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CONCERNING SOME ISSUES OF SMALL MODULAR REACTORS (SMR) IMPLEMENTATION IN UKRAINE

Abstract. *The interest to low-power reactors (SMRs) is growing in many countries. SMR developers consider their application quite promising from many points of view. The growing demand for energy security and low-carbon energy in the context of the climate changes approaches the reality of SMR application. Being composed of separate modules and factory-constructed, SMRs show the promise of significant cost reduction. SMRs can also be used for heat providing for industrial processes, hydrogen production and water desalination. In this regard, balanced and objective information on advances in SMR design and technology development trends is needed by all countries considering application of SMRs. More than seventy SMR projects are under development worldwide. Various types of SMRs are being developed: water cooled, high temperature gas cooled, fast neutron, molten salt and microreactors. The majority of SMRs are in the early stages of design. SMR concepts based on the pressurized water-water reactor technology are in the late stage of design and on the highest levels of technological readiness for deployment. The prospects for the development of water-water SMR technologies have been analyzed based on the published data. The analysis included NuScale (iPWR), SMR-160, Westinghouse SMR, UK SMR advantages and disadvantages, conceptual approaches, characteristics of SF and RW generated during operation and decommissioning, and the existing regulatory documents regarding the selection of sites and disposal of the radioactive waste. Evaluating the prospects for the application of SMR technologies in Ukraine, priority should be given to the water-water projects.*

Key words: *water-water small modular reactors, safety and economic indicators, radioactive waste, site selection.*

Introduction.

The choice of the reactor type is determined by various criteria, including (Nosovskyi, 2019):

– safety at various stages of the life cycle of the reactors, including construction, operation and decommissioning;

– estimated cost, including costs for design, construction, licensing and operation, and the nuclear fuel component costs;

– safety costs, and SF and RW management costs.

The priority attention during the development and deployment of SMRs should be given to the optimal siting and deployment as well as to the assessment of the key chellenges for the SF and RW management. These factors should be taken into account when choosing a technology and considering the nuclear fuel supply security.

The interest to low-power reactors (SMRs) is growing in many countries. SMR developers consider their application quite promising. According to IAEA data, there are more than 70 typical SMR projects integrable to various reactors operaiting now, i.e., Pressurized Water Reactor (PWR), Boiling Water Reactor (BWR), Pressurized Heavy Water Reactor (PHWR/Candu), Advanced Gas-cooled Reactor (AGR), Light Water Graphite-moderated Reactor (LWGR/RBMK), High-Temperature Reactor (HTR). The majority of SMRs are in the early stages of design. SMRs are the reactors that have a power capacity of up to 300 MW(e) or a thermal capacity of up to 1000 MW(t) that can provide about 30 thousand households with the energy. The power of a unit can vary from a very small (for example, a few tens of MW(e) to 300 MW(e). The reactor and other parts of a power plant are considered standardized products that can be serially manufactured in a factory and installed on site as prefabricated modules which can be tramsported by rail or road.

The growing demand for energy security and low-carbon energy in the context of the climate changes approaches the reality of SMR application. The reactors can take a share in the diversified energy balance. They can be used for heat generation for technological needs, water desalination, hydrogen production, etc. SMRs could be competitive if installed in regions with less developed infrastructure due to lower capital and operating costs, shorter construction periods and the possibility of a more optimal return on investment. Among the advantages of SMRs are: safety characteristics (Figure 1), construction terms, a high degree of deployment flexibility and easy maintenance (IAEA, 2023). The declared

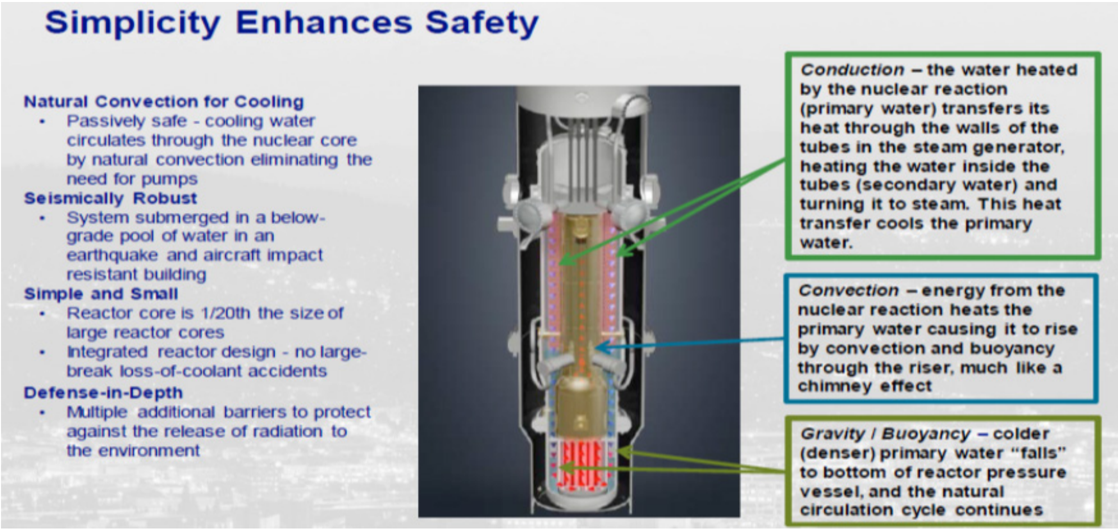

Fig. 1. Safety characteristics of a SMR (IAEA, 2023)
Рис. 1. Безпекові характеристики ММР. Запозичено з (IAEA, 2023)

probability (risk) of the active zone destruction as a result of SMR equipment failure is orders of magnitude lower than at the currently operating and new large nuclear power plants (Figure 2). The probability of the SMR core damage (reactor/year) (NuScale Power LLC, 2020) is 3.0 $\times 10^{-10}$, and that of the operating large NPPs (generation III) is 10^{-4}-10^{-5}. The emergency planning zone radius of the large NPPs (generation III) is 16 km (U.S. NRC regulation), while that of SMRs is limited to the site boundaries. The possibility of combined use of large water-water reactors and water-water SMRs is being assumed.

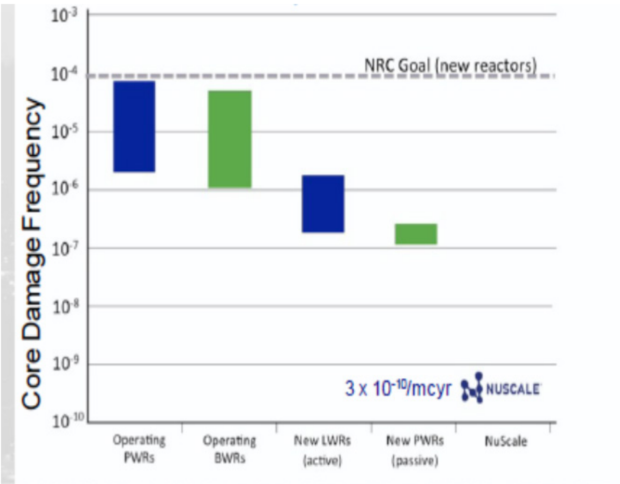

Fig. 2. Risks of the reactor core demage in emergency situations (IAEA Report, 2019)
Рис. 2. Ризики руйнування активної зони реакторів у результаті аварійних ситуацій (IAEA Report, 2019)

In general, SMR concepts based on the pressurized water-water reactor technology (in particular, VVER reactors operated in Ukraine) are in the late stage of design and on the highest levels of technological readiness for deployment. Evaluating the prospects for the application of SMR technologies in Ukraine, priority should be given to water-water projects, taking into account the experience in large VVER reactor operation, the use of the already existing nuclear fuel cycle components and the appropriate infrastructure, and the possibility of the combined use of traditional large water-water reactors (VVER and AP-1000) and water-water SMRs.

The objective of the paper is to analise of the water-water SMR (NuScale (iPWR), SMR-160, Westinghouse SMR, UK SMR / Rolls-Royce) technology development prospects in case the decision on SMRs deployment would be taken in Ukraine. The analysis also included SMR advantages and disadvantages, conceptual approaches, determination of the main technical and economic indicators of the SMR implementation, characteristics of SF and RW, the existing regulatory documents regarding the selection of sites and disposal of the radioactive waste.

Results and discussion.

The positive and negative factors affecting the economic indicators of SMR implementation are estimated in (Mignacca, Locatelli, 2020). They are as follows:

General cost-effectiveness. Cost-effectiveness depends on the SMR power capacity and is considered the main negative factor regarding SMRs as compared to large reactors. The projected costs of generating one megawatt of electricity (in US dollars) can be 50–70% higher for SMRs than for large reactors. The projected levelized cost of electricity for SMRs (water-water reactors) in 2030 is 75–125 USD/MWh (OECD/NEA, 2015).

Modularity is the main characteristic of a SMR. The main aspects of the SMP modularity are the following:

– factory assembly (increases the quality of all components, reduces time and costs at the construction site, decreases the costs for organizing reliable supply chains);

– modularity (increases the quality of all components, reduces construction time and costs, allows organizing reliable supply chains);

– the possibility of transportation by rail or road (reduces the risks of delays, effective project management is essential).

The reduction of capital investment in SMR depends on the SMR modularity type and is estimated by various sources at the level of 15 to 40%.

The possibility of the reactor capacity expansion (scalability). It has a positive effect on the cash flows during the SMR construction as compared to large reactors (receiving income from the first SMR module operation while the construction of others continues, reducing investment risks, refinancing).

Deployment of several modules on one site. This will allow control of the reactors by single control room. Some SMR designs allow reloading fuel into one module with the ongoing operation of the others. By increasing the nuclear fuel reloading period from 12–24 months for large NPPs to 36–48 months for SMRs, the capital costs for SMRs can be reduced by 2–5% and annual maintenance costs – by 3%. The SMR capacity utilization factor is expected to exceed 95% of the infrastructure costs during the construction and operation of multi-module SMRs.

Cogeneration and electric load management. The possibility of using SMRs as balancing capacities for unstable renewable energy and creating hybrid systems.

Personnel training speed. It is expected that the capital costs reduction in mastering the SMR technology will be faster than for large reactors. Safety requirements for SMRs are the same or more strict than those for large NPPs requiring additional training and expences. It is noted that a 10% cost reduction can be achieved after the deployment of 5–7 SMR modules.

Construction period. By reducing the amount of work on the site, simultaneous manufacturing of the components and testing in the production pemises, it is expected that the the SMR construction period can be shortened by 35% (about 2–4 years) depending on the number of the modules constructed. Recently, the company Sheffield Forgemasters (Great Britain) managed to fabricate a reactor vessel in less than 24 hours, instead of the usual 12 months, using an innovative welding technology (Sheffield Forgemasters Co., 2024).

Accessibility. Accessibility to all the components of a SMR should be considered at the design stage to ensure safe operation and maintenance. Owing to the small size of the reactors, the maintenance of SMRs is more challenging as compared to large reactors. If easy accessibility is not ensured, the issues arising during SMR operation and maintenance may cause safety risks for the personnel and environment, and cost increase.

Operating costs. Since several modules are located on the same platform, the operating personnel will be able to service several modules simultaneously from one control point. The SMR operating costs are expected not to exceed those for large NPP. Fuel costs are estimated to be equal to or slightly higher than for large NPPs.

Licensing period. Bearing in mind the specific engineering solutions for SMRs, novelty in the technology and the lack of a legal and regulatory framework, the duration of licensing could have a negative impact on the deployment of SMRs. It is expected that further licensing of series SMRs will be faster than the large NPPs.

*Decommissioning cost*s. It is assumed that due to the modular design of SMRs, the decommissioning can be carried out by removing the modules from the site with further decontamination and disassembly at a factory. The SMR decommissioning costs are expected to be 20% lower than the corresponding costs for the large reactors.

Taking into account the lack of experience of the practical realization of SMR projects, the SMR developers cannot provide reasonable information on the cost of a SMR.

Recently, experts from the Institute of Energy Economics and Financial Analysis (IEEFA) prepared a report (Schlissel, Wamsted, 2024) which consider SMRs as a too expensive, slow and risky project.

Those few SMRs that were manufactured and put into operation somewhat differ from the "advertisement" ones. Costs are growing and the construction schedule is violated, the IEEFA report said. Experts point to the SMR cost as one of the main arguments against its deployment. According to some data, all three SMRs currently in operation and the one under construction in Argentina, have significantly exceeded their budgets.

The authors of the report also stress that the construction of a SMR takes too long. For example, the construction of the Shidao Bay project in China was supposed to take 4 years, but actually took 12 years. The current CAREM project in Argentina was supposed to be completed in 4 years, but is currently in its 14th year of development. A similar situation is observed for large NPPs. It takes much longer than expected to put them into operation. The authors of the report also wonder whether the new SMRs would produce the power claimed in the projects.

Key technical characteristics of water-water SMRs.

The main technical characteristics of the water-water SMRs, which are under consideration in Ukraine, are mostly the same, but there are some differences. The common characteristics include: type of reactors (iPWR) which is much smaller (Figure 3), coolant/moderator (light water), the coolant in the first circuit moves due to natural convection, the first circuit is integral, that is, the steam generator is directly connected to the reactor vessel without a circulating pump and circulation pipelines; type of fuel/fuel assembly (UO_2 tablets in a square array), fuel enrichment (up to 5%), engineered safety features (passive), flexible fuel cycle (up to 36–48 months), design service life (at least 60 years), the reactor modules are immersed into the common pool that is also used for the spent fuel aging (up to 5 years of aging), barriers preventing the radioactivity release – the reactor building, the biological shield at the ground level above the reactor pool (Figure 4), the construction of the pool and its coating, the jacketed reactor vessel; dry spent fuel storage (design life 100–120 years). The SMRs also have some specific characteristics: thermal/electric power, primary circulation, entrance/exit coolant temperature, number of fuel assemblies, fuel burnup, installation area

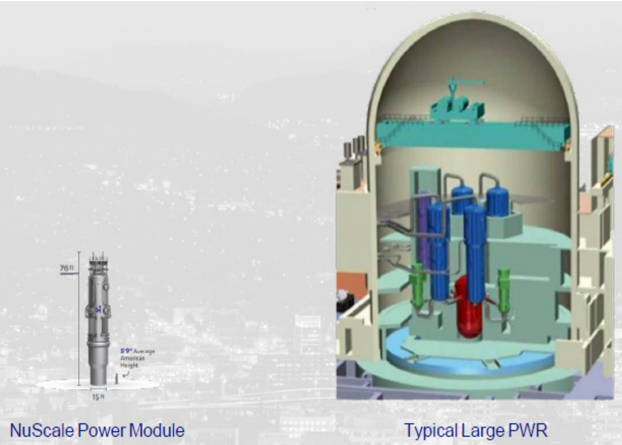

Fig. 3. Comparison of an SMR with a large pressurized water reactor (PWR). 1 ft = 0.3048 m (IAEA Report, 2019)
Рис. 3. Порівняння ММР з великим реактором з водою під тиском (PWR). 1 ft = 0,3048 m (IAEA Report, 2019)

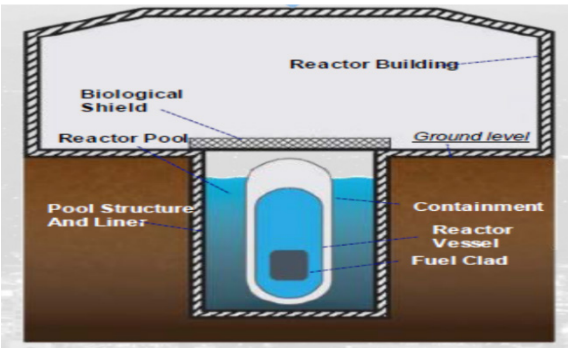

Fig. 4. SMR barriers to prevent the radioactivity release (IAEA Report, 2019)
Рис. 4. Бар'єри ММР від вивільнення радіоактивності (IAEA Report, 2019)

and the reactor vessel dimensions, location of dry spent nuclear fuel storage, design status, etc.

Management of radioactive waste generated by SMR.

The safe management of the nuclear waste generated by SMRs is a key issue of the SMR development and licensing at the international and EU level (Shabalin, 2023). The future investments in nuclear energy, in particular for SMR deployment, require adequate financing for RW management, availability/construction of LILW storage and disposal facilities, and development of a HLW disposal strategy that should be approved by 2050. The existing system of SF and RW management in Ukraine requires significant infrastructural development, training of high-quality personnel and the improvement of the system of RW management facilities. In accordance with the legislation, the new classification of RW distinguishes 4 classes of waste and 4 types of disposal facilities: "surface" (in trenches in a facility on the earth surface), "near-surface" (at a depth of a few tens of meters bellow the surface), "mid-depth" (from several tens to hundreds of meters below the surface), "geological" (usually at a depth over 100 meters below the surface) in order to ensure containment and isolation of radioactive waste from the biosphere. In Ukraine, SF is not recognised as RW. A so-called "deferred decision" – long-term (50–100 years) storage of SF in special dry storage facilities has been established by the Cabinet of Ministers of Ukraine. The deferred decision on SF management leaves the burden of the problem solution to future generations and does not provide income from decommissioning of NPP units that have generated significant volumes of SF and RW. In fact, regardless of considering SF as waste or a valuable resource, a geological repository must be constructed to dispose SF or SF reprocessing products. Currently, Ukraine has no developed and approved concept of a geological repository. This situation requires long-term international research for development of a strategy of safe management, storage and disposal of the SF and RW generated at the Ukrainian NPPs (Project INSC U.04.01/14B, 2021).

SMRs can be located in different parts of Ukraine close to a city or a large industrial enterprise that needs its own energy source. Today, DTEK Energy Holding Company considers the use of SMR technology as a strategic direction of the company's development and thoroughly studies the SMR technology. From the point of view of SF and RW management, the decentralized operation may mean the presence of several operators on the market and construction of small storage facilities that would temporarily store the generated SF and process the RW. On the other hand, waste management can be more centralized.

The characteristics of SF generated by SMRs will differ from those generated by large water-water reactors, due to the difference in the fuel enrichment in the fuel assemblies and the denser flow of thermal neutrons, which will affect the burnup and loading of the fuel.

The performance of a large water-water reactor is compared with that of a hypothetical small modular reactor based on the NuScale SMR concept (iPWR) in terms of the nuclear waste management criteria in (Brown et al., 2017). The results of a series of calculations show that the mass and activity of SF, HLW and LLW are less promising in the available SMR projects compared to large reactors, i.e., the amount of accumulated SF, HLW, and LLW is higher and their activity increases. It should be mentioned that these results were calculated based on one single reactor cycle loading. It is expected that SMRs with a multiple fuel cycle loadings would perform better and the waste generation would be lower compared to a large water-water NPP unit.

It should also be taken into account that each SMR module is immersed into the common reactor pool and shares water with the SF storage pool that has specific chemical and radionuclide composition and, thus, is able to contaminate the circulating water. Larger amount of water-water SMR waste, compared to a large high-power water-water reactor waste, should be treated, stored and conditioned before disposal. These processes will entail significant expenses. Currently, in our country, RW processing complexes are being constructed at the operating nuclear power plants. The RW management systems are being brought in line with modern requirements. Such complexes and systems should take into account the specific characteristics of the RW generated by SMRs, in case they woukd be deployed in Ukraine.

Many SMR concepts are still in the early stages of development, so it is difficult to determine actual RW flows and specific waste management strategies. At the same time, at this early stage, there are great opportunities to make demands on the basic characteristics of the RW treatment systems and influence their design. In any case, the authorities responsible for RW management should be prepared at least for temporary storage of RW flows in the same way as at a large high-power water-water nuclear power plant. In general, the IAEA states (IAEA, 2020, IAEA Report, 2019) that SMR RW will probably be disposed of like that generated by large water-water nuclear power plants and its volume can be reduced by compaction. In this context, it is worth noting that today almost all countries do not have a long-term solution for SMR RW management. The countries that plan to implement SMR technology and construct RW disposal repositories do not expect additional waste flows from other reactors. It can also be assumed that RW flows from the combined use of large water-water reactors (e.g. AP-1000) and water-water SMRs are similar and therefore can be pre-treated and disposed in near-surface and mid-depth geological repositories (based on the KBS-3V concept) within their current designs. Such a statement is quite possible since SE "NNEGC "Energoatom" and Westinghouse Electric Company LLC signed an agreement on the construction of nine new power units (generation III) in Ukraine using the American AP-1000 technology.

Regarding the regulatory framework for the SMR deployment

Each country that plans to build a SMR faces the task of establishing new rules that are understandable to all participants, developing relevant documents and laws regarding the site selection for the construction and operation of SMRs, as well as the RW and SF management system.

The regulatory and legislative framework for the licensing of nuclear installations does not fully comply with the current Ukrainian norms and rules. Now the framework is being worked out in accordance with the principle of "continuous safety improvement". The present framework envisahes only construction of nuclear power plants with the VVER-440 and VVER-1000 reactors. However, special legislation and regulatory legal acts regulating activities related to the design, construction, commissioning and operation of SMRs and AP-1000 have not yet been developed. All other modern reactors (in particular, large power units of other types and SMRs) will not meet the national requirements, although at the same time they will meet significantly higher safety standards.

The main principles of environmental safety during the deployment of SMRs are:

– site selection for SMRs taking into account geological, hydrological, landscape and meteorological characteristics of the sites, biogeocenoses, and population density;

– scientifically based selection of a SMR type and necessary equipment and facilities;

– reduction of the impact of natural sources of ionizing radiation on the health of the population;

– reduction of the impact of other harmful factors on the health of the population and the environment during the operation of the nuclear plants in the operation mode;

– taking into account the joint impact of SMRs and other kinds of human activity on the health of the population and the environment during site selection.

To reduce the impact of various pollutants on the environment, a system of environmental standards must be developed. It should consider the specific natural and geographical features of the region, and measures to reduce the content of artificial radionuclides in the biosphere. To date, in Ukraine, there are no agreed and approved documents that define siting for the possible deployment of SMRs.

The main document that establishes the criteria for nuclear and radiation safety and determines possible external natural and technogenic hazards which might impact the NPPs preventing or limiting the site selection for NPP deployment, is SNRIU NP 306.2.144-2008 "Safety Requirements for NPP Siting". This document is also the basis for reassessment of the site in case of the NPP design extension (with an increase in the installed capacity of the NPP units or their redeployment after decomissioning). The reassessment is grounded on the results of the previous estimation of the site characteristics as regards its suitability for NPP siting basing on the principle of step-by-step differentiation.

The State Nuclear Regulatory Inspectorate of Ukraine developed and approved a new document "Requirements for safety assessment of nuclear power plants with regard to external natural hazards" (NPA 306.2.232-2021). Its main purpose is to esteblish requirements for safety assessment of the NPPs operation as regards natural hazards taking into account the experience of the Fukushima-1 accident and the international practice, in particular the IAEA recommendations. The requirements are obligatory for siting, design, construction, acquisition, marketing, commissioning, operation and decommissioning of structures, systems and elements of nuclear power units.

In 2023, the Ministry of Energy of Ukraine developed and sent for approval the draft law "On Amendments to Certain Laws of Ukraine Regarding the Construction of Nuclear Installations and Facilities for the Management of Radioactive Waste" aimed at creating conditions for restoration, sustainable functioning and further development of nuclear power, accelerating the implementation of investment projects and improving the legislation that regulates the construction of nuclear installations and facilities designed for radioactive waste management, promoting the increase of the state's energy independence. After approval of this law by Verhovna Rada of Ukraine, the Cabinet of Ministers of Ukraine will bring its normative legal acts into compliance with this Law;

Table 1. Indicative roadmap for licensing of SMRs and disposal facilities for waste from SMRs or combined use of large VVER-1000/AP-1000 and SMR

Таблиця 1. Орієнтовна дорожня карта для ліцензування SMR та об'єктів утилізації відходів з SMR або комбінованого використання великих VVER-1000/AP-1000 and SMR

Pre-study phase	– Define regulatory framework; – Define responsibilities (e.g., in case of centralized waste management); – Identify the waste streams (HLW, LILW, SL-LILW, VLLW); – Define interim storages needed at the SMR site (HLW, LILW, SL-LILW); – Identify the predisposal options; – Identify the processes and waste streams from SMR decommissioning; – Identify requirements for a SMR site with an interim storage facility a repository site; – Identify requirements for SNF and RAW transportation; – Start building up a safety case; – Map stakeholder and public opinion.
Conceptual design phase	– Define waste acceptance criteria (WAC); – Define conceptual designs for the final disposal repositories; – Initiate details SMR site screening process; – Define conceptual designs for interim radioactive waste storages; – Development of predisposal radioactive waste management options; – Initiate EBS design development (e.g., encapsulation and canister design); – Evolving safety case and requirements management systems for the site and EBS.
Construction license phase	– Site selection including environment impact assessment (EIA); – Detailed repository design; – Detailed designs for interim radioactive waste storages; – Detailed plans for predisposal waste management; – Detailed EBS designs; – Preliminary safety assessment report (PSAR).
Operation license phase	– Final plan for interim radioactive waste storages; – Final plan for the repository and for EBS; – Plans for closure and decommissioning of SMRs; – Final assessment report (FSAR).

ensure the review and cancellation of the normative legal acts that do not comply with this Law by the executive authorities. In particular, amendments are required in several Laws of Ukraine: "On nuclear energy usage and radiation safety", "On radioactive waste management", "On treatment of spent nuclear fuel for deployment, design and construction of the Central spent nuclear fuel storage facility of the Ukrainian NPP reactors of the VVER type".

As for NAEK Energoatom, the operator of all acting nuclear power plants in Ukraine, the company's final intentions regarding the development of new technologies (except for AP-1000 reactors) have not been published yet. There are no program documents regarding the possibility of implementation of SMRs into the national nuclear industry. Although, taking into account the lifetime of the NPPs operating in Ukraine, development of new technologies, in particular SMR, is urgent.

Evaluating the prospects for the SMR technologies application in Ukraine, the preference should be given to light-water SMR projects. These projects consider the experience accumulated during operation of the acting NPPs with VVER reactors in Ukraine. The international experience shows benefits of early involvement of the regulatory body in the SMR licensing process. Before starting SMR licensing in Ukraine, it is necessary to analyse the existing national regulatory framework taking into account the design features of SMRs and the "differentiated approach". Special regulatory requirements for SMRs should be developed and the scope of application of the existing regulatory documents determined. It is considered appropriate to develop regulatory documents that would determine the procedure and scope of the pre-licensing assessment of a nuclear installation project from a foreign supplier for the national nuclear regulatory authority (Dybach et al., 2024, Zhabin et al., 2020).

There is a number of challenging issues related to the SMR implementation, i.e., reactor emergency mode, beyond-the-design basis accidents, availability of water for cooling and the coolant. A special law should be adopted before the siteselection, since the deployment of any nuclear installation in Ukraine requires a separate law. This process is rather long and complicated. The decision will be made based on the existing infrastructure. It is appropriate to deploy SMRs at the NPP sites after unit decommissioning or at the locations requiring maneuverable capacities.

There are still many more questions concerning SMR application than the answers. The indicative roadmap for licensing of SMRs and disposal facilities for radioative waste from SMRs and combined use of traditional large water-water reactors and SMRs (VVER-1000/AP-1000)-SMR should at least include the phases listed in the Table 1.

Conclusions

The current IAEA recommendations concernining the further studies of water-water SMRs include (ELSMOR, 2019, TANDEM, 2022):

– calculations for a better understanding of the impact of SMR fuel characteristics on the final disposal and the design of the engineered barriers of the facilities (for example, the design of canisters);

– further studies to identify factors that may affect the disposal of LILW generated by SMR units;

– requirements for SMR siting and subsequent location of SF and RW interim storage facilities;

– site selection for storage facilities for SF from SMRs, requirements and management options;

– transportation of SF and RW generated by SMRs for long-term storage and disposal.

The management of SF and RW generated by SMR will depend on various factors, including: transportation of SF and RW within Ukraine and the capacity of interim storage facilities at NPP sites and RW disposal repositories. At the same time, there is a number of uncertainties and related issues regarding the SMRs. There are still many more questions concerning the deployment and application of SMRs than scientifically based answers to them. In this regard, Ukraine participates in a number of international projects related to ensuring safe operation and maintenance of SMRs, for example, "Small Modular ReacTor for a European sAfe aNd Decarbonised Energy Mix" (Shabalin, 2023) and "Towards European Licencing of Small Modular Reactors" (Dybach et al., 2024).

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ЩОДО ПРОБЛЕМНИХ ПИТАНЬ ПЕРСПЕКТИВ ВПРОВАДЖЕННЯ В УКРАЇНІ МАЛИХ МОДУЛЬНИХ РЕАКТОРІВ

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Анотація. *У світі зростає інтерес до малих модульних реакторів (ММР), а їхні розробники вбачають перспективність їх впровадження з різних точок зору. Реальність впровадження ММР наближають зростаючий запит на енергетичну безпеку і низьковуглецеву енергетику. Оскільки ММР складаються з окремих модулів і виготовляються на заводі, витрати на їх виробництво значно зменшуються. ММР також можуть використовуватися для забезпечення теплом промислових процесів, виробництва водню та опріснення води. З огляду на це збалансована та об'єктивна інформація про прогрес у розробці ММР та тенденції розвитку їх технологій потрібна всім країнам, які розглядають можливість їх застосування. У світі розробляється понад сімдесят проєктів ММР. Це реактори різних тиів: з водним охолодженням, з високотемпературним газовим охолодженням, на швидких нейтронах, сольові реактори та мікрореактори. Більшість різних типів ММР дотепер перебувають на ранніх етапах науково-дослідних та дослідно-конструкторських розробок. Концепції ММР, в основі яких лежить технологія водо-водяних реакторів під тиском, є найбільш конструкційно опрацьованими, мають найвищі рівні готовності технології до впровадження. У статті за відкритими літературними джерелами узагальнено та проаналізовано перспективи розвитку технологій водо-водяних ММР: NuScale (iPWR), SMR-160, Westinghouse SMR, UK SMR у разі їх впровадження в Україні, концептуальні підходи, їх переваги і застосування, основні технічні характеристики, оціночні фактори, що впливають на економічні показники застосування ММР, оціночну характеризацію ВЯП і РАВ, що утворюються під час експлуатації і зняття з експлуатації, а також основні проблеми наявної нормативної бази щодо вибору майданчиків і захоронення РАВ. Саме тому, оцінюючи перспективи застосування технологій ММР в Україні, слід віддати перевагу водо-водяним проєктам.*

Ключові слова: *водо-водяні малі модульні реактори, безпекові та економічні показники, радіоактивні відходи, вибір майданчиків.*