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**"INTELLIGENT HUB": BRIDGING HISTORY
AND THE HI-TECH FUTURE**

Embassy of Youth

THESIS TITLE:

**NUCLEAR POWER PLANT – A THREAT TO MY FUTURE
OR A CLEAN AND RELIABLE SOURCE OF ENERGY**

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INTRODUCTION

Is nuclear power a threat or a salvation? In addition to the immense energy demands of artificial intelligence, we face a climate crisis, geopolitical instability, and the inherent limitations of renewable energy sources. The objective of this thesis is to analyze nuclear energy in synergy with pink hydrogen and the GraviMobil gravity battery as a strategic tool for the technological sovereignty of Slovakia. By linking security with innovative energy storage, the structure of this work addresses the question of whether we can transform historical concerns into a clean, predictable, and secure pillar of our future—one capable of withstanding both external threats and energy fluctuations.

1 THESIS OBJECTIVES

1.1 ANALYSIS OF NUCLEAR ENERGY AND ITS UTILIZATION IN A HYBRID SYSTEM

The primary objective of this thesis is to present and technically analyze the concept of a nuclear power plant not as an isolated, static energy source, but as the dynamic heart of a hybrid energy ecosystem. This system integrates the stability of the nuclear fission reaction with innovative storage in the GraviMobil system and the production of pink hydrogen, thereby creating a comprehensive response to the critical challenges facing modern Slovakia.

1.2 NUCLEAR POWER PLANT AS THE KEY TO A SECURE AND PROSPEROUS EUROPE

The primary aspects explaining nuclear energy production, its safety, radioactive waste management, and levels of security and protection. A comparison with energy production from various other sources.

1.3 PRODUCTION OF AN INTERACTIVE MODEL

The intent of this thesis is to present a comprehensive body of arguments confirming that the integration of Nuclear Energy, GraviMobil, and Hydrogen is not merely a technological vision, but a physical and economic necessity. The outcome of the work will be a model that transforms concerns regarding nuclear energy into an understanding of its irreplaceable role in building a clean, reliable, and intelligent energy future for our generation.

1.4 EDUCATIONAL PRESENTATION, WEBSITE, AND DIDACTIC QUIZ

Presenting the research results to first-year secondary school students, including a fun assessment of their acquired knowledge through a quiz titled "Nuclear Energy – Threat or Future?". Creating a dedicated website at www.nuclearenergy.sk.

2 HISTORICAL CONTEXT AND THE PSYCHOLOGY OF FEAR

The term "nuclear energy" immediately evokes images of apocalypse, abandoned cities, and invisible death in many people. This fear is not accidental; it is a product of historical events, the Cold War, and the way our brain evaluates risks. In this chapter, we analyze three key pillars of this fear and contrast them with statistical data.

2.1 CHERNOBYL (1986) - SYSTEM FAILURE AND THE ABSENCE OF BARRIERS

The Chernobyl accident is the "nightmare" of nuclear power. It was a combination of fatal design flaws in the Soviet RBMK reactor and gross violations of safety regulations by the personnel. The key failure factors are: positive void coefficient – upon the loss of coolant, the reactor power increased uncontrollably (modern reactors have a negative coefficient – the reaction stops if water is lost); absence of containment – the reactor lacked a protective concrete envelope. Consequently, the explosion ejected radioactive material directly into the atmosphere; human factor – a safety-oriented experiment paradoxically led to disaster due to the suppression of information and pressure for performance.

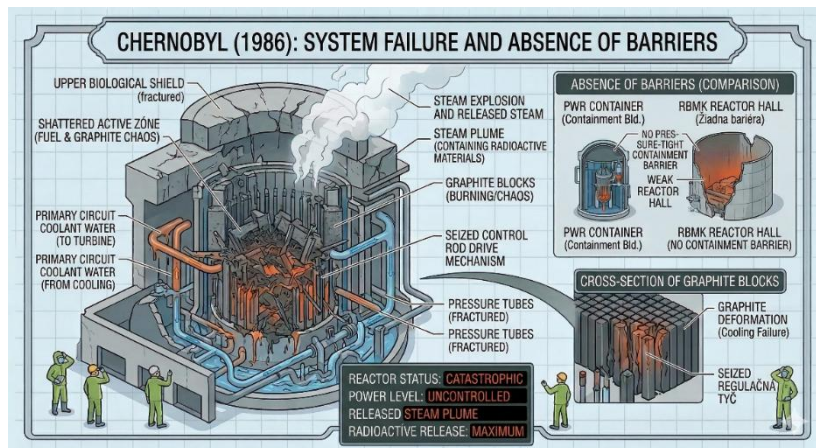


Fig.1: The Chernobyl Accident

2.2 FUKUSHIMA (2011) – LESSONS LEARNED FROM A NATURAL DISASTER

The accident at the Japanese Fukushima plant demonstrated that even a technically advanced country can fail when underestimating extreme natural impacts. The earthquake itself did not cause the accident (the reactors shut down safely). The disaster was caused by a tsunami wave that flooded the diesel generators located at a low altitude. Without electricity, it was impossible to cool the residual heat in the reactors, which led to overpressure and hydrogen explosions. According to a UN report (UNSCEAR), no one in Fukushima died as a result of direct radiation exposure. The majority of the casualties were linked to the physical stress of the evacuation and the tsunami wave itself.

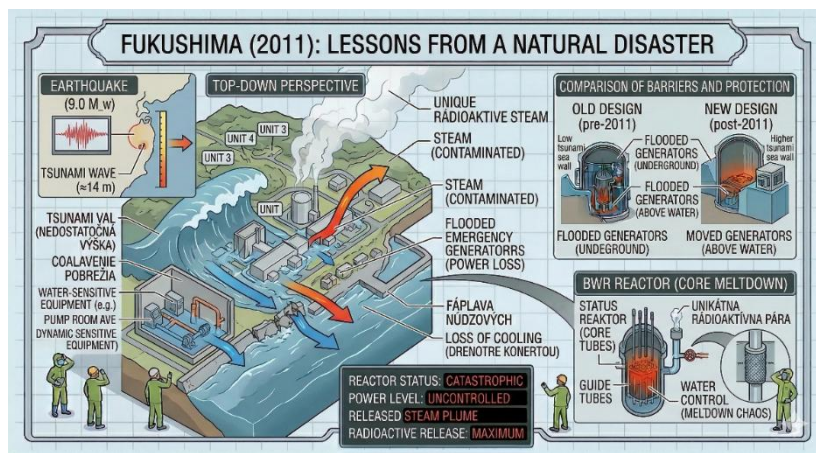


Fig.2: Fukushima – Disaster as a Result of the Tsunami

2.3 TEMELÍN AND BOHUNICE – FEAR VERSUS LOCAL REALITY

Temelín serves as an example of a psychological and political threat in our thesis. During its commissioning in 2000, it triggered massive protests in Austria. Opponents referred to it as the "atom of death." However, after 25 years of safe operation, it has become evident that this was a political narrative. Temelín (VVER-1000) combines robust Russian construction with state-of-the-art Western control systems (Westinghouse). We also note Jaslovské Bohunice A-1 (1977). This was the only serious accident in Czechoslovakia (Level 4 on the INES scale).

The cause was an error during fuel loading. This event led to the decommissioning of the A-1 type and a transition to safer pressurized water reactors (VVER), which remain in use today.

2.4 THE PSYCHOLOGY OF RISK – WHY WE FEAR MORE THAN IS RATIONAL?

Psychologist Paul Slovic defined the phenomenon of "Dread Risk." The human brain evaluates risks based on two primary criteria. First – uncontrollability: we perceive a lack of control over nuclear power, unlike driving a car, where we feel safe despite it being thousands of times more dangerous. Second – catastrophic potential: we fear events that can cause high mortality in a single instance and location, even if their probability is near zero. Conversely, we tend to ignore risks that cause casualties individually and continuously, such as pollution from coal-fired power plants.

Visually, a nuclear power plant can seem intimidating to laypeople due to its cooling towers, which stand dozens of meters tall. This is a unique image of a power plant, unseen in other types and visible from a great distance. It is precisely this sight that can sometimes feel dangerous and daunting. However, these cooling towers contain nothing more than water vapor.

2.5 STATISTICAL REALITY – THE SAFEST ENERGY SOURCE IN THE WORLD?

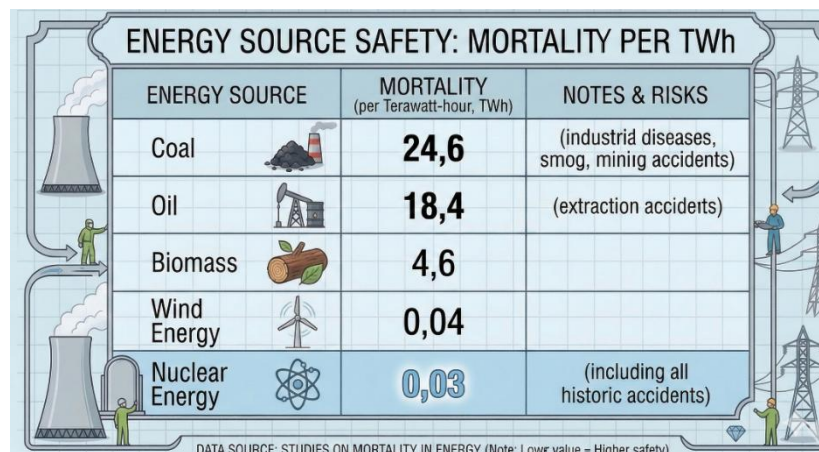


Fig.3: Mortality Rate per Terawatt-hour (TWh) of Energy Produced

If global electricity production were to be replaced entirely by nuclear power, hundreds of thousands of lives that currently end prematurely due to fossil fuel emissions would be saved annually. Consequently, nuclear energy is not a threat, but a statistical savior.

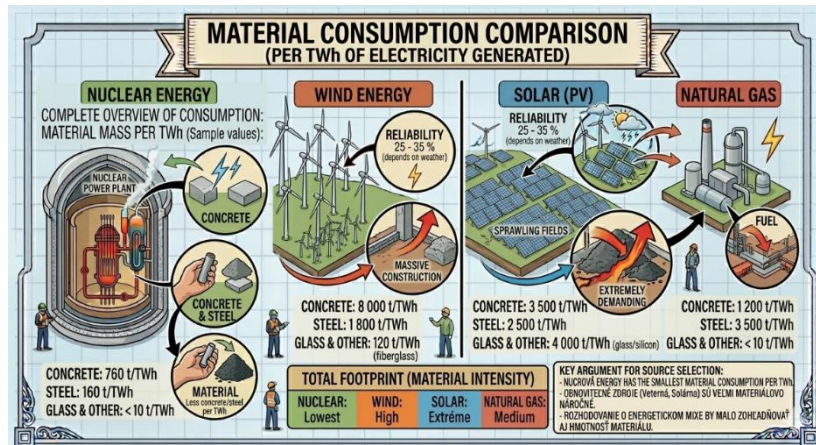


Fig. 4: Comparison of Energy Sources

The reason behind the material efficiency of nuclear power lies in its extreme energy density. Nuclear fuel concentrates millions of times more energy per unit of mass than fossil fuels and thousands of times more than systems capturing energy from the environment (wind, solar). While solar panels or wind turbines operate with "diffuse" energy and require vast surface areas and numerous harvesting units to achieve high output, a nuclear reactor concentrates immense power within a small spatial footprint.

3 TECHNICAL SAFETY: FROM ACTIVE TO PASSIVE PROTECTION

To truly understand why a nuclear power plant is a clean energy source, we must step across the threshold of the reactor hall and examine the technologies hidden from the naked eye. The interior of the plant is divided into the hermetic reactor zone and the turbine hall, where electricity is generated. Understanding the processes occurring inside a nuclear power plant is the key to deconstructing fear. A modern nuclear power plant of the VVER type, such as those in Slovakia, is not a "black box" but a precisely managed environment where energy is extracted from the smallest particles of matter under strictly controlled conditions.

3.1 PRINCIPLE OF OPERATION

How does nuclear power generate electricity? A nuclear power plant is essentially a thermal power plant where a nuclear reactor has replaced the fossil-fueled boiler. The foundation of the entire complex is the Reactor Pressure Vessel (RPV). It is a massive steel cylinder approximately 12 meters high with wall thicknesses of up to 20 cm. Inside is the reactor core, where several hundred fuel assemblies are arranged in a precisely defined geometry. Each assembly contains hundreds of fuel rods filled with uranium pellets.

A glimpse into the interior of an open reactor (during refueling) reveals a fascinating blue light—Cherenkov radiation. This light occurs when charged particles pass through water at a speed greater than the phase velocity of light in that medium. It serves as visual evidence of the immense energy held under our control. The entire energy transformation process takes place across three separate circuits, which in itself is the first safety feature preventing the release of radioactivity into the environment.

The Slovak energy sector relies on Pressurized Water Reactor (PWR) technology, specifically VVER-440 and VVER-1000 units. A controlled chain fission reaction takes place inside the reactor. The core consists of uranium dioxide fuel pellets stacked within zirconium alloy rods, which form the fuel assemblies. Our reactors use ordinary water as both a moderator (a substance that slows down neutrons) and a coolant. This is a critical safety feature—if water is lost or begins to evaporate excessively, the reaction naturally slows down or stops.

To ensure the plant is clean and safe, the electricity generation process is divided into three strictly separated circuits. This isolation guarantees that substances in contact with the nuclear

fuel never reach the turbine and certainly never leave the plant building. Steam generators are located in close proximity to the reactor. If we were to look inside them, we would see thousands of thin U-tubes. Radioactive water from the primary circuit flows inside these tubes, while clean water from the secondary circuit flows around them. This arrangement allows for heat transfer without mixing the radioactive water with the clean water. It is here that steam—the "fuel" for the turbine—is generated.

1. Primary Circuit (Nuclear Island). The heart of the power plant is the reactor, where the controlled fission of uranium ${}^{235}_{92}\text{U}$ nuclei takes place. This process releases an immense amount of heat. This heat is absorbed by cooling water (coolant) that flows around the fuel assemblies. To prevent the water from boiling - despite reaching temperatures of approximately 300 °C - it is maintained under high pressure (roughly 15.5 MPa). This hot water then flows into the heat exchanger, the steam generator. This circuit is radioactive and is housed within a hermetically sealed protective envelope known as the containment.

2. Secondary Circuit (Non-nuclear Part). In the steam generator, water from the primary circuit transfers its heat to the water in the secondary circuit. Because the pressure is lower here, the water begins to boil and transforms into steam. This clean steam—which never comes into contact with the radioactive fuel—drives the turbine blades. The turbine is coupled to an electric generator that converts kinetic energy into electrical power.

3. Tertiary Circuit (Cooling Section). The steam, having transferred its energy to the turbine, must be condensed back into liquid form in the condenser to be returned to the steam generator. This cooling process is performed by the third circuit, whose most visible symbol is the cooling towers. The evaporating water from these towers is pure water vapor—this is the white "plume" seen above the power plant, which contains no harmful substances.

4. Turbine Hall (A Symphony of Steel and Rotation). Upon exiting the hermetic zone, the steam enters the turbine hall. The turbines are the dominant feature of this space. The sight is awe-inspiring—massive rotors with blades spinning at 3,000 revolutions per minute (RPM). An electric generator is coupled to the same shaft as the turbine. Within the generator, a rotating magnetic field induces an electric current in the copper stator windings. It is pure physics on a grand scale—without smoke, combustion, or dust. Compared to a coal-fired power plant, the turbine hall of a nuclear facility is an almost sterile environment.

5. Main Control Room (The Brain of the Power Plant). If the reactor is the heart, the main control room is the brain. It is the place where operators monitor thousands of parameters 24 hours a day. Modern control rooms utilize advanced digital systems and artificial intelligence for predictive diagnostics. Every valve, every pump, and every control rod has its corresponding feedback on the displays. The systems are designed so that as soon as a parameter deviates from the norm, the automation implements corrective actions faster than a human can react.

6. Operational Cleanliness (Life within the Facility Grounds). This internal perspective is further supported by the fact that power plant employees work in an environment where hygiene and safety standards are more stringent than those in hospital operating rooms. Every movement is monitored by dosimeters. Within the grounds of a nuclear power plant, healthy fauna and flora are commonly found (protected birds often nest within the premises of Slovak plants), which serves as the best evidence that the operation has no negative impact on the immediate surroundings.

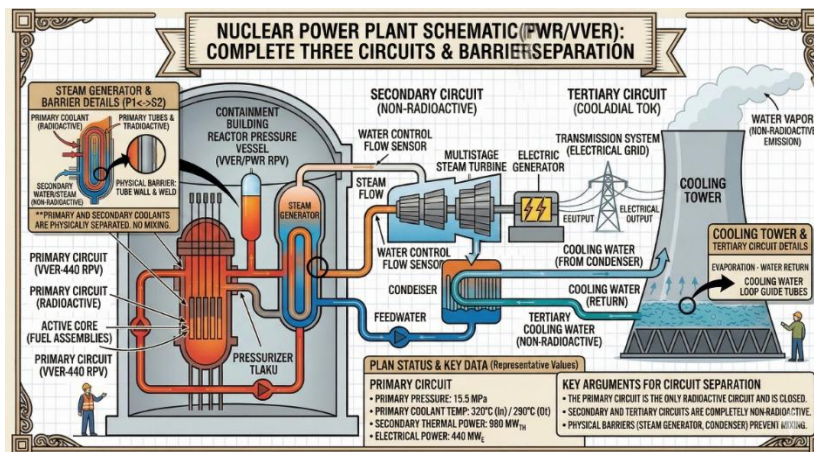


Fig. 5: Diagram of a Nuclear Power Plant

3.2 THE CONCEPT OF DEFENCE IN DEPTH: FOUR IMPENETRABLE BARRIERS

The fundamental principle of safety is to ensure that radioactive substances never enter the environment. The Defense-in-Depth system operates as a series of barriers that any potential fault must overcome. First, we examine the fuel matrix.

The fuel itself consists of ceramic pellets (uranium dioxide), which are extremely resistant to heat and chemical degradation. Most radioactive substances remain trapped directly within this ceramic structure.

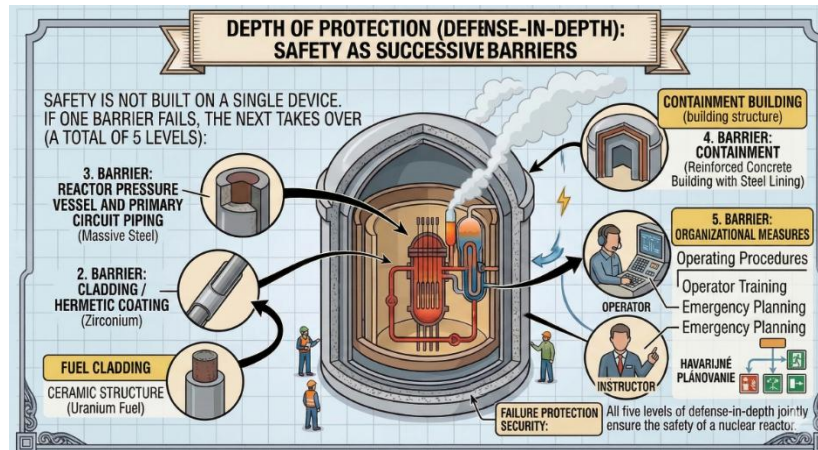


Fig. 6: Defense-in-Depth System (DiD)

3.3 EMPLOYEE CARE – THE HUMAN FACTOR AS A SAFETY GUARANTOR

A nuclear power plant represents one of the most specialized working environments in the world. Employee care in this sector transcends standard legal obligations, evolving into a sophisticated system of monitoring, training, and prevention. The objective is to mitigate the "human factor" as a risk and instead transform it into the strongest link in the safety chain. Every employee operating within the "controlled area" (the zone housing the reactor and the primary circuit) is subject to continuous oversight. Each worker wears a personal dosimeter that monitors the absorbed radiation dose in real-time. This data is evaluated daily, with strict adherence to ensuring that no individual exceeds even a small fraction of the permissible regulatory limits. Furthermore, employees undergo regular screenings using specialized equipment capable of detecting microscopic quantities of radioactive substances within the body. The health status of nuclear personnel is monitored more rigorously than that of commercial airline pilots through comprehensive and frequent medical examinations.

3.3.1 Training on Full-scope Simulators

The training of reactor operators is a fascinating process. Nuclear power plant sites (such as our Bohunice facility) include an identical replica of the main control room. Here, operators train on a simulator that behaves exactly like a real reactor. Instructors simulate thousands of malfunctions—ranging from trivial incidents to the most improbable scenarios. Every operator must undergo regular psychological evaluations and retraining. Their work is built on a foundation of discipline, where every command is repeated aloud and confirmed (the so-called "three-way communication").

3.3.2 Reconditioning stays and mental hygiene

Working in the nuclear sector carries a high degree of responsibility, which can lead to psychological stress. Consequently, employers invest in specialized, above-standard wellness and support programs. By law, employees are entitled to regular reconditioning stays at spas or mountain resorts to facilitate physical and mental recovery. In the modern nuclear industry, a specific culture is fostered where employees are not afraid to admit to an error. If a mistake is made and reported, the individual is not penalized; instead, the error is subjected to rigorous analysis to prevent its recurrence. This "No-Blame Culture" is the key to achieving absolute safety.

A Notable Fact for First-Year Students: Hygiene protocols within a nuclear power plant are so rigorous that employees operating in the controlled area must shower and change into specialized white protective clothing multiple times per day. It represents perhaps the cleanest working environment imaginable.

3.4 PASSIVE SYSTEMS: WHEN SAFETY IS GOVERNED BY GRAVITY

The greatest innovation making nuclear energy a "clean and safe source" is the implementation of systems that operate without electricity or human intervention. Massive tanks filled with water under nitrogen pressure are positioned above the reactor level; should a pressure drop occur within the reactor, such as during a pipe rupture, the nitrogen pressure automatically forces thousands of liters of water into the core. This process requires no pumps,

as it relies entirely on the physical pressure differential. Furthermore, core heat can be dissipated even if all pumps cease to function. Based on the principle that warm water rises and cold water descends, a self-sustaining flow is established. Modern heat exchangers are strategically positioned so that this natural circulation is sufficient to safely cool the reactor for an indefinite period. Systems located on the containment roof utilize natural air currents or water evaporation to cool the plant's interior if the building begins to overheat, operating on the principle of the "chimney effect." A unique physical characteristic of the pressurized water reactors (VVER) used in Slovakia is their inherent internal stability. If the water in the reactor begins to overheat, an increased number of steam bubbles form within it. Since water serves as a moderator to slow down neutrons, its displacement by steam automatically slows or completely halts the nuclear reaction. Consequently, the reactor essentially shuts itself down simply by heating up. This represents a fundamental difference compared to the Chernobyl-type reactor, which increased its power output when overheated.

3.5 CORE CATCHER (CORE MELT LOCALIZATION DEVICE)

For extreme and highly improbable scenarios involving a core melt, state-of-the-art power plants are equipped with a so-called core catcher. This is a massive vessel located beneath the reactor filled with "sacrificial material," typically a mixture of iron and aluminum oxides. Should the fuel melt through the reactor pressure vessel, the catcher captures, dilutes, and safely cools the molten material, thereby preventing its contact with the concrete foundation and groundwater.

3.6 CYBERSECURITY AND DIGITALIZATION (INTEGRATION OF AI)

In the context of 2026, it is essential to address protection against cyber threats. Modern instrumentation and control systems are physically isolated from the external internet, a security measure known as "air-gapping." Furthermore, the utilization of Artificial Intelligence (AI) in diagnostics enables the prediction of material wear and degradation before a failure occurs. This predictive capability enhances power plant reliability to a level that was previously unattainable in the past.

4 NUCLEAR WASTE – A PROBLEM OR AN UNRESOLVED CHALLENGE?

The issue of nuclear waste is often perceived as an insurmountable obstacle to a clean future. However, an objective view reveals that nuclear power is the only industrial sector that takes full responsibility for its residues, precisely monitoring them and financing their disposal. In this chapter, we analyze the journey from spent fuel to its recycling and final secure storage deep within the earth. The greatest myth is the imagery of "mountains of waste." Due to the extreme energy density of uranium, the volume of waste is negligible compared to other sources. A single uranium fuel pellet (the size of a fingertip) produces as much energy as three tons of coal. By comparison, if a person were to obtain all their electricity throughout their entire lifetime solely from nuclear power, the resulting high-level waste would fit into a single soda can. What we call "spent fuel" today still contains approximately 95% of unused energy. From the perspective of a circular economy, this represents a valuable resource for future generations.

4.1 RECYCLING AND MOX FUEL, TRANSMUTATION, AND FOURTH-GENERATION REACTORS

Currently, countries such as France and Russia utilize the process of reprocessing. Residual uranium and plutonium are extracted from spent fuel to produce new MOX (Mixed Oxide) fuel. Through this method, significantly more energy can be obtained from the same amount of mined uranium while simultaneously reducing the volume of final waste.

The future, specifically the 2030–2040 horizon, belongs to fast reactors capable of "burning" today's nuclear waste as their primary fuel. Through the process of transmutation, elements with long half-lives are converted into elements with short half-lives, reducing the time required for the safe isolation of waste from tens of thousands of years to mere hundreds.

The final destination for waste that can no longer be recycled is a deep geological repository. This consists of a system of barriers within stable rock formations at a depth of 500 meters underground. A case study indicates that the Onkalo facility in Finland is built in stable granite that has remained unmoved for millions of years.

The fuel is enclosed in copper canisters with a cast-iron core, surrounded by bentonite clay (which is impermeable to water), and ultimately isolated by hundreds of meters of rock. The repository is designed to safely isolate radioactivity for 100,000 years, a period longer than recorded human history.

4.2 THE SITUATION IN SLOVAKIA AND THE ECONOMIC AND ETHICAL DIMENSIONS

Slovakia possesses a sophisticated radioactive waste management system administered by the state-owned company JAVYS. An interim storage facility is located in Jaslovské Bohunice. After being removed from the reactor, spent fuel is first cooled in pools and subsequently stored in specialized containers within the interim storage facility, where it can safely await recycling or disposal for decades. Every megawatt-hour generated by nuclear power includes a financial contribution toward waste disposal. Unlike coal-fired power plants, which do not pay for the environmental damages caused by their emissions, the nuclear sector pays for its "cleanup crew" in advance. In this section, we argue that leaving behind a small volume of monitored and secured waste is more ethical than releasing millions of tons of greenhouse gases into the atmosphere, which uncontrollably alter the planet's climate. Nuclear waste is under control; climate change is not.

5 HYBRID ENERGY SYSTEM: NUCLEAR, HYDROGEN, GRAVIMOBIL, AND WATER

In the modern energy landscape, we face a fundamental challenge: how to reconcile the stable generation from nuclear power plants with variable societal demand and the intermittent output from renewable energy sources. Nuclear power plants operate most efficiently and safely in a constant power output mode, known as baseload operation. However, during the night when industrial activity subsides, the grid experiences an energy surplus, whereas critical demand peaks occur during the day. The solution is not to regulate the reactor's output, but rather to establish an intelligent hybrid hub that can store excess energy and release it back into the grid at the required time.

5.1 THE NUCLEAR POWER PLANT AS THE SYSTEM'S STABLE HEART

The nuclear unit acts as the primary stabilizer within this system. Unlike gas-fired power plants, which are characterized by high operational costs, nuclear energy provides a cost-effective and continuous power supply. Our objective is for the facility to operate at 100% capacity 24 hours a day. The surplus energy not required by the grid during nighttime hours is redirected into three specific vectors: water management, gravitational energy storage, and hydrogen production.

5.2 THE PRODUCTION OF PINK HYDROGEN: AS CLEAN AS GREEN, AS A FUEL FOR A CLEAN FUTURE

While the production of hydrogen via nuclear energy is categorized as "Pink Hydrogen," it is fundamentally as carbon-free as "Green Hydrogen" derived from wind or solar power. However, nuclear energy offers a significant thermodynamic advantage: the simultaneous production of high-grade heat and electricity. By employing High-Temperature Steam Electrolysis (HTSE) at temperatures of 700–800°C, the electrical energy required to split water molecules is substantially reduced, as thermal energy performs a significant portion of the dissociation work. This process increases hydrogen production efficiency by more than 20% compared to conventional low-temperature methods. Hydrogen generated during the night is stored in high-pressure vessels and serves as a clean fuel for regional hydrogen-powered buses

and heavy industry during the day. In this manner, the nuclear power plant indirectly decarbonizes urban transport and improves air quality in our cities.

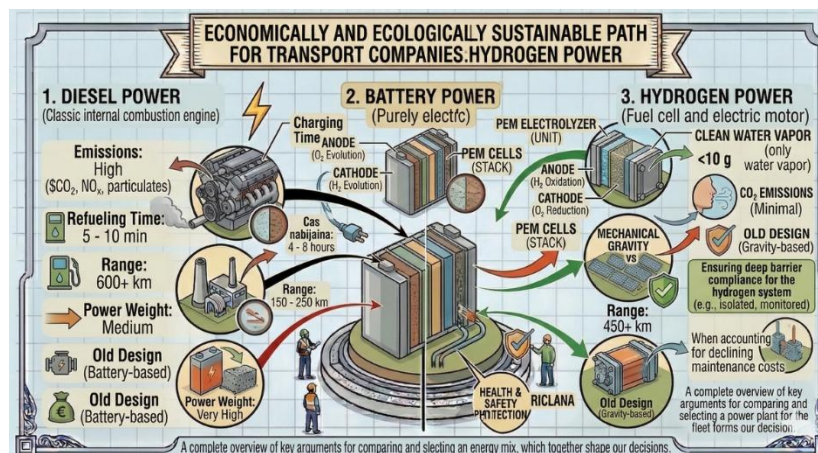


Fig. 7: Hydrogen technology provides operational flexibility comparable to diesel, yet achieves zero local emissions.

While passenger vehicles are gravitating toward battery-electric propulsion, hydrogen represents the most efficient pathway to zero emissions for public transit and heavy-duty freight transport. Within our hybrid system, hydrogen is not merely a byproduct; it is a critical energy carrier that transmits clean energy from the nuclear core directly onto the city streets.

5.3 GRAVIMOBIL - A GRAVITY BATTERY SUPPORTING THE GRID AND PUMPED STORAGE HYDROPOWER

GraviMobil represents an innovative method of mechanical energy storage that requires no rare earth metals (such as lithium or cobalt) and boasts a virtually unlimited operational lifespan. The system operates on the fundamental principle of potential energy. During periods of surplus nuclear power, an electric motor lifts massive weights—constructed from concrete or metal blocks—to a designated height. At peak demand, these weights are released; gravity pulls them downward, and the motor switches to generator mode to produce electricity. In this hybrid framework, Pumped Storage Hydropower (PSH) works in perfect symbiosis with both the nuclear unit and GraviMobil. During the nighttime cycle, nuclear energy drives the pumps to move water from a lower reservoir to an upper one. During the day, the water flows back

through turbines, compensating for sudden increases in grid demand within seconds. While PSH manages large energy volumes for long-term stability, GraviMobil addresses rapid grid fluctuations and frequency stability. Together, they form an impenetrable defense against blackouts.

5.4 TECHNOLOGICAL SYNERGY - THE "SMART HUB" MODEL

The cornerstone of this system is total interconnectivity. When regional Variable Renewable Energy (VRE) generation—such as wind and solar—peaks, the nuclear unit is no longer forced to undergo inefficient and costly power ramping. Instead, the cumulative surplus from both renewables and the nuclear baseload is dynamically arbitrated across the hybrid matrix. One portion is channeled into high-capacity electrolyzers for hydrogen synthesis; a second segment powers the GraviMobil motors to lift its massive weights; and the third drives the pumps of the Pumped Storage Hydropower (PSH) facility to move water to the upper reservoir. This integrated configuration transforms the nuclear power plant into a highly flexible asset, capable of adapting to modern market volatility while remaining fundamentally clean and reliable.

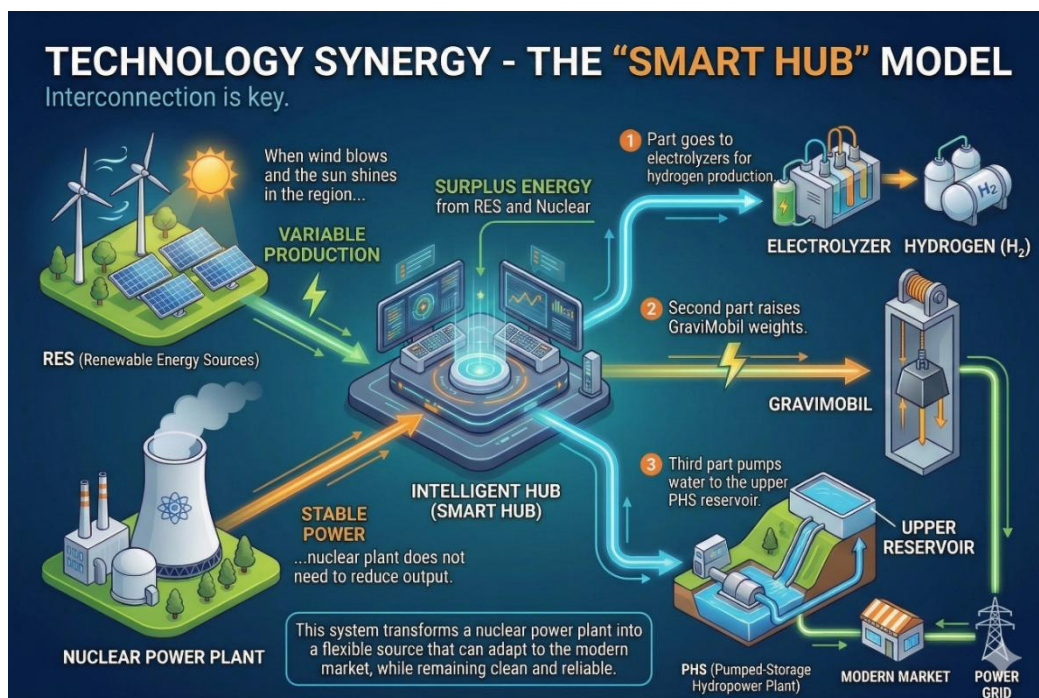


Fig. 8: The "Smart Hub": A Bridge Between Legacy and a High-Tech Future

6 ECONOMIC ANALYSIS OF STORAGE SYSTEMS: LCOS COMPARISON

The economic efficiency of a nuclear hybrid node is directly dependent on the ability to store surplus energy generated during periods of low demand at a low cost. LCOS — Levelized Cost of Storage. Lithium-ion (Li-ion) battery systems dominate the current market due to their high modularity and excellent response dynamics; however, they face fundamental barriers from a long-term economic perspective. Their primary deficit is electrochemical degradation, which limits the system's lifespan to approximately ten to twelve years under standard cycling conditions. From an economic standpoint, this means that for a fifty-year horizon—the typical operating life of a nuclear unit—an investor must calculate for at least a fourfold complete replacement of the battery arrays. The cost of storing 1 MWh in lithium batteries currently ranges from 150 to 250 euros, a figure that must also include the rising costs of recycling and the environmental burden associated with the extraction of rare metals.

In direct contrast to batteries stands the GraviMobil system, which utilizes the principle of the potential energy of weights. GraviMobil contains no chemical components subject to degradation. The LCOS for gravity systems is estimated at 60 to 100 euros per MWh. A fundamental economic argument is the near-zero loss of capacity over time, as a weight with a mass of 500 tons stores the same amount of energy on its first day of operation as it does after half a century of functioning.

Pumped-storage hydropower plants (PSHP) remain the global leader in terms of cost per 1 MWh, with values below 50 euros. Their economic strength stems from their massive scale and the ability to store energy for ten hours or more. However, the disadvantages include extremely high initial capital expenditures for the construction of upper and lower reservoirs and geographical limitations. In this sense, GraviMobil fills the economic gap between expensive short-term batteries and inexpensive but inflexible hydroelectric works. A synthetic view of the hybrid node's economics shows that while lithium batteries suffer from high amortization costs, GraviMobil and PSHP benefit from mechanical durability.

7 PRACTICAL REALIZATION - AN EDUCATIONAL MODEL AND DEMONSTRATION OF TECHNOLOGICAL SYNERGY

The theoretical analysis of nuclear energy safety and environmental cleanliness provided in the preceding chapters established a scientific foundation for understanding these complex issues. To verify the practical applicability of these findings and contribute to debunking prevailing societal myths, we developed a physical demonstrator of the hybrid energy system and conducted a targeted educational activity for the first-year students at our school. This transition from theory to practice serves to validate the proposed "Smart Hub" concept through a tangible model, effectively bridging the gap between advanced engineering principles and public perception.

7.1 THE PHILOSOPHY OF THE MODEL: FROM "THREAT" TO UNDERSTANDING

The primary objective of the model was to visually demonstrate that a nuclear power plant does not represent a static hazard, but rather a dynamic and secure hub of modern energy. The model was designed to showcase stable nuclear generation (CO₂-free), the utilization of nighttime energy surpluses via GraviMobil and hydrogen production, clean transportation, and grid stability during peak daytime hours.

7.2 TECHNICAL DESCRIPTION OF THE CREATED MODEL

For presentation purposes, we have constructed an interactive model. The realization process began with the production of key components using PLA (Polylactic Acid) technology on a 3D printer. The printed segments included models of the reactor, steam generator, turbine, cooling towers, pumping station, a reference hydrogen tank, and the corresponding piping networks. Digital STL files were sourced from available technical repositories. Following the fabrication of the components, the power plant footprint was laid out on a baseboard. Areas designated for static vegetation were color-treated and subsequently fitted with static grass using an electrostatic charge applicator.

All printed components underwent mechanical sanding to achieve a smooth surface finish. The surface treatment of the reactor and steam generator was executed using a color gradient that visually interprets the thermal stress on the material and, in the case of the reactor, simulates the Cherenkov radiation phenomenon. The secondary circuit and turbine were color-coded to clearly demonstrate the functional division of the system. The color scheme of the piping networks strictly differentiates the primary, radioactive circuit from the secondary, non-radioactive circuit.

Within the primary circuit, the flow direction of the coolant is further visualized: red indicates the hot water being diverted from the reactor core, while purple represents the cooled coolant returning to it. This representation emphasizes the hermetic separation of both circuits, guaranteeing the absence of radioactivity in the secondary section.

Pipes lead from the turbine to the cooling towers, which in the model demonstrate the process of removing residual heat from the secondary circuit into the atmosphere in the form of clean water vapor. For the construction of the piping to the cooling towers, which was not part of the original print data, a custom engineering design was applied using thread-tracing and pin fixation to precisely determine the length and curvature of the segments.

The informational value of the model is enhanced by the integration of displays for visualizing data on individual parts of the power plant. Custom frames and pedestals with cavities for hidden cabling routed beneath the polystyrene base were developed and printed for these display units. The model's infrastructure also includes an access road with a parking lot and a charging station for heavy transport, equipped with functional LED indicators. Decorative lighting for the model is implemented via a system of low-power LEDs with ballast resistors and heat-shrink tubing insulation. The reference hydrogen tanks were made from transparent material with an internal cavity for backlighting, achieving a content-visualization effect.

The structural foundation of the model consists of an aluminum profile with PVC walls, the elevated construction of which allows for the secure storage of control electronics and cabling in the interstitial space. It includes an integrated speaker with a 3D-printed cover and PLA dividers that ensure the structural integrity of the polystyrene boards and wire organization. Aesthetic and technical details are complemented by models of trees, shrubs, and electrical pylons with copper windings simulating high-voltage lines.

The entire system is controlled by an interactive interface based on an Arduino microcontroller. The model features the GraviMobil logo, symbolizing the device that balances energy fluctuations in the consumer grid. This comprehensive educational model serves as a tool to debunk myths about nuclear energy and presents it as a safe, clean, and sustainable source for modern society.

7.3 PRESENTATION WORKFLOW AND INSTRUCTIONAL METHODOLOGY

The presentation for first-year students was designed as an interactive workshop. At the outset, most students associated nuclear energy with terms like "waste" or "explosion." These freshmen, who are currently forming their attitudes toward ecology and technology, represented an ideal target group for testing the clarity of our concept.

After the presentation, we conducted a guided discussion with the students. To verify feedback and reinforce the acquired knowledge, we presented a didactic quiz that playfully tested their ability to distinguish between myths and scientific facts. The majority of students struggled with Question No. 5, which addressed the thermodynamics of hydrogen production; this confirmed the need for a deeper explanation of the synergy between heat and electrolysis in our work.

The results of this practical experience confirmed our hypothesis: fear of nuclear energy is directly proportional to the lack of information regarding its operation. Following the model demonstration and the explanation of its synergy with hydrogen and gravity, the students expressed appreciation for the stability of the energy source. The most positively perceived fact was that nuclear power can "clean up" transportation emissions through hydrogen production.

This practical segment proved that nuclear energy, combined with modern technologies (GraviMobil, PSH, and Hydrogen), is not only acceptable to the younger generation but is viewed as technologically fascinating. The model served as proof that if we resolve the issue of grid flexibility, nuclear energy becomes an unquestionable pillar of a secure and clean future.

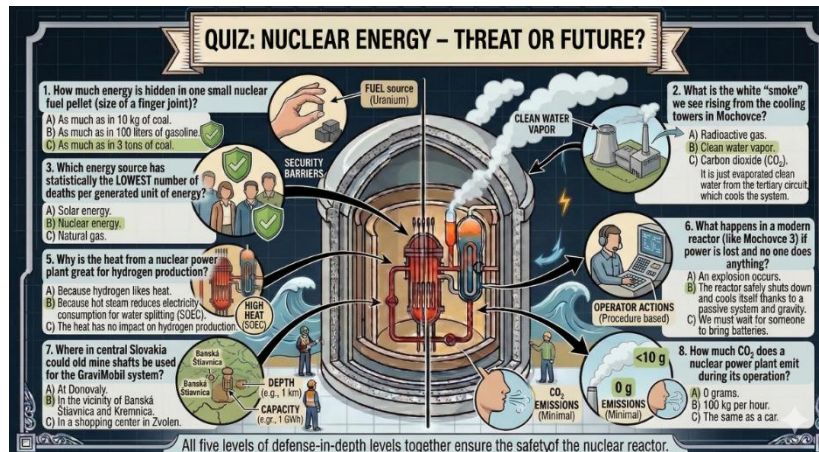


Fig. 9: Didactic quiz: A gamified assessment of student knowledge

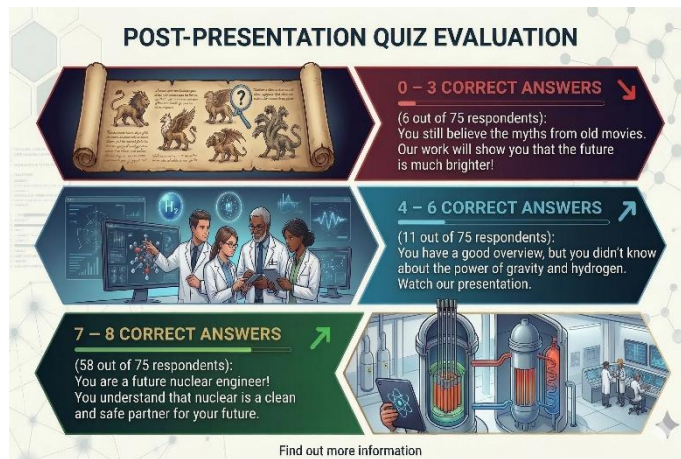


Fig. 10: Post-Presentation Quiz Evaluation

The presentation left a great impression on the audience and clearly demonstrated the progress the participants made thanks to the information provided. For the dissemination of our results, we purchased a domain and hosting and created the website www.nuclearenergy.sk. This resource will serve to inform the general public that nuclear energy is a clean, reliable, and environmentally sustainable source of power.



Fig. 11: QR code for the website

8 FINANCIAL EVALUATION

We present the project budget. Sources of funding: Parents' Council at the Secondary Vocational School of Transport in Zvolen, and Newcom 1, Stráž 223, Zvolen.

- Aluminum profile, expanded polystyrene, PVC board, plywood, adhesive, artificial turf base, acrylic paints, and models of trees, workers, flowers, and shrubs – €49.35.
- CJMCU-9548 multiplexer, TCA9548A - 8-channel I2C, Arduino UNO R4 Minima clone with RA4M1 processor, sensor shield for Arduino UNO, MEGA duemilanove, XT60 2-pin male + female, battery connector, flat ribbon cable (VFL), and LEDs – €44.34.
- ESP32-P4-WIFI6 development board with a 7-inch 5-point touch display with a camera – €67,65.
- PLA filament for the 3D printer – €49.98.
- Domain and hosting for the website – €71.07.

Total project costs – €282.39.

9 FINAL CONCLUSION

The presented thesis, titled "Nuclear Power Plant – A Threat to My Future or a Clean and Reliable Energy Source," aimed to conduct a critical analysis of one of the most debated energy sources of the present day. At a time when the global community faces unprecedented challenges associated with climate change, the energy crisis, and the increasing demands for grid stability driven by the development of artificial intelligence, the question of secure energy becomes a matter of survival for our industrial civilization.

The analysis of the historical context and risks in the second chapter demonstrated that the perception of nuclear energy as a "threat" is largely the result of information asymmetry and the trauma of past accidents, which, however, occurred on technologically distinct systems. The statistical reality of safety, expressed by the number of deaths per terawatt-hour produced, confirmed that nuclear energy is one of the safest and cleanest sources. Its contribution to saving human lives from the pollutants of fossil fuels is scientifically irrefutable.

The internal analysis of the power plant in the third chapter confirmed that modern Generation III+ units (such as Mochovce 3 in Slovakia) represent the technological pinnacle of passive safety. The chapter on material efficiency debunked the myth of excessive strain on natural resources. On a per-unit-of-energy basis, nuclear power requires orders of magnitude less concrete, steel, and critical raw materials than most renewable sources, thereby preserving the landscape.

The most significant contribution of this work, however, is the proposal of a hybrid energy node that integrates nuclear power with the production of green hydrogen and mechanical storage in the GraviMobil system. This addresses the only relevant critique of nuclear power—its low flexibility. The node not only stabilizes the grid but directly decarbonizes transport and industry, making nuclear power a truly clean source across the entire economic cycle.

The practical and most visible outcome of the proposed hybrid system is the decarbonization of regional transport through hydrogen. The analysis showed that utilizing surplus heat and electricity from a nuclear source for solid oxide electrolysis (SOEC) increases the efficiency of "pink" hydrogen production, which is a direct analog to "green" hydrogen. This emission-free energy carrier subsequently transforms mobility in the Central Slovakia region.

A "Hydrogen Valley" connected to a stable nuclear node provides a solution for heavy-duty freight and public transport, where battery-based solutions encounter limits in range, weight, and charging time. Linking "clean atoms" with hydrogen fuel cells in vehicles ensures that only pure water vapor is emitted from the exhausts of buses and trucks. This will lead to an immediate improvement in air quality and a reduction in noise levels. In our project, hydrogen mobility ceases to be a mere theoretical concept and becomes a real tool for achieving carbon neutrality in the region. The nuclear power plant guarantees the stability and economic sustainability of this entire ecosystem. The practical component of this thesis, involving the creation of an interactive model and its presentation to first-year students, yielded a significant societal finding. It demonstrated that when the subject is presented intelligibly and through the lens of modern technological visions, the younger generation ceases to view nuclear power as a threat and begins to perceive it as a fascinating tool for a clean future. The shift in students' attitudes following the presentation serves as the strongest evidence that education and technical outreach are the primary pathways toward understanding nuclear energy.

The analysis confirms the hypothesis:

- A nuclear power plant is not a threat to my future; on the contrary, it is an essential condition for it.
- The hybrid system represents a path toward Slovakia's energy sovereignty and the fulfillment of climate goals without the necessity of reducing living standards—a world where energy is accessible, secure, and environmentally friendly.
- Nuclear energy is the anchor of our stability and the engine of our ecological renaissance.

This project is not merely a theoretical study but a logical call to action to stop viewing nuclear power through the lens of fear and start recognizing it as the key to a secure and prosperous Europe. Energy is the foundation of freedom. If we wish to remain free in a clean world, we must rely on the stability of the atom and the power of gravity. The future of our country lies not in the fear of the unknown, but in the courage to combine the power of the atom with the clean energy of gravity and hydrogen. Let us transform our heritage into the engine of a new era and build a world where the only waste in our streets is pure water vapor, and the primary feeling in our homes is a sense of security based on scientific facts, not myths.

10 REFERENCES

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<https://www.svetenergie.cz/>

OTHER INFORMATION SOURCES:

Consultation with Mgr. Oleksandrom Kaljužnym.

Source Author: Mgr. Valentína Kaljužna, Andrej Sámeľ, Sebastian Mlynarčík

11 PHOTO GALLERY

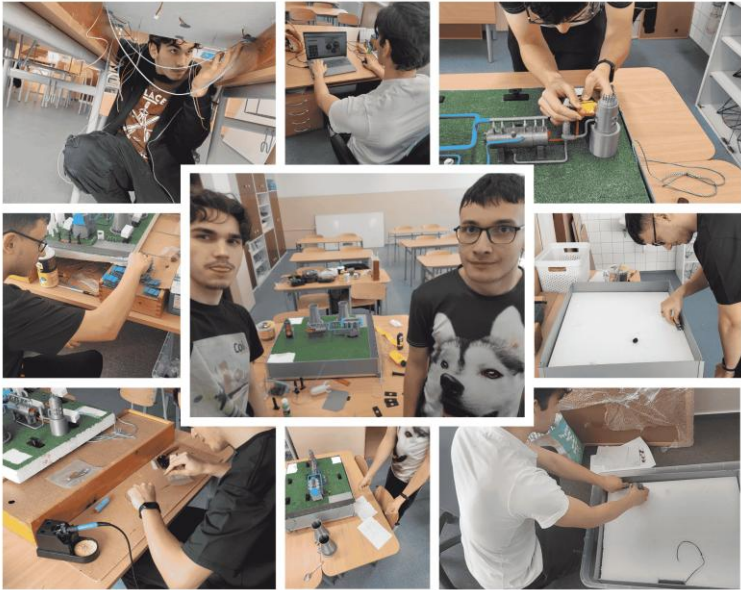


Fig. 12: Work on the construction of the interactive model

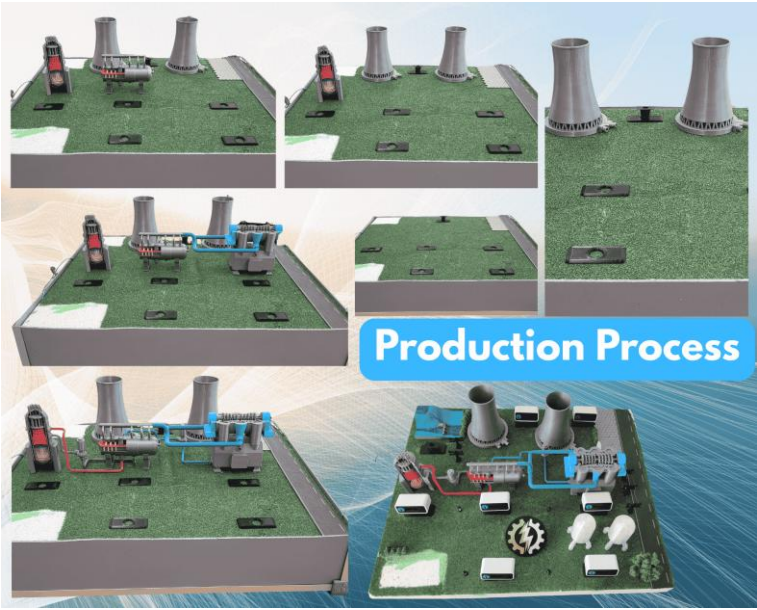


Fig. 13: Production process of the interactive nuclear power plant model

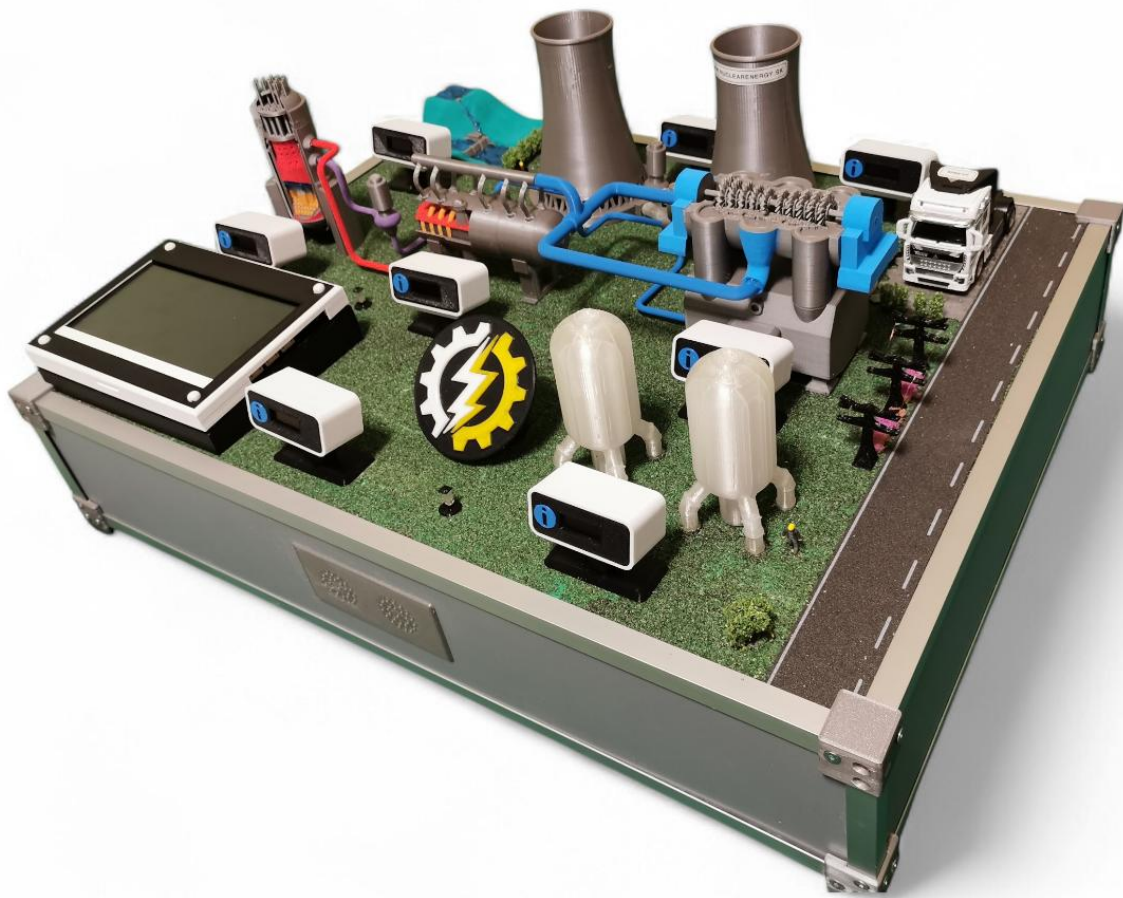


Fig. 14: Final product