

Ukrainian energy sector evaluation and damage assessment - V

(as of December 20, 2022)

**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. The second report covered the period from August 25 to September 24, 2022²; the third brief report – September 25 to October 24, 2022³; the fourth report – October 25 to November 24, 2022⁴.

As of December 20, 2022, 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. After targeted missile attacks on the Ukrainian power system, which started on October 10, 2022, millions of electricity consumers have been temporarily disconnected from the electricity supply due to hostilities or rolling blackouts.

At the end of November, 2022, the estimated damages to the Ukrainian energy sector, including utilities and district heating sectors, were at least **\$9.1 bln** (Kyiv School of Economics, 2022)⁵. 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 (as of September 24, 2022)", 2022,

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

³ Task Force, "Ukrainian energy sector evaluation and damage assessment – III (as of October 24, 2022)", 2022,

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

⁴ Task Force, "Ukrainian energy sector evaluation and damage assessment – IV (as of November 24, 2022)", 2022,

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

⁵ "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/>

KEY CHANGES IN THE UKRAINIAN ENERGY SECTOR (November 25 – December 20)

As outlined in the third report⁶, on October 10, 2022, Russia changed its tactics and resorted to a massive attack on critical energy infrastructure facilities. In response to the critical energy infrastructure damages, the Government of Ukraine (GoU) introduced consumption and capacity-limiting schedules to ensure efficient balancing of the power system during wartime. From November 25 to December 20, 2022, almost all electricity consumers were temporarily disconnected from the electricity supply.

From November 25 to December 20, 2022, the electricity supply deficit in Ukraine remained at 20-30%. It resulted in the continuation of emergency measures, i.e. rolling blackouts and restrictions on electricity consumption for industrial consumers and households. While the energy-industry employees sought to ensure that Ukrainian consumers had electricity access for at least ten hours a day, the scheduled shutdowns were not always respected due to new targeted attacks on the Ukrainian power system by the Russian military forces.

Many power units of thermal power plants (TTPs) and combined heat and power plants (CHPs) were under emergency repair or could not operate due to damages to the power grid that significantly reduced the ability to transmit electricity to consumers. Due to the temporary disconnection of nuclear power plants (NPPs) from the grid after Russia's attacks, Ukraine increased the electricity generation by coal-fired TTPs and hydropower plants (HPPs). The latter used a large amount of water stored in reservoirs for emergencies.

During the tenth month of the war, Russia continued its attacks on Ukrainian energy infrastructure. Apart from targeted missile and drone attacks, Russian military forces attacked the energy infrastructure facilities in the frontline Ukrainian regions almost daily using artillery. The information below provides a concise overview of key attacks and damages inflicted on the Ukrainian energy infrastructure from November 25 to December 20, 2022.

On November 30, 2022, in one of the Zaporizhzhia region settlements, a gas distribution point was damaged, and a fire broke out due to a missile strike (presumably using short-range S-300 missiles).

On December 5, 2022, Russia started its eighth massive missile attack on Ukraine's energy system. More than 70 missiles were launched across the territory of Ukraine. While Ukrainian air defence forces shot down more than 60 missiles, some of the missiles still hit power generation and transmission facilities in the Kyiv, Vinnytsia, and Odesa regions. To mitigate the missile interception and cause the maximum damage to the civil population, Russia hideously resorted to simultaneously launching multiple missiles on the same energy infrastructure facilities. For example, the Russian military forces fired seven missiles at one critical substation in the Odesa region to double down on efforts to ensure that the region was disconnected from the power supply after this massive attack.

On December 10, 2022, Russia attacked the energy infrastructure in the Odesa region with kamikaze drones. While ten of the 15 launched kamikaze drones were shot down, the remaining drones still damaged the power transmission system. As a result, all consumers in the city of Odesa (over 1.5 million people) were disconnected from the power supply. Among other reasons, the targeted attack on the Odesa region presumably aimed to hamper the work of seaports responsible for Ukrainian grain export within the "grain agreement" framework.

In the East of Ukraine, the Russian forces again launched an artillery attack and damaged infrastructure facilities in areas liberated by the Ukrainian army.

⁶ Task Force, "Ukrainian energy sector evaluation and damage assessment – III (as of October 24, 2022)", 2022, https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2022_10_24_UA_sectoral_evaluation_and_damage_assessment_Version_III.pdf

Odesa city during a power outage after critical energy infrastructure was damaged by Russian drones



Source: [REUTERS/Serhii Smolientsev](#)

On December 14, 2022 the Russian army launched a massive attack on the city of Kyiv using kamikaze drones. The Ukrainian air defence forces destroyed all 13 drones and the energy infrastructure facilities were not damaged.

On December 15, 2022, cyber-attacks on the Ukrainian energy sector continued. Russian hackers attacked distribution system operator Lvivoblenergo. Due to a timely warning from the Security service of Ukraine, the company's IT specialists managed to defend against the cyber-attack.

Due to massive artillery attacks on the energy infrastructure, the city of Kherson was wholly disconnected from the power supply. In the evening of the same day, the electricity supply was partially restored.

On December 16, 2022, Russia launched its ninth massive missile attack on Ukraine's energy infrastructure. The main targets were TPP's, HPP's and transmission system substations with voltage of 330–750 kV. As a result of the attack, about 50% of electricity consumers were disconnected in all regions of Ukraine. Apart from the power sector, the attack also caused significant heat, cold and hot water supply interruptions. The attack also resulted in disruptions to the power supply in Moldova.

Many railway facilities in the Kharkiv, Kirovohrad, Donetsk and Dnipropetrovsk regions were disconnected from the power supply, and reserve diesel locomotives were used to ensure the operation of the railway.

NEC Ukrenergo, the Ukrainian TSO, announced an emergency in the power system. With the announcement of an emergency, all trades on the intraday electricity market were suspended.

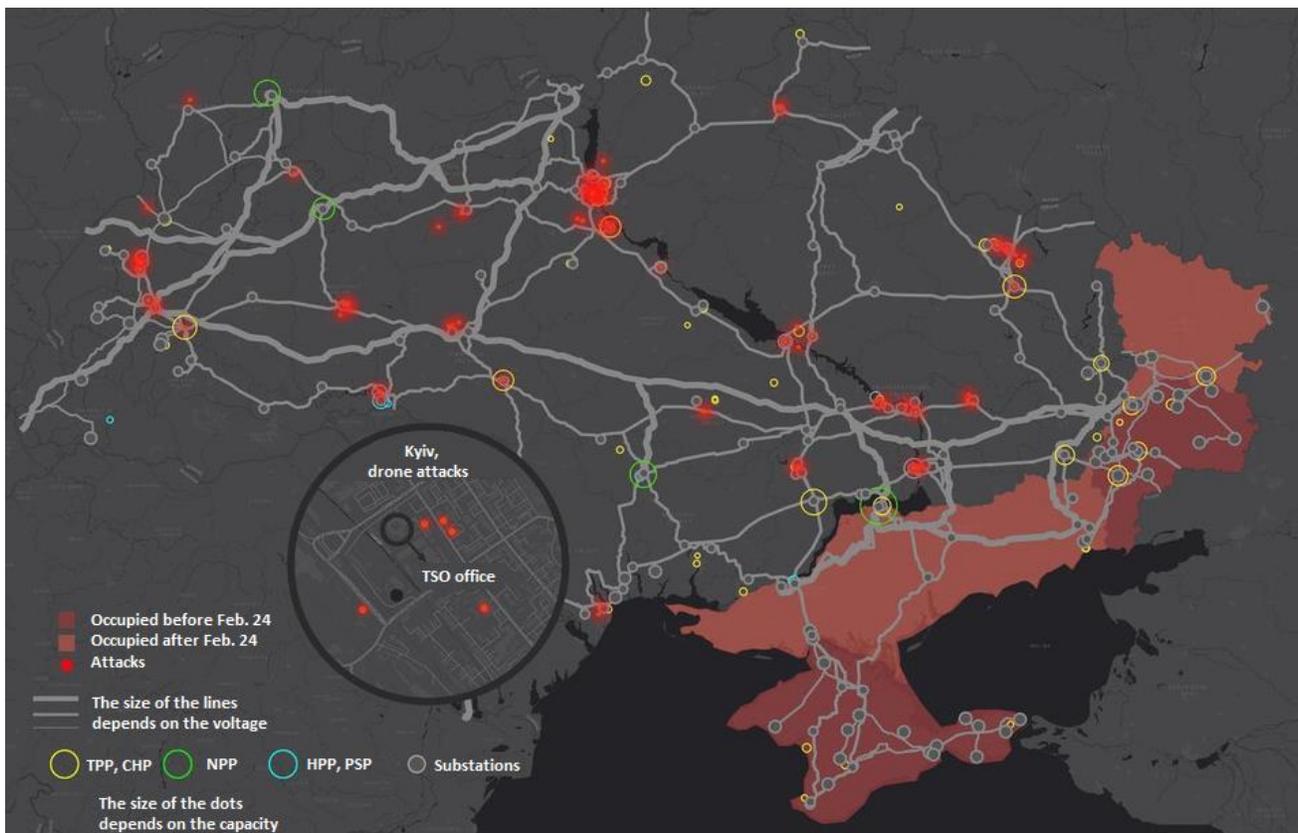
Despite the attack, the repair work continued without interruption, and the electricity supply to almost 6 million consumers was restored the next day. At the same time, the massive attack caused significant problems with the supply of heat, cold and hot water, the restoration of which took a more extended period.

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.

On December 19, 2022, Russia attacked Ukrainian energy facilities located in Kyiv region using 35 kamikaze drones, 30 of which were destroyed by the Ukrainian air defence system. The inflict more damage, the attack was launched during the night to mitigate Ukrainian military forces' ability to destroy drones with conventional weapons during the daytime. Despite the high percentage of intercepted drones, some critical energy infrastructure facilities in the Ukrainian capital were still damaged. It should also be noted that the kamikaze drones' flight trajectory was set up in a way that they crossed the vicinity of Pivdennoukrainska NPP's nuclear reactor and purposely created a threat of attack on the nuclear facilities.

On December 20, 2022, Russia attacked oil and gas infrastructure facilities located in the Kharkiv region.

Russia's targeted missile and drone attacks on Ukrainian energy infrastructure from October 10 to December 15



Source: [TEXTY.ORG.UA](https://texty.org.ua)⁷

As shown on the map above, the main targets for Russia's attacks were high-voltage transmission substations TPP's, CHP's and hydropower facilities.

As described in the third report⁸, one of the main goals of the Russian Federation's launching massive missiles is to leave Ukrainian citizens without electricity, heat and hot water supply during the 2022/2023 heating period.

⁷ Note: The information collected by Texty.org.ua based on open sources and translated by the Task Force. The displayed data may not be complete, as not all information is made public.

⁸ Ibid

From October 25 to December 20, 2022, Russia partially achieved its goal as its massive attacks on the critical energy infrastructure either destroyed or damaged energy facilities that cannot be repaired in the short term. Considering that Ukraine has a different energy system configuration than EU countries, restoring the energy system may be complicated as it may take months to manufacture and restore the damaged facilities.

Liquidation of the consequences of Russia's attack on an energy infrastructure facility in Kyiv



Source: https://twitter.com/SESU_ua

To mitigate the negative impact of Russia's attacks on critical energy infrastructure facilities, the GoU worked in two directions over the last months of the war:

- 1) repairing the damaged facilities and enhancing the security of supply;
- 2) implementing energy efficiency measures to reduce the energy demand and help citizens to survive the winter under the constant interruption of electricity, heat, cold and hot water supply.

Over the last month, local municipalities set up multiple 'Unbreakable Points' and implemented co-financing programs to purchase generators. For example, the Kyiv City Council increased the statutory funds of housing maintenance companies by UAH 150 million and provided additional funds to purchase generators, fuel and other consumables in case of emergency. The local authorities of the Irpin, Kyiv region, announced that the city would compensate 50% of the cost of generators for boiler-housed apartment buildings. Most local authorities implement similar measures to support Ukrainian citizens and local businesses. Despite the rolling blackouts and emergency disconnections, thousands of Ukrainian enterprises, small and medium-sized businesses, and public facilities continued to operate using individual generators.

In December, the GoU announced a new energy efficiency initiative for households. The initiative aims at replacing outdated incandescent bulbs with new LED ones for residential consumers. In total, it is planned to replace 50 million bulbs with the financial support of the European Commission. The proposed initiative is expected to reduce the demand of Ukraine's power system by 1 GW or the equivalent of one nuclear reactor's capacity.

In December, the GoU also continued discussing electricity import from continental Europe's power system (ENTSO-E). While there was the technical possibility of importing electricity, the commercial possibility was rather

challenging due to the significant price difference between the EU and Ukrainian power markets. For example, the wholesale electricity prices in Ukraine were 2-2.5 times lower than in Poland and 2-4 times lower than in Hungary, Slovakia, or Romania in December 2022. Therefore, the emergency electricity import of 2 GW from the EU market during the 2022/2023 heating season would cost around 800 million EUR.

At the same time, the import would not fully cover the deficit in Ukraine's power system caused by Russia's attacks. Therefore, the GoU continued negotiating with the Turkish company Karpowership to place floating power plants of 300-400 MW in the territorial waters of Moldova and Romania to supply electricity to the Odesa region, the daily consumption of which was from 800 to 1400 MW depending on the season.

In December 2022, the European Business Association surveyed top managers about the impact and consequences for their business of massive missile strikes on the energy system of Ukraine. The survey result showed that interruptions in electricity supply forced 66% of companies to change their work schedule, 40% – to reduce production or services, and 12% – to close some offices or branches. 9% of respondents said they suspended some activities or closed part of their premises, and only 1% of companies fully stopped their work. At the same time, 18% of companies were unaffected by the power outages, or the impact was insignificant.



Source: [European Business Association](#)

To mitigate the impact of power outages, 86% of businesses installed generators or other means of uninterruptible power sources (UPS). 65% used alternative sources of communication and the Internet, 25% transferred data to the cloud, and 22% implemented cybersecurity measures. Only 10% of businesses had to relocate their business or staff due to power outages.

However, the mitigation of power outages resulted in high costs to Ukrainian businesses. For example, 40% of the surveyed companies reported that their expenses for ensuring autonomy amounted to \$50,000. 22% – reported that expenses were in the range of \$50,000-100,000, 24% – in the range of \$100,000-200,000, and 14% – spent more than \$200,000.

To conclude, 72% of respondents indicated that prolonged blackouts would not force them to leave the Ukrainian market, 20% hesitated to answer, and only 8% assumed such a possibility in the worst-case scenario.

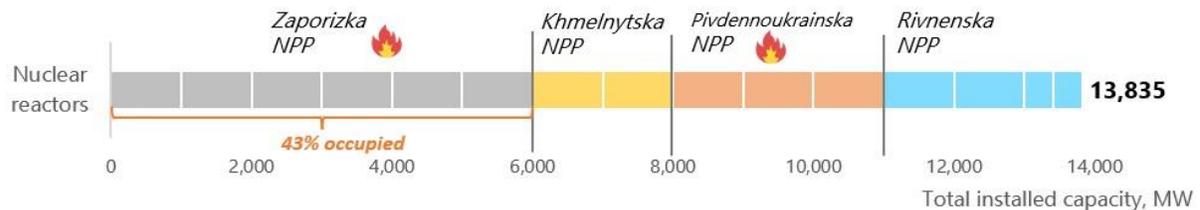
GENERAL SITUATION

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).

Zaporizka NPP (ZNPP), the largest nuclear power plant in Europe and the fifth largest in the world (Power Technology, 2019)⁹, 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 has been suspended. Pivdenoukraisna NPP was shelled. Khmelnytska NPP and Rivnenska NPP were affected due to attacks on transmission system infrastructure.



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

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 November 1, 2022 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.

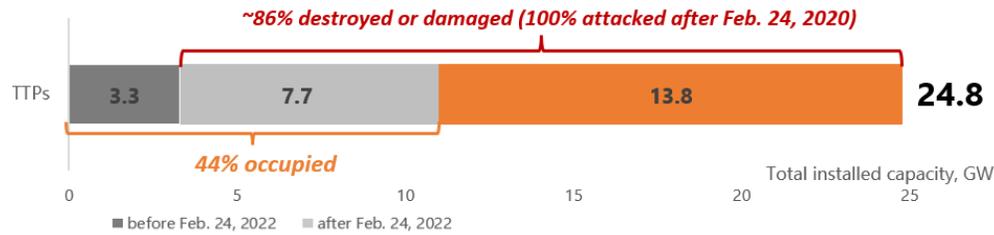
According to publicly available information, in December 2022, the Russian Government continued implementing activities aiming at switching the ZNPP to the Russian power system.

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 Vyglehirska TPP) with a total installed capacity of 7.7 GW. As of today, 44% of Ukraine's total thermal power capacities are under occupation. 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.

⁹ "Top ten nuclear power plants by capacity", Power Technology, 2019, <https://www.power-technology.com/analysis/feature-largest-nuclear-power-plants-world/>

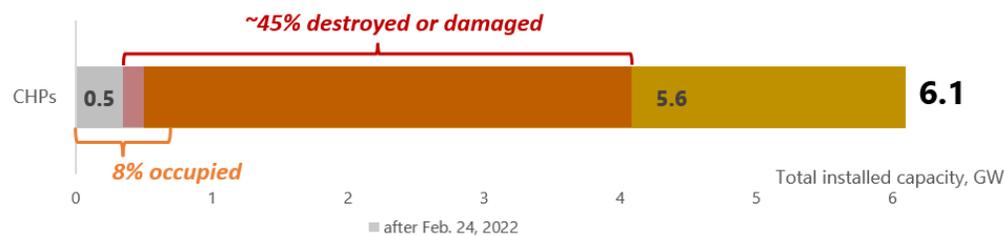


Source: ECS based on publicly available data

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 about 45% of installed capacities are either destroyed or damaged as a result of Russian attacks (see figure below).



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.



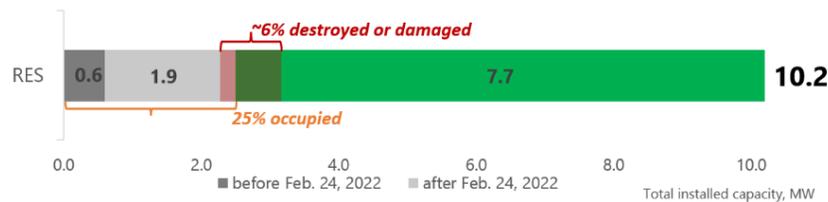
Source: ECS based on publicly available data

Since the first day of the war, Kakhovska HPP (343.2 MW or about 5% of installed capacity) has been occupied and damaged by the Russian army. Public Joint Stock Company (PJSC) "Ukrhydroenergo", the main operator of HPPs and PSPs in Ukraine, has already filed a claim at the European Court of Human Rights regarding the damages caused to the Kakhovska HPP and the unfinished wind power plant on Zmiiny Island. The total amount of the claim is above \$0.5 bln.

Renewable energy (excluding large HPP)

Ukraine has the highest technical RES potential among other countries in Southeast Europe - 874 GW¹⁰, 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.

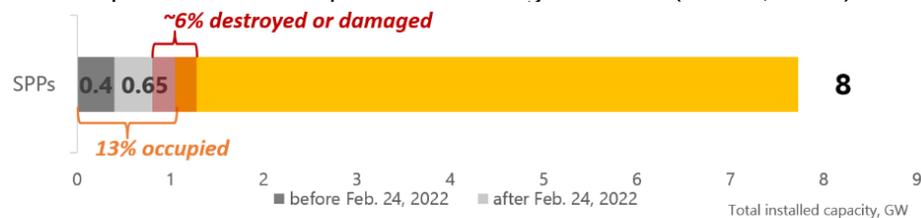
As of today, 2.5 GW (25%) of RES facilities are under occupation. About 6% of the total installed RES capacity has been destroyed or damaged.



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).¹¹



Source: ECS based on publicly available data

Currently, about 13% of Ukrainian PV capacities are under occupation. About 6% of the total installed solar capacity has been destroyed or damaged, including hundreds of prosumer installations.

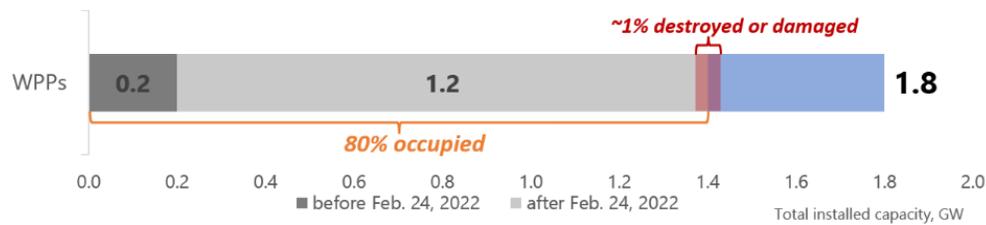
Wind

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 seven 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).

¹⁰ "Renewable energy sources of Ukraine", National Academy of Sciences of Ukraine, 2022, <https://www.ive.org.ua/wp-content/uploads/atlas.pdf>

¹¹ "Renewable Energy Statistics 2022", IRENA, 2022, <https://www.irena.org/publications/2022/Jul/Renewable-Energy-Statistics-2022>

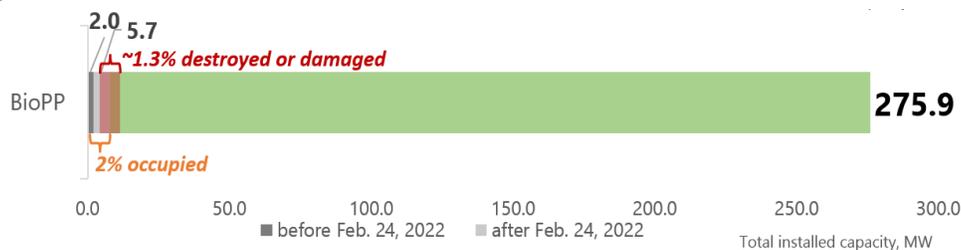


Source: ECS based on publicly available data

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.

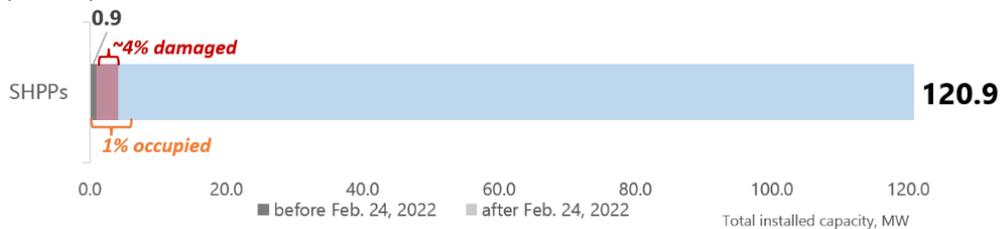


Source: ECS based on publicly available data

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.

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 40% of controlled transmission substations were destroyed or damaged. Some of the substations were attacked more than one time.

Nowadays, more than 40 overhead lines and more than 20 substations with a voltage of 220–750 kV are damaged or disconnected due to continuous attacks and hostilities.

On 16 March, 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 the electricity export to the European Union (EU) starting from October 11, 2022. As of December 2022, the GoU considered the import of electricity from continental Europe's power system (ENTSO-E).

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 November, 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.

As of December 20, 2022, from four to five mln consumers remained without electricity (entirely or partially) due to hostilities or consumption and capacity-limiting schedules. Ukrainian TSO and DSO's restore electricity supply where possible, but regular attacks by Russian forces lead to new damages and destructions.

Natural gas sector

Natural gas production

Ukraine has Europe's third-largest natural gas reserves (up to 719 bln cubic meters (bcm)) (EY, 2020)¹². 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).

¹² "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

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 during October-December 2022.

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)¹³. 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 territories and areas close to active hostilities.

As of mid-December, more than 13.3 bcm of natural gas has been pumped into Ukraine's UGS.

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

¹³ 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)

"Urengoy-Pomary-Uzhhorod" gas pipeline located on the territory of the Russian Federation on December 20, 2022¹⁴. 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 Russia¹⁵.

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 November 24, 2022, 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.

Oil & petroleum products

Oil production

Ukraine's oil reserves are estimated at approximately 85 mln tons (EY, 2020)¹⁶. 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 (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.

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.

¹⁴ Mind.ua, <https://mind.ua/news/20250978-v-rosijskij-chuvashiyi-vibuhnuv-qazoprovid-cherez-ce-u-evropi-rizko-pidskochili-cini-na-gaz>

¹⁵ Trading economics, <https://tradingeconomics.com/commodity/eu-natural-gas>

¹⁶ "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

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/year¹⁷. 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 infrastructure facilities in the Kharkiv region. As a result of the attack, the fire spread to the area of 4,500 square meters¹⁸.

Due to the massive missile attacks on the energy infrastructure in October-December 2022 and consequent rolling and emergency blackouts in Ukraine, the demand for gasoline and diesel fuel has increased significantly because households and businesses actively started using generators during the power outages. According to the Prime Minister of Ukraine, Ukrainian entrepreneurs have already imported 500,000 low-capacity generators, but Ukraine still requires about 17,000 large and industrial-size generators to pass through the winter season¹⁹. According to publicly available data, Ukraine imported record volumes of oil products in December 2022.

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.

¹⁷ 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.

¹⁸ Video of the explosion, NJSC "Naftogaz of Ukraine" <https://www.naftogaz.com/news/rosiya-vkotre-obstrilyala-ob-ekty-grupy-naftogaz-video>

¹⁹ The statement of the Prime Minister of Ukraine D. Shmyhal, December 16, 2022,

<https://www.kmu.gov.ua/en/news/promova-premier-ministra-ukrainy-denysa-shmyhalia-na-zasidanni-uriadu16122022>

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)²⁰.

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 stations²¹. 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)²². 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 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 December 20, 2022, Ukrainian companies accumulated about 1.2 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 takes actions related to suspending activities and transferring industrial equipment from the Chervonyi Partyzan and Kharkivska mines to the Krasnoyarsk region of the Russian Federation²³.

²⁰ 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/>

²¹ "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/>

²² "Coal reserves Europe – Country rankings", TheGlobalEconomy.com, 2022, https://www.theglobaleconomy.com/rankings/coal_reserves/Europe/

²³ Luhansk Regional Military Administration, <https://t.me/luhanskaVTSA/6977>

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.

Lithium

According to preliminary estimates, Ukraine's total lithium resource potential is relatively high (approximately 500,000 tons of lithium oxide) (Vasylenko & Uliana, 2022)²⁴. 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 restored²⁵. Since the local district

²⁴ Vasylenko, Svitlana & Uliana, Naumenko. (2022). PROSPECTS OF DEVELOPMENT OF LITHIUM RESOURCE BASE IN UKRAINE. InterConf. 10.51582/interconf.19-20.02.2022.072.

²⁵ 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/>

heating infrastructure has been severely damaged due to Russian hostilities, there will be 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 cars²⁶.

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, 2022²⁷. 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 February 2022, more than 2,200 crimes against the environment have been recorded. The damage caused to the environment has already exceeded \$37 bln. The material damage from air pollution amounts, including but not limited to burning oil products and forest fires, is estimated at \$25 bln²⁸.

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 grids²⁹.

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.

²⁶ Ukrainian Motor Vehicle Manufacturers Association, <https://ukrautoprom.com.ua/statystyka-prodazhiv-avtomobiliv-u-lystopadi-2022>

²⁷ 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>

²⁸ The statement of the Minister of Environmental Protection and Natural Resources of Ukraine R. Strelets, November 06, 2022, <https://mepr.gov.ua/news/40264.html>

²⁹ Ministry of energy of Ukraine, <https://www.mev.gov.ua/novyina/z-pochatku-viyny-zafiksovano-ponad-12-mln-kiberatak-na-enerhosektor-farid-safarov>

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.