

Nuclear Energy and its Safety

Shamuratova Aysuliw ¹

Xojamuratova Jasmina ²

Annotation: Nuclear energy is one of the most powerful and efficient sources of energy used worldwide. It plays a significant role in meeting global electricity demands while reducing greenhouse gas emissions. This paper explores the fundamental principles of nuclear energy production, including nuclear fission and the operation of nuclear reactors. It also examines the key safety measures employed in modern nuclear power plants, the risks associated with radiation, and the strategies used to prevent accidents. Special attention is given to historical nuclear disasters, such as Chernobyl and Fukushima, and the lessons learned from them. The paper concludes with a discussion on the future of nuclear energy and the importance of balancing energy needs with environmental and human safety.

Key words: Nuclear energy, nuclear power plants, nuclear fission, radiation safety, nuclear reactor, radioactive waste, nuclear accidents, Chernobyl, Fukushima, energy sustainability, environmental impact, nuclear safety measures, clean energy, atomic energy, reactor cooling systems.

^{1,2} Karakalpak state university named after Berdakh, Nukus

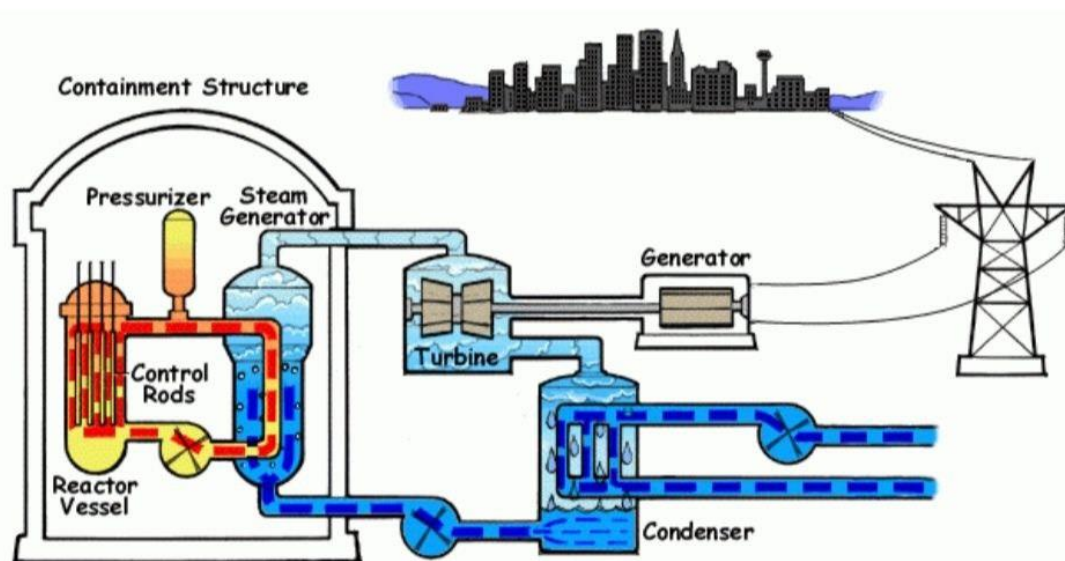
Nuclear energy is the energy obtained by splitting the nucleus of an atom. This type of energy is primarily produced using nuclear reactors and plays an important role in electricity generation in many countries around the world today. The main advantage of nuclear energy lies in its efficiency, as a small amount of fuel can produce a large amount of energy. However, the safety of nuclear energy and its impact on the environment have always been subjects of debate. This article explores the advantages and safety of nuclear energy, as well as its effects on the environment and human health.

Nuclear energy began to develop in the early 20th century following discoveries about the structure of the atom and nuclear reactions. In 1938, German physicists Otto Hahn and Fritz Strassmann discovered the process of nuclear fission, in which the nucleus of a uranium atom splits, releasing a large amount of energy. This discovery laid the foundation for the practical use of nuclear energy. During the 1940s, nuclear technology was first developed for military purposes through the Manhattan Project in the United States, which led to the creation of atomic bombs during World War II. After the war, the focus shifted to the peaceful use of nuclear energy for generating electricity. The world's first nuclear power plant was launched in 1954 in Obninsk, Soviet Union. From that point, nuclear energy began to spread rapidly and became an important source of electricity for many countries.

Nuclear energy is primarily based on the process of nuclear fission. Nuclear fission refers to the splitting of a heavy atomic nucleus into two or more smaller nuclei. This process usually occurs when a heavy nucleus is bombarded with neutrons.

During fission, two fragments of roughly equal mass are produced, and a large amount of energy is released. Additionally, several free neutrons are emitted, which can initiate further fission reactions — resulting in a self-sustaining chain reaction. In nuclear reactors, heavy elements such as uranium-235 or plutonium-239 are commonly used as fuel. The energy released during fission is in the form of heat, which is used to convert water into steam. The steam then drives turbines, which generate electricity.

Nuclear reactors — also known as atomic energy reactors — are devices designed to maintain a controlled, self-sustaining chain reaction. By carefully regulating the arrangement and amount of nuclear fuel, it is possible to sustain the fission process without the need for an external neutron source.



1-picture. Nuclear reactor diagram.

One of the first and most significant advantages of nuclear energy is its high efficiency. Compared to traditional energy sources, the fuel used in nuclear reactors can produce a large amount of energy despite being used in very small quantities. For example, just one kilogram of uranium can generate approximately 24,000 megawatt-hours (MWh) of energy — several times more than the same amount of coal or oil.

In addition, nuclear energy production results in relatively low carbon dioxide (CO₂) emissions, making it a cleaner option with less harm to the environment. For this reason, nuclear energy is increasingly viewed as a sustainable and environmentally friendly energy source in many countries, helping to reduce greenhouse gas emissions during the energy generation process.

Despite these advantages, safety remains a major concern in the development and use of nuclear energy. Accidents in nuclear reactors — such as the Chernobyl disaster in 1986 and the Fukushima Daiichi accident in 2011 — have highlighted the potential risks associated with nuclear technology. These incidents released radioactive materials into the environment, causing serious ecological, health, and social consequences.

In the development of nuclear energy, safety remains one of the most important and pressing issues. Major nuclear accidents in history—particularly the Chernobyl disaster in 1986 and the Fukushima

accident in 2011—have drawn significant global attention to the potential risks of nuclear technologies. As a result, modern nuclear energy systems place a strong emphasis on safety assurance.

Contemporary nuclear reactors are designed to meet high-level safety requirements and are equipped with multi-layered defense systems. These systems are intended to mitigate the risk of accidents even in the event of a failure in one or more components. Continuous cooling systems are in place to regulate the reactor's internal temperature, while emergency core cooling systems and automatic shutdown mechanisms are activated to prevent overheating.

In addition, containment structures made of reinforced, high-resistance materials are constructed to prevent the release of radioactive substances into the environment. In the event of a power outage, backup power sources are available to maintain the functionality of all critical safety systems.

International organizations also play a crucial role in ensuring nuclear safety. The International Atomic Energy Agency (IAEA) develops and enforces international safety standards, provides technical assistance, and conducts inspections and monitoring at nuclear facilities worldwide.

Moreover, scientific research and technological innovations contribute significantly to improving safety levels in nuclear energy. Fourth-generation nuclear reactors (Gen IV) and fast breeder reactors are being developed to provide enhanced safety, improved efficiency, and reduced environmental impact.



2-picture. Safety measures at nuclear plants.

Various factors will influence the development of nuclear energy in the future. Key directions include making nuclear technologies safer and more efficient, implementing new types of nuclear reactions (such as nuclear fusion), and discovering advanced methods for reprocessing and disposing of nuclear waste. Nuclear energy has the potential to play a significant role in the global energy supply in the future, as it is an environmentally clean and highly efficient source of power.

Conclusion. Nuclear energy holds significant importance as an alternative energy source with high efficiency for present and future generations. This energy source contributes to reducing greenhouse gas emissions and plays a crucial role in ensuring environmental sustainability. Furthermore, due to its high energy density, a small amount of nuclear fuel can produce a large amount of electricity. However, safety remains a top priority in the use of nuclear energy. Historical accidents have clearly demonstrated the necessity of strengthening safety measures in this field. As a result, modern nuclear reactors are equipped

with complex safety systems and automated mechanisms that respond effectively to emergency situations. Through international cooperation, scientific research, and the implementation of advanced technologies, the safe and efficient use of nuclear energy continues to expand. Thus, nuclear power is expected to become one of the key factors in ensuring global energy security and maintaining ecological balance in the future.

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