

Russian Military Actions at Ukraine's Nuclear Power Plants

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Russia's ongoing military occupation of Ukraine's six-reactor Zaporizhzhia nuclear power plant (ZNPP)—the [largest in Europe](#)—has raised widespread alarm about potential damage to the plant that could cause large radioactive releases to the environment. Russian forces captured the plant on March 4, 2022, with reported [“heavy fighting and artillery shelling.”](#)

Multiple drone strikes on the plant on April 7, 2024—including the containment dome roof of one of the reactors—constituted “a major escalation of the nuclear safety and security dangers facing the Zaporizhzhia Nuclear Power Plant,” [according](#) to Director General Rafael Mariano Grossi of the International Atomic Energy Agency (IAEA). An IAEA team at the site found no damage to the plant's critical safety systems, but reported blood at the site of one explosion.

Since August 2022, military action in region has severed all off-site power to the Zaporizhzhia plant eight times, [according to IAEA](#). Whenever offsite power has been lost, the plant's emergency diesel generators have been activated to provide electricity for reactor cooling systems. The plant's six reactors have been shut down since September 2022, according to the Organisation for Economic Co-operation and Development [Nuclear Energy Agency](#). However, decay heat from the reactors' nuclear fuel must be continuously removed to prevent overheating and radioactive releases.

After months of negotiation, an IAEA expert team arrived at ZNPP on September 1, 2022, to assess the conditions at the plant. IAEA's [report on the mission](#), issued September 5, 2022, described extensive damage to plant facilities and surrounding infrastructure. The report warned that continued military action “represented a constant threat to nuclear safety and security because critical safety functions (containment of the radioactivity and cooling in particular) could be impacted.” The report called for “establishment of a nuclear safety and security protection zone around the ZNPP.” It also noted that the plant's operating staff is “subject to constant high stress and pressure” which “could lead to increased human error with implications on nuclear safety.” Russian forces have seized control of ZNPP and its management, but the plant's operational personnel have remained on duty. IAEA experts will remain at the plant to monitor safety conditions.

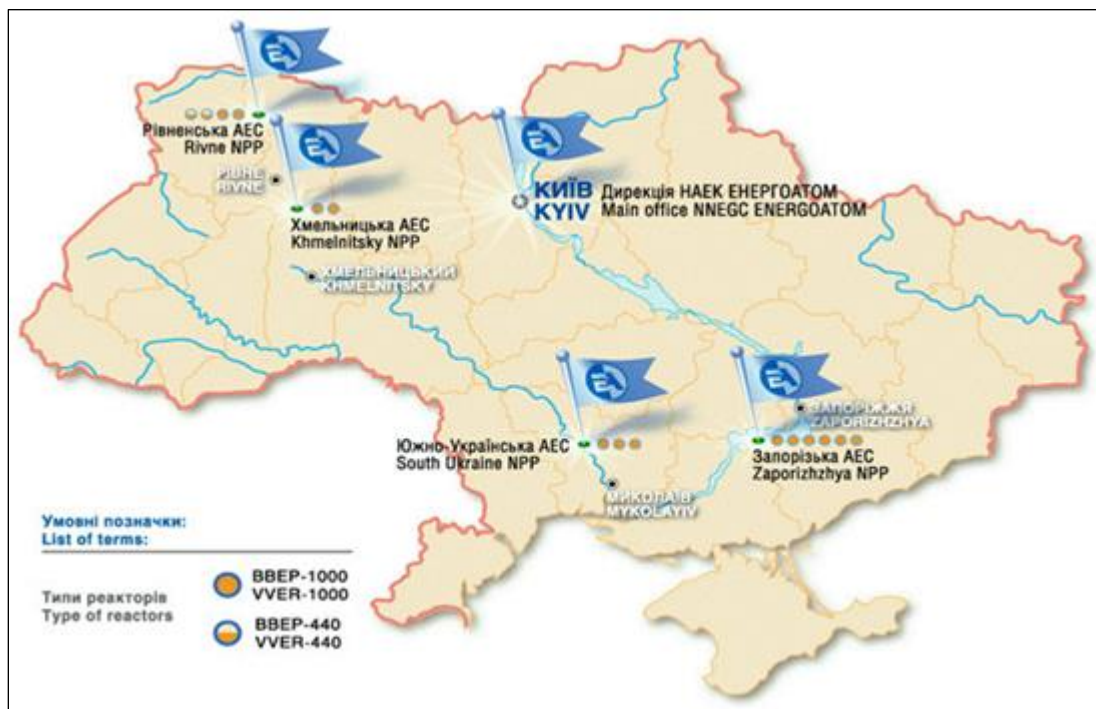
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Nuclear Power Plants Operating in Ukraine

Ukraine has four operating [nuclear power plant sites](#) with a total of 15 reactors, which in recent years have provided about half of Ukraine's total [electricity generation](#). All the operating Ukrainian reactors are light water reactors (cooled by ordinary water), using designs similar in concept to most of the world's commercial power reactors. Ukraine's operating nuclear plants are located throughout the country, as shown by the following IAEA [map](#):



Source: IAEA, 2020

The operable Ukrainian reactors are fundamentally different from those at the [Chernobyl plant](#), which suffered a major explosion in 1986. The four-unit Chernobyl nuclear plant, whose last operating reactor permanently closed in 2000, was occupied on the first day of the Russian invasion of Ukraine, on February 24, 2022. Russian troops [left the plant by April 1](#) as part of a general withdrawal from northern Ukraine.

Reactor Safety Systems

The core of a light water reactor consists of about 100 tons of highly radioactive nuclear fuel producing tremendous heat through a [nuclear chain reaction](#). To slow or shut down the chain reaction, control rods are inserted into the reactor core. Although shutdown happens very quickly during an emergency, substantial amounts of heat continue to be produced from radioactive decay of the nuclear materials in the reactor core after the chain reaction stops. If water does not continue to circulate through the core, decay heat can build up enough to melt the nuclear fuel and breach the steel pressure vessel that holds the core. The heat and pressure could also eventually escape the concrete containment structure that surrounds the pressure vessel and associated pumps and piping. This occurred during the [Fukushima Daiichi accident](#) in Japan at reactors built with a different type of containment from [those in Ukraine](#).

Any reactors that were to continue operating at ZNPP would be considered to pose the [highest risk of radioactive releases](#) at the site, because of the heat produced by their nuclear chain reactions. The current shutdown of all the plant's reactors has reduced that risk. When a reactor is shut down, the nuclear chain reaction stops and no longer generates heat, immediately reducing the reactor's total heat output by about 94%. The remaining 6% of the heat comes from the [radioactive decay](#) of nuclear materials in the reactor core. As the reactor core cools because of falling radioactivity (with heat output [dropping by 99.5% after one day](#)), there is less decay heat that must be removed by plant cooling systems. The risk of overheating could be further reduced by transferring nuclear fuel from the plant's six reactors into [adjoining storage pools](#), although they also must be constantly cooled, such as by adding water.

Reactor Safety Risks from Russian Attacks

The ongoing Russian military action poses a range of potential threats to Ukrainian nuclear plant safety:

- *Direct military damage to one or more reactors.* Nuclear power plants are not designed to withstand military munitions, which could directly penetrate the concrete reactor containment and steel pressure vessel, allowing release of highly radioactive material.
- *Military damage to reactor safety systems.* Even if a military attack did not damage the reactor containment, explosions and fires could disable safety systems vital to avoiding core overheating.
- *Station blackout: loss of electric power.* Nuclear plants rely on electricity to run cooling pumps and control systems. If [power from the electric grid is lost](#), diesel generators produce backup power and are intended to operate long enough for grid power to be restored. Loss of power from both the grid and the diesel generators results in station blackout, the condition that caused the radioactive releases at Fukushima, even though the reactors there had shut down.
- *Disruption of plant personnel.* Plant safety could be at risk if military action hindered or blocked the hundreds of workers needed to operate, maintain, and manage a nuclear power plant.
- *Damage to spent fuel pool or cooling systems.* If damage to a spent fuel pool allowed its water to drain, or if its cooling systems were disabled, the spent fuel could overheat and release large amounts of radioactive material to the environment.

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