



ASSESSMENT OF DAMAGES AND LOSSES TO UKRAINE'S ENERGY SECTOR

DUE TO RUSSIA'S FULL-SCALE INVASION

As of May 2024

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Executive Summary

As a result of the military aggression of the Russian Federation against Ukraine, the energy sector has suffered significant damages and losses. The occupation of the Crimean Peninsula and parts of the Donetsk and Luhansk regions led to the loss of vital natural resources and energy facilities, including coal mines, oil and gas fields, as well as thermal power plants and renewable energy installations. This has significantly impacted Ukraine's energy independence and economic stability. With the full-scale invasion ongoing since February 2022, Russia has inflicted devastating consequences on Ukraine's energy sector, causing extensive damage to energy infrastructure and resulting in financial losses for energy companies and economy overall.

Damages to Ukraine's energy sector due to the full-scale invasion by Russia are estimated by the KSE analytical team to be over \$16 billion. The largest damages were incurred from the destruction of electricity generation objects, transmission facilities, and oil and gas infrastructure. During the Russian Federation's full-scale aggression, approximately over 18 GW of electricity generating capacity was occupied, including Europe's largest nuclear power plant – the Zaporizhzhia Nuclear Power Plant. Additionally, the Kakhovska and Dniprovsk hydroelectric power plants, as well as the Zmiivska and Trypilska thermal power plants, were completely destroyed. Private thermal power plants, including the Ladyzhynska, Burshtynska, Dobrotvirska, Kurakhivska, Kryvoriz'ka, and Prydniprovsk thermal power plants, suffered critical damage of over 80%. Approximately half of the high-voltage substations for electricity transmission were damaged. Russian forces essentially destroyed all oil refineries in Ukraine, as well as a significant portion of the infrastructure for storing oil and petroleum products.

The losses incurred by the energy sector due to the full-scale invasion are estimated at nearly \$40.4 billion. These losses include revenue declines for energy companies, as well as expenses for debris removal and demolition work. Particularly notable was the significant decrease in demand for electricity and natural gas. The revenue decline for electricity sector companies was exacerbated by a series of long-ranged massive attacks, which rendered them unable to fully meet existing demand for an extended period. Almost all internal oil refining capacity, previously responsible for supplying about a third of the demand for petroleum products, was destroyed.

The estimated needs for the restoration of the energy sector amount to \$50 billion, envisioning a complete reconstruction of the destroyed facilities based on the principle of "Build back better." The full-scale war has resulted in widespread destruction and losses in the energy sector, necessitating a comprehensive approach to its restoration and modernization. This approach should aim to ensure the sector's stability soon and preserve its independence and resilience in the long term. In the short term, special attention must be paid to the reconstruction of damaged power plants, the provision of the energy system with small manoeuvrable capacities, energy storage solutions, and other backup power sources. Additionally, efforts should focus on constructing higher levels of

protection for main high-voltage substations and forming reserves of key energy equipment for rapid restoration in case of repeated massive attacks. Furthermore, expanding cross-border electricity trade is essential for enhancing security of supply.

To restore Ukraine's energy sector, it may be beneficial to focus on the following directions:

1. Reconstruction of damaged energy infrastructure, including the restoration of key thermal and hydroelectric power facilities where feasible, to ensure energy supply security in the short and medium term.
2. Expansion of access to external financing to cover restoration costs, as well as giving Ukrainian companies priority access to the necessary equipment for reconstruction.
3. Creating an environment conducive to private investment to build flexible and decentralized energy supply systems, thereby enhancing the resilience of the energy system to potential future attacks and ensuring reliability of supply. This entails gradually developing hundreds of small-scale generation projects, including high-maneuvrability capacities (gas turbine and gas piston power plants, cogeneration units), thermal power plants utilizing renewable fuels, and energy storage systems. Such initiatives will not only reduce dependence on large, centralized facilities but also add flexibility to the energy system, addressing the current capacity deficit during peak load hours and frequent system constraints to the solar power plants production.
4. Efficient utilization of energy resources which necessitates a gradual transition to liberal pricing for energy resources for households, while safeguarding financially vulnerable segments of the population. Additionally, tariff formation reforms for utility service providers are essential. These measures will incentivize the adoption of energy-efficient practices and provide a financial foundation for investments in the restoration and modernization of energy infrastructure.

Table 1. A consolidated assessment of damages, losses, and needs of Ukraine's energy sector due to the full-scale invasion of the Russian Federation, as of May 2024.

Sector	Damages, \$ million	Losses, \$ million	Needs, \$ million
Electric power industry:	11,425	18,607	33,839
Power distribution	801	3,617	1,930
Power transmission	2,100	2,246	2,632
Power generation, including:	8,524	12,745	29,277
<i>Combined heat and power plants</i>	1,433	1,578	3,525
<i>Thermal power plants</i>	3,588	3,804	18,131
<i>Nuclear power plants</i>	843	6,371	1,330
<i>Renewables</i>	2,661	992	5,671
Oil and gas sector, including:	3,331	18,437	14,812
Gas production		3,664	183
Gas transmission	775	644	962
Gas distribution	154	1,132	241
Oil production and refining	2,136	12,993	13,106

Sector	Damages, \$ million	Losses, \$ million	Needs, \$ million
Storage of oil and petroleum products	266	4	320
Coal industry	406	676	521
District heating	972	2,696	1,350
Energy Total	16,135	40,416	50,523

Source: Kyiv School of Economics based on data from the Ministry for Communities, Territories and Infrastructure Development of Ukraine, the Ministry of Energy of Ukraine, energy companies, energy associations.





01

**START OF RUSSIAN AGGRESSION
AGAINST UKRAINE IN 2014 AND
ITS CONSEQUENCES FOR THE
UKRAINIAN ENERGY SECTOR
(UP TO FEBRUARY 24, 2022)**

From 2014 to 2022, Russian aggression caused a significantly adverse impact for the Ukrainian energy sector. The occupation of parts of the territory led to the loss of coal mines, power plants, and oil and gas resources, significantly affecting the country's energy independence. Moreover, thermal, solar and wind power plants were occupied, and later illegally expropriated by the occupation authorities. These factors led to a reduction in electricity production and coal mining, as well as losses in oil and gas extraction, significantly impacting the economy and energy stability of Ukraine.

1.1. Impact on the energy sector: occupation and damages to assets of energy companies

With the occupation of the Autonomous Republic of Crimea by Russian forces in 2014, Ukraine lost numerous energy assets and significant deposits of energy resources. The Russian Federation took control of the peninsula's continental shelf, rich in natural gas reserves, and seized the assets of "Chornomornaftogaz", a company under the state-owned "Naftogaz of Ukraine". Before the occupation, "Chornomornaftogaz" had extracted 2.4 billion cubic meters of natural gas, with total explored reserves exceeding 50 billion cubic meters. From 2014 to 2021, approximately 13 billion cubic meters of natural gas were illegally extracted under occupation.¹ The International Arbitration Court in The Hague ruled that the Russian Federation must compensate \$5 billion in losses for the seizure of "Chornomornaftogaz" assets.

Additionally, Russia illegally nationalized assets of various oil and gas sector companies in Crimea, including the Feodosiya oil products enterprise, "Ukrtansgaz", "Krymgaz", and the mining enterprise "Krymgeologiya", along with Crimea's subsoil and the "Nadra Krymu" and Technical Center of the State Industrial Safety Inspectorate. The occupied region holds 10 oil fields, 27 gas fields, and 7 gas condensate fields.

Local thermal power plants, wind, and solar power stations in Crimea were also occupied and illegally appropriated by the Russian Federation, including the private solar power plant Activ Solar with a total capacity of 0.4 GW. These facilities produced about 1.2 TWh of electricity in 2013, meeting around 16% of the peninsula's total demand. The assets of "DTEK Krymenergo", the company responsible for electricity distribution and supply, were also nationalized by the occupation authorities. The International Arbitration Court in The Hague ruled that Russia must compensate the company \$267 million for these losses.²

Russian occupation authorities also illegally seized the assets of the "Crimean Power Grids" subsidiary of Ukrenergo, which serviced over 1,300 km of high-voltage power transmission lines and 17 substations on the peninsula. Due to the inflicted losses, an arbitration lawsuit is currently being considered by the International Arbitration Court against Russia, filed by Ukrenergo, demanding compensation totalling approximately \$430 million, excluding interest.³

¹ <https://www.epravda.com.ua/news/2020/02/26/657511/>

² <https://dtek.com/media-center/news/dtek-vigrav-sud-proti-rosii-po-krimskikh-aktivakh/>

³ <https://ua.energy/zagalni-novyny/ukrenergo-pozyvayetsya-v-arbitrazh-protiv-rosiyi-na-527-mln-vevro/>

The Center for Economic Strategy (CES) assessed that the total economic losses for Ukraine's energy sector due to the occupation of Crimea amounted to at least \$32 billion, with over \$22.5 billion attributed to the seizure of natural gas and oil fields.⁴

In the Donbas region, Russian military aggression since 2014 led to the occupation of a significant part of the coal industry and power facilities. This includes the Starobeshivska TPP (2 GW) and Zuyivska TPP (1.3 GW), as well as local wind power plants (Krasnodonska, Lutuhynska, and Novoazovska WPPs). The technical condition of these thermal power plants is currently unknown, though reports of shelling have been made. The Ukrainian power system lost about 4 GW of capacity due to the occupation of parts of Donetsk and Luhansk regions from 2014 to early 2022.

The main damages and losses to the Ukrainian energy sector due to Russian military aggression in Donetsk and Luhansk regions during the period 2014-2021 were due to the damage and occupation of numerous coal mines. Of the 97 coal mines operating in these regions, about two-thirds were state-owned and located in territories not under government control. Significant damage was inflicted on coal enterprises located in active combat zones, such as the "Komsomolets Donbasa" mine, which suffered frequent shelling. Facility's mining used to cover all coal needs of Kryvoriz`ka TPP, as well as a portion of Prydniprovsk TPP's needs. As a result of shelling in the summer and autumn of 2014, the mine was damaged and flooded several times, eventually leading to its shutdown. Overall, with the illegal appropriation by occupation forces caused severe difficulties to the uncontrolled mines due to the population exodus, forced mobilization, labour shortages, lack of equipment modernization, and flooding. Over 90% of occupied coal mines were closed, with the rest in the process of liquidation. Additionally, coal enrichment plants "Kindrativska", "Stakhanivska", and "Torezka" were occupied.

1.2. Impact on production, consumption, and external trade of energy resources

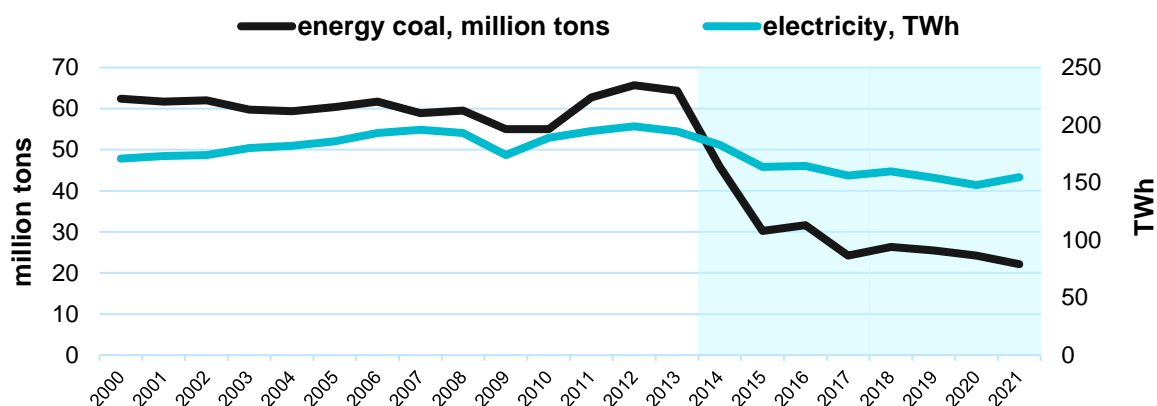
The occupation of Crimea and parts of the Donetsk and Luhansk regions by Russia in 2014-2015 had a profound impact on Ukraine's energy sector, significantly reducing domestic energy demand, production capacity, and export potential, thereby affecting Ukraine's energy independence. The decline in business activity and industrial capacity due to Russian aggression led to a decrease in electricity production. Following the full occupation of parts of the Donetsk and Luhansk regions in 2015, electricity production fell by nearly 16%, down to 163.7 TWh. Ukraine's participation in external electricity markets was similarly affected, with annual net electricity exports from 2015 to 2021 halving compared to pre-war levels.

The occupation severely affected the coal industry, drastically reducing thermal coal extraction. While the average annual coal production was 62 million tons

⁴ <https://ces.org.ua/wp-content/uploads/2021/07/Finale-Crimea-losses-report-clean.pdf>

from 2010 to 2013, it decreased by 26% to 46 million tons in 2014. The continued combat battles in the Donetsk and Luhansk regions, where most of Ukraine's coal mines were located, further exacerbated the decline. By 2021, coal production had dropped to a pre-full-scale invasion low of 22 million tons.

Figure 1.1. Energy coal extraction and electricity production in Ukraine.

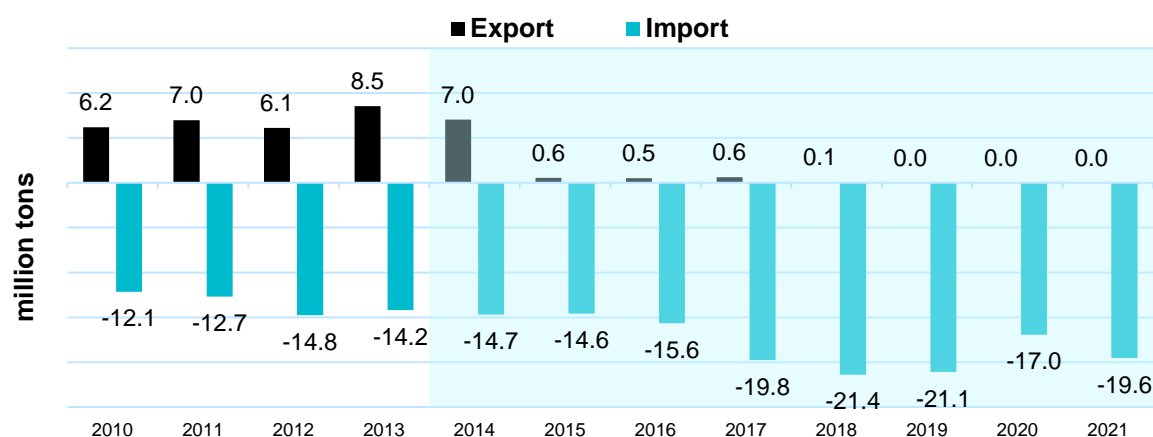


Source: Kyiv School of Economics, based on data from the State Statistics Service of Ukraine.

Note: The highlighted area reflects the period of Russian military aggression against Ukraine.

As a result of the decline in coal production, Ukraine's dependence on imported energy coal increased significantly. Coal generation met about 25-30% of domestic electricity demand. Before the Russian aggression, Ukraine, despite being a net importer of thermal coal, exported approximately 7 million tons of coal annually. However, after the occupation of parts of the Donetsk and Luhansk regions, coal exports fell to minimal levels, while imports gradually increased, reaching 20 million tons annually from 2017 onwards. Consequently, net imports of energy coal rose from an average of 6.7 million tons in 2010-2014 to over 18 million tons in 2015-2021. This shift worsened the trade balance by an average of \$680 million per year.

Figure 1.2. Foreign Trade of Energy Coal in Ukraine.



Source: Kyiv School of Economics, based on data from the State Statistics Service of Ukraine.

Note: The highlighted area reflects the period of Russian military aggression against Ukraine.

In the oil and gas sector, the Russian occupation led to the loss of both oil and gas wells and significant deposits of these resources. The average annual crude oil production decreased by 29%, from 2.4 million tons in 2010-2013 to 1.7 million tons in 2014-2020, as a direct result of Russian aggression. Although total natural gas production remained relatively stable, the occupation of gas drilling platforms on the Crimean shelf resulted in the loss of approximately 2 billion cubic meters of annual production, which accounted for 10% of Ukraine's total annual production.



02

**DAMAGES TO UKRAINE'S ENERGY
SECTOR DUE TO THE RUSSIAN
FEDERATION'S FULL-SCALE
INVASION OF UKRAINE**

According to KSE analytical team estimates as of the end of May 2024, the total amount of damages inflicted by the Russian Federation on the Ukrainian energy sector since the beginning of the full-scale invasion exceeds \$16 billion. The energy sector has been severely impacted by both physical damage to infrastructure from hostilities and targeted long-range strikes, as well as the occupation of energy facilities. This has led to extensive destruction of assets, disruptions in the supply of energy resources, and a significant impact on both the population and the industrial sector. The most significant impacts occurred during the initial weeks of the invasion, including targeted strikes on oil processing and storage sectors, but also during massive shelling of the power system from October 2022 to February 2023, with the destruction of the Kakhovka dam in June 2023, and continued massive attacks on energy infrastructure since March 2024.

2.1. Damages to the electric power industry

The sector of production, transmission, and distribution of electricity suffered the greatest damage due to the Russian Federation's full-scale aggression. Public statements from the Government of Ukraine and other sources indicate that all thermal power plants (TPPs), large hydroelectric power stations (HPPs), and pumped-storage power stations (PSPs) under Ukraine's control, as well as most large combined heat and power plants and over 40% of main electricity transmission networks and distribution infrastructure, were damaged to varying degrees. The estimated damages to the electric power industry amount to over \$11.4 billion, broken down as follows: \$8.5 billion for electricity generation facilities, \$2.1 billion for transmission infrastructure, and \$0.8 billion for distribution facilities.

Table 2.1. Damages to the electric power industry due to the Russian Federation's full-scale invasion of Ukraine, as of May 2024.

Sector	Damages, \$ million
Power distribution	801
Power transmission	2,100
Power generation, including:	8,462
Nuclear power plants	843
Thermal power plants	3,588
Combined heat and power plants	1,433
Large hydroelectric power plants and pumped storage power plants	2,378
Renewables	282
Total: electric power industry	11,425

Source: Kyiv School of Economics based on data from the Ministry for Communities, Territories and Infrastructure Development of Ukraine, the Ministry of Energy of Ukraine, energy companies, energy associations.

2.1.1. Damages to the power generation industry

A significant share of damages in the energy sector falls on electricity generation facilities – almost \$8.5 billion or 53% of the total estimated damages. By type of generation, the damages are as follows:

- Thermal generation: \$3.6 billion for thermal power plants and \$1.4 billion for combined heat and power plants (CHPPs);
- Large hydroelectric power plants and pumped storage power stations: \$2.4 billion;
- Nuclear generation: more than \$0.8 billion;⁵
- Renewable energy sources (RES) producers (excluding large hydroelectric power plants and pumped storage power stations): almost \$0.3 billion.

By ownership type, about 75% or \$6.4 billion of all damages are attributed to state or community-owned energy enterprises, while 25% or \$2.1 billion to by private companies.

During the first weeks of the full-scale invasion, several key electricity generation facilities were temporarily occupied by Russian troops. These include the largest nuclear power plant (NPP) in Europe – Zaporizhzhia NPP (6 GW), Vuhlehirsk, Zaporizhzhia, and Luhansk TPPs (3.6 GW, 2.9 GW, and 1.2 GW respectively), as well as the Kakhovska HPP (0.3 GW), which was completely destroyed by an explosion in June 2023. Damage has been reported at all facilities occupied after 2022, but a comprehensive assessment will only be possible once these facilities are returned to Ukrainian control.

The Zaporizhzhia Nuclear Power Plant (ZNPP), which accounted for over 10% of the Ukrainian power system's installed capacity and provided about a quarter of electricity production before the full-scale invasion, remains occupied by Russian forces. Without access by the National Nuclear Energy Generating Company "Energoatom", the ZNPP does not supply electricity but meets its internal needs from the Ukrainian power system through two power lines – 750 kV and 330 kV. Before the invasion, the ZNPP was connected to four 750 kV and six 330 kV power lines. Regular shelling and provocations by the aggressor frequently led to outages, necessitating reliance on diesel generators as backup energy sources.

The destruction of the Kakhovka dam severed the ZNPP from its main water level support channel for the cooling pond, critical for safe operation. The International Atomic Energy Agency (IAEA) considers the nuclear safety situation potentially hazardous.⁶

According to public statements by "Energoatom". as of April 2023, the cost of destroyed equipment amounted to about \$0.8 billion.⁷ However, a full assessment of the damages to the ZNPP will only be possible after regaining control over it by "Energoatom". Additionally, the temporary occupation of the Chernobyl NPP zone resulted in the destruction of the Central

⁵ According to the public statement of the State Enterprise "National Nuclear Energy Generating Company "Energoatom" as of April 2023 regarding the cost of the company's destroyed equipment, for which information was already available. A revised assessment can only be made after the de-occupation of the Zaporizhzhia NPP.

⁶ <https://www.iaea.org/sites/default/files/23/02/nuclear-safety-security-and-safeguards-in-ukraine-feb-2023.pdf>

⁷ <https://ua.korrespondent.net/business/companies/4581712-enerhoatom-nazvav-sumu-zbytkiv-iz-pochatku-viiny>

Analytical Laboratory, valued at about \$6.5 million.⁸ The laboratory provided various services related to radioactive waste management.

Power generation facilities suffered significant damage from large-scale attacks between October 2022 and February 2023, when Russian forces

launched over 1,500 missiles and suicide drones. These attacks hit most large power plants in Ukrainian-controlled territory, destroying both key operational and auxiliary equipment. Some TPP units were completely destroyed by direct missile hits. By April 2023, 10 GW of available capacity from large power plants had been damaged.⁹ Despite repair efforts, by the end of April 2023, the Ukrainian power system had lost nearly half of its available production capacity due to the occupation and destruction (21 GW out of over 45 GW at the beginning of 2022). By early 2024, 2.2 GW of damaged capacity had been restored.¹⁰

In early June 2023, the Russian occupying forces blew up and completely destroyed the Kakhovka HPP. The destroyed power plant had an installed capacity of 343 MW, and produced 1.1 TWh in 2021. Damages from its destruction were estimated by the KSE team at \$586 million, but building a new HPP of similar capacity may exceed \$1 billion. The destruction of the Kakhovka dam also caused extensive damage in other sectors and increased nuclear safety risks due to the ZNPP's disrupted cooling supply from the Kakhovka reservoir.

As a result of continued Russian Federation's massive attacks on the Ukraine's energy sector since March 2024, power generation facilities suffered critical damage. From March 22, Russia carried out five mass strikes on the energy sector, launching at least 150 missile strikes and over 240 kamikaze drone strikes, marking the most intense attack on the energy sector since the full-scale invasion began. Facilities in Vinnytsia, Dnipropetrovsk, Zaporizhzhia, Ivano-Frankivsk, Kyiv, Kirovohrad, Lviv, Odesa, Kharkiv, Khmelnytskyi, and Cherkasy regions were damaged.¹¹ Due to damage and destruction, about 8 GW of capacity were lost.¹² As a result of the shelling on March 22, about 2 million consumers were de-energized, and thus cut off from heat and water supply. Power outage schedules were immediately introduced in the Dnipropetrovsk, Zaporizhzhia, Kirovohrad, Poltava, Odesa, Kharkiv, and Sumy regions. The extensive destruction indicated a risk for a prolonged electricity shortage through summer 2024 and a worsening situation during the 2024-2025 winter heating period.

The most significant strikes during the series of attacks in spring 2024 were inflicted on thermal generation facilities. All thermal power plants in the controlled territories, which are part of the largest coal generation operator – the DTEK group of companies, suffered significant damage. In particular, critical damage was reported to all units of the Burshtynska and Ladyzhynska TPPs (over 4 GW).¹³ DTEK estimated urgent restoration needs at approximately \$350 million, covering debris removal, equipment procurement, and

⁸ <https://www.facebook.com/dazv.gov.ua/posts/340693271429994>

⁹ <https://www.undp.org/ukraine/publications/towards-green-transition-energy-sector-ukraine>

¹⁰ <https://www.ukrinform.ua/rubric-economy/3814073-v-ukraini-vze-vidnovili-22-gvt-potuznostei-poskodzenih-cerez-ataki-rf-smigal.html>

¹¹ According to official reports, strikes were carried out on the Burshtynska TPP, Dobrotvirska TPP, Ladyzhynska TPP, Zmiivska TPP, Trypilska TPP, Kharkivska CHPP-5, Dniprovska HPP, Dnistrovska HPP, and Kanivska HPP. There were also reports of attacks on large electricity generation facilities in other regions; however, this information has not yet been officially confirmed by the government or representatives of energy companies due to security risks.

¹² <https://kosatka.media/category/elektroenergiya/news/galushchenko-situacija-v-energosistemi-skladna-energosistema-mave-veliki-poshodzhennya>

¹³ <https://www.epravda.com.ua/publications/2024/03/27/711686/>

construction and installation works.¹⁴ A full damage assessment will follow the completion of the debris removal, which is ongoing at the time of this analysis.

Significant damage was also inflicted on generation facilities in the Kharkiv region with the Zmiivska TPP (part of the state energy company "Centrenerg") and Kharkiv CHPP-5 destroyed. Rebuilding these facilities could take years, equating to the cost of constructing new facilities. Additionally, all high-voltage substations around the city of Kharkiv were attacked and damaged, causing severe generating capacity deficits. The city faces critical electricity supply issues from other regions and urgently needs alternative power sources.

On April 11, another massive strike by Russian forces destroyed the Trypilska TPP, last operational power plant of "Centrenerg". Debris removal is underway at the power plant, which had an installed capacity of over 1.8 GW. Detailed destruction consequences will be known later. On May 17, the government allocated the first funds (\$39 million) for the restoration of the Trypilska and Zmiivska TPPs.¹⁵

Despite the catastrophe caused by the destruction of the Kakhovka dam in June 2023, the aggressor continued to attack Ukrainian hydroelectric power. On March 22, 2024, a missile strike damaged the largest power station of the Dnieper cascade, the Dniprovsk Hydroelectric Power Plant (1.6 GW installed capacity). As a result of the attack, the power plant is almost completely destroyed. The strike caused severe damage to the HPP-1 and complete destruction to the HPP-2 from six missile hits. Although the 60-meter dam's integrity remains intact, the bridge crossing and overhead beams were damaged.¹⁶ The total damage to the hydropower industry is estimated at \$2.4 billion, including damages to the Dniprovsk and Kakhovsk HPPs, all part of the state-owned "Ukrhydroenergo".

Producers of electricity from renewable energy sources also suffer significant losses, estimated at \$282 million (excluding large HPPs and PSPs). According to the Energy Charter Secretariat, 13% of solar generation capacity is in temporarily occupied territories, and 8% has been damaged or destroyed.¹⁷ About 80% of wind generation remains uncontrolled, with some facilities damaged by shelling. At least four biogas plants have been destroyed. A detailed assessment of losses is complicated by the lack of access to occupied facilities. However, the de-occupation of certain solar plants in southern Ukraine revealed that besides damages, stations were almost completely looted by occupying forces, often requiring full reconstruction. Renewable energy producers face significant challenges, including the inability to commission new facilities despite substantial financial investments. Industry associations estimate that wind farms with a total installed capacity of about 800 MW were supposed to be commissioned by the end of 2022.

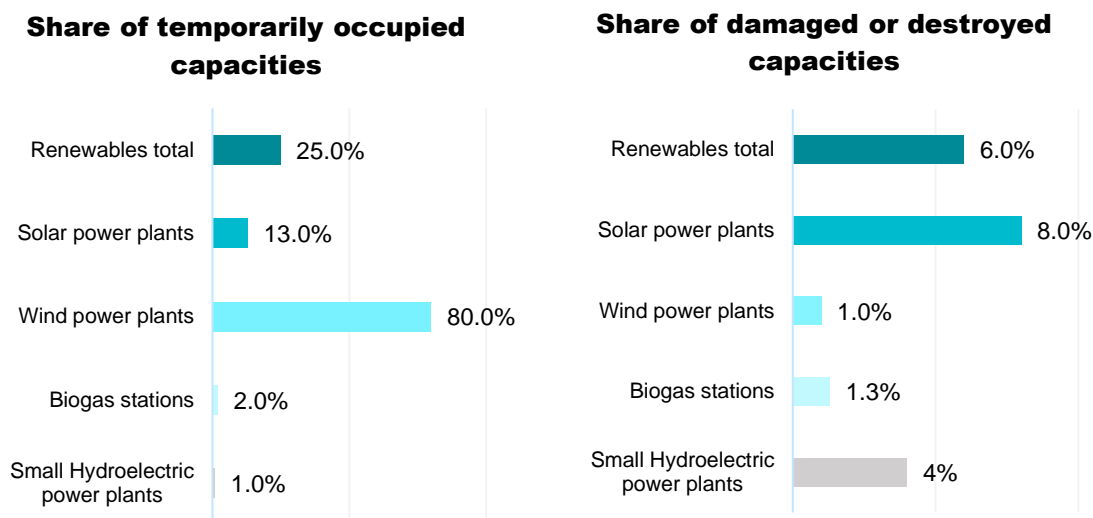
¹⁴ <https://www.epravda.com.ua/news/2024/04/22/712757/>

¹⁵ <https://www.kmu.gov.ua/news/uriad-vydilyv-bilsh-nizh-15-mlrd-hm-na-vidbudovu-krytychno-vazhlyvykh-tes-premier-ministr>

¹⁶ https://24tv.ua/ataka-dniropges-22-bereznya-shho-vidomo-pro-naslidki-raketnogo_n2522007

¹⁷ https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2023_06_30_UA_sectoral_evaluation_and_damage_assessment_Version_XI_final.pdf

Figure 2.1. Share of Renewables temporarily occupied, damaged and destroyed capacities due to Russian Federation's the full-scale invasion of Ukraine.



Source: Energy Charter International estimate based on open sources.

2.1.2. Damages to the power transmission industry

A significant portion of Ukraine's electricity transmission infrastructure was damaged or destroyed due to targeted attacks by the Russian Federation. The infrastructure, which includes major transmission lines and high-voltage substations, is managed by the national energy company "Ukrenergo", wholly owned by the state. The total damages incurred by Ukrenergo due to the Russian Federation's full-scale aggression are estimated at \$2.1 billion.¹⁸

The transmission facilities suffered the most significant damages due to massive attacks between October 2022 and February 2023. As of April 2023, 42 out of 94 high-voltage substations in Ukrainian-controlled territory were damaged.¹⁹ Some substations were attacked multiple times, leading to the destruction of previously restored equipment. Due to this extensive damage, the energy system faced a deficit in its capacity to transmit the necessary volumes of electricity to consumers during the 2022-2023 heating-winter period, despite having sufficient generating capacity. This resulted in systematic power outages and electricity supply limitations for all consumers until the beginning of spring 2023, with the duration and frequency depending on the region's specific situation.

By the heating-winter period of 2023-2024, Ukrenergo managed to restore at least 56 transformers that had been damaged or completely destroyed due to the attacks.²⁰ This repair effort aimed to prevent a recurrence of electricity shortages during the cold months, which see the highest consumption levels. Additionally, multi-level protection of key equipment was initiated at all high-voltage substations to reduce the risks of complete destruction due to

¹⁸ Conducting a comprehensive and detailed assessment of the impact of full-scale war on the electricity transmission infrastructure will only be possible after the de-occupation of all Ukrainian territories.

¹⁹ <https://www.undp.org/ukraine/publications/towards-green-transition-energy-sector-ukraine>

²⁰ <https://www.ukrinform.ua/rubric-economy/3742351-v-ukrenergo-vidnovili-56-transformatornih-pidstancij-se-7-v-roboti.html>

repeated attacks. However, rebuilding all substations to meet the highest level of protection will take years.

Following a series of mass attacks on Ukraine's energy infrastructure from March 22, 2024, the Russian Federation inflicted further damage on electricity transmission facilities. Dozens of high-voltage substations were damaged or completely destroyed. According to the Chairman of the Board of Ukrenergo, the additional damage to high-voltage equipment from just the first of the five massive attacks since March 2024 exceeds \$100 million.²¹ Critical consequences for the integrated functioning of this sector, similar to those experienced in the winter of 2022-2023, were avoided thanks to the construction of protective structures and the formation of a reserve of key equipment for rapid repairs.

2.1.3. Damages to the power distribution industry

The distribution infrastructure of electrical energy has also suffered regular damage due to the full-scale aggression. Ongoing active combat operations across a significant portion of the country's territory have damaged both cable and overhead distribution lines, as well as distribution substations of lower voltage classes (110 kV, 35 kV, 6/10 kV, 0.4 kV). These primary types of electrical distribution equipment are managed by regional Distribution System Operators (DSOs), which include various state and private companies. The total damages incurred by the Ukrainian DSOs are estimated at \$0.8 billion, with the majority of losses occurring in companies located close to or within active combat zones or those that have undergone occupation. The affected regions include Donetsk, Luhansk, Sumy, Kyiv, Zaporizhzhia, Dnipropetrovsk, Chernihiv, and Odesa. Throughout 2022, on average, over 680,000 consumers per day experienced power outages due to active combat operations.²²

2.2. Damages to the oil and gas sector

The oil and gas sector of Ukraine suffered extensive damage due to targeted strikes by the Russian Federation and prolonged active combat across a significant portion of the country's territory. During the initial months of the full-scale invasion, Russian forces used long-range strikes to destroy large facilities for oil and petroleum product refining and storage, including the Kremenchuk Oil Refinery and the Shebelinsky Oil Refinery. Additionally, regular shelling damaged infrastructure for the transportation and distribution of natural gas, and some gas extraction facilities were occupied or remain under temporary occupation. The total estimated losses in the oil and gas sector, including oil refineries, amount to \$3.3 billion.²³

²¹ https://www.facebook.com/story.php?story_fbid=7785735864792710&id=100000691212487

²² Based on Ministry of Energy of Ukraine data. <https://map.ua-enerqv.org/uk/resources/85a0e29e-e9aa-4e5d-8f97-01ba4bf0ed59/>

²³ Previous estimates of damages and losses of the Ukrainian economy as a result of the full-scale aggression of the Russian Federation include oil refineries in the industry section.

2.2.1. Damages to the natural gas industry

Prolonged active combat operations and targeted mass strikes by Russia have severely damaged various facilities involved in natural gas extraction, transportation, and storage. Hundreds of wells belonging to "Ukrgezvydobuvannya", the largest natural gas producer in Ukraine and a subsidiary of the state-owned NJSC "Naftogaz of Ukraine", were either under occupation or located near the front lines.²⁴ Due to Russian shelling, at least 200 km of gas transportation pipelines, dozens of gas distribution and compressor stations, over 7,000 km of gas distribution networks, and 5,000 gas distribution points were damaged or completely destroyed.²⁵ Since the beginning of Russia's full-scale invasion, nearly 198,000 consumers have been left without gas supply daily due to active combat actions.²⁶ During the mass attacks on Ukraine's energy infrastructure in the spring of 2024, underground gas storage (UGS) facilities in the Lviv region were repeatedly targeted. The above-ground infrastructure of these UGS facilities was damaged, but no critical damage affecting their operation was inflicted, according to the chairman of NJSC "Naftogaz of Ukraine".²⁷

The current estimate of damages incurred by state-owned and private companies involved in natural gas extraction, transportation, distribution, and storage is \$0.9 billion. However, this estimate requires further refinement due to the complexity of conducting accurate calculations amidst prolonged active combat operations, the occupation of parts of Ukraine's territories, and limited access to information.

2.2.2. Damages to the oil industry

During the first year of the full-scale invasion, The Russian Federation's precise long-range strikes from destroyed significant portions of the oil and petroleum product storage infrastructure, as well as oil refineries supplying almost the entire domestic production of petroleum products. According to KSE analytical team's estimates, the total damages in this industry are estimated at \$2.4 billion.

Before the full-scale aggression, Ukraine met about 30% of its domestic demand for petroleum products through the operation of two active oil refineries – the Kremenchuk Oil Refinery and the Shebelinsky Oil Refinery. The Kremenchuk Oil Refinery, the largest in Ukraine, was almost completely destroyed due to a series of missile strikes in 2022-2023. The Shebelinsky Oil Refinery, part of "Ukrgezvydobuvannya" and located near the front line, suspended operations on February 26, 2022, but was repeatedly targeted during the summer and winter of 2022, sustaining significant damage.²⁸ Additionally, the Lysychansk and Odessa Oil Refineries, which had not been in active use in recent years, were attacked and practically destroyed. In

²⁴<https://expro.com.ua/novini/ukrgazvidobuvannya-u-2022r-skorotilo-vidobutok-tovarnogo-gazu-na-3-do-125-mlrd-kub-m>

²⁵https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2023_06_30_UA_sectoral_evaluation_and_damage_assessment_Version_XI_final.pdf

²⁶<https://map.ua-energy.org/uk/resources/800bea37-9e21-4068-9d2d-1bd4e87c08eb/>

²⁷<https://www.naftogaz.com/news/oleksiv-chernyshov-vorozha-ataka-na-psg-grupy-ne-vplyne-na-gazopostachannva-ukraintsvam>

²⁸<https://www.naftogaz.com/news/operativna-informatsiya-schodo-roboty-pidprvemstv-grupy-naftogaz-stanom-na-12-00-26-lyutogo-2022-roku>

2023, the Merefa Mini-Oil Refinery, created during the full-scale war, was also destroyed.²⁹ The total damages to Ukrainian refineries are estimated at over \$2.1 billion.

Since February 24, 2022, at least 32 oil depots of various sizes and modernization levels, along with the fuel stored in them, have been damaged or completely destroyed. The estimated damages to fuel storage infrastructure amount to \$266 million.

The destruction of oil storage and processing infrastructure, combined with the complete cessation of petroleum product supplies from Russia and Belarus – which accounted for about 70-90% of imports before the full-scale invasion – caused a severe and prolonged deficit in Ukraine's petroleum product market. In March 2022, imports covered only 10% of petroleum product consumption, a trend that persisted in the following months. A severe fuel shortage began in late April 2022, which was only overcome in August of the same year through a series of government decisions and the reorientation of importers to other markets and delivery routes.

2.3. Damages to the district heating industry

A number of large district heating facilities were destroyed by targeted strikes, and other heat supply infrastructure was damaged or destroyed due to active combat operations and long-range shelling. The current estimate of damages to the district heating sector, excluding major combined heat and power plants, amounts to nearly \$1 billion.

Preliminary estimates indicate that during the period of full-scale invasion, 18 large combined heating and power plants (CHPPs) were damaged or completely destroyed. Some of these facilities were critically important for providing cities with heat and hot water. For example, the Kremenchuk CHPP in the Poltava region, which was destroyed in 2022, covered about 80% of the city's needs. Around 180,000 residents of the community could have been left without heating for the entire heating season if not for timely repair work. The monetary damages resulting from the damage to CHPPs are accounted for in the section assessing damages to electricity generation facilities.

Additionally, combat actions led to the partial or complete destruction of 815 boiler houses, with the highest numbers in the Kharkiv, Kyiv, Chernihiv, Donetsk, Zaporizhzhia, and Mykolaiv regions. Partial or complete destruction affected 182 central heating points, and 354 km of district heating networks were completely destroyed.

Despite massive shelling and active combat operations, most populated areas of the country successfully passed the heating seasons of 2022-2023 and 2023-2024. However, significant damage to the power grid in March-April 2024 and the risks of further attacks on large heat generation facilities pose a serious threat to the uninterrupted operation of the main centralized heating systems in Ukraine.

²⁹<http://reform.energy/news/merefyanskiy-mini-npz-otrimav-kritichni-poshkodzhennya-vnaslidok-povitryanoi-ataki-rf-prezident-aes-group-21537>

2.4. Damages to the coal mining industry

The preliminary estimate of damages incurred by the coal mining industry due to the full-scale invasion of Ukraine amounts to \$0.4 billion. The main negative consequences for the coal industry stem from Russia's military aggression during the period of 2014-2022, when most Ukrainian mines in the eastern part of the country were occupied. After February 24, 2022, Russia occupied several more coal enterprises in the Donetsk and Luhansk regions. About 60% of Ukraine's coal deposits are temporarily occupied by Russian forces.³⁰ During the first months of the full-scale invasion, approximately 10 Ukrainian coal mines were flooded. Additionally, coal mining enterprises under Ukrainian control, located near the front line, are regularly shelled by the aggressor. Other coal mines that have been under occupation for 10 years are in decline, with a significant portion already abandoned or in the process of liquidation. However, access to many mines is currently restricted, making it impossible to obtain information about the extent of damage to mine equipment, particularly regarding the suitability of local coal reserves for resumed extraction.

³⁰https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2023_06_30_UA_sectoral_evaluation_and_damage_assessment_Version_XI_final.pdf



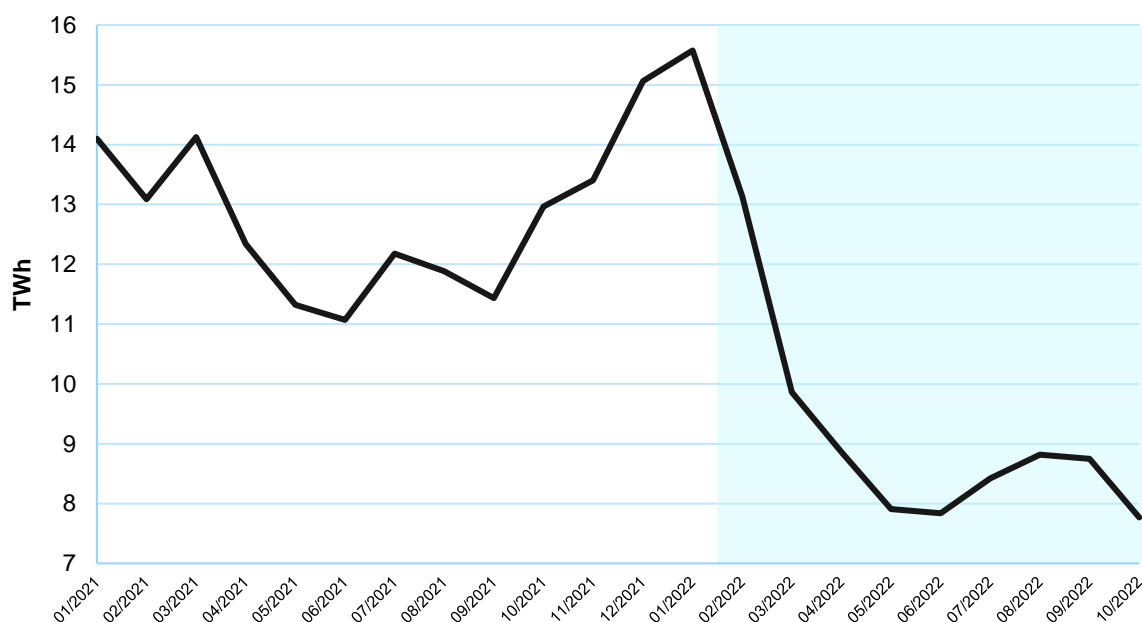
03

**LOSSES TO UKRAINE'S ENERGY
SECTOR DUE TO THE RUSSIAN
FEDERATION'S FULL-SCALE
INVASION OF UKRAINE**

The full-scale invasion of Ukraine by the Russian Federation has led to significant losses in the energy sector, amounting to over \$40.4 billion. This includes \$39.9 billion in lost revenues for energy companies and \$0.5 billion in expenses related to debris clearance and demolition work on damaged facilities. Several factors contribute to these losses, including mass population migration, regular attacks on energy infrastructure, territory occupation, reduced economic activity, and the destruction of assets of major industrial consumers.

Electric power companies have incurred the largest losses, estimated at over \$18 billion. Within the subsectors, the electricity generation sector experienced the most significant losses (\$12.7 billion), followed by distribution system operators (\$3.6 billion) and transmission system operator (\$2.2 billion). From the onset of the full-scale invasion in February 2022 until the first massive attacks on the power sector in October 2022, electricity production decreased by 29% compared to the same period in 2021. By generation type, the most significant decreases occurred in combined heat and power plants (-79% YoY), renewables (-42%), nuclear power plants (-32%), and hydroelectric power plants (-14%).

Figure 3.1. Electricity production in Ukraine.



Source: Kyiv School of Economics, based on Ukrenergo data.

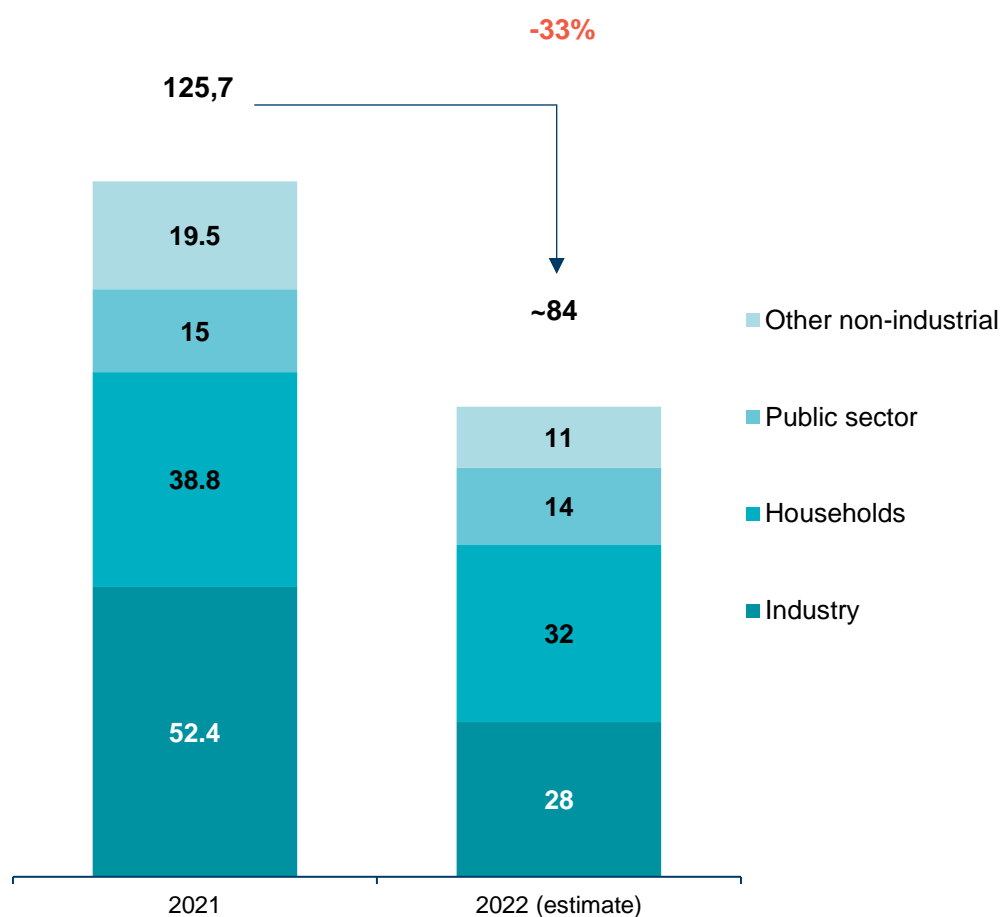
Note: The highlighted area reflects the period of Russian military aggression against Ukraine.

Massive attacks and the destruction of electricity transmission and generation infrastructure exacerbated the decline in production. For instance, electricity supply decreased by almost 34% from January to April 2023 compared to 2021 levels.³¹ The southern and eastern regions experienced the most significant declines in electricity consumption (50-100%), due to factors such as occupation by aggressor forces, population displacement, destruction and shutdown of industrial facilities, and regular supply disruptions due to shelling. The industrial electricity

³¹ <https://www.undp.org/ukraine/publications/towards-green-transition-energy-sector-ukraine>

consumption also significantly decreased, driven by more than a twofold reduction in industrial demand. This exacerbated the financial stability issues of the electricity market due to the financial model of regulation and cross-subsidization of retail prices for household consumers.

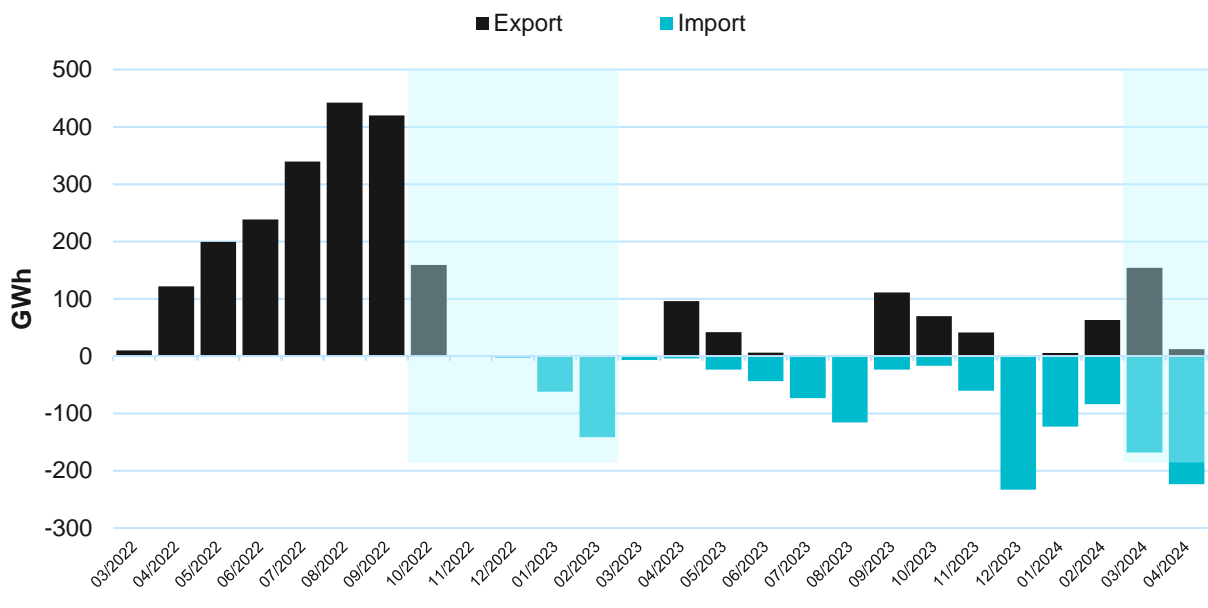
Figure 3.2. Electricity consumption by type of consumer in Ukraine, TWh.



Source: Kyiv School of Economics, based on Ukrenergo data.

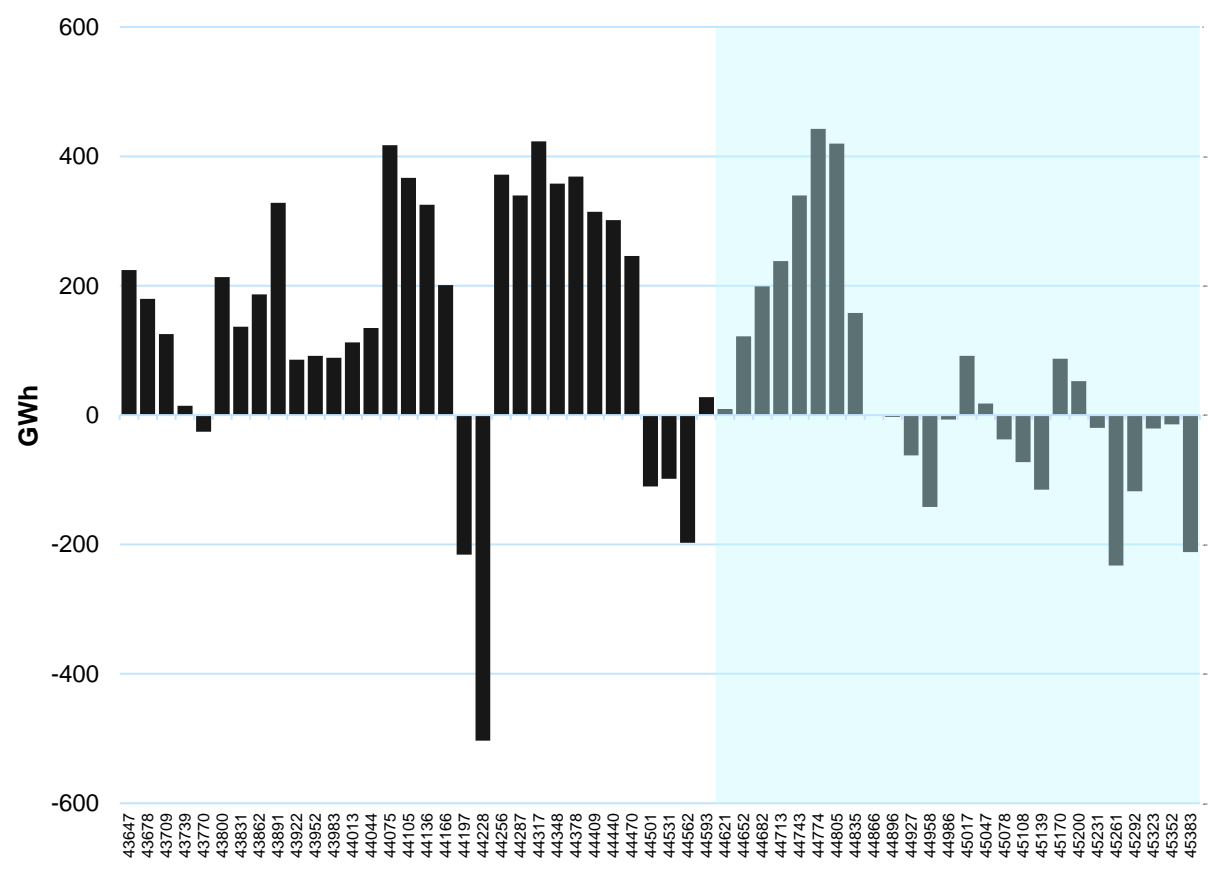
The destruction of Ukraine's electricity infrastructure marked a significant shift in its energy dynamics, transitioning the country from a net electricity exporter to one heavily dependent on imports to sustain peak demand. Upon joining the Continental European power grid through ENTSO-E membership in March 2022, Ukraine consistently exported electricity with minimal reliance on commercial imports. Between March and September 2022, Ukraine exported nearly 1.8 TWh of electricity to neighbouring countries. However, relentless attacks on the energy system forced Ukraine to halt exports from November 2022 onwards. Consequently, commercial imports and emergency assistance increased. While exports resumed from April 2023 amidst a crisis, a new wave of attacks on the energy infrastructure in late March 2024 saw exports drop to a minimum. Import volumes surged again from November 2023, reaching historic monthly highs within the ENTSO-E framework and pushing against its commercial limit (1.7 GW) during certain hours of the day.

Figure 3.3. Electricity external trade and the impact of massive attacks on Ukraine's energy system.



Source: Kyiv School of Economics, based on Ukrenergo data.
Note: The highlighted area reflects the period of massive attacks on Ukraine's electricity infrastructure.

Figure 3.4. Net electricity exports in Ukraine.

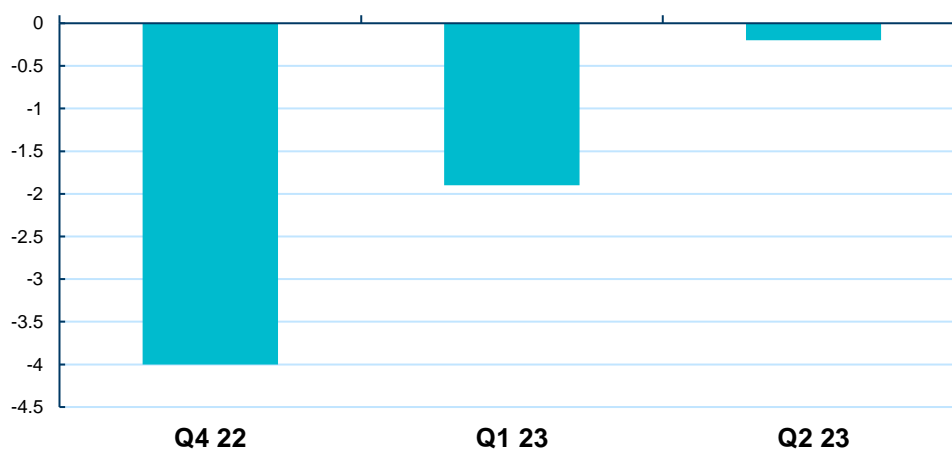


Source: Kyiv School of Economics, based on Ukrenergo data.
Note: The highlighted area reflects the period of Russian military aggression against Ukraine.

The electricity shortage during the heating-winter period of 2022-2023 caused not only energy losses but also broader economic repercussions. According to data and estimates from the National Bank of Ukraine (NBU), persistent electricity shortages led to a 1.6 percentage point slowdown in GDP growth in 2022 and a 0.6 percentage point slowdown in 2023.³² Additionally, increased production costs to secure alternative power sources and reduced output volumes added extra inflationary pressure, amounting to 0.5 percentage points in 2022 and 2 percentage points by the first half of 2023. The widening trade deficit to \$1.8 billion, caused by declining exports and rising imports of energy equipment for reconstruction and alternative power sources, negatively impacted international reserves.

As of the late 2022, 40% of enterprises reduced production or service provision due to the electricity shortage, while 12% closed part of their operational departments, revealed a survey of top executives from European Business Association member companies.³³ Moreover, 9% temporarily halted operations and mothballed portions of their premises, while another 1% completely ceased operations. According to NBU data, businesses reduced goods production or service provision by an average of 19% in November 2022, and by 14% in February 2023 after partially adapting to intermittent power outages.³⁴ Profitability declined due to increased costs and reduced sales forced companies to optimize expenses, including workforce reductions. The survey revealed that 11% of respondents had to cut wages, while 8% were forced to reduce staff.

Figure 3.5. The impact of the electricity shortages on Ukraine's real GDP growth compared to a scenario without a deficit, percentage points.



Source: National Bank of Ukraine estimate.

The reduction in domestic demand for natural gas, the ban on its export, and strikes on gas infrastructure have led to losses in the natural gas sector amounting to \$5.4 billion. By the end of 2022, despite a nearly 7% decline in gas extraction, domestic consumption decreased by 24% (~7 billion cubic meters). This allowed for a reduction in the import of natural gas, which previously covered about a third of Ukraine's demand. In June 2022, the Ukrainian government imposed a ban on the export of domestically produced natural gas to ensure sufficient reserves before the heating season. As a result, due

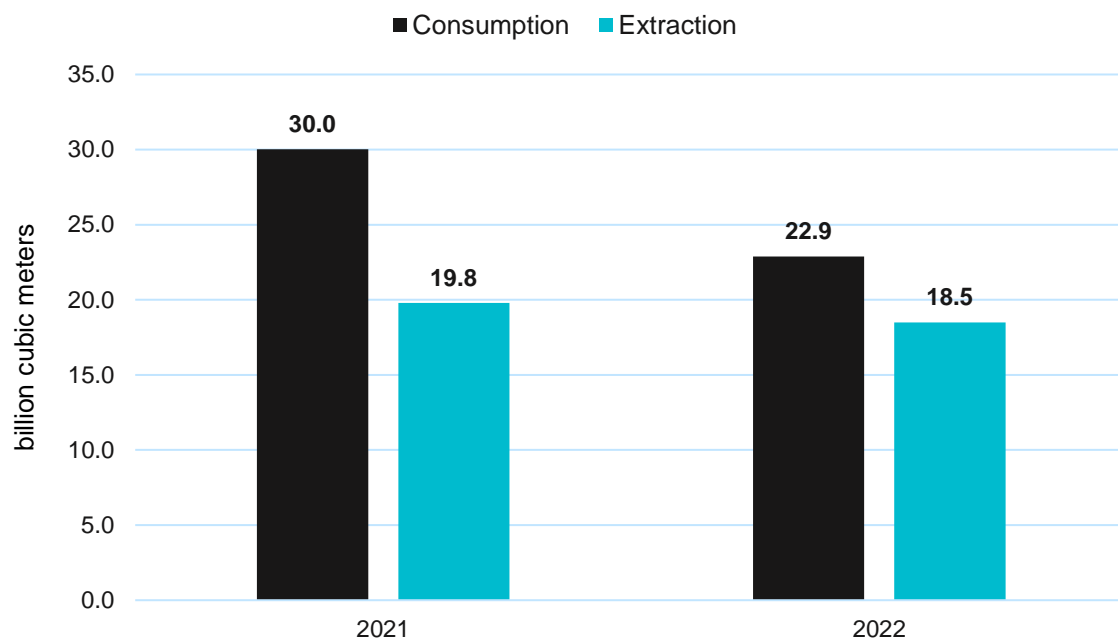
³² https://bank.gov.ua/admin_uploads/article/IR_2023-Q1.pdf?v=4

³³ <https://eba.com.ua/navit-trvvalji-blekaut-ne-zavadyt-72-kompanij-eva-pratsuvuvatv-na-ukravinskomu-rvniku/>

³⁴ https://bank.gov.ua/admin_uploads/article/IR_2023-Q2.pdf?v=4

to the saturation of the domestic market and the inability to export, the gap between the wholesale price of natural gas within the country and quotations on major European exchanges widened. From March to December 2022, the average price of natural gas on the Ukrainian Energy Exchange was about \$900 per thousand cubic meters, while at the Dutch TTF hub, it was \$1,400 per thousand cubic meters. In 2021, Ukraine exported 2.5 billion cubic meters of natural gas (13% of the extraction volume).

Figure 3.6. Natural gas extraction and consumption in Ukraine.



Source: Kyiv School of Economics based on Ministry of Energy of Ukraine, energy companies, and energy associations data.

Private companies in the natural gas sector have suffered the most significant losses. Compared to 2021, the gross production of natural gas by private enterprises decreased by 14% in 2022 and by 26% in 2023. The volumes of gas production by these companies are highly dependent on the levels and regularity of capital investments. Security risks and the ban on exports have become significant negative factors influencing investment decisions. Consequently, the financial losses of these companies may worsen with the continuation of the full-scale war. Additionally, the decrease in domestic consumption negatively affects the revenues of companies involved in gas transportation and distribution.

The destruction of all active refineries has almost completely eliminated the oil refining market in Ukraine, with losses estimated at \$13 billion. Prior to the full-scale invasion, oil refining in Ukraine amounted to about 3.6 million tons per year, covering one-third of domestic demand. The destruction of active refineries like the Kremenchuk Oil Refinery and the Shebelinsky Oil Refinery, as well as inactive ones like the Lysychansk and Odesa Oil Refineries, has forced Ukraine to cover almost all domestic oil product consumption through imports. Furthermore, due to the destruction of oil depots and the redirection of import routes, importers have incurred additional capital and logistical expenses.

The destruction of district heating facilities and the reduction in demand for thermal energy have led to losses in the centralized heating sector amounting to \$2.7 billion. The financial situation for heat supply companies, most of which are municipal, is deprived. The need for financing to rebuild damaged facilities and essential infrastructure modernization is severely limited due to the decline in demand among non-residential consumers and the moratorium on tariff increases in the heating supply sector for residential consumers introduced in August 2022.

The reduction in coal production at state mines and the occupation of coal enterprises have resulted in losses of nearly \$0.7 billion in the coal mining industry. Reports indicate that coal production at state-owned mines, which accounted for about a quarter of total production, halved during the period of full-scale invasion.³⁵ However, in 2022, the DTEK group of companies, which owns private coal mines, managed to maintain production levels at those of 2021.³⁶ Nevertheless, the overall reduction in the capabilities of national producers to supply energy coal due to the war results in losses for them and further increases Ukraine's dependence on imports.

³⁵<http://reform.energy/news/derzhavni-shakhti-za-2020-2022-roki-skorotili-vidobutok-vuqillva-bilshe-nizh-udvichi-qlava-tsentrenergo-21387>

³⁶<https://dtek.com/media-center/press-releases/dlya-zabezpechennya-nadivnogo-vidobutku-vuqillva-na-shakhtakh-dtek-energo-vvedeno-v-robotu-25-novikh-lav-/?amp>



04

**UKRAINE'S ENERGY SECTOR
RESTORATION NEEDS**

The restoration of Ukraine's energy sector requires substantial financial investment, preliminarily assessed by KSE analytical team at \$50.5 billion.

This amount includes the financial requirement for the full reconstruction of destroyed and damaged energy infrastructure, considering the principle of "Build Back Better" (\$48.5 billion), and \$2 billion to address the liquidity needs of energy companies caused by war-related revenue losses.

The total restoration needs for the power energy industry are estimated at \$33.8 billion.

Due to the significant destruction of large thermal and hydro power generation facilities, there is an urgent short-term need to restore partially surviving facilities to prevent potential electricity shortages during the heating season of 2024-2025. Energy companies require prioritized access to critically important equipment such as turbines, generators, and transformers, as well as financial support for reconstruction efforts. The total cost of full-scale restoration of lost generation capacities is projected at \$29.3 billion.

Considering the extensive damage to electricity generation facilities and power grids, the Kharkiv region specifically requires alternative low-capacity power sources, including gas turbine and gas piston power plants, as well as cogeneration units.

In other regions, it is essential to ensure that all critical infrastructure facilities have backup power sources to maintain the reliability of heating, water supply, sewage systems, and social services. This will also provide the necessary flexibility to the power system during intraday electricity consumption peaks.

The needs for transmission and distribution infrastructure amount to \$4.6 billion.

Additional reinforcement of high-voltage substation equipment is necessary to enhance resilience to further mass attacks. Urgent repairs of damaged distribution infrastructure necessitate essential power equipment and auxiliary tools (vehicles and personal protective gear) for repair teams.

The estimated cost of restoring the oil and gas sector reaches \$14.8 billion.

A significant portion of this amount (\$12.5 billion) is attributed to rebuilding all destroyed oil refining plants according to their latest production capacity. Developing a competitive oil refining industry in the domestic market requires economies of scale, thus necessitating the construction of high-capacity plants. Potential investors may consider real projects in this industry after the war ends, factoring in the current high risks of physical destruction of new facilities. Companies engaged in oil products import and wholesale require infrastructure development with a high level of physical protection and the expansion of cross-border logistics to reduce time and costs for fuel imports. For companies engaged in natural gas extraction and transportation, the restoration needs for damaged infrastructure amount to nearly \$1.4 billion.

The needs of the district heating sector are estimated at \$1.4 billion, excluding the needs for the reconstruction of large combined heat and power plants.

Significant external financing is required for reconstruction due to the extensive destruction of boiler houses, central heating points, and heating networks, as well as the challenging financial situation resulting from prolonged tariff freezes for residential

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consumers during the full-scale war. In cities dependent on large heating facilities, ensuring backup heat supply sources is crucial. This includes the installation of cogeneration units and modular boilers capable of operating on gas or solid fuels, including processed biomass.

In summary, Ukraine's energy sector restoration requires substantial financial investment across various sub-sectors to rebuild and enhance the resilience of its infrastructure, ensuring the reliability of energy supply and supporting economic recovery.



05

**RECOMMENDATIONS
ON THE RESTORATION PROCESS
OF UKRAINE'S ENERGY SECTOR**

Reducing the risks of significant electricity deficits in the short term requires coordinated efforts from the government and international partners.

The key prerequisite for restoring the energy system and achieving gradual stabilization is security. Hence, there remains an urgent need to transfer as many air defence assets to Ukraine as possible and ensure their sufficient and timely provision. Additionally, preparation for the heating-winter period of 2024-2025, given the extremely limited time frame, can be focused on the following areas:

- (i) Rebuilding large lost generating capacities, if it is possible to do in the short term. Energy companies require access to funding for reconstruction works, which can be facilitated through preferential financing or grant support. Since the production and delivery of new turbines and transformers is a lengthy process, it's crucial to search for comparable equipment among preserved energy facilities abroad and prioritize Ukraine's access to newly manufactured equipment.
- (ii) Providing alternative power sources for critical infrastructure and installing the maximum available amount of small manoeuvrable generation (such as gas turbine and gas piston power plants) and cogeneration units running on natural gas and biomass, along with durable and powerful energy storage systems. These power sources can be managed by state and municipal energy companies, which have the capacity to promptly install, connect, and efficiently manage such facilities.
- (iii) Increasing the trade capacity for cross-border electricity imports to Ukraine to the maximum technical level, while also creating a more favourable financial environment in the domestic electricity market to boost commercial import volumes.
- (iv) Boosting the construction of fortifications around electricity transmission infrastructure and establishing a reserve of key equipment to minimize the threats of further attacks on the energy infrastructure.

To mitigate security risks, decentralizing the Ukrainian energy system is recommended, involving the establishment of a network comprising numerous small-capacity power plants.

Given the government's strategic initiatives to construct new units for nuclear power plants, the ongoing trend of cost reduction in electricity generation from renewable energy sources, and the shortage of flexible generating capacities, it is imperative to adopt a technically sound approach to develop a decentralized model. Despite the significant attacks on the energy infrastructure in March-April 2024, restrictions on RES production were enforced during specific daytime periods, indicating a persistent challenge. Additionally, there is a considerable deficit of electricity during morning and evening peak load hours. Consequently, among the priority initiatives for revitalizing and decentralizing the energy system, the establishment of such small-scale facilities is deemed pertinent:

- High-maneuvrability power plants capable of utilizing natural gas (gas peaking power plants);
- Thermal power plants and cogeneration units utilizing renewable fuels (such as wood waste, agricultural waste, recycled household waste, etc.) or natural gas;
- Energy storage systems essential for maintaining the balance of the energy system in its current state, and integral to future solar and wind energy projects.

The scaling of such projects may be achievable through private initiative, with support for accessing the funding, simplified procedures for obtaining permits for design and connection of such facilities, a clear and attractive investment horizon, stability, and transparency in regulatory policy, and addressing debt issues in the electricity market.

Energy efficiency should bolster Ukraine's energy resilience and independence. One of the primary reasons for the inefficient utilization of energy resources in Ukraine is the prolonged household price regulation across the electricity, natural gas, heating, and water supply sectors. The current uniform approach to setting retail prices for energy resources dissuades responsible consumption by households, which could otherwise save on expenses through investments in energy efficiency. This issue exacerbates the financial strain on energy companies, with the total debt in the electricity market reaching approximately \$1.3 billion and heat supply companies accumulating debts exceeding \$2 billion for natural gas.^{37 38}

Another consequence of the inefficient use of energy resources is the substantial deterioration of energy infrastructure, leading to significant losses during energy transportation. For instance, the heat network loss rate ranges from 18% to 30%, primarily due to two-thirds of them being operational for over 25 years without modern insulation, and about 38% of the networks are in an emergency state (as of 2021).³⁹ Furthermore, the level of electricity losses during transmission and distribution, even before full-scale intrusion, exceeded 10%, surpassing the 3-7% range observed in European countries.⁴⁰

Gradually transitioning away from current practices of tariff formation, price regulation, and cross-subsidization in favour of a market-driven model, coupled with direct support for financially vulnerable households, will foster efficient energy consumption and the reconstruction and modernization of energy infrastructure, ultimately establishing a resilient and independent system.

³⁷ <https://www.ukrinform.ua/rubric-economy/3848448-zagalna-zaborgovanist-na-rinku-elektroenergii-skorotilasa-priblizno-na-7-milardiv-kudrickij.html>

³⁸ <https://www.naftogaz.com/news/the-debts-of-heat-producers-to-naftogaz-amount-to-uah-95-billion>

³⁹ <https://www.facebook.com/minenergoUkraine/posts/3904431469613100>

⁴⁰ <https://www.ceer.eu/documents/104400/-/-/09ecee88-e877-3305-6767-e75404637087>

Methodology

Within this report, the following types of damages and losses are assessed:

- **Damages** (according to the World Bank methodology) – complete or partial destruction inflicted on the physical infrastructure of Ukraine as a result of the war.
- **Losses** (according to the World Bank methodology) – changes in economic flows due to the war; income losses in the sector, additional expenses related to the war, future losses that the sector incurs due to the war.

The assessment of damages and losses was carried out by the analytical team of the Kyiv School of Economics (KSE) in accordance with the World Bank methodology, taking into account a significant amount of microdata collected by relevant government authorities, local civil-military administrations, and energy companies since the start of the full-scale war, as well as open sources due to limited access to data because of the high risk of disseminating security-sensitive information.

The assessment methodology involves the application of direct and indirect methods based on statistical data and individual expert assumptions, particularly regarding the extent of damage in areas where active hostilities are still ongoing and physical inspection is limited due to danger (e.g., due to explosive ordnance contamination) or which are temporarily occupied by the aggressor.

To calculate the cost indicators of damaged or destroyed assets, we used average costs calculated based on data from the State Statistics Service, relevant ministries regarding purchases made through the Prozorro system, market analogues, etc., applying correction factors according to the level of damage to the objects. For calculating the value of assets of large commercial objects identified by institutions, information from financial statements relevant to the latest available date or information on the cost of construction of objects based on market analogues is used. At the same time, the receipt of information about the actual (compared to previous assessments) condition of damaged objects in liberated and controlled territories of Ukraine is used as a "proxy" to refine assumptions about the level of damage and the extent of destruction regarding other objects.

The assessment of losses of companies consists of lost revenues of energy companies due to the full-scale invasion of Russia, costs for clearing debris and demolition work on damaged or destroyed objects, as well as costs for repairs if objects suffered repeated damage (subject to data availability). The period for calculating lost revenues and additional expenses includes the period from February 24, 2022, to the time of the assessment plus 18 months from the time of its conduct.

The assessment of reconstruction needs is based on the market cost of rebuilding similar objects while preserving the main characteristics of such objects, as well as applying correction factors based on the principle "Build back better." The recovery needs include funds to cover the liquidity shortage of energy companies due to lost revenues resulting from the full-scale aggression. However, given the change in Ukraine's economic structure, strategic goals regarding energy security, and climate policy, necessary investments may vary depending on strategic government decisions and the security situation.

Limitations

The current assessment is complicated by the lack of detailed information on damage to objects currently under temporary occupation or inaccessible due to constant shelling and/or significant risks of mines. The assessment does not include the value of property in temporarily occupied territories. Objects included in the assessment of damages may be included if they were damaged before the occupation or if there is sufficient information about the extent of the damage. Additionally, detailed information on damage to objects in the control of the energy infrastructure is also extremely limited, given the constant threat of new massive attacks. The current assessment of the need for restoration of the energy infrastructure does not take into account further structural changes in the energy sector of Ukraine. Considering the changes in Ukraine's economy, strategic goals regarding energy security, and climate policy, the volume and profile of necessary investments may vary depending on governmental decisions, assessments by system operators, and socio-economic indicators after the end of the war.

