

Energy infrastructure attacks: outlook and impact during 2024–2025 cold season

OVERVIEW

Outlook summary

Attacks on energy infrastructure are highly likely to continue into Ukraine’s upcoming cold season. Since April 2024, damaging countrywide attacks have further degraded the country’s energy production capacity; the country can cover only half of the upcoming winter’s energy demand. Russia is increasing supplies of missiles and drones to not only sustain but also potentially increase the number and volume of air strikes. Ukraine’s defensive capability is likely to either remain the same or deteriorate, making it challenging to counter all missile and drone attacks on energy infrastructure. A worst-case combination of delayed repairs to power grid infrastructure, lower-than-expected electricity imports, and increased damage is likely to result in prolonged power outages amid severe winter conditions.

Impact summary

During the cold season, prolonged power outages, both state-controlled and uncontrolled, will have a direct impact and subsequent negative consequences on essential needs, such as health, shelter, WASH, safety, and education, as well as humanitarian operations. The impact will be countrywide, affecting private industries, small businesses, and the overall economy, with socioeconomically vulnerable families also facing higher living costs and rising inflation. Outages will impact urban and rural areas, with a compounding effect on people living in frontline regions, particularly older people and IDPs.

About the report

Aim: this report aims to highlight the current and expected damage and destruction of energy infrastructure and anticipate the impact on the living conditions of people in general but especially the most affected groups during the cold season from October 2024 to April 2025.

Methodology: this report relies on secondary data. The outlook and impact sections use ACAPS’ anticipatory analysis methodology. Outlooks rely on historical data and trends analysis to outline the most probable – or at least a highly probable – future.

Limitations: this report is not fully exhaustive and does not describe all anticipated impacts. Anticipatory analysis is not an exact science, as new less likely futures can develop. Triggers expected to drive a shift or change in the situation may not occur nor drive the expected change, or new factors may arise that prevent the projected change or shift from happening. Information and data gaps concerning potentially security-sensitive information on energy infrastructure limit the analysis.

TABLE OF CONTENTS

Context background	2
Energy and heat infrastructure in Ukraine.....	2
Attacks on the energy infrastructure.....	4
Outlook.....	6
Anticipated impacts	7

CONTEXT BACKGROUND

The Russia–Ukraine war started in 2014 with the Russian forces' ground invasion of southern Ukraine and subsequent occupation of the Crimea Peninsula. That same year, the war spread into the easternmost parts of Luhanska and Donetsk oblasts bordering Russia. The escalation into a full-scale Russian invasion of northern, eastern, and southern regions of Ukraine took place on 24 February 2022. By September of that year, Russia had occupied and taken partial control of four more regions in the southeast (SCEEUS 22/02/2024; DW 30/09/2023). Since the full-scale invasion, the Russian military has waged its ground offensives in parallel with countrywide air strikes on both military and civilian objects, including combined missile and drone attacks on energy production infrastructure (ICC 25/06/2024). By mid-2024, air strikes on Ukraine's energy infrastructure had resulted in a 50% reduction in power production capacity (UNSC 14/05/2024; OHCHR 03/07/2024; Ukrinform 07/06/2024).

ENERGY AND HEAT INFRASTRUCTURE IN UKRAINE

Electricity generation in Ukraine

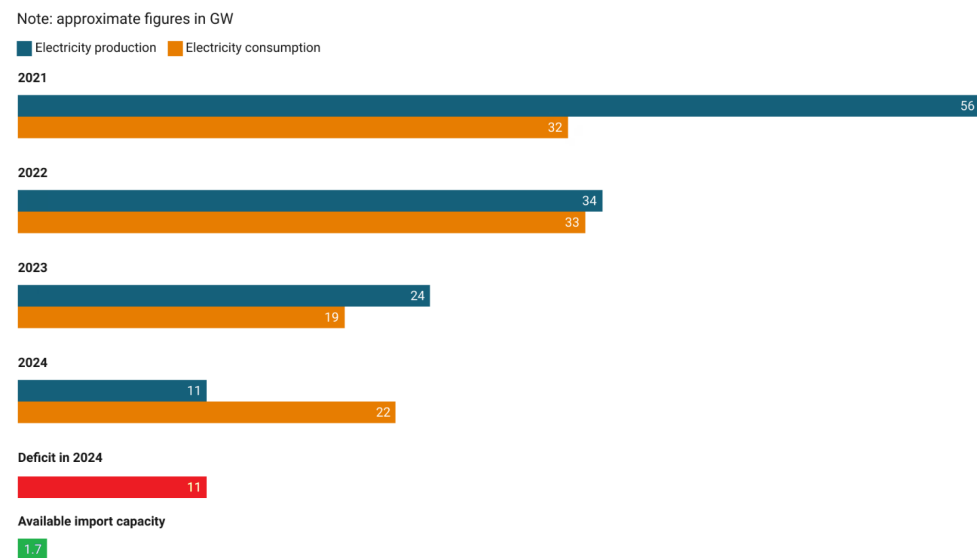
Ukraine's power production relies on a combination of nuclear, coal, hydro, thermal, and renewable energy, with almost 85% of all electricity in the country coming from nuclear and thermal power plants (WFP 08/07/2024).

Before 2022, Ukraine's National Nuclear Energy Generating Company, Energoatom, operated four nuclear power stations, which produced more than half of the country's electricity (54.5% of total production). In March 2022, Russian forces seized the largest nuclear power plant (NPP) in Europe, the Zaporizhzhia NPP, leaving Ukraine with three operating nuclear power plants: Khmelnytskyi, Rivne, and South Ukraine NPPs. The current total nuclear production capacity is almost half (7.8GW) of its prewar capacity (13.5GW).

Before the war, nearly 20 thermal power plants (TPPs) spread out across the country generated 23.5% of Ukraine's total electricity. Russian attacks on Ukraine's energy infrastructure have destroyed or damaged the majority of these thermal plants, however. Current TPP production portion had dropped to less than 5% by mid 2024 (Slovo i Dilo 04/06/2024). By May, Russian attacks on TPPs had dropped their energy production capacity by nearly 86% from 17.1GW in 2022 to 2.5GW (DiXi Group 16/04/2024).

The renewable energy sector has also suffered significant capacity losses (75% wind and 20% solar energy) because of the war, with around 75% of all facilities located in the partially occupied Kherson and Zaporizka oblasts and sustaining damage from shelling, missiles, and drone attacks (MEV 18/04/2023; UE 12/05/2023).

Figure 1. Electricity production versus consumption and deficit



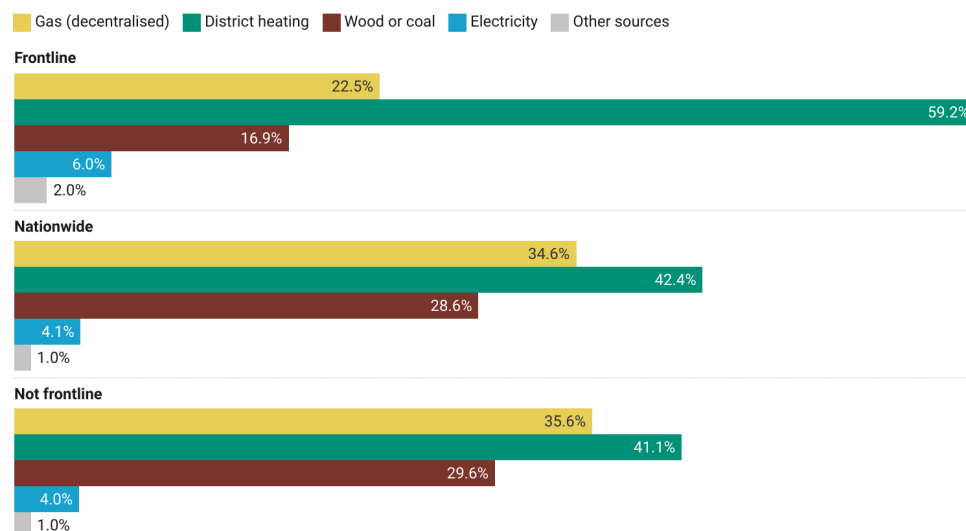
Sources: ACAPS using data from WFP (08/07/2024); UE (10/04/2024); ProstirUA (01/07/2024)

In 2021, prior to the full-scale invasion, Ukraine's total prewar production capacity was at 56GW, and the surplus of energy production for export was almost 24GW of electricity (UE 10/04/2024). By August 2024, however, Ukraine produced a total of 9–11GW, only half of the estimated energy demand during the coming winter (18–22GW). The prognoses of deficit for the 2024–2025 winter varies between 30–35%, depending on the estimates of the repair work for existing NPP capacities and on different estimates of needed power consumptions, which has varied between 19–33GW in previous years. Imports from the European power grid can only provide an additional 1.7–2GW of power, which is much lower than the total need and cannot alone cover the deficit (WFP 08/07/2024; UE 10/04/2024; RUSI 12/08/2024; Interfax 01/07/2024).

Heating sources

Figure 2. Main heating sources used by families in the winter of 2023–2024

Note: based on multiple-choice questions. Respondents were allowed to choose more than one answer.



Source: ACAPS using data from REACH (29/08/2024)

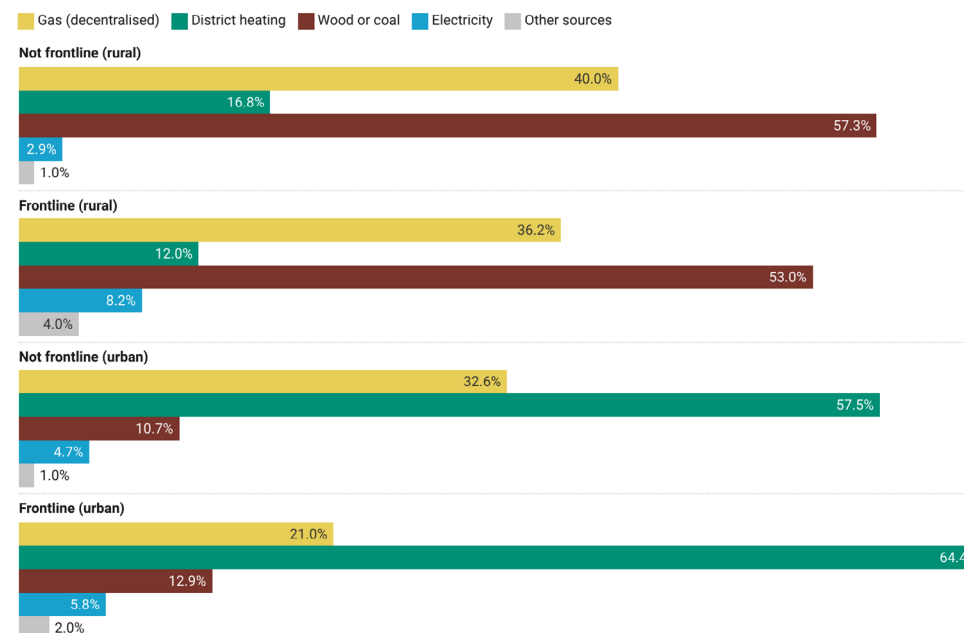
District heating systems are the main source of heating in urban areas, where TPPs, combined heat and power plants, nuclear power stations, and boiler plants produce heat for entire neighbourhoods (IKI 18/07/2023; CASE Ukraine 03/2007). In rural areas, families use individual heating methods more often, either from decentralised gas or solid fuels, such as coal, firewood, briquettes, or pellets (IOM 13/09/2023). As reported in the August 2024 needs assessment by REACH, 57% of the respondents in rural areas relied on wood as a heating source (REACH 29/08/2024).

Natural gas covers a significant portion of heating needs, used both for district heating systems and individual residential heating. Gas plays a critical role in domestic and district heating: about 80% of Ukrainian families rely on a centralised gas supply, and more than half use centralised water supplies heated by gas, coal, or sometimes biomass. Individual gas, electric, and solid fuel heaters are common for the other half of families in rural and suburban areas (CSIS 13/01/2023).

Urban areas in Donetsk, Kharkivska, Khersonska, Luhanska, Mykolaivska, Sumska, and Zaporizka oblasts – some of which include frontline urban areas – are more reliant on district heating than the national average, making them particularly vulnerable to TPP damage (REACH 29/08/2024).

Figure 3. Main heating sources used by families in the winter of 2023–2024 in urban versus rural areas

Note: based on multiple-choice questions. Respondents were allowed to choose more than one answer.



Source: ACAPS using data from REACH (29/08/2024)

ATTACKS ON THE ENERGY INFRASTRUCTURE

2022–2023

Russian forces launched the first wave of combined missile and drone attacks on Ukrainian energy infrastructure in October 2022, and Ukraine introduced the first state-controlled power outages, known as stabilising power outages or rolling electricity blackouts, that same month (Ukrinform 12/10/2022; BBC 10/10/2022). By the end of the year, Ukraine's energy production capacity had fallen by 30%, including the effects after Russian forces took over the largest NPP in Zaporizka oblast as well as two TPPs in southern and eastern regions of Ukraine (Enerdata 03/2024; RUSI 12/08/2024; NV 11/04/2024). Russian forces also extensively targeted the transformer substations connected to NPPs. The destruction of the Kakhovka Dam in June 2023 resulted in the immediate loss of 350MW of hydro generation capacity in the region (RUSI 12/08/2024; SMC 06/06/2023). Overall, 12 million people experienced interrupted electricity access, causing internet, communications, water, and heating system disruptions during the 2022–2023 winter season (WFP 08/07/2024).

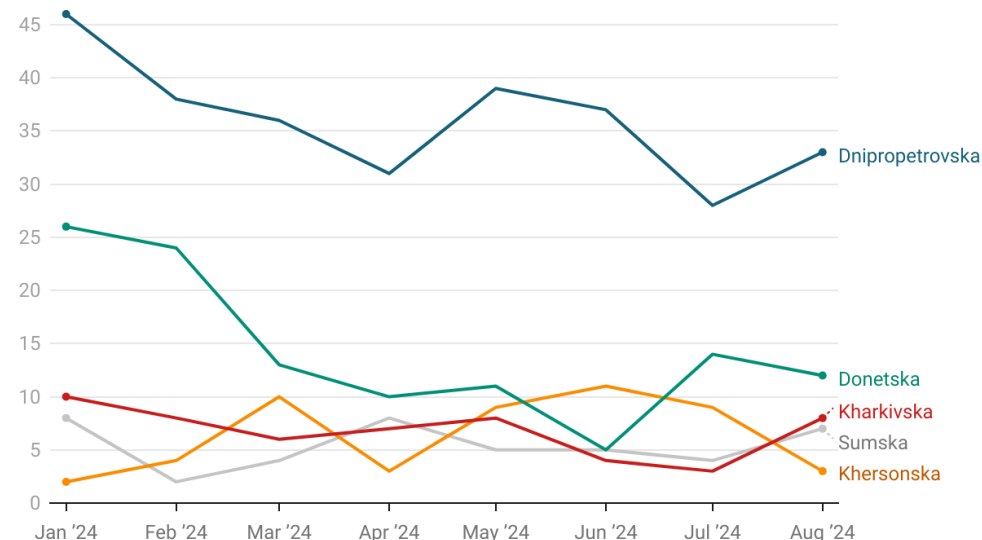
There were no stabilising state-controlled power outages during the 2023–2024 cold season (Suspilne 07/03/2024; RBC-Ukraine 28/08/2023). Ukraine mitigated the attacks' impact by conducting energy infrastructure maintenance, restoring damaged infrastructure, increasing gas production, importing energy from neighbouring countries, and harnessing international in-kind and financial support for its energy sector (WFP 08/07/2024; DiXi Group 12/08/2024).

2024

Since the spring of 2024, Russian forces have shifted their strategy and started using high-precision missiles targeting production capacity in areas where air defence has a lower capacity. Russian missiles, which typically landed 100–200m from their targets earlier in the war, have improved their accuracy to within 1m (RUSI 24/06/2024). The attacks have caused widespread destruction, heavily affecting major TPPs and hydroelectric power plants (HPPs) across the country. In northern Kyivska and eastern Kharkivska oblasts, attacks have destroyed two TPPs that produced 8% of the country's electricity, as well as Trypillia TPP in Kyivska, which powered Cherkaska, Kyivska, and Zhytomyrska oblasts (Slovo i Dilo 12/04/2024; Economichna Pravda 28/11/2022; BBC 12/04/2024). In Kharkivska oblast, the attacks damaged the region's largest TPP in March 2024 before destroying it in April (Slovo i Dilo 12/04/2024; NV 11/04/2024). Similarly, a total of 12 attacks throughout 2022 damaged a TPP in Ivano-Frankivska oblast in May of that year and had destroyed it by June. Attacks on another TPP in Vinnytska oblast caused significant damage in March 2024 (Slovo i Dilo 12/04/2024; Hromadske 28/06/2024; NV 11/04/2024). In northern Sumska oblast, the extent of the damage

from the March 2024 attack on a TPP that provided 75% of the oblast's electricity is not public, nor is the damage on three HPPs in central Cherkaska, western Chernivetska, and eastern Zaporizka oblasts (Slovo i Dilo 12/04/2024; NV 11/04/2024). By May 2024, attacks had destroyed 80% of the TPPs and 50% of the HPPs across the country (UNSC 14/05/2024).

Figure 4. The five oblasts with the highest number of recorded energy infrastructure damage between January–August 2024



Source: ACAPS Damages Dataset (accessed 09/09/2024).

Note: the number of recorded damage does not correlate with the associated impact. This dataset tracks civilian infrastructure damage during the Russia–Ukraine war since 24 February 2022 and relies on publicly available sources.

In comparison, attacks in 2022–2023 targeted high-voltage lines, transformer substations, distribution stations, and control, protection, and measurement systems, which are considered easier to repair than electricity production facilities (BBC 12/04/2024).

Between 22–29 March 2024, Russian forces launched a series of air strikes using high-precision missiles on ten oblasts, damaging the largest hydroelectric power station in Ukraine, the Dnipro HPP in Zaporizka oblast, and a thermal power station in Kharkivska oblast (Ukrinform 22/03/2024; Economichna Pravda 08/08/2024).

On 26 August 2024, Russia launched more than 200 missiles and drones targeting, in part, energy infrastructure in 15 oblasts throughout Ukraine. This attack is considered the largest in terms of the number of missiles and drones specifically targeting energy infrastructure and launched simultaneously since 2022 (AP 26/08/2024). One of the targets in this attack was an HPP in northern Kyivska oblast (TKI 28/08/2024). Electrical substations that are also crucial for nuclear safety were targeted as well (IAEA 05/09/2024). Attacks on energy infrastructure have continued into early September 2024 (Slovo i Dilo 09/09/2024).

By May 2024, the estimated cost of damage to the energy sector was over USD 16 billion. This includes damage to thermal, hydroelectric, and nuclear power plants, electricity and gas production, transmission and distribution facilities, oil production and refineries, oil and petroleum storage facilities, the coal industry, and district heating. Revenue loss for the energy sector alone is estimated at USD 40 billion, and the full restoration and rehabilitation of the energy sector is estimated to cost USD 50 billion (KSE 10/06/2024).

Recent rolling blackouts

There are two types of state-controlled power outages: emergency shutdowns and stabilising outages. Emergency shutdowns are unplanned but necessary to balance the power system and prevent its collapse; otherwise, repairs would last days or weeks. Emergency shutdowns occur within 10–15 minutes after the detection of an overload and can last up to four hours at a time. In May 2024, after the damage and destruction from increased attacks a month earlier caused a power deficit, the Government of Ukraine had to reintroduce rolling electricity blackouts (The Guardian 23/06/2024; TKI 20/05/2024). Depending on the extent of energy repairs and energy demand versus availability, the schedule can be stricter, with rolling blackout sessions lasting up to eight hours instead of the planned four hours. On the other hand, an improved energy situation can lead to a less strict schedule with shorter planned blackout sessions or fewer sessions per day (DTEK accessed 02/09/2024; Yasno accessed 04/09/2024; ISO accessed 05/09/2024). Between April and August 2024, several heatwaves and the limited imported electricity meant that the quantity of energy could not match the demand, and the countrywide rolling blackouts lasted longer per session (all four planned hours up to eight hours) (BBC 06/09/2024; Slovo i Dilo 02/04/2024; Reuters 16/07/2024; WFP 08/07/2024; Radio Svoboda 01/07/2024). In late July, Ukrainian officials announced that there would no longer be strict power outages over the next three months as long as there was no additional significant damage to electrical infrastructure. Cooler summer weather, energy imports from neighbouring countries (Hungary, Moldova, Poland, Romania, and Slovakia), and an increase in the production of renewable energy (including solar energy) will contribute to less strict rolling blackouts until October 2024, with power outages only planned in the evenings (Interfax 30/07/2024).

Since the largest attack on 26 August 2024, planned power outages have become stricter in Kyiv city and Dnipropetrovska, Donetsk, Kyivska, and Odeska oblasts (NV 31/08/2024; TSN 27/08/2024). The attacks involved missiles or drones causing damage or destruction after hitting energy infrastructure. The ensuing power outages have been uncontrolled, localised, and temporary. Government services are working on restoring electricity to the affected raions or neighbourhoods, but the lengths of outages vary and depend on the extent of the damage (Yasno accessed 04/09/2024). Cyberattacks that target energy infrastructure can also cause uncontrolled power outages (RBC 09/11/2023).

Mitigation and repair efforts

Even before 2022, Ukraine's energy system already needed major repairs. Preexisting issues, such as low operating efficiency and high power losses at the district heating and power distribution levels, lowered the energy sector's resilience, making it more fragile to attacks (Foreign Ukraine 23/04/2021; Low Carbon Ukraine accessed 30/08/2024).

Similar to previous years, in 2024, Ukraine has undertaken a series of measures to mitigate the impact on the energy sector while also working on energy infrastructure maintenance and repairs (MEV 02/05/2024; KMU 30/07/2024; Glavkom 22/07/2024; Zaxid 17/07/2024). First, the Government of Ukraine has requested international support, both for increasing defence capabilities and directly for energy infrastructure (AP 15/07/2024; VOA 09/07/2024; EC 09/04/2024). Overall, Ukraine has received more than 7,700 power generators, close to 3,000 transformers, and five large autotransformers since 2022, in part through the support of the EU Civil Protection Mechanism. In July 2024, the European Commission and Ukraine's Ministry of Energy established the Ukraine Energy Support Fund to better coordinate financial and in-kind support to Ukraine (EC 12/07/2024). Ukraine also increased the volume of electricity imports to 850MWh in June from 150MWh in March, with the maximum important capacity being 1.7GWh (WFP 08/07/2024). Electricity imports ensure that industries and businesses have uninterrupted power (UNIAN 03/06/2024). Increasing energy import capacity for Ukraine is also under discussion with the EU (DiXi Group 03/07/2024; MEV 28/08/2024). Power generator allocation has prioritised healthcare facilities to mitigate the life-threatening impacts of all types of power outages (MoH Ukraine 28/06/2024). In early 2024, Ukraine also launched the construction of two additional reactor units out of the four planned for the Khmelnytskyi NPP to make up for the lost capacity resulting from the Russian takeover of the 6GW Zaporizhzhia NPP (Enerdata 16/04/2024).

OUTLOOK

Given these conditions, the winter energy deficit is expected to reach up to 35%, meaning that rolling blackouts are highly likely to remain in place through the cold season. People will likely face stricter rolling blackouts, in part because Ukraine is struggling with restoring already damaged or destroyed energy facilities (Ukrainska Pravda 06/09/2024; WFP 08/07/2024; RAND 22/11/2022; The Guardian 28/08/2024).

A worst-case combination of delayed repairs to the power grid infrastructure, lower-than-expected electricity imports, and a significant increase in infrastructure damage could result in planned rolling blackouts of up to 20 hours per day amid severe winter conditions (NV 21/08/2024; TKI 17/06/2024; TWP 18/05/2024; NISS 29/05/2024).

Driver: energy attacks

Continued attacks and damage to energy infrastructure are highly likely in parallel with the Russia–Ukraine war, which is expected to last through 2025 (The Guardian 15/03/2024; The Interpreter 05/07/2024; CREC 16/05/2024).

Russian production of the missiles and drones used in these attacks has increased since 2022 and will likely continue to increase until 2025. For example, Russia produced 460 Kh-101 cruise missiles in 2023, up by 720% from 56 in 2021, the year prior to the full-scale Russian invasion of Ukraine. During the same period, Russian Iskander ballistic missile production increased by 260% from 50 to 180 (NBC 26/06/2024). Though Iran has been providing self-destructing Shahed drones to Russia since 2022, and which have been used in the attacks on energy infrastructure, the Russian Government has opted to increase its supplies by setting up a Shahed drone factory in its Tatarstan region. The factory aimed to produce 6,000 Shahed drones annually, but just by the end of April 2024, it had already produced 4,500 of such drones (Ukrainska Pravda 28/05/2024).

Russia has also imported weapons from Iran and North Korea and used them in attacks on energy infrastructure. The import of additional supplies is likely to continue through 2025 (CNN 14/04/2024; Stimson 06/03/2024; TWP 22/06/2024). Russia used the ballistic missiles transferred from North Korea in late 2023 in attacks on civilian infrastructure in Ukraine in 2024. Iran is also set to start supplying ballistic missiles to Russia in late 2024 (IISS 17/01/2024; AJ 30/04/2024; Iran International 03/09/2024). The North Korean missiles, which are cheaper and somewhat less precise than the Russian-produced missiles, have mainly been used in attacks on civilian infrastructure in Ukraine (NHK 09/09/2024).

The increase described above in the number of Russian missile and drone supplies likely correlates with the increased missile and drone attacks in 2024. From 2022–2023, Russian forces launched around 3,900 Shahed drones and 7,400 missiles against critical infrastructure in Ukraine (ISW 28/12/2023). From 1 January to 31 August 2024, ACLED recorded 5,967 attacks, more than double the attacks recorded in the same period last year (2,822) and more than the total number of attacks in all of 2023 (5,563) (ACLED accessed 09/09/2024).

To sustain an increasingly destructive impact, Russian forces will continue using tactics that make shooting drones and missiles more challenging for the Ukrainian defence system, particularly given the increased supply and production of missiles and drones in Russia. This includes launching a combination of various types of missiles and drones in large quantities and from several locations inside Russia and then changing their trajectory after entering Ukraine's territory (Informator 22/03/2024 and 26/05/2024; ISW accessed 08/7/2024; NV 19/07/2024). Additional missile supplies from North Korea will likely be used in two ways: as part of the Russian tactic to overwhelm Ukraine's air defence and in combination with more precise missiles to target Ukraine's energy infrastructure (NHK 09/09/2024; BBC 05/05/2024).

The attacks are likely to increase, both in terms of the number of attacks during the cold season compared to the same period in the previous year and the amount of missiles and drones used per attack. This will further stretch Ukraine's defence capacity, worsening the extent of energy infrastructure damage and destruction and leading to a higher energy deficit and stricter, longer rolling blackouts (FDD 18/01/2024). To ensure maximum damage and destruction, Russian forces will also likely continue exploring and adapting their tactics, such as targeting specific components of the energy system more vulnerable to attacks.

Aggravating factor 1: Ukraine's defence capacity

By early September 2024, Ukraine did not have the defensive capacity to intercept all missiles and drones without receiving damage and destruction to energy infrastructure, particularly during combined missile and drone attacks.

The number of available air defence systems in Ukraine is not sufficient to fully protect the energy infrastructure. Despite requesting additional patriot systems, particularly after increased attacks since April 2024, lack of support and delays have persisted and will likely continue (RUSI 24/06/2024; BBC 27/04/2024; Ukrinform 30/08/2024; Breaking Defense 29/08/2024). The continued damage and destruction of energy infrastructure are highly likely in the foreseeable future (RUSI 24/06/2024).

Ukraine also does not have the defensive capacity to effectively destroy production sites of missiles and drones or target launching sites in Russia (ISW 14/01/2024). The major military aid received has specific restrictions for use on Russian territory. While some restrictions on

targeting Russian territory have been softened in areas bordering Ukraine, limits remain on the use of long-range weaponry and deeper strikes that could significantly prevent attacks (BBC 11/09/2024; VOA 16/07/2024; CBC 15/08/2024; AJ 18/06/2024; President of Ukraine 19/08/2024).

As a result, Ukraine's defence capability to safeguard energy infrastructure from damage and destruction will remain insufficient, and the energy system will likely remain vulnerable to further combined missile and drone attacks by Russian forces (BBC 02/06/2024).

Aggravating factor 2: Cold weather conditions

The cold season in Ukraine starts on 15 October 2024 and will last until mid-April 2025. Heating needs will cause the energy demand to peak during this period (Shelter Cluster 04/09/2024; RUSI 24/06/2024). The decision to switch on the central heating system is decentralised, and each oblast authority will activate it when the air temperature remains 8° C or lower for three consecutive days. For example, in 2023, the eastern, western, central, and northern oblasts switched on the heating system on 16 October, while the southern oblasts waited until November because of warmer weather (Channel 24 09/11/2023).

As daylight hours become shorter after the seasonal change, renewable solar energy will decrease significantly, while the need for electricity will increase (Interfax 30/07/2024; World Data accessed 03/09/2024). Solar panel performance in Ukraine drops between one-half to one-third on average during winter (Solar Technology 29/11/2021).

Cold weather will compound the impact of power outages. During the entire six-month period from October–April, the average temperature fluctuates between –5–2° C (REACH 19/06/2024). Temperatures from January–February can reach –20° C in all northern, western, central, and eastern regions across Ukraine, and all regions experience temperature drops of up to –10° C (Teplo 23/10/2019; UkrHMC 23/02/2024; WB accessed 13/08/2024; NV 17/11/2023; TsGO accessed 30/08/2024; REACH 19/06/2024). At this temperature, it will be impossible to balance the power system without stabilising power cuts. Preliminary weather forecasts for the 2024–2025 winter predict cold weather anomalies and higher-than-average precipitation (Severe Weather Europe 26/08/2024).

According to REACH's cold spot assessment, people in Sumskyi raion of Sumska oblast and Bohodukhivskyi, Chuhuivskyi, and Kharkivskyi raions of Kharkivska oblast will face the highest winter-related risks owing to the combination of harsh winter weather conditions, the high level of existing infrastructure damage, and the concentrated presence of groups with specific needs, such as IDPs and older people (REACH 19/06/2024).

ANTICIPATED IMPACTS

Impact on essential needs

Power cuts and attacks will disrupt water infrastructure services, leading to a range of negative outcomes related to shelter, WASH, and health. The interruption of power supply at water pumps will disrupt water access for people living on higher floors of buildings in urban areas (Kyiv Post 26/08/2024; TWP 06/06/2024; LA Times 06/07/2024; WFP 08/07/2024). Apartments and homes that depend on electricity and water pipes will experience heating access disruptions. Power cuts can lead to damage to electrical appliances, such as fridges and water boilers, and repairing or replacing such essential appliances will add additional costs to families (BPM Electric accessed 04/09/2024). There is also an increased risk of water pipes bursting in unheated homes, particularly in rural areas, which would cause further damage and facilitate mould growth. Mould causes respiratory issues, particularly for children, older people, and people with reduced immunity (Medical News Today accessed 23/08/2024). For sewer systems that lack sufficient backup power supply, prolonged power cuts will affect operations, leading to insufficient water treatment capacity and sewer back-ups or overflows (Swisspower/Winterthur accessed 24/08/2024).

Power cuts will also affect IDP collective shelter sites and newly displaced people. Collective IDP sites, which may use boilers, central heating, and electricity for heat, are vulnerable to power cuts (OCHA 26/07/2024). Hostilities along the front line and the escalation of attacks on areas bordering Russia will result in further displacement and mandatory evacuations – including of those providing essential services, such as healthcare staff – particularly (but not exclusively) within and from Donetsk, Kharkivska, and Sumska oblasts (OCHA 22/08/2024; BBC 20/08/2024; ISW accessed 23/08/2024). By early September 2024, a gradually shifting front line in Donetsk oblast alone put almost 40,000 people at risk of displacement, mostly in Pokrovsk city (Ukrinform 28/08/2024; Kyiv24 28/08/2024; Suspilne 28/08/2024). During the cold season, any attacks that destroy energy infrastructure needed for heating could force people to leave their homes or evacuate from areas not necessarily closest to the front lines, such as pre-frontline cities and regions that receive more frequent attacks, including Dnipropetrovska, Kharkivska, Mykolaivska, Odeska, and Sumska oblasts (The Guardian 21/11/2022; TKI 01/09/2024; ACLED accessed 05/09/2024). Newly displaced people will require additional housing, and collective IDP sites will need to be fitted both for winter weather conditions and mitigation measures against the expected power cuts.

Prolonged winter power cuts will have a compounding negative impact on people living in frontline areas, particularly older people. Shelling will cause additional damage to health facilities as well as electricity, gas, water, and heat supply facilities, further limiting access

to these essential services (REACH 05/07/2024 and 31/07/2024; WHO 19/08/2024; OCHA 03/01/2024; *Economichna Pravda* 31/08/2024). People living within 30km of the front line are usually older people who choose to remain instead of facing displacement. Many have severe healthcare needs, which sometimes go unaddressed because insecurity, damage, and destruction have severely limited healthcare access (REACH 22/07/2024 and 31/07/2024). Without adequate mitigation measures and assistance, prolonged exposure to temperatures lower than 18° C is particularly risky for older people and those with mobility issues, and any resulting illnesses will further complicate underlying chronic health issues (Janssen et al. 10/10/2023; Age UK accessed 20/08/2024; UKHSA 16/01/2019).

Attacks on energy infrastructure have negative health implications. People relying on life support machines at home are at the highest risk because they require uninterrupted power access (GPPi 08/08/2024; (OCHA 16/02/2024; LB 12/06/2024). Inadequate access to WASH facilities can lead to infectious diseases, including hepatitis, botulism, and cholera outbreaks (Health Cluster 24/07/2024). The fumes of the diesel used in power generators can worsen underlying respiratory conditions, such as asthma (Science Daily 22/05/2017). The combined psychological impact of the attacks and the negative impact of power cuts during colder months will also affect mental health (Seleznova et al. 25/09/2023).

Power cuts will increase safety risks at home. The increased usage of electrical heaters and gas stoves can cause hazardous accidents, such as fire or carbon monoxide poisoning (Shelter Cluster 04/09/2024; UNICEF 23/01/2023). The risk of fire also increases when power is restored and unattended appliances switch back on (SAMFS accessed 24/08/2024; Sundridge Strong Fire Department accessed 24/08/2024).

Power cuts will increase safety risks in areas with mine and unexploded ordnance contamination. People who cannot afford to buy wood for heating may venture out to collect fuel in areas with mine and unexploded ordnance contamination, risking severe injuries or even death. Ukraine is one of the most heavily contaminated countries, particularly in frontline areas where hostilities are concentrated (REACH 29/08/2024; DRC 18/08/2023; OHCHR 09/08/2024; ACAPS 24/01/2024). By the end of July 2024, contamination-related incidents had killed 391 civilians and injured 878 (OHCHR 09/08/2024).

Power cuts also disrupt telecommunication services, particularly in frontline and remote or rural areas but also when blackouts last longer than ten hours (Ukrinform 01/08/2024). Older people living on their own in remote areas where communications are disrupted during prolonged energy cuts may not be able to call for help in case of a medical emergency.

Energy supply disruptions especially affect children by interrupting online education. Energy disruptions lead to internet outages, which affect students relying on online education during the war. Prolonged power disruptions will affect the education of at least 70% of all students, 40% of whom study exclusively online and the other 30% in hybrid online and in-person modes (OCHA 30/07/2024; Ukrinform 27/06/2024; Education Cluster 04/06/2024).

Socioeconomic impact

Power outages will continue to affect economic activity by forcing businesses to shut down or reduce operating hours, leading to income loss for employees (NBU 25/04/2024; GMK 08/07/2024). The indirect loss of income and revenue and the additional costs of fuel, generators, and insulation will affect micro and small businesses and certain industries that depend on uninterrupted power the most. In May 2024, the Government of Ukraine raised the electricity import coverage for industries from 50% to 80% because of the energy deficit. This will increase the cost of energy production (UNIAN 03/06/2024). In the same month, more than half of all businesses suspended operations because of power outages and lost 8% of their total working hours on average, a number that increased to 14% in July (Rubryka 21/07/2024; BBC 14/08/2024). According to a survey, during the July 2024 rolling blackouts, 83% of businesses had reduced working hours, with higher impacts in Chernivetska, Dnipropetrovska, Kharkivska, Khmelnytska Lvivska, and Zaporizka oblasts (BBC 14/08/2024). Depleted savings and unemployment can push people towards coping strategies with potentially harmful consequences, such as skipping meals, opting for cheaper, less nutritional food, or reducing budget allocation for healthcare (OCHA 26/07/2024; FSC 19/08/2024). These people include groups who are more vulnerable to socioeconomic issues, such as IDPs and older people (REACH 29/05/2024; IOM 15/07/2024).

Because of the attacks, socioeconomically vulnerable families face increased prices for electricity besides extra winter expenditures. On 1 June 2024, electricity rates for families rose by 64% from UAH 2.64 (USD 0.06) to UAH 4.32 (USD 0.1) per kWh. The Ukrainian Government plans to use the additional revenue to repair damaged energy infrastructure (*Economichna Pravda* 14/06/2024). These higher costs, however, are expected to make up 10% of the living wage (Minfin accessed 20/08/2024; WFP 08/07/2024). The electricity price will remain at UAH 4.32 (USD 0.1) per kWh until 30 April 2025. With the approach of the cold season, people will also face extra expenditures for heating in the absence of electricity, such as coal, wood, and fuel (Hromadske 12/07/2024; DRC 16/07/2024; OCHA 26/07/2024).

Rising inflation will aggravate the combined impact of power cuts and winter needs. In 2024, the inflation rate rose from 3.2% in April to 3.3% in May, reversing a monthly prolonged trend of decline from 26% in January 2023 (NBU 10/02/2023 and 10/04/2024). This recent increase is partially attributed to air strikes on energy infrastructure leading to higher energy, storage, and labour costs and processed food prices. By July 2024, the inflation rate had risen to 5.4% (NBU 12/08/2024). According to the National Bank of Ukraine's forecast, inflation is expected to grow to 8.5% by the end of 2024 and remain at around 6% in 2025 (NBU 24/07/2024).

Humanitarian operations

Prolonged power cuts will also affect humanitarian operations in all NGOs, particularly for smaller NGOs and volunteers who are often the main direct responders in frontline communities. Already facing insufficient resources for indirect and operational response costs, they will face the further impacts of increased needs for fuel and generators, power banks, and other communication solutions because of power cuts during winter (REACH 29/05/2024 and 31/05/2024). Power cuts can also disrupt internet and mobile services, limiting access to information and communication and affecting the planning and safety of humanitarian operations. Power cuts disrupting domestic activities such as cooking, showering, and other daily needs will also affect the wellbeing of staff.