



CONSIDERATIONS REGARDING THE ENERGY UNIT TYPE SMALL MODULAR REACTORS SMR AT DOICEȘTI, ROMANIA

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Abstract: Nowadays, the complex energy-mining objectives do not disappear, but it is possible to enter into crisis, since the protection, safety and security along with the environmental issues must evolve on an uncertain curve of knowledge without borders with the help of Artificial Intelligence. That is why it is suggested, it is recommended to reconceptualize objectives of this type, identify new utilities, new forms of investment and operation to support sustainable development. The central objective of the article is to present through the case study the opportunities and advantages of the Modular Nuclear Power Plants (CNM)/SMR, the favorable location of the world premiere SMR in Romania, at Doicești-Dâmbovița, the meanings of risk reduction operations through protection, safety and appropriate security. Also, the understanding and methodological establishment of the transition, for the first time on a global level, to the construction and operation of nuclear power plants with Small Modular Reactors type SMR in Romania, in the EU and worldwide is also considered. The way to establish the guarantee model of the favorable functioning of the SMR is reported as well as the identification of solutions for the problem of radioactive waste management.

Keywords: Small Modular Reactors, investment, protection management, storage of uranium waste

1. Introduction

The intention is to place the reactors in the area of the former thermal power plant from Doicești, inside the town, discussions about risks, costs, being highlighted that practically, the investment has priority, noting that they are among the first SMR reactors of this type built worldwide, that the company's NuScale project meets the working prototype stage.

The NuScale company (USA) together with Nuclearelectrica (Romania) will primarily develop this type of SMR in the country, the planned target being 2029-2030, with a capacity of 300 MW per unit (The plant has 6 SMR modules and, in fact, will have an installed capacity of 462 MWe).

SMR can be assembled in the US company and delivered to the designated area.

In essence, it is found that there are no commercial SMRs in operation globally so far, but some projects are foreseen in the world, considered as key technologies for the future.

Different industrial and research partners are already participating in a consortium for SMRs: Ansaldo Nucleare (Italy), Westinghouse Electric Company (USA), ENEA (Italy), SCK CEN (Belgium), RATEN (Romania), etc.

This plant with nuclear mini-reactors is being developed in Romania, in Doicești, because there is experience on the local level, there have been activities with nuclear energy.

The location of the SMR in Doicești was established taking into account the consultation of the local community.

NuScale Power with its modular reactor technology has direct projects and operations in Romania, through partnership and specific agreements.

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Currently, in Romania, the nuclear sector is managed by Nuclearelectrica, the state company that operates the Cernavoda nuclear power plant, with CANDU nuclear reactors in operation.

The protection of nuclear power plants is a priority, as any nuclear incident or accident can have serious consequences for the environment and human health.

The nuclear power plant protection model involves multiple levels/layers of safety and controls to prevent nuclear accidents and minimize their effects should they occur.

2. Methods, methodologies of scientific reporting

2.1 Modular Nuclear Power Plant (CNM)/SMR for energy Doicești-Dâmbovița: opportunities and advantages

Modular nuclear power plants (CNM) / SMR are units found in innovative structures for the production of electricity, with application in the near future (2030) as a world premiere in Romania.

They are designed to be smaller than traditional nuclear power plants and have advantageous features such as:

- *Modularity*: the individual modules / small-sized reactors are prefabricated, transported and assembled in territorially predefined locations / such as the perimeter of the former Doicești-Dâmbovița coal-fired power plant (costs and risks associated with large nuclear projects are reduced).

- *Safety*: they are less likely to cause serious accidents due to their passive safety features and more controllable and efficient cooling systems.

- *Incremental development*: allow the addition of additional sub-modules/modules to respond to the fluctuating demands of the regional energy market.

- *Use in various applications*: in addition to electricity, they can produce heat or have various purposes for operation (for example, in an extended sense, for water desalination).

- *Clean energy*: they produce electricity without significant greenhouse gas emissions.

- *Reduction of nuclear waste*: it uses quantitatively scaled-down nuclear fuel compared to the large quantities from traditional nuclear power plants.

- *Easier regulations and approvals*: small size and modularity provide the framework for faster, simpler regulations and approvals than for large nuclear power plants.

For SMR modular nuclear power plants there are also challenges such as: high initial costs but not similar in magnitude to those of large plants, concerns about nuclear waste management and risks associated with nuclear weapons proliferation. [8]

In 2014 in Romania, the SMR Regulatory Authorities Forum was established, [9], to examine the regulation of the establishment and operation of the SMR.

In 2017, topics related to licensing, design, safety, functions and operations of SMR in Doicești-Dâmbovița were addressed.

The concepts of "multi-unit" versus "multi-module" specific to SMR were launched, defining the interpretation of "SMR module" as "nuclear installation".

The idea of the "multi-module unit" also appeared, and the power plants are referred to as "multi-module units".

The multi-module unit, according to [1], can comprise a single reactor module in the first stage of development, but allows the addition of several modules next to the same infrastructure; in fact, the different modules being essentially identical.

Specific aspects of protection, safety and security for nuclear multi-units or multi-modules include the potential for interactions between modules, sharing of characteristics, specific hazard situations.

Tab. 1 Basic principles regarding security in SMR Doicești - Dâmbovița

General/overall requirements	Specific requirements
Regulations for protection, safety and security in SMR by Government and Legislature	Evaluation of the location (Doicești) of SMR
Management and leadership for protection, safety and security in SMR	The way the SMR Doicești power plant is designed and built
Radiation protection, safety and security	Nuclear reactor protection, safety and security
Protection, safety and security in relation to nuclear activities	Protection, safety and security from the use of nuclear fuel in cycles
Protection, safety and security from radioactive waste	Protection, safety and security of radioactive nuclear fuel transport

That is why it is considered that for SMR Doicești-Dâmbovița it is necessary to review the levels of protection, safety and security by including the own, local regulatory requirements.

It is recognized that incidents, technical progress and local specificity influence the interactions and dependencies in the field, and it is necessary to estimate the site risk in an integrated manner, examining the simultaneity. (tab. 1)

In essence, it is considered that for the SMR Doicești-Dâmbovița nuclear power plant it is necessary to develop a Guide with the general/overall requirements, respectively the specific requirements in the field.

2.2 Exemplification by similarity: The ACP100 small modular reactor system

It is found that only the existence of large nuclear power plants does not fully satisfy the generation of electricity.

As such, numerous countries are developing small and medium-sized reactors (SMRs); already 13 SMRs are under construction in 6 countries.

Frequently, national agencies (such as the China National Nuclear Corporation - CNNC) make small modular reactors, the most famous being the ACP100. (Zhi Ch., 2013), [2] (fig. 1)

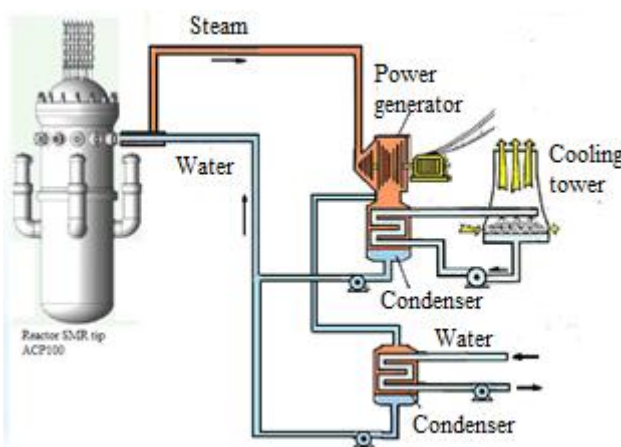


Fig.1 Simplified diagram of the ACP100 type SMR Nuclear Reactor (Source: after Zhi Ch., 2013/ 2022)

It is based on PWR technology, taking over the "passive" safety system and the "integrated" reactor.

The main parameters (technical characteristics) for this type of installation are as follows: thermal power: 310 MWt; electrical power: approx. 100 MWe; lifetime of the construction/project: approx. 60 years; refueling with nuclear fuel: every 2 years; steam generator type: OTSG; steam pressure: 4 MPa.

ACP100 has integrated primary system and equipment, high primary coolant flow rate, low volume of radioactivity, suitable equipment for natural circulation, lower degradation ("passive" safety) of thermal power, and the reactor and spent fuel water zone are located below ground level.

As such, the protection, safety and security within this infrastructure has specific values, additional to the usual situations in the field.

In operational operation, the plant's control systems maintain and restore its normality, reactor protection anticipates failures, initiates protective functions and mitigates the consequences of events, also monitors/controls accidents related to core melting and release of radioactive substances.

At the same time, the ACP100 reactor type has protection systems with diverse actuation, control (reactor, reactor core and monitoring rod), real-time vibration evaluation.

Both automatically and combined with the manual version, the power of the reactor, the feed water of the steam generator, the load variations in steps are controlled.

It is noted that currently (2024), there are the types of large nuclear power plants as follows:

1. *Pressurized Water Reactor* - PWR. Has H₂O at 15 MPa for moderation and cooling, U-235 enriched 3-5%.

2. *Boiling Water Reactor* – BWR. It has as moderator H₂O at 6-7 MPa, cooling with concentrated H₂O 2-3% (heavy water), U-235 enriched 3-5%.

3. *The CANDU reactor*. It has as moderator D₂O at 1 atm., cooling with D₂O at 9-10 MPa, as nuclear fuel Uranium Dioxide.

The exclusive area for these reactors is 1 Km. Nuclear infrastructure, in general, shows a system with inputs and outputs.

In the center, there is a central block (mobile nuclear power plant) representing the system itself, in the form of a rectangular box with arrows indicating input to be processed.

There is another arrow that indicates the exit from the system (output, as an output signal), respectively the result of processing the input signal.

There may be other additional blocks representing additional modules of the system or additional arrows indicating data flows or connections between the various components of the mobile nuclear system. The specific details vary depending on the nature and complexity of the system under analysis.

Between the output of the system and its input there is a line that indicates feedback, representing the communication path between input and output, receiving performance information and adjusting the processing of the input signal.

The feedback is directed in the opposite direction, from the output of the system to the input, forming a loop between the input and the output of the modular nuclear system.

3. Results, discussion

3.1 The location of the SMR Power Plant in the Doicești Dâmbovița area and influences on nuclear protection, safety and security

Doicești commune is a town in Romania, located in Dâmbovița county.

It is a small territorial administrative unit with a small population and is known for its rural environment.

The Doicești Thermal Power Plant (built in the 1960s, initially powered by coal), also known as the Electric Power Plant, operated in the area, having a role in the production of energy for Romania's national energy system.

It was put into conservation in the 2000s due to technical problems and changes in the country's energy policy. (fig. 2)



Fig. 2 The town of Doicești Dâmbovița, - the place where the SMR is located on the surface occupied by the former Caustobiolitic fossil coal-fired thermal power plant (Source: montage – processing, 2022)

Doicești is a town in Dâmbovița county with 4,584 inhabitants on a territory of 10.8 km², in the hilly area, on the Ialomița river, 8 km north of Târgoviște.

The thermal power plant from Doicești produced energy through the thermal conversion of burning coal-type fuels (fossiliferous caustobiolytics).

The Doicești thermal power plant uses inferior coal, lignite, from the mining operations in Șotânga, Filipești, Ceptura, Câmpulung. In frequent situations, fuel oil and gas were used as a fuel.

The thermal power plant is located on an area of 40 ha, with a storage capacity of 450,000 tons of coal and 7,000 tons of fuel oil.

In fact, the operation was stopped in 2009 due to high operating costs and environmental deficiencies.

The caustobiolitic fossil coal thermal power plant from Doicești - Dâmbovița was completely demolished on November 17, 2022.

The demolition of the thermal power plant was carried out by implosion. (fig. 3)

Nova Power&Gas (USA), which is a partner with Nuclearelectrica in the SMR project, is planning the complementary construction of a 30 MW photovoltaic park in the area of the former Doicești thermal power plant, because the vacant site (on the site of the former slag and ash deposits on the 40 ha of the former thermal power plant) would allow such an investment.



*Fig. 3 The moments of the demolition of the Doicești-Dâmbovița Thermal Power Plant on caustobiolitic fossiliferous coal combustion
(Source: editing - processing after A. Costea, 2022)*

The NuScale nuclear power plant with its 6 modules will create 193 permanent jobs, approx. 1,600 jobs in the construction of the unit, further 2,200 jobs in energy production on this variant and the avoidance of emissions of approx. 4 million t CO₂ /year.

An SMR nuclear power plant module has a smaller dimensional configuration. (fig. 4)

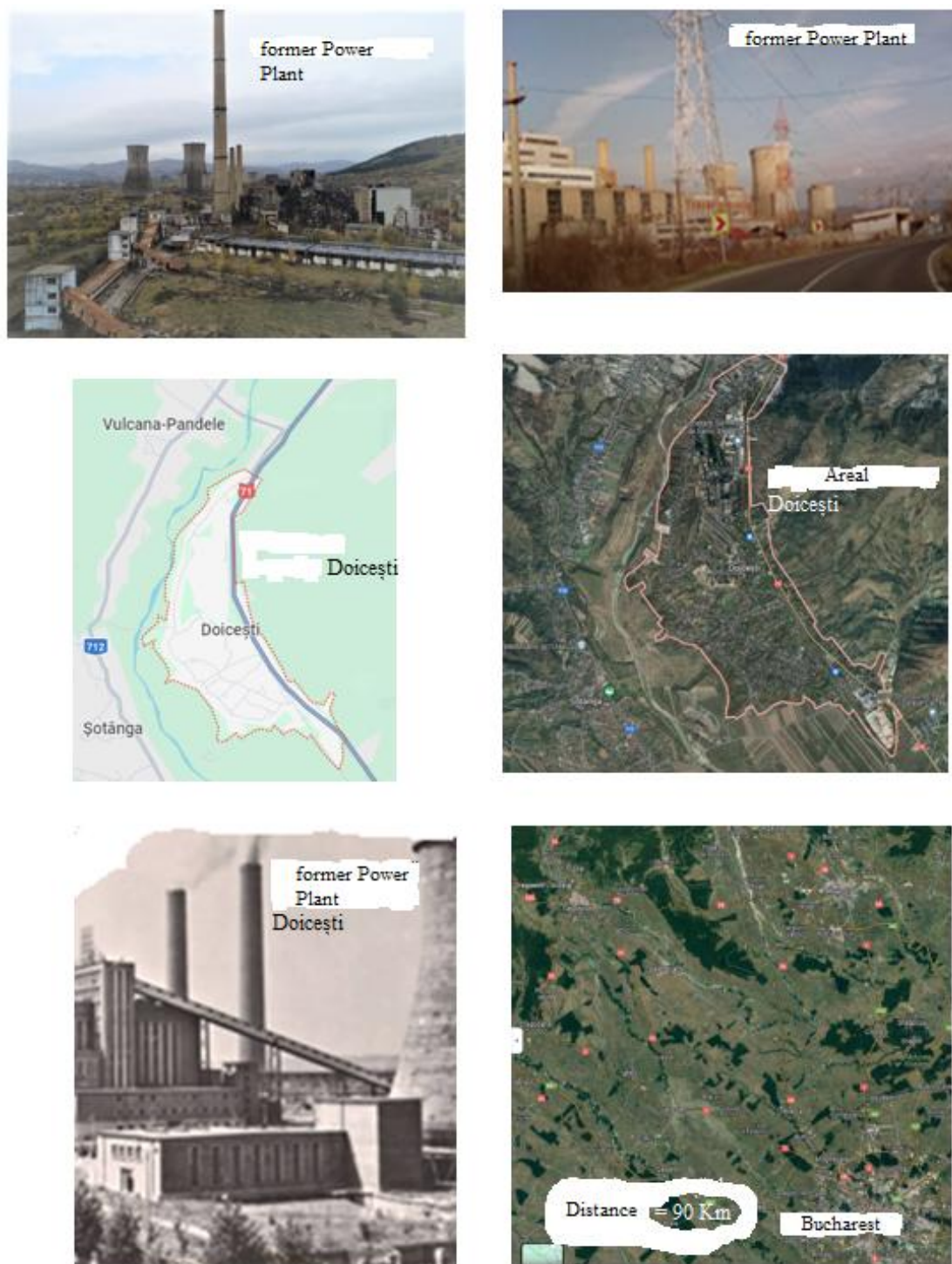


*Fig. 4 Example of SMR Nuclear Power Plant Module / Reactor similar to the one located at SMR Doicești - Dâmbovița
(Source: after NuScale Power, 2022)*

In fact, the version of SMR located in Doicești is similar to the prototype from the Idaho National Laboratory to be completed by the company NuScale Power (USA).

NuScale researchers and practitioners are already engaged in 19 global commitments for SMR plants, and the first module will be commissioned in 2029 at the Idaho National laboratory – USA.

For the Doicești thermal power plant, until the demolition, before the year 2022, the influence of its operation, of the emissions on the soil, the anthropogenic impact with sulfur compounds, the investigation of the soil samples was followed. (fig. 5)



*Fig. 5 The former Doicești Dâmbovița Thermal Power Plant, the perimeter of the town and the positioning in relation to Bucharest, - the capital of Romania
(Source: montage – processing, 2022)*

The analyses, according to the requirements of Order no. 756/1997 of the Ministry of Water, Forests and Environmental Protection, [4], in the laboratories in the area, at the INCD for Pedology and Agrochemistry-ICPA and those at the University of Petroșani show, synthetically, compared to unaffected soils in the area, coefficients of exceedance of the maximum normal content of pollutants, alert and intervention (if the coefficient of exceeding the content considered normal is close to the alert coefficient, the pollution of the area is higher and requires intervention).

At the old Temocentrală Doicești, coal desulfurization was not carried out and 50,000 t of SO₂/year were released into the air.

The content of total humus (%) is medium, the contents of total nitrogen (%) are also medium, and that for mobile phosphorus (mg.kg⁻¹) is medium high.

The contents of mobile potassium (mg.kg⁻¹) are very high due to ash dust pollution.

In the Doicești area, copper is found among the heavy metals in the soil with an excess coefficient between 1-1.25 (up to beyond Târgoviște to Dragomirești, along the river to beyond Pucioasa); zinc has exceeded values along the Ialomița Valley, lead shows contamination on the entire surface, close to the alert coefficient, and cobalt exceeds the maximum allowed content in the Ialomița Valley.

In the same framework, nickel denotes contamination of the perimeter, and sulfur has a coefficient of exceeding the content between 1 and 2.85.

The most serious remains the pollution with thermal power plant ash having a coarse texture, being weakly alkaline, with accumulations in large quantities on the ground, the modification of the edaphic parameters, of the granulometry due to the texture of the material.

The general principle of operation of the SMR to be located in Doicești-Dâmbovița does not depart from the overall principle in the field, but there are some infrastructural (dimensional) and constructive simplifications. (fig. 6)

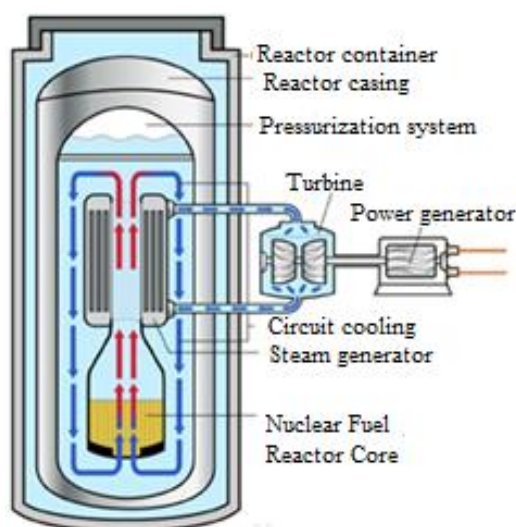


Fig. 6 The general principle of operation of the following SMR to be located in Doicești-Dâmbovița
(Source: processing-adaptation from GAO 15-652, D. of E. Documentation, 2024)

NuScale has approval from the US Nuclear Regulatory Commission obtained in 2020 and certification in 2023 for its 50 MW project (a number of 6 small nuclear modular units at Doicești-Dâmbovița).

In fact, the USA participates with small modular reactors in Romania in the implementation of the "Phoenix Project", to replace coal-fired power plants in Central and Eastern Europe (conversion of fossil coal in multiple neutron reactors).

The US will provide 14 million USD in the preliminary stage of engineering and design studies for SMR in Romania (an amount of 1.2 million USD was received by Nuclearelectrica in 2021, through a USTDA grant to identify and evaluate sites for SMR in Romania).

NuScale develops SMR, but in the US other companies such as Westinghouse, General Electric, TerraPower and X energy also have achievements in this field.

SMR is zero carbon polluting, but their nuclear protection, safety and security (radiation, radioactive waste) remain in focus.

The strategic vision is to expand nuclear power capacity in increasingly unstable global political conditions.

Worldwide, there are approx. 80 types of SMR, but the licensed one belongs to the US company NuScale Power.

The EU strategically plans to achieve 60% nuclear power in total energy in the long term, mainly through the development of SMR (conclusively, the EU promotes the industrial alliance for SMR). [3]

Through the FIRST Program – *Foundational Infrastructure for the Responsible Use of Small Modular Reactor Technology* [7], the USA also grants Romania an SMR simulator.

US reactors (NuScale Power) of the type being installed at Doicești-Dâmbovița have: 1) proven technology, 2) modularity, 3) increased flexibility, 4) low cost and faster construction compared to "large" nuclear reactors; 5) increased safety.

Internationally, the Tennessee Valley Authority has applied for the right to site an SMR reactor, and in addition Utah Associated Municipal Power Systems is applying for a license to build a NuScale SMR reactor by 2029.

The RoPower and NuScale project entity is already carrying out activities and design studies, site analysis on the surface of the former coal-fired thermal power plant from Doicești, the schedule in time and costs, respecting the recommendations of the IAEA (through *External Events Design*).

Therefore, the SMR from Doicești-Dâmbovița is important and timely for energy security and the realization of climate objectives (decarbonization) in Romania and the EU.

3.2 US modular nuclear power plants and NuScale Power's investment in Romania: the nuclear protection model

As of 2021, the US still does not have commercial-scale modular nuclear power plants (MNPs)/SMRs, but there are significant concerns in the development and testing of these technologies.

However, one notable US project focusing on SNM (small modular nuclear reactor) remains NuScale Power.

NuScale technology provides for the small nuclear reactor module with a nominal capacity of 77 MWe.

The NuScale company has international partnerships and has collaborated with researchers from other countries (Canada) to advance its modular nuclear reactor technology.

NuScale Power has been involved in projects to build modular nuclear power plants in Idaho, South Carolina and other locations in the US.

Other US companies and organizations are engaged in the development and refinement of CNM/SMR technologies.

Globally, several companies and organizations are already developing modular nuclear reactor technologies, such as Rolls-Royce in the UK, TerraPower in the US and others.

A simplified protection model for the SMR type nuclear power plant for Doicești-Dâmbovița, in our opinion, involves:

- *Safety of the project*: the design of the plant is strongly focused on safety, resistance to extreme natural variables (earthquakes and floods).
- *Cooling systems*: safety requires an efficient cooling system to keep core temperature under control, including passive cooling solutions in case of failure of active systems.
- *Nuclear reaction control*: Safe shutdown of the chain reaction must be ensured at all times, using automatic control and manual control systems.
- *Protective cover*: concrete casing, which prevents the spread of radiation in the environment.
- *Detection systems*: radiation detection devices and environmental monitors for radiation levels around the plant are in operation.
- *Protection against attacks*: the plants are equipped with robust surveillance security systems to prevent any potential terrorist attack or acts of sabotage.
- *Training and preparation*: extensive and regular staff training is used to deal with emergency situations.
- *Emergency plans*: plans are drawn up in detail, in collaboration with local and regional authorities, to manage any emergency situation.
- *Supervision and regulation*: regulatory and monitoring authorities impose strict safety standards.

3.3 Schematization of the radioactive waste management problem

Radioactive waste [6] is a material for which further use is not expected, being of the type:

- 1) LILW-SL - contain short-lived beta-gamma radionuclides (half-life 30 years), alpha (20 years), with concentrations below 4 kBq/g, respectively thermal power below 2 kW/m³;
 - 2) LILW-LL – have long-lived radionuclides (over 20 years) and over 4 kBq/gr;
 - 3) HLW- have long-lived alpha radionuclides (over 20 years), over 4 kBq/g and heat output over 2 kW/m³.
- Practically speaking, for this type of issue there are strict requirements for protection, safety and security. The most important problem in the field is "storage", i.e. intermediate or final storage of radioactive waste. For example, at large power plants (type CANDU – Cernavodă) separate infrastructures are created for intermediate storage. (fig. 7)

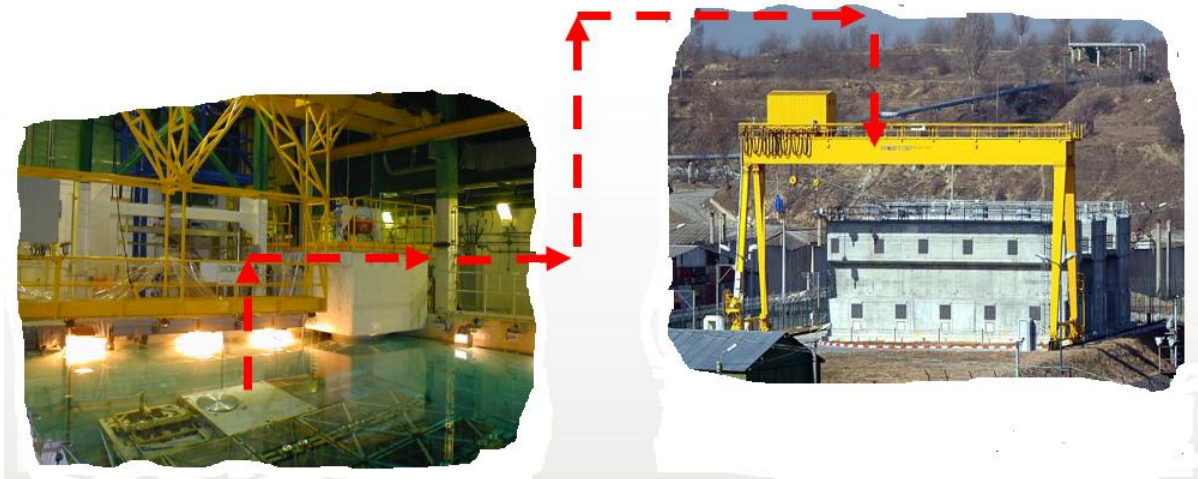


Fig. 7 The wet and dry storage of nuclear fuel burns the Cernavoda nuclear power plant
(Source: Processing adaptation according to CNE Cernavodă, 2023)

The existence of challenges associated with SMRs is also noted, such as the need for specific waste management regulations associated with public perception of safety in the field vis-à-vis them.

Safety against the anthropogenic effects of radioactive waste is a decisive principle of Euratom's research activities.

In the EU there are approx. 40,000 m³/year of radioactive waste and in total, approx. 2 million m³ have already been stored.

The targets related to radioactive waste management are: a) their specific management; b) radiological level without impact; c) research - development programs in the field, while at the European level the objectives refer to a) nuclear and radiological security performance, including for storage; b) radioactive physical protection, including during transport; c) protecting and restoring the environment. [5]

In Romania, there are perimeters for the storage of radioactive waste (repositories) as follows: 1) for Spent Nuclear Fuel, IFIN "HH" Măgurele, 2) intermediate for Burned Fuel, Cernavodă, 3) the Mioveni-Argeș site, 4) the Intermediate repository from Cernavodă, 5) National Warehouse from Băița - Bihor.

4. Conclusions

- The article presented the main opportunities and advantages of SMR, which is a planned investment in Doicești-Dâmbovița: modularity, safety, clean energy, nuclear waste in smaller quantities, regulations and faster approvals.

- Mainly, it is about "units of multiple modules", the basic elements related to security being defined in SMR Doicești - Dâmbovița.

- Considerations regarding the location of the SMR Power Plant in the area and the influences on nuclear protection, safety and security on the surface occupied by the former coal-fired Thermal Power Plant are presented. At the same time, it is concluded on the meanings and sizes of the measures to reduce the risks of SMR in the researched area.

- The USA provides 14 million USD in the stage of engineering and design studies for SMR in Romania, and the 6 SMR modules will have a total installed capacity of 462 MWe, approx. 350 million USD investment cost and constructive dimensional simplifications are assumed.

- The most serious remains in the area (temporarily) the pollution with thermal power plant ash, which has a coarse texture, weakly alkaline, with accumulations in significant quantities on the ground. The modification of edaphic parameters, granulometry due to the texture of the material and other anthropogenic factors affecting the environment (nitrogen, heavy metals, water pollution, etc.) due to the burning of coal in the former thermal power plant is observed.

- Complementary, on the large area of over 40 ha of the former thermal power plant on fossil fuels (remaining free), it is planned to build a thermosolar, photovoltaic park of approx. 30 MW.

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