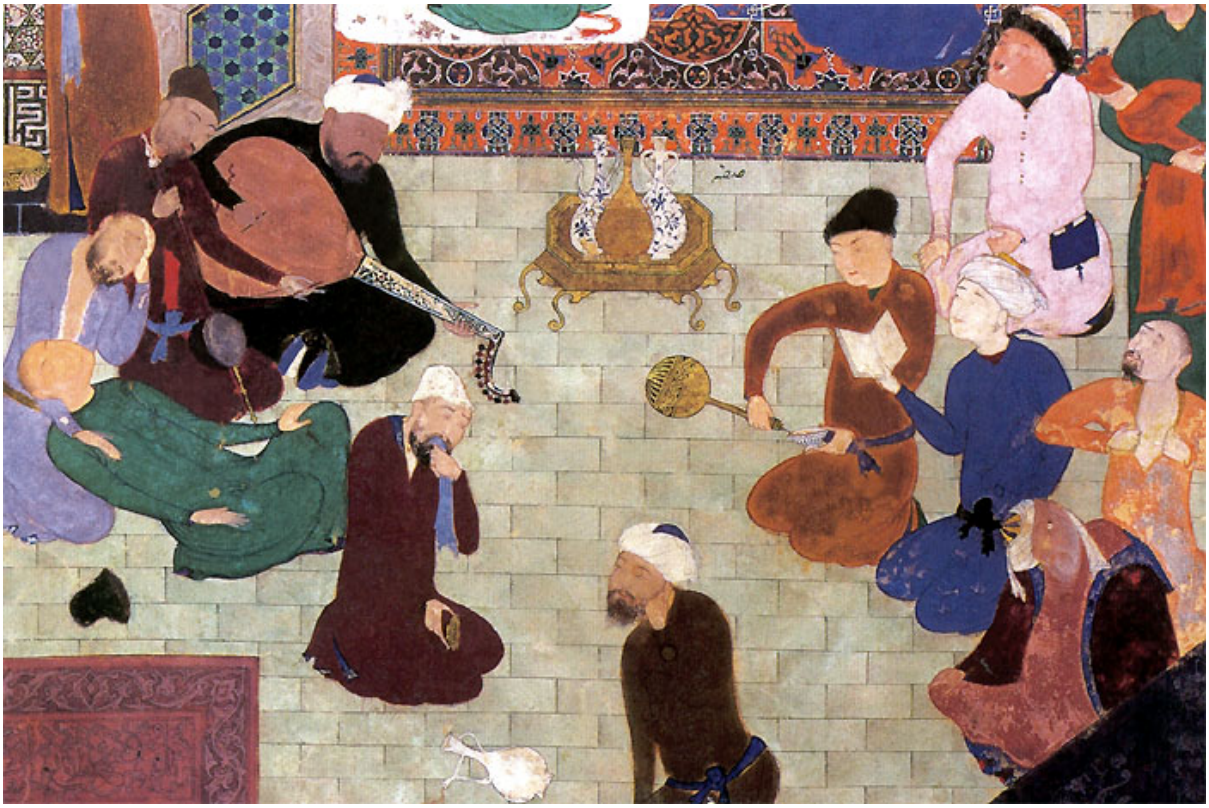
Nuclear battery for the economy

Critical issues of nuclear power plants in Uzbekistan



Kamoliddin Behzod. Miniature illustration (fragment). Sultan Hussein Baykara in his courtyard in Herat. 1488. Edited by the article authors.

Introduction

For the last six thousand years, humanity has been obsessively searching for a universal and safe source of inexpensive energy: Sumerian jars, aeolipile of Heron of Alexandria, Roman watermills. And it seems that in the nineteenth century, we resolved the issue by defining coal, oil, and gas as the main sources of energy. However, the second half of the twentieth century opened completely new prospects – we penetrated the mystery of the subatomic world.

Becquerel first discovered radioactivity. Then Rutherford thought of linking this phenomenon with the special structure of the atom. Then Otto Hahn discovered the splitting of atomic nuclei, and a whole group of scientists, experimenting with the nucleus in every possible way, found out that when bombarded with neutrons, an atom decays into two other atoms with the release of a huge amount of energy. Then Enrico Fermi created the world's first reactor and opened the doors to the atomic age.

The American military quickly realized the potential of this limitless energy and over the protests of physicists and engineers, the 1945 weapons test in New Mexico unleashed well-known events. "I am Death, the destroyer of worlds," Robert Oppenheimer, the father of the

atomic bomb, said. Later, the concentration of technology and knowledge developed by those scientists in New Mexico led to a peaceful atom. So, philosophically speaking, the creative came to us through the destructive.

What is the current situation in the world with nuclear energy?

To date, 31 countries use nuclear energy to generate electricity. France has the highest share of nuclear energy with 70% of total electricity generated by nuclear power plants. Globally, the share of nuclear power is still small and hovers around 10%. However, most experts tend to conclude that the most likely replacement of traditional energy sources is the energy of a nuclear chain reaction.

Hydrocarbon reserves are not infinite. At the same time, traditional combustible minerals account for about 5% of all combustible substances, while uranium and thorium account for about 95%. Thus, the fuel for the nuclear power plant may be enough to support consumption levels for a very, very long time.

Nuclear power plants are expensive. How can we afford it?

Yes, nuclear power plants are not a cheap solution. The average cost of construction is $5 billion. At the same time, as a rule, based on cost optimization, nuclear power plants are built from two power units, each of which produces a little more than one gigawatt (GW). One such station can, for example, fully cover the needs of the population of the Samarkand, Bukhara and Andijan regions combined.

Recently, construction projects for small-sized nuclear power plants (NPP) with a capacity of up to 20 megawatts (MW) have started throughout the world. Such mini-NPPs can supply electricity to individual production facilities and residential complexes, and in the future, to individual homes. Hyperion Power Generation (USA) is currently engaged in the development of mini-NPPs.

If Rosatom Corporation is engaged in the construction of the NPP, then the project will most likely be financed by loans from a consortium of Russian banks or VneshEconomBank (taking into account its membership in the Rosatom Supervisory Board), as well as the Fund for Reconstruction and Development of the Republic of Uzbekistan. The collateral is likely to be a pledge of power units, and possibly the entire property complex. In addition, banks may require a government guarantee.

The average payback period of a nuclear power plant is 20 years, but the life of a nuclear power plant, according to Rosatom, is about 60 years. Thus, the construction of nuclear power plant is always part of a long-term energy security strategy.

In addition, the state could consider the possibility of developing nuclear energy in a public-private partnership format, where investment costs could be “extended” by 15-20 years, and thereby significantly reduce the burden on the state budget. This is not the most popular format of interaction in the nuclear power industry, but there are already successful examples in Turkey, Canada, and the USA.

Can't the existing power plants cope? Isn't it easier to upgrade them?

It may be easier to upgrade existing plants, but that will not address underlying challenges.

Currently, Uzbekistan, with a population exceeding 32 million people, is the most populous country in Central Asia. Uzbekistan produces about 60 billion kilowatt-hours (kWh) per year[i], which are almost entirely produced at thermal power plants.

According to data from the Uzbekenergo website, during the period of independence, electricity generated per capita in Uzbekistan decreased from 2,383 kWh per capita in 1990 to 1,566 kWh in 2017, that is, more than 1.5 times. At the same time, Uzbekistan continues to be one of the most energy-intensive economies in the region, annually spending about 4.5% of Gross Domestic Product (GDP) on the national economy.

The analysis of energy sources in Uzbekistan presents a depressing picture, with an impressive predominance of fossil fuels. At the same time, high energy intensity is observed at all stages of the value chain, starting with high losses in electricity generation (for example, due to gas flaring), losses on power transmission lines, and ending with irrational energy consumption. This results in so-called rolling blackouts.

The problem is not only in modernization of thermal power plants, but rather in having the right amount of natural gas. More than 90% of Uzbekistan's energy production is based on natural gas. Natural gas production in 2017 amounted[ii] to about 56 billion cubic meters. There have been no bright trends over the last decade, but there is a large spread over the years, obviously related to weather conditions.

According to some reports, if trends continued, given the growth in domestic consumption, we would have no natural gas left to meet demand by 2020. It was in this regard that President Mirziyoyev took a radical decision to increase gas production, which was expressed in a number of regulatory acts[iii].

However, this solution is likely to solve only the problem of growing domestic consumption and, in part, exports. Will this provide reliable energy protection in the long term? Almost all the existing hydro-electric power plants (HPP) resources have already been used for electricity production. It will not be possible to purchase electricity from neighbors who are already operating at a deficit. Turkmenistan will not sell its natural gas at an affordable price; it plans to sell it more to India through the Turkmenistan-Afghanistan-Pakistan-India (TAPI) Gas Pipeline project.

Wouldn't it be better to develop "green" energy then? To build plantations of solar panels and wind turbines in the desert and pump cheap energy forever?

In fact, the idea is quite simple and obvious: install the station on a source of inexhaustible energy and, while the station generates current, accumulate its excess in special batteries to direct current into the system when it is dark or there is no wind. Indeed, what could be more attractive than the idea of harnessing the gigantic potential of the sun and wind, especially in Uzbekistan, where the climatic conditions are almost ideal for this?

For all its attractiveness, “green” energy has several significant drawbacks including instability of energy production. For instance, the power of a wind generator is proportional to the third degree of the wind speed, that is, if wind speed drops twice, the generator power will drop as much as eight times. Solar stations, for obvious reasons, cannot generate current at night. We need capacities that will make up for the shortage during peak hours and at night.

In this context, the “green” power plant will necessitate a traditional plant, to compensate for peak consumption. That is, in the evenings (when consumption, by the way, is particularly high) and when the wind speed drops, the current should come from somewhere else, that is, speaking in the language of power engineers, from maneuverable capacities.

It is too early to talk about industrial and widespread use of “green” energy until there is a technological breakthrough, such as the creation of artificial photosynthesis, a dramatic increase in efficiency of green power generation units (still more inefficient than traditional power plants), or the development of a new principle of electricity storage.

It should still be noted that the total capacity of renewable energy sources is steadily growing. According to Asian Development Bank (ADB) estimates, the gross potential of solar energy in Uzbekistan exceeds the equivalent of 51 billion tons of oil. However, huge resources and a serious restructuring of the entire energy system are needed to realize this potential. Today, according to experts, the most likely scenario for the development of solar energy in Uzbekistan is the development of so-called distributed sources of electricity, that is, the construction of small stations to meet the needs of the population and small industrial zones.

For power engineers, stability means having a 20% reserve relative to the available demand at any given time – only in this scenario can effective energy security be ensured. No matter how alternative energy develops, there must be a component in the country’s energy system that generates a stable and necessarily scalable amount of electricity. So far, only thermal power plants, including nuclear power plants, can be such a component.

Now imagine what choices Uzbekistan has.

In ten years’ time, we will need to cover the almost doubled electricity demand. It is possible to continue building traditional thermal power plants. However, even if we put aside environmental issues, where can we get so much natural gas, when Uzbekistan has few reserves? In addition, natural gas could be used for a greater benefit like producing necessary substances including polyethylene, polypropylene, etc., simultaneously creating thousands of jobs and increasing exports. Mendeleev said that heating plants with oil was like burning money. It’s the same story with natural gas.

Solar stations?

Free land is a separate problem for solar power plants. According to the average data, about 50 MW of power can be generated from one square kilometer. The largest solar power plant in the world today – Topaz Solar Farm in the USA – generates 500 MW of power and occupies about 50 km^2, and the cost of construction was about $ 2 billion.

To generate the additional 50-60 billion kWh per year required by 2030, we will need additional stations with a capacity of about 7 GW. Now imagine the area such a station would occupy – almost 1,000 km^2, that is, the area of three Tashkents.

One can, of course, imagine that the land problem would be solved by building a station on the desolate plateau of Ustyurt. However, this does not solve the main issue of supply stability – where to get electricity from dusk to dawn? To date, there are no technologies that would ensure the accumulation of electricity on an *industrial* scale.

The main problems of "green" energy – instability and poor scalability – are *still* a critical obstacle.

This does not mean that alternative energy should not be developed. Of course, it should. One can even imagine that millions of lighting devices can be supplied with their own photocells and at least the problem of lighting could be forgotten. LED lights that don't even have wires or batteries are already available on the market.

Ideally, different power sources should be combined and integrated into a single system so that underproduction in one place is compensated by overproduction in another; the more stations are included in the grid, the greater the stability of the whole system. In an ideal world, it would be possible to cover the entire earth with wind turbines and solar cells and generate electricity around the clock and everywhere. Everything would be perfect if we forget for a moment what an extremely complex control system would require and how much it would cost.

Hydropower?

Today, hydropower is the cheapest way to produce electricity, and in Uzbekistan, hydropower is being developed at full steam. In May last year, President Mirziyoyev adopted a decision[iv] on the development of hydropower, according to which the capacity of electricity produced by water resources should almost double.

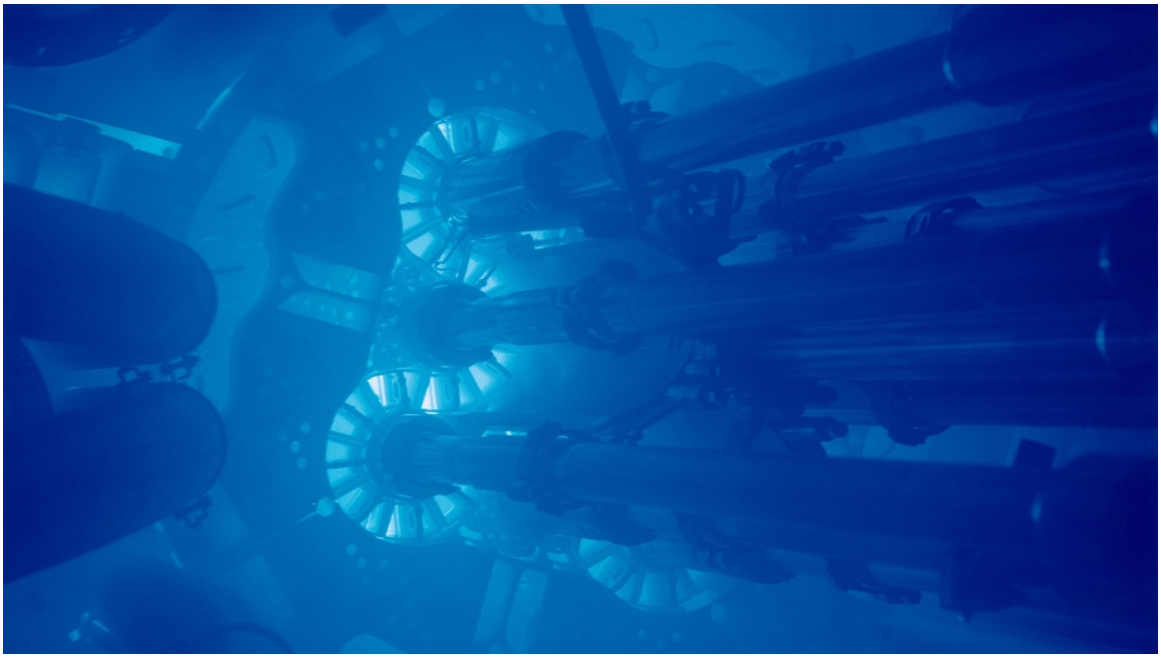
Currently, there are about 35 hydroelectric power plants operating in Uzbekistan, with a total capacity of about 2 GW. Half of the hydroelectric power plants were built 50 years ago and they have seriously depreciated their technical resources. Engineers believe that the amount of energy produced by water in Uzbekistan could potentially be tripled or even quadrupled.

However, the main challenge is the availability of water resources.

Almost all the water in Uzbekistan is "generated" outside its borders, in the initial sections of the Amu Darya and Syr Darya, which are located in the Southwestern Tien Shan, mainly in the territories of Tajikistan and Kyrgyzstan. At the same time, almost 80% of the country's water is used for irrigation.

Even if we imagine that Uzbekistan has agreed on the conditions for the distribution of water resources with its neighbors, solved the most difficult environmental issues, and carried out work on the construction of additional hydroelectric power plants and modernization of existing ones, the main question remains: where to get so much water for hydroelectric power plants? In a region where the value of water is comparable to the value of liquid hydrocarbons, the unreasonable use of water resources can lead to a disaster. To one more disaster.

For these reasons, the recent Presidential Decree underscores the importance of resolving technical, economic, and environmental justifications for the construction of additional hydroelectric power plants. It can be assumed that when all the planned projects are implemented, they will utilize water resources almost at the maximum of the permissible limit.



Vavilov-Cherenkov radiation in a nuclear reactor. University of Idaho.

Since we are talking about water, what about the water supply? After all, a large amount of water is needed for a nuclear power plant, and all of it will be poisoned sooner or later.

A really important issue in the operation of nuclear power plants is the need for a water supply to cool the power plants. At one time, leaked information said that the area near Aydar Lake was designated as the most suitable site for a nuclear power plant, as it was equidistant from Tashkent, Bukhara, and Samarkand. Early nuclear power plants, as a rule, were built next to natural water reservoirs that were used for cooling systems.

Unlike conventional thermal power plants, nuclear power plants have virtually no harmful emissions, as there is no combustion product in the NPP reactor in the literal sense. The only environmental pollution is the so-called thermal pollution, which is especially noticeable with natural water bodies. In this regard, the projects of modern NPPs provide for internal autonomous tanks for water cooling. Some modifications of NPPs can utilize almost all the heat released, directing it to heating systems for residential complexes.

Early types of reactors were single-circuit (as at the Chernobyl nuclear power plant), where water, the coolant, was converted into steam right inside the reactor core, and this also complicated the generation of neutrons. As a result, the water in such a reactor was polluted: the flow of neutrons, bombarding the atoms of water, made it temporarily radioactive.

Modern reactors, such as the Rosatom VVER-1200, for example, or the Westinghouse AP1000, are two-circuit, and some other developments are three-circuit. The circuits are not in contact with each other in this case. Therefore, all available radioactivity remains isolated in the first circuit, and the second circuit remains clean.

How to heat a nuclear power plant and will Uzbekistan have enough of its own raw materials?

The energy source at a NPP is a controlled nuclear reaction, in which the decay of uranium-235 occurs, resulting in a huge amount of heat being released. This heat is then used to heat water and form steam, which spins generators to produce current. In essence, a NPP is a gigantic, complex, and incredibly precise, like a Swiss watch, turbine-powered "boiling pot."

Uzbekistan is among the top 10 countries in the world in terms of uranium reserves. The raw materials are mainly extracted by Navoi Mining & Metallurgical Combine (NMMC), but this uranium is not suitable for use in nuclear power plants, as the uranium-235 isotope must still be increased to about 5%, simply put – enriched. This isotope is needed for the operation of the reactor, since it is best suited for a fission chain reaction.

Fuel enrichment and production takes place using technologies that are currently available to only a few corporations in the world. More than half of the global nuclear fuel market is held by AREVA (France) and Toshiba-Westinghouse Electric Company (US-Japan), while TVEL, which is owned by Rosatom State Corporation owns about 20% of the global market.

In the final form, the fuel is compressed by a very complex technology into Uranium pellets the size of the phalanx of the little finger. They are stacked in three-meter sealed tubes made of heavy-duty zirconium, called *fuel element*. Fuel elements is then bundled into fuel assemblies. This procedure protects against extreme operating conditions inside the reactor where the fuel is loaded for about five years.

The supply of nuclear fuel and disposal of spent fuel are governed by a separate contract between the NPP operator and the fuel supplier. These long-term contracts provide for the supply of control rods to control the operation of a nuclear reactor and the return of spent fuel for reprocessing. Fuel supply is carried out, as a rule, by a company that is engaged in reactor construction.

It is quite possible that within the framework of the same nuclear fuel supply agreement, Uzbekistan will supply uranium concentrate as a kind of raw material for TVEL, which will subsequently produce the necessary fuel assemblies. The world uranium market is very specific and very closed. A lot will depend on the existing contracts, the volume of uranium ore production in Uzbekistan, the price ratio, the cost of ore extraction, and processing.

We don't have any experience yet. Are there nuclear power plant specialists in Uzbekistan?

We have experience, and it is very impressive. Of course, our experience is in the fundamental research of atomic physics, rather than the management of a nuclear power plant as such. The Institute of Nuclear Physics under the Academy of Sciences of Uzbekistan operates a reactor for research and production of radioactive isotopes for medical purposes.

In addition, since the 1960s, the radiation materials science and atomic physics in general have been successfully developing in Uzbekistan. It was represented by a whole galaxy of scientists who made a great contribution to the study of high-energy physics, including B. S. Yuldashev,

the current president of the Academy of Sciences of the Republic of Uzbekistan, K. G. Gulyamov, M. T. Muminov, U. S. Salikhbayev, M. M. Musakhanov, and others.

In the case of the implementation of the peaceful atom program with Rosatom Corporation, the direct management of the NPP will be the subject of a separate, very voluminous and complex agreement, which, among other things, will certainly contain conditions for the training of our specialists.

What is the "Chinese syndrome" and how to ensure safety? And what are the "post-Fukushima standards"?

In the 1960s when nuclear power was rapidly developing in the USA, there was a joke among engineers that if an accident occurred, nuclear fuel would melt the reactor vessel, then the building body, reach the soil, and then burn through the entire planet, reaching China on the other side.

After almost 50 years of industrial operation of nuclear power plants, the industry has developed a huge number of mandatory standards, including the so-called post-Fukushima Standards of the International Atomic Energy Agency (IAEA), aimed at countering natural hazards and guaranteeing power supply for plant equipment. The Parliamentary Investigation conducted in Japan found that outside of the human factor, the technical cause of the accident at the Fukushima Nuclear Power Plant was that the electricity generators flooded with water stopped working, and caused the reactor to melt from overheating.

Safety is, of course, the most important issue for nuclear power plants. Modern reactor designs provide four levels of protection, including so-called sealed traps for dumping nuclear fuel in the event of an accident. Empirical experience and an innate instinct for self-preservation lead to continuous improvement of technologies and increased safety standards.

For the construction of a nuclear power plant in Uzbekistan, of course, it will be necessary to develop and implement the entire set of nuclear standards. In Russia, for example, the main standard is OPB-88/97 – "General provisions for ensuring the safety of nuclear power plants", as well as about 15 more technical standards ensuring the safety of the entire cycle from design to fuel transportation to personnel requirements. In addition to developing standards, Uzbekistan will need to ratify about ten extremely demanding international conventions on atomic safety.

All this is good, but why did Germany abandon the nuclear power plant?

Yes, Germany abandoned the nuclear power plant, but perhaps not completely.

Germany has legislated a decision to shut down eight power units older than 40 years, and the remaining nine are scheduled to be closed by 2022.

There are still disputes about the fact that a complete transition to "green" energy will cost too much and it will not solve the problem of reducing greenhouse gas emissions, since "green" power plants will need to be insured with traditional thermal power plants to compensate for losses. At the same time, there is an imbalance problem that still has no solution: in the north, alternative sources generate electricity in excess, which is either sold to neighbors or simply

dumped, while the industrial south requires huge capacities, which were formerly provided by nuclear power plants.

The three largest energy companies in Germany – E.ON, RWE and Vattenfall – can file lawsuits for $19 billion, after the German Federal Court ruled in December 2016 that companies affected by the shutdown of nuclear power plants are entitled to claim compensation. At the same time, according to the calculations of the German Ministry of Economy, the replacement of nuclear energy with alternative sources will cost about $60 billion, and this is in addition to the fact that the state subsidizes "green" energy at a cost of $14 billion a year[v]. According to unofficial data, the full transition will cost about $300 billion[vi].

Moreover, due to adverse weather conditions in Germany in January 2017[vii], wind and solar power plants provided less than 5% of the total electricity demand, bringing the country to the brink of an energy collapse. Because of this, local electricity prices have reached a ten-year high[viii], reaching 90.5 euros per 1,000 kWh.

It was only thanks to the operation of coal, gas, and nuclear power plants and the introduction of back-up capacity that massive power outages across the country could be averted. Therefore, it is not known exactly how the complete abandonment of the NPP will be carried out. If such an abandonment is possible at all, taking into account today's political and economic realities in Germany.

We should also not forget that other developing countries, such as India and South Korea, on the contrary, are increasing the capacity of nuclear energy. Was it possible to imagine that China's economy, for example, could develop without stable energy sources? It is not surprising that China, in the meantime, is implementing the most ambitious program for the construction of new nuclear power plants.

There are various trends in the world: in some places, as a rule, outdated reactors are being shut down, in some places, on the contrary, new ones are being launched. In the USA, for example, there are 60 nuclear power plants, which is more than France, Japan, Russia, and China combined. Is it possible to imagine that the United States will completely close all its nuclear power plants?

If things are so complicated, maybe the entire population of Uzbekistan should be involved in making a decision? We have heard that Bulgaria, for example, held a referendum on nuclear power plant…

Indeed, according to the legislation of Uzbekistan, a referendum is necessary on the most important issues of public and state life in order to adopt laws. Nuclear energy is such a complex system of relations that it will be necessary to adopt a separate law to regulate it. Given that the construction of a nuclear power plant is an extremely sensitive and important event, it is quite possible that a referendum will be needed, as it was done, for example, in Bulgaria and Lithuania.

The decision may be different if the Government enters into an international agreement. In this case, it is not necessary to hold a referendum, since obligations arising from international treaties of the Republic of Uzbekistan cannot be the subject of a referendum.

In December 2017, an intergovernmental agreement between Uzbekistan and the Russian Federation on cooperation in the use of nuclear energy was signed, where one of the points of cooperation is the development, design, construction, operation, and decommissioning of nuclear power plants. This document creates a legal platform for interaction. However, this is not an international treaty from the point of view of international law, since the document was signed by Rosatom (and not by the government of the Russian Federation), and therefore it would be wrong to consider it as a basis for rejecting the referendum.

At the moment, the production and consumption of electricity in Uzbekistan is regulated by several important regulatory acts, including the laws *On Electric Power Industry* and *On Rational Use of Energy*, as well as *Decree UP-2812* dated February 22, 2001 *On Deepening the Economic Reforms in the Energy Sector of the Republic of Uzbekistan*.

Since the construction of the NPP will be carried out with the participation of state funds, such a project must be registered as an investment project, and all preliminary and final feasibility calculations and studies will need to be approved at the level of government decisions.

The NPP construction project will require a range of regulations that will cover industry regulation, siting of nuclear installations, incentives and benefits for the organisations involved, special conditions for construction, handling of nuclear materials, export and import of the entire infrastructure, and, of course, safety issues.

And yet – why do we need a nuclear power plant?

The emergence of a nuclear power plant will have medium- and long-term effects.

In the medium term, we will find a stable source of energy, which is critically necessary for the implementation of government plans and for solving social and economic problems.

In the long term, the emergence of nuclear energy will accelerate development of other industries, industrial modernization, and more importantly, will give a good impetus to fundamental science.

The energy picture in Uzbekistan is quite depressing. In ten years, the annual demand for electricity could double to about 110 billion kWh judging by the dynamics of economic development, as well as the population growth in Uzbekistan, which, according to the UN, will be around 40 million people by 2030[ix]. Taking into account the coercive force of reality, how can we solve the issue of an almost twofold increase in electricity production?

If the contract for the construction of a NPP is signed in 2018, the first electricity will be received no earlier than 2024-2025. We simply have no time left to discuss NPP issues.

We express our gratitude to: the Academy of Sciences of Uzbekistan, the Institute of Energy and Automation under the Academy of Sciences of Uzbekistan, as well as the Institute of Nuclear Physics under the Academy of Sciences of Uzbekistan.

Written by:

Ziyodullo Parpiev
Head of the Strategic Planning Department
ziyodullo.parpiev@centil.law

Oybek Yuldashev
Head of the Analytics Department
oybek.y@centil.law

Otabek Suleymanov
Partner
otabek.s@centil.law

www.centil.law

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[iv] Resolution of the President of the Republic of Uzbekistan dated May 2, 2017 No. PP-2947 "On the Program of Measures for Further Development of Hydropower for 2017-2021"

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