Nuclear Energy for the Future: Spreading Knowledge and Awareness about Sustainable Power

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Content

1. Introduction

After last year, we learned from our shortcomings and took our project to the next level. This year, we decided to focus our education on nuclear energy to educate young people about the benefits and dispel myths and misconceptions. Our goal is to build trust in nuclear energy and increase interest in it among the younger generation.

2. Power Plants

A power plant is a building that produces electricity by converting mechanical energy into electric energy or, in the case of solar panels, by activating electrons inside. Power plants mentioned in this column will be included in educational activities.

Every power plant has its distinguishable benefits and downfalls, which are as unique as their diversity. The most debated question is which one is the best. Due to poor education and the aimed propagation of fear of Nuclear energy is frequently condemned due to its supposed danger. Chornobyl and Fukushima are gladly used to scare people away. But is there any truth about it? Our project aims to uncover that for elementary and high school students. To do that, we must explain how all types of power plants work and their benefits and shortcomings. There should be no place for biases stemming from, at best, partially truthful sources. Of course, it would be naive to think that nuclear power is without downfalls, which is the other side of the coin. People, in general, are biased by flashing news and trending headlines rather than facts. Future generations should be informed about the ecological options of nuclear energy.

Other types of green energy are emphasized, but future nuclear energy is ignored despite its efficiency. Damocles's sword hanging is only imaginary this time, safety manuals are often written by blood, and the sacrifices of many great men and women will be forever held in our minds. We could climb from their backs to our great systems of safety and precautions. Of course, other green options are viable and have their strengths in specific conditions. Geography is the most limiting factor for all green options except nuclear. And how can we forget about the most used one, coal? It is not green, but some upgrades can make it more viable. It remains necessary for the steady shift to greener alternatives. Coal is like a grandfather; it should be treated with respect for its merits but make room for better solutions and fresh ideas. Gas is undoubtedly more ecological but still not ideal for use alone. We will improve knowledge about nuclear power plants and gladly knock down myths spread among students. This way, we will ensure and promote an educated choice of green energy, which will prevent ecological disasters and ensure the well-being of Earth.

2.1 Nuclear fission powerplants

Nuclear fission power plants harness the energy released by splitting atomic nuclei. This process begins with a neutron striking the nucleus of a uranium-235 atom, which absorbs the neutron and becomes unstable. This instability causes the uranium nucleus to split, releasing a large amount of energy in the form of heat and more neutrons. These newly released neutrons can strike other uranium atoms, causing them to split and release more heat and neutrons. This chain reaction is what we call nuclear fission. The heat generated by this process produces steam, which drives a turbine connected to an electricity generator. The steam is then condensed back into water and returned to the reactor core to be heated, creating a continuous cycle.

There are numerous benefits to nuclear power plants. Nuclear fission releases a tremendous amount of energy from a small amount of fuel. This makes nuclear power plants highly efficient in terms of the fuel consumed to generate power. Unlike fossil fuel power plants, nuclear power plants do not emit carbon dioxide or other greenhouse gases when they operate. This makes them a cleaner energy source in terms of air pollution and climate change. Fission power plants can operate continuously for long periods, providing a stable and reliable source of electricity on the premise that they have regular maintenance.

Of course, nothing is perfect, so there are some serious drawbacks, such as **radioactive waste**, which must be managed and stored for thousands of years. This presents significant technical and political challenges. Even though spillage of such materials is rare, they would bring catastrophic environmental damage to the Earth. While accidents are infrequent, they can have devastating consequences. The Chornobyl and Fukushima disasters are stark reminders of the potential risks that this power generation technique brings. Building a new nuclear power plant is expensive and time-consuming. These high upfront costs can make nuclear power less attractive compared to other energy sources.

There are several types of Fission powerplants, but we will focus on the two most common types for simplicity.

2.1.1. Pressurized Water Reactor (PWR)

This is the most widely used nuclear reactor in the world.

The primary fuel used in PWRs is enriched (3,5-5%) uranium dioxide (UO_2), shaped into small ceramic pellets. These pellets are stacked into long, slender tubes made of a corrosion-resistant material like zirconium alloy. These tubes are known as fuel rods and are typically 4m long. A bundle of these fuel rods is grouped to form a fuel assembly. Multiple fuel assemblies are then arranged in the reactor core.

Reactor Core

The core is the heart of the reactor, where the nuclear fission reaction occurs. It is contained in a protective cover that provides protection from external forces and protects the outer world from radiation. The reactor core is immersed in water, which acts as a neutron moderator. It slows down fast neutrons, making them more likely to cause further fission of uranium-235 atoms. The reaction is controlled by control rods made of boron, silver, indium, or cadmium.

Primary Coolant Loop

High-Pressure Water: The water in the primary loop is kept under high pressure (approximately 155 bar) to prevent it from boiling, even at temperatures around 315°C.This pressurized water absorbs the heat produced in the reactor core and transports it to the steam generators. It can be borated to better function as a controlling element.

The steam generator consists of thousands of thin tubes. The hot, pressurized water from the reactor core flows through these tubes, transferring heat to the water in the secondary loop. The secondary loop water, heated by the primary loop, turns into steam. The steam generated in the steam generator is at high pressure and temperatures. This steam is directed to the turbines. The high-pressure steam expands through the turbine blades, causing them to spin and drive the connected generator to produce electricity.

Steam Condensation: After passing through the turbine, the steam enters the condenser, where it is cooled and condensed back into liquid water. The condenser typically uses a separate water source, such as a river, lake, or ocean, to cool the steam. This process involves passing the cooling water through tubes that absorb the steam's heat, condensing it into water.

Circulation: The condensed water is then pumped back to the steam generators to reheat, completing the cycle.

Control and Safety Systems

The reactor protection system (RPS)monitors the reactor's critical parameters and can automatically shut down the reactor if unsafe conditions are detected.

In case of a loss of coolant accident, the ECCS (Emergency Core Cooling System) provides additional cooling to prevent the reactor core from overheating.

2.1.2. Boiling Water Reactor (BWR)

This type of nuclear reactor uses water as a coolant and a neutron moderator. The nuclear fuel used is enriched uranium in the form of oxide since it facilitates the generation of nuclear fissions. Thermal energy generated by nuclear fission chain reactions is used to boil water.

Just like PWRs, BWRs use enriched uranium dioxide (UO_2) as fuel, but they are inserted from the bottom since steam is generated directly at the top of the reactor. The uranium dioxide pellets are placed in zirconium alloy tubes to form fuel rods. These rods are grouped into fuel assemblies and placed in the reactor core. Between these fuel rods are control rods.

The reactor core is where the nuclear fission reaction takes place. Neutron Moderator and Coolant: Water is the coolant and the neutron moderator. It slows down the neutrons, making them more likely to cause further fission of uranium-235 atoms, the same as PWR. In a BWR, the water in the reactor core boils directly due to the heat generated by nuclear fission. This produces steam within the reactor vessel itself. Unlike in PWRs, there is no separate primary loop. The water boils in the reactor core and directly produces steam.

The steam-water mixture produced in the reactor core passes through steam separators and dryers. These components ensure that only dry steam exits the reactor vessel while the remaining water is recirculated within the reactor core. Steam Transfer: The dry steam generated in the reactor vessel is routed directly to the turbines. Electricity Generation: The high-pressure steam expands as it passes through the turbine blades, causing them to spin and drive the generator, producing electricity. After passing through the turbine, the steam enters a condenser, cools, and condenses back into water. The condensed water is then pumped back into the reactor vessel to be reheated, continuing the cycle.

BWRs have robust containment structures designed to prevent the release of radioactive materials; the reactor and associated systems are housed within a containment building to ensure multiple layers of safety. Reactor Protection System (RPS): This system monitors the reactor's critical parameters and can automatically shut it down if it detects unsafe conditions.Emergency Core Cooling System (ECCS): In case of a loss of coolant accident, the ECCS provides additional cooling to prevent the reactor core from overheating.

Comparison of PWR and BWR reactor

Aspect	PWR	BWR
Reactor Core	Fuel rods immersed in high-pressure water	Fuel rods immersed in water that boils directly
Primary Loop	Separate high-pressure loop	No separate primary loop; water boils directly
Steam Generation	Steam is produced in a secondary loop via a heat exchanger	Steam generated directly in the reactor vessel
Water Pressure	High pressure (approx.. 155 bar) to prevent boiling	At lower pressure, water boils directly in the reactor vessel
Steam Production	Steam produced in the secondary loop	Steam produced directly in the reactor vessel
Control of Neutron Flow	Via control rods and borated water	Primarily via control rods
Thermal Efficiency	Typically, around 33%	Slightly higher, around 34-35%
Construction Cost	Generally higher due to complex design	Generally lower due to simpler design
Operating Cost	Higher due to maintenance of high-pressure systems	Lower due to simpler operation and maintenance
Advantages	Stable and predictable operation, well-suited for high-power output, efficient heat transfer	Simpler design, lower construction cost, slightly higher thermal efficiency, direct steam production simplifies turbine operation
Disadvantages	Higher construction and operational costs, complex safety systems required for high-pressure operation	Direct boiling can cause more wear and tear on the reactor vessel and potential for more radioactive contamination in the steam.

2.2 Other Types of power plants

2.2.1. Coal power plant

Coal Power Plant: The process begins with coal pulverization, where coal is broken into a fine powder in a silo-pulverizer. The pulverized coal, small enough to be lifted by hot air, is then supplied to the boiler. Simultaneously, water is treated in a deaerator to remove dissolved gases, leaving only pure H_2O. This water is then pressurized to around 300 bar using a feedwater pump and sent to a water tube boiler. In the boiler, the water is heated and converted into steam. The steam passes through an economizer and a preheater before entering the turbine. After the turbine, the steam is condensed back into water in a condenser and cooled in a natural cooling tower. The cooling tower forms water droplets and lets them fall, resulting in cooling.

The coal power plant is the oldest type of power plant. It is very efficient, cost-effective, affordable, and simple. There are a variety of add-ons that can use byproducts and make it more ecological, but no matter the upgrades, it remains the most pollution-producing one.

2.2.2. Gas power plant

The process begins with a gas turbine. A compressor increases the pressure of the natural gas, which is then combusted, driving the power turbine. The mixture is burned at temperatures of more than 1000 degrees Celsius.

As the hot combustion gas expands through the turbine, it spins the rotating blades. These blades perform a dual function: drive the compressor to draw more pressurized air into the combustion section and spin a generator to produce electricity.

While gas power plants emit 50 to 60 percent less carbon dioxide (CO_2) than regular oil or coal-fired power plants, combustion also releases methane and lowers air quality. Methane is a potent greenhouse gas, and the uncertainty over the level of methane emitted to the atmosphere raises questions about the extent of the climate benefits that gas can bring.

In conclusion, gas power plants are more efficient and less polluting than coal or oil power plants, but they still have significant environmental impacts. The shift towards renewable energy sources is crucial for reducing greenhouse gas emissions and combating climate change.

2.2.3. Wind power plant

Wind power harnesses the wind's power to move wind turbines. These turbines convert the wind's kinetic energy into mechanical energy and then into electricity. The electricity is then transmitted to the power grid and distributed to consumers.

One of the primary benefits of wind power is its status as a renewable resource. Unlike fossil fuels, which are finite and deplete over time, wind is an inexhaustible natural phenomenon. This makes wind power a sustainable energy source that can be relied upon in the future.

In addition to its renewability, wind power also boasts low operating costs. Once the initial investment for the installation of wind turbines is covered, the ongoing costs are relatively low. This is because wind is free, and the turbines require minimal maintenance. As a result, the cost of producing electricity from wind decreases over time, making it an economically viable option for many countries.

Furthermore, wind power is environmentally friendly. It does not emit greenhouse gases or other harmful pollutants contributing to climate change and air pollution. This makes it a clean energy source that can help countries meet their environmental targets and commitments.

However, wind power is not without its challenges. One of the main disadvantages is the visual and sound pollution caused by wind turbines. Some people find the sight and sound of wind turbines disruptive, particularly in rural and scenic areas. This has led to opposition against installing wind turbines in specific locations.

Another challenge is the need for suitable sites. Wind turbines must be located in areas with consistent and strong winds to operate effectively. This limits the locations where wind farms can be installed and can also lead to variability in power generation.

2.2.4. Geothermal power plants

Make use of energy is heat from within the Earth. We can extract this heat as steam or hot water to heat buildings or generate electricity.

Geothermal power plants work by tapping into the heat within the Earth's crust. The Earth's core, about 4,000 miles beneath the surface, is so hot that it melts rock into magma. This magma rises towards the surface, heating stones and water in the Earth's crust. Power plant operators drill wells into geothermal reservoirs to bring hot water and steam to the surface. Once the hot water and steam reach the surface, they are separated. The steam is then used to turn a turbine. As the turbine spins, it drives a generator that produces electricity. Cooling and Re-injection: After the steam is used, it is cooled back into water and re-injected into the Earth to be used again. This makes geothermal power a sustainable power generation option.

Geothermal energy is both renewable and sustainable. The Earth's heat is continuously produced and expected to remain for billions of years. Geothermal power plants emit 97% less carbon dioxide than fossil fuels. Unlike solar and wind energy, geothermal energy is not dependent on weather conditions, making it a highly reliable power source.

The biggest downfall of geothermal energy is that it can only be harnessed in areas where the Earth's heat is easily accessible. These areas are often near tectonic plate boundaries and are prone to earthquakes. Building a geothermal power plant and drilling into the Earth can and will be expensive. Possible Depletion of Resources: If the water used in geothermal power plants is not managed correctly, the geothermal source can deplete or be altered due to the movement of the crust

Geothermal energy is a promising source of renewable energy. While it has challenges, its benefits make it an exciting area of study and development. As we continue seeking sustainable and environmentally friendly energy sources, geothermal energy will play a significant role in the future of energy.

2.2.5. Solar Energy

Solar energy is often called the energy of the future, and solar power uses the energy of sunlight to generate electricity or heat. This is most often done using solar panels that contain photovoltaic cells. These cells absorb sunlight and convert it into direct current electricity. This current can be used to power homes, businesses, or infrastructure. Individuals, businesses, and communities can reduce dependence on centralized power grids and foreign energy sources by harnessing solar energy.

Solar energy can be utilized in various ways, from generating electricity through photovoltaic panels to heating water and spaces using solar thermal systems. It can be deployed at different scales, from individual residential rooftops to large-scale solar farms covering vast expanses of land.

Thanks to technological advancements and increased manufacturing efficiency, the cost of solar energy has steadily decreased. As a result, solar power has become increasingly competitive with traditional energy sources in many regions worldwide.

Continued research and development in solar technology are driving innovation and efficiency improvements. From more efficient solar panels to energy storage solutions like batteries, ongoing advancements are making solar energy increasingly viable and accessible to various applications and regions.

Even though solar energy has many benefits, we must also watch out for disadvantages, such as weather dependence, where solar panels do not work when it's raining or just cloudy. Another thing is that installing solar panels can require large land areas, but this can be fixed by installing solar panels on buildings rather than in unrestricted areas.

2.2.6. Hydroelectricity and power plants

Hydroelectricity, also known as hydropower, is renewable energy generated by passing water through a turbine to produce electricity. It is one of the oldest and most widely used forms of renewable energy, with reservoirs and dams constructed to harness the energy of flowing water. Hydropower is clean, dependable, and sustainable, so it can contribute significantly to the world's electricity generation. It is a key factor in reducing greenhouse gases and controlling climate change.

A hydro plant is a facility that produces electricity using water that flows down or falls. Water is usually deposited in a reservoir and released to turn the turbines, producing electricity. This renewable energy source is considered the cleanest and most reliable as it provides a consistent power source that produces no greenhouse gases. Hydropower plants vary in size from small-scale ones to large dams and can supply electricity for residential, commercial, and entire communities.

Different types of hydropower plants can exploit the potential energy of the water. While hydropower plants may provide several positive aspects as a renewable energy source, these operations also have several drawbacks. The main issue is the environmental impact of the construction of these plants, which may involve the destruction of habitats, alteration of river ecosystems, and the denial of migrating fishways. There is additionally a risk of dam failure. The effect can be disastrous floods, representing a danger to lives and property. Moreover, hydropower plants rely on a regular flow of water, so they might become unable to produce enough power during droughts when there is not enough water or in the case of climate change. The relocation of communities from large-scale hydro projects causes social disruptions and conflicts. On the other hand, the high price of investing in the construction of hydropower plants could cause the latter to be less attractive in regions or countries with limited financial capabilities.

Hydropower stations provide many benefits as renewable energy sources. Water is the most critical component, as the system relies on the water cycle for the continuous energy supply. In addition, hydroelectric facilities do not emit high levels of greenhouse gasses, helping to improve environmental conditions. Such plants have the added advantage of guaranteeing a regular and constant energy supply, as the releases can be regulated to serve the required demand. Furthermore, hydropower can be considered a cost-effective generation after infrastructure projects have been implemented successfully. The construction of hydropower plants can also help mitigate the negative impacts of floods and ensure that irrigation is available. In addition, these projects create job opportunities, stimulate economic growth, and strengthen the local community by collecting various fees and providing infrastructure.

3. Education on Nuclear Energy: The Key to a Sustainable Future for the Young Generation

Why educate the younger generation on nuclear energy? Young people can potentially be key drivers in the energy transition. To harness this, they need a strong foundation in energy systems, including power plants and electricity generation. By sparking their interest in these topics, we can inspire them to create innovative solutions and pursue careers focused on decarbonizing the energy sector. With a solid understanding of how power plants work, they can actively move away from fossil fuels and embrace renewable energy sources.

Equipping the future workforce with the necessary skills for a fair and just energy transition is crucial. Expanding clean energy career opportunities, especially for vulnerable or underrepresented youth, is vital.

Young people are natural advocates for change. They challenge powerful fossil fuel industries and demand greater accountability for their environmental and social impacts. Their voices can push for policy reforms, influence corporate practices, and speed up the adoption of sustainable energy solutions.

As climate change continues to be a pressing global issue, young people are leading the charge. They are calling for an end to coal, oil, and gas exploration and financing. By educating them about the role of power plants, we help them see how energy decisions shape the environment, motivating them to advocate for cleaner alternatives and make informed choices.

4. Activities

As part of the education, we prepared several activities to demonstrate or explain physical and scientific phenomena better.

The first activity in our lecture on the functionality of nuclear reactors is 3D-printed models depicting PWR and BWR reactors. With these tools, we can better demonstrate the function and visualise the functional difference between these two reactors.

Next, we have prepared an activity to compare other energy sources. It is supposed to point out the shortcomings and demonstrate that nuclear energy is the right choice.

We are trying to debate and refute some myths or conspiracy theories about nuclear energy's good name. In this way, we want to awaken students' curiosity and critical thinking regarding energy issues.

At the end of the program, the knowledge gained will be tested using a quiz that will check whether the participants paid attention during our presentation. The individual with the highest number of points will receive a small reward, and at the same time, this quiz will function as feedback for us as presenters.

5. Myths and Facts: Debunking Misconceptions About Nuclear Energy

In the following paragraphs, we have addressed well-known myths in the field of nuclear energy and nuclear power plants, and we have tried to refute them as follows:

1. Myth: Nuclear energy is dangerous and unsafe.

Fact: Modern nuclear plants are built with multiple safety measures to prevent accidents. Technology has advanced significantly since the 1980s, and today, nuclear energy is one of the safest sources of large-scale energy production.

2. Myth: Nuclear waste is impossible to manage.

Fact: While nuclear waste is a concern, it is manageable with current technology. Long-term storage solutions, like geological disposal, are being developed and have already been successfully implemented in some countries. The amount of waste generated is relatively small compared to the waste produced by fossil fuels.

3. Myth: Nuclear energy contributes to climate change.

Fact: Nuclear energy is a low-carbon energy source. It produces virtually no greenhouse gas emissions during operation, making it an essential part of efforts to reduce carbon emissions and combat climate change. It can complement renewable energy sources in a clean energy mix.

4. Myth: Nuclear plants are expensive and take too long to build.

Fact: While the upfront costs of building nuclear plants can be high and construction can take several years, they are highly cost-effective over the long term. Nuclear plants operate for decades, providing a reliable and stable energy source. Additionally, the cost of building them is decreasing due to technological advancements and modular reactor designs.

5. Myth: Nuclear energy is not environmentally friendly.

Fact: Unlike fossil fuels, nuclear power generates large amounts of electricity without producing air pollution or significant greenhouse gas emissions. Nuclear energy's environmental impact is primarily related to mining and waste management. Still, it remains one of the cleanest options for large-scale power generation compared to coal, oil, and gas.

6. Myth: Nuclear power plants must be built near water, harming marine life.

Fact: Nuclear plants often use water for cooling, but the environmental impact on marine life is minimal when proper safeguards are in place. Additionally, many plants are now exploring cooling solutions that reduce the need for large amounts of water or use closed-loop systems to minimize environmental disruption.

7. Myth: Nuclear energy is too complex and difficult to understand.

Fact: While nuclear energy involves complex technology, the basic principles of how it works are pretty simple. Education and outreach can help people understand the science behind nuclear energy, making it more accessible to the public. Many countries have effective nuclear energy education programs that simplify the concepts and demonstrate the benefits.

8. Myth: Nuclear power is not cost-effective.

Fact: While the initial costs of building nuclear power plants are high, they are cost-effective in the long run. Nuclear plants have long operational lifetimes (often 40-60 years or more) and provide a stable, reliable energy source at relatively low operating costs. When you factor in the price of coal and gas power plants over time, nuclear energy can be competitive or even cheaper in many cases.

6. Report of activity

Our activities were a great success. The older secondary school students could process more data and understand the complicated nuances, while the younger students were more enthusiastic and responsive. This outcome reflects our previous mistake of focusing solely on secondary school students.

The quiz was particularly effective in encouraging critical thinking and helping students develop their opinions. This interactive learning approach efficiently builds students' confidence and nurtures their curiosity.

Overall, the activity was better designed than last year, thanks to the availability of 3D physical models, which helped explain how things function. The hands-on learning experience provided by the checkpoints and the interactive nature of the quiz kept the students engaged. It was a great way to inspire the next generation of energy experts and instil a passion for their subject matter.

7. Expenditures

We are committed to providing affordable education through a highly adaptable system. This approach allows us to maintain high efficiency while keeping costs low. Our only significant expenditures are on 3D-printed models that are, of course, reusable. These models are helpful but not mandatory for the learning experience. This means students can benefit from these innovative tools without incurring unnecessary expenses. Our ultimate goal is to be self-sufficient, ensuring we can offer quality education without relying on external funding or resources.

Materials	Price
Resin	15€
Fdm	25€
Total	40€

8. Conclusion

This activity was a resounding success, capturing the attention of both bright-eyed elementary school students and their more developed secondary school peers. We are optimistic that our initiative to shine a light on nuclear energy will resonate throughout the wider community, sparking thoughtful discussions and deeper understanding. Moreover, we take great pride in our ability to enlighten so many individuals, empowering them not only with knowledge about energy but also nurturing their critical thinking skills and encouraging them to formulate their own informed opinions.

9. Sources

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10. Attachments

Picture 1: students from primary school examinig pwr reactor

Picture 2: High school students during explanation of functioning of pwr reactor

Picture 3: students of primary school taking kahoot quiz

Picture 4:High school students during debate on myths of atomic energy