Ukraine's Energy Security and the Coming Winter

An energy action plan for Ukraine and its partners

International Energy Agency

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Abstract

This special report from the IEA, *Ukraine's Energy Security and the Coming Winter*, provides an energy action plan for Ukraine and its partners to help the country meet its energy needs through the challenging months ahead.

Ukraine's energy system has been targeted since Russia launched its full-scale invasion of the country in February 2022. These attacks on key infrastructure have recently increased and intensified, posing a huge threat to reliable access to power, heating and communications services across Ukraine this winter.

This special report lays out 10 key energy actions to reinforce the country's energy security – essential to its security overall – at this critical juncture. It will take stock of the war's impact on Ukraine's energy sector, identify key risks for the coming winter and outline immediate actions that Ukraine and its partners could take in response. While the main focus is on Ukraine, the report also examines the energy situation in Moldova.

Acknowledgements, contributors and credits

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Note on data: because of the ongoing conflict, a significant portion of Ukraine's energy data has been restricted and is not accessible to the public. All data and other information in this report is based on publicly available sources.

Executive summary

This year has seen a step change in the intensity of attacks on Ukraine's energy sector, creating risks that extend far beyond energy as Ukraine approaches the winter months. While Russia has regularly targeted energy infrastructure in Ukraine since its full-scale invasion of the country in February 2022, its most recent bombardments have been unprecedented in scale; a concerted attack in late August 2024, for example, involved more than 200 missiles and drones. Air defence measures have been unable to prevent major damage. The primary targets have been in the electricity sector – including generation, transmission and distribution – but district heating networks and some gas infrastructure have also been hit.

Rolling blackouts and other unscheduled interruptions to supply have become the norm, limiting electricity provision in the worst-affected regions to a few hours per day. While Ukrainians have showed immense solidarity, courage and ingenuity – and support from Ukraine's international partners has been crucial in keeping systems functioning – the power system is increasingly fragile. During the summer of 2024, Ukraine experienced a major power deficit as generation capacity fell more than 2 gigawatts (GW) below peak demand of 12 GW. Unreliable electricity is having knock-on effects on all aspects of daily life. Strains that are bearable in the summer months may become unbearable when temperatures start to fall and supplies of heat and water falter, triggering further displacement of affected populations across the country and abroad.

Ukraine's energy system made it through two successive winters since Russia's invasion, but the third promises to be the sternest of tests. 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 approximately half of large network substations were damaged by missiles and drones. Strains on Ukraine's energy sector through the first two winters of war were mitigated by significant reductions in demand, relatively mild weather and a major collective effort to repair damaged facilities and mobilise alternative sources of supply. However, intensified attacks between March and May 2024 left Ukraine with only around a third of its pre-war electricity generation capacity by mid-year, even before the latest strikes. The stresses on the system are now immense. Ukraine is increasingly dependent on the three remaining operational nuclear power plants and the over-crowded links between these plants and the main cities closer to the front lines in the east.

Ukraine's international partners have been providing much-needed equipment and aid throughout the war, but today's acute situation demands further support. After years of dependence on Russia for its energy supply, Ukraine is now looking west not only for short-term fixes, but also for integration, infrastructure links and, ultimately, a better kind of energy future. This report proposes tangible and immediate actions that Ukraine and its partners can take to address its pressing energy security vulnerabilities and to bolster Ukraine's longer-term resilience. The central focus is naturally on Ukraine, but a coordinated regional approach is essential to address implications for Moldova. Four issues stand out:

- **Ukraine's severe electricity deficit**. Peak demand could increase to 18.5 GW this winter. Even with the return of nuclear units from maintenance over the summer, and the continued import of 1.7 GW of electricity from Ukraine's European neighbours, the supply deficit could reach as much as 6 GW, equivalent to peak annual demand in Denmark. Further attacks on infrastructure, unforeseen equipment failures and missed maintenance cycles add further risks.

- **Heat supply to Ukraine's major cities**. Most attacks on heating infrastructure have occurred in regions close to the front lines. The Kharkiv region is now without large-scale heat generating capacity and other frontline regions – particularly Chernihiv, Donetsk, Zaporizhzhia, Sumy and Mykolaiv – have suffered severe damage to their heat generation capacities. Heat supply is also at risk in Ukraine's capital, Kyiv.

- **Potential strains on Ukraine's natural gas balance**. Under average weather conditions, Ukraine could meet all its gas demand requirements from domestic production and storage, but a colder-than-average winter would increase the need for imports. Once Russian transit volumes halt in January, after current contracts expire, additional supply would require physical west-to-east gas flows piped to Ukraine from Central and Eastern Europe.

- **Disruption to gas and electricity supply arrangements in Moldova**. Moldova no longer relies directly on Russian gas to meet demand on the territory that it controls, but indirect dependence is still strong because it receives around two-thirds of its electricity from a large power plant based in the breakaway, Russian-backed region of Transnistria. The upcoming expiry of the transit arrangements for Russian gas through Ukraine, at the end of 2024, creates significant uncertainty for gas deliveries to the region of Transnistria and for Moldova's electricity security.

10 key energy sector actions

These 10 actions are designed, first and foremost, to safeguard an essential level of energy services in Ukraine through the coming months. This necessarily involves actions outside the energy sector, with effective air defence being by far the most important, alongside the provision of essential energy equipment, imported supply, and back-up capabilities. Quick responses are crucial, and Ukraine's international partners will need to be creative and nimble to minimise delays and do what it takes to help. At the same time, it will be important to build in structural changes, wherever possible, that will increase Ukraine's resilience over the medium term and put the country's energy sector on a sustainable pathway towards modernisation and integration with the rest of Europe. Many of these actions are already underway or under consideration, but time is of the essence.

1. **Bolster the physical and cyber security of Ukraine's critical energy infrastructure**. Repair and construction work needs to be done with a view towards protecting assets against further attacks, especially at crucial nodes in the system like the network substations near nuclear power plants. This includes not only fortification, concealment and defence measures against modern military technologies, but also protection against attempted cyberattacks, which have tripled since the invasion.

2. **Expedite the delivery of equipment and spare parts for repairs**. The donation, sale or lease of essential equipment – such as transformers, generators and spare parts – has been an essential component of international support to Ukraine. This is now more important than ever and needs to be facilitated by streamlined import procedures and a clear prioritisation of needs.

3. **Increase and decentralise power supply**. Large energy assets are more vulnerable to attack, so decentralisation brings clear security benefits. Ukraine has seen a massive influx of diesel generators to provide back-up power. Accelerating deployment of smaller-scale gas-fired combined heat and power plants, and solar PV and wind systems complemented by batteries and other storage technologies is crucial to increase the resilience of supply. A particular focus is needed on supply for hospitals, schools, water pumps and mobile networks.

4. **Expand electricity transmission capacity with the European Union**. Ukraine and its partners swiftly moved to synchronise Ukraine (and Moldova) with the main European electricity system after the 2022 invasion, but the current limits on transmission capacity are set by relatively

conservative guidance on network risk management. An expansion of west-to-east electricity flows in support of Ukraine is possible but requires political support.

5. **Engage consumers in energy saving and demand response, while continuing investments in energy efficiency**. A social tariff that safeguards a certain volume of consumption at subsidised rates, after which consumers pay a higher price, would help to incentivise efficient practices and investments, supported by public information campaigns that advise on energy efficiency measures for immediate impact as well as longer-term gains. Lowering the default temperature for district heating can also provide quick savings.

6. **Prepare back-up options for winter heating**. Expedited delivery of smaller combined heat and power units should focus on bolstering supply in the worst-affected regions in the east. Investment in reliable back-up options should also include liquefied petroleum gas (LPG) heaters, wood and coal stoves, and associated reserves of fuel, especially for rural areas.

7. **Build up natural gas storage levels**. Ukraine's storage sites play a key role in meeting winter gas demand. Ukraine and its international partners need to ensure that inventory levels are adequate ahead of the winter to ensure that the gas system can react to unexpected demand or supply shocks.

8. **Strengthen firm gas import capacities from the European Union**. Some of the current arrangements that guarantee the availability of capacity for gas flows to Ukraine are expiring. They need to be extended and reinforced, as necessary, to provide Ukraine with assured options for import. Operating the trans-Balkan pipeline system in reverse mode, with a more competitive tariff structure, would enhance gas supply security for Ukraine and Moldova.

9. **Coordinate approaches to Ukraine and Moldova**. While not subject to the same physical risks from attacks, the coming winter could also be destabilising in Moldova, including Transnistria, as gas and electricity flows and relationships move to a new footing. Energy security issues in Ukraine and Moldova are closely linked, and investments in new sources of supply, energy efficiency and reinforced interconnections with neighbouring countries bring both national and regional gains. This requires coordinated strategies that recognise the inter-related nature of risks across the region and act quickly to mitigate them.

10. **Lay the groundwork for a modern, market-based, resilient and sustainable Ukrainian energy system, well integrated with the EU system**. The immediate priority is to mitigate the extreme risks over the

coming winter, but it will be vital to start actions that have a longer lead time – including investment in reinforced transmission corridors with western neighbours – and to integrate, wherever possible, a medium-term vision for a new Ukrainian energy system into the immediate response.

Ukraine's energy system under attack

Introduction

On the morning of 26 August 2024, Russia fired more than 200 missiles and drones in one of its largest aerial attacks on Ukraine; the main targets were the country's energy infrastructure. Around 8 million households lost power without warning; the capital, Kyiv, experienced its first unscheduled blackout since November 2022. Ukraine's air defences provided some protection, but the scale of the attack and the resulting disruption highlighted once again the vital strategic importance of Ukraine's energy sector, as well as the ever-present risks to the country's energy supply.

Ukraine's energy system[1] has been regularly targeted by Russia since its full-scale invasion in 2022, with attacks intensifying since the spring of 2024. The targeting of energy infrastructure has had wide-ranging consequences for the provision of energy to Ukrainian households and other consumers. Over the course of 2022-23, about half of Ukraine's power generation capacity was either occupied by Russian forces, destroyed or damaged, and approximately half of the large network substations were damaged by missiles and drones. The occupation of the Zaporizhzhia nuclear power plant, on its own, reduced available Ukrainian power generation capacity by 6 gigawatts (GW). In the wave of attacks between March and May 2024, Ukraine lost another 9 GW of generation capacity; this was mainly thermal and hydro assets, although some smaller solar PV units also came under attack, as well as numerous substations. This left Ukraine with only around one-third of its pre-war capacity, even before the most recent round of summer attacks. Ukraine's district heating and natural gas infrastructure has also been targeted. Since 2022, 18 large combined heat and power (CHP) plants have been damaged or completely destroyed, along with more than 800 boiler houses. Some above-ground natural gas storage infrastructure has been damaged, although underground inventories remain unaffected.

Ukraine experienced an acute power deficit over the summer months of 2024, when its generation capacity fell 2.3 GW below its peak demand of 12 GW, despite electricity imports from Ukraine's western neighbours. The deficit has been managed by Ukraine's state-owned electricity transmission system operator, Ukrenergo, through rolling cuts to supply, limiting electricity

[1] See Annex for background information on Ukraine's energy sector

provision in the worst-affected regions to a few hours per day. While Ukrainians have shown immense solidarity, ingenuity and resilience, and support from Ukraine's partners, including equipment and spare parts, have been instrumental in maintaining a functioning system, the possibility of an even deeper shortfall in energy supply during the upcoming cold winter months presents profound risks.

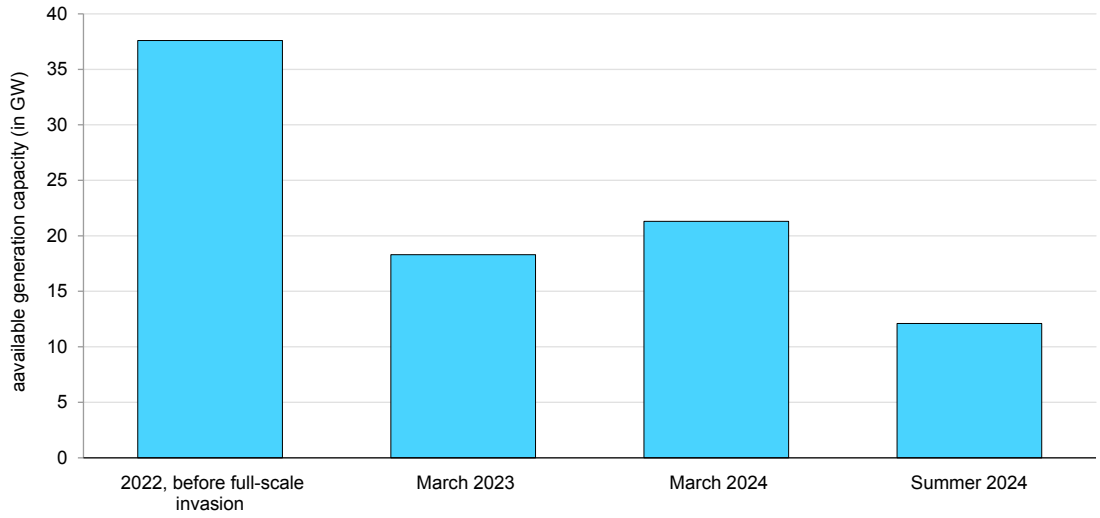
This report describes the urgent challenges facing Ukraine's energy sector and outlines tangible actions that can be taken by Ukraine and its partners to address its immediate energy security vulnerabilities ahead of the winter, while bolstering long-term resilience. The central focus is on Ukraine, but the report also incorporates analysis of the situation in Moldova, whose energy system is closely interlinked with that of Ukraine. The remainder of this section of the report provides background on the status of electricity, heat and gas supply in Ukraine, the second section examines the risks facing the energy sector during the upcoming winter. The final section identifies 10 key energy actions to address these risks.

Electricity

Since 2022, Russian targeting of Ukraine's power infrastructure has sought to destabilise the electricity system by disabling large coal and gas-fired generation units and key parts of the transmission network. Prior to Russia's full-scale invasion in 2022, nuclear power generated half of the country's electricity, followed by coal-fired plants at 23% and gas-fired plants at 9%. As of the end of May 2024[2], about 70% of Ukraine's thermal generation capacity was either occupied or damaged, and the Zaporizhzhia nuclear power plant (whose 6 GW of capacity generated around one-quarter of Ukraine's electricity supply prior to 2022) remained under Russian control. Additionally, approximately half of Ukrenergo's very high voltage substations had been damaged, as well as many distribution substations, leading to intermittent unavailability of parts of the electricity network despite ongoing repairs. Recent attacks underscored the risks to supply from Ukraine's other nuclear plants, as damage to nearby substations can prevent these plants feeding the grid or endanger the backup supply that keeps the reactors safe. The electric power industry is the part of the energy sector that has suffered the greatest damage since the Russian invasion in 2022, estimated in June to top USD 11.4 billion, with three-quarters of the losses in generation facilities and the remainder in networks. Full like-for-like restoration of all the lost generation capacities is not aligned with Ukraine's vision for the future, but early estimates for the cost of building back are around USD 30 billion.

[2] The extent of the additional damage caused by more recent attacks, notably the large attack on 26 August, was still uncertain at the time of writing.

Estimated electricity generation capacity available to Ukraine at selected times since 2022



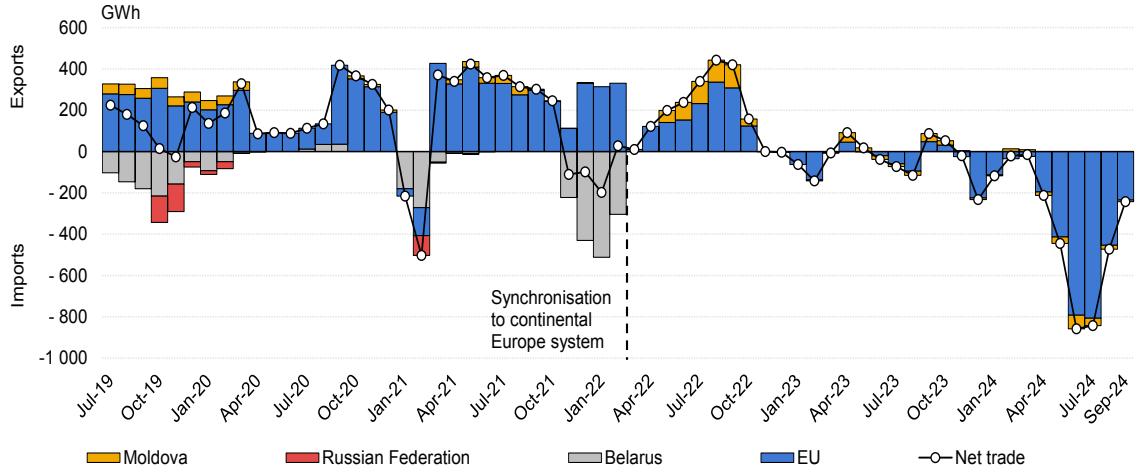
Sources: UNDP (2023), Update on the Energy Damage assessment June 2023, Towards a green transition of the energy sector in Ukraine, https://www.undp.org/ukraine/publications/towards-green-transition-energy-sector-ukraine
Ukrainian Government (2024), Герман Галущенко: Ми відновили і додали до енергосистеми 3 ГВт потужності https://www.kmu.gov.ua/news/herman-halushchenko-my-vidnovyly-i-dodaly-do-enerhosystemy-3-hvt-potuzhnosti
Ukrainian Government (2024), За два роки росія атакувала українську енергетику понад 1000 разів – Герман Галущенко, https://mev.gov.ua/novyna/za-dva-roky-rosiya-atakuvala-ukrayinsku-enerhetyku-ponad-1000-raziv-herman-halushchenko

Industrial power consumption has halved since the 2022 invasion, and even though household electricity use is down 20%, it now constitutes the largest share of overall demand. The composition and level of Ukrainian electricity consumption has shifted significantly. Industrial demand has plummeted. The 20% fall in residential demand is largely due to the effect of 6.5 million Ukrainian refugees leaving the country, although some policies and initiatives have helped save electricity. For example, an EU-funded program that replaced incandescent bulbs with LED bulbs reduced demand by as much as 1 GW. Many utilities are now facing extreme financial difficulties due to lost assets, lower revenues due to reduced economic activity and additional expenses such as clearing debris or the cost of repairing or demolishing damaged facilities. While donors have been providing much-needed equipment and assistance to restore damaged infrastructure, including standalone generators for critical infrastructure such as hospitals, water systems and district heating companies, the scale of the challenge remains huge.

Despite the high investment risks, the construction of a more decentralised system has begun, increasing resilience to attack and laying the groundwork for a distinctive longer-term transition pathway. In contrast with other countries, where decentralisation has been driven by sustainability concerns, the clear driver in Ukraine is energy security. Large-scale generating units are easier targets for missiles and drone attacks, so the Ukrainian government gave guidance early on to deploy decentralised generation, mainly

small modular gas turbines in the range of 5 to 40 megawatts (MW), and to speed up the deployment of rooftop solar with storage in administrative buildings, hospitals, schools, households and businesses. Almost 1 500 MW of consumer-installed solar PV was in place by the beginning of 2024, with deployment continuing at a regular pace in recent years.[3]

Net monthly trade of electricity of the Ukrainian power system

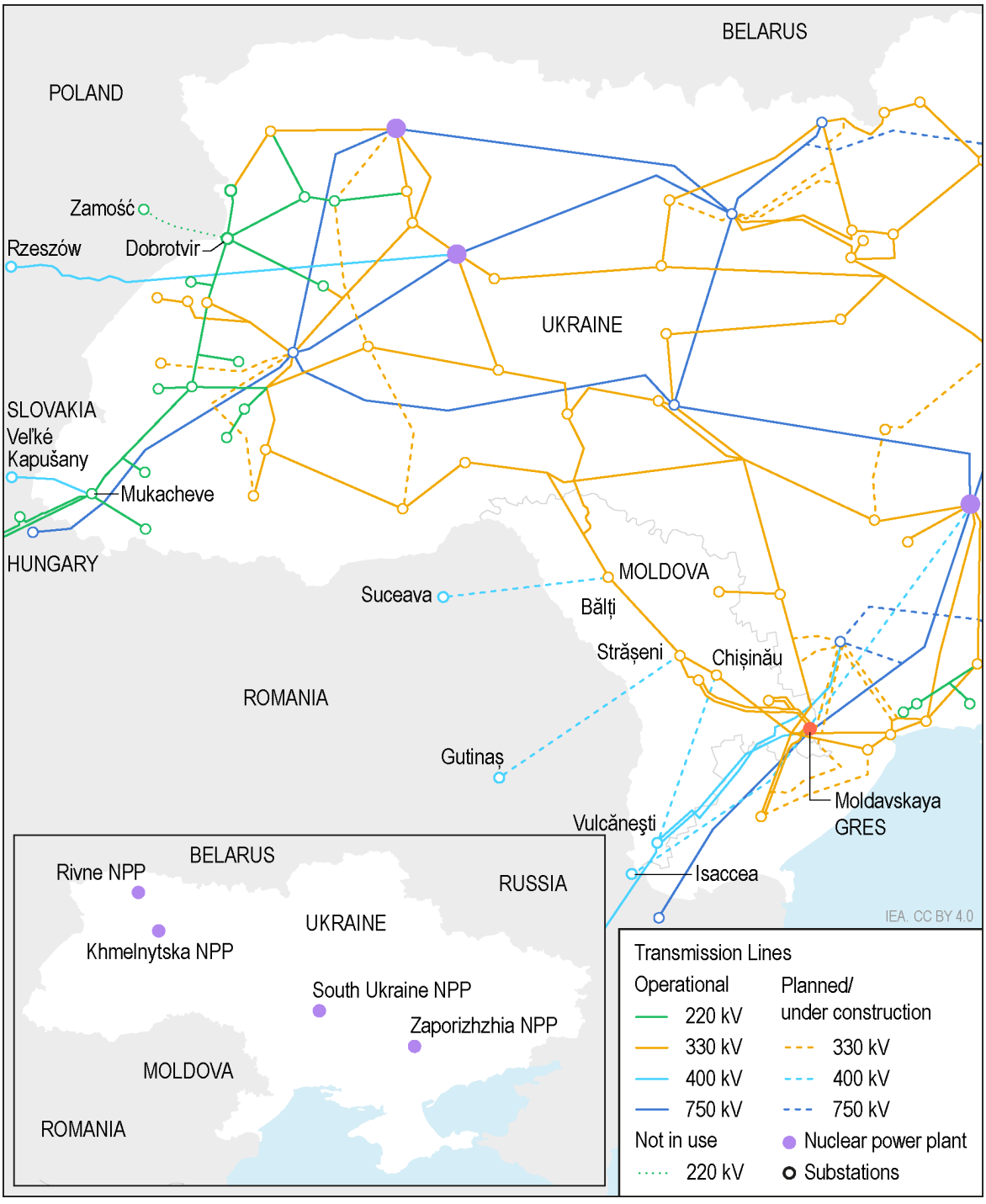


Interconnection with the main European system[4] has made a crucial contribution to Ukraine's electricity security, with the limit on cross-border trade[5] increasing to 1.7 GW in November 2023. Before the 2022 invasion, Ukraine's power system was interconnected with the Russian and Belarussian grids. Plans had been in place since 2017 to synchronise with the continental Europe system in 2023. On the day of the invasion, Ukraine had just disconnected from the Russian and Belarusian system, performing a planned test of "isolated mode" operation. Soon after the invasion, Ukraine (along with Moldova) requested an emergency synchronisation, which was achieved in record time: an initial timeline of months was brought down to a matter of weeks thanks to an extraordinary effort from the involved European transmission system operators (TSOs) and Ukrenergo, coordinated by the European Network of Transmission System Operators for Electricity (ENTSO-E), with the strong support of the European Commission. Since then, integration with the European system has been a priority. Trade started in June 2022 with trade limits gradually increasing. Currently, the trade limit from continental Europe to Ukraine and Moldova stands at 1.7 GW, complemented with a non-firm emergency inter-TSO agreement that can provide a few hundred megawatts of support for a few hours if network

[3] A law adopted in July 2024 exempts energy equipment imports from duties and taxes and introduced favourable loans for energy investments. By another government decision, businesses generating at least 80% of their electricity consumption, or importing at least 80% of their electricity consumption from the rest of Europe, are exempted from rolling blackouts.
[4] Continental Europe is the largest synchronously interconnected system in Europe, spanning from Portugal to Ukraine and West Denmark to Italy. It will be further expanded in 2025 to include the Baltic states.
[5] See Annex for information on how cross-border capacity limits are defined.

conditions permit. In June 2024, Ukraine's total imports were close to 2 GW for a few hours every day, and joint efforts with neighbouring system operators are continuing to increase the trade limit further.

Map of the western portion of the Ukrainian grid and its existing and planned interconnectors with Moldova and the continental Europe system



Note: The corridors for proposed/under construction transmission lines from have been estimated based on substation locations.

Sources: ENTSO-E Transmission System Map, Green Deal Ukraina (2024).

Even so, the summer electricity deficit has resulted in daily power cuts, disrupting lives and businesses and heightening social and humanitarian risks. During the months of June and July, even with power imports, the estimated supply-demand gap ranged from 0.8 GW to 2.3 GW – the latter equivalent to Slovenia's peak demand. This has led to rolling blackouts across the country. Most citizens have faced these daily power cuts with solidarity, but the limited availability of electricity-dependent facilities such as elevators and water has made daily life difficult. The end of the scheduled maintenance to nuclear power plants eased the situation in August, but this was before the recent intensification of attacks. Many households and businesses have purchased small-scale diesel generators and power banks as back-up options to maintain supply during the blackouts.

Heating

Ukraine's extensive district heating network, which provides most of the hot water and space heating in large cities, has been repeatedly targeted by Russian forces since the 2022 invasion. In 2022, more than one-third of Ukrainian households were connected to the district heating network, according to the State Statistics Service. Most of the heat production (about 70%) is fuelled by natural gas, and about a third of Ukraine's heat supply is generated by combined heat and power (CHP) plants, while the remainder comes from conventional heat plants and other sources. Between February 2022 and May 2024, a total of 18 large-scale CHP plants were damaged or destroyed, as well as 815 boiler houses, 152 central heating points, and 354 kilometres of district heating pipes, according to the Kyiv School of Economics. The direct damage resulting from these attacks (excluding social and economic costs) is estimated at USD 2.4 billion, with more than half attributable to attacks on CHP plants[6].

As with the attacks on electricity infrastructure, damage to heat supply is highly disruptive to the population. Ukraine was spared catastrophic losses to its heat supply during the 2022-23 and 2023-24 winters, when attacks were more limited and the winters relatively mild. With the escalation of attacks against Ukraine's energy infrastructure in 2024, the risks are significantly higher this winter. Temperatures can routinely drop below -10 °C between December and March, posing a serious humanitarian risk if heating is not available.

Heavily subsidised residential heat tariffs have led to significant fiscal strains and a build-up of debt. Large subsidies to district heat producers had previously been reduced thanks to price reforms between 2014 and 2016 (which led to a five-fold increase in residential tariffs). By 2021, the public service obligation (PSO) requiring Naftogaz, Ukraine's national oil and natural gas

[6] These aggregates exclude damages incurred in Ukrainian territories occupied by Russia.

company, to supply discounted gas to district heating companies was phased out. It was re-introduced shortly after the 2022 invasion, fixing gas prices for residential heat producers at less than half the market rate, and has been extended until at least 30 April 2025. The current PSO scheme has contributed to significant financial challenges and large arrears to Naftogaz. The company was forced to restructure its foreign currency-denominated debt in 2023, and by October 2023, it estimated its accumulated debt from district heating companies stood at UAH 95 billion (USD 2.6 billion). No provision for Naftogaz's losses was included in Ukraine's 2024 budget.

Natural gas

Russia's 2022 invasion was followed by a one-third decline in Ukraine's natural gas demand: consumption in 2022 fell below 20 billion cubic metres (bcm), the lowest level since independence in 1991. This was largely driven by the decline in demand from district heating companies, industry and households. Ukraine's natural gas demand increased by 2.5% (or 0.5 bcm) in 2023, with growth primarily driven by a partial recovery in industrial and commercial activity. First indications are that gas demand in 2024 is similar to 2023, with natural gas use in power generation limited to peak hours. The PSO scheme that was re-introduced in 2022 extends to nearly all segments of the market, regulating prices at levels below market rates. This offers protection to consumers but, as noted above, comes at significant cost and disincentivises efficiency improvements, as well as new investments.

Ukraine's natural gas production has been more resilient than its demand, but it still fell by 6% in 2022 to 18.5 bcm – its lowest level since 1999. Production rose slightly in 2023 and there are some tentative signs of higher output in 2024: Production numbers for the first seven months of 2024 for Naftogaz, Ukraine's largest producer, rose by 7% year-on-year, supported by a concerted effort to develop new wells and increase productivity rates at old wells. The company is targeting 15 bcm of natural gas production in 2024, up from 14 bcm in 2023.

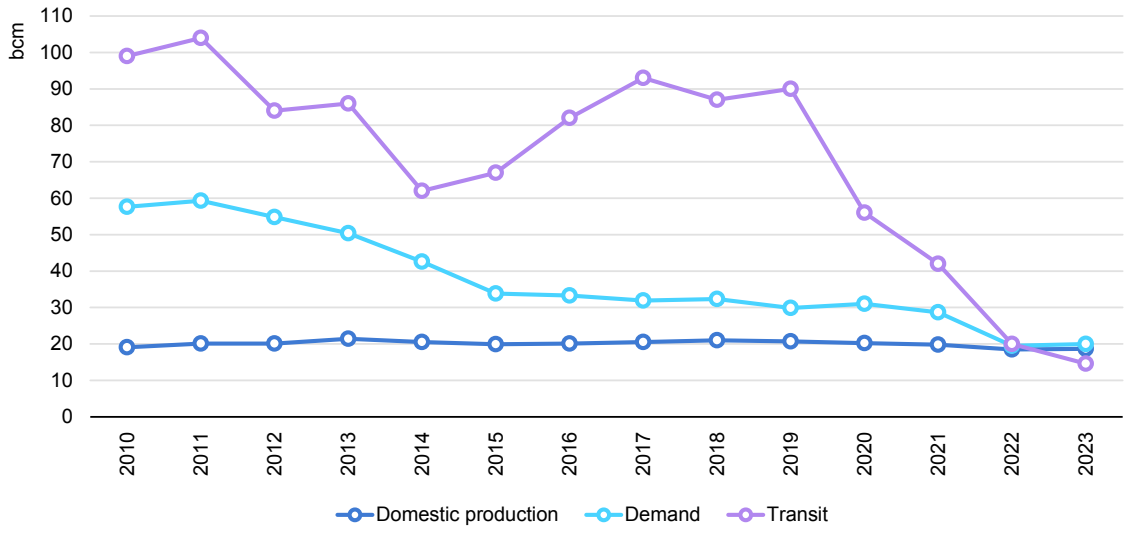
The steep decline in natural gas demand has brought Ukraine close to self-sufficiency in gas, and the need for imports has decreased significantly. A similar pattern of reduced import demand is visible in Ukraine's coal sector[7]. According to Naftogaz, Ukraine did not import natural gas during the 2023-24 heating season, with all demand met through domestic production and storage

[7] In 2023, Ukraine produced 16.4 million tonnes (Mt) of coal and imported less than 1 Mt, a big drop from imports of 4.6 Mt in 2022 and from almost 20 Mt in 2021. Almost two-thirds was used in the electricity sector, almost one-third was used in steel mills and around 10% for building heating. Efforts are being made to enhance domestic production: DTEK Energy, the largest coal producer in Ukraine, announced that it began operating 26 longwalls in 2023, and 11 more in 2024 (as of August).

withdrawals. Naftogaz expects that Ukraine will not need gas imports through the 2024-25 winter. Ukraine has the capacity to import around 60 million cubic metres (mcm) of gas per day from the European Union and Moldova; however, not all of this capacity can be considered firm[8] on a long-term basis (i.e. longer than a quarter), which can pose risks in a security of supply crisis.

Russian gas transit volumes via Ukraine continued to decline in 2023. Russian transit flows dropped by 65% from more than 40 bcm in 2021 to less than 15 bcm in 2023. This is less than half of the capacities booked by Gazprom under its long-term contract. The main countries that still receive Russian gas via Ukraine are Austria and Slovakia, although Czechia and Hungary also receive limited volumes. Gas also transits Ukraine to the Transnistria region of Moldova.

Natural gas production and demand in Ukraine and Russian transit flows



The transit and interconnector agreements between Ukraine and Gazprom expire at the end of 2024. Ukraine's gas TSO has explicitly stated that it will not renew the interconnector agreement, although it would not hinder other parties' direct discussions. It is not excluded that some sort of continued arrangement for transit flows might yet be found, but the base case assumption is that Russian transit flows via Ukraine will be discontinued from January 2025.

Russia has been targeting some natural gas infrastructure in Ukraine, including production sites and transmission and distribution networks, as well as gas storage facilities. While gas storage in deep underground facilities is unaffected, above-ground facilities are more easily targeted and have sustained

[8] Firm capacity refers to natural gas transmission capacity contractually guaranteed as uninterruptible by the transmission system operator.

some damage. Production sites in the east of the country have been most vulnerable, although the sharp decline in output seen in the first months of the invasion was reversed as Ukraine regained territory in the Kharkiv region in late 2022. Parts of Ukraine's transmission and distribution system were also damaged, again primarily in the eastern part of the country.

Several gas storage facilities in the east have faced operational limitations or been damaged by Russia's invasion, but the bulk of gas storage is in western Ukraine. The Krasnopopivske (0.42 bcm) and Verhunske (0.4 bcm) underground storage sites are located under territory occupied by Russia, and there have been reports of damage to surface facilities at other sites. Gas storage facilities were also damaged in Russia's major missile and drone attack in late August, although the storage operator remains able to fulfil nominations to customers. Ukraine can offer the bulk of its large storage sites (30 bcm, mainly in Western Ukraine) for use by European companies, but security risks mean that European traders have so far made limited use of this option[9]. Lower storage utilisation weighs on the revenue and profitability of Ukraine's system operator.

Gas metering facilities on the border between Russia and Ukraine have been in the spotlight. In May 2022, the Gas TSO of Ukraine declared force majeure at the Sokhranivka gas metering station, claiming illegal actions and unauthorised gas offtakes by Russian forces. According to the Gas TSO of Ukraine, flows could have been temporarily rerouted through the Sudzha gas entry point, although Gazprom declined to accommodate this option. This led to a significant decline in transit volumes. More recently, as part of a Ukrainian cross-border offensive into Russia's Kursk region in August 2024, Ukrainian forces reportedly took control of the Sudzha gas metering station – the only remaining entry point for Russian gas into Ukraine. For the moment, this has not resulted in any further decline in gas transit flows, which have remained steady at around 40 mcm per day.

Implications for Moldova

Moldova has strong energy infrastructure links with Ukraine, and its energy security has also been strongly affected by the war and the attacks on Ukraine's energy assets. In recent years, Moldova has pushed to diversify away from its historical dependence on Russian gas; the gas consumed within the

[9] Injections into Ukrainian storage sites in June and July 2024 by European companies were ten times lower than in the same period of 2023 (declining from 0.69 bcm in June-July 2023 to less than 0.1 bcm in June-July 2024).

territory controlled by the Moldovan government (i.e. excluding the breakaway, Russian-backed region of Transnistria) is now imported through Romania.

However, Moldova retains a strong indirect reliance on Russia because it receives around two-thirds of its electricity from a large power plant based in the Transnistrian region. This plant – Moldavskaya GRES, or MGRES – has an installed capacity of 2 520 MW and is fuelled by gas imported from Russia via Ukraine. The region of Transnistria currently receives 2.1 bcm per year of Russian gas, essentially free of charge, through a contract between Gazprom and national operator Moldovagaz and sells the electricity on to Moldova. These electricity sales are a mainstay of Moldova's energy security and represent an important source of revenue for Transnistria. While MGRES can also use coal to generate electricity, the plant's coal reserves have dwindled since 2022, and the plant is configured to use a type of coal imported from the Russian-occupied Donbass region of Ukraine.

The expiry of the transit arrangements for Russian gas through Ukraine creates significant uncertainty for gas deliveries to the region of Transnistria and for Moldova's electricity security. Moldova is preparing for different scenarios but faces tangible risks to the security and affordability of its energy supply.

Moldova has been working to diversify its electricity supplies and modernise energy infrastructure: attracting further investment is a major priority. Moldova has increased its installed renewable capacity after adopting legislation to promote deployment in 2018, but more needs to be done to bring forward new projects for generation, grid infrastructure and energy efficiency. As of 2023, wind and solar made up roughly 10% of total electricity generation.

Strengthening interconnections with neighbouring European markets is essential to bolster Moldova's energy security, with benefits for the wider region. A third 400 kilovolt (kV) high-voltage power line between Moldova and Romania (Straseni-Gutinas) has been approved and is scheduled to be operational by 2031, alongside the planned Vulcanesti-Chisinau and Balti-Suceava lines that should come online in late 2025 and 2027, respectively. The 400 kV line currently under construction between Isaccea (Romania) and Ukraine would increase the import capacity of Ukraine and Moldova by at least 1 GW[10]. In the short-term, Moldova's winter preparedness plan also includes diesel generators and building stocks of biofuels and firewood, in addition to securing additional imports of electricity from Romania and the wider Europe.

[10] Originally planned for 2028, an accelerated commissioning by 2026 is possible if the line were included in the priority list of Projects of Common Interest (PCIs) and supported by the European Commission, helping to reduce Moldova's dependency on MGRES.

The upcoming winter will be a critical test

Intensified attacks since spring 2024 have left Ukraine's energy infrastructure in a very fragile state for the coming winter. Russia's strategy has focused on generation and transmission assets and has used combinations of missiles and drones to evade Ukraine's air defences. As a result, Ukraine has sustained more widespread and lasting damage to its energy infrastructure compared with the attacks in earlier stages of the war, even with ongoing support for repairs from donors.

Energy supply has already been challenging over the summer months for many Ukrainians, but the full effects of the infrastructure losses have been masked by the warm weather and longer days. Diesel generators have allowed shops and restaurants to stay open, with many facilities using outdoor spaces to help with the effects of rolling blackouts.

However, once temperatures begin to fall and the heating season officially begins in October, it will become much more difficult to live and work with limited access to electricity and heat. Home to roughly 70% of the population, Ukraine's urban centres are particularly vulnerable to unreliable electricity supply, given the strong concentration of high-rise buildings that need electricity for elevators and water pumps.

The winter season can last for up to six months, with the coldest months between December to March, when temperatures can drop as low as -20 °C, and average between -4.8 °C and 2 °C. All regions, or oblasts, in Ukraine experience days with temperatures below -10 °C during the standard heating season. In the current context, this would result in huge risks for people across the country. A period of extreme cold over the coming winter would take a massive toll on the overall population and put enormous pressure on the already overstretched health system. If the winter is accompanied by inadequate provision of heat or electricity, this could lead to a renewed wave of refugees moving to other parts of Ukraine and abroad, as some places in the country become simply unliveable.

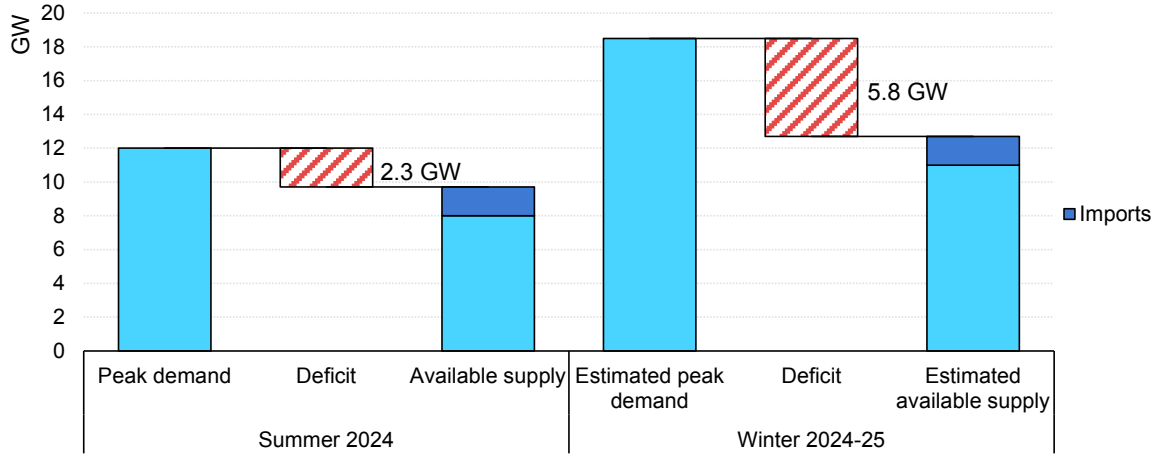
Since 2022, and especially since March 2024, Ukraine's energy infrastructure has been degraded in ways that make this winter the sternest test yet for Ukraine's energy system. These risks are already visible and foreseeable; they can be exacerbated by continued targeting of energy infrastructure by Russia and mitigated by successful air defence, as well as a

range of other national and international actions, including expedited repair and reconstruction. Some of these risks spill over to Moldova, requiring a coordinated, regional approach.

The key risks are the following:

- **A growing deficit of electricity supply relative to much higher winter demand.** Peak demand is expected to increase to 18.5 GW this winter (from around 12 GW in the summer). Despite the return to service of nuclear units from maintenance over the summer and an expected 1.7 GW of electricity imported from the European Union, the deficit of electricity supply could reach as much as 6 GW, an amount equivalent to Denmark's peak demand[11]. Since March, rolling blackouts that have left households without electricity for hours every day have been faced with solidarity by citizens, but longer electricity cuts in the winter months will lead to enormous strains, including on centralised water supply. Repair and reconstruction work is ongoing, but it may be impossible to bring back a significant portion of the lost assets. There is also the risk that damage from new Russian attacks outpaces the speed at which infrastructure can be repaired, undermining system stability even further.

Estimated electricity deficit versus peak demand in Ukraine in summer 2024 and for the winter of 2024-25



- **Inability to provide district heating to major cities.** Regions close to the front lines are the most vulnerable, as most attacks on heating infrastructure have occurred in these areas. The Kharkiv region has been without large-scale heat generating capacity following the destruction of the Zmiivska thermal power

[11] Source: IEA analysis based on exchanges with ENTSO-E, the European Commission and papers by Green Deal Ukraïna (Six options to boost power grid transfers from continental Europe to Ukraine, for the next two winters, August 2024; Modelling the Electricity Deficit in Ukraine and Potential Policy Responses for the period June 2024 – May 2025, June 2024).

plant and Kharkiv CHP-5 plant in late March. Other frontline regions (particularly Chernihiv, Donetsk, Zaporizhzhia, Sumy and Mykolaiv) have also suffered severe damage to their heat generation capacities. Heat supply is at risk as well in Ukraine's capital, Kyiv, where 98% of the population is connected to the district heating grid and three large CHP plants provide the bulk of supply during the winter months.

- **Possible need for gas imports to ease strains on the gas supply balance.** Ukraine's may require additional imports during the coming heating season. While under average weather conditions Ukraine could potentially meet all its demand requirements from domestic production and storage, a colder-than-average winter could increase import requirements through the heating season, assuming that heating intensity[12] remains close to last winter's levels. A particularly cold winter – similar to the one Ukraine faced in 2016-17 – could increase gas used for space heating in households by 25% (or 1.5 bcm) compared with the 2023-24 winter season. The expected halt of Russian gas transit via Ukraine from January 2025 will mean the end of possibilities for backhaul (or virtual reverse flows) from the European Union. This means physical west-to-east gas supplies from Central and Eastern Europe will be needed to bring additional gas into Ukraine, which could raise procurement costs (due to transmission tariffs). The adequacy of supply is also subject to risks from further attacks on gas infrastructure.

- **Disruption to prevailing gas and electricity supply arrangements in Moldova.** The likely end of Russian gas transit across Ukraine to the region of Transnistria from January raises major questions over how the region will receive its gas and, by extension, over the availability and cost of the electricity that it provides to the rest of Moldova. Russian gas delivered to Transnistria through a longer and more circuitous route, via Türkiye and the Western Balkans, would incur additional transit charges that would push up the price of gas to Transnistria. This would be a major shock to a region that has become used to getting gas at minimum or zero cost. An adjustment towards market prices would in turn increase electricity generation costs and the price paid by Moldovans for electricity, a politically and socially sensitive issue. If electricity production from MGRES needs to be replaced with imports from Romania, some 600 to 650 MW of interconnection capacity will be needed, exceeding the current 255 MW quota for Moldova from the allowed 1.7 GW of trade capacity with continental Europe that is shared between Moldova and Ukraine[13]. If gas flows to Transnistria were interrupted for any reason (including non-payment),

[12] Heating intensity refers to natural gas use per heating degree day.

[13] The trade limit with continental Europe is shared between Ukraine and Moldova. The two countries agree bilaterally on how to use the capacity at a given moment in time. In case of failure to reach an agreement, the capacity is split in proportion to the number of interconnectors each country has, meaning that Moldova would receive one-sixth of the capacity.

this would have immediate and damaging implications for Moldova's electricity supply and for Transnistria's budget, the bulk of which comes from selling electricity to Moldova. The consequences would represent an additional source of instability for the wider region.

The coming winter and the tense geopolitical context in the region could have ramifications for the energy security of other European nations. Risks include cyber-attacks and physical threats to critical energy infrastructure that may be used to supply Ukraine, requiring increased vigilance and emergency preparedness. There could also be implications for market balances and prices, although these will be determined, as ever, by multiple factors. Electricity prices in Europe have slightly moderated since the peaks of 2022, but wholesale electricity prices in Southeast Europe, in particular, remain elevated compared with pre-war levels. Most countries in Southeast Europe are highly reliant on gas for electricity generation, and over the summer months tight gas markets have combined with congested energy corridors, warm weather and low hydropower generation, resulting in notable price disparities with the rest of Europe.

This winter will also see the scheduled decoupling of the electricity systems of the Baltic states of Estonia, Latvia and Lithuania from Russia-Belarus on 7 February 2025, prior to synchronisation with continental Europe. Following synchronisation, the energy security of the Baltic states will be strongly dependent on imports from neighbouring countries Poland, Sweden and Finland. While the Baltic transmission system operators (TSOs) have deployed much of the necessary equipment to ensure stable, independent operation, the full reinforcement of interconnectors and required IT system upgrades are set to take place between 2025 to 2030. In the meantime, there will be a lack of redundancy in the single synchronous interconnection with Poland, which will be the only link between the Baltic grid and the continental Europe system until these upgrades and reinforcements are complete.

An energy action plan

This section proposes ten actions that can help to address Ukraine's pressing energy security vulnerabilities. Many of these measures are already underway or under consideration, but time is of the essence. They focus on issues directly related to the energy sector, but a first-order consideration and priority for the upcoming winter is to counter further attacks and avoid or minimise further damage to infrastructure by providing effective air defence.

The energy sector measures respond to an immediate need, but where possible, they are designed with a view to structural changes that will increase Ukraine's resilience over time. Ukraine's energy system faces an emergency, and any effective solution needs to be on the table, but there are still possibilities to prepare for a different and more sustainable energy system for Ukraine and avoid becoming stuck in a repeated loop of damage and repair to existing assets. The actions proposed below encompass immediate measures to enhance resilience (1, 2), actions focused on the electricity sector (3, 4), energy efficiency (5), heat (6) and natural gas (7, 8), as well as the need to factor in implications for Moldova (9) and integrate short-term responses with medium-term goals (10).

Action 1 – Bolster the physical and cyber security of Ukraine's energy infrastructure

As Ukraine repairs and reconstructs its energy infrastructure, build in a high level of physical and cyber security. Ukraine's historically centralised system for the provision of power and heat, based on a relatively small number of large assets, makes it vulnerable to Russian attack. Restoration of vital infrastructure such as generation capacity and grid infrastructure, especially at crucial nodes in the system like the network substations near nuclear power plants, needs to be accompanied by efforts to bolster the resilience of the system, based on an assessment of key system vulnerabilities, comprehensive costing that includes physical and cyber protection measures, and a broadening of options to include more decentralised generation and distributed energy resources.

Expand and intensify the construction of anti-drone protection measures for critical energy infrastructure, including high-voltage equipment. Reconstruction and restoration efforts for Ukraine's energy infrastructure, in particular power and heating (via cogeneration) systems, need to include "passive defence," including fortification, concealment and other defence measures against modern military technologies – especially drones – that are used to identify and

destroy energy infrastructure. Greater investment in measures such as cement fortifications, cage roofs and sandbags, as well as moving equipment underground that does not need access to outside airflow, can make key assets more resilient. Installing air defence capabilities at the most critical energy generation and storage facilities could further maintain and strengthen security.

Assist Ukraine in bolstering its defences against cyberattacks, which can be as damaging as physical attacks. Attempted cyberattacks against energy infrastructure have tripled since the beginning of the invasion and remain a permanent threat. Assistance should intensify as the Ukrainian power system builds more decentralised generation and cogeneration capacity. This is changing the power system from one whose Soviet-era characteristics are well understood by Russia to one that is significantly more secure, resilient and flexible. However, its expanded digital footprint opens up a range of potential vulnerabilities in the absence of appropriate cyber security measures. Ukrenergo has made impressive progress in this area, but enhanced access to world-leading expertise and technology is needed to help Ukraine establish strong safeguards for the digital security of its energy system.

Action 2 – Expedite the delivery of equipment and spare parts

Expand and accelerate the supply of replacement equipment and technology for damaged facilities. The donation, sale or lease of essential equipment – such as transformers, generators, spare parts and other critical components – has been an essential component of international support to Ukraine. This is more urgent than ever. Clear prioritisation of Ukraine's needs, alongside standardisation of technologies on the ground, can help minimise downtime for both network and generation-level assets. Key partner-led initiatives provide platforms to centralise financial support and coordinate the supply of necessary equipment. The Energy Community's Ukraine Energy Support Fund, for example, enables governments, international financial institutions and international organizations as well as corporate donors to provide financial support to the Ukrainian energy sector's efforts to repair damage and keep functioning, while the G7+ Energy Coordination Group is working closely with donors to mobilise equipment donations, ensuring that Ukraine has the resources needed to repair, restore and defend its energy infrastructure. The USAID Energy Security Project has been working to support Ukraine's energy sector resilience, collaborating with the Ukrainian government and utilities to repair and stabilise the energy sector. Increasing production and stockpiling replacement parts for key energy infrastructure in neighbouring countries can aid rapid restoration and repairs.

Streamline procedures for cross-border equipment import. The process of importing critical energy equipment into Ukraine has faced administrative challenges that have slowed down repairs and the deployment of distributed energy resources. Supply chain and procurement bottlenecks have also hindered the ability of donors to respond quickly to Ukraine's needs. Recognizing this, the Ukrainian government removed import duties and value-added tax (VAT) on certain energy equipment in July 2024. Quickly implementing these changes and considering extensions to include all critical components, such as the main components of wind turbines, will shorten timelines for the repair and retooling of Ukraine's energy infrastructure. A clear priority list of equipment needs can serve as guidance to the Ukrainian authorities for those items that need streamlined import procedures.

Provide technical expertise and training to Ukraine's energy workforce to help them manage and repair a system operating under severe stress. Ukrainian energy professionals – both the existing workforce and new recruits – need to be well-equipped to operate, maintain and restore energy infrastructure. Technical expertise and training for Ukrainian energy engineers and technicians is crucial to enhance their capacity to deal with increasingly challenging conditions. This needs to include advice and expertise on managing the transition to a more decentralised model.

Action 3 – Increase and decentralise power supply

Deploy decentralised generation capacity as quickly as possible. Alongside the diesel generators that are widely deployed already as back-up for grid supply, this should include small-scale gas-fired combined heat and power plants (< 40 MW), solar PV[14] and wind systems, as well as batteries and other storage technologies. Solar PV and batteries, including behind-the-meter installations, can be deployed quickly with the right incentives in place, allowing them to help meet energy needs while increasing the physical resilience of the system. Supportive regulatory changes are needed to accelerate the connection of new resources and energy storage, including innovative approaches, such as non-firm connections in congested areas. Off-grid and mini-grid solutions should be part of the solution. Working with partners to provide back-up generation for water supply, mobile networks and hospitals will also be key to ensuring resilience for critical infrastructure.

Coordinate decentralisation efforts with the availability of existing networks, while considering flexibility needs for system balancing. The country's

[14] Solar PV production potential is lowest during winter months, particularly in December and January, when capacity factors drop to below 10%. As a result, complementary energy technologies, such as wind or batteries, and dispatchable generation, e.g. gas-fired plants, are essential to maintain reliable supply.

extensive gas network offers multiple potential sites for small-scale gas turbines, providing a flexible and resilient source of power generation that can help to integrate variable renewables. This decentralisation has to align with gas network and flows, and it must consider the prospective halt to transit flows from January 2025 and a constrained domestic gas market.

Action 4 – Enhance electricity transmission capacity with the European Union

Increase electricity imports from the European Union to Ukraine. Ukraine is interconnected with continental Europe through Poland, Slovakia, Hungary and Romania, and via Moldova. The current firm transmission capacity for trade towards Ukraine and Moldova is 1700 MW and can be complemented, when the network allows, with a non-firm emergency inter-TSO agreement that can provide additional support for a few hours. In June, Ukraine's total import was close to 2000 MW for a few hours every day, triggering a request from Ukraine and Moldova to further raise the trade limit. The transmission capacity is mainly constrained by grid congestions in neighbouring countries and in Ukraine, where constant network repairs are required to keep imports at their current levels.

Enhance short-term transmission capacity. TSOs aim to maximise the available capacity from continental Europe to Ukraine and Moldova by increasing the frequency of calculations to a monthly basis, with automated calculations including remedial actions for congestions, starting from November. Most observers expect this improved process to deliver an increase of the capacity by around 200-300 MW. While this represents a clear improvement to the current situation, further improvements can and should be made. Increasing the frequency of capacity calculations to weekly or daily could enable more capacity to be made available part of the time. EU legislation requires TSOs to minimise the risk to their system when calculating available capacities, thereby making available cross-border capacity the outcome of a calculation that is risk-averse by design. Political support for accepting higher risk on the EU side should enable making more interconnection capacity available. In parallel, innovative technologies, including software solutions such as dynamic line rating, could be deployed in a matter of months and deliver higher capacities during cold or windy conditions.

Address regulatory impacts on import demand. Ukrainian demand for interconnection capacity is influenced by a rule exempting industrial consumers from rolling blackouts if they secure 80% of their power consumption from direct

imports[15]. The impact of this rule on import patterns and grid efficiency warrants further examination to assess if it does not lead to inefficient demand for the already constrained interconnection capacity.

Action 5 – Engage consumers in energy saving and demand response, while continuing investments in energy efficiency

Implement immediate energy-saving measures to improve energy security and thermal comfort. There are quick, low-cost actions that can improve efficiency in residential buildings, which account for close to one-third of the country's total final energy consumption. Support of simple weatherisation measures – such as weatherstripping windows and doors, minimising air leaks in buildings, and replacing inefficient windows and doors – can help to reduce heat losses by up to 30%. Lowering the default heating temperature for district heating, as well as (even localised) insulation of district heating pipes, can help improve the reliability of service and provide quick energy savings.

Launch energy efficiency campaigns to raise awareness of short-term measures that citizens can take to keep warm. The Ministry of Energy, Ministry of Infrastructure and Ministry of Environmental Protection have special teams focusing on behavioural campaigns. The State Energy Efficiency Agency has conducted energy efficiency campaigns including public service announcements, social media outreach and partnerships with local community groups. Redesigning these existing measures to reflect the current situation that consumers face, in conjunction with the provision of energy-saving products and services, can lead to a reduction in energy consumption and mitigate the impact of energy shortages. Swift action is required to be prepared for the winter ahead. The initial focus should be on short-term, easy-to-implement measures for immediate impact and to help in case of grid failure, but they should also include longer-term structural measures to help improve efficiency. Engaging with multiple stakeholders, including media, utilities, community groups and business organisations, will help the campaign reach as many Ukrainian households as possible.

Enable demand response to help balance supply and demand. Clear price signals during shortages and transparent communication towards energy consumers are crucial. Analysing potential demand-saving options ahead of the winter period can help to ensure the appropriate design of emergency demand-side policy measures and awareness-raising campaigns. Metering improvements are necessary for this winter and beyond. Consumer protection can be maintained

[15] Another rule exists that also exempts industrial consumers from rolling blackouts if they self-produce 80% of their power consumption.

through reform of the price cap in the Ukrainian electricity market, introducing instead a system whereby a social consumption volume is charged at a subsidized rate, after which consumers pay the market price.

Action 6 – Prepare back-up options for winter heating

Expedite the delivery of small CHP (combined heat and power) units, prioritising the worst-hit areas. Reinforcing Ukraine's heating infrastructure ahead of the winter requires a localised approach, focusing on the most affected regions, such as Kharkiv, Mykolaiv and Sumy. By the end of July 2024, Kharkiv had installed 22 cogeneration units and 31 autonomous boiler houses, but the city needs as many as 140 units (with a total capacity of 340 MW) to ensure adequate heat supply this winter. Kyiv's municipally-owned Kyivteploenergo has ordered 15 small CHP units (with a combined capacity of 60 MW), but they will not be delivered until December 2025 – too late to supply heat this winter. To the extent possible, Ukraine should expedite and prioritise these deliveries with the help of international partners. Industrial-scale heat pumps could also play a useful role in some areas, although these systems are more feasible for baseload heat supply than as a backup due to their high capital cost, and they rely on electricity to operate. Though outside the scope of this report, humanitarian assistance, such as heating tents and the distribution of thermal blankets, proved vital in alleviating hardship during the previous two winters and should continue to complement the energy-related actions.

Distribute backup heating equipment in rural areas. In addition to procuring small CHP units, Ukraine should prepare reliable backup heating options. This might include LPG heaters, packaged boiler systems, hot water tanks and, given the emergency conditions, wood stoves and coal stoves for rural areas, though the health and fire hazards associated with stoves require careful consideration. These measures can help ensure sufficient heat supply even in the event of gas and power cuts. Electric boilers coupled with thermal energy storage could be a suitable backup option in areas where the power supply is stable or in surplus. Deploying small-scale CHPs and decentralized heating solutions could bolster the resilience of Ukraine's heating network against targeted Russian strikes on energy infrastructure.

Action 7 – Build up natural gas storage levels

Ensure that Ukrainian storage sites are filled up to adequate levels ahead of the heating season. Storage sites play a key role in meeting Ukraine's natural gas demand over the winter and in preserving its ability to react to unexpected demand and/or supply shocks. We estimate that net storage withdrawals met around 30% of Ukraine's natural gas demand requirements over the 2023-24 heating season. Ukraine reduced its gas storage target from 14.7 bcm ahead of

the 2023-24 winter to 13.2 bcm ahead of the 2024-25 heating season and needs to ensure, with international support, that the revised target is met in full.

To accelerate storage injections, Ukraine could require additional piped gas imports from the European Union; international partners should continue to support Ukraine in building-up adequate inventory levels. We estimate that Ukraine would need around 0.6 bcm of imports in September and October to reach its storage target ahead of 1 November. International support, including via loans and grants, is needed support Ukrainian gas companies to ramp-up their imports ahead of this winter season and to enhance interconnectivity with the rest of Europe ahead of forthcoming winters. Based on spot prices at the beginning of September, the cost of procuring 0.6 bcm of natural gas would be just over EUR 250 million. The European Bank for Reconstruction and Development (EBRD) signed an agreement on a EUR 200 million loan under government guarantees in November 2023 to support the creation of strategic gas reserves. The corresponding agreement on guarantees was signed in July 2024, and Naftogaz started buying natural gas using the loan in August 2024. AggregateEU, the EU's demand aggregation and joint purchasing platform, could also be a mechanism to support Ukraine's natural gas procurement.

Action 8 – Strengthen firm gas import capacities from the European Union

Ensure and strengthen long-term firm import capacities from the European Union to bolster Ukraine's access to natural gas. Ukraine has around 60 million cubic metres per day (mcm per day) of import capacity from the European Union today. However, some of this capacity cannot be considered as available on a long-term, firm basis. Ukraine and its European partners should work together to ensure that firm capacity offerings are extended and ensured ahead of forthcoming winter seasons.

- **Slovakia:** Between February 2022 and March 2024, the Slovak gas transmission system operator (TSO) Eustream increased firm exit capacity to Ukraine from 27 mcm per day to 42 mcm per day. Since 1 April 2024, the firm capacity has been reduced to 27 mcm per day.

- **Hungary:** Since January 2022, Hungary's gas TSO offered over 9 mcm per day of firm exit capacity towards Ukraine. However, this agreement is set to expire starting from 1 January 2025. Parties need to work together to evaluate options on how the offer of firm capacity can be extended.

- **Poland:** Firm capacity between Poland and Ukraine is not provided on a permanent basis, though there is capacity of over 6 mcm per day. This capacity is offered as interruptible under long products (yearly, quarterly and

monthly products), although it can be offered as firm capacity on daily and intraday auctions. TSOs should consider options offering firm capacity products on a long-term basis, at least for the upcoming winter season.

Operating the Trans-Balkan pipeline system in reverse would further enhance Ukraine's natural gas supply security. Ukraine already imported 0.5 bcm of natural gas via the Trans-Balkan pipeline in 2023, according to Ukraine's gas TSO. However, the current high tariffs are discouraging the use of this route. This situation requires a structural regional approach involving all relevant stakeholders. The countries along the Trans-Balkan pipeline system (Bulgaria, Romania, Moldova and Ukraine) should work together to develop a more competitive transmission tariff structure and further harmonise gas qualities. Market participants are also evaluating a potential expansion of reverse capacity over the medium-term. The Gas TSO of Ukraine and Moldova's "Vestmoldtransgaz" are working to enhance the firm capacities of gas transmission along the Trans-Balkan route towards Ukraine from 1 mcm per day to at least 7 mcm per day by April 2025.

Action 9 – Coordinate approaches to Ukraine and Moldova

Carefully manage the knock-on effects of the situation in Ukraine for Moldova over the coming winter, including the halt of transit flows. While not subject to the same physical risks from Russian shelling, the coming winter could also be destabilising in Moldova, including Transnistria, as gas and electricity flows and relationships move across to a new footing. This requires integrated strategies for the broader region that recognise the risks to gas and electricity security in Moldova and act in an early and coordinated manner to mitigate them. Moldova will need to be adequately prepared for the winter in terms of gas, with adequate storage levels in nearby markets such as Romania and Ukraine. In addition, taking advantage of all possible import routes for gas, including the Trans-Balkan pipeline, will be key to securing stable flows. A continued and transparent dialogue with international financial institutions and donors is needed to ensure stable gas supplies for the winter season and to manage the implications of any price increases as the Gazprom transit agreement comes to an end.

Accelerate structural changes, including renewables deployment, grid upgrades and energy efficiency improvements in Moldova. Moldova is moving to accelerate deployment of utility-scale wind and solar, with 165 MW of tenders launched in August 2024. Boosting energy efficiency, particularly in buildings and industry, through updated regulations and incentives can likewise help to balance the energy relationship with the Transnistrian region by reducing reliance on electricity from MGRES and improve national and regional energy

security. Given that transmission capacity with the continental Europe system is shared between Ukraine and Moldova, any improvement to Moldova's electricity security is also beneficial to Ukraine. In case of shortages in Moldova, the two countries need to agree to a distribution of imports. By default, one-sixth of the available capacity would be allocated to Moldova, proportional to the number of interconnectors.

Enhance Moldova's energy connectivity with its neighbours. Stronger coordination between Ukrainian and Moldovan TSOs with their neighbours – notably through accelerated transposition and the implementation of EU provisions on electricity integration – can help prioritise and accelerate the construction of new interconnectors and transmission lines that will strongly benefit both Ukraine and Moldova, as well as broader European energy security. New 400 kV lines are planned between Romania, Ukraine and Moldova that are scheduled to start operation between 2025 and 2031.

Action 10 – Lay the groundwork for a modern, market-based, resilient and sustainable post-war energy system, well integrated with the European Union

The immediate priority for action must be to mitigate the extreme risks over the 2024-25 winter season. But it will also be vital to start actions that have a longer lead time and to integrate, wherever possible, a vision for a new Ukrainian energy system into the response. While Ukraine's most urgent concern remains the welfare and safety of its citizens through the upcoming winter, there is a strong need to put foundations in place for future winters and to meet the longer-term needs of Ukraine's energy sector by adopting measures that facilitate system security, affordability and sustainability, and the country's ambition to develop its potential as a supplier of clean energy. These measures should support Ukraine's drive to integrate into the broader European system, as set out in its commitment under the Energy Community framework to align with EU energy legislation in the context of EU accession talks. The government's work to develop a 2050 Energy Strategy and a National Energy and Climate Plan through 2030 are important steps, which now need to be underpinned, wherever possible, with implementation strategies that prioritise a favourable regulatory environment for investment.

Integrate longer-term viability and affordability into decision-making on short-term assets. Emergency situations require emergency measures to limit, as much as possible, the impact of continued Russian attacks on the provision of electricity and heat. These include creative solutions, such as the transfer of decommissioned equipment from Ukraine's European neighbours. However, investment in new capacity and the restoration of either damaged or destroyed

assets may impose unwanted long-term consequences on Ukrainian consumers if they come with very high operating costs. Longer-term viability should be a factor in near-term decision-making.

Reinforce the transmission corridors with neighbouring grids to enable increased exports to Ukraine and Moldova. Two late submissions were added to the list of projects in the ongoing cycle of ENTSO-E's Ten-Year Network Development Plan to reinforce the interconnections of Ukraine with Slovakia and Romania, with completion expected in 2026-27. In the context of winter 2025-26, further efforts could be made to increase the firm capacity by deploying phase-shifting transformers, upgrading equipment, reconductoring and deploying software solutions, such as dynamic line rating, on congested corridors. Together with early commissioning of planned reinforcements, imports could be increased by over 1 GW before winter 2025-26. In parallel, the market coupling process in Eastern Europe should be sped up to maximise the utilisation of cross-border capacity, based on the EU and Energy Community regulatory framework and building on the work of the relevant High-Level Working Group.

Incentivise private investment in the energy sector. Ukraine's goal of modernising its energy system and increasing its resilience will require the engagement and support of private investors, and they will require an appropriate level of risk-adjusted return. This means bringing down risks that can affect such investments though a clear policy vision, a readiness to work with the private sector, and a commitment to transparency, regulatory stability and predictability over time. In the power sector, for example, key issues include sector regulation, the reliability of revenues – dependent mainly on the off-taker's ability to pay on time – and the availability of transmission infrastructure or land, as well as how all these issues are defined in contracts. The reliability and credibility of the offtake system can be bolstered by new risk-sharing facilities backed by international partners and/or the government. Political risk can be mitigated by international mechanisms that protect against losses, as well as by export credit agencies like the Danish Export and Investment Fund or the US International Development Finance Corporation.

Move towards cost-reflective tariffs for electricity and heat, with appropriate safeguards for vulnerable households. Price caps in wholesale markets or other regulatory measures that hinder the incentive for private investment in new assets, including price caps for ancillary services, should be reviewed and, where possible, reduced or eliminated. In the place of broad price caps, the regulator should consider retail tariffs designed to protect vulnerable consumers. Cost-reflective tariffs, allied with other supportive regulatory provisions, are instrumental to support investment in new infrastructure for power and heat, including distributed energy resources, and to encourage more efficient and system-friendly electricity consumption.

Prioritise investments in energy efficiency. Almost 80% of the residential building stock in Ukraine was categorised as energy inefficient as of 2021. Increasing the energy efficiency of the existing building stock, particularly by targeting building fabric improvements, could halve their energy consumption. New construction, reconstruction of buildings damaged during the war, and the renovation of existing buildings should be carried out with a view to embedding high efficiency standards in buildings. Projects of the Energy Efficiency Fund of Ukraine and the recently established State Fund for Decarbonization and Energy Efficient Transformation should provide financial mechanisms to improve the efficiency of buildings.

Accelerate the modernisation of Ukraine's heating systems. The modernisation of Ukraine's district heating network is long overdue and needs to be accelerated in conjunction with the modernisation of the country's building stock. Much of Ukraine's heating equipment and infrastructure is close to, or beyond, the end of its design life and network losses (at over 20%, even before the full-scale invasion) are more than double the typical losses in EU countries. According to a government estimate, about 44% of the district heating network is dilapidated. The lack of investment in the heating grid, combined with poor end-use energy efficiency, means that more than half of the fuel currently used to produce heat is wasted[16]. The Ministry of Infrastructure has already developed a thermal modernisation strategy through 2030 and a Priority Action Plan, adopted in February 2024, includes a draft resolution to improve energy efficiency in buildings and reduce heat losses from the sector, with a focus on upgrading the building envelope and heating systems and integrating renewable energy. This now needs a more detailed roadmap of measures to support its implementation

Implement smart meters for electricity and universal heat metering. Developing a plan to roll out smart meters and adding demand-response devices to major electricity appliances and equipment can lay the groundwork for future automated demand response programs for load management and reducing peak demand. Ukraine's ongoing efforts to implement universal heat metering should be continued, and heat tariffs should enable consumption-based billing to encourage the installation of automated meters and end-user temperature controls in buildings.

Ensure that strong corporate governance standards are upheld to maintain energy sector stability and investor confidence. Maintaining and strengthening corporate governance for Ukraine's energy companies in accordance with OECD and EU standards will allow for smoother cooperation with European institutions

[16] The energy saving potential from upgrading district heating systems in Ukraine is substantial. A renovation project in Odesa demonstrated a 50% reduction in total energy consumption, a 30% reduction in direct system costs, a 40% reduction in electricity costs, and 95% water consumption.

and investors. A near-term priority is to ensure that equipment procurement and imports can ramp up and that donations are managed efficiently. Implementing best practices for transparency is essential, as is ensuring the independence of corporate boards.

Utilise Ukraine's significant potential for biogas and biomethane production. Incentives to promote investment in biogas and biomethane-based installations (including for combined heat and power generation) could provide an alternative to natural gas-based district heating systems and increase the resilience of Ukraine's heat supply in the face of ongoing gas supply security risks. Ukraine has two operational biomethane plants and several under construction, according to the country's industry group. It plans to open ten new facilities with a capacity of 1.5 million cubic meters per year in 2024-25. This work could build on the 2023 EU-Ukraine Memorandum of Understanding on a Strategic Partnership on Biomethane and Hydrogen.

Integrate the Ukrainian gas storage system in the European and global gas market. Ukraine has the largest natural gas storage capacity in Europe, at about 30 bcm. Most of its storage sites are located in the western part of the country, close to the European Union, and Ukraine has offered 10 bcm of storage capacity to European market players. Ukrtransgaz, the storage system operator, underwent successful certification according to new EU rules in 2023. That year, European companies stored around 2.5 bcm in Ukrainian storage sites, although they significantly reduced their storage operations in 2024 due to ongoing security issues. In addition to enhancing European gas supply security, storing natural gas in Ukraine provides much-needed income to Ukraine's storage system operator.

Enable Ukrainian citizens to gain the most from their energy system and engage them in the process of change, while managing the system's use and cost. Energy efficiency policies that prioritise people can build connections between energy consumers and the energy system – a vital element in achieving quick short-term actions, but also in meeting longer term energy transition goals. Policies must be designed with the Ukrainian people at the centre, allowing Ukrainians – as consumers, producers, operators or users – to engage with and benefit from their energy system. Potential actions include the upscaling of energy efficiency skills, capacity-building measures (education, training and mentorship), the provision of clear and consumer-friendly energy-related product information (labels on energy use, rating, etc.) at or before the purchasing stage, and the inclusion of behavioural insights in the design of energy efficiency policy.

Annexes

Ukraine's energy background

Prior to Russia's 2022 invasion, Ukraine's energy system depended primarily on fossil fuels and nuclear energy. Total energy supply totalled 88 million tonnes of oil equivalent (Mtoe) in 2021, with oil, natural gas and coal accounting for nearly 70%, and nuclear power for around 25%.[17] Coal, nuclear and most renewable energy sources were used for the most part in power generation, while oil and gas were used primarily in the end-use sectors. Ukraine produces significant quantities of coal and natural gas, but domestic production has historically not been enough to cover demand. In 2021, domestic energy production totalled 55 Mtoe, or almost two-thirds (62%) of the country's total supply. Although renewable energy sources contributed only modestly to the energy mix, solar and wind power generation had been expanding quickly from a low base.

Total final consumption (TFC) was 49 Mtoe in 2021, with natural gas accounting for 27%, electricity and oil for 21% each, heat for 15%, coal for 11% and bioenergy for 5%. The industry sector was responsible for 39% of TFC, followed by the residential sector (28%), transport (19%) and services and other sectors (13%).

Before 2022, nuclear power generated half of the country's electricity, followed by coal-fired plants at 23% and gas-fired plants at 9%. Renewable energy contributed to 11% of the mix, with hydropower comprising the largest share at 6.5%, followed by solar (4.2%) and wind (2%). Ukraine's power generation capacity was the seventh largest in Europe, with a nominal capacity of 56 GW, which allowed Ukraine to export electricity to neighbouring European countries until late 2022.

Before 2022, natural gas was the second-largest element in Ukraine's primary energy mix behind oil, with a share of around 28% of the total. Most of this gas went to produce heat and power, which accounted for 38% of total gas demand, followed by consumption in the residential sector (27%) and by industry (21%). Ukraine traditionally met its gas needs through a combination of domestic production and gas imports from Russia. However, the gas relationship with Russia was a consistent source of tension and instability. Ukraine stopped direct gas imports from Russia in November 2015, replacing some of it with indirect imports via the European Union. Coal imports grew after Ukraine lost control of its

[17] Source: IEA (2022), World Energy Statistics and Balances (database).

main coal mining region in the Donbass after 2014; it moved from being almost self-sufficient in coal to being a major importer (40% of coal supply).

Defining cross-border electricity capacity limits

The calculation of cross-border capacity limits by transmission system operators (TSOs) involves careful balancing between maximising cross-border electricity flows and maintaining grid reliability. The key risks TSOs manage in this process are system instability and grid congestions, which can arise from unexpected power flows and equipment failures.

Since the grid in continental Europe is highly meshed, the power flows between two countries can affect, and be affected by, grid conditions in neighbouring countries. As required by EU legislation, cross-border capacities are co-ordinated at the regional level by Regional Coordination Centres, but the process is only starting for the newly-connected Ukraine and Moldova. Capacities are calculated for each direction separately. As of today, Ukraine and Moldova share a single area for the capacity calculations, meaning that the trade limit of 1.7 GW applies to the imports of both countries together, through the grids of Poland, Slovakia, Hungary and Romania. In the other direction (Ukraine and Moldova exporting to Europe), the current limit is set to 550 MW, due to stability risks for the interconnected system.

The transmission capacity calculation relies on system models and forecasts about resources and network availability. For borders within the EU, the calculations are performed at regular intervals to assess the limits valid for various durations, from yearly down to intradaily values. Capacities available for trade tend to be higher closer to the time of delivery given the higher certainty of the forecasts. For the trade with Ukraine and Moldova, the 1.7 GW and 550 MW trade limits was the result of a calculation for a long-term commitment with complete network availability, taking into account likely outages outside of wartimes. TSOs are currently proceeding towards a monthly capacity calculation that may deliver more capacity, in the order of magnitude of 200 to 300 MW, thanks to a shorter duration of the commitment and the incorporation of available remedial actions.

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