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Situational Brief

“Do Russia’s attacks on power infrastructure drive forced migration from Ukraine?”

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"Energy services are essential for basic human protection and dignity. Lighting, heating, cooking and powering a radio or cell phone all use forms of energy. Energy is essential for health care services, and water and sanitation provisions, and extremely useful for education and community facilities" (Grafham 2020: 2).

Key takeaways

- Surveys show that lack of electricity, heating and water can drive forced migration
- By January 2025, 80% of Ukraine's energy infrastructure has been damaged or destroyed. However, the heating system remains largely intact.
- Pre-war overcapacities, a drop in demand, rationing, quick repairs, energy and fuel imports, generator imports, and Western aid prevented the collapse of Ukraine's energy system.
- 26.8% of all households, notably in rural areas, have alternative heating sources such as wood or coal burners.
- As a result, there has been little to no net forced migration due to Russia's attacks of Ukraine's energy system.

By late December 2024, Russia had launched 13 major attacks on Ukraine's critical infrastructure, notably power plants, heating plants and boiler stations, but also hospitals and schools (OHCHR 2024). This continued into January 2025. As a consequence of such attacks, the Helmholtz Centre Berlin (31/10/2024), among others, concludes that "many of the combined heat and power plants and cogeneration plants are damaged, and there isn't enough electricity to go around, which means that control systems and pumps can temporarily shut down. As a result, poorly insulated homes, particularly in urban areas, have less heating. This leads to unacceptable conditions for residents – especially children, the elderly and the sick – and will drive more people to flee, even from areas not directly affected by the fighting". The energy situation in Ukraine may seem dire at first glance, but a closer look reveals it is less severe than anticipated.

This brief assesses the state of Ukraine's energy system, and its impact on the population, and discusses the potential for further forced migration to the EU.

Ukraine's energy situation

Ukraine's energy industry consists of two main sectors: electricity and heating, complemented by regional extraction of fossil fuels. The electricity-producing sector is highly centralised, relying on large nuclear, gas, coal-fired, and hydroelectric power stations. The heat-producing sector is more decentralised and primarily dependent on gas. Before the war, Ukraine had 33 power stations (4 nuclear, 11 hydroelectric, 18 thermal), along with 11 solar and 9 wind parks, many of which also generate heat, and around 100,000 dedicated boiler stations (2007) (CASE 2007). However, the heating infrastructure, notably pumps, depends on electricity.

Before the war, Ukraine generated 56 Gigawatt (GW) of energy, consuming 32 GW and exporting a surplus of 24 GW (ACAPS, 13/9/2024). "Over the course of 2022 and 2023, about half of Ukraine's power generation capacity was either occupied by Russian forces, destroyed or damaged, and ap-

proximately half of large network substations were damaged by missiles and drones" (IEA, September 2024)[1]. Up to that point, the overcapacities largely cushioned the destruction. However, by July 2024, further attacks had left only "around a third of its pre-war electricity generation capacity" operational (ibid). In winter 2022, this resulted in 35 days of power cuts over six months (UNDP 2023). By December 2024, following attacks in August and November, energy generating capacity has dropped to possibly 20%, or around 11 GW. Simultaneously, by early 2024, energy consumption fell by a third due to the emigration of 16,2% of the population and a 20% decline in economic activity, with peak demand in 2024/2025 assumed to be 12 GW in summer and 18.5 GW in winter (IEA, September 2024). Regarding heating, only around 800 of the 100,000 boiler stations were damaged, leaving the heating system largely intact (IEA 2024).

Before a major attack on 28 November 2024, the 'most realistic scenario' for the winter was that the country could face electricity supply limitations for 8-14 hours a day for both industry and households (News Ukraine 2024). In Kyiv, for example, "daily blackouts of eight hours are common, and people plan their days around when power is scheduled to be available" (Reuters 2024). A similar situation occurs in other parts of the country. After the latest wave of Russia's attacks in December 2024 and January 2025, power cuts are likely to last even longer. If energy production capacity were further reduced to 20%, the country could face up to 70 full days or 140 half-days without power during the 180-day heating season, meaning almost every day would be affected[2]. But there are also exceptions, notably in the frontline city of Kharkiv, where despite daily rocket attacks, local informants indicated few power cuts and nearly continuous 24/7 electricity supply in November/December 2024.

An important element in Ukraine's energy production is the supply of coal and gas. So far, the supply of fossil energy sources has remained stable. Ukraine's resources are considerable and most of them remain under government control in Lviv, Volyn, Zakarpattya and Dnipropetrovsk provinces. Notably, natural gas production increased during the war, reaching 18,7 billion cubic metres in 2023 (Reuters 2023), covering almost 92% of domestic demand (IEA 2022). However, reports from early 2025 suggest that Russia also intensified targeting Ukraine's gas production and storage capacities, even in the west. Therefore, the remaining demand is increasingly met through imports of gas and liquified natural gas (LNG) from Europe and, since December 2024, the US. Before the war, Ukraine met 100% of its crude oil demand from domestic sources, was a net exporter (IEA 2022), and recently even drilled new oil wells (Euromaidan Press 2024). At the same time, due to limited and outdated facilities, up to 97% of refined oil products were imported. Following the destruction of the key Kremenchuk oil refinery by Russian shelling (Kyiv Post 2022), "Ukraine's entire oil sector has been forced to halt refining operations", making imports of refined oil products, such as petrol, diesel and kerosene necessary. As of January 2024, coal demand was also met by domestic resources (IEA 2022)[3], with 53% of coal used for energy production and the rest for industrial purposes. In January 2025, the country's largest coal mine, west of Pokrovsk – primarily producing coal for steel production – halted production due to Russian advances and the evacuation of the city[4]. This development will affect steel-making and exports but is unlikely to affect domestic electricity and heating production. Ukraine still has significant coal resources, notably in the Dnepropetrovsk oblast (Petlovanyi et al. 2018), where most of thermal coal including all brown coal is mined. Moreover, the country had already begun reducing reliance on coal, from 164 million tonnes in 1990 to around 38 million tonnes in 2019.

[1] All data in this paper come with a caveat. Many figures are imprecise or conflicting, certain information is classified. The sums presented here are approximate and rather indicators or trends than hard figures.

[2] This calculation is based on UNDP 2023 and extrapolated to 2024

[3] In 2023, coal production was 23.341 million tonnes, of which 1.8 million tonnes were exported in 2024; hence, despite the war and Russian occupation of many mines in Donbas, there was still some over-production. However, certain types of coal are still also imported.

[4] Before the invasion 88 of 121 coal mines in Donbas were in the occupied territory, of which at least a third was flooded or destroyed

The impact of winter weather on energy demand is another important factor, but no reliable forecast for winter 2025 temperatures is available. By mid-January, temperatures across Ukraine – west, east and south – have oscillated around zero. This is around the historical average, neither particularly cold nor mild. However, the coldest months are typically from January to March. “Every oblast in Ukraine is prone to experiencing days with temperatures below -10 °C, resulting in a nationwide exposure to severe cold temperatures“ (REACH 2024). As a consequence, “exposure to severe cold weather increases the risk of mortality by exacerbating chronic conditions like heart disease, strokes and respiratory illnesses. It may also result in cold-related injuries, hypothermia, and frostbite”(ibid.).

Any shortfall in energy supply due to Russian attacks potentially affects businesses, transportation, and private households. Factories, including those producing much-needed arms and ammunition, (hot) water supply, public and finance services, supermarkets (notably refrigerators), lifts in apartment blocks (impacting the elderly), internet and telephone services, as well as trams and trolleybuses may be left without power and cease functioning. Long-term damage is also a risk, notably due to frozen water pipes and pumps, leading to lasting disruptions in water and heating services, as well as flooding once temperatures rise again. To assess the actual shortfall, the impact of mitigating measures shall be analysed.

Table: Summary of key data

Pre-war energy industry **33** power stations, **20** wind/solar parks **100,000** boiler stations	**Destruction of energy generating capacity** **80%** (max., before restauration)	**Damaged boiler stations** **800** (0,8%)
Pre-war energy production **56** GW	**Pre-war energy consumption** **32** GW	**War 2022/2023 production** **28** GW
War 12/2024 production **11,2** GW	**War 12/2024 consumption** **11** GW	**2024/25 winter peak demand** **18,5** GW

Gas production

18, bcm **/ 92%** of demand

Oil production

Meets **100%** of demand

Refined oil products

Nearly **100%** imported before and during

Coal production

23 million tonnes (meets **100%** demand)

Winter peak demand energy gap

7.3 GW

2024/2025 power cuts

140 half-days during **180** days

Restoring damaged capacity

4-5 GW (aim)

Energy imports

4.4 GW

Solar panels, new

1.5 GW

Generator imports

2 million units approx.

Petrol, diesel etc imports

10 TWh annually (average)

Electricity storage equipment imports

2 billion Euro

Coal/wood burners

28.6% of all households (**3.43** million households)

Aid towards energy security

640 million Euro (UESF)
749 million $ (ESP) **42** million Euro (UK emergency support)

People in need of winter/energy aid

900,000

Coping strategies

The gap of 7.3 GW between energy supply and peak (winter) energy demand has been addressed through five strategies: rationed power supply via scheduled power cuts, repairs to the damaged grid, energy and generator imports, the use of coal and wood, and the installation of solar panels.

1. Rationed power supply

During the first war winter in 2022/2023, when energy production capacity stood at around 40%, "the average Ukrainian household endured five cumulative weeks without power [...] That is 35 days", spread over around six months (UNDP 2023). This equals 70 half-days of power outages, with energy supply usually rationed to a few hours per day, out of 180 days.

2. Continuous repairs

Efforts are made to repair damaged infrastructure. The Ukraine Energy Support Fund, worth over 640 million Euro, was set up by Western allies to facilitate energy infrastructure repairs (BMWK 2024), partly through a dedicated Ukraine Support Task Force. "Ukraine has repeatedly managed to repair damaged infrastructure and mitigate the consequences of power outages, avoiding a collapse of the power system" (Swedish Defence Research Agency 2024). "With ongoing repairs ... Ukraine aims to restore about 4-5 GW of power generation by winter" (EEAS 2024), equivalent to 27% of overall demand. Observers have noted the "high pace of repairs by Ukrainian actors", with anecdotal evidence suggesting large numbers of affected households could be reconnected within hours rather than days (Swedish Defence Research Agency 2024).

3. Energy and generator imports

In 2024, the Ukrainian energy grid, integrated into the Western European grid as of March 2022, facilitated the flow of electricity from west to east (EUNeighboursEast 2024). Electricity imports rose by +333% ($669 million) amounting to 4.4 GW in 2024, equivalent to around 22,5% of peak winter demand, and almost double previous estimates. These energy imports are complemented by liquified gas from the US via Greek ports (DTEK 2024). In addition, in 2022, the first year of the war, 640,000 power generators were imported (OSW 2023), this number increased by around 20% (Berlin Economics 2024) to an estimated 777,000 units[5] in 2023, although it declined in 2024. Energy storage equipment (batteries) was imported at a cost of 2 billion Euro (ibid), with imports increasing from the summer of 2024. By 2024, about half of all energy equipment imports were power generators (Vox Ukraine 2024), without considering in-kind imports. Additionally, in 2024, imports of batteries and transformers increased by 103% ($950 million) and 108% ($596 million), respectively. Through the EU Civil Protection Mechanism, over 6,500 power generators were sent to Ukraine by June 2024 (DG NEAR 2023, ECPHAO 2024), with plans to increase to 10,000 transformers and generators (DG NEAR). German aid, including generators and boilers, is meant to secure energy and heat supply for 2.6 million people (BMZ 2024). This is complemented by generator deliveries from the UK, further aid from the UK[6] while US aid through the Energy Support Programme (ESP) totals $749million. By the end of 2024, Ukraine could have had over 2 million small power generators and about 10,000 large generators. Whereas small generators have "been crucial in meeting the electricity needs of critical facilities and public 'points of resilience,' enabling people to access essential services such as phone charging, internet connectivity, heating, and lighting" (Berlin Economics 2024), the EU's large energy items alone "will generate power to meet the needs of 6.5 million people" (EEAS 2024). Meanwhile, China has persistently been the main supplier of energy equipment. To facilitate these imports, energy-generating devices are exempted from taxation.

[5] "The highest imports were the smaller size engines with an output smaller than 75 kVA", Berlin Economics 2024, p. 8

[6] The UK announced 42 million Euro (35 million GBP) in emergency support to repair the energy grid

4. Solar panels

In Kyiv, "official data showed that about 1.5 GW of new solar generation has been installed", with the government subsidising 70% of the costs of solar panels (Reuters 2024). In Odesa, new solar power plants deliver energy to several institutions, including hospitals, a school and social services centres (Lithuania 2024). More solar panels are planned for other parts of the country. Also, humanitarian organisations (e.g. Hope for Ukraine 2024) provide portable solar panels to frontline communities disconnect from electricity supply. These systems are "designed to meet essential daily needs, such as cooking, lighting, and communication". But because not all private initiatives are recorded, the number of solar power installations is likely higher.

5. Wood and coal burners

Nationwide, 28.6% of all households have wood or coal burners (ACAPS 2024) for heating, with up to 57.3% in rural areas but only up to 12.9% in urban areas. Households in villages, (semi)detached houses, and some pre-WWII buildings are more likely to have coal and wood heating facilities, which do not exist in post-WWII apartment blocks. Accordingly, possibly 3,43 million households, with 8,58 million household members, may rely on such alternative means of heating, whereas 8,5 million households, with 21.5 million household members, do not have access to these alternatives.

In total, Ukraine's remaining energy production capacity, including repairs and imports, totals approximately 19.9 GW, which should largely cover a winter peak demand estimated at 18.5 GW. Another indicator of the energy situation's stability is that it "even allows for commercial exports of electricity during certain hours, which helps to balance the system and generates additional revenue for energy companies" (CES 2025). A key challenge, given the damaged grid, is to transport energy to consumers. However, small-scale generators are proving effective in bridging some supply gaps, notably during scheduled power cuts. While this suggests that the energy situation is broadly under control and its impact on most people in Ukraine is not devastating, "local authorities report that nearly 900,000 people in ... [communities near the frontline] will require urgent winter support to survive the freezing months ahead" (World Vision Ukraine 2024).

Consequences for forced migration

Some migration literature identifies inadequate infrastructure, such as electricity and water, as drivers of migration or at least as exacerbating factors (e.g. Munoz et al. 2017). The results of a small-scale survey conducted in larger Ukrainian cities in May 2024 (Gradus 2024) suggest that for 49% of respondents, the lack of water, heating and light would be a driver of migration. These shortages ranked seventh, after security concerns or worries about children's development, but ahead of issues like lack of employment. Accordingly, only 15% of respondents considered this the main driver for leaving their domicile. Another survey by UNHCR in Switzerland in 2023 found that for 75% of respondents, access to electricity and water services was important or very important for return migration aspirations. This suggests that the destruction of critical infrastructure and interruption to the energy supply could act as a driver of forced migration.

There are still 31 million people in government-controlled parts of Ukraine who could be affected by an energy crisis, whereas around 6,6 million, or 16.9% of the pre-war population (2021), have fled the country. Before the war, there were around 16.5 million households in Ukraine (2020), with an average household size of 2,58 members (2020). By October 2024, 18% of the country was occupied by Russia (CFR 2024), meaning approximately 13,53 million households remain in government-controlled territory. The number of households in which all members have fled is unknown, as male adult household members are restricted from leaving the country and tend to stay. By late

2024, the number of households remaining in the country may have declined to below 12 million, with the number of household members likely reduced due to forced migration, possibly to around 2.07 million or fewer[7].

During the winter of 2023/2024, the already decimated energy and heating supply had no measurable impact on forced migration. Instead, the number of Ukrainian forced migrants in the EU increased by only around 10 % during the summer and winter months. Over the past 12 months, the total number of Ukrainians under temporary protection in the EU remained stable at 4.2 million (Eurostat) to 4.4 million (EUAA)[8]. The absolute numbers, however, shroud certain dynamics, notably the balance between returnees and new applications for temporary protection. For example, according to ICMPD (2025), there were 660,000 new applications for temporary protection in 2024. There is little evidence of a correlation between these dynamics and the energy crisis in Ukraine, as the number of returnees seems to match the number of those leaving. Among the various drivers of forced migration – such as security, economic hardship, separation from family, and evading conscription – there is no clear evidence linking the lack of electricity and heating to current migration trends.

In fact, those who are hit the hardest by adverse and deteriorating conditions – such as the elderly, poor, and handicapped, often in frontline communities – are typically the least mobile. The most vulnerable, possibly around 900,000, are likely to remain trapped in increasingly harsh conditions. If not supported or collected by relatives, evacuation might be their only option.

Conclusion

Until January 2025, Ukraine, supported by its allies, has managed to mitigate the energy crisis. Through a combination of measures, the breakdown of energy and heating supply – an issue that could act as another driver of forced migration – has been largely prevented. In most parts of the country, apart from some frontline communities, at least a temporary energy supply has been maintained. This has been an ongoing, Herculean task. As a consequence, while one survey shows that lack of electricity could drive forced migration for some, another recent survey suggests that the current level of degradation of the energy situation has had little, if any, impact on the resilience of the people of Ukraine, and thus does not significantly contribute to current migration trends.

Despite plausible warnings from various actors, no major outflow of people has been observed during the winter of 2024/25. Presently, the direct impact of the electricity and heating shortfall on migration appears limited. Domestic capacities, bolstered by Western technical and development aid, have prevented the worst, ensured enough energy supply for people to remain in the country, and contributed significantly to preventing further large-scale forced migration.

[7] Pre-war average number of household members of 2,58 minus 16.9% of people who fled the country

[8] From October to November 2024, according to Eurostat data, there was a marginal increase of around 36,000, less than 1 %

Disclaimer

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