Nuclear energy – Ukrainian experience Poland can draw from

A memorandum summarising the discussion dedicated to the Ukrainian power industry that took place during the second roundtable of the Energy and Climate Forum of the Union of Entrepreneurs and Employers.

- **In pre-war Ukraine, there were four nuclear power plants with a total capacity of nearly 14 GW,**
- **In January 2023, a decision was made to build two new AP 1000 reactors, and Ukraine plans to build a total of 9 new blocks,**
- **Technically, it is possible to replace Russian nuclear fuel with alternative sources, and would take approx. 4-5 years, therefore the discussion concerning sanctions for Rosatom should primarily be seen as political,**
- **Ukraine has developed competencies and advanced infrastructure enabling it to transfer its know-how to Poland, where the nuclear industry is currently picking up momentum.**

On 7th February 2023, the second debate in the "Energy in the context of Ukraine's reconstruction" series took place as part of the Union's project "Europe-Poland-Ukraine. Rebuild Together. 2023". The discussion titled "Nuclear energy – Ukrainian experience Poland can draw from" was chaired by Dominika Taranko, Director of the Energy and Climate Forum of the Union of Entrepreneurs and Employers.

The discussion aimed to illustrate the current state of Ukrainian nuclear energy and the country's plans in this area for the coming years. During the meeting, participants elaborated on such issues as:

- What kind of cooperation can we plan between Poland and Ukraine in the field of nuclear energy?
- Can the nuclear energy developed in Ukraine over decades be an example for Poland?
- How was the atomic energy sector organised prior to the war and what changes have the military operations brought about?
- In spite of military threats, is this infrastructure still operational and to what extent?
- Is it realistic to export Ukrainian atomic energy as of today and in the future, including its imports to Poland and other EU member states?

- Should we expect a transfer of knowledge from Ukraine to Poland, which is currently working on nuclear projects? Which experiences will investors benefit from?

The following guests were invited to the debate:

- **Andrzej Chmielewski**, Professor at the Warsaw University of Technology, Director of the Institute of Nuclear Chemistry and Technology, Vice-Chairman of the Programme Council for Nuclear Safety and Radiation Protection at the National Atomic Energy Agency
- **Robert Jankowski**, President of the Board at the Polish Climate Forum
- **Adam Juszczak**, Advisor in the Climate and Energy Department at the Polish Economic Institute
- **Oleh Kazanishchev**, Counsellor at the Embassy of Ukraine in Poland
- **Olga Kosharna**, Independent Expert on Nuclear Energy and Safety
- **Bogdan Pilch**, General Director at the Polish Chamber of Power Industry and Environmental Protection
- **Hennadii Radchenko**, Advisor at the Ukraine Business Center
- **Ivan Grygoruk**, Vice President at the Energy Club, who submitted his position in writing due to internet disruptions during the debate.

Ivan Hryhoruk who spoke on behalf of the Energy Club presented the current state of Ukrainian energy. Prior to the full-scale military aggression in Ukraine, there was a surplus of generated power, including that from renewable energy sources. Energy demand in recent years reached 19-20 GWh, with close to 15,5 GWh during the pandemic.

As for the energy balance, before the war, nuclear power production accounted for 50-60% of the electricity generated in Ukraine. There were four nuclear power plants (NPPs) in Ukraine, producing electricity in as many as 13 PWR-1000 nuclear reactors and two PWR-440 reactors with a total capacity of 13.8 GW. The nuclear industry in Ukraine also includes nuclear waste storage facilities, research reactors, uranium production facilities, and the Chernobyl Nuclear Power Plant Zone of Alienation. The remaining 40% of pre-war electricity produced in Ukraine was generated by hydroelectric, thermal, and pumped-storage power plants, and wind farms

Currently, electricity production and consumption have significantly decreased as a result of the Russian aggression. The damage to the energy infrastructure is enormous, and Ukrainian power plants, including the Zaporizhzhia NPP, are also occupied by Russian terrorists. The exploitation of seized power plants violates all safety standards, which could lead to a global nuclear disaster and serious consequences for the entire region.

In Europe on the other hand, on average, 25% of energy consumption comes from nuclear power. Some countries, like Poland, are only at the beginning of their journey towards nuclear energy, and Ukraine's experience and resources can play a significant role in the region.

Olga Kosharna and **Ivan Grygoruk** discussed the history of Ukraine's nuclear energy and the industry's current state of affairs. After the collapse of the Soviet Union, Ukraine inherited 12 nuclear power blocks, significant mechanical infrastructure, and the ability to construct technical equipment. During Ukraine's independence, all reactors were modernized, and three new blocks were added: No. 6 in the Zaporizhzhia NPP, No. 2 in the Khmelnytskyi NPP, and No. 4 in the Rivne NPP.

Understanding the need for full independence from Russia in the nuclear industry and the associated significant risks, Ukraine had already negotiated with American companies General Atomics and Westinghouse in 1992 and 1993, respectively. As a result, in 1994, a decision was made to enter into a protocol of cooperation with Westinghouse – a considerable event that in fact gave rise to the programme for nuclear power plants transition from old Russian nuclear fuel to a new fuel produced with Westinghouse technology.

In 2005, Westinghouse's nuclear fuel was loaded into power blocks at the South Ukraine NPP and partially in the Zaporizhzhia NPP, whose block No. 5 became the second in Ukraine to operate solely on Westinghouse nuclear fuel in 2019.

Beginning in 2014, when the threat of a full-scale war with Russia first arose, Ukraine would systematically reduce the supply of goods and services from the Russian Federation. Before the invasion a year ago, Ukraine was already receiving almost 50% of its nuclear fuel from a non-Russian producer, the US-based company Westinghouse. Therefore, while Ukraine remains partially dependent on fresh nuclear fuel supplies from the Russian Federation, Westinghouse according to their contract with Ukraine is able to compensate for losses in the Russian market by producing fuel for PWR-1000 and PWR-440 reactors in No. 1 and No. 2 power blocks of the Rivne NPP.

Incidentally, Ukraine in 2019 became the first country in the world to successfully implement a nuclear fuel diversification project for PWR-1000 reactors. In 2020, the Rivne NPP was also in line to use Westinghouse nuclear fuel for PWR-440 reactors. At the same time, accompanying programs were being developed and implemented to introduce spent fuel management technology and build a central repository for spent nuclear fuel.

Ukraine has unique enterprises that have modernised all of its nuclear power plant blocks through their own efforts. A prominent example of such a company is “Impuls” from Sievierodonetsk, which produces automatic systems for controlling technological processes as well as devices controlling the flow of neutrons inside a reactor. Other enterprises producing IT-and-control systems include “Radii” from Kropyvnytskyi, and Kharkiv-based “Vestron”, a Ukrainian company cooperating with Westinghouse, and “Khartron”. This means that all control panels in every Ukrainian NPP are currently Ukrainian-made.

Ukraine has competitive enterprises that produce dosimetric instruments and radiation control systems, such as “Ekotest”, the scientific and production enterprise “AtomKompleksPrylad”, the joint enterprise “Atomprylad Design Bureau”, and the “Ukrainian Devices and Atomic Systems” corporation. Everyone knows “Turboatom” from Kharkiv, which has just merged with the Kharkiv Machine-Building Plant and “Elektrovazhmash”. Ukraine has enormous potential when it comes to production of goods and services for the development of its own nuclear power industry, including new construction projects. Even as much as 70% of goods and services, excluding ready-made nuclear fuel, can be provided independently by Ukraine.

Due to the Russian invasion, “Impuls” relocated to Kiev. Sievierodonetsk, where the company had been founded, was completely destroyed following the second occupation of the city since 2014. “Radii” from Kropyvnytskyi is operating as usual, along with all other enterprises. However, the war is still raging, and Kharkiv-based “Turboatom” came under fire – its facilities were partially damaged, but the company remains operational.

Prof. Andrzej Chmielewski reflected on his Ukrainian professional relationships and personal memories: *“On one of my early projects, I was involved with IBOGEM, a company from Kharkiv. Currently, my colleagues who worked with me had to move to Germany because of the war and destruction of the city. We signed an agreement with Mrs. Olga Kosharna and her institute, and we hosted Ukrainian professors for lectures, while our students from Warsaw University of Technology visited Chernobyl to see the devil’s not so black as he is painted on the one hand, and on the other to see the well-organised radioactive waste processing and storage facility located there. Polish-Ukrainian cooperation has solid foundations. Later, the pandemic interrupted these academic trips, but virtual conferences were held in their stead.”*

The Institute of Nuclear Chemistry and Technology, headed by Professor Chmielewski, offers support to Ukrainian doctoral students. More specifically, it has funds at its disposal allowing it to host doctoral students for a half-year period. The students need not to change their research

topic and can continue their doctoral studies in a peaceful environment in Poland. Given the shortage of personnel for planned nuclear investments in Poland, strengthening scientific cooperation can be valuable for both sides.

Uranium and sanctions

According to data from 2021, Russia supplied around 20% of uranium to the European Union for use in nuclear power plants. Kazakhstan supplied even more, approx. 23%, whereas Niger came in the first place with deliveries in the ballpark of 24%. Even the French, with their developed nuclear industry, imported 20% of their uranium from Russia.

This year, due to Russia's unacceptable policies, a discussion regarding the import of nuclear fuel from Russia began at the European Parliament, where several countries, including Poland, Lithuania, Latvia and Estonia, called in September of last year for a complete severance of all contacts with Russia in the field of nuclear technology. Germany came in support of this this cause. However, unanimous agreement was required for sanctions to be put in place, and two countries, Bulgaria and Hungary, refused to agree to them. Especially since the Hungarians had already begun the construction of two new nuclear blocks using Russian loans. Making these commitments null and void would be difficult for them.

In Europe, there are 18 Russian-made reactors in operation, mainly in CEE, including the Czech Republic, Hungary, Bulgaria, Slovenia and Slovakia. In the event of sanctions being imposed on Russian uranium, these countries would need to switch to alternative fuel sources. Romania, however, does not have this problem, as it produces its own fuel for CANDU reactors, which run on natural uranium. Westinghouse already supplies fuel to eight different blocks in Ukraine, and this will eventually be possible for all 15 blocks. Finland no longer imports fuel from Russia, and Vattenfall in Sweden stopped importing Russian fuel on 24th January. Canada and Australia also previously relied on Russian fuel, but are determined to cut these ties.

In Poland, the Maria research reactor, located in Świerk – more or less 25-30 km from Warsaw, initially used highly enriched fuel, with a concentration of 60%. The reactor was built by Poles, which proves that Poland is capable of working with nuclear technologies. The first fuel was of Russian origin. Later, when the United States imposed restrictions on the level of uranium enrichment, it was gradually reduced in the Polish reactor to 28%, then to 22%, and now it is at 19%. As of now due to economic factors, Poland still uses Russian fuel. For many years, Poland was also a member of the Joint Institute for Nuclear Research in Dubna, but withdrew last year in the fall.

The reactor in Świerk has already switched to the French fuel supply. It is decidedly more difficult to develop a transition to a different fuel for smaller reactors than for larger ones, where certain standards apply. In Świerk, a neutron flux is used, meaning a flow of neutrons on the order of 10^{14}. It is used to irradiate uranium for molybdenum plates in order to obtain technetium-99m, which is then used for thyroid and other organ scans. When one of the Canadian reactors was temporarily shut down, Świerk provided approx. 18% of the total global supply of these plates. However, the plates were not processed locally and were sent further to Belgium.

Currently, it seems that from a technical point of view, switching nuclear installations to fuels other than Russian is not a major problem. However, it remains unknown whether all the factories that produce enriched uranium are prepared for this change. They would have to supply larger quantities of fuel to the market at a rapid pace.

As Professor Andrzej Chmielewski emphasised: *"When it comes to fuel, the Warsaw Institute, which was founded in 1956, was mainly established to process nuclear fuel, including to obtain uranium oxide or metallic uranium. When I saw the nuclear fuel factory in Wilmington, USA, it was not in fact a huge facility, like a petrochemical or a large power plant. Some of these facilities are not much bigger than what we have had in the research hall at the Institute. Nonetheless, the enrichment process is difficult, very expensive, and characterised by high energy consumption. For example, the French have two enrichment stations, and their two nuclear power plants basically work solely for this enrichment system."*

The competences to restore the nuclear industry in Europe, including uranium enrichment, exist because modern technologies are already available. These are cascade installations. The enrichment ratios are very low, so the process must be repeated multiple times. Therefore, it is quite a complex installation. And in order to make a decision to build a uranium enrichment facility, someone must want to buy such a product later on. In other words, enrichment stations are built in response to specific demand, and such installations are not built speculatively.

Technology is constantly evolving, for example in the direction of laser processing. In the United States, there is already a system for uranium enrichment using laser methods. This involves "hitting" uranium using a laser in a precise manner, ionising it, which then makes it very easy to separate uranium isotopes. It is possible, therefore, that we will be taking this direction in terms of uranium enrichment.

On the other hand, some nuclear power plants are already worn out and close to being shut down. In light of the collective departure from Russian fuel, it would be worthwhile to assess which atomic units will still be used and how long. Perhaps natural replacement of old nuclear blocks with new ones would also smoothly introduce change in fuel in power plants.

Increasingly often, it is said that the uranium enrichment stage is the bottleneck, because obtaining hydrogen and uranium is not a complicated process. However, the problem of political influence from Russia remains actual. Production in Kazakhstan is largely controlled by Rosatom. Currently, the Western world is looking for new ways of transporting uranium, as previously about 40% of fuel passed through St. Petersburg. Recently, a connection was established over the Caspian Sea, which could transport materials to Europe by planes. China is considered an alternative, but would de facto bypass enforced sanctions.

The time horizon for moving away from Russian fuel is estimated to be circa 5 years. This is more or less how long power plants can store fuel. This is possible thanks to the efficiency of nuclear fuel. From one gram of uranium, we obtain roughly the same amount of energy as from 2-3 tonnes of coal. So, for a 1000-megawatt power plant, such as APE1000, approx. 25 tonnes of fuel are needed annually. A coal-fired power plant would require 3 million tonnes of coal for that same amount of power. In this case, storing fuel would not be possible. But in the case of nuclear power, it is a customary practice.

Ukraine has long been building nuclear independence

In 2005, Ukraine began a project to replace Russian nuclear fuel with fuel from another producer. The fuel exchange occurs in cycles, taking four years for the entire reactor core to be loaded with fuel from a single supplier, in this case, Westinghouse. This process was started by Ukraine many years ago, and considering the current 4-year cycle, now is a good time to exclude Rosatom from the process of delivering fresh nuclear fuel to 18 reactors in Central Europe. If this were to happen, almost all of Europe could use uranium from other sources in 4-5 years.

Regarding the expected operating period of Ukrainian nuclear power plants, there is an inspection of these facilities every ten years, and a safety analysis report is then prepared, based on which the operating term is extended for another 10 years.

In the United States, the operating term of nuclear power blocks has been extended to 80 years. In Europe, countries that have nuclear power today are also planning to extend it (with the exception of Germany). Currently undergoing the aforementioned analyses in Ukraine are blocks

No. 1 and No. 2 of the Rivne NPP, and it is likely that their operation will be extended for another ten years, until the mid-2030s. Therefore, nuclear fuel for Soviet-designed reactors will still be needed until around the 2050s.

Before the full-scale invasion in 2022, Ukraine had reserves of nuclear fuel produced by the Russian company "TVEL". However, since 2014, Ukraine has had a contract with Westinghouse, which includes a provision that if Russia refuses to supply nuclear fuel (which was a real risk), Westinghouse would try to fill that gap by using an additional assembly line for fuel rods constructed using technology that is suitable for PWR-1000 reactors. In Sweden, there are possibilities for producing fuel for PWR-1000 units currently present in Europe. Moreover, until 2007, the Czech Republic was receiving fuel from Westinghouse for their PWR-440 post-Soviet reactors, and the Temelin Nuclear Power Station launched its operations with nuclear fuel produced by Westinghouse. However, Rosatom used corrupt mechanisms and unfair competition to push Westinghouse out of the market in the Czech Republic and Finland.

In spite of these experiences, the licensing process for Westinghouse's improved fuel (for Ukrainian Soviet-era reactors) is expected to be most efficient and fastest in the Czech Republic and Finland, as these countries already have experience in using American nuclear fuel.

To summarise, from a technical perspective, there are no obstacles to imposing sanctions on Rosatom. It is a political and partly economic issue. Entities like Rosatom or Gazprom should be perceived as directly supporting military actions. Until 2022, many decision-makers believed that we could not survive without Russian gas or oil. However, Europe survived the winter quite smoothly. Today, we must understand that even if Russian nuclear fuel or services for the nuclear industry are cheaper, it is a price paid in blood. The Russians, by occupying Ukrainian NPPs, behaved with their staff in a barbaric manner. Attempts by Russians to take over installations that will not operate according to their schemes, on their fuel, are less likely in the future. Hence, the consistent pursuit of establishing sanctions for Rosatom seems to be the only right direction.

The Polish-Ukrainian Cooperation

During the discussion, **Oleh Kazanishchev**, Counsellor at the Ukrainian Embassy in Poland, informed that while there is no special unit for nuclear affairs at the embassy, there is a commercial department that operates with professionals representing various industries, including nuclear energy as part of the broad energy sector. Currently, there are no plans to create a dedicated position responsible solely for the nuclear affairs.

However, the Embassy in Poland is the largest Ukrainian diplomatic mission in the world, which proves how a significant partner Poland it to its eastern neighbour. Particularly after 24th February of last year, Poland has become a partner of strategic importance. Ukrainian employees are very grateful to the Polish government and people of Poland for their support and assistance to Ukraine.

In the area of energy cooperation and plans in this field, everything changed after the start of the war. As a diplomatic mission, the Embassy is responsible for developing cooperation in various areas, including the energy sector. The Embassy is involved in several joint projects in different segments of this industry, such as gas, oil, and nuclear energy. Its employees participate in conferences and monitor the development of the nuclear industry in Poland. The Embassy is open to further cooperation, including combining the competencies of Ukrainian and Polish companies.

Even before the announcement of the construction of the third nuclear power plant in Poland, a report by the Polish Economic Institute authored by **Adam Juszczak** was published, which addressed the economic aspects of nuclear investments in Poland, their impact on business, the labour market, and local communities. Even then, it was evident that the economic and social potential of building a nuclear power plant was significant. The first two nuclear power plants planned in the Polish nuclear energy programme will require about PLN 200 billion in total. This is the average cost estimate for both units combined. This means that really big money is at stake in Poland, and businesses will compete for it. Participation of "local content", according to announcements and examples from other countries, can reach between 50 and 70%. The money that can go to domestic businesses from these two investments might come up to PLN 130-140 billion.

Despite the fact that there has thus far been no market for nuclear energy in Poland, there are companies interested in nuclear activities. Some of them have until now provided their services outside Poland. However, there are of course also certain areas to catch up on, because some competencies could not be developed without such investments in Poland. And this is a potentially good opportunity for cooperation between the Polish and Ukrainian communities.

According to the catalogue created by the Ministry of Climate and Environment in Poland, over 300 companies in Poland are interested in nuclear energy. Only a small fraction of them have experience in previous nuclear investments anywhere in the world. The reason is simple – these are not easy investment projects. A number of different certificates are required. Some

companies, despite their interest in the nuclear industry, will certainly be concerned about whether they will be able to meet these requirements. Therefore, it would be necessary to build an appropriate climate around these investments, enable cooperation with qualified entities, and encourage the entire community to develop.

And there is much to strive for. Just take a look at France, for example, which has a developed nuclear industry. The nuclear sector, both energy production and companies offering services for nuclear power plants or manufacturing components for NPPs, employs approx. 400,000 people. It is a really big piece of cake to share. If we were to look at individual sectors where development is most likely, these would be the machine industry and services related to the machine industry, as well as electrical and automation engineering, and metalworking. There is potential there. There are companies in Poland that have already worked on foreign investments, so this transfer of know-how is very much possible.

In the context of cooperation with Ukraine, it should be noted that there is currently a shortage and will be a long-term shortage of personnel in the nuclear energy sector in Poland. The personnel gap results from the fact that such investments could not start for a long time, and some qualified specialists were unable to find employment in the country. So they went abroad, and only a few remained in scientific research institutions. Today, most students choose to specialise in RES, as it is already an existing market with potential for development. In the case of nuclear energy, there is still a lot of uncertainty, which may discourage young people from choosing such a career path. Ukrainian personnel, on the other hand, exist and have broad experience, and their involvement in the construction of Polish nuclear power plants would certainly be of high value. Polish-Ukrainian cooperation could then lead to Ukrainian investments: asset modernisation, reconstruction, and construction. Over the next few decades, a lot of new investments will be made in Ukraine. Circa 90% of Ukrainian wind turbines and as many as 50% of photovoltaic panels were destroyed as a result of military operations, and all this infrastructure will need to be restored.

The presence of the atom in Ukraine's recovery

Currently, experts and officials at the Ukrainian Ministry of Energy and the National Regulation Commission for the Ukrenergo system are discussing what kind of energy system should be Ukraine built after the war has been won. As Ukraine is a party to the Paris Agreement on climate action, and nuclear power, along with renewable energy, is low-emission and – above all else – something that Ukraine already has, its role in the post-war energy mix should be

significant. Many voices advocate for the development of decentralised energy generation, including the use of small and medium modular nuclear reactors. Ukraine also declares that it will pay more attention to wind power than before.

Before the war, the breakdown of renewable energy generation amounted to more or less 75% photovoltaic energy and 25% wind farms. Experts argue that these proportions should be reversed and supplemented by biogas. The symbiosis between stable nuclear power generation and emerging decentralised RES could prove very effective. According to Olga Kosharna, one of the Union's roundtable discussion panellists, even the construction of additional 1000 MW blocks in the Khmelnytskyi NPP using Westinghouse technology may not be as good a solution as building small and medium-sized modular reactors. This opinion is shared by the private Ukrainian business. DETEK, one of the interested companies, is currently looking into the construction of small and medium modular reactors. From the perspective of reconstruction of the energy sector and point of view of achieving a complementary energy system in Ukraine, this direction seems highly desirable.

The business and the Atom

The Polish Chamber of Power Industry and Environmental Protection, chaired by **Bogdan Pilch**, brings together over 100 entities from the universally understood energy sector. The Chamber represents both large energy groups and construction companies, and representatives of foreign companies in Poland along with construction companies. The organisation covers the entire Polish sector – from conventional energy through RES and hydrogen industry to nuclear power. In the field of nuclear investments, we focus on maximising the participation of the Polish industry, the so-called "local content". In the Chamber's opinion, this participation might potentially reach 50%, up to even 60%. However, the path to achieving this goal is long, as obtaining the qualifications to become a certified contractor or subcontractor is a very lengthy and costly process. Currently, there are about 80 companies in Poland that have any experience whatsoever in building or operating nuclear facilities.

Following the thread of Polish-Ukrainian cooperation, the Chamber's General Director drew attention to the issues of fuel and its disposal as potential areas for joint action. Then again, during the construction phase, the experience of seasoned professional from Ukraine might come in handy. However, since this will be an American technology, and Ukrainians are experienced in Russian technology, knowledge transfer will naturally not be 1:1. However, some processes are very convergent, so the participation of Ukrainian companies or professionals is

highly likely. If the Ukrainian-Polish nuclear marriage succeeds, then these entities would not only have the potential to build one power plant, but also the potential to export their services. Since last year, we have been observing a kind of renaissance in nuclear energy. MMR and SMR are compatible technologies. They complement each other next to full-scale atom facilities, rather than compete.

Interest of Polish companies in cooperation with Ukraine in the energy sector is increasing, as reported by the Chamber, which receives inquiries from numerous entities. Previously, those that approached the Chamber were directed to the Ministry of State Assets, which has already created a database of around a thousand companies. Unfortunately, little is heard on this topic whether it is actively pursued or not. A business approach to this cooperation would be optimal to take advantage of this opportunity, meaning entrepreneurs instead of politicians would take the initiative. The Polish-Ukrainian Chamber of Commerce is also ready to provide support.

The Polish Chamber of Power Industry and Environmental Protection also provides training for companies with regard to execution of nuclear projects, and participates in various industry meetings and conferences, prepares field study trips, and has a good relationship with active technology suppliers on the Polish market, such as Westinghouse, as well as EDF and KHNP. In its activities, the Chamber tries above all to make those interested aware that the process of becoming a subcontractor is very difficult, complex, lengthy and costly. It does not of course go equally for everyone, as each company is at a different stage of development. In 2022, under a ministerial grant, the Chamber conducted an intensive training programme, providing 60 hours of training per participant. Around 180 people from approx. 150 companies were trained, and technologies and requirements related to becoming a subcontractor, sub-supplier, or supplier in the field of technology were presented during this training. Technologies from the US-based Westinghouse as well as those from EDF and KHMP were discussed. The trainings will continue in 2023. It is also possible to organise “supplier days”, during which technology suppliers would show a clear roadmap on how to become a part of the nuclear investment supply chain.

Until now, not many people believed in the success of the nuclear project, and this scepticism among companies was a consequence of so many failed attempts to implement such a project in Poland that few believed that these investments would eventually pick up pace. The choice of a technological partner does not yet determine the success of the project, but it greatly increases its likelihood. Today, it seems already certain that nuclear power plants will be constructed in Poland. However, whether this will be done on time and within budget is a completely different issue and requires a separate discussion. Nuclear energy as the basis and renewable energy

sources as a supplement, and in the future also the use of hydrogen - this is currently recognised as a certain standard, a model to which it is worth striving for in many countries.

Energy cooperatives and SMRs

According to **Robert Jankowski**, another round table panellist, the old energy system that was invented in the 19th century and established in Poland in the 1950s has expired. The new technical means and modern technologies that have appeared are causing the decomposition of the old system right before our eyes. Therefore, the Union guest believes we should now work on creating an entirely new system that reflects the energy industry worthy of the 21st century.

It would be a system of autonomous areas the size of a municipality or two municipalities, or a parish, which balance energy consumption internally. The concept would be based on a cooperative system. After all, it was the cooperative system that won the great war against the Prussians in Greater Poland in the 19th century. According to Robert Jankowski, the best way to reduce corruption (for instance, Ukrainian oligarchs) would be to build a system where the cooperatives themselves are the owners of what they have.

Within this system of autonomous areas, we should from the very beginning integrate electricity with heat and electromobility. Lately, there has also been talk of adding healthy food and local individual construction to the system. An essential element of such a system is a stabiliser, that is, a source of electricity generating between 15 and 25% of energy. The Polish Climate Forum estimates that there is room in Poland for about a thousand SMRs that would operate as such a stabiliser. The remaining energy needs would be secured by biogas plants, geothermal energy, hydroelectric power, or thermal biomass processing facilities. Energy supply security and low prices are the overriding goal.

And although these goals are also a priority throughout the European Union, particularly at the level of the European Commission and the Parliament, there are also many conflicting interests at play. To limit the influence of various interest groups, it is necessary to build local citizen energy initiatives. Neither Poles nor Ukrainians have any social objections to nuclear power. From a climate neutrality perspective, this is a very clean, zero-emission energy source.

The aspect of communication is also important, reaching directly to communities with the message about the European “Green Deal”. It is not possible to join the European Union if a candidate state does not have a clear plan to achieve climate neutrality. Polish companies could certainly help in developing the energy transformation concept in Ukraine. On the other hand,

there are many nuclear energy specialists in Ukraine and, above all, there is infrastructure in place. Despite the ongoing conflict, there are still factories developing equipment. If we were to develop SMR systems on a large scale in Poland, there is also potential for cooperation in this area.

Educating nuclear energy personnel

In Ukraine, even some high schools specialise in nuclear energy. In Poland, there used to be a nuclear technical school in Otwock. However, to train personnel for the entire industry, a comprehensive approach is needed. On the other hand, the nuclear sector is a highly regulated field. Every gram of uranium or plutonium must be reported to the European Union, even when it is transferred from one laboratory to another. In Poland, we have research universities, but there are only 10 of them. Without research and practice, we cannot teach or guarantee development. Our students must learn from practitioners. Simply sending an intern to the United States for a month is not enough. A comprehensive educational programme is necessary.

Participation in European projects is must-have, such as cooperation with renowned universities and the French EDF. It is worth taking advantage of experiences and training in other countries. In the context of Polish-Ukrainian cooperation in the field of nuclear energy, the most important thing is that nuclear energy has been operating in Ukraine for many years. Combining the efforts of both Ukrainian universities, Polish research institutes, and industrial training organisations would be highly desirable. For example, one of the first accelerators in the world was built in Kharkiv. Ukraine has very good physicists, including those involved in the work of the International Atomic Energy Agency.

We also have a well-organised National Atomic Energy Agency in Poland, which also cooperates closely with the IAEA as well as nuclear energy centres in Europe and North America. Many trainings are taking place, and we can hear Polish names among the world's nuclear industry personnel.

Safety

Politically, we observe today in Poland the unification of both the government and opposition parties, all of whom are in favour of nuclear energy, including green parties. Local authorities are counting on job creation, a boost of funds from investments, and the development of local entrepreneurship. However, the safety rules in the nuclear industry have changed dramatically.

Nuclear energy has become so expensive because many installations, even chemical ones, must now be secured like nuclear power plants. The more modern generation 3+ systems have passive safety systems. The problem with the Fukushima disaster was that the reactor defended itself for 8 hours during cooling. However, after 8 hours, in case cooling is not restored, the fuel may melt. In Fukushima, there were also hydrogen explosions. Hydrogen and oxygen are an explosive mixture. Today, most power plants have different safety systems. In the mentioned 3+ system, even if there is no electricity supply, the safety systems are still active. In the American Westinghouse AP 1000, when water boils, it takes heat away and there is also a metal shield that condenses the water. Unfortunately, in Fukushima, the generators were located in the basement, and the tsunami wave was thirteen metres high. Another power plant also had a similar safety system problem, but a power cable was pulled to the power plant in time to restore cooling.

It is important for nuclear investment supervision to have a national "technical support organisation" with a panel of experts in construction, steel, chemistry, and other relevant fields. Finland has a system called STUK, which is the equivalent of Poland's National Atomic Energy Agency, and has various institutions at its disposal to conduct research at STUK's request. Meanwhile, Hungary has a strong Institute and 32 specialised units that perform tasks within the nuclear sector. Poland must develop such a system. The National Atomic Energy Agency has already established an authorisation certificate that can be applied for not only by Polish companies, but also those from Ukraine. Any and all authorised entities will have the right to participate in nuclear safety projects, research, development, and consulting. It is crucial not to allow entities without the necessary qualifications, know-how, or personnel to participate. All of this must be refined to ensure the safety of Poland's nuclear sector. The experience of Ukrainian nuclear supervision and how it was organised could be very interesting.

An impulse for the economy

According to OECD calculations, only 2 nuclear power plants in Poland would create up to 40,000 direct and indirect jobs, as well as jobs in the surrounding area. The benefits are also enormous for local communities, who must of course be informed about the plans. There is often a question in the public space about the cannibalisation of RES and nuclear power, competition of power generation – what if we end up with excess power? Nothing like that will happen. The reason is simple: we will be decarbonising the Polish economy for decades to come. To achieve EU climate goals, we will need significantly more electricity than before. Whether we want to electrify transport or use hydrogen, whether it is purple energy from nuclear sources or green from renewables, it will require more electricity production. Heat pumps and a range of other

innovations within households and industry will increase our demand for electricity. There is no reason to suspect that the Ukrainian economy, especially considering that a large part of their RES were destroyed during the war, will not need energy or new generating capacity during recovery and reconstruction.

Especially since we are considering the gradual decommissioning of coal units or limiting gas units. We should plan for enough reactors to meet our future demand in both Poland and Ukraine, of course in the right synergy with RES. Therefore, SMR projects should not be presented as competition for large NPPs. SMRs can become additional sources and they have several very interesting applications, such as district heating systems, particularly in smaller regions, or energy production facilities for large industrial plants. However, they will not in any way constitute major competition for full-scale NPPs, which primarily must power the national power system.

Rebuilding the Ukrainian economy and the future of nuclear power

The war is still raging, but discussions on the post-war reconstruction of Ukraine's energy infrastructure, which is a major component of the economy of a country that strives for EU membership, take place at the very same time. There is a predicted possibility of a significant increase in demand for electricity by various industries.

Just as the price of gas, oil, refining products, and therefore electricity has significantly skyrocketed globally due to the pandemic in the years 2020-2022 and the Russo-Ukrainian war, production in the EU industry has become very costly due to the significant increase in costs and ecological requirements.

The modernisation of production facilities in existing plants always involves a temporary limitation of production or even a halt in production, which carries the risks of significant loss of a competitive position on the global market and financial losses.

The phenomenon of relocating businesses to Poland, Romania, Hungary, and even Balkan countries or Ukraine is not out of the question. These countries offer predictable conditions for business operations and offer a skilled workforce. In Ukraine, migration of industry can be observed: in times of war, many state-owned enterprises have already moved their production to central or western regions of Ukraine, and in the post-war period, this trend might only increase. According to Ivan Grygoruk, electricity consumption after the war will not only return to pre-war levels, but will increase by at least 30%. However, there will be a certain shift in the

generation and consumption of energy – the entire infrastructure will physically and technologically move closer to Europe.

In January of this year, the Cabinet of Ministers of Ukraine approved the construction of two new AP 1000 reactors. The blocks will be installed in the Khmelnytskyi NPP, with Westinghouse as the supplier. Ukraine has ambitious plans for the development of its nuclear industry, with the construction of as many as nine new AP 1000 blocks across the country in the pipeline.

The first reason for the construction of new reactors is of a more political nature. It is a strategy for building independence through diversification of nuclear supplies and technologies in Ukraine.

The second reason is to increase the level of safety and security in the operation of existing nuclear reactors by using new nuclear fuel, building new third- and, in the future, fourth-generation reactors with the ultimate goal to further decommission outdated AES power blocks and introduce technology to manage spent nuclear fuel.

The oldest working nuclear reactor in Ukraine was put into operation in 1980, and the newest two power blocks in 2004, with the end of the term of operation of the newest scheduled for 2035. Ukrainian reactors, both PWR-440 and PWR-1000, belong to the second generation, which has long been considered outdated worldwide.

It is worth noting that AP 1000 nuclear reactors differ significantly from PWR-1000 in the following basic characteristics:

- reduction in overall costs and shorter construction time;
- higher utilisation rate and longer operating period;
- more reliable design that is simpler to operate during the exploitation process and less prone to operational risks;
- low probability of accidents related to the melting of the active zone;
- increased fuel burn-up providing higher efficiency and reduces the amount of waste;
- use of burnable absorbers to extend the life of fuel cells;
- smaller environmental impact.

Ukraine has everything except peace that is necessary for further development of its nuclear industry. It has scientific potential, almost 50 years of experience in operating NPPs, developed material and technical infrastructure. Ukraine ranks 12th in terms of uranium resources and 11th in uranium production in the world. It has organised logistics for nuclear fuel supply and

actively introduces strategies related to the safe handling of spent nuclear fuel from power reactors. It is also characterised by a huge capital of talents within the nuclear industry.

For the past 30 years, Ukraine has been fighting for the possibility to construct modern nuclear reactors. It is a very difficult, but well justified path. This way, it gains invaluable experience which it will gladly share with such partners as Poland.