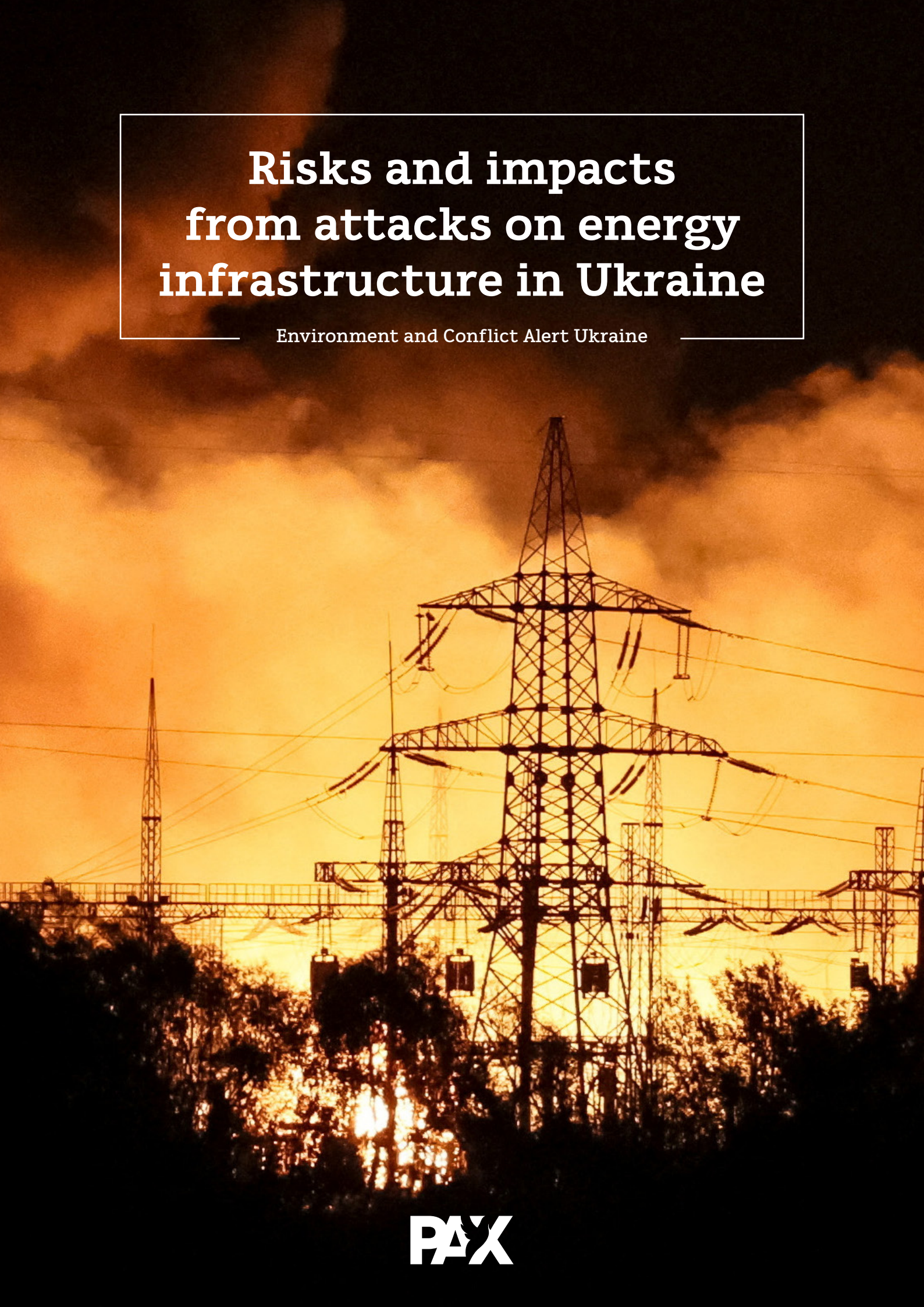
Risks and impacts from attacks on energy infrastructure in Ukraine

Environment and Conflict Alert Ukraine



PAX

December 2022

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If you have questions, remarks or comments on this report, you can send them to info@paxforpeace.nl

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Cover image: A view shows a burning 5th thermal power plant hit by a Russian missile strike, amid Russia's attack on Ukraine, in Kharkiv, Ukraine September 11, 2022. REUTERS/Gleb Garanish

Centre for Information Resilience

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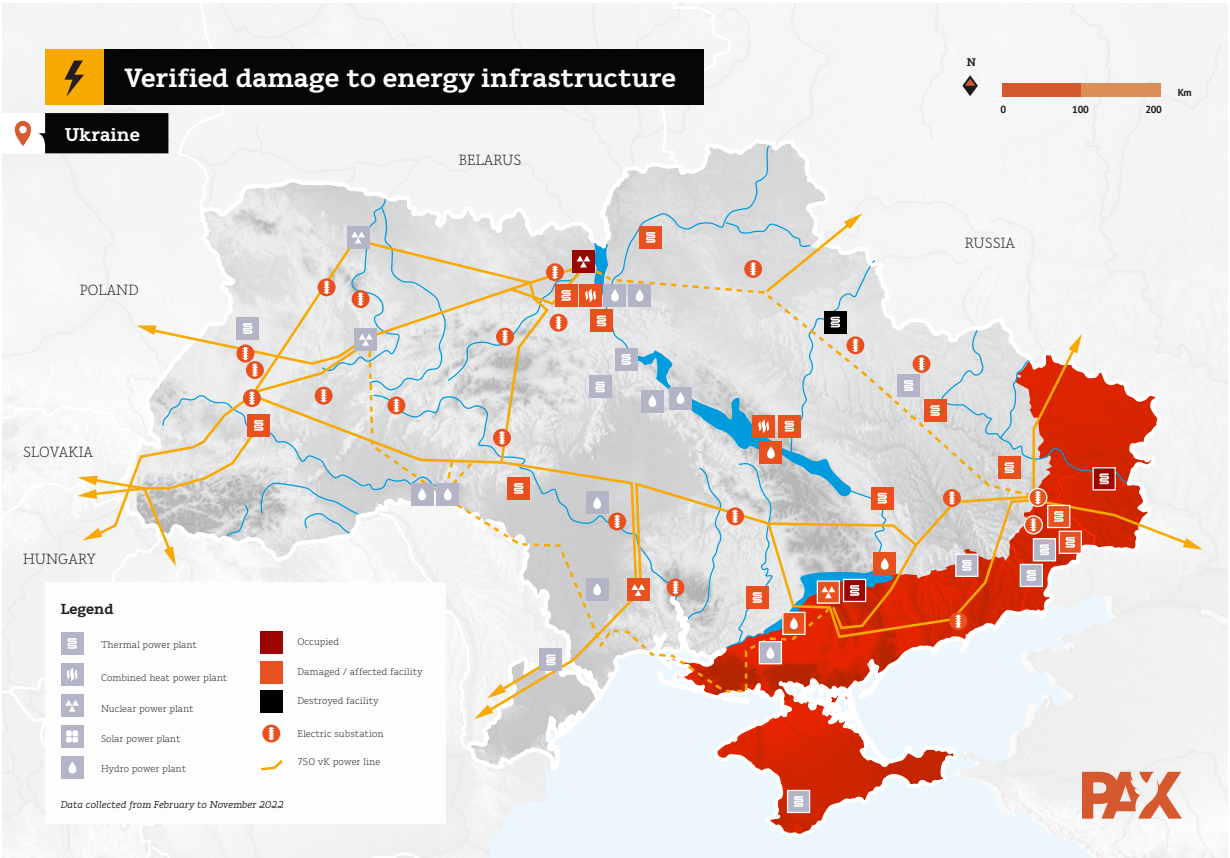
Executive Summary

Winter, cold and harsh, has arrived in Ukraine. Russia has accordingly stepped up its attempts to inflict suffering on the Ukrainian population by targeting energy infrastructure across the country. Dozens of strikes against power plants and substations have had serious impacts on access to heating, drinking water, sewage facilities and power in general, including for military, governmental and industrial purposes. These deliberate strikes have worsened the humanitarian situations for millions of Ukrainian civilians, risking wider long-term environmental challenges and potentially posing serious transboundary risks of pollution and even nuclear fallout.

To determine the magnitude and impacts of these attacks, PAX monitored open-source reporting in conjunction with high-resolution satellite imagery for verification and damage identification. This is part of a broader effort on environmental data collection in relation to the war in Ukraine that should help build accountability and support rapid assessment and remediation efforts.

In the period February – November 2022, PAX identified 213 reported incidents from military actions on energy infrastructure, 63 of which were verified. The largest attacks on Ukrainian energy infrastructure were launched by Russian forces in October 2022. The October attacks damaged 40% of Ukraine's electricity generation and transmission facilities, causing temporary blackouts in most of the country as well as creating both environmental risks and a humanitarian crisis, leaving millions of Ukrainian civilians without electricity, heating and water.



To understand the public health and environmental risks involved, this report explores a case study to highlight how an interrelated pattern of impact on the environment occurs when an energy facility is damaged. This case focuses on the energy relationship between two objects that are more than 100 km apart; namely, how a power substation damaged by an attack carries the risk of causing an accident at a nuclear power plant. The wider context of environmental damage linked with attacks on energy infrastructure is further discussed in-depth at the end of the report, outline the acute and long-term pollution risks and impacts on public health. This is followed by recommendations to the international community to address the humanitarian and environmental dimensions of the war in Ukraine.

A black smoke is seen near Slovianska heat power station in the Donetsk region on October 13, 2022, amid the Russian invasion of Ukraine.

Introduction

The February 2022 Russian invasion of Ukraine has had tremendous impact on Ukrainian civilians and civilian infrastructure. Russia's targeting of critical infrastructure, widespread use of explosive weapons on Ukrainian towns and cities and use of controversial weapons such as landmines, cluster munitions and incendiary weapons has led to over 16,784 civilian casualties by the end of November, and enormous levels of destruction throughout Ukraine.

Military actions also pose a serious threat to environmental safety in affected areas. Consideration of environmental aspects during armed conflicts is crucial because it is often linked to long-term environmental degradation, including damage to ecosystems and biodiversity. Determining the conflict-related impact on the environment and public health is of utmost importance to mitigate harm. As such, the impacts of military actions need to be identified, assessed and addressed. The ongoing work by Ukrainian civil society groups, humanitarian organizations, international conservation groups, various United Nations programs and government-linked agencies such as NASA are essential to understand the full scope of environmental damage from the war in Ukraine. This Environment and Conflict Alert will outline the current identified impact on energy infrastructure throughout Ukraine, both reported in (social) media and locations verified through open-source monitoring. Findings will be assessed in the context of the public health and environmental risks associated with damage to energy infrastructure in affected areas.

Ukrainian's Energy Infrastructure

The United Energy System of Ukraine (UES) is a set of power plants, electric and thermal networks, and other electric substations united by a common mode of production, transmission and distribution of electric and thermal energy under the UES centralized management.

Ukraine's UES is one of the largest energy associations in Europe. It includes seven regional electric power systems: Dnipro, Western, Crimean, Southern, South-Western, Northern and Central, all of which are connected by main power transmission lines forming one system. In 2020, Ukraine's installed capacity was 54.5 GW, with more than 1 million km of total length of distribution transmission power lines. Power generation is based on nuclear energy, coal burning, fuel oil, natural gas, biofuel, and renewable energy sources (RES) like wind, water, and solar.

Ukraine's four operational nuclear power plants (NPPs) contain 15 nuclear reactors, as well as two research nuclear reactors, radioactive waste disposal facilities, and radioactive sources used in medicine and industry. The Chernobyl NPP, while decommissioned in 2000, still hosts two storage units off spent nuclear fuel units. Ukraine has 16 thermal power plants (TPPs), 49 combined heat and power (CHP) plants, three hydro-accumulating power plants and eight hydropower plants (HPPs). The main cascade of HPPs is built on the Dnipro river.

In total, Ukraine's power production and distribution network is enormous, with many vulnerable nodes that present easy targets for Russian drones and missiles. Just a few Russian strikes can impact millions of Ukrainian civilians, while also creating reverberating public health and environmental effects.

Nuclear Power Plants

Zaporizhzhya 6,000 MW	**Pivdennoukrainska** 3,000 MW	**Rivneska** 2,880 MW	**Khmelnytska** 2,000 MW

Thermal Power Plants over 1000 MW

Kryvorizka 2,820 MW	**Burshtynska** 2,400 MW	**Zmiivska** 2,175 MW	**Ladyzhynska** 1,800 MW
Trypilska 1,800 MW	**Starobeshivska** 1,600 MW	**Kurakhivska** 1,487 MW	**Luhanska** 1,425 MW
Zuivska 1,245 MW	**Vuhlehirska** 1,200 MW	**Zaporizhska** 1,200 MW	**Dniprovska** 1,569 MW

Renewable energy in Ukraine has been actively developed since 2016. In 2021, renewable energy constituted roughly 10% of all electricity in Ukraine. According to Ukraine's Ministry of Energy, in 11 months of 2021, 11 TWh of energy was generated from renewable energy sources. The largest wind and solar power plants are located in southern Ukraine (Mykolaiv, Kherson and Odesa regions).

Documenting Attacks on Energy Infrastructure

PAX began monitoring conflict-linked environmental incidents from military actions in Ukraine since the full-scale Russian invasion on February 24. Data collection is based on credible media reports and social media channels such as Facebook, Twitter and Telegram. PAX's database also includes information provided by REACH and the Center for Environmental Initiatives EcoAction. Monitoring and verification of incidents is performed together with PAX's partner, the Centre for Information Resilience (CIR), which conducts wide-scale monitoring in Ukraine. Incidents are verified where possible through satellite imagery, using public high- and medium-resolution satellite images from NASA and ESA and commercial very-high resolution imagery provided by Planet and MAXAR.

PAX's database contains information on 213 incidents involving energy infrastructure, 63 of which have been verified (last entry dated on December 2022).

Number of category	Category in DB area of incidents	Number of incidents	Subcategory in DB affected facilities	Number of incidents
1	Energy infrastructure	63	1.1 Thermal power plants	26
			1.2 Nuclear power plants	14
			1.3 Substations	22

Timeline attacks against power plants Ukraine

PAX

KEY EVENTS

At midnight on February 24, the energy system of Ukraine was **disconnected from the energy systems** of Russia and Belarus. Ukraine has been in the joint power system with these countries since Soviet times. This disconnect was planned.

On March 16, against the backdrop of the Russian military invasion, more than a year ahead of schedule, **Ukraine's energy system was fully synchronized** with the ENTSO-E power grid of continental Europe

On October 11, **Ukraine stopped exporting electricity**. The Minister of Energy of Ukraine made a statement: "Russia continues to carry out energy terror against Ukraine, and also increases energy pressure on the European Union. Missile attacks that hit thermal generation and electrical substations force Ukraine to suspend electricity exports from October 11, 2022 in order to stabilize its own energy system"

The Minister of Energy of Ukraine stated that on October 10-11, about **30% of Ukraine's energy infrastructure was hit** by Russian missiles

As a result of these attacks **40% of energy infrastructure is significantly damaged** as of 19 October 2022. NEC Ukrenergo has started applying restriction schedules for consumers of various categories, population and industrial consumers throughout the country

The strategic meeting on security at energy supply facilities was held under the chairmanship of the President of Ukraine, on October 19, 2022, where various scenarios and measures in case of Ukraine's energy system breakdown were discussed.

From 27 October, in order to prevent the blackout of the capital and central regions, NEC Ukrenergo introduced **unprecedented emergency restrictions**: the use of long-term power outages without a schedule.

Legend

- Stopped
- Occupied
- Damaged / affected
- Destroyed

- Thermal power plant
- Combined heat power plant
- Nuclear power plant
- Solar power plant
- Hydro power plant

POWER PLANTS AFFECTED BY MILITARY ACTIONS

FEBRUARY

- **Chernobylska NPP** — non-operated since 2000
- **Luhanska TPP** — 1,425 MW
- **Trypilska TPP** — 1,800 MW
- **Kakhovka HPP** — 335 MW

MARCH

- **Zaporizhska TPP** — 1,200 MW
- **Okhtyrska CHP** — 12.75 MW
- **Chernihiv CHP** — 210 MW
- **Zaporizhzhya NPP** — 6,000 MW
- **Zuivska TPP** — 1,245 MW

APRIL

- **Vuhlehirska TPP** — 3,600 MW
- **Kremenchuk CHP** — 255 MW
- **Kryvorizska TPP** — 2,820 MW

MAY

- **Slovyanska TPP** — 880 MW

JUNE

- **Vuhlehirska TPP** — 1,200 MW
- **Pivdennoukrainska NPP** — 3,000 MW

JULY

- **Vuhlehirska TPP** — 3,600 MW
- **Zaporizhzhya NPP** — 6,000 MW
- **Zaporizhska TPP** — 1,200 MW
- **Vuhlehirska TPP** — 3,600 MW

AUGUST

- **Zaporizhzhya NPP** — 6,000 MW

SEPTEMBER

- **Zmiivska TPP** — 2,175 MW
- **Slovyanska TPP** — 880 MW
- **Zaporizhzhya NPP** — 6,000 MW
- **Pivdennoukrainska NPP** — 3,000 MW

OCTOBER

- **Prydniprovska TPP** — 1,765 MW
- **Kyiv TPP #5** — 700 MW
- **Burshtynska TPP** — 2,400 MW
- **Ladyzhynska TPP** — 1,800 MW
- **Trypilska TPP** — 1,800 MW
- **Kremenchuk HPP** — 700 MW
- **Kyiv CHP #1** — 36 MW

NOVEMBER

- **Kremenchuk HPP** — 700 MW
- **Kyiv TPP #5** — 700 MW
- **Dnieper HPP** — 1,548 MW
- **Kakhovka HPP** — 351 MW

Verified incidents have occurred in 17 of Ukraine's 24 regions. The largest number of incidents occurred in the Zaporizhzhia, Donetsk, Kharkiv, Dnipropetrovsk, Kyiv and Mykolaiv regions.

The majority of verified incidents in this reporting period involved transformer substations, notably 330kV substations, the second highest voltage level and most prominent transmission voltage across Ukraine. In most cases, these substations were the primary substations for their respective cities, meaning their damage or destruction often had severe consequences for energy consumption in these cities. Thermal power plants (TPPs) were also frequently targeted. Not all claims regarding TPPs could be verified.

The Russian invasion has had severe and long-term impact on Ukraine's energy infrastructure, both from damage by Russian strikes and from loss of access to facilities in Russian-occupied areas of Ukraine. The report will outline the main findings from the data on energy infrastructure damage documented since the start of the war with a timeline of attacks and key events. Next, a case study will be presented on the complexity of risks surrounding the Zaporizhzhia Nuclear Power Plant. The second part of the report will provide an overview of the public health and environmental risks associated with damage to infrastructure and will end with a number of recommendations for the international community to address these concerns.

Autumn 2022 attacks on Ukraine's energy systems

The largest Russian attacks on Ukraine's energy system have occurred from September to November.

On September 11, Russia carried out its first major wave of specific attacks on Ukraine's energy infrastructure, damaging two thermal power plants and three substations.

On September 19, the Russian army conducted a missile strike on the industrial site of the Pivdennoukrainska nuclear power plant (NPP) hitting just 300 meters from the plant's reactors. A hydropower unit of the Oleksandrivska HPP, a part of Pivdenoukrainskiy power complex, was shut down as a result of the missile strike. Three high-voltage power lines were damaged as well.

On October 10, Russian forces conducted their largest missile strikes of the war to date, firing more than 80 cruise missiles. Energy facilities were damaged in Kyiv city and 11 of Ukraine's 24 provinces: Kyiv, Lviv, Zaporizhzhia, Dnipro, Vinnytsia, Khmelnytskyi, Ivano-Frankivsk, Sumy, Kharkiv, Zhytomyr, and Kirovohrad. Millions of Ukrainians were left without electricity and water.

On October 11, Russian missiles and drones targeted energy infrastructure in the Lviv, Vinnytsia, and Dnipropetrovsk regions.

On October 15 and 17, Russian missiles and drones caused severe damage to energy infrastructure in Kyiv city and the Kyiv region.

On October 18, Russian strikes hit energy facilities in the Kyiv, Kharkiv, Dnipro, Zhytomyr, Sumy, Zaporizhzhia, Dnipropetrovsk, and Donetsk regions.

On October 19, Russia again struck critical infrastructure in the Chernihiv, Vinnytsia, Ivano-Frankivsk, and Zaporizhzhia regions, causing large-scale fires.

On October 20, Russia forces fired missiles at energy facilities in the Kryvyi Rih region.

On October 26-27, more than six Russian drone attacks hit targets in central Ukraine. As a result, Kyiv city and Kyiv region experienced a 30% reduction in their power supply.

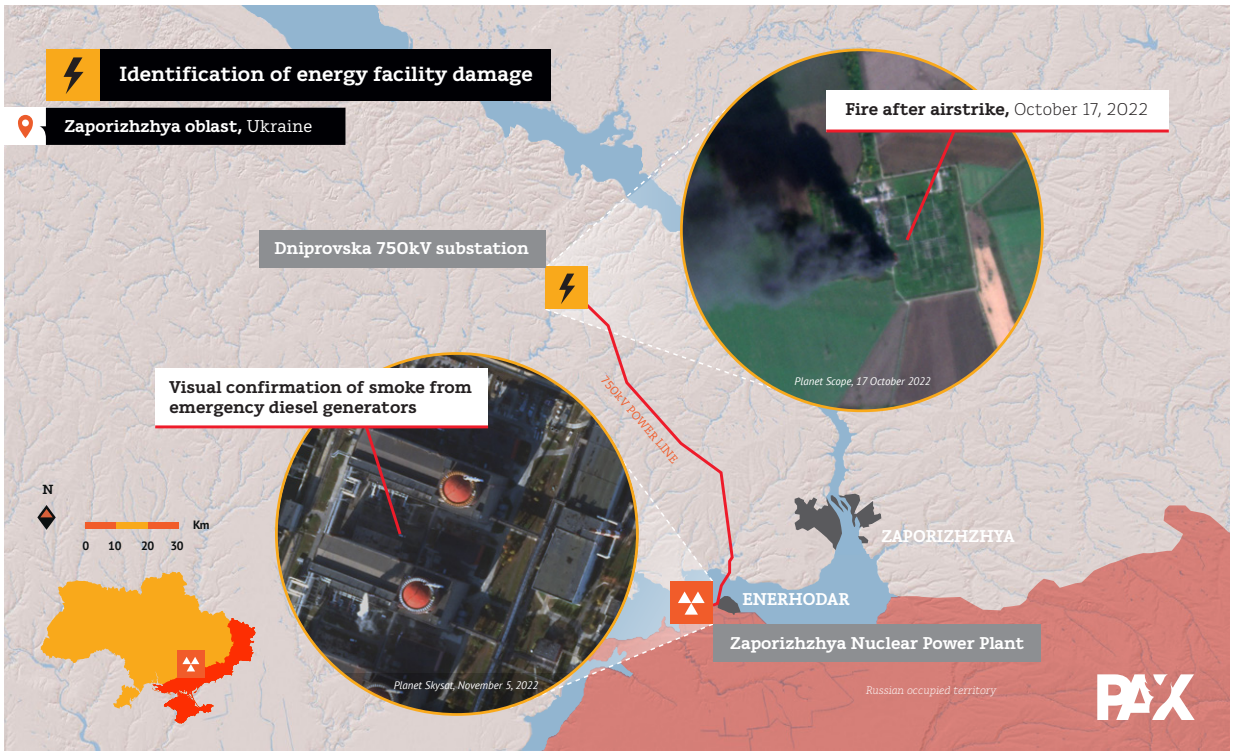
On October 31, a large-scale Russian missile attack struck energy infrastructure facilities in Kyiv city as well the Kharkiv, Zaporizhzhia, Cherkasy, Kyiv, Kirovohrad, Chernivtsi, and Dnipropetrovsk regions.

Case Study: Attacks on Zaporizhzhya Energy Grid and Zaporizhzhya Nuclear Power Plant

One of the greatest concerns in Ukraine's energy sector in the current war is the Zaporizhzhya nuclear power plant (ZNPP) and potential radiation dangers. Europe's largest nuclear power plant, the Zaporizhzhya NPP's six reactors are in cold shutdown as of the end of October, not generating electricity but still requiring power for cooling and other essential nuclear safety functions. The power supply situation at the ZNPP remains vulnerable - only one external 750 kV power line is operating instead of the four that were in operation before the invasion, putting the safety of the plant at high risk. In November, the Zaporizhzhya NPP was shelled again resulting in multiple explosions, posing grave risks to nuclear security as the IAEA warned.

The present situation began to develop on March 4, when Russian troops captured the Zaporizhzhya NPP. Russian troops established a base at the ZNPP, placing heavy artillery in violation of international laws on the safety of nuclear power plants. Despite that, the ZNPP's regular management and staff have continued to operate the plant over the past nine months.

Many months of shelling near and around the plant periodically disabled its one remaining external power line. Emergency diesel generators are used during these periods to provide cooling systems for the plant's six reactors in order to prevent the start of a meltdown.



The case study below examines how attacks in October 2022 on the final active power line of the ZNPP with the United Energy System of Ukraine, the "Powerline-750 kV ZNPP – "Dniprovska", affect the safety of the ZNPP located at a distance of more than 100 km from the attacked substation "Dniprovska" in the Dnipropetrovsk region.

Strike Location

On October 11, 2022, satellite imagery analysis showed smoke rising from a 750kV transmission substation to the south of the nearby town of Vilnohirsk, Dnipropetrovsk oblast. The site was apparently struck in a wave of Russian missile and drone attacks against Ukrainian energy infrastructure. The facility, known as the 'Dniprovska 750 Substation' (or Дніпровська-750), is operated by Ukrenergo.

Imagery from October 11 shows dark smoke emanating from a large fire at the center of the facility. The fire appears to be concentrated at the site of several shunt reactors connected to the 750kV switchgear. Although there is no publicly available evidence of the munition type used against the facility, the strike would align with the wider pattern of attacks against Ukrainian energy facilities over a two-day period between October 10-11.

A second fire was spotted on satellite imagery in the same location within the same week, on October 17th, apparently following another Russian attack.

The October 17th fire was in a similar location to the fire identified on October 11th, suggesting the site was repeatedly targeted. Very-high-resolution imagery from Planet Skysat, dated October 19 would show the extent of the damage to the facility. Burn scarring in the immediate proximity of four of the six shunt reactors are indicative of the facility being taken out of operation.

Furthermore, a large crater was identified in a larger structure (purpose unknown) in the area of the 330kV switchgear. This further suggests that the site was targeted by missile strikes. The damage to this structure was not detected in the initial imagery from October 11th, but was visible on October 13th, suggesting the facility was subjected to multiple strikes during these days.

Consequences of the strikes

On October 12th, the State Enterprise National Nuclear Energy Generating Company "Energoatom" reported a failure of a 750kV transmission substation in the Dnipropetrovsk oblast, resulting in an insufficient supply of energy for the stable continuity of the Zaporizhzhya Nuclear Power Plant. The damage, according to the statement, was a consequence of Russian missile strikes. The Dniprovska substation matched the description provided by Energoatom, and was verified as the most immediate 750kV substation in relation to the ZNPP, with the facilities connected directly via 750kV power lines. Later the same day (October 12th), Energoatom announced that specialists had restored the functionality of the 750kV line from the Dniprovska substation to the ZNPP.

Energoatom made a subsequent statement on October 17th, in the wake of the second identified fire at the Dniprovska facility (below). They stated, on both October 12th and October 17th, that the ZNPP would be forced to rely on diesel generators in lieu of sufficient energy supply from the Ukrainian energy grid.

Analysis of imagery of the ZNPP shows that the buildings storing the diesel generators have been periodically observed producing smoke from their chimneys, suggesting diesel generator usage. The Dniprovska substation is one of seven substation facilities damaged by Russian strikes over the course of two days (October 10-11). Systemic targeting of these facilities has had a devastating impact on Ukrainian energy infrastructure and endangers the safe operation of systems like the ZNPP, as well as other immediate consequences to human security as outlined in this paper.

Public Health and Environmental Risks Associated with Damage to Energy Infrastructure

Understanding how wars contribute to conflict-pollution and environmental degradation is key to the prevention, minimization and mitigation of these risks for both civilians, livelihoods and the ecosystems they depend on. It is therefore crucial to identify the different types of conflict-linked environmental impacts that can result in detrimental effects in order to develop effective policies concerning environmental protection in armed conflicts. Some of the issues PAX is monitoring in Ukraine are described below .

Industrial sites. Attacks on oil depots, warehouses storing or processing hazardous substances and ammunition, and chemical waste storage facilities affect almost all components of the environment – air, surface and underground water, and land resources. Attacks on energy facilities create cascading effects on the industrial sector as well as contributing to humanitarian crises.

Toxic remnants of wars. Another significant burden of armed conflict on the environment is waste – destroyed military equipment, munitions, hazardous substances and destroyed buildings, occupying huge areas of land. Toxic substances can seep through soil cover into the groundwater, exposing civilians to a range of hazardous materials.

The use of explosive weapons in populated areas is associated with many environmental risks, such as large amounts of (often contaminated with asbestos and heavy metals) rubble and disruption of critical services. When water infrastructure is damaged, uncontrolled release of wastewater or sewage can enter the environment. When solid waste management is disrupted, this will lead to unsafe landfills and open-air burning of solid waste. Ecosystem services of water, forest and land resources are being lost due to landmines or areas contaminated with unexploded ordnance (UXO). Explosives also cause heavy damage to forests, contaminate fertile soil, pollute bodies of water and damage civilian infrastructure. Large-scale damage to forests is an almost inevitable consequence of armed conflict, owing to both shelling and landmines.

Movement of military equipment pollutes the air with emissions of toxic substances including greenhouse gasses, contributing to climate change. Large-scale use of land-based equipment destroys soil cover and wetlands in the conflict area. Fuel and lubricants used for military equipment contaminate soil and pollute bodies of water. All of this leads to the death of living organisms and loss and degradation of habitats and biodiversity.

Public health. The quality of air, drinking water and soil are all negatively impacted by armed conflict due to increased risks of exposure to a range of toxic substances and general break down of environmental governance that poses additional health risk from communicable diseases. Critical infrastructural facilities, such as energy, fuel and water infrastructure, also suffer from conflict. In general, military actions change the quality of the environment's components, which leads to the loss of ecosystems service for many years and requires significant efforts in restoring the environment to its pre-conflict state.

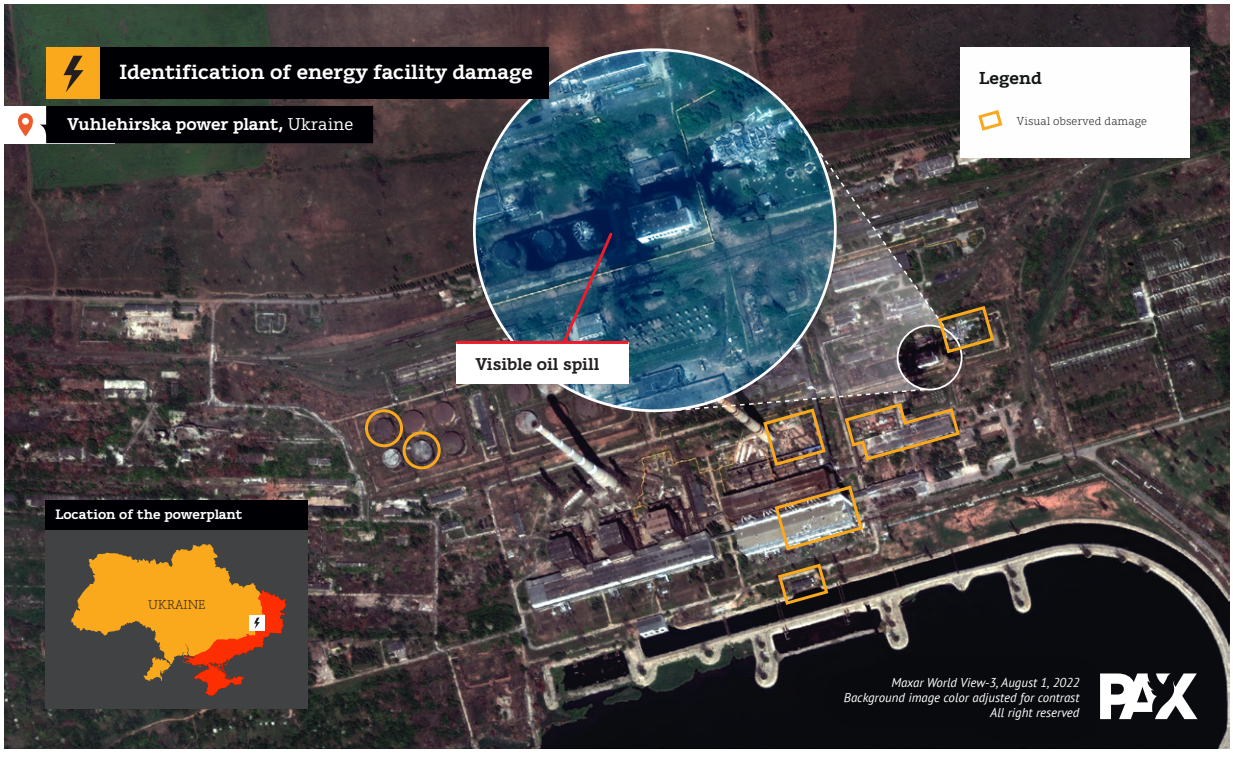
Damage to energy infrastructure from bombing can result in the release of hazardous materials such as heavy fuel oil, asbestos, or polychlorinated biphenyls, a highly carcinogenic compound present in power stations. Exposure to these materials can pose both acute and long-term health problems and has been noted in other conflict zones, such as the research conducted by UNEP in Iraq that identified similar issues in Mosul. Energy facilities often have tailing storage areas nearby that hold industrial wastewater; a direct attack can cause this to be released. In the case of strikes against nuclear power plants, the direct release of radioactive material can lead to acute radiation exposure and long-term contamination risks for the civilian population.

Lack of electricity can have wider impacts on public services and critical energy needs, including public health risks. Without electricity, water pumping systems, water filtration and sewage facilities fail to work, leaving the population without access to clean water. Polluted water and lack of access to clean water increases the risk of communicable diseases and severely impacts public health. According to UNICEF, children under 15 living in countries with conflicts are, on average, almost three times more likely to die from diarrheal diseases linked to unsafe water, sanitation and hygiene (WASH) than by direct violence linked to armed conflict. There is a high risk of preventable diseases without safe and effective WASH services.

Lack of electricity further also impacts food security as refrigerator and freezer units stop working, potentially leading to food poisoning and elevated risks of long-term health problems linked with food-borne pathogens causing miscarriages and meningitis. Damage to power infrastructure also impacts heating of houses, leading to increased risk of cold-related illnesses and hypothermia.

Apart from these impacts on public health, absence of energy also impacts communication, resulting in lack of information, critical for security awareness and the ability to alert emergency response services. Failure of power also disrupts movement due to failure of public railway transport, leading to increased usage of cars, buses and tracks, with the resultant increase in CO2 emissions.

Another public health affecting factor is related to the extensive use of generators in densely populated urban areas affecting air quality. Increase of indoor use of firewood and hydro-carbon heaters will likely result in increased risk of exposure to pollutants and more fires as people attempt to find alternative ways to generate heat.



Environmental impact from attacks on energy infrastructure

An area of specific environmental concern in military operations are consequences of attacks on energy infrastructure that provide power to facilities used in the industrial sector. Even prior to the Russian invasion of Ukraine in February, there were risks of radioactive and chemical contamination associated with industrial enterprises in the Donbas conflict zone.

The full-scale Russian invasion in February 2022 made it far more difficult to monitor the state of industrial facilities across Ukraine and their impact on the environment. Targeted attacks on energy infrastructure increasingly threaten the failure of facilities processing or storing hazardous materials, whose operation is dependent on a steady power supply. Industrial accidents can bring significant long-term consequences to the environment and public health and increase the risk of transboundary water and air pollution. A stable power network is required in order to maintain environmental and technogenic safety.

> "As a result of nonoperational wastewater treatment facilities taken offline by military attacks, the polluted effluents from these treatment plants enter rivers and other bodies of water directly, increasing the environmental and public health risks related to unsafe water. Signs of inefficient operation of treatment facilities have been recorded following the resumption of monitoring in the Donbas region: there are increased concentrations of ammonium nitrogen in the Siversky Donets river."

The pumping of industrial waste to storage facilities is a constant process for the chemical, energy, metallurgical and oil industries. Some livestock enterprises of the agroindustry have a technological process as a seasonal pumping out of large-tonnage toxic liquid animal waste. Even temporary power interruptions can create an uncontrolled release of liquid waste into the environment, with potential transboundary effects on water bodies quality.

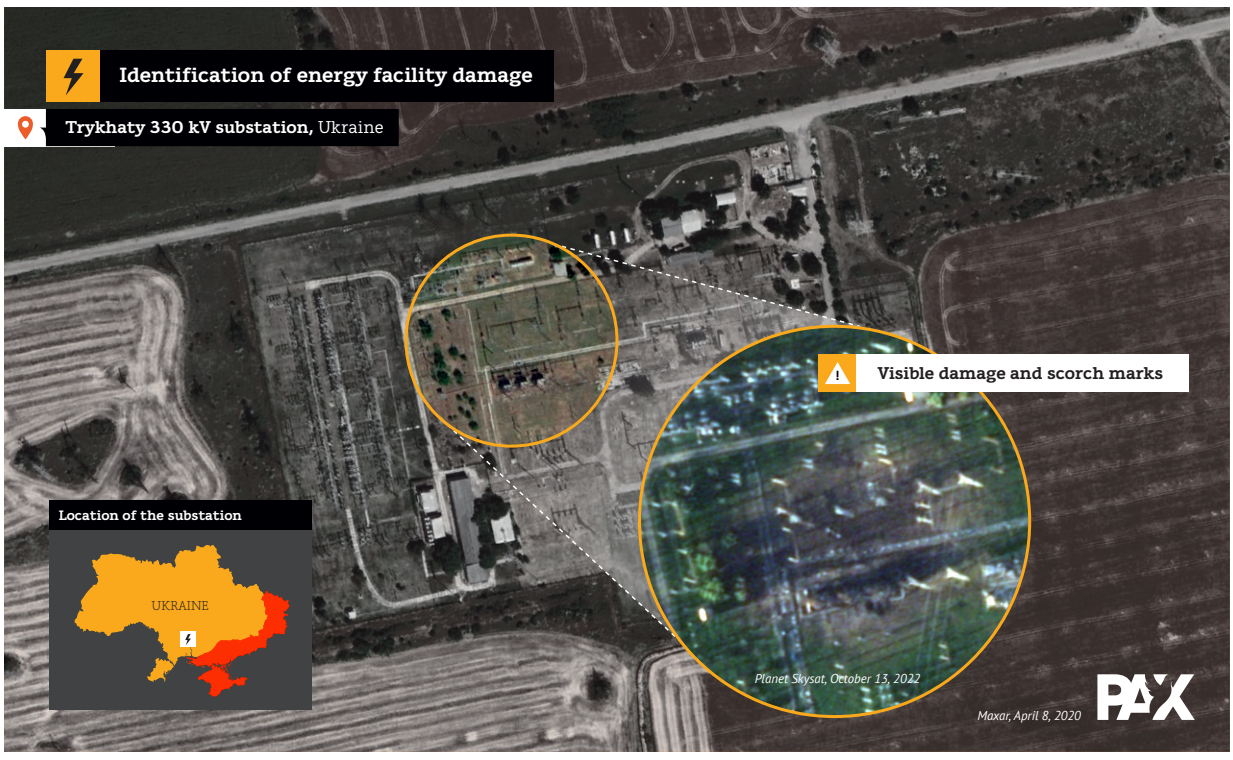
> "465 tailings storage facilities (TSFs) have been identified in Ukraine, storing over six billion tons of waste from various industries – extractive, processing (metallurgical, chemical, machine-building, oil refining), energy sector and others (as of 2019). 200 TSFs with 939 million tons of industrial waste, are being concentrated in eastern Ukraine, in the area of active hostilities."

An additional crucial safety issue is the power plants' cooling process, dependent on the availability of power supply. This is especially dangerous in the case of nuclear power plants (NPPs), as conflict-related damage to power lines supplying NPPs can risk a nuclear accident. When the cooling system stops functioning, the fuel rods of the reactors begin to melt. This process led to the nuclear disaster at the Fukushima nuclear power plant in Japan: the power supply system was destroyed by a tsunami, and after three hours the rods began to melt.

Ukraine has 16 thermal power plants and four nuclear power plants with 15 nuclear reactors, including six reactors at the occupied Zaporizhzhya NPP, Europe's largest nuclear power plant. These plants need a stable power supple for cooling processes to maintain technogenic and radiation safety.

The disruption of energy supplies also creates serious problems in the mining sector. For coal mines, a power cut can halt the pumping of both mine waters and methane, causing flooding and a buildup of explosive gas in the underground galleries. This can have a catastrophic impact on water quality and pose additional explosive risks.

The Donbas coal basin consists of 220 coal mines: 97 are operational, 14 are in drainage mode, 39 are slowly flooding, and 70 are in the process of closure. Research conducted in 2020 and 2021 highlighted the importance of keeping mines dry by pumping out mine water and/or floodwater, which often halts during armed conflict. In 2022, constant shelling of energy infrastructure is increasing the risk of power cuts to crucial drainage systems, leading to the possible release of mine water into rivers and groundwater.



Another example is the impact on coke plant operation. A halt in pumping fresh service water leads to a shortage of steam production, which can cause the shutdown of the plant's chemical workshops and consequently the termination of coke oven gas purification, resulting in high levels of air pollution.

> The Avdiivka coke plant, located in Donbas, is the largest in Europe and the main producer of coke in Ukraine. Much of the plant has been destroyed since February 24: the railway connection, conveyor tracts along which raw materials are supplied, and buildings. For reasons of human and environmental safety, production was stopped in April 2022 — coke batteries were transferred to cold preservation mode for the first time in the plant's history since its opening in 1963.

Lack of access to regular energy resources could also result in an rapid increase in deforestation by illegal logging for firewood, both in Ukraine and more broadly in Europe as energy prices soar. Ukrainian experts already estimated a need for over seven million cubic meters of forest used for firewood, based on current requests made to the government from conflict-affected regions. Besides the impact on natural forests, the use of firewood in houses is also linked with both indoor air pollution and associated health risks, and an increase of carbon monoxide in the atmosphere.

Conclusion

Attacks on energy facilities in Ukraine can result in environmental and humanitarian disasters with potential transboundary effects. Damaged energy systems pose a serious threat of water pollution by mine water, industrial liquid waste and sewage water. For urban areas, it means a lack of water, electricity and other vital services in cities of millions, and also in small villages where immediate response is difficult, especially in occupied areas. Outbreaks of disease and epidemics are inevitable when water, air and soil are contaminated with radiation and toxic or pathogenic substances. This then leads to long-term environmental degradation, loss of ecosystem services and biodiversity.

Evaluation of environmental damage resulting from military action in Ukraine consists of three steps: damage identification, fixation and assessment. This is important for decision-making to develop a plan for restoration of the environment in Ukraine. The remote monitoring and verification of incidents from military actions, such as those performed by various Ukrainian and international organizations (including PAX), can contribute to the first step and second steps using open sources and satellite imagery.

To get the whole picture of damage and carry out further assessment, fieldwork should be conducted: taking samples of water and soil, measuring spills, and identifying destroyed buildings that contain substances hazardous to the environment and public health. Such fieldwork could be organized during emergency response or as humanitarian aid.

To assess environmental damage, it is necessary to establish an automatic environmental monitoring system (air, surface water and groundwater), the data of which will be used to track and record the dynamics of environmental pollution following armed conflict.

Environmental and humanitarian organizations can contribute to the development of plans and strategies for Ukraine's recovery. It is important to continue monitoring and mapping environmental and health risks, as well conducting pilot projects on the ground to assess the extent of the damage to the environment. Combining the efforts of relevant organizations during the period of active conflict and in the post-war period is crucial for preventing environmental degradation and preserving Ukraine's nature, the lives of people now and future generations.

Mitigating Harm: Immediate and Long-term Perspectives

Ukraine needs major support from its international partners to cope with the ongoing Russian campaign against its energy system and the environmental and humanitarian crises that have resulted. Necessary measures to mitigate environmental harm and decrease public health risks in Ukraine are presented below.

Immediate needs

Technical Support for Ukraine's Energy System. There is an urgent need to ensure the resilience of the country's energy system by provision of air defense systems to protect against missile and drone attacks. Continually damaged power generation and transmission facilities need to be replaced, and appropriate spare parts to quickly restore power supply after an attack are a significant expense. To reduce the load on Ukraine's degraded power system, auxiliary solutions will also help: the provision and use of mobile generators, as well as energy generation technologies based on alternative fuels.

There are two ongoing initiatives for support of Ukrainian energy infrastructure:

- The International Energy Advisory Council (IEAC) was established on November 1, 2022 under the Ministry of Energy of Ukraine. It aims to provide support and assistance to Ukrainian energy companies, in fields such as energy security, repairs and protection.
- The Energy Community, a regional organization established to address energy needs in Eastern Europe and the Black Sea, established the Ukraine Support Task Force (USTF). This body coordinates shipments of critical specialized energy equipment to Ukraine, donated by private companies. The process is simple and burden-free for companies: the USTF coordinates the entire donation process, including the door-to-door delivery of donated items with transport provided at no cost, thanks to the European Commission's Emergency Response Coordination Centre.

Radiation Safety. There is an urgent need for the demilitarization and de-occupation of the Zaporizhzhya Nuclear Power Plant in order to prevent a possible nuclear accident. The International Atomic Energy Agency calls for the establishment of a nuclear safety and security protection zone around the plant. On October 22, the G7 Non-Proliferation Directors General urged Russia to immediately return full control of the Zaporizhzhya NPP to Ukraine.

Humanitarian Aid. The work of humanitarian missions is crucial for regions where the power supply is disrupted and need to be scaled-up, including providing access to clean drinking water, sanitation and hygiene; Assistance of people in preparing for the cold season; organization of delivery of solid fuel, firewood and heating appliances, provision of winter clothes; Support in restoring of damaged homes like repairs of windows and isolation of buildings.

There is also reason to consider environmental aspects as part of the humanitarian response in Ukraine. The UN OCHA initiative on creation of an Environment Working Group has helped coordinate and share information between environmental and humanitarian actors in Ukraine, improving local capacity and decision-making on environmental concerns.

Capacity Building for the relevant Ukrainian authorities and experts (including financial, technical and methodological support, as well as trainings):

- Emergency response to incidents resulting from military actions. Immediate action is crucial to repair damaged energy infrastructure, especially facilities providing critical infrastructure with electricity.
- Environmental monitoring is critical for decision-making and risk mitigation. Monitoring surface and groundwater quality is crucial to assess the impact of conflict incidents on the power supply of water infrastructure facilities. Air quality monitoring after the release of pollutants or radioactive substances will allow timely measures to be taken for protecting the civilian populace from harmful effects. Monitoring is also important for determining how best to ensure long-term recovery from war damage.
- Data collection and verification procedures. In order to create a reliable database of environmental damage caused by military operations it is necessary to create a unified approach to monitoring and verifying incidents. Collecting evidence of crimes against the environment in Ukraine is important for the possibility of filing claims in international courts for reparations and damage compensation. Data collection and verification methods should include on-site techniques, open source information, and satellite monitoring, as well as trainings on determining of incident's impact to the environment, including potential transboundary pollution
- Methods of calculation of environmental damage from military actions in monetary equivalent.

Long-term measures

The following steps are proposed for energy infrastructure restoration:

- On-site environmental risks assessment of energy facilities in affected areas
- Mapping of destroyed/damaged sites, prioritizing ones for clean-up/remediation measures
- Mobilizing investments in low- or zero-carbon assets on rebuilding energy infrastructure in an environmentally friendly way.

Advocacy support

The increasing risks posed by military actions to civilians and their environment demonstrate the need for a more coherent, coordinated UN-system-wide approach. An Environment, Peace and Security (EPS) agenda should be established to improve international prevention, mitigation, and response efforts to environmental damage in conflicts, both in Ukraine and beyond. Such an EPS agenda should prioritize: (1) preventing and minimizing the environmental and subsequent humanitarian consequences of conflicts; (2) identifying, monitoring and responding to environmental consequences; and (3) the inclusion of the environment as an essential component of sustainable peacebuilding programs.

An EPS agenda would also complement and strengthen existing normative agendas discussed at the UN Security Council (UNSC), such as the Protection of Civilians in Armed Conflict, Sustaining Peace, and Women,

Peace and Security agendas, among others. A UN system-wide EPS agenda could be utilized as a foundation from which the international community could formulate a coherent and actionable response to conflict-related environmental degradation in Ukraine, coordinating with various UN agencies currently working on environmental issues within their own respective mandates.

A family cooking outside the basement of their house. Due to the Russian bombardments, light and electricty were cut.