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Small Modular Reactors in Denmark: A Technology and Cost Review

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Executive summary

The Danish Energy Agency has asked Ea Energy Analyses and VTT Technical Research Centre of Finland to investigate the possibilities and consequences of integrating the compact nuclear reactor technology called Small Modular Reactor technologies (SMR technologies) into the Danish energy system. The project covers two subtasks: 1) a technical analysis of SMR technologies in a Danish context and 2) a system analysis that will assess the effects and value of integrating SMR into the Danish energy system. This report constitutes the reporting of the first part.

Denmark removed the possibility to include nuclear power in the energy mix in 1985. In recent years, the topic has returned to political debate in the context of rising concern on climate change mitigation and energy security, with growing media attention and studies particularly on small modular reactors (SMR). Denmark has a limited experience on nuclear from operating research reactors from 1960 to 2000s, which required basic regulation, education, and operational capacity. However, there is more than 20-year gap at the moment, and research reactors differ greatly from commercial nuclear power plants in scale, safety requirements, licensing, and long-term responsibilities. Historical experience therefore offers background, but not readiness for deployment. Building national expertise will require investments in education, training, and international collaboration, drawing on the experience of neighbouring countries with nuclear power such as Sweden and Finland. Public engagement is also essential, both for identifying potential sites for nuclear power plants and for fostering public acceptance.

The most mature SMR technologies are based on light water reactor (LWR) designs, which build on decades of operational experience and established safety records. The term SMR includes a wide range of technologies with different sizes. Some SMRs on the larger range might have electric power up to 470 MW, although the usual definition limit is up to 300 MW. Some LWR-SMRs are developed by scaling down existing large-scale reactors, while adding passive safety solutions, modularity, and partial factory fabrication. Some SMRs are very small (microreactors) and might provide only 20 MW electricity or 50 MW heat, but also these share the passive safety, modularity, and serial manufacturing design principles.

LWR-SMRs are advancing fast through licensing and demonstration phases in North America, Europe, and Asia. Their modularity, passive safety features, and potential for standard licensing are expected to address the high cost and delays of construction projects that have hindered large-scale nuclear projects in Western countries. As a result, LWR-SMRs are anticipated to be the first new nuclear technologies to reach commercial operation. The first Western LWR-SMRs are expected to be operational around 2030 followed by more manufacturers during the 2030s. However, as the technologies are still under development and Denmark is in the initial phase of possible nuclear deployment, the earliest expected timeline for LWR-SMRs in Denmark is in the 2040s, although ambitious and robust political and industrial efforts could enable slightly earlier deployment.

Generation IV SMRs offer significant long-term potential by providing high temperature heat for industry, higher thermal efficiency, wider range of nuclear fuels, possibility to breed additional fuel, and advanced waste management by burning used fuel or converting transuranic elements. However, Gen IV SMRs remain less mature, with limited operating experience and ongoing requirements for demonstration and regulatory approval. Their possible commercial deployment is generally expected to follow LWR-based SMRs as further research, pilot projects, and international cooperation are needed to realize their full benefits.

The expected costs of SMRs in the 2040s and 2050s are extremely difficult to project, because Western manufacturers are still proceeding towards their first units. There are very large differences on the estimated construction cost levels of the first-of-a-kind (FOAK) units ranging from 6 M€/MWe to 16 M€/MWe and uncertainty on what manufacturers include in construction cost estimates. Due to long lead times and high capital costs, it is critical for the manufacturers to reach successful FOAK projects that would take their SMR technologies on more favourable cost trajectories. The first actual realized cost data can be expected when the first experiences from actual serial production in Canada, UK and maybe Sweden could be expected between 2035 and 2040. Therefore, a main conclusion from this work is, that it is probably 10 – 15 years too early to make trustworthy cost projections. With that said, it is our central estimate that the overnight construction costs in a Danish context could decrease to 8 M€/MWe in 2040 and approach 7 M€/MWe in 2050 with large uncertainties towards both optimistic and pessimistic trajectories.

1 Introduction

Rapid electrification and increasing shares of wind and solar alongside the reduced share of dispatchable power generation capacity in Europe have opened a discussion on whether new nuclear technologies could support European and Danish climate and energy goals.

Recent experiences with very large nuclear reactors have been difficult in Europe and North America. Small Modular Reactors (SMRs) are aiming to address the challenges by harvesting benefits of series manufacturing, simplified design, standardized technology licensing, factory fabrication, flexible operation, and modular deployment. However, a part of these phases will always remain site specific. In addition to electricity-only, many SMR concepts offer also combined heat production in varying temperature levels to cogenerate district heating and industrial steam. Manufacturers see multiple outputs as additional income and improved load following options.

The purpose of this report is to give a clear and fact-based overview of the global status of SMRs by reviewing the main developers, technologies, and demonstration activities. The report also discusses nuclear industry on a more general level by giving an overview of licensing and regulation, and nuclear fuel and waste management.

There are currently over 100 SMR designs that we narrow down to Group 1 and Group 2 technologies according to criteria documented in Chapter 4. Chapters 5 and 6 introduce these designs. To be clear, not all SMRs are the same scale. Some SMRs at the higher end of the scale might have electric power up to 470 MW. Some are developed by scaling down large-scale reactors, adding passive safety solutions, modularity, and partial factory fabrication. Some SMRs are very small (microreactors) and might provide only 20 MW electricity or 50 MW heat, but also these share the passive safety, modularity, and serial manufacturing design principles.

The SMR cost estimates are yet very uncertain as only few are built, none in western countries. Chapter 7 summarizes the information available from recent experiences with very large reactors, data available from SMR manufacturers, and other modelling studies. In the end, we try to summarize the cost estimates to form a solid source of information and to form three general cost trajectories usable in further works.

2 From large scale nuclear to Small Modular Reactors

2.1 Challenges to build new large-scale reactors in Western countries

In 2025, 31 countries had 416 operational nuclear power reactors with a total capacity of 376 GW. The largest three nuclear countries are USA, France, and China. The EU currently has 100 operational reactors with 98 GW capacity, which generated 23 % of EU's electricity in 2023.

In the last decade, nuclear capacity has been increasing in Asia and declining in Europe. Main reasons for the decline are Germany's phase-out from nuclear combined with significant difficulties in building new large nuclear power plants.

While South Korea has achieved decreasing nuclear construction costs and successful delivery schedules, recent large-scale reactor projects have struggled in Europe and the United States. There have been multiple reasons: Flagship designs like the EPR and AP1000 began constructions before detailed designs were complete, leading to redesigns during construction. The long pause between nuclear power plant generations thinned supply chains and manufacturers needed to buy nuclear-grade components from a shrinking pool of suppliers. Quality-control issues, such as faulty welds and concrete flaws, added delays. Regulatory requirements were different across national borders. The sheer scale of these projects made it difficult to manage them effectively.

Realized costs have reflected these developments and the completed projects in the EU and US landed to a cost level of 7 000–8 000 USD/kWe. Four projects under planning or construction in EU and USA even have estimated costs above 12 000 USD/kWe[1]. However, South Korea has achieved a cost level of 3 500 USD/kWe showing that this issue is not only about technology, but also legislation, regulation, and experience on building nuclear. Construction costs are discussed in detail in chapter 7.

[1] Hinkley Point C, Sizewell C, Vogtle 3&4, Lubiatowo-Kopalino

SMR manufacturers are learning from recent projects and are planning to solve these issues with benefits of modularity, simplified design, and standard licensing. In addition, SMR manufacturers are aiming for new markets, such as heat and steam.

2.2 From economy of scale to economy of modularity

The current state and past development of the nuclear energy industry has led to heavy regulation which in addition is different in each country. This has been one of the reasons why the manufacturers have increased the reactor size to larger and even larger nuclear power plant designs to maximize the economies of scale. The recent very large plant project challenges have shown that while maximizing the scale, the nuclear power plant construction projects have been very challenging from the civil engineering and very large multinational co-operation project management perspectives.

The main aim of the SMRs is to solve these previous challenges with different approach utilizing modern industry methods and designing series manufactured nuclear power plants with a modular design. The goal is to aim for economy of modularity and modern factory-made and pre-assembled components and elements to standardize the production and to minimize the on-site construction needs. Smaller designs also enable simpler passive and inherently safe systems.

The expected benefits of modularity can be seen only when manufacturers have produced large enough fleet of units. The First-of-a-kind (FOAK) is still a hurdle for SMR manufacturers.

2.3 Simplified design and passive safety

More than 90% of existing nuclear power plants are Light Water-cooled reactors typically categorized into either Boiling Water Reactors (BWR) or Pressurized Water Reactors (PWR). In a BWR, water boils in the reactor and the generated steam is routed directly to the turbine. In a PWR, the water does not boil in the primary loop. Instead, the heat is transferred to a secondary loop through steam generators, which produces steam for the turbine. These designs have proven reliable over decades of operation, but they rely on complex systems with multiple pumps, extensive piping, and active safety mechanisms. This complexity increases construction time, costs, and operational risk. SMRs aim to simplify this architecture by integrating major components, reducing reliance on active systems such as pumps, and introducing passive safety features. Rather than simply scaling down traditional reactors, SMRs are designed to combine the reactor core, steam generators, and pressurizer into a single reactor module, eliminating large piping and reducing the number of components as well as the volume of steel and concrete. See Figure 1 below. The integral design also eliminates the possibility of large break loss of coolant accidents, enhancing safety. Some SMRs are located underground to simplify the durability requirements of the concrete structures.

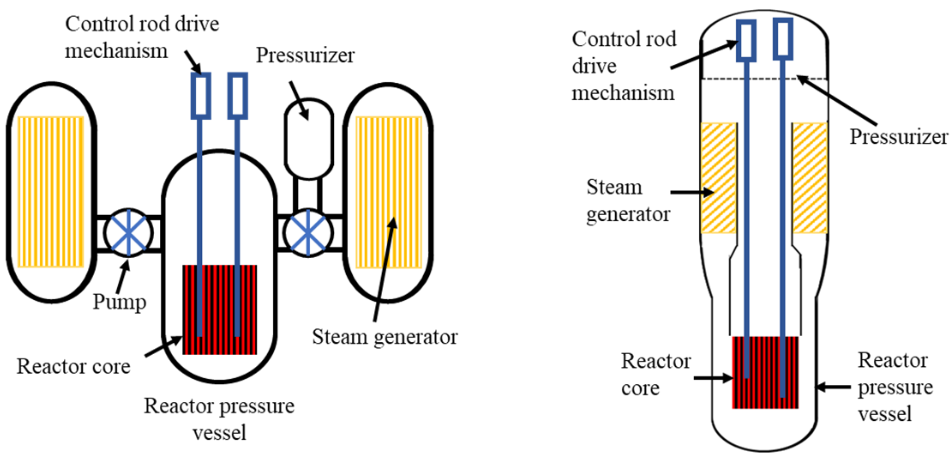

Figure 1: Comparison of a conventional two-loop PWR and an integral SMR. Left: Traditional PWR layout with separate steam generators, reactor coolant pumps, and large primary coolant loops. Right: Integral SMR configuration where the core, steam generators, pressurizer, and primary circuit components are all housed within a single reactor pressure vessel.

2.4 From single licensing to standard licensing

The SMR manufacturers are treating SMRs as repeatable products applying design-level approvals that could support multiple sites reducing duplication, speeding deployment, and lowering costs. If standard licensing approach succeeds, SMR licensing will evolve from the fragmented, site-specific reviews into a more coherent and scalable system.

Rolls-Royce SMR is progressing through the UK Generic Design Assessment (GDA) and is now in its final step. The UK GDA process is framed as a "standard" design approval that separates design review from later site licensing, with the aim that a single, nationally accepted design can be used in multiple projects after the planned first three Wylfa units in North Wales.

NuScale and i-SMR provide more examples. NuScale's 50 MWe module was the first SMR to receive an US National Regulatory Committee (NRC) design certification, and the uprated 77 MWe module received Standard Design Approval in May 2025. In South Korea, the i-SMR project is being developed specifically with the goal of obtaining national Standard Design Approval (SDA) from the Korean Nuclear Safety and Security Commission by around 2028. The approach follows the earlier SMART100 SMR, which already received SDA and is now moving into safeguards review.

BWRX-300 development shows how vendors try to turn this logic into an international standard design. GE Vernova Hitachi has completed two phases of the Canadian vendor design review and secured a licence to construct at OPG's Darlington site. In the USA, it is leveraging the already-certified ESBWR design through topical reports to streamline NRC review, and in the UK the design has entered the second step of the UK GDA.

From the perspective of a country with no earlier nuclear energy plants, the international licensing development aiming for standard type licenses allows to utilize the licensing work and experience of other countries' regulators.

However, it is not yet fully known what will be included in standard licenses and what will remain under national licensing. For example, UK General Design Agreement (GDA) is a design-level safety review before proposing any site. It covers four themes: nuclear safety (how the design prevents accidents, manages faults, etc.), radioactive waste and decommissioning strategy (generated waste, on-site storages, decommissioning strategy, etc.), environmental protection (effects on air, water, etc. including discharges and normal operation), and security and safeguards (protection again physical threats, cyber security, handling of nuclear material, etc.). The most often suggested approach in literature is division of licensing into technology-specific standard design license and separate site-specific approval, which is still required for each site. [1], [2]

2.5 From electricity only to deep decarbonization

Europe's energy system isn't just about electricity — it's also about heat, steam, and hydrogen. Roughly half of the EU's final energy consumption goes into heating and cooling. Europe's district heating (DH) networks supply about 600 TWh of heat annually. Most district heating networks across Europe run at temperature levels around 100 °C, which is well within the output range of modern light-water SMRs. Some reactor types are being designed specifically for district heating production while other SMRs can provide a cogeneration option.

Industry presents a difficult deep decarbonization challenge. In 2022, industry consumed a quarter of EU's final energy consumption. Natural gas and electricity dominate as energy sources. A substantial part of the industrial heat is at temperature levels well within the reach of light water SMRs and especially novel generation IV technologies, such as the Saltfoss' and Copenhagen Atomic's molten salt reactors.

Some expanding technologies, such as large-scale data centres and desalination plants are targeted as probable customers for steady power supply, where SMRs could be an option.

It is important to note that produced and supplied energy carriers, e.g. electricity, district heating, steam, have a significant impact on siting and regulation. Electricity only units can be built further away from the populated areas, district heating production units are closer to cities, and steam suppliers should be very close to industrial end users. Chapter 3.3 provides more information about licensing and regulation.

3 Small Modular Reactors

3.1 Developers and Industrial Actors

Currently, SMRs are actively developed in several countries worldwide. The first IAEA's Status of Small and Medium Sized Reactor Designs booklet was published in 2012, including over 45 designs and started demonstration constructions, but including also medium sized (<700 MWe) reactors [3]. In December 2025 IAEA's Advanced Reactors Information System (ARIS) database holds 119 designs at different stages of development in December 2025 [4].

Figure 2 gives examples on the global view on SMR development. In the US and Canada, the governments have supported the development for a longer period, and there are tens of designs and projects. China has several already on-going demonstration projects, and Russia has a long history and an existing ship reactor. South Korea has also long history of nuclear industry and several designs. In Europe, the UK has long supported the development and included nuclear power in the Net Zero Strategy, and has started Advanced Nuclear Fund, including developing domestic SMRs and Advanced Modular Reactor demonstration by the early 2030s. In France, SMR design development has also received support and there are several designs.

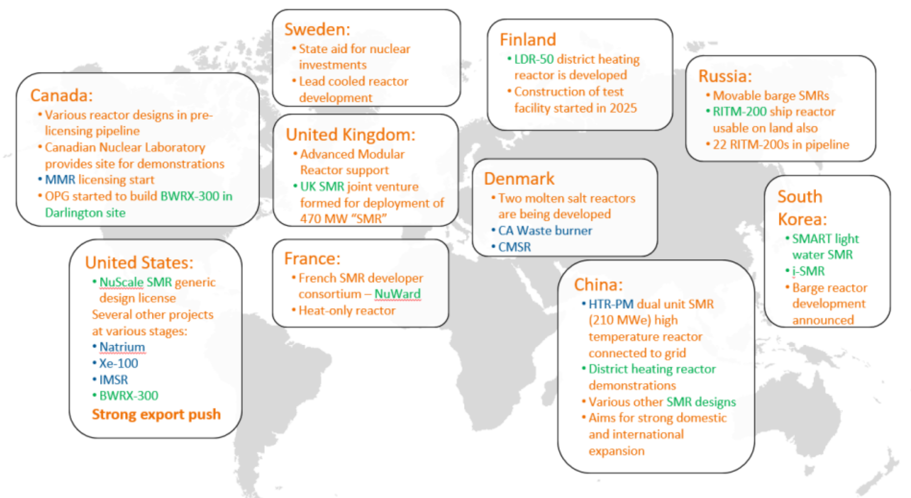

Figure 2. Global view of SMR developers. Text colour indicates reactor type: Light-water SMRs are shown in green, and Generation IV SMRs in blue.

The European Commission recently launched the European Industrial Alliance on SMRs in February 2024, with the target to accelerate the development, demonstration, and deployment of SMRs in Europe by the early 2030s [5]. Besides many European actors developing designs, there are also countries where there are plans for deployment and demonstration projects. These include Norway, Finland, Sweden, Estonia, Poland, France, Czech Republic, Netherlands. Several European projects are multinational and in co-operation with global actors involved in total supply chains. The most actors and projects target for the deployment around early 2030s and aiming for serial production by 2040.

The first SMRs are moving towards the demonstration phase. Canadian regulator has authorized construction of one BWRX-300 in April 2025 [6] and Poland is aiming for a demonstration of the same SMR type [7]. UK is progressing through roughly 4-year project of Generic Design assessment of BWRX-300, Rolls Royce SMR, and SMR-300 [8]. In the US, Kairos Power is building an engineering test unit of KP-FHR reactor [9]. In Finland, Steady Energy is planning to build a similar engineering test unit of heat only SMR LDR-50 to Helsinki district heating grid [10].

China is developing multiple SMR designs. The most mature project is the ACP100 (Linglong One), a 125 MWe pressurized water SMR under construction at Changjiang and possibly in operation during 2026, reflecting the same core goals seen internationally: modular construction, passive safety, and serial manufacturing [11]. China has also demonstrated modular advanced reactor technology through the HTR-PM, a high-temperature gas-cooled reactor configured primarily for electricity generation, with industrial heat and cogeneration remaining potential future applications [12]. China has developed also heat-only reactor concepts, most notably the DHR-400, a low-temperature light-water reactor intended for district heating [13].

3.2 Main Technologies

SMR technologies include several different types of technologies, which can be grouped into technological families: Light water reactors, High-temperature gas-cooled reactors, fast reactors, and molten salt reactors.

Light Water-cooled SMRs are based on similar technology as the currently most used conventional nuclear plants and are typically categorized into either Boiling Water Reactors (BWR) or Pressurized Water Reactors (PWR). Water has two functions in light water reactors: it is a moderator which slows down the neutrons to the thermal spectrum where the likelihood of nuclear fission reactions increases, and a coolant transferring heat out from the core. PWRs consist of two loops: primary circuit and secondary circuit which are connected through a steam generator. PWRs have high pressure (up to 150-160 bars) to prevent water from boiling, while in BWRs, steam is produced in the reactor which is directly circulated to the turbines. BWRs have relatively high pressure (~70 bars) to allow controlled boiling, higher operating temperature and thermal efficiency. LWR reactor temperatures are limited to relative low temperatures (280 - 330 °C) despite high pressure to avoid corrosion and stress-cracking of long-lived steel components. Increasing the temperature further would require even higher pressure and wall strength, bringing challenges in manufacturing technology. Conventional PWRs are generally loop-type, but SMR designs also include integral PWRs where the primary circuit components are integrated inside the reactor pressure vessel. There are currently 14 land-based and 6 marine-based water-cooled SMR designs. [4]

In most PWR designs, boric acid is diluted in the coolant to compensate consumption of the nuclear fuel as the reactor operates over time. Boric acid is not used in BWRs because the water boils, instead, they rely on control rods and burnable absorbers, commonly containing gadolinium, to compensate the nuclear fuel consumption. Also, Some SMR designs based on PWR technology are designed to operate without borid acid during normal conditions to enhance safety by avoiding risks such as boron dilution accidents and reducing corrosion. [14], [15]

High-temperature gas-cooled reactors (HTGR or GCR) use gas (usually helium) as coolant and offer higher core outlet temperatures and higher power efficiency. The high temperature is suitable for industries needing higher temperatures (≥ 750°C) and hydrogen production. Very-high-temperature-reactors technology (VHTR) is the advanced variant of HTGRs, offering even higher temperatures, from 700 °C to 900 °C, and potentially up to 1000 °C in the future. VHTR designs are usually based on prismatic core or pebble bed core types. The designs based on prismatic core are composed of stacked graphite elements which hold fuel and coolant channels. The pebble bed designs are based on novel TRISO (Tri-structural isotropic particle) fuel which improves the capability to withstand higher temperatures while also retaining fission products under all operating conditions. Another advantage is passive safety: the core structure and moderator have high thermal conductivity enabling efficient heat removal and thus, emergency core cooling systems used in LWR nuclear power plants may not be needed. Also, HTGRs and other generation IV designs exclude potential accident scenarios involving high pressure phenomena. However, the main drawback for TRISO fuel is the cost of manufacturing and the requirement of specialized fuel fabrication facilities. HTGRs and VHTRs are ideal for cogeneration of electricity and heat, and the extremely high temperatures make them capable of providing high efficiency hydrogen production. HTGR power plants were demonstrated already in 1960s, but many of these early reactors had economic, operational or regulatory and political difficulties. More recently Japan and China have been testing HTGR reactors in 2000s and in 2023, the modern prototype Chinese High Temperature Gas-Cooled Reactor – Pebble-bed Module (HTR-PM) entered commercial operation [12], [16], [17]. [18]

Fast reactors (sodium/lead-cooled) can breed more fuel or use waste as a fuel and reach higher temperatures. Sodium-cooled fast reactors (SFR) are the most developed Generation IV technology with over 20 reactors operated historically. The use of liquid sodium coolant allows operation at atmospheric pressure; however, the maintenance is challenging in sodium filled environments. For example, maintenance of primary circuit pump requires remote operations and SFRs have experienced numerous sodium leaks in the past. [18]

Molten-salt reactors (MSR) use molten fluoride or chloride salt as coolant and fuel and MSRs can reach high temperatures. MSR can be designed to operate in thermal spectrum or fast spectrum. This liquid form of fuel in MSRs allows continuous online refueling and removal of fission products, providing flexibility in fuel composition. The liquid state of the fuel also contributes to passive safety features, as the salt can drain into a cooled configuration in emergency conditions, while supporting efficient recycling of actinides and minimizing waste generation. The liquid fuel used in molten-salt reactors presents drawbacks similar to the TRISO fuel, as both rely on fuel technologies that fall outside the current commercial nuclear fuel cycle. MSR designs would require new fuel-salt handling facilities and the development of a dedicated fuel cycle, especially if the fuel is based on thorium. Two research reactors have operated in the past: the Aircraft Reactor Experiment (ARE) which operated in 1950 for around 221 hours and Molten Salt Reactor Experiment (MSRE) which operated from 1965 to 1969, roughly 4 years. In China, a modern MSR prototype focusing on thorium fuel cycle, TMSR-LF1 (liquid fuel thorium-based molten salt experimental reactor), started operating in 2023 [19]. But so far, there isn't any publicly available information about the reactor operation experience. As drawback, the use of molten salt creates challenging operation conditions: molten salts are extremely corrosive, complex chemistry of coolant and fuel salts require continuous monitoring. [18], [20]

Some MSRs are designed to use thorium-based fuel, even though it could be used in other reactor types also. Thorium-232 is the only naturally occurring isotope of thorium. It is a fertile nuclide that can be converted into the fissile uranium-233 through neutron capture followed by beta decay. Because thorium itself is not fissile, thorium-based reactors require an initial inventory of fissile material such as U-235, U-233, or Pu-239 to sustain criticality. While the conversion ratio is generally higher in fast reactors, thorium can also be used in thermal reactors to breed additional fissile fuel. The conversion ratio refers to the fissile production from fertile material relative to fissile consumption. [21]

The Generation IV technologies with less operating experience require more testing and demonstrations before licensing approval are thus generally expected to be commercially available later than LWR SMRs. However, they have also several potential future benefits, which is the reason they are also currently developed further with several different designs, companies and countries. Their potential future opportunities include more compact design, if not using water as a moderator and coolant. Also, passive safety system design can be designed simpler e.g. with molten salt, that solidifies instead of releasing to the containment. Although Generation IV technologies such as the aforementioned SFRs and MSRs aim to reduce long-lived waste through higher burnup and actinide recycling, geological disposal of nuclear waste remains necessary.

3.3 Licensing and regulation overview

3.3.1 Current status

Nuclear energy is regulated on a country-by-country basis. International cooperation is conducted in IAEA's regulatory framework and many related frameworks and forums such as IAEA Safety standards and SMR Regulators Forum [22]. Each country utilizing nuclear energy has its own national nuclear energy policy. Nuclear energy regulation is usually implemented on top of other regulations on energy, construction, land use, and environmental issues, and it usually includes more heavy and detailed regulation on fuel cycles, technical solutions, permitting processes etc. The nuclear plants need to fulfil all the common and also nuclear energy specific regulations.

The conventional nuclear energy regulation has led to permitting plants one by one, which has led to maximizing the economies of scale, as the very detailed permitting process has also large costs. The rationale for SMRs is to design and license several plants that have one single "type approval permit", which could be applied in several countries. However, as each country's regulations are different, there are challenges to fit the different regulations together. This challenge has been identified and has been worked on in several regulation development forums and research projects, e.g. ELSMOR (towards European Licensing of Small Modular Reactors). [23]

Most SMR designs implement passive safety systems, representing a significant shift from conventional nuclear power plant designs. Passive safety systems take advantage of natural forces such as gravity and natural heat convection, whereas active safety systems rely on active driving devices such as electrical or diesel motors. The passive safety systems have the potential to simplify licensing, while reducing the costs of safety systems and the need for maintenance. However, safety demonstrations of passive safety systems are still under development, and nuclear regulators worldwide might be cautious of licensing these systems.

The use of passive safety systems, together with the smaller reactor core and reduced radioactive inventory, aim to limit the consequences of possible accident scenarios. On this basis, some SMR designs may justify smaller precautionary action and emergency planning zones subject to regulatory approval. As a result, SMRs may provide greater flexibility in siting, including closer proximity to population centres when the safety demonstrations justify it. This is particularly relevant for district heating applications, where reduced emergency planning requirements could allow SMRs to supply heat directly to urban areas while maintaining a high level of nuclear safety.

While emergency planning requirements remain a national responsibility, recent developments in Finland indicate that some regulators are beginning to adapt existing frameworks to better account for the characteristics of SMRs. The Finnish Radiation and Nuclear Safety Authority (STUK) has updated its guidance on emergency response arrangements, replacing fixed planning zones with a plant-specific approach. Under the new framework, precautionary action and emergency planning zones are determined on a case-by-case basis, taking into account reactor design and site characteristics. This represents a departure from the previous regulation, which mandated a uniform 5-kilometer exclusion zone and a 20-kilometer emergency planning zone for all nuclear power plants. [24]

Despite these developments, most countries continue to apply emergency planning frameworks that were originally developed for large nuclear power plants, relying on fixed or distance-based planning assumptions. This highlights the potential value of regulatory harmonization and shared technical approaches as SMR deployment advances.

3.3.2 Harmonization of Nuclear Regulatory in the Nordics

Within the Nordic region, the harmonization of nuclear regulatory frameworks has become increasingly important as countries respond to growing energy needs, the green transition, and evolving geopolitical circumstances. The Nordic countries have a long tradition of cooperation in nuclear and radiation safety, supported by their cultural and geographical proximity. This collaboration has been reinforced by the recognition that nuclear safety challenges and public debates often transcend national borders.

Recent developments, such as Finland and Sweden adopting policies that enable new nuclear builds and advanced technologies, have highlighted the need for more consistent regulatory approaches. The Nordic Strategy Group has identified that, despite strong foundations for cooperation, there is currently no dedicated forum for sharing expertise and aligning regulatory practices in the nuclear field. To address this, the group recommends establishing a formal forum for knowledge sharing on nuclear regulation, including public communications and stakeholder engagement for new projects. Such a forum would help ensure that regulatory reviews and processes are as consistent as possible, support the development of joint training programs, and enhance the competence of regulators across the region. [25]

Harmonization efforts are not limited to technical standards but also extend to public engagement and emergency preparedness. The Nordic countries recognize the importance of monitoring public opinion, exchanging information on public debates, and ensuring transparency in regulatory decisions. By aligning their regulatory approaches and strengthening cooperation, the Nordics aim to streamline licensing for new technologies like SMRs, improve cross-border emergency response, and present a unified voice in international nuclear safety discussions. Through enhanced cooperation, knowledge sharing, and strategic alignment, the Nordic countries are working to ensure that their regulatory systems remain robust, agile, and prepared for the challenges of a rapidly evolving nuclear landscape.

KELPO project in Finland and in Sweden has recently aimed at modernizing and streamlining the licensing and qualification processes for the systems and equipment of nuclear plants [26]. The old regulation practices have led to problems of supply chains of components, as the components have not been accepted to order off-the-self, but every component had to be specially made for nuclear plant, which in practice has not improved the quality, and the current serial manufacturing quality e.g. in pumps and valves and other common components has increased much during the decades. This has led to the development of better practices in cooperation with companies and regulators, which directly affect practical project and engineering processes, i.e. delivery times and costs on single components. The main approach is now also published in IAEA document [27], sharing the good practices, calling it the graded approach principle in KELPO cooperation, evaluation of utilizing commercial grade components.

3.3.3 Regulation in Denmark

There are no current nuclear power plants in Denmark, but there have been three research reactors DR-1, DR-2, and DR-3, which were located at the former Risø National Laboratory, but all are now decommissioned. The Danish regulatory authorities responsible for regulating nuclear safety and security, including waste safety, are the Danish Health Authority, Radiation Protection (DHARP) and the Danish Emergency Management Agency (DEMA). The Nuclear Regulatory Authorities are hence formed by DHARP and DEMA. [28]

The International Atomic Energy Agency conducted Integrated Regulatory Reviews Service (IRRS) mission for Denmark in 2021, noting that Denmark's current legislation is outdated and insufficient for future activities related to nuclear power [29]. IAEA recommended in the IRRS to review the legislation and revise the policy and strategies for management of radioactive waste, enhance the alignment of national regulations with IAEA safety standards focusing on public exposure and emergency preparedness and response, and revising or developing new guidance documents, as well as improving DHA and DEMA management systems [30].

Another significant challenge is Denmark's limited regulatory capacity and technical expertise in the nuclear field. In the IRRS, IAEA observed that the number of qualified experts in Denmark is low and that most are concentrated in the medical sector, with very few available for other areas such as waste management or industrial applications. The report also highlights that there is no systematic procedure for developing and maintaining the competence and skills of regulatory staff, and that human resource planning and training programs are lacking. As a result, Denmark will need to prioritize capacity building, which may involve sending personnel abroad for specialized training and, at least initially, relying on external expertise to fulfil regulatory functions and oversight. The IRRS team concluded that without sufficient qualified staff and a structured approach to competence development, even a robust legal framework would not be effective in ensuring nuclear and radiation safety. [29]

On the other hand, Denmark has the opportunity to accelerate the development of its nuclear regulatory framework by drawing on the experience of neighbouring countries such as Sweden and Finland [31]. Both have established modern regulatory systems and possess extensive practical expertise in the safe disposal of nuclear waste. Danish regulators can benefit from adopting proven best practices and lessons from these countries, of which one good example are the on-going harmonization projects of regulatory practices in Nordic countries. Additionally, Denmark can learn from collaborative exchange of information arising from assessments of new reactor designs conducted by regulators in other countries. Such regional and international cooperation is recognized as a key strategy for building regulatory capacity and ensuring alignment with international safety standards. [25]

3.4 Nuclear fuel and waste management

3.4.1 Nuclear fuel cycle

The nuclear fuel cycle begins with the mining of uranium ore. Uranium is mined in open pit mines, underground mines or through in situ leaching where the uranium is leached directly from the ore. Kazakhstan, Canada and Australia are the largest producers of uranium, which is a naturally occurring metal with large widely distributed low-grade deposits in several countries also in EU, including Sweden, Finland, Denmark, Czech Republic, Germany, Italy, Poland, Portugal, and Spain. After mining, uranium ore is crushed and chemically treated to produce triuranium octoxide (U_3O_8), known as yellowcake. This material is then converted into uranium hexafluoride (UF_6), which becomes gaseous at moderate temperatures (~56 °C) and is suitable for enrichment. Conversion involves purification of U_3O_8, reaction with hydrogen fluoride to form UF_4, and fluorination to produce UF_6. The UF_6 is packaged in cylinders and sent to enrichment facilities, where the U-235 content is increased using centrifuges that separate isotopes by mass. Older technologies such as gaseous diffusion, which forces UF_6 through porous membranes, are largely obsolete. After enrichment, UF_6 is reconverted to oxide for fuel fabrication. [32], [33] Enrichment levels vary by reactor design. Low-Enriched Uranium (LEU), containing about 3–5% U-235, is widely used in commercial reactors due to its abundant supply, established regulatory framework, and low proliferation risk. High-Assay Low-Enriched Uranium (HALEU), enriched to 5–19.75%, is primarily intended for research reactors and generation IV reactor, offering higher power density and longer fuel cycles but requiring stricter security measures. However, current HALEU supply is limited and concentrated in Russia. Highly Enriched Uranium (HEU), enriched above 20%, has historically been used in research and naval propulsion reactors but it has been unsuitable for power generation due to economic reasons and significant proliferation risks. Global efforts focus on converting existing HEU inventories to LEU.

Enrichment is a critical process in the nuclear fuel cycle. With enrichment, the proportion of uranium-235 relative to uranium-238 is increased. This is because uranium-235 is the only naturally occurring fissile isotope capable of sustaining a nuclear chain reaction. In a nuclear fission reaction, a U-235 nucleus absorbs a neutron and undergoes fission, splitting into smaller nuclei and releasing energy along with two to three neutrons. The neutrons released from nuclear fission interact with the surrounding medium, either getting absorbed by other materials, causing further fission events, or escaping the system. If, on average, one neutron from each fission induces another fission, the reaction becomes self-sustaining.

In most commercial light-water reactors, nuclear fuel consists of uranium dioxide (UO_2) formed into cylindrical pellets with high density (92–97% of theoretical). These pellets are then loaded into zirconium-alloy cladding tubes to form fuel rods. Then, fuel rods are grouped into fuel assemblies for use in nuclear reactors. UO_2 offers a high melting point (≈2,850 °C), chemical stability in water-cooled environments, compatibility with zirconium-based claddings, and excellent irradiation stability and ease of fabrication. [34]

3.4.2 Nuclear waste management

Nuclear waste management is a critical phase of the nuclear fuel cycle, ensuring the safe handling, storage, and disposal of radioactive materials generated during reactor operation. Its primary objectives are to protect human health and the environment, maintain long-term containment of radionuclides, and comply with stringent regulatory frameworks.

Sustainable and secure disposal of nuclear waste is essential for public acceptance and the long-term success of nuclear energy [35]. For newcomer countries such as Denmark, careful planning and investment in waste management infrastructure are necessary as an initial step before reactor deployment, regardless of reactor size or design, to meet international safety standards and build public trust [36].

The International Atomic Energy Agency classifies radioactive waste into five categories: very-short-lived, very-low-level, low-level, intermediate-level, and high-level waste. High-level waste (HLW), primarily spent nuclear fuel, represents only about 3% of the total volume of radioactive waste but accounts for approximately 95% of its radioactivity. Spent fuel contains a mixture of fission products, transuranic elements such as plutonium and minor actinides, and residual uranium. HLW is the most demanding category due to its high radioactivity and heat generation, which can exceed 2 kW per cubic meter and significantly raise the temperature of storage systems and surrounding materials.

When fuel assemblies are removed from a reactor, they are extremely hot and highly radioactive. Initially, spent fuel is stored in the reactor pool, where water provides both cooling and radiation shielding. Nuclear spent fuel is composed of fission products, highly radioactive elements, which are produced during fission in reactor operation. The fission products continue to undergo radioactive decay releasing energy as heat, commonly referred as decay heat. After several years, the fuel can be transferred to an interim storage facility. This facility may involve wet storage, where spent fuel remains in water pools, or dry storage, where fuel is placed in sealed casks or canisters made of metal and concrete to provide passive safety and containment. Both decay heat and radioactivity decline over time; the fuel's radioactivity is roughly a thousand times lower after about forty years than at removal [37]

After wet and dry storage, the final step is disposal in a deep geological repository. The spent nuclear fuel can be disposed as it is without removing radioactive elements from the fuel rods. However, the spent fuel can be reprocessed for reusable uranium and plutonium from unusable waste. Uranium from spent fuel is returned to conversion plants, converted to UF_6, and re-enriched for new fuel. The recovered uranium along with plutonium can be then mixed to fabricate mixed oxide (MOX) fuel for reactors. Spent fuel is composed of mostly uranium, about ninety-six percent of the fuel, and plutonium, which accounts for about one percent, while the remaining three percent consists of high-level waste products. This approach reduces waste volume and radiotoxicity but requires complex infrastructure and strict safeguards. Even more advanced techniques would involve recycling spent fuel in a reactor operating at fast spectrum. On the other hand, these advanced approaches bring challenges regarding proliferation, high costs, and secondary waste streams. [33]

3.4.3 Final disposal of nuclear waste

Many countries are planning to permanent store HLW in stable geological formations such as granite or clay found deep underground. These formations are chosen for their long-term stability, favourable geochemistry, and minimal water movement. Different countries adopt different approaches based on local geology and regulatory frameworks. Final disposal concepts are based on multi-barrier system combining engineered barriers such as metal canisters and the natural containment provided by chosen geological formation.

Denmark currently stores its low- and intermediate-level radioactive waste at Risø, with a national strategy that foresees safe interim storage until around 2073 and eventual geological disposal. Recent policy discussions have focused on the suitability of Danish clay formations for deep repositories, drawing on international experience, particularly Belgium's Boom Clay studies. The thick clay layers found in Denmark's subsoil offer a promising host rock for future repository. The clay formation offers low permeability, self-sealing properties and strong radionuclide retention. The Geological Survey of Denmark and Greenland has conducted Phase 1 studies to evaluate claystone formations at depths of approximately 500 meters for their thermo-hydro-mechanical stability and geochemical buffering capacity [38]. Countries such as France and Belgium are also considering deep geological disposal of nuclear west in deep clay formations. An alternative strategy for Denmark would be to export the nuclear waste to countries such as Finland or Sweden, where geological disposal programs are among the most advanced in Europe. Thus, following sections explains the nuclear waste disposal strategies of France, Belgium and Finland. [39]

France has selected the Callovo-Oxfordian clay formation for its deep geological repository, located at approximately 500 meters depth. The host rock's very low permeability and strong sorption capacity provide natural containment for radionuclides over very long periods. The French concept, developed by Andra, uses vitrification for high-level waste: the waste is embedded in a durable glass matrix that dissolves extremely slowly. Then, the vitrified HLW is hot cast into stainless steel canister which will be conditioned in thick steel overpacks to prevent glass leaching. Over time, the glass and metal overpacks will gradually degrade, but the clay formation limits water movement and radionuclide migration. Only a few long-lived, mobile isotopes such as chlorine-36 and iodine-129 may migrate, and even then, their release would be extremely slow and dispersed over millions of years. [40], [41]

Belgium's disposal concept is based on the Boom Clay formation, located at about 225–230 meters depth. Unlike France, Belgium does not vitrify high-level waste; instead, spent fuel and HLW are sealed in corrosion-resistant steel containers. These containers are placed in horizontal galleries excavated within the clay. Two backfilling strategies are considered: either the tunnels are filled with excavated clay to restore natural conditions, or the waste is emplaced in unlined secondary tunnels, allowing the clay to gradually deform into contact with the waste containers. Boom Clay's self-sealing properties, low permeability, and strong radionuclide retention provide a strong natural barrier, complemented with the engineered containment. [42]

In Finland, the spent fuel is first sealed in corrosion-resistant copper canisters reinforced with cast iron. Then, the canisters are placed in vertical boreholes drilled into tunnels about 430 meters deep in stable bedrock. The space around the canisters is filled with bentonite clay, which swells when wet and forms a tight barrier that limits water flow and radionuclide migration. Once all canisters are emplaced, the tunnels are backfilled and sealed. This design uses a multi-barrier concept: the fuel matrix, metal cladding, copper canister, bentonite buffer, and bedrock work together to ensure containment for tens of thousands of years. [43]

The copper canister is designed to remain intact long enough for short-lived fission products such as cesium-137 and strontium-90 to decay before any contact with groundwater [32]. Long-lived but mobile radionuclides like iodine-129 and technetium-99 are controlled by reducing conditions, bentonite's sorption properties, and extremely slow groundwater movement. Non-mobile species, including most actinides, have very low solubility and strong retention in bentonite and rock, meaning they pose little migration risk even over geological timescales. Finnish regulations also require that waste remains retrievable for a period after emplacement, allowing flexibility if future technologies enable recycling of actinides or other advanced fuel cycle options [44].

4 Technology screening

The selection of SMR designs for detailed assessment in this analysis is based on a screening of approximately 85 SMR concepts listed by the IAEA[2] [45], NEA [46], and DOE Reactor Pilot Program[3] [47].

The SMR screening process is based on the following criteria:

1. Origin of developer/manufacturer: Only SMRs from Western countries,[4] South Korea, or Japan are considered. SMRs from other countries are excluded.

2. Only technologies with electricity output have been included in group 1 as technologies prioritized for deeper analysis[5]. Heat Only technologies can be included in group 2.

3. Design status is evaluated using the "IAEA design status" scale 5 levels are included:

    1. ***Conceptual design:*** Early-stage concept; main principles and key technical parameters defined, but many details still open.
    2. ***Basic design***: Overall plant layout fixed; major systems sized and main design choices made.
    3. ***Detailed design:*** Components and systems fully sized, specified, and documented for procurement and construction.

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[2] IAEA is the United Nations' nuclear watchdog with 178 Member States, mandated to promote safe and secure nuclear energy and to provide independent, science-based assessments for governments worldwide, which underpins its legitimacy as a source. The SMR Catalogue [36] compiles concise, developer-supplied design descriptions across main SMR technology lines, screened and structured by IAEA, but not formally peer-reviewed as an official publication.

[3] Being included in the DOE Reactor Pilot Program [38] has been given almost the same weight in the evaluation as having a memorandum of understanding with a Western electricity supply company, since both are assumed to provide comparable advantages in securing project financing.

[4] Western countries include North America (US and Canada), Western Europe and the EU countries in Central and East Europe.

[5] According to our understanding of TOR of the project.

    4. ***Under construction:*** Construction of the demonstration or first-of-a-kind unit is actively in progress.
    5. ***In operation:*** Plant in routine service, delivering electricity to users.

    - Only SMRs with a design status of "Detailed Design" or higher are eligible for inclusion in group 1.

4. Fuel qualification and supply security:
    - The readiness of the fuel chain is given positive weight; the NEA fuel classification, NEA [46] which includes manufacturing capabilities, supply contracts, etc., is used for scoring.
    - The NEA classification is agnostic to the uranium-enrichment level even though higher enrichment levels can add significant complexities to the licensing, transportation and regulations. The current fuel supply chains are mainly for the low-enriched uranium (LEU).
5. Interest from energy companies: SMRs receive a score if
    - Interest from an energy company has been publicly announced,
    - or if the design development is supported by DOE Reactor Pilot Program.

6. SMRs developed by Danish companies are included at least in group 2.

The criteria lead to a selection of twelve SMRs. Four main electricity producing designs with the highest score prioritized (Group 1) and analysed in detail. The other eight form Group 2 and are evaluated at less detailed level. Table 1 (Group 1) and Table 2 (Group 2) show the selected SMRs and summarize their screening results.

*Table 1: Group 1, The prioritized SMR designs selected for detailed analysis. Main sources: IAEA SMR Catalogue 2024 [48], The NEA SMR dashboard 2024 [46], and DOE Reactor Pilot Program, 2025 [47]. * Indicate that the parameter is updated based on more recent information.*

Design	MW(el)/ MW(th)	Core outlet temp	Type[6]	Designers	Devel-oper country	Design status	Documented interest from energy company
BWRX-300	300/870	288	BWR	GE Vernova Hitachi Nuclear Energy	US, JP	Under construction*	Vatenfall, Fortum, Fermi Energia (EST), Poland (OSGE), Norsk Kjernekraft
i-SMR	170/520	321	PWR	KHNP & KAERI	S.KOR	Detailed design *	Korean companies and cities, Trondheimsleia Kjernekraft AS
NuScale Power Module	77/250	321	PWR	NuScale Power Inc.	US	Detailed design	RoPower-Romania, Poland replacing coal
Rolls-Royce SMR	470/1358	325	PWR	Rolls-Royce	UK	Detailed design	Vatenfall, Fortum, UK, CEZ Group

[6] All Group 1 reactors are Generation 3+ reactors. Gen III+ reactors are evolutionary designs building on Gen III, with even stronger passive safety, lower core-damage probabilities, and better severe-accident mitigation (e.g. core catchers and extended passive cooling). Gen III+ development started in the 1990s, with first commercial construction and deployment generally from the mid-2000s onward. Gen IV reactors are not included in Group 1 because Generation IV reactor concepts are still in the development and demonstration phase and are not expected to be commercially deployed at scale for electricity generation and in serial production before around 2050.

*Table 2: Group 2 of the selected SMR technologies for less detailed analysis. Main sources: IAEA SMR Catalogue 2024 [48], The NEA SMR dashboard 2024 [46], and DOE Reactor Pilot Program, 2025 [47].** Saltfoss has advanced contracts with Korean industrial partners indicating Basic Design status, but this cannot yet be confirmed from public sources. *** IAEA Aris database [48] does not currently list LDR-50 and the design status is our own estimate based primarily on The NEA SMR Dashboard [46].*

Design	MW(el)/ MW(th)	Core outlet temp °C	Type[7]	Designers	Developer country	Design status	Publicly announced interest/contact
AP300	330/990	285	PWR	Westinghouse Electric Company, LLC	US	Basic design	
CA Waste Burner	n.a./100	560	MSR	Copenhagen Atomics	DK	Detailed Design	Ocean-Power AS
CMSR	110/250	650	MSR	Saltfoss Energy (previously Seaborg Technology)	DK	Conceptual Design**	Norsk Kjernekraft, Thailand, Indonesia, Multiple Korean companies
IMSR 400	195/884	700	MSR	Terrestrial Energy Inc.	CA	Detailed Design	
LDR-50	0/50	150	LWR-pool type	VTT/ Steady Energy.	FI	Basic Design***	Finnish DH companies, Korea District Heating corp.
PWR-20	20/80	300	PWR	Last Energy	US	Detailed Design	
SMR-300	300/1050	290	PWR	Holtec International	US	Detailed Design	EDF UK, Palisades Energy (US),
Xe-100	82,5/200	750	HTGR	X-Energy LLC	US	Basic Design	Norsk Kjernekraft

Note: The screening is weighting the current information and is subject to changes with the news from the field. SMR-300 completed of Step 2 of the UK Generic Design Assessment in December 2025 and it received 400 million USD support from U.S. DOE also in December 2025 just while we were finishing this report. In general, SMR-300 has gained significant momentum during the work and would likely be qualified in Group 1 if the screening would be rechecked.

[7] MSR reactors are Generation IV reactors.

5 Technologies in Group 1

All four designs in Group 1 are light-water reactors (LWRs), but they represent different design branches. BWRX-300 is the only boiling water reactor (BWR) in the group, using a direct steam cycle with natural circulation, while NuScale, i-SMR, and Rolls-Royce SMR are pressurized water reactors (PWRs). Among the PWRs, NuScale and i-SMR adopt an integral reactor vessel concept, whereas the Rolls-Royce SMR follows a more conventional three-loop PWR layout. The designs span a wide electrical output range, from 77 MWe modules to 470 MWe approaching the scale of traditional plants. Despite these differences, all aim for the benefits of modular construction, passive safety systems, and serial manufacturing. All group 1 technologies have a heat generation option.

5.1 BWRX-300

The BWRX-300 is a 300 MWel modular boiling water reactor developed by GE Vernova Hitachi, based on the licensed ESBWR (Economic Simplified Boiling Water Reactor) [49]. It retains ESBWR's passive safety and natural circulation features but is significantly smaller and more modular, aiming for faster and lower-cost deployment.

Figure 3 shows a simplified diagram of the BWRX-300. It is designed as a compact power block that integrates the reactor building (RB) with a steel-plate composite dry containment (SCCV) housing the reactor pressure vessel (RPV). The containment structure, about 19 m in diameter and 38 m high, is integrated into the RB foundation and includes a core-catcher for severe accident management. BWRX has three adjacent structures: the turbine building (TB), control building (CB), and radwaste building (RWB).

The reactor employs a passive Isolation Condenser System (ICS), using water pools above the containment dome to remove decay heat by natural circulation without external power. Reactivity is controlled through control rods containing boron carbide, inserted from below the core by hydraulic drives, and by the inherent negative void and fuel temperature coefficients. Backup power and safety systems include two diesel generators for essential loads and batteries capable of sustaining critical safety functions for at least 72 hours [49].

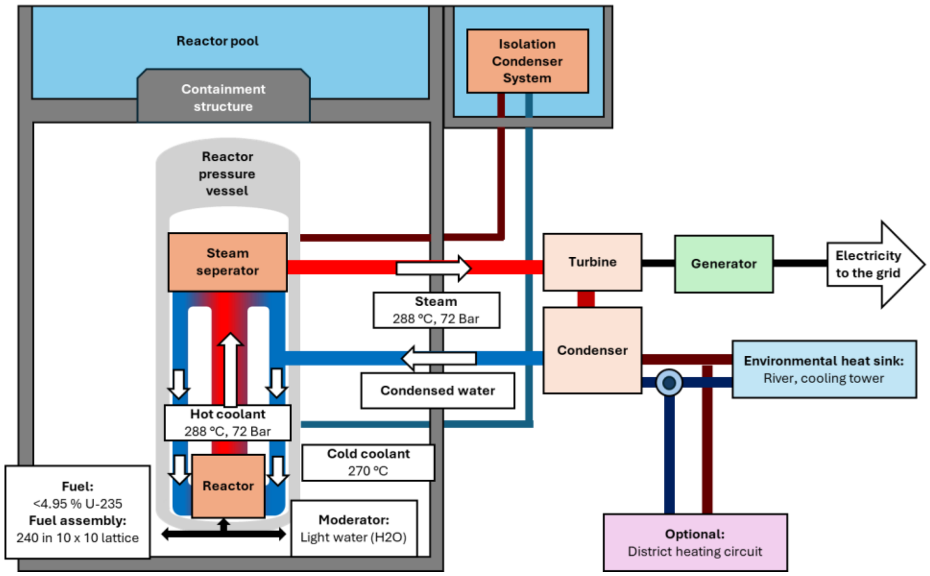

Figure 3: Simplified schematic of the BWRX-300 direct-cycle system, showing steam generation, power production, and passive cooling via the isolation condenser. Optional district heating integration is also illustrated.

The BWRX-300 uses standard uranium dioxide (UO_2) ceramic fuel pellets enriched to less than 4.95 % uranium-235 (U-235). After each fuel cycle, spent fuel assemblies are removed from the core using the fuel handling machine and transferred to the spent fuel pool located within the Reactor Building. The pool provides passive cooling and shielding until the fuel can be transferred to dry cask storage on site. The BWRX-300 can store at least two years of new fuel on-site.

The BWRX-300 is based on standard BWR technology that has been developed and proven over generations of earlier BWR designs. However, BWRX-300 adds also new system components and slightly compresses the design. The overall Technological Readiness Level (TRL) level is estimated at TRL7-8, but this is improving quickly as the first unit is under construction at Ontario Power Generation's Darlington site in Canada.

BWRX-300 has gained a significant interest among energy companies, particularly in the U.S. [50], [51], [52], Sweden, and Estonia [46]. The design is advancing through licensing in several countries: Canadian Nuclear Safety Commission (CNSC) granted BWRX-300 a license to construct 1 BWRX-300 unit at the Darlington project site, Nuclear Regulatory Commission in the United States has approved multiple topical reports as a part of pre-application activities, BWRX-300 has completed General Design Assessment step 2 in the UK, and Decisions-in-Principle from the Polish nuclear regulator (Państwowa Agencja Atomistyki, PAA) [48]. Early pre-application dialogues are also underway in other countries to align the design with national codes and identify issues in advance, shortening and de-risking formal licensing.

*Table 3: Data for BWRX-300, source: BWRX-300 General Description, GE Vernova Hitachi Nuclear Energy Americas LLC, 2025 [45], [49] *Construction time is calculated from the start of construction to the point at which the plant enters commercial operation. Construction start refers to the point at which the first concrete for the reactor building is poured. Current large-scale reactors typically have 5–10 years from initial decision to first nuclear concrete, with 1–3 years of intensive on-site enabling works immediately before construction start.*

General		*Technical*	
Design	**BWRX 300**	Size (th) [MW]	870
Type	BWR	Size (elec) [MW]	300
Fuel	<4.95 % U-235	Core outlet (°C)	288
Design status:	Under construction	Reactor coolant system pressure (bar)	72
TRL	7-8	Min load:	50%
Registered interest	CA ontario, VF, Fortum, UK, Fermi Energia (EST), Poland (OSGE), Norsk Kjernekraft	Ramp % / minute	0,5%
Possible operational	2030	Construction time (years) *	2-3
Lifetime (year)	60	Site footprint (ha)	2.7

Some early public estimates for individual units were as low as about €0,7 billion, but recent public cost estimates give the First Darlington roughly a cost of €4.9 billion (6.1 billion CAD) [53]. In addition, the first unit project covers also €1 billion infrastructure serving all four units that will be built on the site. The estimates for the second, third, and the fourth unit are not yet as developed, but the developers are expecting the fourth unit to cost 33% less than the first unit. Developers expect to build each unit on Darlington site in 24-36 months that would be significantly faster than on existing units. BWRX-300 reports a 1 ha footprint for plant and 2.7 ha footprint for site, not including the possible safety zone which can depend on country, regulation, and site.

BWRX-300 General description states that "*The BWRX-300 can manoeuvre from 100% and 50% power, with a ramp rate of +0.5%/minute, and return to full power with the same ramp rate, daily.*" The unit should be able to change the electric output faster if the unit is cogenerating and can adjust the ratio of outputs. The available information is not enough for definitive conclusions about load following and reserve provision capabilities.

5.2 i-SMR

The i-SMR (Innovative Small Modular Reactor) is an integral Pressure Water Reactor (PWR) producing 170 MWel [48]. The i-SMR development is based on merging two technological branches: South Korean APR large reactors, and SMART small modular reactor. Korean companies have a proven track-record on successfully building new large-scale reactors (see chapter 2.1) and SMART was the first SMR that received a Standard Design Approval 2012, in Korea).

Figure 4 shows a simplified diagram of the i-SMR plant. It consists of the reactor building (RB), the control building, the turbine generator building, and the compound building. The RB includes four integrated reactors, each in their own containment vessel, safety systems, and a spent fuel pool with a capacity of 20 years.

The core of the i-SMR module has 69 fuel assemblies composed of standard 17 x 17 PWR fuel assembly with fuel composed of uranium dioxide and uranium-235 enriched up to 4.95 %. The reactivity is controlled during normal operation with control rods, burnable absorbers, and moderator temperature. The i-SMR design includes features that minimize radioactive waste generation such as boron free core. The waste is planned to be possessed with conventional PWR waste treatment.

Energy is generated through Rankine cycle similar to other PWR designs. However, the i-SMR design features load following capability allowing it to adjust power output from 100% to 20% and back to 100% within 2 hours. Operational flexibility is enhanced by boron-free operation.[54]

The i-SMR reactor module is installed in a dry space, and the coolant tank for the safety system is designed to be separated from the reactor. Normal operation of i-SMR uses integral pumps for forced circulation, but the safety systems adopt passive approach: Passive containment cooling systems (PCCS), Passive Auxiliary Feedwater system (PAFS), and Passive Emergency Cooling System (PECCS). These main systems are designed to function automatically on demand to cope with design-based accidents and design extension conditions [55]. With an integrated reactor coolant system, helical once-through steam generator, boron-free core, and fully passive safety systems. Modular factory fabrication and dry reactor building aim to shorten construction and simplify maintenance [56].

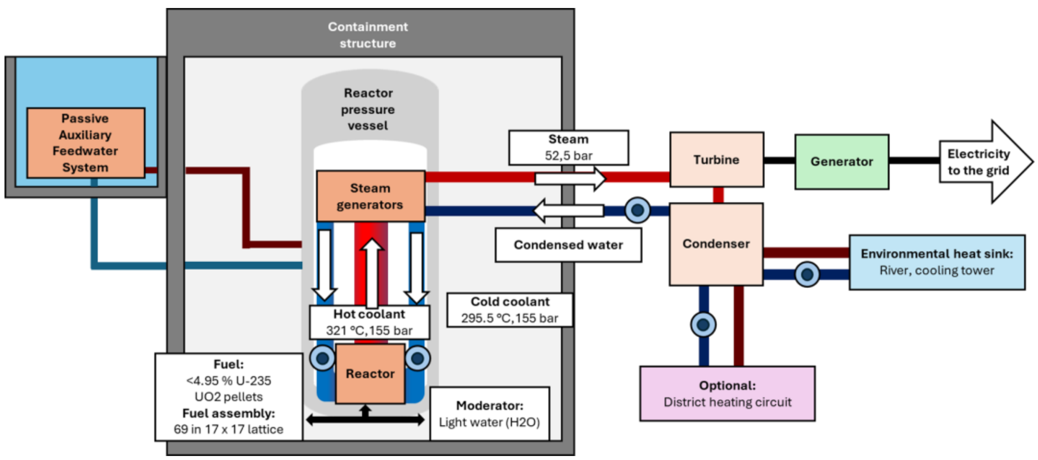

Figure 4: Simplified schematic of the i-SMR power conversion system, showing primary heat transfer through the integrated steam generators and electricity production via the turbine–generator. The diagram also highlights passive safety feedwater systems

The Innovative Small Modular Reactor Development Agency was founded with support from the ministry of Science and ICT and The Ministry of Trade, Industry, and Energy, to coordinate national research and development efforts of the i-SMR. The project involves major Korean nuclear industry partners including the Korean Atomic Research Institute (KAERI), KEPCO E&C and more than 10 private partners [57]. Primary partners are Korean (KAERI, KEPCO E&C, Doosan); international cooperation is developing (e.g., MoU with Turkey 2025) and domestic cities like Daegu are evaluating deployment [58], [59]. Limited direct western utility involvement reported.

The i-SMR is in standard design/pre-licensing phase due 2025, aiming for standard design approval and licensing actions through 2026–2028 with target certification by 2028 [60]. The Korea's 11th Basic Plan on Electricity Supply and Demand includes the construction of two new large-scale nuclear power units, and one SMR unit [58], [59] This could likely be a 4x i-SMR module plant, but public confirmation was very difficult to find. The company plans to start the construction of the First-of-a-kind (FOAK) in 2031 and have the first operational unit in 2035.

The Technological Readiness Level of i-SMR is by merging the components and designs characteristics of very well-established APR-1400 and OPR-1000 large LWR units into new features such as redesigned containment structure, modular layout, and new power level leading to different balance of plants assumptions. The overall TRL level is estimated to 6-7, but this is improving quickly when the concept is progressing in the design phase. The manufacturer is targeting sub 42 month construction times.

*Table 4: Data for i-SMR, source: Source: i-SMR catalogue 2025 [61], IAEA 2024 [45],*See construction time definition from Table 3.*

General		Technical	
Design	**i-SMR**	Size (th) [MW]	520
Type	PWR	Size (elec) [MW]	170
Fuel enrichment level	5%	Core outlet (°C)	321
Design status:	Detailed design	Reactor coolant system pressure (bar)	155
TRL	6-7	Min load:	20%
Registered interest	Korean companies and cities, Trondheimsleia Kjernekraft AS	Ramp % / minute	5%
Possible operational	2035	Construction time (years) *	2
Lifetime (year)	80	Footprint (ha)	

International cooperation is also part of the agency's development pathway. In September 2025, the innovative SMR Development Agency signed a Memorandum of Understanding with the Nuclear Industry Association of Turkey to promote collaboration in SMR development. Turkey aims to secure 12 GW of nuclear power by 2035 and 20 GW by 2050, of which 5 GW of SMRs by 2050. [59]

The i-SMR plans to address economic feasibility by manufacturing modules in factories and completing construction within 24 months [54]. The design choices to cut down the construction time are particularly the reactor vessel and containment vessel which are both capable of being transported by land. Other design features affecting more economic operation are boron free core and separated coolant tank. Additionally, operational costs are reduced by reducing operating personnel in the plant. The developer has a long-term target level of $3500/kWel and LCOE of 65 USD/MWh [57]. The FOAK cost estimates were not yet publicly available.

5.3 NuScale Power module

NuScale power module is a modular integral PWR, with each 77 MWe power module containing core, reactor coolant system, steam generators and pressurizer in a single vessel with operation based on natural circulation, enabling passive safety and factory fabrication. Reactor pressure vessel, control rod drive system, and associated components are housed inside steel containment vessel. Each NuScale Power Module (NPM) is submerged in the reactor pool, which works as a passive heat sink for the removal of containment heat. The NuScale fuel assembly is based on the standard 17x17 PWR design, but with a much shorter height than the standard fuel assembly. The reactor core consists of 37 fuel assemblies and 16 control rod assemblies. Fuel is standard uranium dioxide with U-235 enrichment limited to 4.95 percent. Reactivity is controlled using soluble boron in the primary coolant and the control rod assemblies. Each NPM has its own dedicated passive safety systems, emergency core cooling system, and decay heat removal systems. Normal operation of the reactor, as well as the safety systems operate without the use of pumps or external energy [62]. See Figure 5 below.

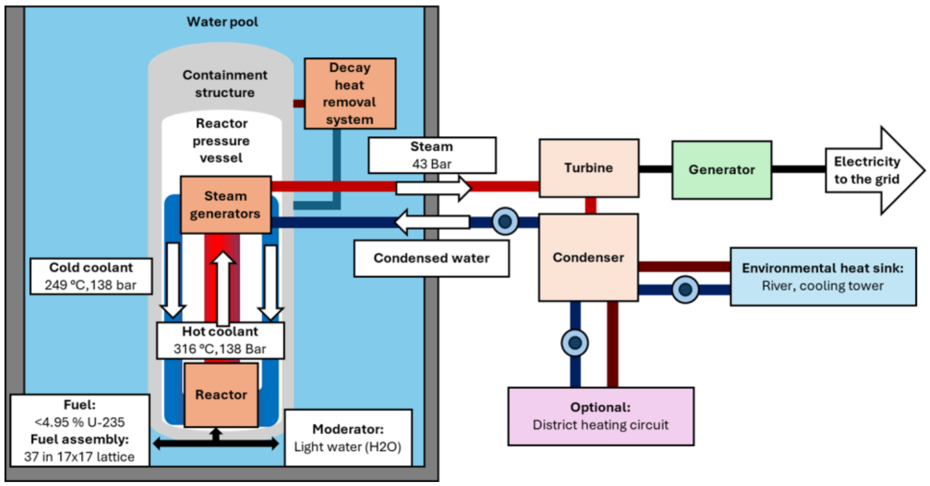

Figure 5: Simplified schematic of the NuScale Power Module. The integral PWR design places core, steam generators and primary system components in one vessel submerged in a water pool for passive heat removal, with natural circulation driving steam production for the turbine–generator cycle. The secondary circuit usually has pumps.

The NuScale plant consists of a reactor building, a control room building, turbine generator building, a radwaste treatment building, wet-cooled condensers, a switchyard and a dry-cast storage area for discharged fuel. Plants scale from 1 to 12 modules in a shared reactor pool.

NuScale is the only SMR with an approved U.S. NRC design certification (50 MWe in 2020; 77 MWe in 2025) [63]. Standard plant design work is ongoing, with first international deployments advancing through national licensing (e.g., Romania and Poland). The upgraded 77 MWe module was licensed; manufacturing of initial RPV and steam generator components began in 2023; major partnerships expanded; however, the first U.S. FOAK project was cancelled in 2023 due to escalating costs, shifting focus to Romanian and Polish projects [64]. Strong international engagement: partnerships with Romania's RoPower, Poland's KGHM, Fluor as EPC lead, Doosan and BWXT for manufacturing, Samsung C&T and JGC for global deployment, and TVA for a 6-GW U.S. development agreement [65], [66], [67], [68], [69], [70], [71], [72].

NuScale TRL level is difficult to estimate due to redesign. The previous 50 MWe version was already quite far, but the redesign affected a large range of critical components and their characteristics. NuScale still has deep expertise from the previous licensing process, but we have evaluated the redesign to a lower TRL 6-7 level. NuScale targets 3- year construction time.

Early NOAK estimates were €0,9 billion per unit (600 MW), while FOAK costs rose sharply. 2022 estimates reached €19,2 million/MWe (€8,7billion per unit of 462 MW),IEEFA 2024 [73].

*Table 5: Data for Nuscale Power Module, source: IAEA 2024 [48], INL 2023[74] and NuScale, 2021 [75] *See construction time definition from Table 3.*

General		Technical	
Design	NuScale PM	Size (th) [MW]	250
Type	PWR	Size (elec) [MW]	77
Fuel	<4.95 % U-235	Core outlet (°C)	316
Design status:	Detailed design	Reactor coolant system pressure (bar)	138
TRL	6-7	Min load:	40%
Registered interest	GS Energy (Kor), Ropower (RO), Standard power (US), TVA (US)	Ramp % / minute	10%
Possible operational	2035	Construction time (years) *	3
Lifetime (year)	60	Footprint (ha)	1,05

5.4 Rolls-Royce SMR

The Rolls-Royce SMR is a 470 MWe, factory-built three-loop PWR using low enriched uranium, operating at ~15.5 MPa and 300–325 °C. It builds on proven large-reactor PWR technology but introduces modular manufacturing to reduce cost and construction time. The Rolls-Royce SMR is built around four main functional zones: the reactor island, the turbine island, the cooling water island, and the balance of plant. The Reactor Island forms the nuclear heart of the facility, housing the reactor pressure vessel (RPV) and all primary safety systems. The turbine island converts steam to electricity, while the cooling water manages heat rejection via cooling towers. [48], [76] Rolls Royce SMR uses standard fuel, UO_2, with uranium-235 enriched to less than 4.95 percent. The fuel assembly design is also based on the standard PWR 17×17 design with an active length of 2.8 m. The reactor core contains 121 fuel assemblies and uses reactor coolant pumps to generate sufficient coolant flow in the primary circuit. The reactor uses control rods for power regulation and omits soluble boron for reactivity control, simplifying operation and reducing chemical waste. Rolls Royce safety features include multiple active and passive safety systems. [48]

The Rolls-Royce SMR utilizes a large share of well-proven components and systems from larger reactors, but the new design features to enable the modularity are not proven at the same level. The overall TRL level is estimated to 6-7.

The design is progressing through the UK Generic Design Assessment. Step 1 was completed in March 2023; Step 2 in July 2024 found no major environmental barriers. Step 3 (2024–2026) includes detailed design, safety and environmental assessment, aiming for Statement of Design Acceptability and Design Acceptance Confirmation around 2026 before site licensing [77], [78]. Rolls-Royce is aiming for 500 days of on-site construction works and roughly 2.1 ha site footprint.

Major advancement through GDA stages, increased UK government backing via the £2.5 billion Great British Energy – Nuclear programme, and selection as preferred bidder in 2025. Multiple new partnerships and project evaluations across Europe: Selected or shortlisted by ČEZ for Temelín (Czech Republic), Vattenfall for Ringhals (Sweden), and approved for Poland's Central Hydrogen Cluster.[79][80].

The only available economic data is Rolls-Royce's own estimate from 2021 of €3 billion per unit. First commercial unit could be deployed in the mid-2030s depending on licensing and financing [81]. See Figure 66 below for the simplified diagram for the Rolls Royce reactor.

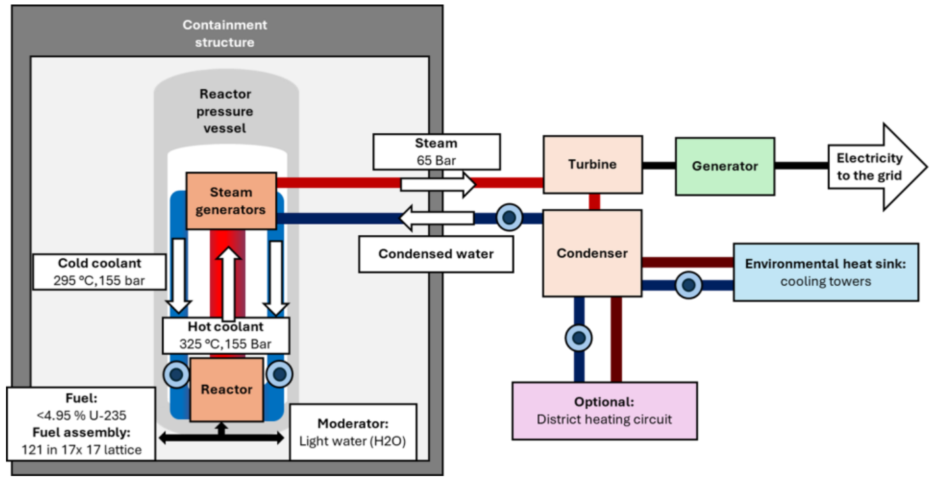

Figure 6: Primary coolant transfers heat from the reactor to the steam generators, producing steam for the turbine–generator, with condensation and cooling handled through the condenser and heat-sink system. Optional district-heating integration is also shown.

*Table 6: Data for Rolls-Royce SMR, source [82]. *See construction time definition from Table 3.*

	General	Technical	
Design	Rolls Royce SMR	Size (th) [MW]	1358
Type	PWR	Size (elec) [MW]	470
Fuel	<4.95 % U-235	Core outlet (°C)	325
Design status:	Detailed design	Reactor coolant system pressure (bar)	155
TRL	6-7	Min load:	40%
Registered interest	Vattenfall, Fortum, UK, CEZ Group (CZ); ULC-Energy (NL)	Ramp % / minute	4%
Possible operational	2035	Construction time (years) *	2
Lifetime (year)	60	Footprint (ha)	2

6 Technologies in Group 2

6.1 AP300

AP300 is a 300 MWel pressurized water reactor from Westinghouse Electric Company in the USA with a design life of 80 years. Based on the proven AP1000 technology, it features passive safety and a simplified single-loop design maintaining pressure at 155 bar in the primary circuit and 73.5 bar in the secondary circuit. The reactor operates on an extended fuel cycle of 3 years with the capability of extending cycle length to 4 years. [48]

The AP300 design includes two primary pumps driving the coolant flow, a pressurizer, a single steam generator connected to a single hot leg, and two cold legs. The reactor core consists of 121 fuel assemblies arranged in a standard 17x17 PWR configuration, 45 control rod drive mechanisms employing both reduced-worth grey and high-worth black rods control rods, and soluble boron systems. The control rod design of AP300 includes the mechanical shim operational strategy, which automatically compensates for reactivity changes from fuel depletion, allows rapid shutdown capability and performance of load following manoeuvres without changing the soluble boron concentration. The nuclear fuel is based on UO2 pellets with U-235 enrichment limited to 4.95%. The passive safety systems for decay heat removal and containment cooling rely completely on natural driving forces such as natural circulation without the use of pumps or diesel generators. [48]

The AP300 is currently in the conceptual design phase, with licensing progressing through the U.S. NRC design certification process, which is expected to conclude by 2027 [83]. In addition, Westinghouse has submitted applications for the UK Generic Design Assessment and continues pre-licensing activities with the Canadian Nuclear Safety Commission [84], [85]. In 2023, Westinghouse revealed that AP300 could be built under construction cost of $1 billion per unit (around $3,3 per kW) by the end of the decade [86].

AP300 is supported by a range of strategic agreements with public and private stakeholders. SaskPower and Cameco in Canada have signed a Memorandum of Understanding with Westinghouse to assess AP300 as a clean-energy option, while Westinghouse also collaborates through the Texas Nuclear Alliance to advance nuclear deployment in the United States [87], [88]. In the United Kingdom, Community Nuclear Power plans a privately financed fleet of four AP300 reactors in North Teesside and DATA4 Group is evaluating AP300 for powering future European data centres [89], [90]. Additional siting and development agreements include partnerships with Indigenous communities in Canada and MoUs with Finnish Fortum, Slovak JAVYS, and Ukrainian Energoatom to explore AP300 deployment opportunities across Europe [91], [92], [93], [94]

6.2 CA Waste Burner

The Copenhagen Atomics (CA) Waste Burner is a thorium-based generation IV molten salt reactor developed in Denmark. Each reactor unit produces 100 MWth, operating at 560 °C and low pressure with forced circulation and a passive safety approach. The reactor is designed with a negative temperature coefficient providing inherent power regulation, while the molten salt's excellent heat transfer properties support efficient decay heat removal without reliance on active cooling systems. [95]

The Waste Burner design integrates the reactor core and primary systems into a sealed module. Each module fits into a standard 40 feet shipping container, enabling rapid transport and deployment. The reactor module is replaced every 5 years without the need for refueling, human intervention, or maintenance during its design life. The CA Waste Burner uses heavy water moderator and a liquid fuel salt mixture of thorium fluoride (ThF_4) and lithium fluoride (LiF), together with recycled radioactive materials from spent nuclear fuel as a kick-start fuel. Over time, the reactor breeds uranium-233 from thorium, enabling sustained operation while consuming long-lived actinides and reducing the time nuclear waste is hazardous to the environment. [48]

Copenhagen Atomics provides Energy-as-a-Service model globally, owning and operating the nuclear facilities. This approach eliminates customer responsibility for licensing, operation and decommissioning of nuclear facilities. Copenhagen Atomics estimates the reactor to have LCOE below $20/MWh in a mass manufacturing scenario. Copenhagen Atomics is planning to provide only the core nuclear components and assumes that the power producer or energy end user does the required conversions, such as power generation. [96]

The design is in the pre-licensing phase and CA has built non-fission prototypes along with a plan to build 1 MWth demonstration reactor by 2027, and commercial Waste Burner units are expected to be available in the 2030s [96]. Copenhagen Atomics has signed large-scale experimental collaboration agreement with Swiss Paul Shrerrer Institute to validate the technology and provide experience in design, licensing, construction, operation and decommissioning of the new MSR technology [97]. Similarly in the UK, CA has signed a Memorandum of Understanding with UK and National Nuclear laboratory to advance study of MSR technology [98]. Strategic collaborations, such as with DeepGEO for spent fuel management, reinforce the Waste Burner's role in closing the nuclear fuel cycle and transforming waste into a valuable energy resource [99].

6.3 CMSR

The Compact Molten Salt Reactor (CMSR) is a Generation IV molten salt reactor concept developed by Saltfoss Energy (Formerly Seaborg Technologies) in Denmark [100]. Each CMSR unit produces 100 MWel, 250 MWth and is designed for deployment on floating power barges, enabling manufacturing in shipyards and flexible siting near industrial hubs or coastal grids. The floating CMSR power barges host two to eight reactor modules with power output scaling from 200 MWe to 800 MWe. [48]

The CMSR operates at low pressure using a molten fluoride salt fuel mixture that serves as both fuel and coolant. The nuclear fuel is based on LEU with enrichment limited to 4.95% U-235. CMSR design integrates the reactor core and primary systems into sealed modules with advanced corrosion-resistant materials, supporting a 24-year operational life without refueling. The reactor uses a graphite moderator, and the design incorporates a negative temperature coefficient, providing inherent power regulation and automatic shutdown in abnormal conditions. Heat from the fuel salt is transferred via heat exchangers to a secondary loop for electricity generation or high-temperature industrial applications such as hydrogen and ammonia production. [48]

CMSR design is in the early conceptual phase with the first commercial units expected in the early 2030s. Development milestones include American Bureau of Shipping feasibility certification for maritime deployment and strategic partnerships with Samsung Heavy Industries and Korea

Hydro & Nuclear Power to co-develop floating nuclear plants [101], [102]. Saltfoss Energy has also signed Memorandum of Understanding on MSR development with KAERI, and the company is preparing to start licensing activities with the nuclear authorities in South Korea [103], [104].

6.4 IMSR400

IMSR400 is a generation IV molten salt reactor developed by Terrestrial Energy, delivering 195 MWel and 442 MWth per module with a design life of 56 years. Built on Oak Ridge National Laboratory's molten salt reactor experience, IMSR400 uses a dual-module configuration to produce 884 MWth and 390 MWel at high temperature (585 °C) and low pressure. The reactor can be designed for production of electricity, heat, or cogeneration for a broad range of commercial and industrial applications. [105]

IMSR400 employs a replaceable reactor vessel, which integrates primary circuit components into a single module. Each module is composed of a graphite moderator, buffer salt liner, and primary circuit filled with molten salt and associated components. The reactor module is designed to be replaced every 7 years. The molten salt, serving as both fuel and coolant, is based on uranium tetrafluoride, UF_4, with U-235 enrichment limited to 4.95%. The buffer salt liner manages decay heat passively, and the reactor design incorporates a negative temperature coefficient, providing inherent power regulation and automatic shutdown in abnormal conditions. [39]

IMSR400 employs three circuits: a primary loop with heat exchangers and pumps, and two intermediary molten salt loops transferring heat to steam generators. The reactor is designed to burn fuel more efficiently, reducing generation of plutonium and fission products while the liquid form of fuel allows removal of transuranic waste, reducing drastically the time nuclear waste is hazardous to the environment. [48]

Commercially, Terrestrial Energy has secured approximately $292 million through a merger with HCM II Acquisition Corp to accelerate deployment. Partnerships with EnergySolutions and Texas A&M University target siting opportunities, including a planned 1 GW facility at the RELLIS campus by the mid-2030s. Collaborations with Westinghouse and Ameresco strengthen the fuel supply chain and enable hybrid energy applications.

Public engagement includes U.S. Department of Energy programs and co-operation with the Texas Nuclear Alliance. [106], [107], [108]

IMSR400 is in the detailed engineering phase with active regulatory engagement with USA and Canada. In 2025, the U.S. Nuclear Regulatory Commission approved Terrestrial Energy's Principal Design Criteria topical report, validating its safety approach [109]. In Canada, the design completed Phase 2 of the CNSC Vendor Design Review [110]. Next steps include U.S. Standard Design Approval and advancing pre-licensing with the Canadian Nuclear Safety Commission.

6.5 LDR-50

LDR-50 is a 50 MWth thermal light water reactor (pool-type) developed by Steady Energy, a Finnish company spun off from VTT and partially owned by VTT [99]. LDR-50 is designed for district heating, and it operates at low pressure (below 10 bar) and temperature (~150 °C) in natural circulation mode without the use of pumps. The reactor is intended for underground siting and factory-built deployment with an operating lifetime of 60 years and the possibility to scale production by adding reactor modules to the heating plant. LDR-50 is simplified drastically: the design excludes the use of boron, and the turbine cycle is cut as the reactor produces exclusively heat.

LDR-50 design is built upon standard PWR designs and passive safety systems. Each reactor unit is enclosed by two pressure vessels: a reactor pressure vessel and a containment vessel. The reactor module is submerged in water, and the intermediate space between the pressure vessels is partially filled with water, providing passive cooling from the RPV to the reactor pool. The RPV includes all the components needed for heat generation such as the reactor core, heat exchangers, and pressurizer. The reactor core is composed of 37 fuel assemblies and control rods in standard 17x17 PWR lattice. The nuclear fuel is standard UO2 pellets with U-235 enriched to around 2.5 percent. The LDR-50 design includes two main heat exchangers connected to independent secondary loops. The secondary circuit loops are connected further to the district heating network through their own heat exchangers. The pressure in the primary circuit is designed as the lowest, directing possible leaks towards the reactor module. [112]

Steady Energy has received a €32 million funding round to support the development of its reactor design and construct a pilot plant led by 92 Capital, LocalTapiola, Tesi, Move Energy, and Valo Ventures. The estimated investment cost for an LDR-50 reactor is €75–100 million, based on a specific cost of €1.5–2 million per megawatt depending on the siting of the plant. [113], [114]

Steady Energy has signed agreements with three Finnish utilities, Helen, Keravan Energia and Kuopion Energia to explore investments and develop small-scale nuclear power plant for district heating [115]. Steady Energy has also made an agreement with the South Korean district heating provider Korea District Heating Corp to cooperate in the field of heat-only SMRs [106].The LDR-50 design has received preliminary safety approval from the Finland's Radiation and Nuclear Safety Authority, and it is currently in the pre-licensing phase in Finland, with the first unit expected to be in operation by 2030 [107].

6.6 PWR-20

PWR-20 is a micro modular PWR developed by Last Energy for power generation and industrial applications. Each unit produces 20 MWel, 80 MWth and is designed for factory fabrication, promising delivery and commissioning within 24 months. Its compact footprint, about 1.2 km², allows siting near industrial facilities or data centres, minimizing land and water requirements. [108]

The reactor uses proven PWR technology, employing standard UO2 based fuel, enriched to <4.95% U-235, arranged in a 17x17 lattice. PWR-20 operates at 300 °C outlet temperature, with a closed-cycle air-cooled tertiary loop. In the primary circuit, the design incorporates a four-loop configuration with forced circulation driven by pumps. The reactor aims to achieve a 95% capacity factor, with a 72-month fuel cycle and a short three-month refueling period [109].

Last Energy adopts Energy-as-a-Service model simplifying deployment by taking full responsibility for design, construction, operation, and decommissioning [109]. The PWR-20 design is in the pre-licensing phase with active engagement with US NRC and Last energy has successfully completed a Preliminary Design Review conducted by the UK's Office for Nuclear Regulation [110], [111].

Commercialization milestones include power purchase agreements for over 80 units across Europe, targeting data centres and industrial hubs in Poland, Romania, and the UK [112]. The first UK project aims to repurpose the former Llynfi coal plant site in South Wales, deploying four PWR-20 units (80 MWe total) by 2027 [113]. Strategic partnerships with NATO Energy Security Centre of Excellence explore military applications, while financing agreements with the U.S. Export-Import Bank support international deployment [114], [115].

6.7 SMR-300

SMR-300 is a 300 MWe pressurized light-water reactor (PWR) developed by Holtec International from United States. The design is a scaled and simplified PWR intended for grid electricity generation and potential co-generation applications. SMR-300 builds on established large-reactor PWR technology while emphasizing modular construction, passive safety systems, and reduced on-site construction requirements. The reactor is designed for a 60-year operating lifetime, with factory fabrication of major components and deployment either as single units or in multi-unit configurations. [126], [127]

The reactor core uses conventional UO_2 fuel with uranium enrichment below 5 % U-235, arranged in a standard PWR lattice making it compatible with existing fuel supply chains. The design incorporates passive safety features, including gravity-driven cooling and natural circulation-based heat removal systems, allowing the reactor to achieve safe shutdown and decay heat removal without external power or operator intervention. [126]

SMR-300 adopts an integrated plant layout with emphasis on construction modularity. Major systems, structures, and components are designed to be fabricated off-site and assembled at the plant location, with the goal of reducing construction schedules and project risk compared to traditional large nuclear units. [126]

In the United Kingdom, Holtec Britain is progressing the SMR-300 through the Generic Design Assessment (GDA) process, supported by funding from the UK government's Future Nuclear Enabling Fund [128]. Development agreements have been announced with EDF UK and Tritax Management to explore deployment at the former Cottam coal power plant site [129]. SMR-300 passed UK GDA step 2 in December 2025 [130].

In the United States, SMR-300 has ongoing pre-licensing activities with the U.S. Nuclear Regulatory Commission [127]. Holtec has identified the Palisades nuclear site in Michigan as a candidate location for the first-of-a-kind SMR-300 deployment. In December 2025, the SMR-300 received 400 million USD support from U.S. Department of Energy programs to catalyse the FOAK unit at Palisade site. [131]. The project is also supported by engineering partnerships with Hyundai Engineering & Construction, alongside UK-based firms Balfour Beatty and Mott MacDonald for construction and delivery frameworks[128].

6.8 Xe-100

The Xe-100 is a Generation IV high-temperature gas-cooled reactor (HTGR) developed by X-energy in the United States. Each reactor produces 200 MWth and 80 MWe and can be deployed in modular unit configurations for up to 320 MWe per plant. The design uses helium coolant and a graphite-moderated pebble bed core, operating at 750 °C outlet temperature and 60 bar pressure, enabling efficient electricity generation, cogeneration and production of high temperature heat for industrial applications such as hydrogen production and petrochemical processes. The reactor is designed for a 60-year operational life, promising up to 95% plant availability. [116]

The Xe-100 employs novel TRISO fuel pebbles, each containing thousands of coated fuel particles that provide multiple barriers against fission product release. The nuclear fuel in Xe-100 is based on HALEU with enrichment limited to 19.5% U-235. The fuel pebbles are gravity-fed and continuously rotated through the core, supporting online refueling. Helium is circulated in the core, absorbing heat and becoming superheated. The superheated steam transfers its energy through novel helical-coil steam generators, to generate steam in the secondary circuit, and subsequently electricity or heat. The TRISO based fuel, combined with the reactor’s strong negative temperature coefficient, provides inherent safety and eliminates the risk of core meltdown. Passive heat removal and large thermal inertia allow the reactor to withstand loss-of-coolant scenarios without external intervention. [117]

The design is in the basic design phase, with demonstration projects advancing, especially regarding the use of TRISO fuel and reactor design, in the U.S. and Canada [134], [135], [136]. Deployment under the U.S. Department of Energy's Advanced Reactor Demonstration Program, with the first four-unit plant planned at Dow's Seadrift site in Texas to provide electricity and process steam for industrial operations [137], [138]. Additional projects include the Cascade Advanced Energy Facility in Washington, developed with Energy Northwest and supported by Amazon, as part of a broader goal to deploy up to 5 GW of Xe-100 capacity by 2039 [139]. X-energy has also signed strategic partnerships with KHNP, Doosan Enerbility, and Amazon to meet increasing power demand of data centre industry, electrification and advanced manufacturing [140].

7 Projected capital costs, O&M costs and LCOE

Projection of the cost to build and operate Danish SMR's in this analysis is based on the following primary sources:

- Experienced and projected capital costs (overnight costs) for traditional reactors.
- Expected overnight costs and target values published by SMR developers[8] with special focus on the Darlington project in Ontario Canada.
- Projected overnight costs for SMR´s in literature.
- Estimates of O&M (including fuel and waste handling) based on literature.
- Estimated cost reduction potential (Learning Rate).

It is not always clear what is included in published cost estimates. The figures we estimate as "overnight costs" include land acquisition, preparation for construction, all necessary construction costs, supporting buildings and local connection costs to grid. Necessary grid reinforcements and connection to district heating is not included.

Regarding our central estimate we focus on SMR's based on well-proven light-water technology. Timelines for possible serial production and cost projections are vastly more uncertain for Gen IV technologies.

In general, the energy technology cost is lower in countries like China and Korea than in Europe and USA. This is definitely also the case for nuclear technologies. Thus, historical and projected costs in those countries cannot easily be translated to a European context. There are several reasons for lower cost levels in those countries. For nuclear power plants some reasons are probably government supported supply chains, well experienced work force and less complicated approval processes.

Two main reasons for focusing on SMRs compared to traditional reactors among suppliers are 1) To increase the market volume by reducing project size and 2) Reducing costs by serial production and modularity. It is still

[8] Group 1 technologies in focus

uncertain if, and to what extent, SMR's in the future in fact will show lower overnight costs per MWe installed.

Published "target costs" from different developers can be as low as 3 million €/MWe. The most mature SMR project at present is probably the BWRX-300 project (Darlington Canada), with projected costs for the 4th reactor at 9.6 million €/MWe expected to be constructed before 2035. The cost level is still an estimate, because the construction of the first unit has just started.

Renowned organisations like International Energy Agency (IEA), Energy Indormation Agency (EIA), National Renewables Energy Laboratory (NREL) and others publish energy sector projections, including technology cost developments. Their most recent projections for SMR show cost levels from 8,4 – 10 million €/MWe for the first reactors around 2030, followed by anticipated cost reductions over time. It appears that these publications are reasonably at par with the published 4th reactor estimate for the Darlington project. The cost estimates typically do not give a specific list about the included costs.

Cost reductions

By backtracking technology costs and projected SMR buildout from 2030 to 2040 in the IEA publication "The Path to a New Era for Nuclear Energy", a Learning Rate (LR) of 10% in Western countries can be extracted. In two IEA scenarios, the LR increases to around 20% after 2040. This seems to be a high number taking into account that a substantial part of project cost is civil works. 20% is not explained but could be due to a "technology jump" towards Gen IV technologies with low anticipated CAPEX.

In 2040 the SMR buildout in the IEA report (IEA 2025)[141] is projected to be between 6 GW and 40 GW in advanced economies, with a projected cost in 2040 between 5 million USD/MWe and 7.5 million USD/MWe. It is not clear in literature how the projected cost reductions will be obtained from a technical perspective. There are possible gains when building several reactors on the same site by the same crew, but a substantial part of the SMR cost is civil works. Even with SMR's, we are speaking about vast construction sites if 3-6 reactors are constructed in convoy. Other possible methods for cost reductions include increased factory manufacturing, utilizing standard off-the-shelf components, and reduced on-site works.

Another yet unknown factor is the market structure. At present there are 5-10 Western designs with a reasonably high maturity, that might be able to commence serial production in the period 2030-2040. Too large number of designs might divide the resources and reduce the learning rate gains and possibilities for standardized licensing when looking at the overall fleet.

The cost estimates of the following sections are presented from the technical perspective without additional non-technological costs such as regulation development and workforce training. Such possible extra costs are difficult to assess. All cost estimates in the following sections 7.1 to 7.5 are shown in 2025 EURO.

7.1 Overnight capital costs estimated in literature studies

Table 7 presents nuclear overnight capital cost values (OCC) reported in literature, which show considerable variation. The average OCC estimate for large reactors is around 7.2 M€/MWe, with the lowest-cost project about 30% below this average and the highest-cost project almost 50% above it.

The estimates for NOAK SMRs fall within two distinct ranges. Three of the references give a central estimate and these lie between 7 M€/MWe and 8 M€/MWe. The two other sources that provide NOAK estimates, specify only low and high values, that are between 5 and 7 M€/MWe.

Table 9 in the following chapter shows that most SMR developers' target NOAK cost levels around 3.1 M€/MWe, which is significantly lower than general literature assumptions.

Author	Publication	Capacity	Overnight capital cost 2030 [M€/MWe]		
Large nuclear plants, 2030					
			Central	Low	High
Finansdepartementet, SE (2023)[126]	Finansiering och riskdelning vid investeringar i ny kärnkraft	Large	7,9		
IEA(2025)[127]	WEO 2025 APS*	2035 EU_ large	4,8		
EIA(2025)[144]	Annual Energy Outlook (AEO) 2025	Large	6,7		
Lazard (2025)[145]	LCOE	Large new	10,6	8,0	13,2
NTNU(No), Applied energy (2025)[146]	The total costs of energy transitions with and without nuclear energy,	Large	6,4	4,4	10,5
AAU(2023[130])[147]	Fakta om atomkraft V2, 2023	Large 1600/1000 MW	6,6		
Rystad Energy (2023)[148]	Kjernekraft i Norge		8,2	5,2	
SMR, , 2030					
NREL(2025)[149]	NREL ATB (2024)	SMR/300 MW	7,9	5,4	9,9
EIA(2025)[144]	Annual Energy Outlook (AEO) 2025	SMR 4X80 MW	7,6		
JRC(2014)[150]	ETRI 2014	SMR/225 MW	7,5	4,7	9,2
MIT (2018)[151]	The Future of Nuclear Energy in a Carbon-Constrained World	SMR	6,3	6,0	6,6
IEA (2025)[141]	The Path to a New Era for Nuclear Energy	SMR-FOAK	9,5		
IEEE(2025)[152]	Overview of Small Modular and Advanced Nuclear Reactors…	SMR FOAK PWR 77-470		7,6	15,7
EY Parthenon(2024)[153]	The true power of small modular reactors on the road to a sustainable energy future	SMR-demo		15,5	20,7
		SMR-FOAK		8,3	13,5
		SMR-NOAK		5,2	7,2
Rystad Energy (2023)[148]	Kjernekraft i Norge	SMR NOAK (developer target)		2,8	5,0

Table 7: Projected overnight capital cost (OCC) around 2030 from literature. All values for IEA (2025) and AAU (2023,2025) are for 2035, no data for 2030 is shown in these references, OPEX data (excluding fuel and waste) in AAU (2023, 2025 is based on IEA (2025). All cost in 2025 €. It is not clearly specified for all examples whether the reported costs include local infrastructure such as site preparation, auxiliary buildings, cooling systems, tunnels, and other supporting facilities, but in the present analysis it is assumed that they do.

7.2 Recent large reactor costs in Europe and the US

In Table 8 below, overnight capital costs (OCC) are presented for large nuclear reactor projects that are completed, under construction, or planned between 2005 and 2025 in Europe and the United States. All plants in Europe and the U.S., except for the Polish project and a few in the French EPR2 program, are brownfield projects[9].

The expected overnight capital cost (OCC) for Poland's first nuclear power plant is shown as 12 M€/MWe, which is approximately 50% higher than the expected costs for the French EPR2 programme and the Czech project. This difference may be attributed to the fact that it is the first nuclear facility in Poland or that the project is more mature. Cost data is drawn from EU state aid investigation documents[147]. Cost data for the French and Czech projects are based on earlier-stage projections.

The project planned in Bulgaria shows an OCC of 5.7 M€/MWe, which is the lowest per MWe cost among all plants listed in Table 8. This could also reflect the early-stage status of the project, furthermore the Kozloduy 7 & 8 reactors will be placed at in connection the Kozloduy 5 & 6 which is in operation and Bulgaria a long experience with nuclear power. Conversely, the OCC for the Sizewell C project in the United Kingdom is estimated at 14.4 M€/MWe, which is more than two times higher than the estimate for the Bulgarian project, and about 10% higher than the Polish project.

[9] Brownfield nuclear: New nuclear units built on a site where nuclear reactors already exist or have existed.

Project Name	Country	Con-struc-tion start (Year)	Start up operation (Year)	Number of reactor x type (unit cap.)	Latest cost es-timate bn € (2025)	Overnight Capital Cost [M€/MWe]
EPR2program[155], [156]	FR	2030	2035+	6×EPR2 (1,450 MWe)	67	7.7
Dukovany 5&6 [157], [158], [159]	CZ	2029	2036+	2×APR1000(1,055 MWe)	17	7.9
Lubiatowo-Kopalino [154],	PL	2027-2028	2036	3×AP1000 (1,250 MWe)	45	12
Kozloduy 7&8 [160], [161], [162]	BG	2027	2035-2037	2×AP1000 (1,150 MWe)	13	5.7
Sizewell C[10] [163]	UK	2026	2036	2×EPR (1,600 MWe)	50	14,4
Hinkley Point C[11] [154] [164]	UK	2018	2029-2031	2×EPR (1,600 MWe)	61	16.3
Flamanville-3 [165], [166],	FR	2007	2024/2025	1×EPR (1,650 MWe)	13	8.0
Olkiluoto-3 [167] , [168]	FI	2005	2023	1×EPR (1,600 MWe)	11	7.1
Vogtle 3&4[169]	US	2013	2023-2024	2×AP1000 (1,117 MWe)	31	13,5

Table 8: Large nuclear reactor projects completed, under construction, or planned between 2005 and 2025 in Europe and the United States. All costs are expressed in 2025 €, for all countries except Poland, nuclear has been a part of the electricity system in more than 40 years. The reactor design considered (APR1000, AP1000, ERP, and ERP 2) are all PWR III+ reactors. AP1000: developed by Westinghouse Electric Company (US), development started in the 1990-ties, first safety and design approval granted in 2005, 9 units in operation in China and US. first came in operation in 2018 in China. EPR: developed by Framatome (FR), EDF(FR) and Siemens/KWU(D), development started in the 1980s/1990s, first safety and design approval granted in mid-2000s, 4 units in operation in China, Finland and France, first reactor came in operation in 2018 in China. ERP 2: simplified and standardized successor to the EPR. Developer: Framatome and EDF (FR), development started in the 2010s, first ERP2 is still in the process of getting full construction license. APR1000 is developed by South Korea's KHNP[12] and is a downscaled, export-oriented evolution of APR1400, optimized for modular construction and shorter build time. Dukovany 5&6 are the first APR1000 to come in operation. The first APR1400 came in operation in South Corea in 2016. It is not clearly specified for all examples whether the reported costs include local infrastructure such as site preparation, auxiliary buildings, cooling systems, tunnels, and other supporting facilities, but in the present analysis it is assumed that they do.

[10] Sizewell C: site preparation works have started

[11] full project cost estimates in out-turn (2024) prices and exclude only financing elements such as interim interest for Hinkley C is estimated to 18.9 M€/MWe, and 15.6 M€/MWe for Sizewell C.

[12] KHNP (Korea Hydro & Nuclear Power, daughter company for the national electricity company in South Korea Electric Power Corporation (KEPCO))

The cost estimate for Sizewell C (UK) is partly based on the expected cost of its "sister plant," Hinkley Point C (UK), which is under construction and for which an OCC of 16,3 M€/MWe is reported. This is approximately 10% higher than the estimate for Sizewell C and represents the highest OCC per MWe among the projects included in the table.

For the two plants that have been built in the US between 2005 and 2023, an OCC of 14 M€/MWe is reported, which is approximately 15% higher than for the Polish plant, more than double the OCC estimate for the plant planned in Bulgaria, and about 75% higher than for the plant planned in the Czech Republic, but still lower than the estimates for the plants under construction and planned in the UK.

From Table 8, the construction time [13] can also be derived. For the three completed projects, the construction periods are approximately 10 and 18 years, respectively. For the two projects where construction or site preparation has started, the expected construction time is around 10 years, while for the four projects that are still in the early planning phase, the construction time is estimated at 5–10 years.

7.3 SMR project cost and OCC estimates and target levels

Table 9 shows costs for SMRs in Group 1 and Group 2. The table indicates whether the figures refer to FOAK, the fourth unit in a project, or a target NOAK value. It also presents the first estimate and the latest estimate where available. The table illustrates very large differences between FOAK costs across the projects, their status in terms of progressing towards financing, and the targeted NOAK levels. There are also substantial differences between the initial FOAK estimates and the most recent ones. Darlington SMR cluster is a brown field nuclear project, while the NuScale project in Utah was a green field project (stopped in 2023).

[13] Construction time is calculated from the start of construction to the point at which the plant enters commercial operation. Construction start refers to the point at which the first concrete for the reactor building is poured. For the five plants in the bottom of the table "construction start" is/ have been preceded by a lengthy planning, licensing and site-preparation phase, typically on the order of 5–10 years from initial decision to first nuclear concrete, with 1–3 years of intensive on-site enabling works immediately before construction start. [177] IAEA 2020

It is seen in Table 9 that the target NOAK cost is 3.1 M€/MWe for three of the four SMRs for which a target NOAK value is reported, while only Rolls-Royce indicates a higher target of 5.3 M€/MWe. This estimate for target NOAK of 3.1 M€/MWe is less than half of average of the central cost estimates for NOAK (7.3 M€/MW) reported in literature listed in Table 9.

In general, it is not clearly specified how many SMR units per plant the estimated cost per unit is based on. The literature [145] indicates that, due to the "economy of multiples," the unit cost for SMRs in plants with 2, 4, and 8 units can be assumed to decrease by approximately 10%, 20%, and 30%, respectively, compared to the cost of a single unit in a one-unit plant[14].

For the first construction projects, the plan is to install four BWRX-300 units at the Darlington site in Canada. For the NuScale project in Utah, USA, it was planned, at the end of the project period, to install six 77 MW SMR units. Here multiple units installed per plants can be expected to affect the cost per unit. However, given the substantial uncertainty associated with estimating SMR costs in general, the effect of the economy of multiples has not been taken into account in this note.

Furthermore, the delimitation of the cost estimates is generally not clearly specified in the literature or in the available project estimates. It is often unclear whether the figures include local infrastructure costs, such as site preparation, non-reactor buildings, cooling water systems, tunnels, workshops, and other supporting facilities.

Only for the four BWRX-300 units planned and under construction at the Darlington has a cost estimate been explicitly published for the local infrastructure. The most straightforward interpretation of the announced overnight capital costs (OCC) for NOAK reactors is that they exclude local infrastructure.

For the Darlington project, the total cost for shared infrastructure is reported to be approximately 3.4 M€/MW for the four BWRX-300 SMRs, corresponding to about 0.85 M€/MW per reactor on average. According to [145] multi-unit SMR clusters comprising two, four, and eight units are

[14] Together with the effect of the "economy of multiples," the costs will also be influenced by economies of scale. In addition, the costs of the first plants will be significantly affected by the learning rate (LR), as described in more detail later in this chapter.

estimated to reduce construction costs by approximately 10%, 20%, and 30%, respectively.

Thus, the estimated cost of local infrastructure amounts to app. 1.06 M€/MW, 0.96 M€/MW, and 0.90 M€/MW for one, two, and three SMRs located at the same site on a brownfield, respectively. These amounts should therefore be added to the target NOAK cost estimates if the local infrastructure is not already included. As it is assumed that all construction work, materials, and equipment related to the local infrastructure can be regarded as well-known and based on very mature technology, no cost reduction for the local infrastructure is expected between FOAK and NOAK [170].

Project Name	Developer	Status	Plant setup, reactor name (unit cap. MWe)	First/lowest cost estimate M€)/MWe	Latest cost estimate M€/Mwe	Comments
GROUP 1						
Darlington SMR-cluster (CA)[53]	GE Vernova Hitachi Nuclear Energy	Target NOAK/FOAK	1×BWRX-300 (300 MWe)	3.4_{2018}	13.9_{2025}	Project cost, Nominal, including capitalized Interest
Darlington SMR-cluster (CA)[171]		No 4	4×BWRX-300 (300 MWe)		9.6_{2025}	Project cost, Nominal, including capitalized interest.
NuScale (Utah, CFPP) (US)[172]	NuScale Power Inc.	FOAK	6×NuScale SMR* (77 MWe)	4.2_{2018}	19.3_{2023}	Project cancelled January 2023
Rolls-Royce SMR (UK) [173]	Rolls-Royce	Target FOAK	1×Rolls-Royce SMR (470 MWe)		6.3_{2021}	Statement by CEO
Rolls-Royce SMR (UK)[173]		Target NOAK	1×Rolls-Royce SMR (470)		5.3_{2021}	Statement by CEO
i-SMR (S COR)[61]	KHNP & KAERI	Target NOAK	4xi-SMR (170 MWe)		3.1_{2025}	
GROUP 2						
AP300 (US)	Westinghouse	Target NOAK	1×AP300 (300 MWe)		3.1_{2023}	
CA Waste Burner (DK)	Copenhagen Atomics	Target NOAK	1×CA Waste Burner (100 MW-th)			
CMSR (DK)	Saltfoss	Target NOAK	1×CMSR (250 MW-th)			
IMSR-400 (CA)	Terrestrial Energy Inc.	Target NOAK	IMSR-390 (2×195 MWe)		3.1_{2016}	
LDR-50(FI)[174]	Steady Energy	Target NOAK	2×LDR-50 (50 MWth total) *	*1.5_{2025} *per MW_{th}*		Heat only technology. Cost estimate is per MW_{th}.
PWR-20 (US)	Last Energy	Target NOAK	1×PWR-20 (20 MWe)			
SMR-300 (US)	Holtec International	Target NOAK	1xSMR-300 (300 MWe)			
Xe-100 (US)	X-Energy LLC	FOAK	1×Xe-100 (80 MWe)	$10_{2020\text{-}21}$	20_{2023}	Including fuel factory for the enriched 15.5 % fuel

*Table 9: Overview of SMR cost estimates, presented either as "target NOAK cost" or as project-specific costs. The cost estimate for the Darlington SMR cluster (FOAK, 2025) includes on fourth of the expenses for buildings, cooling water systems, tunnels, workshops and other shared support facilities designed for all four planned reactors (0.9 M€/MWe) which is a fourth of 3.4 M€/MWe). The same for "No 4" BWRX-300 unit on the same site[15]. *Nuscale Power Module cost estimate for 12x60 (720 MW) plant in 2018 and a 6 x 77 MW (462 MW) plant in 2023. In the case of the Xe-100, cost statements also include the establishment of a dedicated fuel fabrication facility. This is because the Xe-100 uses TRISO fuel based on HALEU, which is incompatible with existing LWR fuel-fabrication infrastructure. Under the U.S. DOE ARDP program, the aim is to demonstrate a complete supply chain both to strengthen supply security and to de-risk future Xe-100 fleets. No references provide quantitative estimates for how these costs are distributed between the reactors and the fuel-factory. The figures should therefore be regarded only as illustrative examples reflecting the high uncertainty of SMR. All costs are in 2025 €, and the years shown as subscripts are the years that the cost estimates are announced. It is not clearly specified for all examples whether the reported costs include local infrastructure such as site preparation, auxiliary buildings, cooling systems, tunnels, and other supporting facilities, but in the present analysis it is assumed that they do.*

7.4 OPEX from literature

Table 10 shows operational expenditures (OPEX) for 2030 based on literature studies, on data from Swedish nuclear power plants (before 2020), and Finnish nuclear power plants (2024, 2025 Q1+Q2). Some studies report central, low, and high estimates.

There are large differences between the central estimates; If the total OPEX, including fuel and waste treatment costs, is calculated based on an assumed capacity factor of 88%, the average of total OPEX amounts 30 €/MWhe. The highest estimate for total OPEX is 41 €/MWhe found in the WEO 2025, which is about 34% higher than the average, while the lowest estimate is 20 €/MWhe found for the Swedish nuclear, which is about 34% lower than the average. There is also a substantial variation in the expected price of fuel including waste management. The average estimate is 7.9€/MWhe. The lowest estimate is 5 €/MWhe based on TVO's data for the Finnish plants. And the highest estimate is around 10€/MWhe based on the data from the NREL ATB 2024.

In general, OPEX includes staffing, repairs, servicing, spare parts, and safety upgrades. Whether costs for fuel and waste treatment and storage are included in the reported O&M varies. Some sources break down OPEX into fixed and variable components, while others provide only an aggregate OPEX figure. This has been considered in the calculation of the total OPEX in the examples shown in Table 10. Unfortunately, most sources for nuclear OPEX do not explicitly state whether the reported OPEX figures include insurance. Based on the way OPEX is typically defined, it is likely that insurance is included, although this is not clearly specified in the available documentation.

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[15] GEH and TVA signed an agreement in 2022 to support the potential deployment of the BWRX-300 at the Clinch River site in Tennessee, USA. The plant is expected to be commissioned in 2033, with an OCC cost projection higher than that of the Darlington project, namely 16.6 million €/MW [178], Table 3-3: *Overnight Capital Costs*.

Author	Publication	Capacity	Capital cost 2030 [M€/MWe]	Fixed OPEX [€/kWe]	Var OPEX [€/MWhe]	Fuel and waste treatment [€/MWhe]	Calculated total OPEX [€/MWhe]*
		Large					
	Year 2030		Central	Central	Central	Central	Central
TVO**[175]	Interim Report Q2 2025	Olkiluoto1-3		161		5	25
Finansdepartementet, SE (2023)[142]	Finansiering och riskdelning vid investeringar i ny kärnkraft	Large	7.9	101		7	20
IEA (2025)[143]	WEO 2025 APS	2035 EU_ large	4.8		33		41
EIA (2025)[144]	Annual Energy Outlook (AEO) 2025	Large	6.7	147	2		29
Lazard (2025)***[145]	LCOE 2025	Large new	10.6		9	8	33
NTNU(No), Applied energy (2025)[146]	The total costs of energy transitions with and without nuclear energy,	Large	6.4	135	2	9	28
AAU (2023)[176], [147]	Fakta om atomkraft V2, 2023	Large 1600/1000 MW	6.6	110	16	9	40
		SMR					
NREL (2025)[149]	NREL ATB (2024)	SMR/300 MW	7.9	121	2	10	28
EIA (2025)[144]	Annual Energy Outlook (AEO) 2025	SMR 4X80 MW	7.6	115	3		26
JRC (2014)[150]	ETRI 2014	SMR/225 MW	7.5	147	2		29

*Table 10 Examples of OPEX values for 2030 are taken from literature studies, except for the two entries at the top, which are based on collected operational data. *Total OPEX incl. fuel [€/MWhe] is calculated assuming an annual capacity factor of 88%. In cases where the studies provide no estimate for fuel and waste treatment costs, a value of 7.9 €/MWhe has been assumed, corresponding to the average from the studies that include these cost components. ** For Olkiluoto 1–3, the OPEX data are reported as total expenditures divided into "fuel and waste" and "other". The "other" category is assumed to be fixed. The cost for waste is negative in 2024. ***For Lazard (2025), only a cost range is provided; therefore, the reported values represent the average of the lower and upper boundaries. All OPEX values from IEA (2025) and AAU (2023, 2025) refer to 2035, as no data for 2030 are presented in these references. The OPEX data (excluding fuel and waste) in AAU (2023, 2025) are based on IEA (2025). It is not clearly specified for all examples whether the reported costs include local infrastructure such as site preparation, auxiliary buildings, cooling systems, tunnels, and other supporting facilities, but in the present analysis it is assumed that they do.*

7.5 Projected costs of SMRs

Literature is ambiguous regarding cost projections for SMR. We base our cost projection on what we consider the most substantiated cost estimate from the planned 4* BWRX300 under construction in Darlington Canada. According to published data, the estimated cost for the 4th reactor is 9,6

M€/MWe$_{2025}$, including the proportional part of necessary local infrastructure (nominal, including capitalized interest). The site is an existing nuclear PP site (brownfield).

When converting the Darlington cost to OCC$_{2025}$ in a Danish context, the public figures must be adjusted by:

- Estimate what inflation rate and WACC has been used (the budget is nominal and includes capitalized interest).
- Estimate what part of cost reduction between R1 and R4 is due to construction of four reactors in one work stream (assumed to be less relevant in Denmark), and what part is general learning.
- Estimate additional costs for planning, land acquisition licensing, infrastructure etc. in a Danish context where only 1-2 reactors are expected to be built in one site.

The resulting calculated OCC based on the Darlington cost budget is 9.1 M€/MWe$_{2025}$

We assume that 2-4 other designs simultaneously could undertake construction processes in the Western world, including in Europe. We use three buildout scenarios, with Learning Rates (LR) between 8% and 12.5% to project the development of overnight costs from 2035 and onwards. The Learning rate applies to the machinery part, estimated to be 70% of the investment in 2035. We define 30% as civil works following a general productivity-gain estimated to be 1% p.a. in the Western world.

Assuming a capacity factor of 88%, the estimate of total O&M including fuel and waste handling is between 15 and 40 €/MWh (Table 10). There is no clear difference between large scale technologies and SMRs in literature. We estimate costs for fuel and waste handling to be 7.9 €/MWh, and "all other O&M costs" to be 1.5% of OCC. These assumptions yield a total of 26 €/MWh.

We have no evidence to project increasing or decreasing costs for fuel/waste handling over time. We project other O&M costs to decrease as OCC decreases in each scenario. The resulting cost projections can be seen in the following tables.

Central scenario		2035	2040	2045	2050
LR			10.0%	10.0%	10.0%
Central buildout	GW. Adv econ	3.6	10	20	30
Doublings per 5 year			1.5	1.0	0.6
Cost	M€/MW	9,1	8,0	7,5	7,3
F&W	€/MWh	7,9	7,9	7,9	7,9
Other	% of inv.	1,5%	1,5%	1,5%	1,5%
Total:	€/MWh	26	24	23	22

Table 11: OCC and O&M cost projection central SMR buildout scenario.

In the central scenario, we assume a total buildout of 30 GW SMR capacity in the western world. Furthermore, we assume that the development is mainly based on well-known light water technologies, and that buildout is concentrated on few designs in order to benefit from learning. Also, it is probably a necessary precondition that buildout is undertaken as "convoy projects", where 3-5 reactors are built at the same site in one continuous workflow.

Optimistic scenario		2035	2040	2045	2050
LR			12.5%	12.5%	12.5%
Fast buildout GW	GW. Adv econ	3.6	13	44	154
Doublings per 5 year			1.8	1.8	1.8
Cost M€/MW		8,2	6,8	5,9	5,3
F&W	€/MWh	7,9	7,9	7,9	7,9
Other	% of inv.	1,5%	1,5%	1,5%	1,5%
Total O&M	€/MWh	24	21	19	18

Table 12: OCC and O&M cost projection High SMR buildout scenario.

In the optimistic buildout scenario, we assume a total buildout of more than 150 GW SMR capacity in the western world towards 2050. The higher Learning Rate is probably only achievable if GEN IV technologies are deployed already from around 2040. Again, it is probably a necessary precondition that buildout is undertaken as "convoy projects", where 3-5 reactors ore more are built at the same site in one continuous workflow, or if floating power plants are adopted at scale.

Pessimistic scenario		2035	2035	2040	2050
LR			8.0%	8.0%	8.0%
Slow buildout GW	GW. Adv econ	3.6	5	8	12
Doublings per 5 year			0.6	0.6	0.6
Cost M€/MW		10,1	9,6	9,2	8,7
F&W	€/MWh	7,9	7,9	7,9	7,9
Other	% of inv.	1,5%	1,5%	1,5%	1,5%
Total O&M	€/MWh	28	27	26	25

Table 13: OCC and O&M cost projection Slow SMR buildout scenario.

In the pessimistic buildout scenario, we assume a total buildout of only 12 GW SMR capacity in the western world towards 2050. The lower Learning Rate indicates that the modularity in SMR buildout never really dominates cost reduction. In this scenario, SMR technologies struggle to reduce costs below estimated costs of traditional nuclear technologies.

7.6 LCOE

Using the above construction and operational costs and an expected technical lifetime, the LCOE can be calculated. It is important to note, that the LCOE shown in the two tables below is under the assumption of electricity only production (no heat production).

- High WACC (8% real) assuming that investments in nuclear energy are more risky than other investments in electricity production technologies. Higher risk due long economic lifetime (exposure to market and regulation risks in 40-60 years).
- Market based WACC used for all energy technologies in Europe in the systems modelling part of this project (6% real).
- Socio-economic interest rate according to Danish Ministry of Finance (3.5% real)

With a 60-year time horizon and 6% real interest, the LCOE decreases from 107 €/MWh for plants constructed in 2035 to 88 €/MWh in 2050 in the Central scenario. 60 years anticipated payback can be a long time for commercial investors. With a 40-year time horizon the LCOE is 114 €/MWh in 2035 and 93 €/MWh in 2050.

When using the socio-economic rent published by the Danish ministry of Finance, the LCOE decreases from 76 €/MWh to 63 €/MWh (60 years life-time). LCOE in the two other scenarios can be found in the figures below.

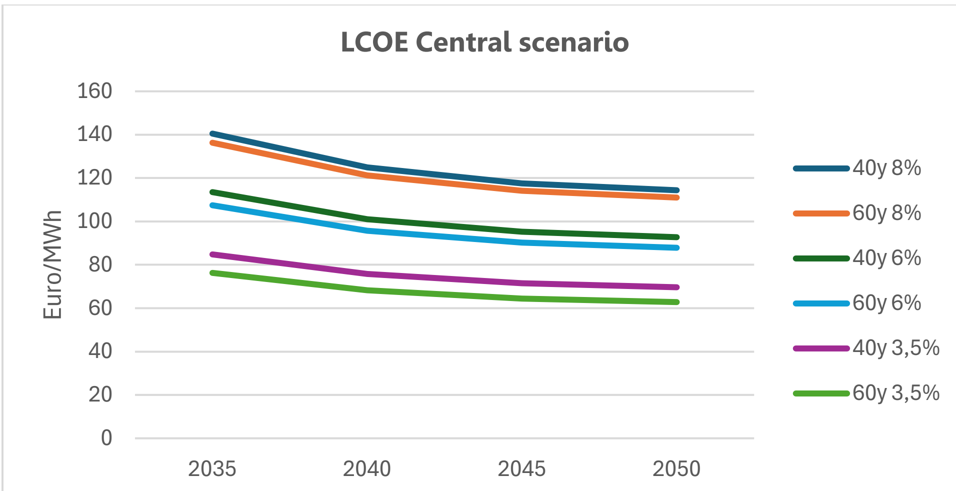

Figure 7: Calculated LCOE in the central buildout scenario. Capitalised interest in 4 year construction period included.

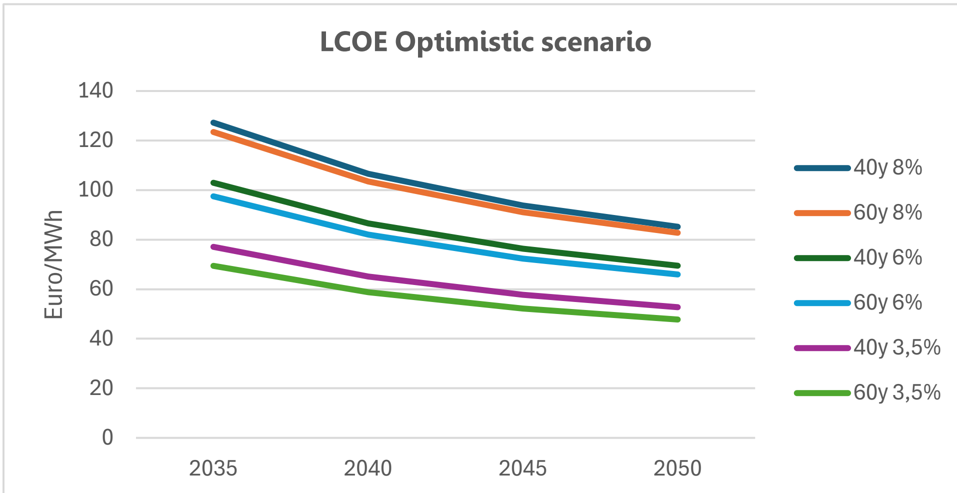

Figure 8: Calculated LCOE in the optimistic buildout scenario. Capitalised interest in 4 year construction period included.

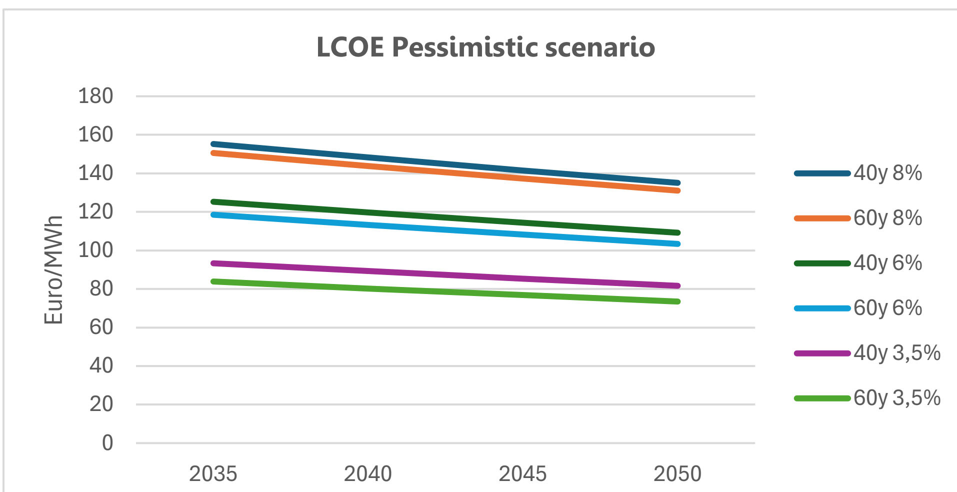

Figure 9: Calculated LCOE in the pessimistic scenario. Capitalised interest in 4 year construction period included.

A LWR SMR plant can have potential for utilizing the heat from turbine outlet, if the plant can be situated in a suitable proximity to a DH network. The figure below shows the net LCOE when assuming income from heat sales. The analysis assumes a 6% real WACC, a 40-year payback period, and a 4-year construction phase including capitalized interest. For the Combined Heat and Power (CHP) configuration, a maximum heat-to-power ratio of 66% and a power loss factor (Cv) of 15% were applied, with heat valued at 34 €/MWh.

Across optimistic, central, and pessimistic projections, the cost delta between CHP and condensing configurations remains at similar level.

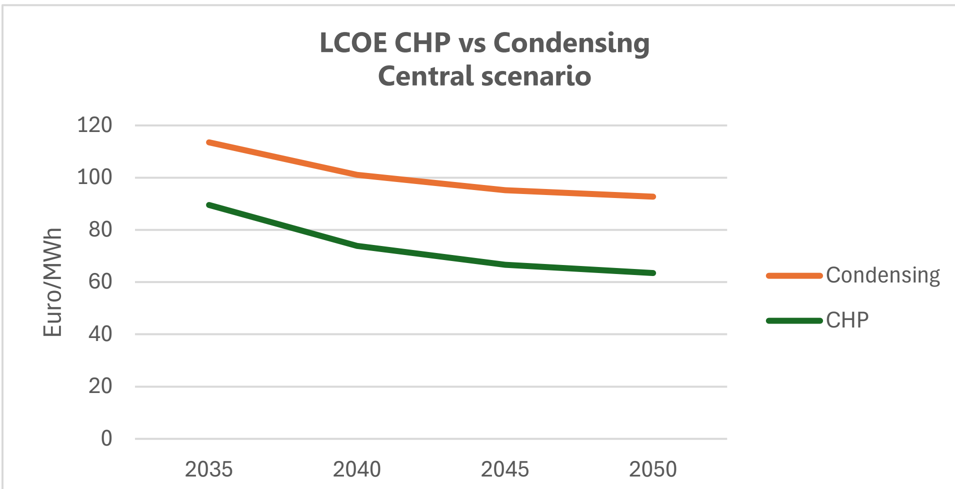

Figure 10: Calculated LCOE for a CHP plant and a Condensing plant in the central scenario.

Bibliography

[1] Cooperation in Reactor Design Evaluation and Licensing (CORDEL) Working Group of the World Nuclear Association, “Facilitating International Licensing of Small Modular Reactors,” World Nuclear Association, 2015. [Online]. Available: https://world-nuclear.org/images/articles/REPORT_Facilitating_Intl_Licensing_of_SMRs.pdf

[2] K. Söderholm, “Licensing Model Development for Small Modular Reactors (SMRs) - Focusing on the Finnish Regulatory Framework,” 2013. [Online]. Available: https://lutpub.lut.fi/handle/10024/92375

[3] International Atomic Energy Agency, “STATUS OF SMALL AND MEDIUM SIZED REACTOR DESIGNS: A Supplement to the IAEA Advanced Reactors Information System (ARIS),” 2012, *International Atomic Energy Agency, Vienna*. [Online]. Available: https://aris.iaea.org/Publications/smr-status-sep-2012.pdf

[4] International Atomic Energy Agency, “Small Modular Reactors, Advances in SMR Developments,” 2024, *International Atomic Energy Agency, Vienna*. [Online]. Available: https://www-pub.iaea.org/MTCD/Publications/PDF/p15790-PUB9062_web.pdf

[5] European Commission, “European Industrial Alliance on Small Modular Reactors,” 2023, *European Commission, Brussels*. [Online]. Available: https://single-market-economy.ec.europa.eu/industry/industrial-alliances/european-industrial-alliance-small-modular-reactors_en

[6] Canadian Nuclear Safety Commission, “Commission authorizes Ontario Power Generation Inc. to construct 1 BWRX-300 reactor at the Darlington New Nuclear Project site,” 2025, *Canadian Nuclear Safety Commission, Ottawa*. [Online]. Available: https://www.canada.ca/en/nuclear-safety-commission/news/2025/04/commission-authorizes-ontario-power-generation-inc-to-construct-1-bwrx-300-reactor-at-the-darlington-new-nuclear-project-site.html

[7] World Nuclear News, “Site of Poland’s First SMR Selected,” 2025, *World Nuclear News, London*. [Online]. Available: https://www.world-nuclear-news.org/articles/site-of-polands-first-smr-selected

[8] UK Government, "New nuclear power stations: assessing reactor designs," 2019, *UK Government, London*. [Online]. Available: https://www.gov.uk/guidance/new-nuclear-power-stations-assessing-reactor-designs

[9] Kairos Power, "Kairos Power Begins Nuclear Safety-Related Construction of Hermes Low-Power Demonstration Reactor," 2025, *Kairos Power, Alameda*. [Online]. Available: https://kairospower.com/external_updates/kairos-power-begins-nuclear-construction-of-hermes-demonstration-reactor/

[10] Steady Energy, "Steady Energy to build small nuclear pilot plant inside a former coal plant in central Helsinki," 2025, *Steady Energy, Helsinki*. [Online]. Available: https://www.steadyenergy.com/news-article/steady-energy-to-build-small-nuclear-pilot-plant-inside-a-former-coal-plant-in-central-helsinki

[11] C. Howe, "China to start commercial operation of first small modular nuclear reactor in 2026," Reuters, 2025. [Online]. Available: https://www.reuters.com/business/energy/china-start-commercial-operation-first-small-modular-nuclear-reactor-2026-2025-12-11/

[12] World Nuclear News, "China's demonstration HTR-PM enters commercial operation," 2023, *World Nuclear News*. [Online]. Available: https://www.world-nuclear-news.org/Articles/Chinese-HTR-PM-Demo-begins-commercial-operation

[13] World Nuclear News, "CNNC completes design of district heating reactor," 2018. [Online]. Available: https://www.world-nuclear-news.org/Articles/CNNC-completes-design-of-district-heating-reactor

[14] UK National Nuclear Laboratory, "Boiling Water Reactor Technology - International Status and UK Experience," https://uknnl.com/innovation-science-and-technology/121-2/position-papers/.

[15] A. Worrall, "4 - Core and fuel technologies in integral pressurized water reactors (iPWRs)," in *Handbook of Small Modular Nuclear Reactors (Second Edition)*, D. T. Ingersoll and M. D. Carelli, Eds., Woodhead Publishing, 2021, pp. 69–93. doi: https://doi.org/10.1016/B978-0-12-823916-2.00004-7.

[16] Y. Xu, S. Hu, F. Li, and S. Yu, "High temperature reactor development in China," *Progress in Nuclear Energy*, vol. 47, no. 1, pp. 260–270, 2005, doi: https://doi.org/10.1016/j.pnucene.2005.05.026.

[17] World Nuclear News, "MHI to Lead Development of Japanese HTGR," 2025, *World Nuclear News, London*. [Online]. Available: https://www.world-nuclear-news.org/Articles/MHI-to-lead-development-of-Japanese-HTGR

[18] P.-P. Koistinen, "Operational Maturity of GEN IV Nuclear Reactor Designs," 2025, *Lappeenranta–Lahti University of Technology LUT, Lappeenranta*. [Online]. Available: https://urn.fi/URN:NBN:fi-fe20251124110444

[19] World Nuclear News, "Chinese molten salt reactor achieves conversion of thorium-uranium fuel," 2025, *World Nuclear News, London*. [Online]. Available: https://www.world-nuclear-news.org/articles/chinese-msr-achieves-conversion-of-thorium-uranium-fuel

[20] International Atomic Energy Agency, *Status of Molten Salt Reactor Technology*. 2023. doi: https://www.iaea.org/publications/14998/status-of-molten-salt-reactor-technology.

[21] H. Rifai *et al.*, "Innovative thorium-based fuel assemblies for LW-SMR: In-depth assembly-level neutronic analysis and safety considerations in solid and annular configurations," *Nuclear Engineering and Design*, vol. 442, p. 114274, 2025, doi: https://doi.org/10.1016/j.nucengdes.2025.114274.

[22] International Atomic Energy Agency, "Nuclear Installations," 2025, *International Atomic Energy Agency, Vienna*. [Online]. Available: https://www.iaea.org/topics/nuclear-installations

[23] S. Lansou, L. Ammirabile, N. Bakouta, and et al., "ELSMOR – towards European Licensing of Small Modular Reactors: Methodology recommendations for light-water small modular reactors safety assessment [version 2; peer review: 2 approved, 3 approved with reservations]," *Open Research Europe*, vol. 3, p. 158, 2024, doi: https://doi.org/10.12688/openreseurope.16360.2.

[24] STUK, "According to STUK's new regulation, nuclear power plant's precautionary action zone and emergency planning zone are defined on a case-by-case basis," https://stuk.fi/en/-/according-to-stuk-s-new-regulation-nuclear-power-plant-s-precautionary-action-zone-and-emergency-planning-zone-are-defined-on-a-case-by-case-basis.

[25] Nordic Nuclear and Radiation Safety Authorities DEMA, DSA, GR, SIS, SSM, and STUK, "Nordic Strategy Group Report," 2025, *Nordic Strategy Group*. [Online].

Available: https://www.dsa.no/en/publications/nordic-strategy-group-report/Nordic-Strategy-Group-Report.pdf

[26] M. Palo, J. Tuominen, K. Hassinen, L. Pajunen, H. Jokineva, and J. Pöytäniemi, "KELPO: Development of the licensing and qualification processes for the systems and equipment of nuclear facilities in Finland," 2019. [Online]. Available: https://energia.fi/en/julkaisut/kelpo-development-of-the-licensing-and-qualification-processes-for-the-systems-and-equipment-of-nuclear-facilities-in-finland-2/

[27] International Atomic Energy Agency, "Graded Approach Principle in KELPO Cooperation. Appendix VIII," 2023, *International Atomic Energy Agency, Vienna*. [Online]. Available: https://inis.iaea.org/records/mwjyg-q8d93

[28] European Nuclear Safety Regulators Group, "Denmark," 2021, *European Nuclear Safety Regulators Group, Brussels*. [Online]. Available: https://www.ensreg.eu/country-profile/Denmark

[29] International Atomic Energy Agency, "Integrated Regulatory Review Service (IRRS) Mission to the Kingdom of Denmark," 2021. [Online]. Available: https://www.iaea.org/sites/default/files/documents/review-missions/irrs_denmark_final_report.pdf

[30] International Atomic Energy Agency, "IAEA Mission Says Denmark is Committed to a High Level of Safety, Sees Areas for Further Enhancement," 2021. [Online]. Available: https://www.iaea.org/newscenter/pressreleases/iaea-mission-says-denmark-is-committed-to-a-high-level-of-safety-sees-areas-for-further-enhancement

[31] E. Ahonen, J. Heinonen, N. Lahtinen, M. Tuomainen, and O. Lång, "Preconditions for the Safe Use of Small Modular Reactors – Outlook for the Licensing System and Regulatory Control," Säteilyturvakeskus (STUK), 2019. [Online]. Available: https://www.julkari.fi/server/api/core/bitstreams/7a1aa9bf-a230-472d-8272-b65716d8a382/content

[32] International Atomic Energy Agency, "Nuclear Fuel Cycle," 2025. [Online]. Available: https://www.iaea.org/topics/nuclear-fuel-cycle

[33] International Atomic Energy Agency, "The Nuclear Fuel Cycle," 2019, *International Atomic Energy Agency, Vienna*. [Online]. Available: https://www.iaea.org/sites/default/files/19/02/the-nuclear-fuel-cycle.pdf

[34] M. T. Simnad, “Nuclear Reactor Materials and Fuels, Encyclopedia of Physical Science and Technology (Third Edition), Academic Press,” 2003. doi: https://doi.org/10.1016/B0-12-227410-5/00498-1.

[35] P. Fernández-Arias, D. Vergara, and Á. Antón-Sancho, “Global Review of International Nuclear Waste Management,” *Energies (Basel).*, vol. 16, no. 17, 2023, doi: 10.3390/en16176215.

[36] H. Tohver, S. Salupere, and M. Jeltsov, “Operational radioactive waste management strategies for small reactors in nuclear newcomer countries,” *Nuclear Engineering and Design*, 2025, doi: 10.1016/j.nucengdes.2025.114327.

[37] Posiva, “Spent Fuel.” [Online]. Available: https://www.posiva.fi/en/index/finaldisposal/long-termsafety/spentfuel.html

[38] J. Kazmierczak, S. Karan, and R. Jakobsen, “Geological Disposal of Radioactive Waste in Denmark: Phase 1 Studies,” 2021. [Online]. Available: https://www.geus.dk/Media/637781284982472434/Report%208.pdf

[39] Dansk Dekommissionering, “National Strategy for Radioactive Waste Management,” 2025. [Online]. Available: https://dekom.dk/en/affaldshaandtering/#affald-2

[40] G. Armand, F. Bumbieler, N. Conil, R. de la Vaissière, J.-M. Bosgiraud, and M.-N. Vu, “Main outcomes from in situ thermo-hydro-mechanical experiments programme to demonstrate feasibility of radioactive high-level waste disposal in the Callovo-Oxfordian claystone,” *Journal of Rock Mechanics and Geotechnical Engineering*, vol. 9, no. 3, pp. 415–427, 2017, doi: https://doi.org/10.1016/j.jrmge.2017.03.004.

[41] A.--F. N. R. W. M. Agency, “Geological Disposal Protection.” [Online]. Available: https://international.andra.fr/projects/cigeo/protection-most-hazardous-radioactive-waste/geological-disposal-protection

[42] World Nuclear Association, “Storage and Disposal of Radioactive Waste,” 2024. [Online]. Available: https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-waste/storage-and-disposal-of-radioactive-waste

[43] Posiva, “Disposal Canister.” [Online]. Available: https://www.posiva.fi/en/index/finaldisposal/releasebarriers/disposalcanister.html

[44] Posiva, "Geological Final Disposal." [Online]. Available: https://www.posiva.fi/en/index/finaldisposal/geologicalfinaldisposal.html

[45] IAEA, "Small modular reactors Catalogue 2024," 2024. Accessed: Oct. 23, 2025. [Online]. Available: https://aris.iaea.org/Publications/SMR_catalogue_2024.pdf

[46] NEA, "The NEA Small Modular Reactor Dashboard: Third Edition," Sep. 2025. Accessed: Oct. 23, 2025. [Online]. Available: https://www.oecd-nea.org/jcms/pl_108326/the-nea-small-modular-reactor-dashboard-third-edition?details=true

[47] Energy Tech. com, "DOE Names 10 Companies to Fast-Track SMR by 2026," Aug. 2025, Accessed: Oct. 24, 2025. [Online]. Available: https://www.energytech.com/print/content/55309652

[48] IAEA, "Small modular reactors Catalogue 2024," 2024. Accessed: Oct. 23, 2025. [Online]. Available: https://aris.iaea.org/Publications/SMR_catalogue_2024.pdf

[49] GE Vernova Hitachi Nuclear Energy Americas LLC, "BWRX-300 General Description," Oct. 2025. Accessed: Oct. 24, 2025. [Online]. Available: https://www.gevernova.com/content/dam/gevernova-nuclear/global/en_us/documents/carbon-free-power/005N9751-BWRX-300-General-Description.pdf

[50] D. H. Dorman and R. Jammal, "Executive Vice-President and Chief Regulatory Operations Officer Canadian Nuclear Safety Commission Charter: CNSC and USNRC Collaboration on the review of the BWRX-300," Sep. 2022. Accessed: Feb. 13, 2026. [Online]. Available: https://www.cnsc-ccsn.gc.ca/eng/corporate/agreements-partnerships/international-agreements/cnsc-usnrc-smr-advanced-reactor-charter/

[51] European Nuclear Society, "GEH and TVA to Cooperate on BWRX-300 SMR Deployment in the US," *European Nuclear Society*, Aug. 2022, Accessed: Feb. 13, 2026. [Online]. Available: https://www.euronuclear.org/news/geh-tva-cooperation-bwrx-300-smr-deployment-us/

[52] Hitachi GE Vernova Nuclear Energy, "Tennessee Valley Authority submits application for construction of first BWRX-300 small modular reactor in the U.S.," KNOXVILLE, Tenn., May 2025. Accessed: Feb. 13, 2026. [Online]. Available: https://www.gevernova.com/https://www.hitachi-hgne.co.jp/en/news/2025/2025news03.html

[53] World Nuclear News, “Canada’s first SMR project: How is CAD20.9 billion cost calculated?”

[54] S. G. Lim, H. S. Nam, D. H. Lee, and S. W. Lee, “Design characteristics of nuclear steam supply system and passive safety system for Innovative Small Modular Reactor (i-SMR),” *Nuclear Engineering and Technology*, vol. 57, no. 10, p. 103697, Oct. 2025, doi: 10.1016/J.NET.2025.103697.

[55] H. O. Kang, B. J. Lee, and S. G. Lim, “Light water SMR development status in Korea,” *Nuclear Engineering and Design*, vol. 419, p. 112966, Apr. 2024, doi: 10.1016/J.NUCENGDES.2024.112966.

[56] IAEA, “Small modular reactors Catalogue 2024,” 2024. Accessed: Oct. 23, 2025. [Online]. Available: https://aris.iaea.org/Publications/SMR_catalogue_2024.pdf

[57] i-SMR, “Uniqueness.” Accessed: Oct. 23, 2025. [Online]. Available: https://ismr.or.kr/eng/sub/uniqueness

[58] i-SMR, “innovative SMR Development Agency Signs MOU with the Nuclear Industry Association of Türkiye (NIATR) for SMR Cooperation.” Accessed: Oct. 23, 2025. [Online]. Available: https://i-smrkr.com/news/36

[59] World Nuclear News, “Korean city to study feasibility of i-SMR deployment.” Accessed: Oct. 23, 2025. [Online]. Available: https://www.world-nuclear-news.org/Articles/Korean-city-to-study-feasibility-of-i-SMR-deployme

[60] i-SMR, “About us, Introduction.” Accessed: Nov. 04, 2025. [Online]. Available: https://ismr.or.kr/eng/sub/introduction

[61] Ministry of Science and ICT and I. and E. Ministry of Trade, “i-SMR catalogue,” 2025.

[62] NuScale, “NuScale Small Modular Reactor Integration for Hydrogen and Ammonia Production,” May 2025, Accessed: Oct. 21, 2025. [Online]. Available: https://www.nuscalepower.com/press-releases/2025/nuscale-powers-small-modular-reactor-smr-achieves-standard-design-approval-from-us-nuclear-regulatory-commission-for-77-mwe

[63] NuScale, “NuScale Power’s Small Modular Reactor (SMR) Achieves Standard Design Approval from U.S. Nuclear Regulatory Commission for 77 MWe.” Accessed: Oct. 20, 2025. [Online]. Available: https://www.nuscalepower.com/press-

releases/2025/nuscale-powers-small-modular-reactor-smr-achieves-standard-design-approval-from-us-nuclear-regulatory-commission-for-77-mwe

[64] Adam Duckett, “NuScale cancels first planned SMR nuclear project due to lack of interest.” Accessed: Oct. 24, 2025. [Online]. Available: https://www.thechemicalengineer.com/news/nuscale-cancels-first-planned-smr-nuclear-project-due-to-lack-of-interest/

[65] NuScale Power, “NuScale and Romanian Energy Company Sign Agreement to Explore SMRs for Romania,” 2019. [Online]. Available: https://www.nuscalepower.com/press-releases/2019/nuscale-and-romanian-energy-company-sign-agreement-to-explore-smrs-for-romania

[66] NuScale Power, “Strategic Partners.” [Online]. Available: https://www.nuscalepower.com/about/strategic-partners

[67] World Nuclear News, “NuScale, KGHM agree to deploy SMRs in Poland,” 2022. [Online]. Available: https://www.world-nuclear-news.org/Articles/NuScale,-KGHM-agree-to-deploy-SMRs-in-Poland

[68] S. Patel, “TVA, ENTRA1 Sign Agreement for 6 GW Six-Plant Nuclear SMR Collaboration,” 2025. [Online]. Available: https://www.powermag.com/tva-entra1-sign-agreement-for-6-gw-six-plant-nuclear-smr-collaboration/

[69] K. Kraev, “Poland / New Schedule Sees Three-Year Delay for First Nuclear Power Plant,” 2024. [Online]. Available: https://www.nucnet.org/news/new-schedule-sees-three-year-delay-for-first-nuclear-power-plant-12-4-2024

[70] V. Spasić, “Final Investment Decision for Romania’s SMR Project Could Be Delayed,” 2025. [Online]. Available: https://balkangreenenergynews.com/final-investment-decision-for-romanias-smr-project-could-be-delayed/

[71] World Nuclear News, “NuScale, KGHM agree to deploy SMRs in Poland,” 2022. [Online]. Available: https://www.world-nuclear-news.org/Articles/NuScale,-KGHM-agree-to-deploy-SMRs-in-Poland

[72] NuScale Power, “NuScale Proudly Supports TVA and ENTRA1 Energy Announcement of Landmark 6-Gigawatt Small Modular Reactor (SMR) Deployment Program,” 2025. [Online]. Available: https://www.nuscalepower.com/press-releases/2025/nuscale-proudly-supports-tva-and-entra1-energy-announcement-of-landmark-6-gigawatt-small-module-reactor-smr-deployment-program

[73] Institute for Energy Economics and Financial Analysis, “SMRs: Still Too Expensive, Too Slow and Too Risky,” May 2024. Accessed: Oct. 23, 2025. [Online]. Available: https://ieefa.org/sites/default/files/2024-05/SMRs%20Still%20Too%20Expensive%20Too%20Slow%20Too%20Risky_May%202024.pdf

[74] A. Abou-Jaoude, L. Lin, C. Bolisetti, E. Worsham, L. M. Larsen, and A. Epiney, “Literature Review of Advanced Reactor Cost Estimates,” 2023, Accessed: Oct. 27, 2025. [Online]. Available: http://www.ies.inl.gov

[75] NuScale, “nuscale-smr-technology-an-ideal-solution-for-coal-plant-replacement,” 2021, Accessed: Nov. 19, 2025. [Online]. Available: https://www.nuscalepower.com/hubfs/Website/Files/Technical%20Publications/nuscale-smr-technology-an-ideal-solution-for-coal-plant-replacement.pdf?hsLang=en

[76] Rolls Royce SMR, “Our technology,” 2025. [Online]. Available: https://gda.rolls-royce-smr.com/our-technology

[77] Environment agency Office for Nuclear Regulation Natural Resources Wales, “GDA Step 2 of the Rolls-Royce SMR: fundamental assessment full report,” 2024. [Online]. Available: https://www.gov.uk/government/publications/gda-step-2-of-the-rolls-royce-smr-fundamental-assessment/gda-step-2-of-the-rolls-royce-smr-funda

[78] Department for Energy Security and Net Zero, “Rolls-Royce SMR selected to build small modular nuclear reactors,” Jun. 2025. [Online]. Available: https://www.gov.uk/government/news/rolls-royce-smr-selected-to-build-small-modular-nuclear-reactors

[79] Department for Energy Security and Net Zero, “Rolls-Royce SMR selected to build small modular nuclear reactors,” Jun. 2025. [Online]. Available: https://www.gov.uk/government/news/rolls-royce-smr-selected-to-build-small-modular-nuclear-reactors

[80] Nuclear Energy Agency, “The NEA Small Modular Reactor Dashboard: Third Edition,” Sep. 2025. Accessed: Oct. 23, 2025. [Online]. Available: https://www.oecd-nea.org/jcms/pl_108326/the-nea-small-modular-reactor-dashboard-third-edition?details=true

[81] Rolls Royce SMR, “Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 9B: Civil Engineering Works and Structures,” 2024. Accessed: Oct. 23, 2025. [Online]. Available: https://gda.rolls-royce-

smr.com/assets/documents/documents/rr-smr-e3s-case-chapter-9b---civil-engineering-works-and-structures-v2-public-issue-clean.pdf

[82] M. Salisbury, "Rolls-Royce SMR Design Overview White Paper- Approved," Jul. 2025. Accessed: Nov. 05, 2025. [Online]. Available: https://www.nrc.gov/docs/ML2521/ML25212A115.pdf

[83] United States Nuclear Regulatory Commission, "Design Certification Applications for New Reactors." [Online]. Available: https://www.nrc.gov/reactors/new-reactors/large-lwr/design-cert

[84] Government of Canada, "Vendor design review," Jul. 2025. [Online]. Available: https://www.cnsc-ccsn.gc.ca/eng/reactors/power-plants/pre-licensing-vendor-design-review/

[85] Office for Nuclear Regulation, "Generic Design Assessment (GDA) of new nuclear power stations." [Online]. Available: https://www.onr.org.uk/generic-design-assessment

[86] D. Dalton, "Westinghouse AP300 / US Company Unveils 'Game-Changing' Mid-Sized Nuclear Reactor," 2023. [Online]. Available: https://www.nucnet.org/news/us-company-unveils-game-changing-mid-sized-nuclear-reactor-5-4-2023

[87] Westinghouse Electric Company, "SaskPower, Westinghouse and Cameco Sign MOU to Explore Reactor and Fuel Supply Potential," Jun. 2024. [Online]. Available: https://info.westinghousenuclear.com/news/saskpower-westinghouse-and-cameco-sign-mou-to-explore-reactor-and-fuel-supply-potential

[88] Westinghouse Electric Company, "Westinghouse Joins Texas Nuclear Alliance as a Founding Member," Aug. 2025, Accessed: Oct. 24, 2025. [Online]. Available: https://info.westinghousenuclear.com/news/westinghouse-joins-texas-nuclear-alliance-as-a-founding-member

[89] Westinghouse Electric Company, "Westinghouse and Data4 to Collaborate on European Data Center Project," Mar. 2025, Accessed: Oct. 24, 2025. [Online]. Available: https://info.westinghousenuclear.com/news/westinghouse-data4-to-collaborate-on-european-data-center-project

[90] Westinghouse Electric Company, "Westinghouse and UK's Community Nuclear Power Collaborate to Deploy Fleet of AP300™ Small Modular Reactors," Feb. 2024, Accessed: Oct. 24, 2025. [Online]. Available:

https://info.westinghousenuclear.com/news/westinghouse-and-uks-community-nuclear-power-collaborate-to-deploy-fleet-of-ap300-small-modular-reactors

[91] D. Dalton, "Westinghouse Signs SMR Agreement With Canada First Nations Communities," May 2025, Accessed: Oct. 24, 2025. [Online]. Available: https://www.nucnet.org/news/westinghouse-signs-smr-agreement-with-canada-first-nations-communities-5-2-2025

[92] Westinghouse, "Westinghouse and Fortum Sign MoUs to Evaluate AP1000 Reactors and AP300 Small Modular Reactors in Finland and Sweden," 2023. [Online]. Available: https://info.westinghousenuclear.com/news/westinghouse-and-fortum-sign-mous-to-evaluate-ap1000-reactors-and-ap300-small-modular-reactors-in-finland-and-sweden

[93] World Nuclear News, "Slovakia's JAVYS signs AP1000 and AP300 MoUs," 2023. [Online]. Available: https://world-nuclear-news.org/Articles/Slovakia-signs-MoU-over-AP1000-and-AP300-SMRs

[94] Westinghouse, "Westinghouse and Ukraine's Energoatom Pursuing Deployment of AP300 Small Modular Reactor to Meet Climate, Energy Security Goals," 2023. [Online]. Available: https://info.westinghousenuclear.com/news/westinghouse-and-ukraines-energoatom-pursuing-deployment-of-ap300-small-modular-reactor-to-meet-climate-energy-security-goals

[95] Copenhagen Atomics, "Technology," 2024. [Online]. Available: https://www.copenhagenatomics.com/technology/

[96] T. Honney, "Copenhagen Atomics: The Story So Far," 2024. [Online]. Available: https://www.modernpowersystems.com/analysis/copenhagen-atomics-the-story-so-far/

[97] Copenhagen Atomics, "Cooperation in Reactor Research," 2024. [Online]. Available: https://www.copenhagenatomics.com/news/cooperation-in-reactor-research/

[98] Copenhagen Atomics, "MoU to Further Advance the Study of Molten Salt Technology," 2024. [Online]. Available: https://www.copenhagenatomics.com/news/mou-to-further-advance-the-study-of-molten-salt-technology/

[99] Globe Newswire, "Solving the Waste Challenge of New Nuclear Technologies," 2024. [Online]. Available: https://www.globenewswire.com/news-

release/2024/11/26/2987597/0/en/Solving-the-waste-challenge-of-new-nuclear-technologies.html

[100] World Nuclear News, “Denmark’s Seaborg changes name and adds to board,” 2025. [Online]. Available: https://www.world-nuclear-news.org/articles/denmarks-seaborg-changes-name-and-adds-to-board

[101] Saltfoss Energy, “Korea Hydro & Nuclear Power, Samsung Heavy Industries and Seaborg Technologies Form Consortium to Develop CMSR-Based Floating Nuclear Power Plants,” 2023. [Online]. Available: https://saltfoss.com/korea-hydro-nuclear-power-samsung-heavy-industries-and-seaborg-technologies-form-consortium-to-develop-cmsr-based-floating-nuclear-power-plants/

[102] Saltfoss Energy, “Seaborg Technologies Clears First Classification Milestone for Maritime Deployment of Nuclear Power Barges with ABS Statement,” 2020. [Online]. Available: https://saltfoss.com/seaborg-technologies-clears-first-classification-milestone-for-maritime-deployment-of-nuclear-power-barges-with-abs-statement/

[103] Saltfoss Energy, “KAERI and Seaborg sign MoU on MSR Development,” 2024. [Online]. Available: https://saltfoss.com/elementor-1738/

[104] World Nuclear News, “Seaborg ‘ready to start licensing activities in South Korea,’” 2025. [Online]. Available: https://www.world-nuclear-news.org/articles/seaborg-ready-to-start-licensing-activities-in-south-korea

[105] Terrestrial Energy, “How it works,” 2025. [Online]. Available: https://www.terrestrialenergy.com/technology/molten-salt-reactor/

[106] Globe Newswire, “Terrestrial Energy to Become First Publicly Traded Molten Salt Nuclear Reactor Developer Through Combination with HCM II Acquisition Corp,” 2025. [Online]. Available: https://www.globenewswire.com/news-release/2025/03/26/3049757/0/en/Terrestrial-Energy-to-Become-First-Publicly-Traded-Molten-Salt-Nuclear-Reactor-Developer-Through-Combination-with-HCM-II-Acquisition-Corp.html

[107] Globe Newswire, “Terrestrial Energy and Ameresco Announce Collaboration to Develop IMSR Plant Projects for Customized Energy Supply,” 2025. [Online]. Available: https://www.globenewswire.com/news-release/2025/06/24/3104171/0/en/Terrestrial-Energy-and-Ameresco-Announce-

Collaboration-to-Develop-IMSR-Plant-Projects-for-Customized-Energy-Supply.html

[108] U.S. Department of Energy, "Energy Department Selects Four Companies for Advanced Nuclear Fuel Line Pilot Projects," 2025. [Online]. Available: https://www.energy.gov/articles/energy-department-selects-four-companies-advanced-nuclear-fuel-line-pilot-projects

[109] Globe Newswire, "NRC Completes Safety Evaluation and Approves Terrestrial Energy IMSR Principal Design Criteria Including its Mechanism for Inherent Reactor Power Control," 2025. [Online]. Available: https://www.globenewswire.com/news-release/2025/09/10/3147707/0/en/NRC-Completes-Safety-Evaluation-and-Approves-Terrestrial-Energy-IMSR-Principal-Design-Criteria-Including-its-Mechanism-for-Inherent-Reactor-Power-Control.html

[110] World Nuclear News, "Terrestrial SMR Completes Canadian Pre-Licensing Review," 2023. [Online]. Available: https://www.world-nuclear-news.org/articles/terrestrial-smr-completes-canadian-pre-licensing-r

[111] J. Leppänen *et al.*, "A Finnish District Heating Reactor: Background and General Overview," in *Proceedings of the International Conference on Nuclear Engineering*, American Society of Mechanical Engineers, 2021, p. V001T04A009. doi: https://doi.org/10.1115/ICONE28-64346.

[112] Steady Energy, "Solution," 2025. [Online]. Available: https://www.steady-energy.com/solution

[113] Steady Energy, "Steady Energy completes €32 million funding round, accelerates towards world's first commercial SMR, constructs pilot plant in Helsinki city centre," 2025. [Online]. Available: https://www.steadyenergy.com/news-article/steady-energy-completes-eu32-million-funding-round-accelerates-towards-worlds-first-commercial-smr-constructs-pilot-plant-in-helsinki-city-centre

[114] StartupRise, "Finland's Steady Energy raises €32M to build the world's first commercial nuclear heating reactor by early 2030s," 2025. [Online]. Available: https://startuprise.co.uk/finlands-steady-energy-raises-e32m-to-build-the-worlds-first-commercial-nuclear-heating-reactor-by-early-2030s/

[115] Steady Energy, "Third city in Finland to pioneer SMR for heating," 2024. [Online]. Available: https://www.steadyenergy.com/news-article/third-city-in-finland-to-pioneer-smr-for-heating

[116] Steady Energy, “Finnish Steady Energy signs first international deal with Korea District Heating Corp: Underground heating reactor attracts interest in South Korea,” 2025. [Online]. Available: https://www.steadyenergy.com/news-article/finnish-steady-energy-signs-first-international-deal-with-korea-district-heating-corp-underground-heating-reactor-attracts-interest-in-south-korea

[117] Steady Energy, “Steady Energy’s SMR received first preliminary regulator evaluation – concept can be developed to meet Finnish nuclear safety requirements,” 2025. [Online]. Available: https://www.steadyenergy.com/news-article/steady-energys-smr-received-first-preliminary-regulator-evaluation---concept-can-be-developed-to-meet-finnish-nuclear-safety-requirements

[118] Last Energy, “Technology,” 2025. [Online]. Available: https://www.lastenergy.com/technology

[119] Last Energy, “PWR-20 Technology Fact Sheet,” 2024. [Online]. Available: https://www.lastenergy.com/resources

[120] U.S. Nuclear Regulatory Commission, “Pre-application activities for Advanced Reactors, Last Energy.” [Online]. Available: https://www.nrc.gov/reactors/new-reactors/advanced/who-were-working-with/pre-application-activities/last-energy

[121] Last Energy, “Last Energy completes preliminary design review milestone in United Kingdom,” 2025. [Online]. Available: https://www.lastenergy.com/news-press/last-energy-completes-preliminary-design-review-milestone-in-united-kingdom

[122] World Nuclear News, “Funding and commercial agreements grow for Last Energy,” 2024. [Online]. Available: https://www.world-nuclear-news.org/Articles/Funding-and-commercial-agreements-grow-for-Last-En

[123] Nuclear Engineering International, “PWR-20 microreactor clears key UK review,” 2025. [Online]. Available: https://www.neimagazine.com/news/pwr-20-microreactor-clears-key-uk-review/

[124] Last Energy, “Last Energy announces NATO micro nuclear energy partnership,” 2024. [Online]. Available: https://www.lastenergy.com/news-press/last-energy-announces-nato-micro-nuclear-energy-partnership

[125] World Nuclear News, “Last Energy’s South Wales nuclear project gets US Export Bank backing,” 2024. [Online]. Available: https://www.world-nuclear-

news.org/articles/last-energys-south-wales-nuclear-project-gets-us-export-bank-backing

[126] International Atomic Energy Agency, “SMR-300 Overview (IAEA ARIS Database),” 2024. [Online]. Available: https://aris.iaea.org/DsrDetails/103/

[127] U.S. Nuclear Regulatory Commission, “Pre-Application Activities for Advanced Reactors, SMR-300,” 2025. [Online]. Available: https://www.nrc.gov/reactors/new-reactors/advanced/who-were-working-with/pre-application-activities/holtec/smr300

[128] Holtec Britain, “Holtec Signs Agreements with its Global Partner Hyundai E&C and UK-Based Companies Balfour Beatty and Mott MacDonald for the SMR-300 Program in the United Kingdom,” 2024. Accessed: Dec. 15, 2025. [Online]. Available: https://holtecbritain.com/holtec-signs-agreements-with-its-global-partner-hyundai-ec-and-uk-based-companies-balfour-beatty-and-mott-macdonald-for-the-smr-300-program-in-the-united-kingdom/

[129] EDF Energy, “Holtec International, EDF UK and Tritax announce plans to develop Cottam site with data centres and advanced nuclear technologies,” 2025. [Online]. Available: https://www.edfenergy.com/media-centre/holtec-international-edf-uk-and-tritax-announce-plans-develop-cottam-site-data-centres-and

[130] GOV.UK, “GDA Step 2 of the GE Vernova Hitachi SMR: Fundamental Assessment Public Summary,” 2025. [Online]. Available: https://www.gov.uk/government/publications/gda-step-2-of-the-ge-vernova-hitachi-smr-fundamental-assessment/gda-step-2-of-the-ge-vernova-hitachi-smr-fundamental-assessment-public-summary

[131] Holtec International, “Holtec Receives Coveted ‘Tier 1 First Mover Award’ from the USDOE to Accelerate Deployment of its Dual-Unit SMR-300 Plant at the Company’s Palisades Energy Site,” 2025. [Online]. Available: https://holtecinternational.com/hh-40-24/

[132] X-energy, “XE-100.” [Online]. Available: https://x-energy.com/reactors/xe-100

[133] E. J. Mulder and W. A. Boyes, “Neutronics characteristics of a 165 MWth Xe-100 reactor,” *Nuclear Engineering and Design*, vol. 357, p. 110415, 2020, doi: https://doi.org/10.1016/j.nucengdes.2019.110415.

[134] X-energy, “X-energy Delivers Second Information Package for CNSC Pre-Licensing Canadian Vendor Design Review,” 2021. [Online]. Available: https://x-

energy.com/media/news-releases/x-energy-delivers-second-information-package-for-cnsc-pre-licensing-canadian-vendor-design-review

[135] X-energy, "X-energy Completes First Joint Regulatory Review Under CNSC-NRC Memorandum of Cooperation," 2021. [Online]. Available: https://x-energy.com/update/x-energy-completes-first-joint-regulatory-review-under-cnsc-nrc-memorandum-of-cooperation

[136] X-energy, "X-energy Begins Commercial Qualification Testing for TRISO-X Fuel at Idaho National Laboratory," 2025. [Online]. Available: https://x-energy.com/media/news-releases/x-energy-begins-commercial-qualification-testing-for-triso-x-fuel-at-idaho-national-laboratory

[137] D. Dalton, "X-energy and Amazon assemble team KOREA to advance nuclear deployment in US," 2025. [Online]. Available: https://smr.nucnet.org/news/x-energy-and-amazon-assemble-team-korea-to-advance-nuclear-deployment-in-us-8-2-2025

[138] X-energy, "NRC publishes 18-month review schedule for XE-100 construction permit application," 2025. [Online]. Available: https://x-energy.com/media/news-releases/nrc-publishes-18-month-review-schedule-for-xe-100-construction-permit-application

[139] S. Patel, "Amazon unveils Cascade Energy: Northwest's XE-100 SMR project targeting construction by 2030," 2025. [Online]. Available: https://www.powermag.com/amazon-unveils-cascade-energy-northwests-xe-100-smr-project-targeting-construction-by-2030/

[140] X-energy, "X-energy, Amazon, Korea Hydro & Nuclear Power, and Doosan Enerbility Announce Partnership to Scale Advanced Nuclear Energy for AI Infrastructure," 2025. [Online]. Available: https://x-energy.com/media/news-releases/x-energy-amazon-korea-hydro-amp-nuclear-power-and-doosan-enerbility-announce-partnership-to-scale-advanced-nuclear-energy-for-ai-infrastructure

[141] IEA, "The Path to a New Era for Nuclear Energy," Jan. 2025. Accessed: Dec. 15, 2025. [Online]. Available: https://www.iea.org/reports/the-path-to-a-new-era-for-nuclear-energy

[142] S. Finansdepartementet, "Promemoria Finansiering och riskdelning vid investeringar i ny kärnkraft," Aug. 2024. Accessed: Dec. 12, 2025. [Online]. Available:

https://www.regeringen.se/contentassets/785ee941726840229ed69135ca8f890c/finansiering-och-riskdelning-vid-investeringar-i-ny-karnkraft.pdf

[143] IEA, "World Energy Outlook 2025," 2025. Accessed: Dec. 12, 2025. [Online]. Available: www.iea.org/terms

[144] C. EIA and Allison, "Annual Energy Outlook 2025," Apr. 2025. Accessed: Dec. 12, 2025. [Online]. Available: https://www.eia.gov/outlooks/aeo/

[145] Lazard, "Levelized Cost of Energy+ Report," Jun. 2025. Accessed: Dec. 15, 2025. [Online]. Available: https://www.lazard.com/news-announcements/lazard-releases-2025-levelized-cost-of-energyplus-report-pr/

[146] K. A. Moen, M. Hjelmeland, J. K. Nøland, and N. U. of S. and T. (NTNU), O. S. B. plass 2E, T. 7034, N. Department of Electric Energy, "The total costs of energy transitions with and without nuclear energy," *Appl. Energy*, vol. 402, Dec. 2025, doi: 10.1016/j.apenergy.2025.126888.

[147] J. Z. Thellufsen *et al.*, "Cost and systems effects of nuclear power in carbon-neutral energy systems," *Appl. Energy*, vol. 371, Oct. 2024, doi: 10.1016/j.apenergy.2024.123705.

[148] Rystad, "Kjernekraft i Norge Endelig rapport," Nov. 2023. Accessed: Dec. 15, 2025. [Online]. Available: https://www.nho.no/contentassets/220ef13d98a3415abc745b7ec5e88939/20231121-kjernekraft-i-norge.pdf

[149] NREL now NRL, "ATB _ NREL_ 2024 Nuclear _ Electricity," 2024, Accessed: Dec. 12, 2025. [Online]. Available: https://atb.nrel.gov/electricity/2024/nuclear

[150] C. . Moles *et al.*, *Energy Technology Reference Indicator (ETRI) projections for 2010-2050*. JRC Publications Office, 2014. Accessed: Dec. 12, 2025. [Online]. Available: https://publications.jrc.ec.europa.eu/repository/handle/JRC92496

[151] MIT Energy Initiative, "The Future of Nuclear Energy in a Carbon-Constrained World AN INTERDISCIPLINARY MIT STUDY," Sep. 2018. Accessed: Dec. 12, 2025. [Online]. Available: https://energy.mit.edu/research/future-nuclear-energy-carbon-constrained-world/

[152] J. K. Nøland, M. Hjelmeland, C. Hartmann, L. B. Tjernberg, and M. Korpås, "Overview of Small Modular and Advanced Nuclear Reactors and Their Role in the

Energy Transition," *IEEE Transactions on Energy Conversion*, vol. 40, no. 3, pp. 1933–1945, 2025, doi: 10.1109/TEC.2025.3529616.

[153] EY-Parthenon France, "The true power of small modular reactors on the road to a sustainable energy future," Mar. 2024. Accessed: Dec. 12, 2025. [Online]. Available: https://www.ey.com/content/dam/ey-unified-site/ey-com/fr-fr/insights/energy-resources/documents/ey-etude-nuclear-energy-smr-pov-20240322.pdf

[154] EU commission press corner, "European Commission-Press release Commission opens in-depth State aid investigation into Polish support for nuclear power plant," Dec. 2024. Accessed: Dec. 15, 2025. [Online]. Available: https://ec.europa.eu/commission/presscorner/detail/en/ip_24_6437

[155] Sfen in English, "The Cost of the New EPR2 Nuclear Program_ A Few Orders of Magn," *Sfen in english*, Jun. 2025, Accessed: Dec. 15, 2025. [Online]. Available: https://sfeninenglish.org/epr2-nuclear-program-cost-analysis/

[156] nuclear energy Bat info. com, "Nuclear: the forecast cost of the six future EPRs will increase by 30% Nuclear energy," Mar. 2024. Accessed: Dec. 15, 2025. [Online]. Available: https://batinfo.com/en/actuality/nuclear-the-forecast-cost-of-the-six-future-EPR-will-increase-by-30_27545?id=

[157] world nuclear news., "KHNP sets out plans for USD18.6bn Czech nuclear project," Jun. 2025. Accessed: Feb. 12, 2026. [Online]. Available: https://www.world-nuclear-news.org/articles/khnp-sets-out-plans-for-usd186bn-https://www.world-nuclear-news.org/articles/khnp-sets-out-plans-for-usd186bn-czech-nuclear-project

[158] world nuclear org, "Nuclear in CZECH REPUBLIC- COUNTRY PROFILES," Dec. 2025. Accessed: Dec. 18, 2025. [Online]. Available: https://world-nuclear.org/information-library/country-profiles/countries-a-f/czech-republic

[159] LTS Innovate - Future Nuclear, "Dukovany Nuclear Power Plant Expansion Enters Implementation Phase," Aug. 2025. [Online]. Available: https://europe-nuclear-smr.ltsinnovate.com/ConferenceNews/1305.html

[160] Serbia Energy, "Bulgaria advances NPP Kozloduy nuclear expansion with first AP1000 reactors in Europe ," *https://serbia-energy.eu/bulgaria-advances-npp-kozloduy-nuclear-expansion-with-first-ap1000-reactors-in-europe/*, Aug. 23, 2025. Accessed: Dec. 17, 2025. [Online]. Available: https://serbia-

energy.eu/bulgaria-advances-npp-kozloduy-nuclear-expansion-with-first-ap1000-reactors-in-europe/

[161] SeeNews, "New reactors at Bulgarian NPP to cost up to $14 bln in total - energy min," *https://seenews.com/news/new-reactors-at-bulgarian-npp-to-cost-up-to-14-bln-in-total-energy-min-1243885*, Feb. 12, 2024. Accessed: Dec. 17, 2025. [Online]. Available: https://seenews.com/news/new-reactors-at-bulgarian-npp-to-cost-up-to-14-bln-in-total-energy-min-1243885

[162] World Nuclear Association, "Nuclear Power in Bulgaria country profiles," Apr. 2024. Accessed: Dec. 18, 2025. [Online]. Available: https://world-nuclear.org/Information-Library/Country-Profiles/countries-A-F/Bulgaria

[163] Sustainability Magazine, "Go-Ahead for Sizewell C - But Why has Cost Soared to £38bn?," *Sustainability Magazine*, Jul. 2025, Accessed: Dec. 18, 2025. [Online]. Available: https://sustainabilitymag.com/news/go-ahead-for-sizewell-c-but-why-has-cost-soared-to-38bn

[164] C. A. Da Silva, "UK: Nuclear Energy Updates," Oct. 2025. Accessed: Dec. 18, 2025. [Online]. Available: https://www.gov.uk/government/organisations/nuclear-decommissioning-authority

[165] Nuclear News Wire, "Flamanville-3 reaches full power -- ANS _ Nuclear Newswire," Dec. 2025, Accessed: Feb. 12, 2026. [Online]. Available: https://www.ans.org/news/article-7625/flamanville3-reaches-full-power/

[166] S. Patel, "Flamanville 3_ Europe's Hard-Won Nuclear Milestone 2025," *POWER*, Dec. 2025, Accessed: Dec. 15, 2025. [Online]. Available: https://www.powermag.com/flamanville-3-europes-hard-won-nuclear-milestone/

[167] A. F. et al Mycle Schneider, "The World Nuclear Industry Status Report 2019," Paris, Sep. 2018. Accessed: Mar. 02, 2026. [Online]. Available: https://www.worldnuclearreport.org/IMG/pdf/wnisr2019-v2-lr.pdf

[168] Jonas Kristiansen Nøland, "Rystad Energy Spreads Misinformation Abou Europe's Largest Nuclear Reactor," Jan. 24AD. Accessed: Feb. 12, 2026. [Online]. Available: https://jonasnoeland.substack.com/p/rystad-energy-spreads-misinformation

[169] World Nuclear Association, "Nuclear power in the USA country profiles," Dec. 2025. Accessed: Dec. 18, 2025. [Online]. Available: https://world-nuclear.org/information-library/country-profiles/countries-t-z/usa-nuclear-power

[170] Carbon Commentary, "BWRX 300 The first test for new Small Modular Reactors (SMR) _ Carbon Commentary," May 2025, Accessed: Jan. 27, 2026. [Online]. Available: https://www.carboncommentary.com/blog/2025/5/11/the-first-test-for-new-small-modular-reactors-smr

[171] S. Patel, "Ontario Authorizes OPG to Start Construction of First Commercial Nuclear SMR," *Power_mag*, May 2025, Accessed: Nov. 04, 2025. [Online]. Available: https://www.powermag.com/ontario-authorizes-opg-to-start-construction-of-first-commercial-nuclear-smr/

[172] G. A. Black, F. Aydogan, and C. L. Koerner, "Economic viability of light water small modular nuclear reactors: General methodology and vendor data," Apr. 01, 2019, *Elsevier Ltd*. doi: 10.1016/j.rser.2018.12.041.

[173] Rolls-Royce, "More power and updated design revealed as nuclear power team targets first place in the assessment queue in A," *RR SMR*, May 2021, Accessed: Nov. 07, 2025. [Online]. Available: https://www.rolls-royce-smr.com/press/more-power-and-updated-design-revealed-as-nuclear-power-team-targets-first-place-in-the-assessment-queue-in-autumn-2021

[174] J. P. Ikonen, T. J. Lindroos, and P. Hiltunen, "Feasibility of small modular reactors for decarbonizing district heating systems: a case study of the Helsinki metropolitan area," *Nuclear Engineering and Design*, vol. 442, Oct. 2025, doi: 10.1016/j.nucengdes.2025.114262.

[175] H. TVO Teollisuuden Voima Oyj, "Interim Report Q2 2025 operation of Olkiluoto1-3, OSAVUOSI-KATSAUS Q2," 2025. Accessed: Dec. 12, 2025. [Online]. Available: https://www.tvo.fi/material/sites/tvo/sijoittaja-sivut/tuqqeadeg/TVO_OVK_Q2_FI.pdf

[176] J. Z. Thellufsen *et al.*, "Corrigendum to 'Cost and systems effects of nuclear power in carbon-neutral energy systems,'" *Appl. Energy*, vol. 371, Oct. 2025, doi: 10.1016/j.apenergy.2024.123705.

[177] IAEA, "IAEA Nuclear Energy Series @ Management of Nuclear Power Plant Projects," 2020. [Online]. Available: www.iaea.org/publications

[178] Tennessee Valley Authority, "2025 Draft Integrated Resource Plan Volume 1," Sep. 2024. Accessed: Feb. 13, 2026. [Online]. Available: https://www.tva.com/environment/integrated-resource-plan

Declaration of generative AI in scientific writing

During the preparation of this work, the authors have used Microsoft Copilot in order to improve grammar and readability of the text. After using this tool, authors have reviewed and edited the content as needed and take full responsibility for the content of the published article.