wind Energy Association, financial losses from the destruction, damages or theft of wind power plant equipment by the Russian Military Force were

¹⁷ "Renewable Energy Statistics 2022", IRENA, 2022, <https://www.irena.org/publications/2022/Jul/Renewable-Energy-Statistics-2022>

estimated at more than 50 million euros. At the same time, the lost revenue of the Ukrainian wind power industry due to the war was estimated at more than 500 million euros.

In May 2023, one of Ukraine's largest private energy companies, put into operation phase I of the Tyligulska Wind Power Plant (WPP) located just 100 km away from the frontline in the Mykolaiv region. The plant has 19 turbines with an installed capacity of 114 MW, generating up to 390 MWh, i.e. enough to power 200,000 households.

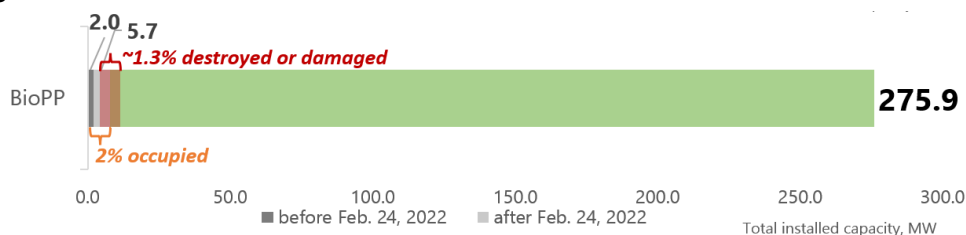


Source: ECS based on publicly available data

Bioenergy

At the beginning of 2022, the total installed capacity of bioenergy power facilities was 273.9 MW (excluding the 2 MW biomass power plant located in the territories temporarily occupied by Russia before February 24, 2022). In 2021, the share of bioenergy in electricity production was 0.6%.

As of today, 5.7 MW (1.3%) of bioenergy facilities are under occupation. It is known that at least four plants were shelled and damaged.

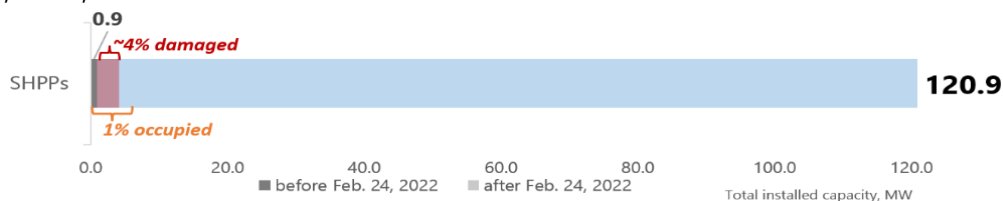


Source: ECS based on publicly available data

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 one SHPP (0.9 MW) located in the territories temporarily occupied by Russia before February 24, 2022). In 2021, the share of SHPPs in electricity production was 0.1 %.

Due to the liberation of Ukrainian territories in November, 2022, all SHPPs occupied by the Russian Federation after February 24, 2022, returned under the control of Ukraine.



Source: ECS based on publicly available data

Storage

In 2021, the first pilot energy storage facility with an installed capacity of 1 MW was built at the Zaporizka TPP, while 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.

On June 8, the National Commission for the State Regulation of Energy and Utilities issued the first energy storage license.

Transmission system

The Ukrainian electricity transmission system includes 23,600 km of overhead lines and 141 substations with a voltage of 110–750 kV operated by the Ukrainian transmission system operator (TSO) National Energy Company (NEC) "Ukrenergo". 25% of transmission substations were located in the territories temporarily occupied by Russia before February 24, 2022 and 12% were occupied after.

Due to Russian targeted attacks on transmission system infrastructure, about 43% transmission grids and about 50 % of transmission substations were destroyed or damaged. Some of the substations were attacked more than one time. In total "Ukrenergo" substations were hit 250 times.

On March 16, 2022, Ukrainian and Moldovan Power Grids 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 EU countries. Within 10 months in 2022, Ukraine exported electricity worth \$542.5 mln. The massive attack and consequential damages to the power sector also resulted in the Ukrainian government's decision to stop electricity export to the European Union (EU) starting from October 11, 2022.

As of April 2023, Ukraine continued importing small volumes of electricity from continental Europe's power system (ENTSO-E) as well as started exporting electricity to European countries. On April 18, 2023, Transmission System Operators of Continental Europe increased cross-border capacity for import to Ukraine to 1,050 MW. On June, ENTSO-E increased cross-border capacity for import electricity to Ukraine and Moldova to 1,200 MW

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 200,000 6-150 kV transformer substations operated by 32 distribution system operators (DSOs).

As of the beginning of January 2023, more than one thousand overhead lines (6-150 kV) and more than eight thousand transformers (6-150 kV) were damaged or disconnected due to continuous shelling and hostilities (not including power infrastructure disconnected due to emergencies).

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, almost all consumers have been temporarily disconnected from the electricity supply.

According to estimates based on "Ukrenergo" data, the average Ukrainian household had to endure five cumulative weeks without electricity from October 10 to December 31, 2022¹⁸.

Ukrainian TSO and DSO's restore electricity supply where possible, but regular attacks by Russian forces lead to new damages and destructions.

¹⁸ Ukraine Energy Damage Assessment Report, <https://www.undp.org/ukraine/publications/ukraine-energy-damage-assessment>

Natural gas sector

Natural gas production

Ukraine has Europe's third-largest natural gas reserves (up to 719 bln cubic meters (bcm)) (EY, 2020)¹⁹. The largest reserves are located in the Poltava, Kharkiv, and Lviv regions and on the Black and Azov Seas shelf. In 2021, there were about 542 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 (about 55 mln cubic meters (mcm)/day). Ukraine's main gas production regions (excluding the temporarily occupied territories by Russia before February 24, 2022) are the Poltava and Kharkiv regions (about 90% of total production).

After February 24, 2022, approximately 15% 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% (about 49 mcm/day).

At the end of October 2022 JSC "Ukrgezvydobuvannya" restored the operation of several infrastructure facilities in the de-occupied territory of Ukraine and has been preparing to launch others. The result will be additional production of about 0.5 mcm/day. However, in mid-November 2022, Russia started attacks on natural gas production infrastructure. The information on damages to natural gas production facilities is restricted.

Since the beginning of the Russian full-scale military aggression, 350 gas and oil facilities of the Naftogaz group were destroyed. The number of damaged Naftogaz facilities significantly increased in October-December 2022.

In 2022, about 18.5 bcm of natural gas was produced in Ukraine or only 6% less than in 2021 (19.8 bcm) However, it was lowest level of Ukraine's natural gas production over the last 20 years²⁰.

The main reason for the reduction in production is the full-scale war that Russia started in Ukraine at the end of February 2022. The occupation of part of the territory of Ukraine (especially the Kharkiv region, where significant reserves and gas production capacities are concentrated) had a negative impact on gas production in these regions and near-front line.

As of February 2023, state-owned company Naftogaz estimated its war-related damages of gas infrastructure at \$1 bln.

Underground gas storage

Ukrainian underground natural gas storages (UGS) are the largest in Europe and 3rd in the world after the US and Russia (Cornot-Gandolphe, 2018)²¹. There are 13 UGS facilities in Ukraine with a total working gas storage capacity of 31.95 bcm/year (including two UGS with a total capacity of 1.4 bcm/year located in regions temporarily occupied by Russia before February 24, 2022), with maximum gas injection and withdrawal capacities of above 250 and 260 mcm/day, respectively. Most UGS capacities are in Western Ukraine (25.32 bcm/year or 79%).

After February 24, 2022, the operation of one UGS in the East (0.42 bcm/year) was suspended due to hostilities, and one UGS in the central part of Ukraine (capacity 0.31 bcm/year) was damaged. Thus, about 8% of UGS capacities remain unavailable, including 5.7% (1.82 bcm/year) in the temporarily occupied territories, and 2.3% are damaged. There is no information about damages and losses on UGS located in the temporarily occupied

¹⁹ "National report of Ukraine 2020", EY Extractive Industries Transparency Initiative, 2020,

https://www.geo.gov.ua/wp-content/uploads/presentations/en/UA_EITI_Report_2020_EN.pdf

²⁰ <https://expro.com.ua/novini/ukrana-v-2022r-skorotila-vidobutok-gazu-na-6-do-185-mlrd-kub-m>

²¹ Sylvie Cornot-Gandolphe, "Underground gas storage in the world - 2018 status", *Cedigaz Insight* ed. 31, November 2018,

[https://cdn2.hubspot.net/hubfs/1982707/Overview%20of%20Underground%20gas%20storage%20in%20the%20world%202018%20\(1\).pdf](https://cdn2.hubspot.net/hubfs/1982707/Overview%20of%20Underground%20gas%20storage%20in%20the%20world%202018%20(1).pdf)

territories and areas close to active hostilities.

As of June 2023, the Ukrainian UGS system stored more than 10 bcm of natural gas.

Gas transmission system

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, from May to November 2022, the gas transit through Ukraine's territory decreased to 40-42.5 mcm/day or 37-39% 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.

Despite the suspension of natural gas transit via the Nord Stream 1 pipeline and increased demand on EU gas markets in August-November 2022, the Russian Federation did not increase the transit via Ukraine's GTS. On the contrary, Russia cut its natural gas production and increased flaring to keep EU market prices high.

In December 2022, the average volume of gas transit through the territory of Ukraine was 42.6 mcm per day which corresponded to 39% of the capacity officially contracted by Gazprom (109 mcm per day). It should also be noted that there is a high risk of a further reduction or suspension of gas transit via Ukraine's GTS due to the explosion of the "Urengoy-Pomary-Uzhhorod" gas pipeline located on the territory of the Russian Federation on December 20, 2022²². The pipeline crosses the Russian-Ukrainian border through the "Sudzha" gas measuring station, currently the only entry point for transiting natural gas from Western Siberia to Europe. The explosion further influenced the gas exchange prices on the European market. For example, the Dutch natural gas futures went up from €106.6/MWh to €115/MWh on the same date of the explosion in Russia²³.

At the end of December 2022, all heat only boilers in Donetsk region were forced to shut down as a result of the damage to the main gas pipeline in Kharkiv region, caused by the shelling, the main gas pipeline was damaged..²⁴

In 2022, Russia transported about 20.35 bcm of natural gas via the Ukrainian gas transportation system. This was the lowest level of transit flow since Ukraine became an independent state in 1991. Compared to the previous year, the volume of transit of Russian gas decreased by more than two times, i.e. from 41.6 bcm in 2021 to 20.35 bcm in 2022.²⁵

In 2022, Gazprom reduced gas supplies to Europe by 45%, or from 185 bcm in 2021 to 100.9 bcm in 2022, the lowest level in the history of Russian Federation. The sharp reduction in Russian gas supplies is directly related to the Russian invasion of Ukraine and the response of EU Member states reducing the dependence on Russian gas import. In addition, Russia reduced gas supplies to "unfriendly countries" that refused to pay for gas in rubles.

On January 7, 2023, as a result of the explosion of the main gas pipeline in the city of Lutugino in the Luhansk region (under temporary occupation), about 13,000 consumers were left without natural gas supply. According to "Operator GTS of Ukraine" LLC, the explosion had no effect on the transportation of natural gas from the Russian Federation through Ukraine²⁶.

²² Mind.ua, <https://mind.ua/news/20250978-v-rosijskij-chuvashi-ivibuhnuv-gazoprovod-cherez-ce-u-evropi-rizko-pidskochili-cini-na-gaz>

²³ Trading economics, <https://tradingeconomics.com/commodity/eu-natural-gas>

²⁴ <https://expro.com.ua/novini/na-harkvschin-poshkodjeno-magstralniy-gazoprovod-gazov-koteln-donechchini-zupinen>

²⁵ <https://expro.com.ua/novini/tranzit-rosyskogo-gazu-cherez-ukranu-vpav-do-storichnogo-mnimumu-20-mlrd-kub-m-u-2022r>

²⁶ <https://expro.com.ua/novini/na-magstralnomu-gazoprovod-v-lugansky-oblast-stavsya-vibuh>

In January 2023, Moldova officially allowed for all companies to use virtual natural gas reverse flow. It opened opportunities for both Ukrainian (gas imports from Greek and Turkish LNG terminals through the Trans-Balkan Corridor in reverse mode) and foreign (gas transmission via the same route to Ukrainian storages) system users.

On January 19-21, 2023, the volume of gas transit through the territory of Ukraine ranged 24.5-24.7 mcm per day, i.e. only 22-23% of the capacity contracted by Gazprom (109 mcm/day). On February 22, 2023, Gazprom increased transit through the Ukrainian GTS to 42,2 mcm per day, i.e. about 40% of the contracted capacity. As of March 7, 2023, the volume of transit was 42,37 mcm per day.

Gas distribution networks

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

Since February 24, 2022, more than 7,000 km of distribution networks in Eastern and Southern Ukraine have been destroyed or damaged (approximately 12% 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 January 24, 2023, about 600 thousand households were without the gas supply (5% of the total). Due to damages, natural gas consumers of the Donetsk region are almost entirely disconnected from the gas supply. Kherson, Dnipropetrovsk, Luhansk, Zaporizhzhia, Mykolaiv and Kharkiv regions had the most challenging situation. DSOs regularly restore gas supplies where possible, but regular attacks by Russian troops lead to new damages and destructions.

According to experts estimates, the consumption of natural gas in Ukraine in 2022 is expected to be 30% lower than in 2021, or 8.7 bcm less below the level of 2021. The volume of gas imports from the EU to Ukraine in 2022 decreased by 42%.

In 2022, due to war and regular damage to energy infrastructure facilities, households and the public sector significantly increased the use of liquefied gas. As a result, about 190,000 gas cylinders were imported into Ukraine in 2022, or six times higher than the corresponding figure for 2021²⁷.

Oil & petroleum products

Oil production

Ukraine's oil reserves are estimated at approximately 85 mln tons (EY, 2020)²⁸. 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, 25 large companies were 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

²⁷ https://enkor.ua/uk/news/ukrana_rekordno_zblshila_mport_gazovih_baloniv_uasg/255109

²⁸ "National report of Ukraine 2020", EY Extractive Industries Transparency Initiative, 2020, https://www.geo.gov.ua/wp-content/uploads/presentations/en/UA_EITI_Report_2020_EN.pdf

(up to 20% of total oil production).

After February 24, 2022, almost 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.

According to Ukrnafta, the largest oil extraction company in Ukraine, the company's oil production decreased by 8.6% in 2022 compared to 2021. There is no publicly available data about the overall reduction of oil production in Ukraine in 2022.

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 cubic meters. 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 oil transit and transportation volume will be significantly reduced due to destroyed oil transmission facilities and Ukrainian refineries and the reduction/suspension of transit to Belarus in 2022.

On November 15 and November 23 2022, the oil transportation to Hungary, Czechia, and Slovakia via "Druzhba" oil pipeline was suspended due to the damages inflicted on the substation powering the pipeline by the Russian military forces. However, the oil pipeline operation was restored the same day due to Ukraine's coping mechanisms and the efforts of the power sector employees.

Oil refinery and gas processing

In 2021, there were six refineries and one gas processing plant (GPP) in Ukraine, with a total designed oil processing capacity of over 50 mln tons/year²⁹. Still, the actual production capacity was about 7.5 mln tons/per year. It was mainly based on the capacities of two plants: Kremenchuk Refinery (up to 7 mln tons/year) and Shebelynka Gas Processing Plant (about 0.5 mln tons/year). The two plants covered about 25% of the needs of the Ukrainian demand for oil products, which was 12.35 mln tons 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. In September 2022, the Russian military forces continued regular shelling of the Shebelynka GPP and its fuel reservoirs. Multiple missile attacks destroyed the Kremenchuk Refinery (in total, Russia shot 32 missiles at the Kremenchuk Refinery) and damaged the facilities of Odesa and Lysychansk Refineries (the latter is owned by the Rosneft - the second largest Russian state-controlled Company after Gazprom).

As a result, the Ukrainian oil refinery industry has been destroyed, and the country is almost 100% dependent on imported petroleum products. According to the State Customs Service, Ukraine imported 5.8 mln tons of petroleum products (gasoline, diesel fuel, fuel oil, jet fuel, etc.) in January-October 2022, which is 13.1% less than in the same period last year (6.67 mln tons). Despite the reduction of the import volume, the costs of the imported oil products were 70.2% higher than in January-October 2021. On December 20, 2022, Russia attacked oil and gas

²⁹ 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 ageing refinery equipment.

infrastructure facilities in the Kharkiv region. As a result of the attack, the fire spread to an area of 4,500 square meters³⁰.

On February 16, 2023, Russia launched its 15th massive attack, primarily targeting oil refinery infrastructure. Multiple missiles hit Kremenchuk and Drohobych oil refinery plants although the plant in Kremenchuk had not been operating due to the damages inflicted during the previous attacks, and the plant in Drohobych had been stopped about 10 years ago. Apart from large refineries and other energy facilities, the massive attack also targeted mini refineries, one of which was damaged in the Kyrovograd region.

KSE estimates damages and losses at the Kremenchuk oil refinery at \$405 million and at Lysychansk (LYNIK) at \$126 million³¹. The equipment of both plants was seriously damaged due to Russia's attack in the first months of the war. In June 2023, Russia destroyed a new oil refinery in the Kharkiv region with a net worth of \$200 million.

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 30 oil depots have been destroyed or significantly damaged in almost all regions of Ukraine.

According to the Ministry of Environmental Protection and Natural Resources of Ukraine, the destruction of oil depots by the Russian military forces resulted in the additional emission of 499,000 tons of pollutants into the atmosphere. For comparison, the emissions of Ukraine's largest industrial polluter are estimated at 220,000 tons annually. The additional emissions pose substantial risks for neighbouring countries as, depending on the wind direction, dangerous pollutants from burnt oil products may move to the territories of other countries and fall there as acid rain. Since the beginning of Russia's invasion, the estimated volume of pollutants emissions has reached 46 mln tons. For comparison, this indicator was ten times lower in 2019 - about 2.4 mln tons, and in 2021 - 2.25 mln tons (Krechetova, 2022)³².

Fuel stations

In 2021, there were more than 7,500 fuel stations in Ukraine, including petroleum, natural gas and electricity charging stations. The vast majority of stations belong to private companies.

Since the beginning of the full-scale invasion, Russia's attacks either destroyed or damaged more than 300 fuel stations³³. 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 (TheGlobalEconomy.com, 2022)³⁴. According to various estimates, the total proved coal reserves are about 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

³⁰ Video of the explosion, NJSC "Naftogaz of Ukraine" <https://www.naftogaz.com/news/rosiya-vkotre-obstrilyala-ob-ekty-grupy-naftogaz-video>

³¹ Damages caused to Ukrainian business as a result of Russian aggression are estimated at \$13 billion — Kyiv school of economics, 2023

<https://kse.ua/ua/about-the-school/news/zbitki-zavdani-ukrayinskomu-biznesu-vnaslidok-rosiyskoyi-agresiyi-otsinyuyutsya-v-13-mlrd/>

³² Diana Krechetova, "How did the destruction of oil depots and Russian missile attacks affect air pollution? The Ministry of Environment is in charge", Life Pravda, 2022, <https://life.pravda.com.ua/society/2022/09/13/250436/>

³³ "The total amount of damage caused to Ukraine's infrastructure is more than \$136 billion" — Kyiv school of economics, 2022, <https://kse.ua/about-the-school/news/as-of-november-2022-the-total-amount-of-losses-caused-to-the-infrastructure-of-ukraine-increased-to-almost-136-billion/>

³⁴ "Coal reserves Europe – Country rankings", TheGlobalEconomy.com, 2022, https://www.theglobaleconomy.com/rankings/coal_reserves/Europe/

located in the Donetsk hard coal basin (Donbas). In 2021, Ukraine produced about 29 mln tons of hard coal. For comparison, the average coal production before Russia occupied Donbas's territories in 2014 was 80 mln tons per year.

Currently, about 60% of the country's coal deposits are temporarily occupied by Russia. As of May 2023, Ukrainian companies accumulated about 1.5 mln tons of coal reserves in their warehouses.

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).

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

In the occupied city of Dovzhansk (Luhansk region), Russia suspended activities and transferred industrial equipment from the Chervonyi Partyzan and Kharkivska mines to the Krasnoyarsk region, the Russian Federation³⁵. At the end of January 2023, Russia also closed down coal mines named after Zasiadko, Academician Skochynskyi and Kalynovska-skhidna which were also located on the territories temporarily occupied by the Russian Federation³⁶.

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.

The exclusion zone of the Chornobyl NPP was under occupation from February 24 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 Odesa Port Plant in Yuzhny city. The length of the pipeline is 2,417 km, of which 1,021 km passes 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 in the Bakhmut district of the Donetsk region.

The UN calls for the restoration of the Tolyatti-Odesa ammonia pipeline. The President of Ukraine, Volodymyr Zelenskiy, said that Ukraine would agree to resume the supply of Russian ammonia through the pipeline through Ukraine only if Russia returned the Ukrainian prisoners of war.

³⁵ Luhansk Regional Military Administration, <https://t.me/luhanskaVTSA/6977>

³⁶ <https://ru.slovovidlo.ua/2023/01/25/novost/obshhestvo/okkupanty-donbasse-zakryli-shaxtu-im.-zasyadka>

Lithium

According to preliminary estimates, Ukraine's total lithium resource potential is relatively high (approximately 500,000 tons of lithium oxide) (Vasylenko & Uliana, 2022)³⁷. 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 in Zaporizhzhia and Donetsk regions.

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.

At end of November, 444 HOBs, 128 central heating points and more than 200 km of district heating networks were either destroyed or damaged. At the same time, 316 damaged facilities were restored³⁸. Since the local district heating infrastructure has been severely damaged due to Russian hostilities, there are no heating season in some regions of Ukraine.

Electric vehicles

In 2021, there were 33,522 electric cars in Ukraine or about 1% of the total car fleet. Despite the energy crisis provoked by Russian attacks on energy infrastructure facilities in Ukraine, the demand for electric vehicles continues to grow. During November 2022, 1,447 battery electric vehicles (BEVs) were added to the car fleet of Ukraine, which is 60% more than last year but 10% less than in October this year.

Since the beginning of 2022, more than 12,500 cars with battery power sources have been registered for the first time in Ukraine, which is one and a half times more than in the same period of 2021. The total fleet of electric cars and hybrids in Ukraine exceeded 100,000 cars³⁹.

Climate impact

Among other aspects, Russia's attacks significantly affected and negatively impacted the global efforts to reach the objectives of the Paris Agreement. According to the latest study, greenhouse gas (GHG) emissions caused by Russia's full-scale invasion of Ukraine totaled at least 100 mln tons of CO₂e (carbon dioxide equivalent) from February 24 to September 24, 2022⁴⁰. This is the equivalent of the total GHG emissions of The Netherlands over the same period. These figures are likely even higher considering the massive attacks from September 25 to November 24. Therefore, the more Russia continues its aggression, the higher the negative impact on climate will be.

Since the beginning of the war, in 2022 about 2,300 crimes against the environment have been recorded. The damage caused to the environment has already exceeded \$46 bln.

According to the Ministry of Natural Resources of Ukraine, at the end of April 2023, damages due to environmental pollution as a result of attacks only on facilities producing, processing, and storing fuel and lubricant materials

³⁷ Vasylenko, Svitlana & Uliana, Naumenko. (2022). PROSPECTS OF DEVELOPMENT OF LITHIUM RESOURCE BASE IN UKRAINE. InterConf. 10.51582/interconf.19-20.02.2022.072.

³⁸ The Ministry of Communities and Territories Development of Ukraine,

<https://www.minregion.gov.ua/press/news/minregion-vidbulos-11-zasidannya-shtabu-z-pidgotovky-do-opalyvalnogo-sezonu/>

³⁹ Ukrainian Motor Vehicle Manufacturers Association, <https://ukrautoprom.com.ua/statystyka-prodazhiv-avtomobiliv-u-lystopadi-2022>

⁴⁰ Initiative on GHG accounting of war, CLIMATE DAMAGE CAUSED BY RUSSIA'S WAR IN UKRAINE, 2022, <https://climatefocus.com/wp-content/uploads/2022/11/ClimateDamageinUkraine.pdf>

were about \$90 mln⁴¹.

According to the Kyiv School of Economics, as of May 2023, about 1.2 million tonnes of pollutants had been released into the air as a result of hostilities, including 430,000 tonnes of carbon monoxide, 700,000 tonnes of dust, and 40,000 tonnes of non-methane volatile organic compounds, as well as a significant amount of heavy metals and other harmful substances. The air pollutants caused losses reaching almost \$4.2 billion. In particular, \$1.8 billion was caused by forest fires, \$1.6 billion by grass fires and \$752 million by the burning of oil and oil products. The above figures did not include the direct damage caused by the destruction of the Kakhovka HPP and the Nova Kakhovka dam on June 6, 2023⁴². The total environmental damage caused by the destruction of the HPP and the Nova Kakhovka dam is estimated at 1.5 billion dollars⁴³.

Cyber security

From February 24 2022, more than 1.2 mln cyberattacks have been carried out on energy infrastructure facilities. In comparison, there were 0.9 mln of cyber-attacks in 2021. It should also be mentioned that Russia began intensive cyber-attacks on the Ukrainian energy sector even before the full-scale invasion on February 24, 2022. Namely, from December 2021 to February 2022, Russia repeatedly tried to inflict maximum damage to the work of Ukrainian energy companies, including interfering with the work of dispatch centres and smart grids⁴⁴.

In 2022, more than 3 million cyberattacks were carried out on Naftogaz's network infrastructure or 12 times more than in 2021.

Information security

Since the beginning of Russia's full-scale military invasion of Ukraine, Russia has fabricated a set of false narratives and used disinformation and propaganda to inflict damage on the Ukrainian energy sector.

Even before the massive attacks on energy infrastructure, Russian media was trying to spread panic not only in Ukraine but in Moldova and EU member states. Another example of Russia's disinformation is fake news about GoU's request to citizens in March 2022 to turn off the lights in the evening. This information attack was aimed at complicating power system balancing, mainly when the Ukrainian power system was operating in an autonomous mode before joining ENTSO-E.

Since October 2022, Ukrainian citizens have been living under conditions of scheduled rolling and emergency blackouts. At the same time, Russia's false narratives, disinformation and propaganda are aimed at increasing public dissatisfaction and undermining citizens' trust in energy companies and Ukrainian authorities. Through manipulation and false narratives, Russia attempts to shift the responsibility for the blackouts and energy crisis from Russia to Ukraine, both in Ukrainian and European media.

For example, on December 18, 2022, Russian media launched an information attack by distributing a fake letter allegedly sent to the Ministry of Energy (MoE) by the CEO of NEC Ukrenergo. The fake letter allegedly requested the MoE to decrease the power supply to some Ukrainian regions to resume electricity exports to the EU countries. Thus, Russian media attempted to create fake narratives and to shift the responsibility for power outages from Russia to Ukraine, i.e. to convince the audience that blackouts were caused by allegedly deceptive decisions of the Ukrainian decision-makers rather than by the nine massive Russian missile attacks damaging energy facilities. The DTEK group also informed its clients that dozens of fake accounts using the company's name were created on social networks for disinformation, manipulation of public opinion and spreading panic among Ukrainian citizens.

⁴¹ The Russian Federation destroyed 35 oil depots in Ukraine and caused UAH 3.3 billion in damage to the environment - Ministry of Natural Resources, <https://interfax.com.ua/news/greendeal/907725.html>

⁴² What environmental consequences has Ukraine suffered during the war, apart from the damage caused by the explosion of the Kakhovka hydroelectric power station? , <https://kse.ua/about-the-school/news/what-environmental-consequences-has-ukraine-suffered-during-the-war-apart-from-the-damage-caused-by-the-explosion-of-the-kakhovka-hydroelectric-power-station/>

⁴³ <https://www.rbc.ua/rus/news/zbitki-ekologiyi-cherez-pidriv-kahovskoyi-1687389886.html>

⁴⁴ Ministry of energy of Ukraine, <https://www.mev.gov.ua/novyna/z-pochatku-viyny-zafiksovano-ponad-12-mln-kiberatak-na-enerhosektor-farid-safarov>