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SMR Safety – Advantages and Challenges

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ABSTRACT

Because of their announced versatility, flexibility, ability for cogeneration and supposed increased safety features, SMRs (Small and Modular Reactors) are being considered by many countries and even some industries as a potential and viable option to contribute replacing traditional thermal power plants and therefore to climate change mitigation.

SMR designs often take advantage of overall system simplification. Due to their smaller reactor cores, very large water inventories and lower power densities, Light Water Reactor technology SMRs, which are the most mature SMR concepts, may benefit from reduced shielding requirements and reduced or eliminated offsite emergency planning zones. Inherent passive safety systems could also provide some SMRs with greater and, in some cases infinite (if long-term natural circulation of the coolant can be established), coping times in case of a loss of offsite power. Some SMRs are designed to be installed below ground level resulting in higher physical protection and protection from external hazards. Advanced SMRs use reviewed cooling systems or fuels (molten salts, liquid metals or helium gas) and bear the promise of 'game changers' in terms of high intrinsic safety (walk-away safety), new functionalities, high proliferation resistance and, importantly, expected lower capital costs mainly due to design simplicity and the absence of high pressure and lower generation costs.

These features and the diversity of applications (electricity plus heat and/or hydrogen) explain that there are more than 70 different design concepts under development around the world with different technology and licensing readiness levels.

However, though significant advancements have been made in various SMR technologies in recent years, some issues still need great efforts in particular regarding safety assessment and licensing. In this regard, this paper aims at presenting a general overview and an assessment of safety features of the main concepts of SMRs (light water cooled, high temperature, fast neutron and molten salt) without bias and independently of any of the designers.

1 INTRODUCTION

Looking at the historical evolution of nuclear power reactors, the long-term trend so far has been to increase the size of the reactors to maintain their economic competitiveness through economies of scale. However, over the last five years, advanced reactor concepts, among which SMRs (Small and Modular Reactors), have progressed faster than anyone predicted ten years ago, and it is highly likely that over the next ten years we will see the construction and operation of several FOAK (First of a kind) SMRs and the development of a global supply chain to support them.

One of the reasons for this keen interest is that SMRs could become one of the main drivers of the deep decarbonisation of the global economy, thanks to their versatility, flexibility, and ability for cogeneration (electricity, heat for heating and industry, water desalination, hydrogen production). This interest and the diversity of applications (electricity in remote areas, low and high enthalpy heat for heating and industry, water desalination, hydrogen production) explain that, according to IAEA [1], there are more than 70 different design concepts under development around the world with different technology and licensing readiness levels. Moreover, most SMR designs rely on higher levels of intrinsic safety and/or passive safety systems compared to Gen III/III+ LWRs which should facilitate their acceptability by the public and allow their operation within existing industrial sites or closer to large cities.

However, it is important to underline that most of the SMRs still must overcome significant technical hurdles in domains such as nuclear fuel reliability, materials behaviour, component manufacturing and more globally safety assessment and licensing. In this regard, it can be noted that, except the Russian barge-mounted SMR, the first of which (Akademik Lomonosov) is already operational, the Chinese HTR-PM (high temperature gas-cooled pebble bed generation IV reactor) which achieved criticality on September 12, 2021 and the SMR Nuscale which obtained a "Standard Design Approval" from the NRC in September 2020, all the other SMR designs have still to be licensed in a context where most of the existing regulatory frameworks have to be reviewed and, presumably modified to some extent, to make them applicable to this new type of reactors.

2 THE SMR CONCEPT

The SMRs are relatively low power nuclear reactors (typically up to 300 MWe) based on a modular way of construction. That means the sub-systems and systems are built on modules in factory then transported to be assembled on site and on a multi-unit NPP (Nuclear Power Plant) concept, which enables to incrementally extend the power of the overall plant.

The SMR concept has been around for decades but it did not materialise as an industry. Today, SMRs present some key economic drivers which make them quite attractive to replace fossil fuels for electricity production and decarbonisation of hard-to-abate industrial sectors. These key economic drivers are (see Figure 1 below):

- Modularisation and factory build: It is estimated that 60-80% factory fabrication levels are possible for SMRs.
- Design simplification: Passive mechanism improvements and greater design integration would reduce the number of components and result in containment building savings and facilitate ease of operation and maintenance.
- Standardisation: Compared to large reactors, the lower power output and smaller footprint of SMRs reduces the need to adapt to local site conditions.
- Harmonisation which should make easier access to a global market if it includes regulatory harmonisation.

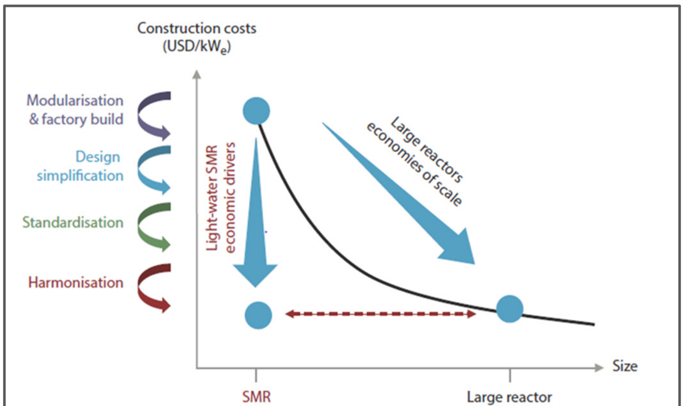

Fig 1: SMR economic drivers compensating the diseconomies of scale
Source: (NEA2020)

Moreover, as regards investment, SMRs present a-priori some attractive features [2] [3] [5] compared to large reactors, such as: lower capital costs, smaller upfront investment, possibility of sequencing which gives scalability and flexibility, lower risks in terms of construction time overruns, and possibilities of self-financing after deployment of the first SMR modules.

Public acceptance is another key challenge for SMR deployment, though it may differ significantly from country to country. The claimed intrinsic safety characteristics of SMRs are no doubt favourable to obtain public acceptance in an energy-constrained world. While much attention related to SMR development is duly focused on their competitiveness, the demonstration of SMR safety, reduced waste generation and proliferation resistance will be crucial for their public acceptance.

2.1 Safety Requirements for SMRs

The safety criteria are aimed at preserving the safety functions of the nuclear installations despite failures of materials and components and/or human inadvertent and / or malevolent behaviour. Accordingly, the same (and well known) main safety functions of conventional reactors must be transposed to the SMRs to guarantee their safe and secure operation in any circumstances and at any time in their life from design to decommissioning.

The safety of each SMR design will rely on its inherent or specific provisions which must be carefully examined. Nevertheless, the SMR designs may bring forward opportunities to enhance - at the early design stage - the robustness and independence of the Defence in Depth levels and enjoy an extended resilience compared to the conventional GEN II&III reactors for different types of hazards and, mainly, those addressed in the “EU Stress Tests specifications”.

As SMRs may use shared systems because of their compact configuration and proximity, the selection of initiating events should include enhanced consideration of common-mode initiators. Moreover, the capacity of mitigation of the consequences of severe accidents is to be enhanced for SMRs to fulfil the requirement of avoiding any need for evacuation of the population in the neighbouring of the plant site.

2.2 All SMR designs target and share a high level of safety

In relation to the SMRs small size, the implementation and effectiveness of advanced safety features is strongly dependent on the arrangement of components, that is demanding a suitable optimization of the overall architecture, through a conservative design and, say, a risk-informed driven approach. The development of SMRs offers multiple opportunities to enhance safety. This ambitious objective may be achieved for any SMR design profiting from several features and/or opportunities which are common and shared by any concept, such as:

- The low (in absolute terms) fissile material inventory, which leads to low residual heat, a small source term, and overall low releases in case of major accidents;
- The reduced overall cooling requirements, allowing for a wide selection of sites, through a suitable optimization of modules number per site;
- The feasibility of the IVR (In Vessel Retention) of the molten core, which has a higher probability of success for SMRs considering the lower fissile inventory, and which is an important element of their overall safety demonstration;
- The strong plant integration, which can turn out to be beneficial for a safe and secure operation (the integrated design allows a direct coupling among main components, e.g., the steam generators with the vessel, the primary pumps with either the vessel or the steam generator etc.). That enables eliminating by design any risk of large breaks, which are a major threat in large size loop reactors.
- The option for LW (Light Water) SMR of a core control without soluble boron, which eliminates the RIA (Reactivity Initiated Accidents) likelihood due to dilution error (including the inadvertent start-up of pumps in steady-state conditions);

- The inherent compacity of SMRs that enables minimizing the risk engendered by most external aggressions and hazards by underground construction or even by submersion (immerged NPP). That is also advantageous in view of the resistance to earthquake;
- A reduced plant size, that may be really advantageous because of:
  - the increased resistance to earthquakes,
  - the smaller cross-section vs. impacts of missiles of any kind,
  - the possibility to ensure a better accessibility for inspection, maintenance, and repair,
  - the adoption and operation of natural convection when possible, which increases the robustness vs. pump incident of any kind;
- The low pressure of certain designs which results in system simplification, exclusion by design of all accidents caused by high pressure, easy factory fabrication, and expected cost reduction;
- The use of simpler components, and the presence of fewer dependencies (that simplify the manufacturing, validation and, eventually, the licensing processes);
- The simplification of the systems that effectively prevents from the presence of common modes;
- The adoption of convenient operation / replacement requirements and procedures, depending on the design features.

As already emphasized, in close relation to the SMRs small size, the implementation and effectiveness of advanced safety features is strongly dependent on the arrangement of components that requires a suitable optimization of the overall architecture. In some cases, certain fast-developing accidents such as LOCAs (Loss of Coolant Accidents) in LW SMR can be inherently eliminated by design and operation.

These improvements may provide opportunities to ease the burden on operating staff and for more effective accident management and should therefore result in a more efficient and eased licensing process.

The assessment of such new and advanced reactor concepts, as well as the development of innovative materials, component and fabrication processes require the fulfilment of specific safety requirements. Such requirements would greatly benefit from multilateral regulatory harmonization. In Europe, that could be achieved on the basis of the EU Directive 2014/87/EURATOM of July 8, 2014 which establishes a Community framework for safety of nuclear installations.

More generally, the development of SMRs creates an opportunity but also calls for the necessity to develop harmonized safety requirements and to apply widely agreed methodologies in the licensing process, as mentioned in the WNA report "Facilitating International Licensing of Small Modular Reactors" [4].

The Memorandum of Cooperation on advanced reactor and SMR technologies between the US NRC and the Canadian Nuclear Safety Commission is an example to follow. In Europe, organizations such as ENSREG, WENRA, and ETSON should participate in the elaboration of such a set of recommendations. Also, the IAEA ongoing initiatives on SMR licensing are to be mentioned.

2.3 … But many challenges are still to be overcome

As said, most SMR designs incorporate inherent and/or passive safety features. This enables the plant either efficiently facing malfunctions and aggressions, or passively evacuating the residual heat and allotting time for recovery. The reduced power and extended adoption of passive systems and/or off-operated systems (e.g., in the case of sub-marine concepts) should facilitate severe accident management, e.g., by providing extended grace periods in case of station black out, as well as to the emergency preparedness and response.

However, demonstrating safety relying on inherent physical phenomena and passive systems is often a challenging task. Specific care must be put in the development of safety requirements criteria and rules for their assessment, including:

- The reliability of activation and raise to required capacity;
- The reliability to perform the assigned function;
- The dependence on external energy sources for initialization and execution of the assigned function;
- The physical phenomena and the environmental conditions that could lead to the loss of the assigned function;
- The uncertainties and margins, because the combination of interfacing inherent and passive design features can engender cliff-edge effects. Accordingly, specific care should be paid to integrated test activities during the design and the commissioning phases;
- The multi-unit concept which increases the risk of propagation of incidents and accidents among the units;
- The methodology for the evaluation of performance and its integration into Probabilistic Safety Assessment (PSA);
- The specific requirements for Severe Accident Management and Emergency Preparedness Plan, because the accident progression at the neighbouring units can hamper the management activities at the unit the transient originates from.

Moreover, the following specific topics shall be accurately and in-depth addressed as preliminary considerations for licensing:

- The safety requirements must be accurately revised and updated to account for the modular assembling and the remote construction and qualification of equipment;
- The SMR designs should incorporate redundancy, diversity and, where practicable, physical separation for safety systems to mitigate common cause failures. Moreover, exclusive adoption and deployment of passive safety systems merit specific care;
- The SMR design can profit from the combination of passive and active systems to ensure the safety functions, which can improve resilience to common cause failures,
- Any combination of active and passive safety systems matching the Defence in Depth and the safety design principles is acceptable. Nevertheless, a suitable prioritization should favour inherent characteristics and passive features or continuously operating systems over systems that need actuation;
- Licensing methods should be harmonized to anticipate the possible incremental extension of the installed capacity of the target plant through the addition of modules.

3 SAFETY CHARACTERISTICS OF THE MAIN SMR TYPES

The family of SMRs includes an exceptionally large diversity of concept designs, each of them presenting specific safety advantages with respect to conventional large power reactors. Certain challenges are common to SMRs regardless of the type:

- the multi-units concept of the NPP which increases the risk of propagation of incidents and accidents among the units;
- the sensitivity to cyber-attacks;
- the real size experience which remains limited.

In the following sections, the safety features of the main SMR families are addressed based on advantages vs. points of vigilance approach. This analysis is based mainly on publicly available information [1] [5] and on previous safety assessments of the different technologies by the authors [6] [7] [8].

3.1 Light Water SMRs (LW SMRs)

The LW SMR concepts are evolutionary variants of mature light water Generation II and III reactors and may benefit from decades of operating and safety experience [6]. They represent approximatively half of the SMR designs currently under development. These LW SMRs are moderated and cooled by ordinary water, of pressurized or boiling water type, for electricity or heat generation. They can also be of pool type reactors for district heating.

The PWR (Pressurized Water Reactor) NSSS (Nuclear Steam Supply System) may be either an integral one, with the complete high-energy primary system contained inside a single pressure vessel, or a compact design with steam generators connected directly to the reactor pressure vessel. Primary cooling flow may be achieved by natural circulation (with the steam generators above the core) for low power reactors, or by forced circulation for higher power reactors with primary pumps (ex: leak-tight canned motor pump or wet coil pump), with natural circulation capability in emergency conditions.

The BWR (Boiling Water Reactor) NSSS may be cooled by natural circulation of the coolant, thus eliminating the recirculation pumps, allowing for a simplified and compact reactor pressure vessel and containment, and simplified reactor internals and systems.

The LW SMRs have similar operating conditions and fuel arrangements, with use of uranium oxide fuel with enrichment below 5%, which may facilitate the licensing process. The core reactivity excess may be controlled using Gd2O3 as burnable poison in specific fuel rods and movable absorbing elements, thus avoiding adoption of soluble boron in the so-called boron-free operation.

Safety features - Potential Advantages

Among safety advantages, benefiting from the small size and depending on each specific design and power level, different options may be implemented such as:

- Passive management of accident scenarios with no need for operator's action, or with simple diagnosis and implementation of diversified systems;
- Large reactor coolant inventory which may provide inertia versus power transients;
- Adoption of a boron-free operation which may provide large and constant moderator counter-reaction and avoid boron dilution accidents;
- Integrated reactor coolant architecture which is likely to reduce the maximum LOCA break size, thus providing more time for coping with LOCA;
- Internal CRDMs (Control Rod Drive Mechanisms) which avoid any penetration of the reactor vessel, thus preventing from inadvertent road extraction and ejection accidents;
- Metallic submerged containment which may provide passive cooling, or air-cooled containment;
- Small core in large vessel which may facilitate the in-vessel retention strategy;
- Possible use of passive systems, depending on design: decay heat removal system, emergency core cooling system, containment, air cooling system, reactor automatic depressurization system, meeting criteria of single failure, independence, diversity, or multiplicity;
- Direct current power source to support accident mitigation for extended period, along with auxiliary power units to recharge the battery system;
- Load follow operation using grey rods with lower worth to avoid adjusting soluble boron concentration, which results in a substantial reduction in wastewater generation and treatment;

- Passive hydrogen recombiner system installed to control the hydrogen concentration in containment;
- Safety features to prevent criticality risks: sub-criticality with clear water with the most efficient absorber stuck in upper position.

Safety features - Potential points of vigilance depending on any specific design

- The small size of equipment and / or the compactness of equipment can create difficulty for nondestructive testing;
- The small distance between the core and the vessel may induce larger radiation level on the vessel which can turn out penalizing for metal embrittlement;
- The very high compacity of the architecture can reduce the easiness of the inspection and repair operations.

3.2 High Temperature SMRs (HT SMRs)

The HT SMRs enjoy all the advantages of the SMRs, including the high modularity and the economic competitiveness, jointly with those of the HTGR (High Temperature Gas Reactor) / VHTGR (Very High Temperature Gas Reactor) concepts belonging to GEN IV [7], such as inherent safety, fuel economy, low waste volume, as well as high resistance to nuclear proliferation and capacity to incinerate both plutonium and minor actinides.

The thermal HT SMRs are intrinsically safe by design, due to their very low power density, their very long prompt neutron lifetime, which excludes any prompt reactivity surge, and the huge amount of moderator surrounding the core, which enables the passive evacuation of the residual heat without external intervention and addition of complementary systems.

Safety features - Potential Advantages

- The fuel margins of the HT SMR are very high, therefore the entire mission of fuel products retention is accomplished by the TRISO particles;
- Helium, the gas used for cooling, is an inert, radiologically transparent single-phase gas, avoiding boiling or flashing. It does not react chemically with the fuel and the reactor components. Though it has a propensity to escape, it is quite easy to control the pressure in the reactor;
- Moreover, the HT SMR has some other intrinsic safety features:
  - in case of RIA, the system does not undergo a sudden exponential increase of power, due to the very long prompt neutron lifetime,
  - in case of major accidents, the reactor core does not melt down, because all the heat dissipates passively into the environment, whatever the scenario, the plant has no need for active safety systems to remove heat. Additionally, it does not need outside support (even electricity) to operate safely.

Safety features - Potential points of vigilance depending on any specific design

- The physical features of the HT SMR make it sensitive to air and water ingress from the external environment, which can initiate and feed-up severe accidents;
- For some concepts, the high temperature and / or the presence of salts in the coolant demand for extensive qualification of the materials resistance to corrosion;
- The underground operation, if any, can turn out to be risky in case of flooding. Moreover, the system can be sensitive to extreme weather conditions;
- The TRISO particles are not perfectly tight and allow leakage of some low yield fission products, such as Ag, during long term operation at very high temperature,

3.3 Molten Salt SMRs (MSRs)

The concept of Molten Salt Reactor was originally developed at Oak Ridge National Laboratory (ORNL) in the ‘60s, and three experimental MSRs have already been constructed. Nowadays, several MSRs are under design, and preliminary licensing activities are going on in different countries, including Canada, United Kingdom, and the United States.

The Molten Salt SMRs adopt an advanced reactor technology, which belongs to Generation IV [7]. The MSRs generally use molten fluoride or chloride salt, both as liquid fuel and coolant. Designed either in thermal or fast neutron spectrum, MSRs aim for long fuel cycle of up to 150 months, online refuelling (with addition of fuel under molten salt form, and on-line fission products cleaning) and continuous operation. Enrichment of fuel spans from less than 5% up to 19.7%.

The vast majority of innovative MSR designs are not yet industrially implemented; a few are at demonstration stage and most of them at R&D level, with an industrial maturity which is still to be confirmed. The safety objective with the SMR designs is to achieve high inherent safety, and a walk-away safe nuclear power plant.

Safety features - Potential Advantages

- The exclusion of fuel melting;
- The inherent safety features associated to the salt expansion. When the temperature rises, the liquid expands and the average mean free path of neutrons increases, thus inducing a negative reactivity feedback;
- A very high level of inherent safety thanks to an integrated, pipe-less, fail-safe systems architecture;
- A near-to-zero reactivity swing during the cycle, which prevents the core from any risk of major RIA;
- A thermally and chemically stable low-volatile fuel-coolant mixture, inert at high temperature, which allows low pressure operation and eliminates any need for large containment;
- The absence of fuel structure or cladding, which prevents the fuel from being subject to failures because of high burnup or mechanical damage;
- A melt core which provides with enhanced safety, because it avoids any risk of severe consequences to the vessel integrity and a possible fission products release;
- No need for operator action, electricity, or externally powered mechanical components, to assure the primary safety functions of control, cooling, and containment;
- The availability of all required control and heat sink functions, which eliminates any dependence on support systems, valves, pumps, controls, or operator actions for cooling.

Safety features - Potential points of vigilance depending on any specific design

- The quite high design and operation complexity, including the on-line continuous operation of the salt cleaning function;
- A cumbersome reactor overall lay-out;
- A quite high vulnerability to hazards, including flooding and earthquakes;
- The low capacity for inspection, repair, and replacement of components;
- A quite poor industrial maturity;
- The likelihood of hurdles in the licensing process, due to the unusual reactor features and operation mode.

3.4 Fast Neutron SMRs

Global interest in fast reactors has been growing since their inception in 1960 because they can provide efficient, safe, and sustainable energy for the long-term nuclear energy resources as well as contribute to decrease the burden of nuclear wastes, mainly long-lived minor actinides. In addition to the current fast reactor operation or construction projects underway, several countries are engaged in intense R&D programs for the development of innovative, Gen IV, fast reactors, as proposed by the Generation IV International Forum. They include three fast neutrons concepts: the SFR - Sodium Fast Reactor -, the LFR - Lead (or Lead-Bismuth) Fast Reactor - and the GFR (Gas Fast Reactor), as well as the MSR (Molten Salt Reactor) which can be declined both in a thermal and a fast neutrons version (see § 3.3).

While Gen IV-based SMR designs do not enjoy the long operating and regulatory experience of LWRs, they benefit from an extensive history of past research and development, which developers and regulators may rely upon [7].

The most mature Gen IV designs are the metal-cooled systems with some units currently in operation or under construction, which may also provide specific opportunities for non-electric applications due to their high outlet temperatures as well as their advanced fuel cycles. Among these three systems (alkali metals, metal, and gas), the SFR (Sodium Fast Reactor) is, by far, the most widely spread-out technology worldwide. It has an acknowledged maturity due to the numerous constructions and because it accumulated years of operation in several countries, including France, Russia, China and India.

Combining the specificities of fast neutron reactors (breeders or burners) with the benefits of SMRs in terms of standardization, modularity and power generation flexibility could turn-out quite attractive for some countries and in specific geographic conditions (isolation, insufficient grid capacity…). That explain why several SMRs designs are under advanced development worldwide. Among others, the Brookhaven National Laboratory, NATRIUM, ARC-100, as well as the GE-Hitachi (PRISM). In Russia, the Brest-OD-300 (LFR) received the construction license in February 2021; the prototype will be built in Seversk.

Safety features - Potential Advantages

The safety advantages of the fast neutron SMRs basically depend on their nature and design (and mainly on the coolant features and properties), but, overall, they share some advantages which are inherent to their size and architecture, such as:

- The small fissile inventory, which turns out advantageous both in normal and degraded operation, as well as in case of accidents. Moreover, it reduces the production of waste (i.e., long-lived actinides);
- The small size of the core which contributes to enhanced safety both in case of RIA and coolant void transients, due to the increased neutron leakage (to reduce the risk of reactivity increase);
- The neutron system behavior which is close to the fundamental mode (the reduced core size and the high leakage contribute to the core stability through a very quick elimination of all flux harmonics engendered by the perturbations) in any circumstances (with e.g., an increased reliability of the ex-core measurement devices);
- The reactivity swing over the cycle, which is quite low, thus reducing the needs for excess reactivity compensation;
- The likelihood of the IVR (In Vessel Retention) of the melt core in case of severe accident, due to the small fissile inventory, the low power and the vessel design;
- The passive safety features, depending on the design;
- The coolant which possesses very good thermal inertial capacity and thermal properties (good conductivity and high boiling temperature).

Safety features - Potential points of vigilance depending on any specific design

The fast reactor SMRs share the main drawbacks of their large-scale reference, such as:

- For all concepts, the fuel design and qualification which requires either specific irradiation capacity in high flux facilities, which are poorly available, or long per assembly in-reactor testing;
- For a large majority of concepts, the likely difficult periodic in-service inspection due to the integration of the design;
- For SFRs, the violent exothermic reaction of sodium with water and air, the risk of core melt in case of blockage of the flow in the subassembly and the risk for either a sharp increase or a stagnation of reactivity in case of loss of coolant;
- For LFRs: the corrosion and abrasion of fuel and components due to the high operating temperature, due to the melting point of the coolant metal;
- For GFRs: the difficulty of evacuation of the residual power in case of severe accidents, which needs specifically engineered systems.

4 CONCLUSIONS

While long-term forecasting of the evolution of energy systems and energy transitions is a perilous exercise, it seems quite difficult to imagine future low-carbon energy systems without reliance on nuclear power.

Even though the large Gen III/III+ reactors have now gone through their initial teething troubles and are being successfully deployed, demonstrating their reliability and enhanced safety, their development remains a considerable undertaking for any country, requiring long and thorough preparation and considerable human, and financial resources per unit. Also, their GW-scale capacity and large size may be an impediment for use in smaller grids or in locations to which transportation of the large components may be difficult or impossible.

In this context, Small Modular Reactors (SMRs) could be the future of nuclear industry, with the potential to provide energy without greenhouse gas emissions to countries or remote communities and for a wide range of applications, from electricity generation whatever the grid size or off-grid, to various uses of heat for industrial and domestic applications, including the production of hydrogen to decarbonize hard-to-abate industrial sectors and heavy transport.

High inherent safety, favourable design and operational characteristics, compactness and modularity allowing for a high level of standardization, enhanced capacity to face external aggression and hazards, potential resistance to proliferation, reduced investment per unit - all these features will allow SMRs to effectively contribute and positively solve the present-day challenges of nuclear power, including its wider public acceptance and the acknowledgement of its key role on the path to net zero carbon emissions. However, the SMRs promise must be evaluated with lucidity and rigor. This is in particular true for their safety demonstration, the importance of which cannot be overstated. Moreover, global harmonization and coordination of licensing approaches is crucial for SMRs large-scale deployment.

Drawing from the experience of NucAdvisor experts in nuclear safety, this paper provides an overview of the promising safety characteristics of the different SMR concepts and the challenges that need to be overcome before their industrial deployment. Moreover, offering informative safety-grounded arguments to support the decision-making process in view of the development and the deployment of SMRs, it should be helpful to stakeholders, potential clients, and partners both in developed and emerging countries.

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