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PERIODICAL OF THE „KAGANEK” FOUNDATION ŚWIĘTOKRZYSKIE INDUSTRIAL GROUP INDUSTRIA

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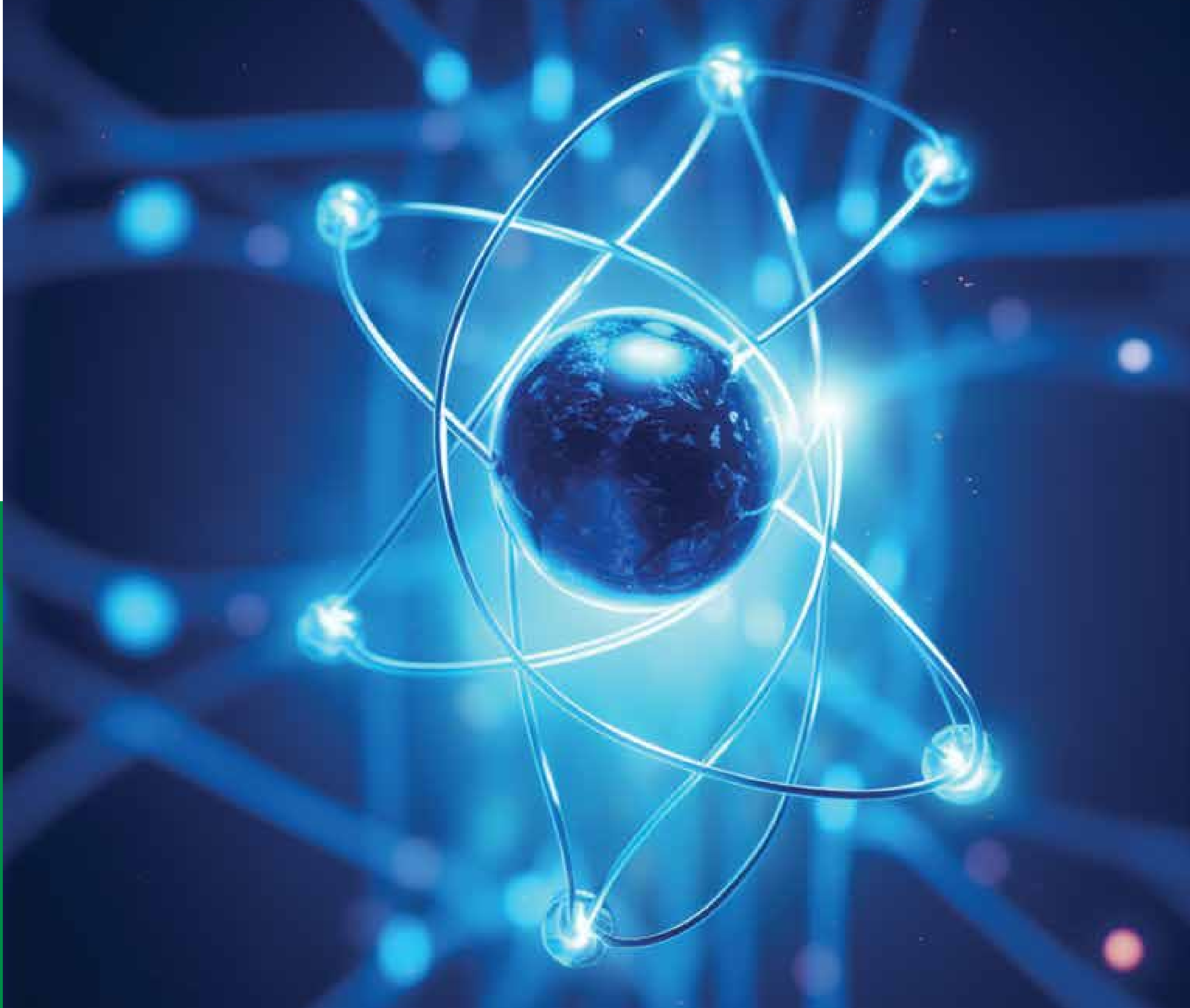
The atom is the basis



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The atom is the basis

The latest analyses show that the economy of the future will be even more energy-intensive than previously thought. Artificial intelligence technology itself is expected to consume as much energy as the Netherlands or Sweden in three years, and data processing centres already account for 30% of energy consumption in Ireland. The exponentially growing energy consumption in this sector of the economy adds to the already huge needs related to the electrification of transport, the chemical industry and the decarbonization of energy and heat production. In this context, renewable energy is only a partial and temporary answer: the only answer to such outlined needs is nuclear energy - only it enables the stable production of huge amounts of energy for many decades, from small amounts of fuel. Nuclear energy will become the basis of every modern economy in the coming decades.

Szczepan Ruman

INDUSTRIA Świętokrzyska Grupa Przemysłowa

Immediately after reaching the milestone of establishing The Łaszczyński Brothers Central Hydrogen Valley Association, we started further activities. At the end of the year, the SMR Supply Chain Team was established to implement the goals of the Central Hydrogen Valley based on the cooperation of ŚGP INDUSTRIA with Rolls-Royce SMR in order to implement SMR units using Rolls-Royce technology in Poland, as well as the development of the supply chain based on companies associated in the Central Hydrogen Cluster. These activities take place in the context of, among others: including nuclear energy on the list of technologies considered sustainable in terms of zero emissions and new regulations in the EU „Net Zero Industry Act" package.

The main assumptions of the SMR Supply Chain Team are:

- determining the potential of companies associated in the Association in terms of participation in the supply chain and activities aimed at the participation of Polish companies in the supply chain;
- close cooperation with Rolls-Royce SMR in order to develop a common company certification strategy (British Fit for Nuclear model);
- taking steps to build an R&D centre in Kielce, modelled on the British NAMRC;
- activities to create certified module factories in Poland (where the modules will be assembled and tested, and then transported to the construction site).

The establishment of the team resulted in the organization of the first international conference, INDUSTRIA NUCLEAR DAYS, which is held on March 11-12, 2024 in Korzecko. Especially for this event, we present the fifth issue of the Szklane Domy periodical, devoted entirely to nuclear energy. In this issue you will find information about the future of nuclear energy as a key technology leading to a sustainable future in the production of energy and heat. Rolls-Royce SMR business development manager Michael Crawforth describes the distinctive aspects of SMR technology from other technologies on the market, in particular its modularization and Rolls-Royce's responsibility to build the power plant on time. Business Development Manager at Rolls-Royce SMR Matt Moore presents the possibilities of using nuclear energy to produce green hydrogen.

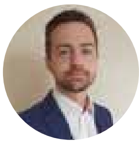
ŚGP Industria experts discuss topics related to the technical aspects of the operation of SMR reactors and the development of hydrogen technologies in the automotive sector. In the social part, you will find an article on the potential benefits for the Świętokrzyskie Voivodeship resulting from the construction of the SMR power plant and an interview between editor Aleksandra Niemczyk and the Mayor of the Choczewo commune presenting the process of implementing a nuclear power plant in the first location in Poland, including the benefits for the commune and its inhabitants.

I wish you pleasant reading!

Szczepan Ruman
The President of the Management
Board of the Świętokrzyskie
Industrial Group Industria S.A.

Rolls-Royce SMR Modular Delivery Approach

Rolls-Royce SMR was created to revolutionise the way nuclear power is delivered. Taking well-understood technology and applying a unique manufacturing philosophy to its fabrication and assembly. The Rolls-Royce SMR offers a modularised, standardised, factory-built product that is affordable, deliverable and investable.



Michael Crawforth

Underpinning this; the principles of 'Build Certainty', 'Modularisation' and 'Standardisation' form key parts of the Rolls-Royce SMR delivery approach, to ensure that the roll out of the global Rolls-Royce SMR fleet can be performed in a cost effective, predictable and repeatable manner.

Through the implementation of our Modularisation and Standardisation principles the Rolls-Royce SMR Plant achieves a high degree of modularisation across all aspects of the complete power station, a unique position within the industry. The Rolls-Royce SMR approach employs a combination of Rolls-Royce SMR designed modules with readily available 'commercial of the shelf' modules which can be integrated seamlessly into the standardised and repeatable design developed by Rolls-Royce SMR.

The six build certainty objectives for the SMR programme are defined as:

1. Maximise off-site build and assembly
2. Simplify Logistics Flow for on-site Build
3. Minimise variation across all areas
4. Reduce and Simplify Interfaces (plug and play)
5. Increase Robustness to Variation
6. Reduce Human Interaction

During the design process, the build certainty objectives have formed a key input and consideration into the development of the overall architecture, system concepts, and component design, all of which have been embedded into the design development ensuring repeatability and standardisation across the components, systems and modules.

In addition to this unique approach, we have employed the proven techniques utilised within the Aerospace and Defence sector to ensure the maturity of the design is developed in advance of the manufacturing of the components. A suitable gated process ensures data maturity at key points in the design development enabling control without sacrificing speed. For example, enabling the early release of manufacturing to secure the delivery of long lead time components, thus further reducing the risk of delay in the schedule.

Modularisation and Build Certainty

Rolls-Royce SMR believes the build certainty principles of "Maximise Off Site Build and Assembly" and "Reduce and Simplify Interfaces (Plug and Play)" have the highest impact on the overall product time, cost and risk and so are the most important aspects for the business to address consistently and effectively. To this end it was decided early in the project that modularisation would form one of the key differentiators between this project and traditional nuclear, and to be effective the modularisation had to extend across the whole power plant.

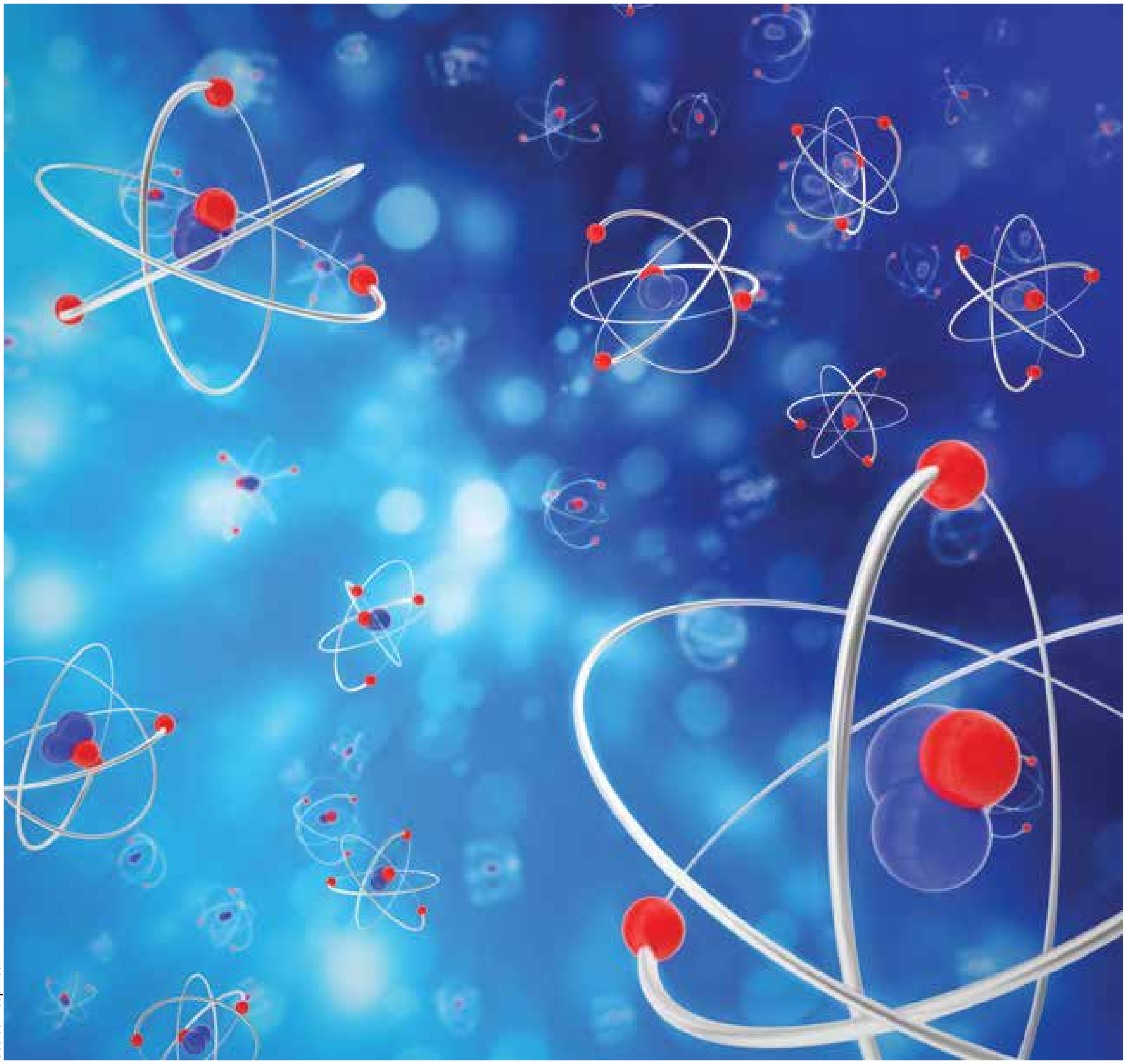
It is intended that the bulk of the Rolls-Royce SMR plant will be assembled in factories and will be delivered and installed as a series of modules. Modules must be designed to allow as many complex processes as possible to be completed in the factory and for the installation on site to be as simple as possible with as few interfaces as possible.

The build certainty requirements drive up module size and weight as they push designers to maximise the use of the off-site factory and minimise the number of processes on site. However, the competing constraints placed on build certainty by the road transport regulations set limits that have led to the project's module sizing strategy and associated requirements. This 'upper limit' to module sizing is the constraint that leads to the maximum Rolls-Royce SMR output power of 470MW net electrical output. This is the sweet spot between economies of size and economies of scale.

It is important to note that modularisation itself is not the aim, the aim is to achieve build certainty and modularisation is seen as one of the most effective tools at our disposal for achieving this. Therefore, when modularising systems, it is important to ensure that the process is achieving the desired build certainty benefits.

Standardisation

Along with Modularisation, Standardisation is one of the key tools deployed



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by Rolls-Royce SMR to achieve build certainty, lower cost and risk mitigation. By standardising components, processes, tooling and almost any aspect of plant assembly we gain significant build certainty and a number of cost advantages that can continue throughout the entire plant life cycle.

1. Reduction in the Part Number Count for the Bill of Materials, subsequently reducing logistics costs, maximising economy of scale and reducing spare parts inventory requirements.

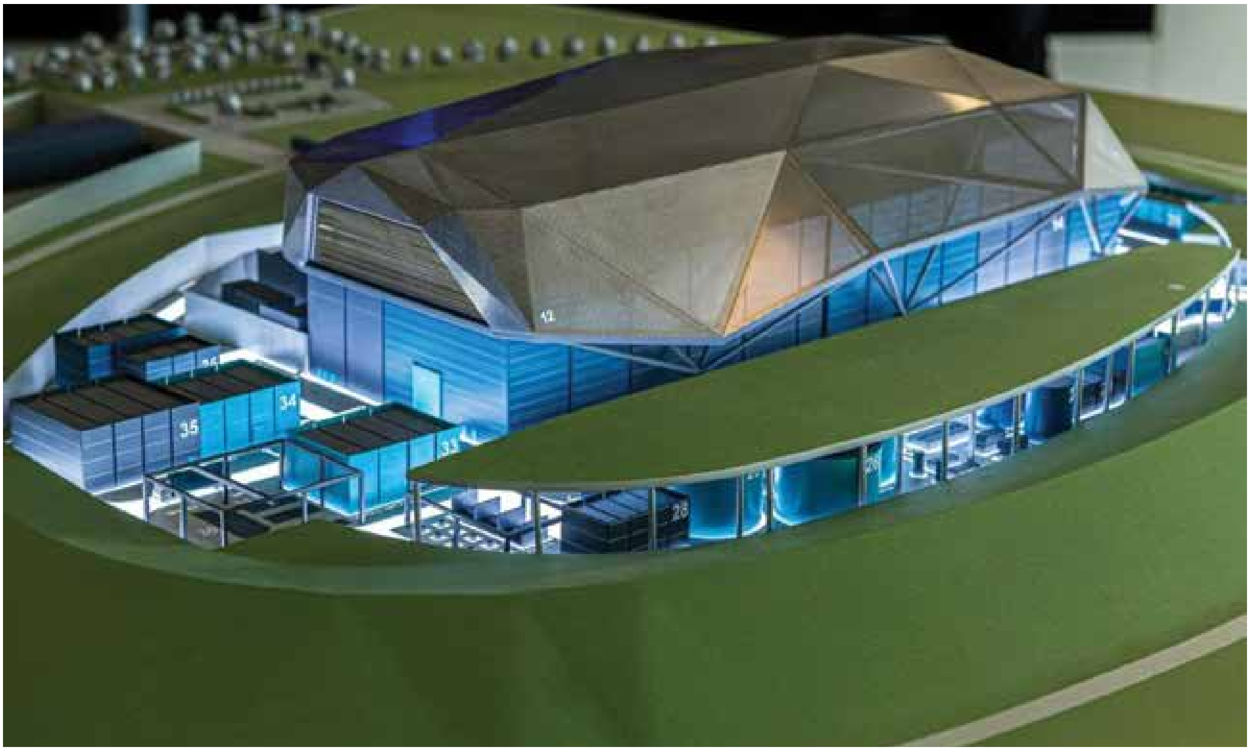
2. Greater proficiency and increased learner curve efficiencies, through the standardisation of processes and procedures. Increases build quality, resulting in a higher "Right First Time" success rate.

3. Increased robustness to unexpected changes in build schedule demand requirements, enabling changes to manufacturing schedule to meet the needs of the construction sequence.

4. Reduced numbers of scarce skilled workers required to complete the manufacturing processes through the introduction of mechanised tooling to achieve the required process standards. Enabling automation to provide consistency of activity further increasing quality and reducing the number of man hours required to perform a process.

5. We achieve the aim of delivering a "Product Line Approach" by having a design that is flexible to be installed unchanged at a variety of sites, avoiding the costs and delays of site specific re-designs.

The benefits of standardisation are well documented across industry and are not a new concept. However, its application in a controlled way coupled with the modularisation unique to Rolls-Royce SMR enables the delivery of a complete solution incomparable to any other SMR offering on the market.



Factory Production

Rolls-Royce SMR are developing a repeatable module factory design capable of supporting the growing global demand for clean power. Rolls-Royce SMR manage the factory design and build using the Rolls-Royce Plc. Factory Project Model (FPM) process. FPM is a proven, robust governance process used to support the design and development of all Rolls--Royce factories.

Factory production brings a wide range of benefits to manufacture, supporting build certainty and standardisation. The consistency of the factory environment improves product quality and consistency and enables greater realisation of the learner curve benefit to drive down cost.

One of the major challenges in deploying SMRs at scale is the growth required across the nuclear supply chain and the skilled workforce within it. Minimising the activity on site and maximising the activity within the Rolls-Royce SMR factory ensures skilled jobs can be located in one place for decades to come, enhancing recruitment, retention and utilisation across key skills and delivering long term economic benefits to host communities.

The Rolls-Royce SMR factory solution, with modularisation across the entire power plant, supports the growth of production capacity where it is required to meet regional demand. Manufacture within key nuclear markets will enhance the opportunity for local supply chain participation and provide new market opportunities for the global Rolls-Royce SMR supply chain supported by the programme.

Transportation Philosophy

The transport philosophy affects and interacts with the build certainty philosophy directly. The Rolls-Royce SMR power plant is designed to be deployable to a large range of sites including in-land sites and brownfield sites that might not fit the profile of a traditional civil nuclear site. All Rolls-Royce SMR modules must be road transportable and optimised to minimise the impacts to the local road network and local communities. This does not mean that other methods of transport cannot be used where appropriate.

Countries with advanced rail networks but unsuitable or overloaded road networks may see a huge benefit in maximising the use of rail for the transportation of Rolls-Royce SMR modules. Rolls-Royce SMR has already had commercial interest from countries that wish to make use of their rail networks to handle as much of the Rolls-Royce SMR logistics as possible.

***Mike Crawforth** is the Business Development Manager for Rolls-Royce SMR, bringing experience of 12 years in the nuclear industry to help meet the twin challenges of decarbonisation and energy security. Specialising in technology introduction programmes, Mike has worked across the breadth of the nuclear industry including the UK's submarine programme, decommissioning, the upcoming challenges in the European medical radioisotope supply chain, the development of a micro reactor to decarbonise deployed power, and the genesis of a UK space nuclear programme.*

Mike, now with Rolls-Royce SMR, is working with industrial energy users and policy makers to develop new ways to apply nuclear solutions to the energy ecosystems of tomorrow, driving down the system costs of the energy transition.

Nuclear Powered Hydrogen Production

Matt Moore

Rolls-Royce SMR

What can hydrogen be used for?

Hydrogen has a key role to play in achieving Net Zero, it can be used directly as a fuel source, used for electricity, used for high temperature heat and also as a feedstock into alternative fuels and other chemical processes.

By burning hydrogen gas, it is possible to decarbonise high temperature industrial processes that are currently powered by carbon intensive methods, for example glass manufacturing and steelmaking.

Hydrogen is also a key feedstock in the manufacturing of many products such as ammonia (used for fertiliser and a potential future fuel to decarbonise the shipping industry) and plastics. Future use cases, including Sustainable Aviation Fuel (SAF), long term energy storage and heating could drive a significant increase to the demand for clean hydrogen.

How can nuclear energy be used to create green hydrogen?

The production of clean hydrogen requires large amounts energy, for production at the scale required to decarbonise society we will need vast amounts of clean energy. Nuclear power is capable of efficiently and economically scaling to the volumes of energy required and has several benefits for the production of hydrogen and follow on products.

Nuclear energy has a low impact on the environment with the lowest CO_2 and lowest materials use per kW of energy generated[1]. The low lifecycle impact of nuclear power is further enhanced through the production of hydrogen and follow on products. The continuous energy production of a nuclear power plant drives high utilisation factors in the equipment used to produce hydrogen resulting in a decrease in total demand and ensuring hydrogen can be produced with the lowest use of materials and the lowest release of carbon dioxide and equivalent greenhouse gasses.

Due to the high cost of electrolyser equipment and production plants the high availability factor of nuclear drives high utilisation factors thus minimising the cost of hydrogen produced. Rolls-Royce SMR have completed studies with electrolyser technology providers, production plant integrators and gas wholesalers to develop the proposition for nuclear enabled hydrogen and its follow-on products. The production processes for many follow-on products, such as fuels and chemicals, need to operate continuously and at scale to support the economics of production. It is in these follow-on products where the power density and continuous load factor of nuclear power creates further economic potential.

The continuity of hydrogen production supports a wider range of hydrogen off-take models enabling delivery assurance without the need for costly storage solutions or grid imports with associated carbon and price uncertainty.

Co-location

The high-power density of nuclear power and the siting flexibility of SMRs allows for the co-location of energy source with demand removing the need for the cost and power loses associated with grid transmission of electricity which can represent a significant proportion of the final energy cost. This enables nuclear power to be used to produce power, and hydrogen where it is needed, removing the costs and risks associated with long distance hydrogen transmission in addition to the savings on grid transmission.

The advantages of co-location further differentiate the cost of nuclear produced hydrogen and could de-risk large scale hydrogen production projects sufficiently to solidify the business case enabling large scale continuous production of, low cost, low carbon hydrogen which will be essential to decarbonisation.

Cogeneration Opportunity

Nuclear reactors work by generating thermal power from the controlled fission of atoms, which is then converted, through steam and a steam turbine, into electricity. However, this extraction of electrical energy from heat comes with losses, the laws of thermodynamics restrict the amount of thermal energy that can be converted into electricity. For Pressurised Water Reactors operating around 300°C this conversion efficiency is typically assumed to be ~36%.

Using a high temperature electrolyser technology such as Solid Oxide Electrolysis Cell (SOEC) to produce hydrogen, which uses thermal power to offset electrical input, can improve the efficiency of the full system by avoiding the losses associated in converting thermal energy to electricity. The higher input temperature reduces the electrical energy required to split the steam into Hydrogen and Oxygen improving the efficiency of the

Source: freepik.com

electrolysis process in addition to the improved energy output of the SMR. The compound nature of these effects result in a significant increase in system efficiency that dramatically reduces the costs in the generation of hydrogen and increases the volume produced. A Rolls-Royce SMR coupled with SOEC technology can produce up to 270 tonnes of hydrogen per day at a competitive price.

SOEC is a type of fuel cell that can be run in reverse to produce electricity from hydrogen during times of peak demand offering further options for flexible production modes of operation to support local grid stability. However, SOEC technology is currently at a lower maturity than that of electrical only solutions such Proton Exchange Membrane (PEM) with current estimates having a Technology Readiness Level (TRL) of 6 with the expectation of hitting TRL 9 in 2030 aligning to the deployment timescale of SMR's throughout the 2030's, 2040's and 2050's.

It is possible to utilise hydrogen cogeneration as a way of increasing the flexibility of an SMR. In instances where renewable energy generation is low, resulting in high energy prices, an SMR plant can produce electricity and feed energy to the grid achieving a premium compensating for the loss in hydrogen production. When there are large amounts of renewable energy generation, the SMR plant can focus on producing hydrogen. This flexibility allows for the plant operator to choose the production that is most economically attractive at a given time, both improving the economics of SMR deployment as well as supporting the stabilisation of the grid against the swings of intermittent generation.

By using a Rolls-Royce SMR the production cost of clean hydrogen can be minimised and the volumes maximises. A Rolls-Royce SMR will also enable the continuous production required for follow on products such as SAF and ammonia to supply into existing markets, thus de-risking the large-scale hydrogen production projects that will be essential to decarbonisation and Net Zero.

Matt Moore *is a Mechanical Engineering Nuclear Graduate on secondment as a Business Development Lead for Rolls-Royce SMR with a Master's in Mechanical Engineering from Loughborough University. Taking experience from GE-Aviation, UKAEA and Rolls-Royce Submarine as an engineer, bringing a technical understanding to give a different perspective. Externally to Rolls-Royce SMR, Matt is the Managing Director of Explore Nuclear, an online website promoting the nuclear industry to young people in an engaging way to try and tackle the nuclear capability workforce gap the industry is facing.*

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Decarbonization of transport using hydrogen and purple hydrogen (from the atom)

Green reform and transportation decarbonization

Transportation is crucial to modern society because it facilitates trade, fosters social interactions, and ensures worldwide mobility. However, as the number of vehicles on the road and transportation-related activities has increased, so has the amount of greenhouse gas emissions and other air pollutants. Decarbonizing transportation has emerged as a primary goal in response to climate change and the need to reduce CO_2 emissions. Fossil fuels, such as gasoline and diesel, dominate the traditional mode of transportation. Unfortunately, when these fuels are used, they emit large volumes of carbon dioxide (CO_2) and other dangerous pollutants into the environment. To minimize its environmental impact and create a cleaner future, the transportation sector must emphasize the development of alternative, sustainable energy sources. In the quest for alternative fuels, hydrogen has emerged as a viable competitor for decarbonizing transportation. With the ability to totally remove CO_2 emissions and reduce air pollution, it has enormous potential as a clean energy source. Burning hydrogen yields just pure water as a byproduct, releasing no CO_2 into the atmosphere.

Konrad Piotrowski

CENTRALNA DOLINA WODOROWA

If hydrogen technology is embraced for transportation, the automotive industry may face a drastic upheaval. Vehicles powered by hydrogen and equipped with fuel cells, or FCEVs, have an extended driving range, emit no emissions, and operate similarly to traditional internal combustion engines. However, the broad usage of hydrogen in transportation confronts hurdles. Building the infrastructure required for hydrogen production and refueling presents a considerable hurdle. The high expense of building fuel cells adds to the barriers to widespread use of hydrogen technology. However, as rules tighten and environmental awareness rises, manufacturers, public transportation providers, and investors are becoming more interested in researching sustainable alternatives. Hydrogen is becoming more appealing for the future since it bears the potential for a cleaner and more sustainable transportation industry. The following sections of this article will look at current activities aiming at improving hydrogen technology, as well as possible hydrogen applications in various transportation industries. We will explore the benefits and drawbacks of using hydrogen to decarbonize transportation within the context of worldwide climate change efforts.

The multicolored world of hydrogen

Despite being one of the simplest elements, hydrogen's diversity may surprise many. The variety of hues that hydrogen comes in represents different production methods and levels of purity. In this chapter, we will dig into the intriguing world of hydrogen's brilliant hues and investigate their importance.

Grey hydrogen, commonly used in everyday applications, is produced by distilling petroleum or natural gases. This approach, commonly used in the chemical industry, is relatively simple. However, gray hydrogen frequently contains impurities such as sulfur and heavy metals, giving it its distinctive grayish look.

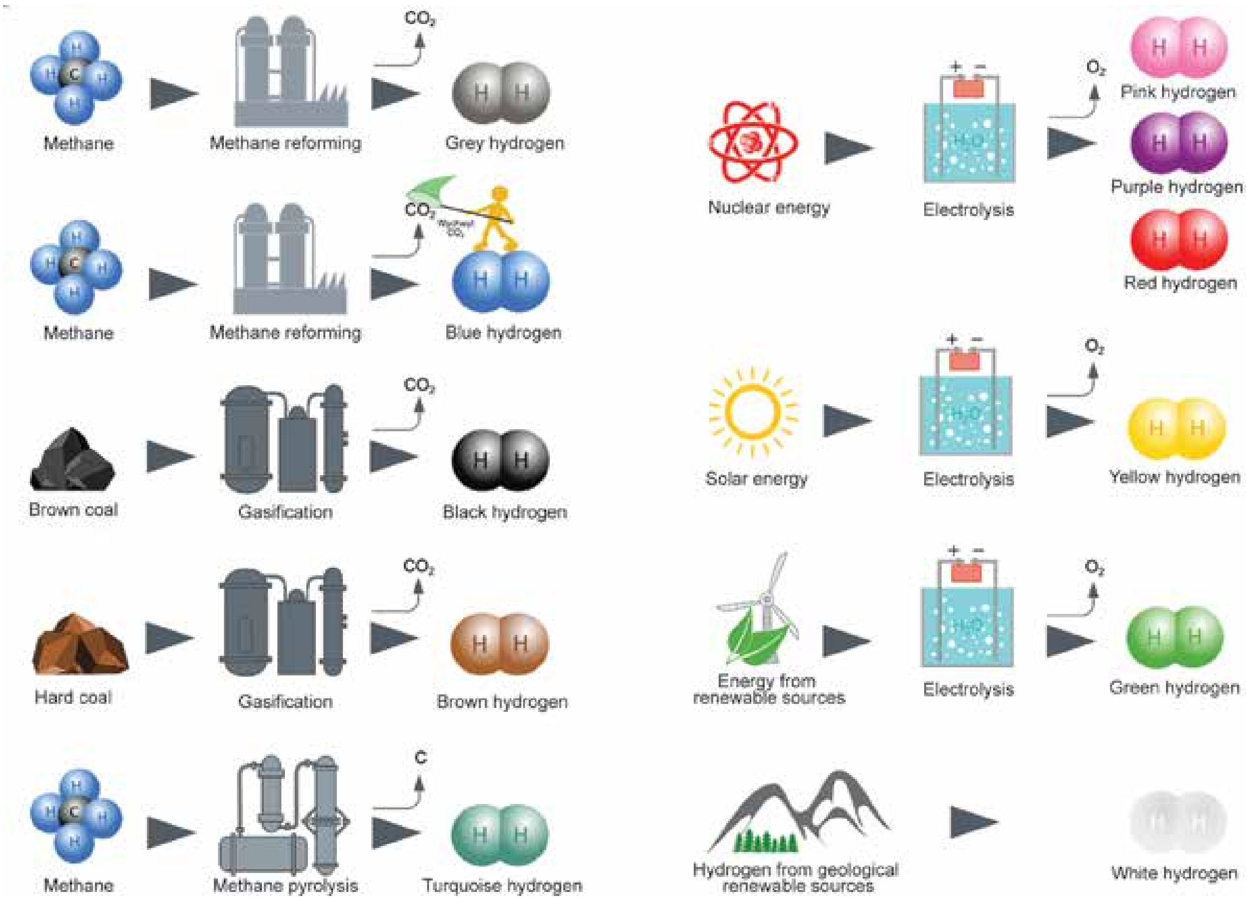
Green hydrogen is a sign of purity and sustainability. It is created using the electrolysis of water with renewable energy sources such as solar or wind. This process produces hydrogen without producing CO_2 or other pollutants, resulting in its unique green color.

Purple hydrogen is a form of hydrogen created with nuclear energy. The production process is difficult and requires modern equipment, resulting in hydrogen of extraordinary purity. The purple tint is frequently symbolic, reflecting its relationship to nuclear energy.

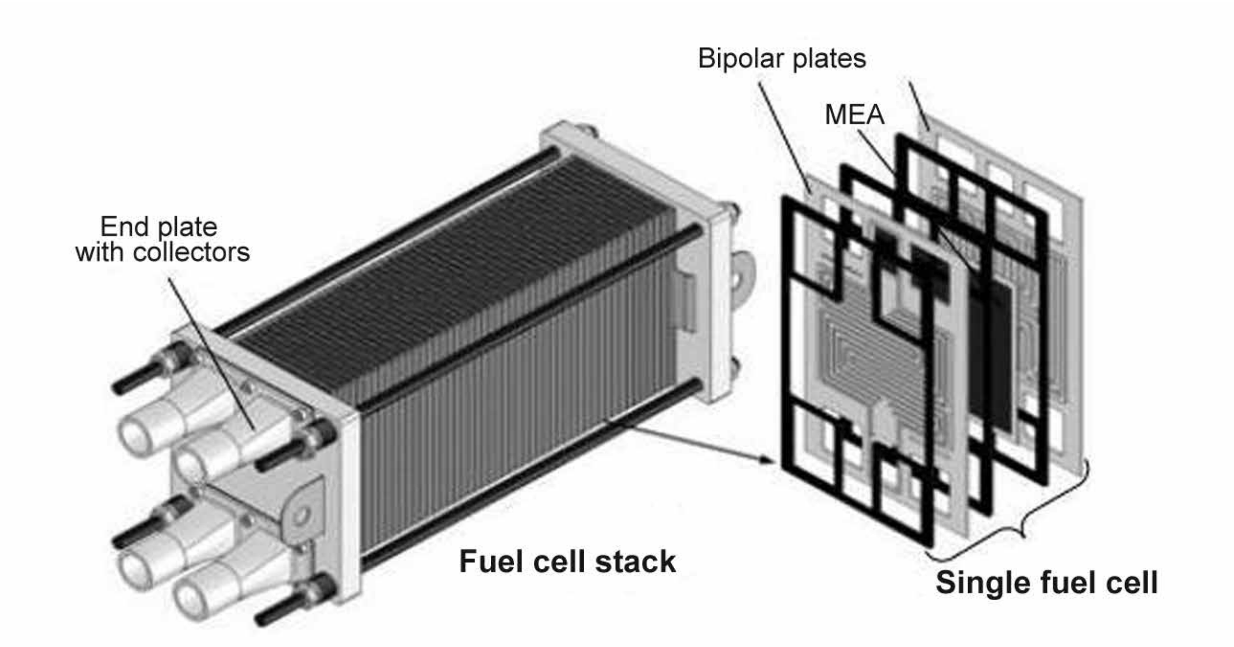
The term blue hydrogen refers to hydrogen created through steam or natural gas reforming. This method converts hydrocarbons from natural gas or oil into hydrogen, producing CO_2 as a byproduct. Despite its application in a variety of sectors, blue hydrogen is still linked to greenhouse gas emissions. Understanding how hydrogen is produced and its environmental impact necessitates a knowledge of its color spectrum. Exploring this diversity will provide us with insights into how hydrogen may have a huge impact on our planet's energy future.

Purple Hydrogen: The New Frontier of Sustainable Transportation

In the context of ongoing technological advancement, researchers and engineers are actively investigating unconventional methods to decarbonize the transportation industry. Purple hydrogen has acquired popularity in the world of sustainable energy activities and is seen as a viable path of exploration. The term „purple hydrogen" refers to hydrogen produced by nuclear energy. Electricity from nuclear reactors is used to electrolyze water, resulting in renewable hydrogen with no greenhouse gas emissions. Purple hydrogen is produced through thermonuclear fusion, a technology used in specialized nuclear reactors. This involves mixing light elements such as tritium and deuterium to generate enormous amounts of energy. It requires extremely high temperatures and pressures to function effectively. The energy produced during the fusion process can subsequently be used to split water into hydrogen and oxygen molecules using electrolysis. Hydrogen can be produced through the process of electrolyzing water, which utilizes the substantial amount of energy released by fusion to separate its hydrogen and oxygen molecules. Once collected, hydrogen must be cleaned and carefully stored to ensure that all impurities have been removed and that it can be utilized. Purple hydrogen research is still an active and growing area. However, because nuclear power needs complex procedures and high costs, its usage remains economically and technically challenging, despite its enormous promise. However, as a replacement for traditional fuel and energy sources, the benefits of producing purple hydrogen may stimulate more technological advancement in this field. The use of purple hydrogen for transportation may also provide new opportunities to reduce carbon emissions. Purple hydrogen, which is both powerful and clean, might power ships, trucks, cars, and other vehicles. The aviation industry,



Source: https://www.lafrentz.pl/aktualnosci-blog/180-wszystkie-kolory-wodoru



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where traditional propulsion sources present serious environmental problems, could undergo a radical change due to its potential.

Energy source of hydrogen vehicles

The fuel cell in a hydrogen-powered automobile uses electrochemical technology and operates on the „reverse" principle of water electrolysis. When electricity powers electrolyzers, hydrogen is created in the P2G (power to gas) process, whereas hydrogen gas is delivered to the fuel cell in the reverse G2P (gas to power) process. The fuel cell uses both oxygen and hydrogen to generate electricity. The anode, one of the fuel cell's components, receives hydrogen (H2) at the commencement of this operation. Hydrogen remains compressed or liquefied in the car's hydrogen tank, ready to react. A catalytic process converts hydrogen molecules into hydrogen ions (protons) and electrons at the anode. Protons travel through an electrolytic membrane, also known as a proton exchange membrane (PEM), while electrons flow through an external circuit to generate electric current. This current powers the vehicle's electric motor. In parallel, hydrogen ions traverse the electrolytic membrane and reach the cathode, where they mix with oxygen (O_2) molecules absorbed from the surrounding air. The only consequence of the electrode process involving protons, electrons, and oxygen is pure water (H_2O). Fuel cells are well-known for their high efficiency and purity throughout the process. They operate by converting hydrogen's chemical energy into electrical power. It is the essential attribute that makes hydrogen-powered vehicles affordable and environmentally sustainable.

Hydrogen Car – Green Alternative in Transportation

A fuel cell generator uses hydrogen and oxygen to produce electricity, which powers the electric motor of a hydrogen vehicle, also known as a fuel cell vehicle (FCEV). Hydrogen-powered vehicles have several distinct benefits over battery-electric vehicles. The range is by far the most significant advantage they have, which helps to counter the range limits that typically prevent people from buying electric vehicles. Furthermore, refueling hydrogen is more convenient for users because it requires less time than recharging batteries. One of the key benefits of hydrogen-powered cars is that they reduce carbon emissions. CO_2 and other atmospheric pollutants are completely eliminated. Furthermore, there are no emissions throughout the entire transportation process if the hydrogen is generated using energy from sustainable sources such as solar or wind power. Operating hydrogen-powered vehicles is quite similar to operating traditional gasoline-powered or electric vehicles. Users have access to all of the amenities and features provided in regular vehicles. The method of recharging with hydrogen is simple and fast. The operation is similar to that of refueling a normal combustible vehicle: the driver connects a hose to the vehicle's hydrogen tank, and high-pressure hydrogen (either H350 - 350 bar or H70 - 700 bar) is pumped into the tank.

Refueling is a simple and quick operation that typically requires three to five minutes. Another important feature of fueling with hydrogen is safety. The

Source: freepik.com

strictest safety standards are considered when developing hydrogen filling stations. At hydrogen filling stations, it is critical to provide consumer reassurance and safeguard them from any risks related with handling this type of fuel. The layout of hydrogen fueling stations, which are part of the infrastructure supporting the growth of hydrogen vehicles, complies with the highest safety standards. Hydrogen leak detectors are an important part of station safety for hydrogen refueling. The innovative devices are designed to detect even the slightest hydrogen leaks that may occur during filling or tank maintenance. These detectors immediately inform drivers and station personnel to any possible threat by sounding an alarm when a leak is detected. Furthermore, hydrogen refueling stations are precisely built to reduce the possibility of leakage while increasing security. Specialized materials and methods are used to ensure the installation's tightness and lifespan, lowering the risk of damage or failure. Personnel working at hydrogen filling stations play an important role in ensuring safety. When a fueling problem emerges, skilled staff closely monitor it and respond appropriately. Furthermore, they have gained the essential training and expertise to manage emergencies calmly while providing consumers with a safe environment.

Source: https://motofakty.pl/toyota-mirai-2019-oto-ii-generacja-auta-na-wodor/ar/c4-16278131

Hydrogen vehicles have the potential to significantly decrease greenhouse gas emissions and improve air quality, thus becoming the mode of transportation of the future. However, attaining their full potential necessitates increased government support, infrastructural expansion, and continued technical and scientific advancement.

M.Sc. Konrad Piotrowski*, Manager for Energy Projects Industria S.A.*

Cooling Systems for Thermal Power Plants

Characteristics, Current State, and Development Trends

Power plants based on thermodynamic cycles are typically either based on the water-steam cycle, for which the Clausius-Rankine cycle is used as a comparative cycle, or on the gas cycle, for which the Brayton cycle is used as a comparative cycle.

Tomasz Hanusek

INDUSTRIA Nuclear Solutions

The vast majority of thermal power plants (with the exception of simple cycle gas plants) are based on the water-steam cycle. Examples of such power plants include nuclear, coal-fired, combined cycle gas, oil-fired, or biomass-fired power plants. All of the mentioned power plants require a cooling system, which is responsible for condensing wet steam at the turbine outlet.

The parameters that determine the amount of heat extracted are the efficiency of the power plant and its capacity. Nuclear blocks have an efficiency of about 33-35%, while coal-fired power plants have efficiencies of about 35-45% (and higher). Therefore, a nuclear block with a given electrical capacity will require a more efficient cooling system than a coal-fired block with the same capacity.

There are two basic cooling systems:

1. Open-loop system - used for cooling with seawater, near large rivers, or lakes. In such systems, the cooling water passes through the condenser, and then, after being heated by a few to several degrees, it is discharged into the same reservoir (sea, large lake) or watercourse.

2. Closed-loop system - used in places where the availability of cooling water for open-loop systems is insufficient. It can be divided into various types:

a) Wet cooling, which can be further divided into two subcategories:
- Wet cooling using cooling towers or fan systems - in this case, the cooling water after exiting the condenser is directed into the cooling tower. There, the water is atomized and cooled by the upward movement of air. High hyperbolic cooling towers (or fan cooling towers) ensure airflow. As a result of this process, some water is evaporated (3-5%), so the evaporated water must be constantly replenished.
- The second possibility for wet cooling is the use of cooling ponds. These are artificial reservoirs created for the cooling of generating units. The cooling water is drawn from the pond and directed to the condenser for steam condensation. Then, the heated cooling water returns to the pond. Heating the water in the cooling pond causes it to evaporate, so the water in the pond needs to be replenished.

b) Dry cooling - this solution has two subcategories:
- The first, where the working fluid after exiting the turbine goes directly to an air-cooled condenser - called direct dry cooling.
- The second possibility involves the use of an intermediate loop - called indirect dry cooling.

For indirect dry cooling, cooling towers or fan systems can be used - similar to wet cooling. However, in the case of a dry system, the water entering the cooling tower does not have direct contact with the air - the water heated in the condenser goes to the cooling tower, where it passes through a heat exchanger cooled by passing air. The use of a heat exchanger prevents water evaporation.

One variant of indirect dry cooling is the Heller system. In such a system, the cooling water goes to the condenser, where it is atomized. In this configuration, the condenser is not piped. The cooling water is atomized in the same space where the steam exits the turbine. Therefore, the condensed steam and cooling water mix and return to the cycle as feedwater (about 2-3% of the working fluid) and to the cooling tower (respectively 98-97%).

In the context of closed cooling systems, it is worth mentioning that there are power plants with hybrid cooling systems. In such a configuration, they can be two separate devices, or they can be integrated together: within one cooling tower (or fan system) that has two sections: for dry cooling and for wet cooling. During cooler months, dry cooling is used, while during warmer periods, wet cooling is used.

In summary, cooling systems in thermal power plants can be divided according to the scheme presented in Figure 1. It should be noted that the diagram below does not include hybrid cooling.

All the above-described cooling methods have their advantages and disadvantages.

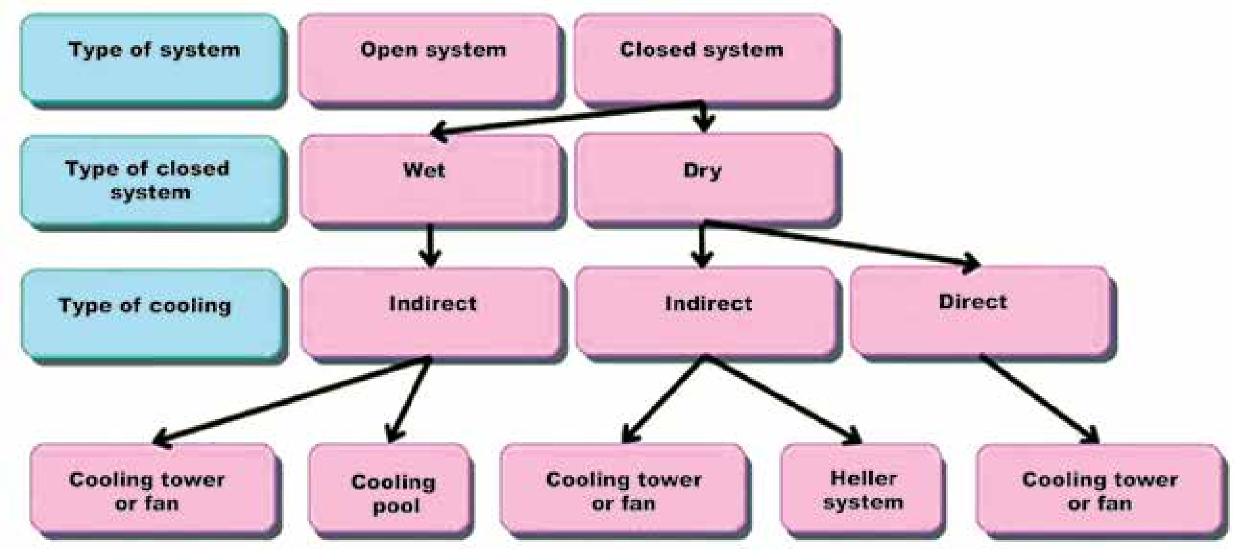

Figure 1. Basic cooling systems used in thermal power plants, based on [3]

Cooling with seawater in an open loop ensures lower cooling temperatures than other cooling systems, minimal temperature fluctuations throughout the year, and no issues with water availability. Lower temperatures mean higher power plant efficiency. The downside of this solution is the need to build the condenser with higher-grade materials - seawater is more corrosive than freshwater.

Cooling with freshwater taken from rivers or lakes carries several issues: the temperature of the cooling water will generally be higher than that of seawater, and fluctuations in freshwater temperature throughout the year will be higher than those in seawater. This is especially important during the summer, on days with very high temperatures. Firstly, the higher temperature of the cooling water may cause a deterioration of vacuum in the condenser, leading to a decrease in power plant efficiency and consequently a decrease in the amount of electricity supplied to the grid. Secondly, summer periods may be characterized by lower water levels, which potentially could lead to limitations in the withdrawal of cooling water. Attention should also be paid to regulations regarding the discharge of cooling water. An example is paragraph 13 of the regulation regarding the discharge of cooling water[4], which reads as follows: „Cooling waters from open cooling systems and closed cooling systems may be discharged into waters or into the ground provided that their temperature does not exceed 35°C." This entails further limitations, especially during periods of very high temperatures.

Regarding closed-loop cooling systems, they consume significantly less water than open-loop systems. In the case of wet cooling towers, they consume water in amounts corresponding to that evaporated during cooling. However, concerning dry cooling, they generally do not consume water for cooling purposes because it is not evaporated in the process. Due to the fact that air is the medium that absorbs heat in a closed-loop system, these systems are also prone to problems related to sufficient cooling during extremely high temperatures. Moreover, fluctuations in air temperature are generally noticeably greater than fluctuations in water temperatures in streams or bodies of water. Nevertheless, the amount of water needed for cooling is much smaller, as presented in Table 1.

Another important comparative factor of power plant cooling systems is their cost. In the publication „Power Plant Cooling System Overview for Researchers and Technology Developers"[6], a comparison was made for 500 MW coal-fired blocks. Several significant parameters were taken into account - one of them being the costs of these systems, which (in relative units) are presented in Table 2.

It is clearly visible how much lower the cost of an open cooling system is compared to other systems. This variant is about 2 times cheaper than wet cooling in a closed system and up to 10 times cheaper than dry cooling or hybrid cooling.

Figure 2 presents the number of generating units commissioned in a given decade in the United States, broken down by cooling system. The data comes from publications from 2017, so the last bar (2018 - 2022) was only a forecast at that time. To observe the change in trends in cooling systems, it was decided to present data from the United States, which has a large number of generating units and is therefore well suited for statistical purposes.

Figure 2 shows that in the 1960s and 1970s, many generating units with an open cooling system were commissioned. However, starting from the 1980s, their share in newly commissioned generating units decreased significantly. At the same time (except in the 1960s), the most commonly used system was a closed, wet

Table 1. Cooling water demand for different cooling systems [5]

Type of power block	*Cooling system*	*Cooling water demand, l/kWh*
Coal/biomass	Open loop	76–189
Węglowy/biomasowy	Closed loop wet	1,89 - 2,27
Coal/biomass	Dry cooling	0
Nuclear	Open loop	95-227
Nuclear	Closed loop wet	3-4,16
Nuclear	Dry cooling	0.0

Table 2. Comparison of cooling system costs for 500 MW power plants [6]

Type of cooling	*Cost of cooling system in relative units*
Wet cooling in a closed system	1,0
Cooling in an open system	0,4 - 0,75
Dry cooling in a closed system	2,4 - 5
Hybrid cooling	2 - 4

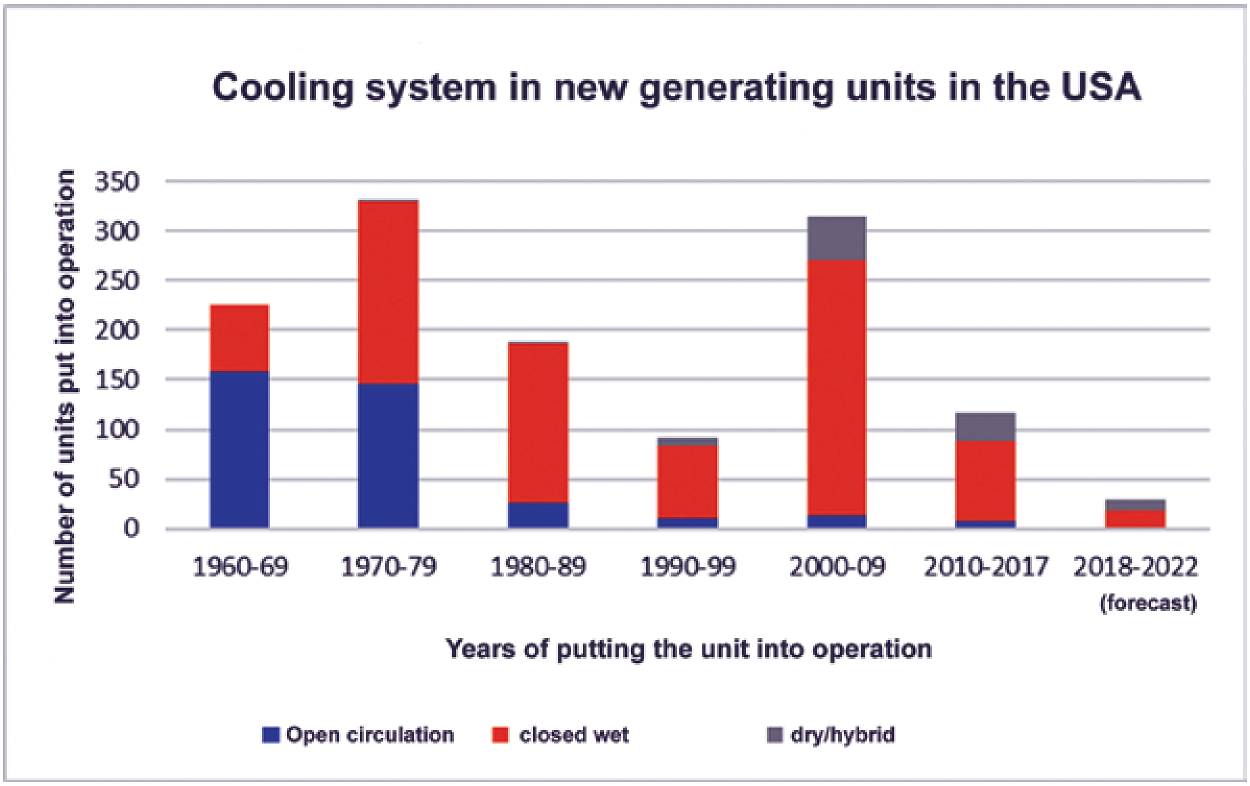

Figure 2. Number of new generating units put into operation in a given decade in the USA, broken down by type of cooling system [7]

cooling system. The discharge of heated water by several or a dozen meters into the river affects the flora and fauna living there. In order to reduce the impact on the environment, in many places, including the USA and Europe, as a result of legal changes, closed cooling systems began to be used more often - hence the significant decline in open circuits since the 1980s. Importantly, in order to further reduce water consumption, hybrid or dry systems have been successfully used. Starting from the beginning of the 21st century, they began to be used more often than open systems, as shown in the chart below.

In the context of the need for high water availability in the case of open systems, it is worth paying attention to surface water

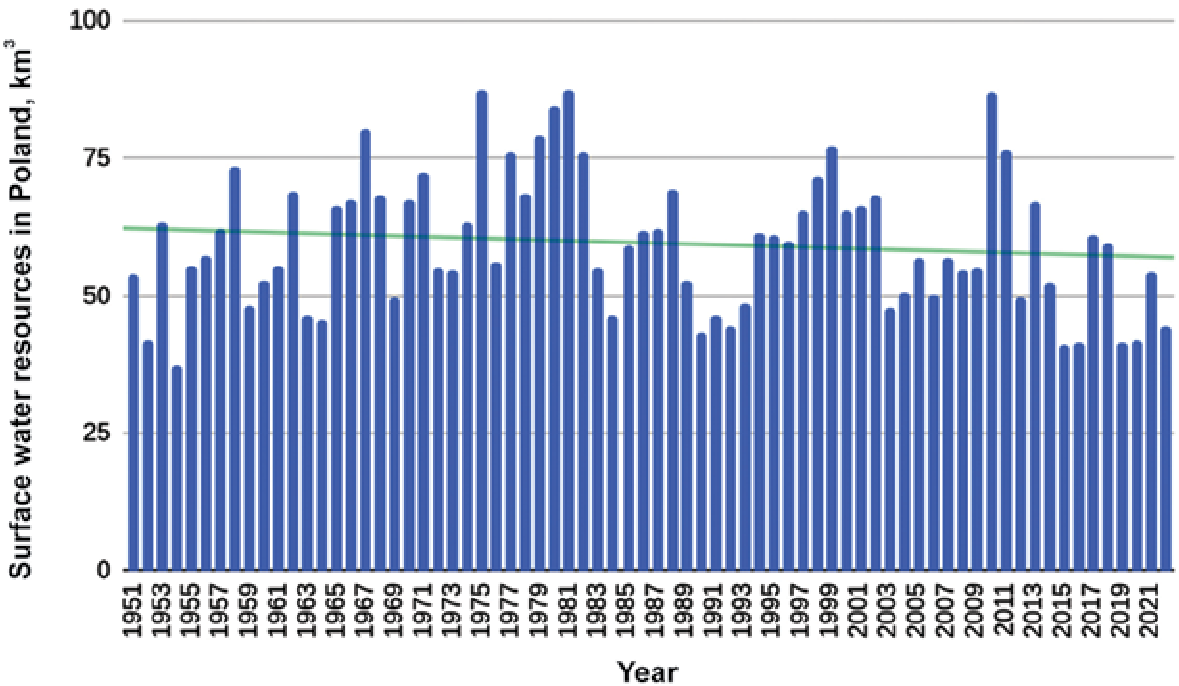

Figure 3. Surface water resources in Poland in 1951-2022, based on [8]

resources in Poland, which are presented in Figure 3. It can be seen that for the last 70 years, there is a downward trend (in green on the chart), from approximately 62.2 km^3 to 57 km^3, which means a decrease of approximately 8.3%. Therefore, the use of cooling systems requiring less water or no water at all seems fully justified.

In addition to issues broadly related to reducing the environmental impact of cooling systems, another significant consequence of using low-water cooling systems is the availability of more locations. This could potentially reduce the need to build long extra-high voltage lines.

In the case of the heat market in Poland, potential new locations of generating units with relatively small cooling needs may be an opportunity to build new heat and power plants or expand existing ones. Hybrid or dry systems are used primarily in places where water availability is very limited.

To sum up, the method of cooling a power plant depends on many factors, such as environmental conditions and the availability of cooling water. On the other hand, it is an important factor when choosing the location of a power plant, because it may exclude certain locations and significantly affect the profitability of the investment, which is the construction of a generating unit.

Tomasz Hanusek, *Industria S.A*

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Phenomena of pressurized water reactors

Sustainable energy supply is one of the most critical factors of economic growth. However, in today's highly polluted world, fueled by the products of fossil fuels, clean energy has become an unquestionable priority. Nuclear power offers carbon-free energy, is the most efficient energy source, and plays a vital role in the world's energy supply.

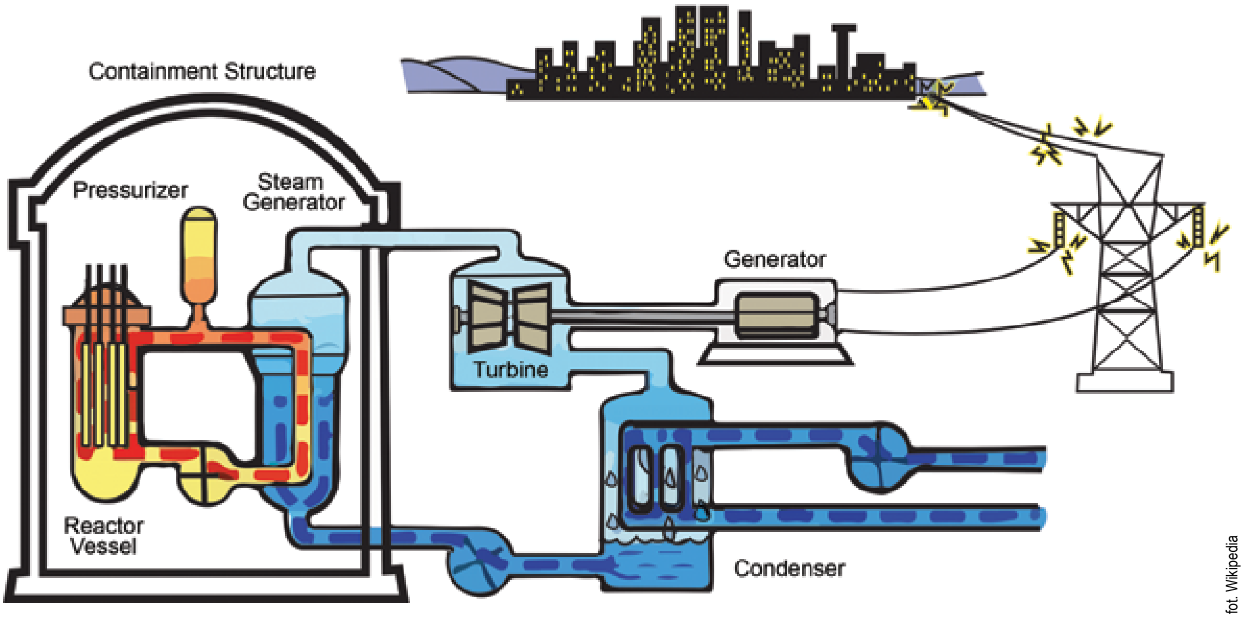
Katarzyna Zasadni

WOMEN IN NUCLEAR POLSKA

According to the International Atomic Energy Agency information system, 413 large nuclear reactors are currently in operation, and 58 new units are being constructed worldwide. The majority of operating units represent light water reactors with 304 units of Pressurised Light-Water Moderated and Cooled Reactor (PWR), and 41 units of Boiling Light-Water Cooled and Moderated Reactor (BWR). Analogically, Light water reactors also represent the majority of units under construction, with 49 PWR and 2 BWR units. Water is a cheap, abundant, and very effective reactor core coolant. Water is also an efficient neutron moderator, which, with specific chemical additives, can suppress fission reactions in the core to control reactor power. Therefore, it is unsurprising that light water reactors have been the number one choice in nuclear energy technology. Both PWR and BWR are considered good technologies with pros and cons. However, PWR operating units outnumber BWRs significantly, with an increasing tendency for units in the construction phase. Poland is also planning to build two large nuclear power plants of PWR technology to be delivered by different suppliers; why those are not BWR units? There could be several potential reasons that can explain the phenomenon of PWR technology application, including operation and maintenance, safety, supply chain matters, and expertise. Let us start with a general comparison of the main differences between those technologies. However, we must remember that several PWR technologies have technical differences, resulting in more reliable, operational, or safety-oriented solutions.

In general, PWR and BWR reactors are very similar in many technological aspects, and they are both primarily meant to produce the steam needed to spin turbine generator blades for electricity production. The thermal energy from the steam is changed inside the steam turbine into the mechanical energy used to generate the electricity. In both plants, cooled steam is next condensed, polished in high-efficiency demineralizers, reheated, and pumped back into the reactor pressure vessel (RPV) to repeat the cycle. The main difference between PWR and BWR reactors lies in the steam generation process. In BWR, the water heated by the reactor core boils, producing steam directly inside the RPV. So, in this reactor technology, only one loop cools the reactor, acts as a reactor moderator, and powers the turbine. Since the water is allowed to boil inside the reactor, the pressure of the cooling circuit can be kept at a lower level, reducing the need for a pressurizer and other components. A decreased number of primary circuit components lowers the capital costs of the power plant. In the PWR unit, a secondary circuit separates the reactor cooling circuit from the turbine. Here, the water heated by the reactor core is kept under higher pressure to prevent it from boiling and a pressuriser maintains that pressure. The water heated to over 300°C is pumped into steam generators where it can pass its heat into the secondary water circuit, changing it into steam.

The primary and secondary circuits do not mix in steam generators; therefore, the secondary circuit and, consequently, the turbine are free from the contamination with fission products. In a radiological sense, the turbine generator in a PWR unit does not differ significanty from a conventional power plant turbine generator. It does not need to be directly adjacent to the reactor and is fully accessible during the operation without extra radiation control and protective measures. The turbine generator and, possibly the condenser in BWR units can be subject to contamination with short-lived fission products carried with the steam from the reactor in case of a leak in the reactor core. The possibility of such a risk induces several additional necessary safety measures. In BWR reactors, the turbine belongs to the controlled access zone and is located adjacent to the reactor. The turbine hall is also not accessible during plant operation, and for a short time after, so additional radiation shielding is required in this area. However, the expected fission products have a very short half-life (counted in seconds), so entering this area is allowed after that time. Applying steam generators in PWR units

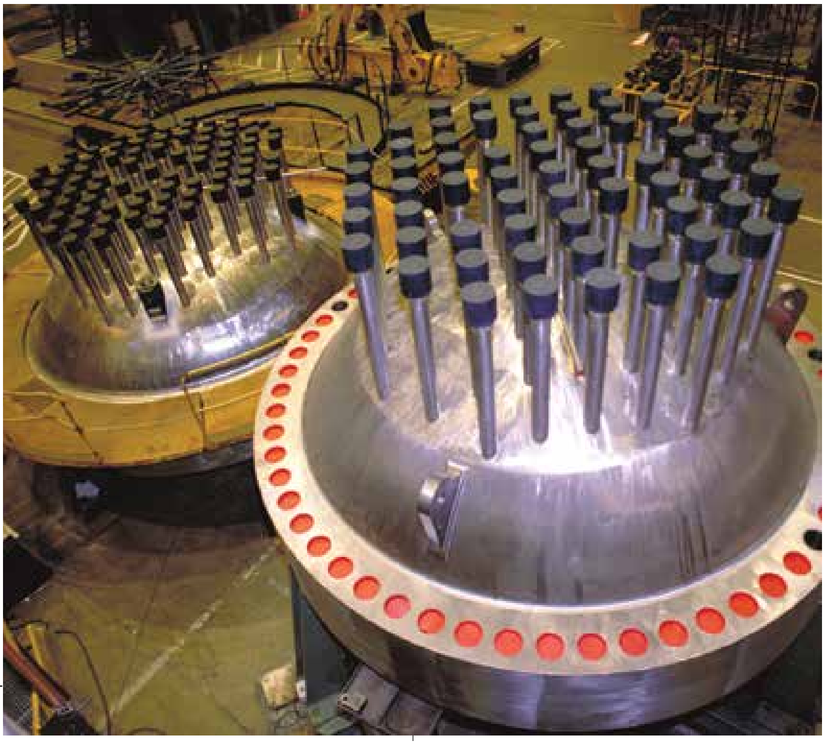


Pressurized water reactor (PWR)

enables the cooling water quality to be maintained separately and precisely adjusted to the conditions of the reactor and turbine side. For example, a portion of the secondary circuit water-steam mixture is continuously blown down for quality check and purification to be returned to the secondary cycle. The system responsible for that activity serves as a primary cleaning tool of the circuit, leaving condensate demineralizers for specific use only.

BWR reactors use UO 2 fuel similar to PWR units, but BWR fuel assemblies are smaller. Then, BWR's RPV is larger than the PWR unit's. Another difference between the two types of reactors involves the reactivity control. PWRs use mainly boric acid for reactivity control; the acid needs to be dissolved in the primary circuit, and therefore, it needs to be dosed during operation. Boric acid dosing must be carefully controlled because this compound is quite corrosive for the steel components, lowering water pH. Therefore, pH needs to be regulated carefully with additional alkaline additives, which makes the chemistry regime a critical feature in this technology. However, boron delivered with boric acid is a very efficient medium for neutron capture and is also applied for emergency injections in both reactors. Boric acid cannot be used for reactivity control during normal operation of BWR units. It would not be sufficiently effective in the steam bubbles environment of RPV because it needs water to dissolve. The reactivity in BWR units is controlled by other means, including burnable poisons, control rod movement, and coolant flow control in the higher load range. So, the BWR reactor should be capable of load following more flexibly in the upper load range. The process of forming steam bubbles and steam drying in the upper part of RPV is why control rods in BWR must be located at the reactor's bottom. There is no such requirement in the PWR plant, and control rods can be inserted from the top of RPV, although they are mainly applied for startups, shot downs, power level change control, and transients.

Now, let us analyze some of the consequences of harsh conditions created in those reactors during the operation to realize some hidden differences. Typically, nuclear reactors are designed for 60 years of operation. It means that many systems and components used there will need to serve that time without being changed unless they fail. The aging, wear out, and corrosion of the material can be a big problem in this case, leading to serious accidents and unforeseen costs. The reactor's working conditions do not make it easier, considering that the coolant temperature in discussed light water reactors is around 300°C. Demineralized water is used as a coolant to decrease the likelihood of corrosion, but stress corrosion cracking is a problem still encountered during the operation of existing plants. The oxygen content is a significant factor in corrosion development. Proper water chemistry is the precondition for plant long-term operation, free from corrosion incidents encountered in the operational experience of both BWR and PWR reactors. In the case of BWRs, the stress corrosion cracking of steel piping, leakage or radioactive material from fuel cladding, high occupational radiation doses, and tendency to intergranular stress corrosion cracking (IGCC) were revealed in so far operation. PWR has also experienced some problems, especially concerning primary circuit and stress corrosion cracking in steam generator tubes and welds, that resulted in additional protection measures for steam generators. Therefore, the water chemistry adjusted to plant operation states is crucial in preventing those issues.


fot. Wikipedia

PWR Reactor Vessel Heads

Some PWR units apply zinc injections for corrosion control, and in general, the alkali additives are used to eliminate the oxygen from the water. The oxygen can be eliminated thanks to those additives and the effect of hydrogen dosing due to radiolysis. There is also ammonia dosing to support hydrogen and reduce dissolved oxygen; lithium used in pH stabilization or hydrazine applied in Russian pressurized reactors (VVER). On the other hand, BWR reactors operate on high-purity water with hydrogen water chemistry, zinc injections, and noble metal applications on reactor internals and piping. These measures are meant to address the above deficiencies expressed by cases of IGCC and higher radiation doses.

As can be seen, there are many differences in those similar light water technologies, and going even deeper into their details will reveal many other specifics of each technology. Further details and specifics of each technology solution will only be the consequences of their principal differences specified earlier. Now, based on the above technical differences, let us try to formulate some conclusions, possibly affecting the amount of PWR plants being operated and built:

- PWR plants use abundant and cheap light water as a coolant, moderator, and energy carrier.
- Using two circuits, PWR reactors contain all potentially radioactive fluids that may occur during operation within the reactor plant. This decreases the risks of radioactive contamination, keeping the turbine free from fission products and fully accessible. The staff expertise from conventional turbines is relevant for PWR nuclear power plants.
- Control rods in PWR units are placed on the top of the reactor pressure vessel, similar to most other nuclear power plants. So, in case of a power loss event, they can be fully inserted by gravitation (this argument could also be questioned as the power of the bottom inserting pneumatic mechanism will be more reliable in case of clogging).

The secondary circuit is free from contamination, so the cogeneration heat for use in other industries or district heating could hypothetically be taken from any part of the loop without the need for additional separating circuits.

The above conclusions are reasonable enough arguments to justify the most significant number of currently operated PWR units, but it is doubtful they are enough to justify the increasing factor of constructed PWRs and nearly no competition in the number of future planned units. Looking at 3 important accidents in the history of nuclear power, there is no conclusive pattern to apply. Three Mile Island accident that happened 45 years ago involved PWR, the Chernobyl disaster that occurred 38 years ago happened to a boiling water reactor moderated by graphite, and the latest Fukushima accident involved BWR. The fact that Fukushima was the latest event may impact the general population's feelings about the technology, but in reality, the most significant impact comes from the operating practice. PWR reactors are the most deployed technology worldwide, meaning they have the most extensive operating experience and lessons learned to qualify the technology as the most mature. The increasing factor of constructed units only confirms this tendency, broadening a large pool of suppliers, experienced contractors, and component manufacturers. Consequently, PWR technology is an excellent option for new nuclear power plants, especially in newcomer countries like Poland without nuclear power experience. Let us not forget the construction site experience from recently constructed PWR units such as Olkiluoto 3, where Poles were the largest group of foreign workers.

To conclude, PWR technology has all the cards to be and remain a leader in nuclear energy, especially if no game-changing discoveries in the energy field are expected on the horizon. New nuclear technologies and changes in nuclear power applications have great potential. However, as long as they do not offer significant cost reduction and reliability benefits, they must wait to prove their worth during a few decades of operation.

Katarzyna Zasadni, Senior Lead Engineer, Pallas reactor, Netherlands

Benefits of Rolls-Royce SMR building in the Świętokrzyskie Voivodship

All population forecasts predict a significant decline in Poland's population to 30,4 million people in 2060[1]. Unfortunately, these data indicate that the biggest utmost population decline will occur in the Świętokrzyskie Voivodeship. Analyses show that over the next 11 years the population in Kielce city will reduce to nearly 27 000 people[2]. Regrettably it will be an mainly outflow of people one the working age group of 25-45. One of the reasons is fact, that the Świętokrzyskie Voivodeship is characterized by one of the lowest rate of economic innovations. The low level of outlays for research and development activity leads to a small amount of innovative enterprises. All of this translates into one of the lowest competitiveness' indicator for the region on the European scale. In 2022 it was 187th place among 235 region of the European Union (among the 235 European Union's regions)[3]. What can be done to stop such dangerous trend of depopulation in the region and also stimulate it development.

Sławomir Malara

INDUSTRIA Nuclear Solutions

The answer is industrialization of the Świętokrzyskie Voivodeship. Locating here huge & large factories and business will ensure jobs and a magnet not only for remaining but also for migrating to this area. There is no „strong" industry without investment in research and development activities, so industrialization will ensure an increase in expenditures in this sector. However for this to happen, a factor which attracts investors is needed. Stable, reliable, low-emission sources of electricity and heat with the possibility of hydrogen production SMR (small modular reactor) is just such magnet.

Building SMR units in the Świętokrzyskie Voivodeship with Rolls-Royce SMR technology gives not only opportunity for industrial development but also offers many other benefits. The first basic one is tax revenue. Estimated data allows to determine that the direct tax revenues during the operational stage of SMR (two units) will amount to approximately 100 million PLN annually. It is necessary to note that the operational period is at least 60 years. This sum includes anticipated revenues from personal income tax (PIT) of employees, corporate income tax (CIT) and property tax. These revenues will be distributed according to the following key:

- Municipality where SMR is located, adjacent municipalities, other municipalities in the region where employers of NPP are registered: **17.3%**
- Kielce county: **4.3%**
- Świętokrzyskie Voivodeship: **10.4%**
- State Treasury: **68%.**

According to the data provided over 17 million PLN annually will be allocated solely in municipality where SMR will be located and other municipalities for at least next 60 years. Whereas the total revenues for the Świętokrzyskie Voivodeship, Kielce county and municipalities amount to approximately 32 million PLN annually also for at least the next 60 years.

The increase in tax revenues to the multicipal budget as well as budgets of all levels of the local governments, will enable these authorities to meet their expenditure needs and actively stimulate new investments and economic activity. This includes financing necessary infrastructure, development the lands for investitions and vocational training. These revenues will be not one-off but will be continued throughout the entire operational period of the power plant, which provides a tremendous opportunity for the stable, planned development of the whole region.

Another benefit associated with the construction of SMRs is related to migration processes driven by the need to provide an expanded workforce.

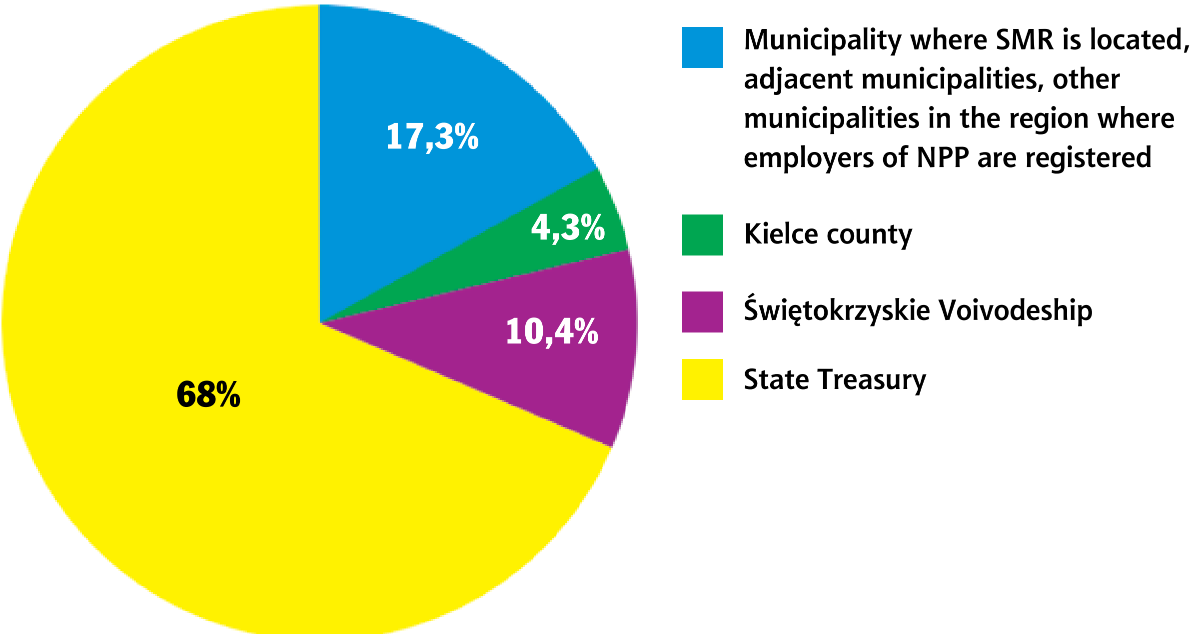


Chart 1. Distribution of income from personal income tax (PIT) of employees, corporate income tax (CIT) and property tax

Table 1. Estimated Number of Workers Involved in the Project Implementation and the Significance of Inflow Processes

	Number of workers	*Possible share of inflow workers*	*Settlement character*
CONSTRUCTION STAGE	1000	(60-80%*)	Mostly **temporary**
OPERATION STAGE	~ 600	(50-60%*)	**Permanent,** potential settlement with families

The construction and commissioning of a small modular nuclear power plant using Rolls-Royce SMR technology takes approximately 4-5 years, including an additional 2 years for preparatory work on the plant site. Concurrently, work on accompanying infrastructure will be carried out. It is estimated that during the construction of one unit, approximately 500 people will be employed, while during operation, around 300 workers will be required. Assuming the construction of two units and based on experiences from other nuclear power facilities (such as Hinkley Point C, Sizewell B, and Flamanville-3), it can be assumed that the percentage of migrant workers will be between 60-80% during the construction phase and 50-60% during the operational phase.

At the current stage, it is not yet possible to determine the detailed strategy for the employment of labour and staff, including the precise share of local workers in the employment structure. Despite this, it can be assumed that the construction of SMR units will lead to the permanent settlement of hundreds of people, often with their families. It will be particularly beneficial in the context of the demographics of the Świętokrzyskie Voivodeship.

Employing workers in the construction and operation phases stimulates the local economy and service sector. Based on analyses of other nuclear power projects, including Sizewell B and Flamanville-3, it is assumed that:

- Local suppliers from the region may cover orders of up to 2-4% of the value of construction costs at the construction site[4]. Due to the modular nature of the Rolls-Royce SMR, this coefficient may be lower than in the aforementioned NPP in France and the United Kingdom. Nevertheless, even if it remains at the level of 1%, it will still represent orders in the region worth millions of PLN.
- New workplace will be created, approximately 300 additional jobs outside the power plant itself. They will be related to the stimulation of the local economy and the service sector due to the inflow of workers for the construction and operation of

photo: Patryk Ptak Photography

the facility. According to the data, the so-called "indirectly created jobs" may constitute up to 60% of the number of jobs needed during the operation of the power plant[5].

- Inflow workers (both during the construction and operation stages) will spend a significant portion of their earnings locally (accommodation, utilities, food, services, etc.). Taking into account both the scale of expected settlement processes (hundreds of people, often with families) and their significantly higher earnings than the national average, this will have a significant impact on the local economy.
- Each Rolls-Royce SMR will require regular refueling and maintenance outages during operation. Based on experience from existing NPP usually it is done in 18- or 24-months periods and take from 9 – 25 days. During these refueling and maintenance periods, an increased number of workers will be employed on-site at the nuclear power plant (NPP) – For gigawatt scale plants the International Atomic Energy Agency suggests employing up to 1200 people during such outages. This is confirmed by industry practice - for example, EDF Energy assumes an average of 1000 people for outages at Hinkley Point C. Such a large number of workers will generate a significant increase in demand for services in the region during their stay.

The presented data became significant when we applied to the Świętokrzyskie Voivodeship, particularly to Kielce County. Creating a total of approximately 800 jobs directly and indirectly over a 60-year period of power plant operation will significantly reduce the number of unemployed individuals and will also have an impact on the revenues of the local community. For comparison, in absolute terms, the number of unemployed people in Kielce County and the city of Kielce in July 2023 was 8,500. The new job opportunities, based on the assumptions presented in Table 1, will reduce this ratio by over 6%.

The placement of Rolls-Royce SMR units will also involve the construction or expansion of concomitant infrastructure, such as transportation, electrical, or sanitation infrastructure. The scale of the necessary projects is closely related to the final location of the facility, i.e., its distance from existing infrastructure. The Rolls-Royce SMR technology is fully adapted to transport all necessary components by road for the construction of the nuclear power plant. It is essential to provide suitable transportation routes for both heavy construction transport and future power plant workers. Additional modernizations will also bring benefits to local residents, such as bicycle lanes, pedestrian sidewalks, and bus stops. This is also associated with an expanded transportation network between the target location and major cities, such as Kielce. Depending on the location, this may involve not only the expansion of the road network but also the railway network, which will be advantageous for the surrounding residents. The investment will also require the expansion of the local power infrastructure, due to the need for high-voltage and extra-high-voltage lines, as well as power substations in close proximity to the location boundaries. All of this will enable the transmission of electricity from the SMR to the National Power Grid. Making the necessary investments will be beneficial for the region, as it will provide an impetus for the modernization of existing or the construction of new power grids and substations. This will improve the availability of the grid for potential industrial and service facilities, making the region suitable for energy-intensive industries.

Similarly to the expansion of transportation and power infrastructure, the sanitation infrastructure must also be adapted to the needs of the power plant construction. As in previous examples, this will improve the living conditions of local people.

It should also be noted that the investment in building SMR units will significantly impact the economic activity in the region. The influx of workers will necessitate investments in housing, the hotel industry, catering, and services sectors.

The implementation of the nuclear power plant construction investment is associated with significant human resource challenges at every stage of the project - from the preparatory-permitting period, through construction, to reactor operation. One of the measures towards ensuring the investor's readiness in this area is cooperation with university and school centers, as well as the supervising state authorities. In the region, there are only two public universities (Jan Kochanowski University in Kielce and Świętokrzyska University of Technology in Kielce) and 10 private universities. In total, universities and their branches are located in 6 cities in the region, with approximately 90% of all students studying in Kielce[6]. Collaboration with universities in Kielce to launch dedicated courses of study (or at least specializations) focused on employment in the planned power plant would help reverse the declining trend in interest in their educational offerings. According to data from the Central Statistical Office (as of the end of 2022), only 21.6 thousand people were studying in the Świętokrzyskie Voivodeship, which accounts for 1.8% of the total number of students in the country. This places it as the third lowest result among all voivodeships (only fewer students are studying in Lubusz and Opole voivodeships)[7]. At the same time, there is also a problem of decreasing student numbers and the associated pressure to close universities. For comparison, in 2008, there were 25% more universities (15) operating in the voivodeship, and the number of students was more than twice as high[8]. The creation of stable and well-paying jobs in the immediate vicinity of universities that educate in these fields will certainly encourage future students to choose these universities.

The described benefits associated with the construction and operation of a nuclear power plant using Rolls-Royce SMR technology in the Świętokrzyskie Voivodeship are not the only ones. It should be remembered that the construction of SMR units would become a flywheel for industrial development in the region. Providing clean, stable, and reliable electric and thermal energy, with the simultaneous possibility of hydrogen production, would become a magnet attracting both Polish and foreign investors. A special economic zone would be established in the immediate vicinity of the power plant. Factories and businesses would directly utilize the produced energy. Therefore, the construction of a stable and emission-free energy source such as SMR in the Świętokrzyskie Voivodeship becomes a remedy for the dangerous depopulation trend and an extraordinary opportunity for the region's development.

Sławomir Malara, *Deputy Director of the SMR Program*

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Interview with the Mayor of the Choczewo commune, Wiesław Gębka – interview by Aleksandra Niemczyk

Indication of the benefits in the commune and presentation of the process, PEJ

The first nuclear power plant in Poland is to be built in the Choczewo commune - in the Lubiatowo-Kopalino location. We talk with Wiesław Gębka, mayor of the Choczewo commune, about the investment and its importance for the local environment.

Wiesław Gębka

Do you believe that thanks to this investment, the Choczewo commune will become one of the richest in Poland?

Certainly, when this investment is completed, we will be a wealthy commune.

Are you convinced about this investment and are you glad that your commune was chosen as the location of the power plant?

I don't know whether to be happy or not. It is a beautiful commune, but this investment will devastate it. On the other hand, it will offer huge prospects. This is not easy. When the power plant is built, it will definitely be different.

What made you choose Choczewo as the location of the power plant?

It is known that the cheapest power plants are by the sea, which is why this location was chosen because there were no other better ones in this area. In such situations, we also look at the number of inhabitants, population and social acceptance.

Here, in Żarnowiec, a power plant was already being built and society accepts such investments because people remember those "prosperous times" when that power plant was built, but in the end it was not built. These are the most important arguments: acceptance by society and location by the sea.

The construction of the power plant will take approximately 10 years. To what extent do you think this will impact the local labour market and how?

In the initial phase, the greatest number of reinforcers and concrete workers will be needed - we do not have such a number of employees, it may even be difficult to gather specialists throughout Poland - so as not to disrupt many projects. So there will definitely be many visiting workers from all over the world.

Currently, wind stations are being built in our country - this is the next big investment that will guarantee the same amount of electricity produced as the nuclear power plant. So we have two such large investments.

When it comes to the economic aspect: this will certainly be a time of great changes for us and people will live richly thanks to this.

How will this investment translate into indirect jobs and the development of industries such as trade, catering, and accommodation?

We are fighting for accommodation. This is a big "pie" and everyone would like to make money here, and we believe that we deserve it.

Likewise, these 10 to 12 thousand employees will have to be fed - companies will certainly guarantee them lunches. We would like to build a big kitchen and cook for all these people. We will certainly strive to make this our task and give us a sort of "compensation" for the destruction of the commune and its transformation into an industrial commune. It must be remembered that these two large investments (note: nuclear power plant, windmill stations) mean that our small commune will produce 30 percent of the demand for the entire country.

Can you indicate how many people in total will be involved in the construction of the power plant?

Our companies can be subcontractors or they can transfer employees, which is what we fight for with every investment. I cannot determine what scale of employment we are talking about, but it is not only about employees from our commune, but about people from the entire voivodeship and from Poland.

How much land will be allocated for the power plant?

Approximately 150-190 hectares will be allocated for the needs of the power plant itself, and 330-335 hectares of forest will be cut down. After the facility is built, part of the area will be reforested. Because the construction site requires space for storage and other things, a larger area will be allocated for this purpose during construction, and a smaller one after the construction of the power plant.

And how much will the road and railway infrastructure change? Is the construction of new roads or railway lines planned?

The General Directorate for National Roads and Motorways is certainly already designing the road through Łęczyca from the construction site. When it comes to railways, there are a few controversial points, but PKP also has its own concept. While we have reached an agreement with the General Directorate, the remaining roads are very problematic, some are not prepared for such heavy traffic. The drama will be on the "internal" roads, which will be demolished. We proposed to create a fund so that after the power plant is built, it will be possible to improve it - there will be these types of problems and it will not be easy. That is why we want to create a special fund so that the government will guarantee funds for renovations after these roads have been devastated.

The most measurable benefit will be taxes paid to the local budget, how much can these amounts be?

It's hard to know when it comes to energy investments because some things are not taxable.

I think that the investment will cost about 150 billion PLN: 1 percent will remain for the commune, 1 percent for neighbouring communes - this is in the act, part of the tax will have to be paid, but it will definitely be a lot of money.

We were in similar communes in the west. In October they still have millions of euros left - they have a problem how to spend it. We would also like to take over water from cooling to heating. We suggested that we should think about this in the project, so as to build a heating network within the commune or even further, and there would be no need to pump water into the Baltic Sea, because we would use it that way.

Unlike commonly used non-renewable sources, nuclear energy is produced with almost no emissions of harmful pollutants, such as carbon dioxide or other gases, into the atmosphere. Unlike, for example, wind energy, a nuclear power plant produces less noise, making it less burdensome for residents of areas located in its immediate vicinity. What other environmental advantages can you point to?

It is certainly incomparably more attractive for everyone and for the environment. Nothing better has been invented. The most important thing is that it can be easily controlled, because windmills cannot be controlled. A nuclear power plant certainly has many advantages, except that its biggest disadvantage is that it is large and ugly.

Are you not afraid of contamination in the event of a failure of such a power plant?

If there were any failures, they were minor, a consequence of design errors or the stupidity of those who performed the experiments. It must be remembered that the technical issue is the most important here.

After the nuclear power plant disaster in Fukushima, no one conducts experiments anymore, conclusions were drawn so that humans should not control it, automatic safety was developed. A second tank was added under the reactor, which will turn off everything at the right time, there will be no chain reaction and there will be no explosion.

Scientists have drawn conclusions, so I am not afraid of it.

How will the problem of hazardous waste generated at this power plant be solved in the commune?

In the same way as in any other power plant. It will be stored on site, and after years it will be transported to specially created landfills.

There will be containers prepared for waste, which will "wait" here until transported. There are such places all over Europe: Finland, Sweden, and they can be stored there without any problems, but I think that sooner or later such landfills will be built here, because someone will be interested in making money from it.

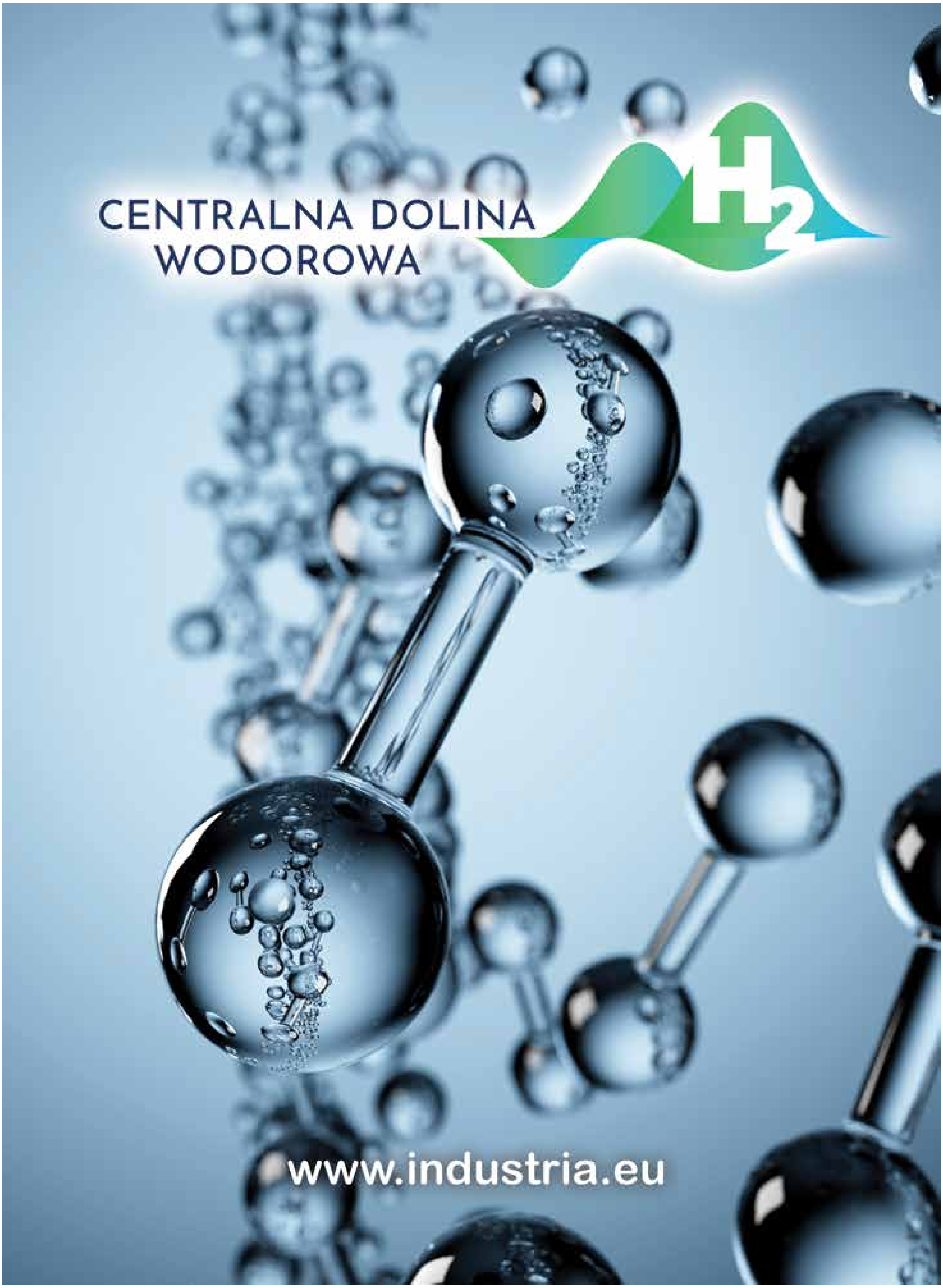
At what stage is the entire investment currently?

For now, the technical infrastructure, i.e. roads, railways and a pier, must be prepared to accommodate large dimensions.

Currently, it is being cut down for research purposes - a forest, on plots of 20 - 30 hectares.

By the end of 2026, a part of the road to the provincial road was to be built by the General Directorate for National Roads and Motorways, and a railway from Wejherowo to Łeba and from Lębork to Łeba. It's supposed to be a loop. We'll see - but we know that at this point there are already a year or two delays.

Thank you for the conversation.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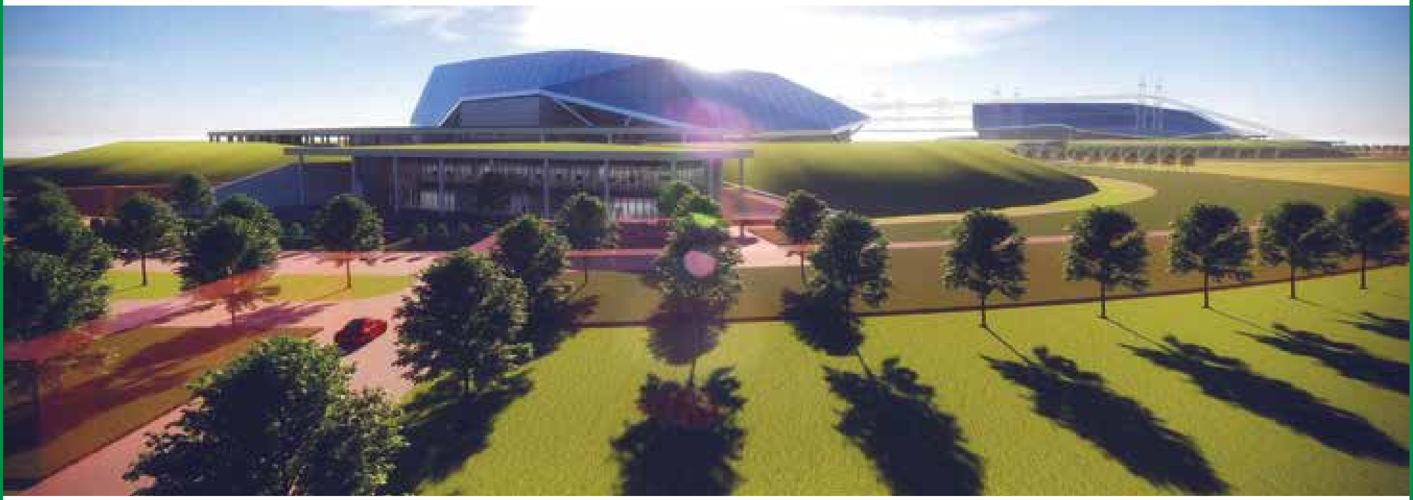

Members of the Valley

Entrepreneurs	Local government units	Scientific and research units and universities
47	19	5

Goals

Creating an appropriate amount of zero-emission energy sources to meet the participants' demand for energy and hydrogen, with the cluster's goal to achieve production of 4tWh per year in 2030.

Hydrogen production from zero-emission energy sources and available water resources, e.g. from drainage of mining plants, and the cluster's goal is to achieve production of 50,000 tons of green hydrogen per year in 2030.

Supporting the installation of hydrogen production equipment to meet the needs of machinery, logistics and energy storage.

Creating installations for storing, distributing and refueling hydrogen, as well as fleets of machines and car fleets powered by hydrogen.