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Conc.: Viewpoints in reaction to the Notification according to Article 3 of the Convention on Environmental Impact Assessment in a Transboundary Context (Espoo Convention) regarding **proposed environmental impact assessment programme regarding plans for nuclear facilities in Varberg municipality, Sweden**

Submitted by:
**Föreningen Greenpeace Norden / Greenpeace Nordic**
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The in Sweden registered environmental NGO Föreningen Greenpeace Norden / Greenpeace Nordic and the in the Netherlands registered environmental NGOs *Stichting Greenpeace Nederland* and *Vereniging WISE* (World Information Service on Energy) would like to submit the following viewpoints on the documentation in the scoping phase of an environmental impact assessment regarding plans for nuclear facilities in Varberg municipality, Sweden. These observations are not comprehensive, but give a first reaction on the documentation. We would welcome an opportunity to discuss (on-line or in person) details of our submission with the relevant authorities.
We would like to stress that the quality of this scoping report was very much lower than the material provided by the Norwegian authorities in their recently started scoping procedure for SMRs in the municipalities of Aure and Heim.

## Viewpoints

1. Figures in the EIA will have to be translated into English.

2. **Justification** – An Environmental Impact Assessment (EIA) will not only have to clarify consequences of a planned project for society and environment, it has to deliver an important basis for the justification of the project. Under national and international EIA legislation, such a justification has to show that the project is necessary for its stated goals and that no other solution with less environmental

and health impact can fulfil its objectives. It also has to justify any environmental and health impacts as acceptable and proportional. On top of that, on the basis of the ALARA principle (as low as reasonably acceptable) it has to justify that any radiation exposure (under normal operation as well as under emergency and accident circumstances) is reasonable, and reasonably acceptable and proportional for the objective of the project. This all in comparison with reasonable alternative technical and siting solutions of providing the objectives of the project.
**The "Basis for scoping consultation" from Vattenfal from 10/02/2026 (further: scoping report) does not deliver the essential basis for coming to the above mentioned legally required justifications.**

**3.** **Site choice** – The scoping report describes on several places that an extensive assessment was carried out of potential sites for the project. It does not become clear, however, whether this planning phase was submitted to a Strategic Environmental Assessment (SEA) as prescribed under the Kiev Protocol to the Espoo Convention and the EU SEA Directive (2001/42/EC), nor whether such plans for potential sites and the accompanying SEA were submitted to public participation, as required under the Aarhus Convention art. 7. This undermines the status of the site choice. If such preliminary assessments were not submitted to the required procedures and public participation, it is to be recommended that this will take place before any further steps are taken in the scoping phase.

4. **Siting alternatives** – Also when there has been a SEA procedure concerning the site choice, with required public participation, the EIA will have to examine in some detail the environmental and health impacts of several reasonable siting alternatives. The current proposal does not include this explicitly. It is not sufficient when only one location is assessed, when other locations are only roughly described. There has to be a solid justification for the final location choice, and this needs to be robustly argued.

5. **Timing alternatives** – One of the open questions is why Vattenfal does not wait until the existing Ringhals site has been fully decommissioned, so that alternative use can happen instead of devastating an existing nature reserve. This question has not at all been addressed in the scoping report. Given the lack of necessity of the project (delivering very little, and coming late for any decarbonisation efforts in 2040), timing is definitely not as urgent as suggested.

6. **Alternative developments** – The EIA will have to include reasonable and comparable zero alternatives (no project at any site). A simple "zero option" in which the project is not carried out, only relating to the chosen location, is not sufficient. The EIA needs to include the impacts of alternative energy developments based on a 100% renewable energy system development, the use of efficiency and demand management measures, storage capacity and power exchange with other countries. The conclusion on page 37, chapter 5, par. 5.1 last paragraph lacks any thorough assessment of any viable zero option. Based on existing literature, there are several scenarios in which Sweden would be able to meet its 2040 full decarbonisation goals of the power sector without any new nuclear capacity, even when existing nuclear capacity is phased out around that time.

In order to be able to justify the project, comparison with such scenarios is crucial. When it is not necessary to expose the population and environment to extra radiation, because there exist reasonable alternative options without such exposure, exposure by this project is not justified and the project should not be accepted. Therefore reasonable zero-options need to be included in the EIA for comparison.

7. **Nature protection** – The scoping report explicitly mentions that areas with high natural values will be used, resulting in a loss of natural values. This means that under the Habitats and Bird Directives the bar for justification of the project is extremely high. In case there are reasonable alternatives for the activity, no justification for the above mentioned loss of natural values can be given. For this project there are reasonable alternatives, which have to be worked out in detail in the zero-options. We insist that the attention to justification under the Habitats and Birds Directive gets more attention than currently given by Vattenfal in this scoping report.

8. It could be recommended to follow the recently started Norwegian EIA scoping procedure concerning SMRs in the Aure and Heim municipalities, in which a special Justification document was published by the responsible authorities. It contained vital considerations to be implemented in detail.

9. Although from extensive media coverage, it is already clear that Vattenfal has chosen for the **SMR designs** from GE Vernova Hitachi (five units BWRX-300 with 300 MWe) or Rolls Royce (three units Rolls Royce SMR with 460 MWe), this choice is not mentioned explicitly in the scoping report. This is misleading. There are a lot more details already known about these designs, so that the level of quality of the information included could have been a lot higher. This will also hold true for the EIA.

10. The project is very large – five units of up to 300 MWe or three units of 460 MWe. Why does it have to be so large and **centralised**? Why not in the form of one large nuclear power plant of 1500 MWe? Is there a need for centralisation of power generation? The option of one large plant of 1200 to 1658 MWe should at least be taken along as potential alternative. Also the alternative of a larger spreading of capacity over several locations (hence also spreading risks) should be take into account.

11. Because **SMRs are still not a proven technology**, it is important to establish whether the construction of 1500 MWe of capacity in the form of 3 or 5 small reactors is indeed beneficial in comparison with the construction of a large 1500 MWe or two smaller 800 MWe reactors. This includes issues around safety, spatial impact, environmental impact etc. Both then need to be compared with reasonable zero-options, including those based on the development of a 100% renewable energy based system. It is highly likely on the basis of current available information that the option of 3 or 5 small reactors will be scoring worst in costs, spatial footprint, environmental footprint and risk profile (including risks from deliberate events like malevolent attack – sabotage, cyber attacks, terrorist attack and acts of war). This should be a reason to reject the project.

12. Sweden already has a **surplus production of power** with 19,4% electricity exports in 2024 (trend upwards) (source: www.eia.org), with 67,7% from renewable sources (also: trend upwards). How can an addition of a few percent by using an expensive, high risk, ultra-hazardous generation source in a valuable nature protection area ever be justified?

13. **Too tight schedule** – The scoping report claims that the project has to deliver for the goal of completely fossil-free electricity production in 2040. Given the unproven status of both chosen SMR designs, given the fact that no industrial production capacity for these designs currently exists, given the fact that not only Sweden, but many countries are looking to the development of these designs and may well be earlier in obtaining production capacity from the design builders, it is not very likely that Sweden will be able to have any of the reactors running before 2040. In that case, it will be locked-in in a small bit of fossil fuel use in its power sector after that date, because of its choice for this technology.

14. **Cost** – Because of the urgency of the climate problem and need to develop a decarbonised grid as soon as possible, the high cost of the project is relevant for the environmental impact assessment. The EIA should therefore also look into the financing model for the construction of this project and compare that with what can be delivered by similar financing efforts in reasonable alternatives – both in delivery of a stable grid in 2040 as well as in the amount of greenhouse gas decrease before that time.

15. **Security** – The issue of security is not at all addressed in the scoping report, whereas nuclear installations count as potential targets in times of political instability, as can be currently seen in Ukraine, Russia, Iran, UAE and Israel, and in the past in Iraq and Slovenia. The issue of risk in times of political instability for people and environment has to be assessed and justified.

16. **Security measures for enhanced safety** – Experiences in Ukraine have shown the vulnerability of nuclear installations in times of war. This relates not only to defence-related security issues, but also should have consequences for the safety robustness of the design. Any new nuclear power plant should in its design take into account safety measures that increase the robustness in case of war situations – e.g. protection of vital equipment by bunkering against potential drone attacks, availability of larger and diverse stocks of emergency fuel for emergency generators, availability of large stocks of emergency cooling water or extra redundant pump and piping systems for access to cooling water, extra redundancy of off-site power connection, etc. These are not security issues in the traditional sense, but belong to the safety base that a nuclear power station should have to prove.

17. The EIA needs to contain a **full assessment of impacts from the entire fuel chain**, including mining, extraction and refinement, enrichment, fuel production, transport of radioactive substances, radioactive waste production and management. Not requiring such assessment cannot be justified and leads to false comparison with

reasonable alternatives and hence undermines the obligation of justification of the project.

18. The **front end of the fuel chain** is not mentioned at all, whereas uranium mining, milling, extraction, and fuel production all have considerable impacts, including radiological ones, that need to be compared with impacts from reasonable alternatives.

19. The **back end of the fuel chain** – **radioactive waste** – is mentioned but excluded from the procedure. This is unjustified. New nuclear capacity produces new spent fuel and radioactive waste, for which the planners are fully responsible. In order to come to a balanced justification of the choice for the project, or not, all available information about the entire back-end, including final disposal of radioactive wastes, needs to be presented in the EIA. The lack of assessment of the back-end in similar recent scoping procedures for new nuclear projects in other EU countries, including the Netherlands and Norway, was severely criticised and had to be added.

20. **Radioactive waste** – This issue needs to be addressed and organised in sufficient detail before any waste is produced. The experience of the current global nuclear fleet is that, without exception, all nuclear countries are struggling with management of especially high-level wastes, but also intermediate wastes, large volumes of low-level wastes, and ultra-long-lived TENORM wastes from enrichment. When waste complications are only considered after a nuclear project has gone into operation, they form a *fait accompli* and *de facto* unacceptable burden for future generations.
It is rightly noted in the scoping report that the current facilities for managing radioactive waste in Sweden are only covering current nuclear power reactors. It is important that the duty for the development of **new structures for new waste are fully – in cost and organisation – the responsibility of the operator proposing the new project**. These duties may not be socialised, causing an unjustifiable market advantage for new nuclear projects in comparison with cleaner renewable and system solutions. Steps by the current Swedish government that appear to go in exactly that direction[1] are in breach with Euratom law, art. 3(e) of 2011/70/Euratom,[2] and hence illegal.

21. **Safety case of the project**: This must include not only safety during regular operation, in case of design based accidents (based on a probabilistic risk assessment or PRA, sometimes called PSA), but also a deterministic assessment of beyond design based accidents (BDBAs), including those caused by malevolent attack (terrorist attack, sabotage and/or acts of war). The Norwegian authorities recently stipulated explicitly the need for assessment of the role of deliberate events including malevolent attack in their Justification document for the Aure and Heim project. It is advisable that also Sweden requires this for the Varberg project.

1 https://www.svt.se/nyheter/inrikes/regeringens-besked-183-miljarder-till-nytt-lager-for-karnavfall
2 2011/70/Euratom, art. 3(e): *National policies shall be based on all of the following principles: (e) the costs for the management of spent fuel and radioactive waste shall be borne by those who generated those materials;*

22. It is likely that a centralised project like this **attracts further industrial activity**. This could include datacentres or other large energy consumers. Are there already indications this will happen? What will be the synergetic impacts on the environment and health? In case the attraction of major energy consumers is specific policy goal, who will carry the responsibility for issues like liability, radioactive waste management, etc.?

23. **Nuclear fuel** – although the project promoter is currently referring to the use of light-water designs using currently used nuclear fuel types in 12-18 month cycles, it opens the possibility for a 24 month cycle, with a higher burn-up rate than currently usual. This would cause a fundamentally different safety, security, radioactive waste and proliferation picture. These consequences need to be described and taken into account in the final justification.

24. **Radioactive pollution** – Special attention should be given to potential releases of tritium into the atmosphere and water and sea environment. There have been over the last decades increased concerns about the impact of tritium exposure (e.g. the IRSN / ASN Tritium white paper, but also others). New reactor designs likely will have another tritium release profile.

25. **Decommissioning** – History shows that the complexity of decommissioning work has always been underestimated during the development phase of new reactor designs. This has also resulted in a structural underestimation of decommissioning costs, which in many cases are socialised, because they otherwise would disrupt the business case of nuclear power. This should be prevented already in the planning phase.
The EIA must include detailed descriptions and cost estimates of decommissioning and waste management and clear and secured ways to guarantee sufficient financing at all times. Sufficient total funds should preferably already be available in an early stage of operation (after less than a few years), so that continued operation or socialisation of decommissioning costs are not needed for accumulation of decommissioning funds, when safety, security or other reasons would require an early shut-down. Also, only in this way truly independent safety oversight is possible, without any economic pressure on political decision makers for accumulation of sufficient funds for decommissioning and waste management.

**26. Nuclear accidents** – The scoping report fails to give any detail about how large accidents will be addressed in the EIA. It is important to acknowledge that in spite of an evolution in reactor safety, there still remains a chance on a severe accident with the release of a substantial part (>10%) of the volatile nuclear reactor content. With multiple reactors, there exists the chance of common-cause multiple reactor accidents (as we have seen in Fukushima Daiichi in 2011).
The EIA report needs to address this issue in sufficient detail and not down-play it in generalities.

27. We explicitly ask attention for the spread of radioactive substances after a severe accident with release of a substantive part (>10%) of the volatile nuclear content of

one or more reactors into the atmosphere and sea environment and the consequences for the sea environment in the Baltic Sea region.

28. **EP&R** – Modelling of potential impacts and necessary Emergency Preparedness and Response (EP&R) should be included with assessment of the impacts of severe beyond design accidents with a substantial release of >10% of volatile radioactive isotopes I-131, Cs-134, Cs-137 and Sr-90 in the core for a one, as well as a multiple (common cause) reactor accident.

29. **Liabilities** – Current liability legislation socialises over 90% of potential liabilities in the case of a severe accident with substantial release of radioactive substances. The exact impacts of the current liability regime need to be assessed and described in the EIA, and compared with liability regimes for reasonable zero-alternatives. Also the impacts of an upgraded liability regime in which the operator is obliged to organise at least a financial reserve in the order of magnitude of the necessary liabilities in the first year after a severe accident with substantial release of radioactive substances, need to be worked out and presented in the EIA.

30. **Climate vulnerability** – The EIA should take into account that the proposed reactors may be operational until in the next century, and maybe even until or past the midst of the 2100s. Changed climate circumstances until 2200 should therefore be taken into account, and for waste management for even longer periods.

31. **"Plannable electricity" – load-following** – It is assumed in paragraph 1.2 of the scoping report that the reactors will be able to load follow and be used as a dispatchable source. This possibility is, however, not solidly substantiated for any of the SMR designs currently under development and highly unlikely to be practicable. First of all there are economic reasons why load-following is undesirable for any of the SMR designs, and that is the fact that most of the cost of the SMR reactor is up-front and will have to be recuperated through high availability power production, or the source will price itself even further out of the market. It is highly likely any operator will require 24/7 preferential access to the grid in order to reach a high load factor and recover as much as possible over income from power sales. The second reason is technical: increasing and decreasing load over short times, as required by most load-following, introduces extra stress on vital parts of the reactor, including the reactor vessel and primary piping and welding, as well as thermal shocks. Although some load-following may be possible within the technical parameters of the reactor, there is only experience with large reactors and the reaction of smaller designs still needs to be investigated in detail. In reality, historically, smaller reactors (built in the 1960s, 1970s and early 1980s) have not been used for load-following for obvious technical reasons. There is therefore no relevant experience available for how these new designs will react on high levels of dispatchability.

32. Furthermore, the description in par. *1.2 The purpose of the operations*, of how a grid with high level variable generation capacity functions is **so amateurish that it made us blush**. There is too much utterly nonsense in this paragraph. The EIA needs to

contain a solid chapter on the role of the project in a grid with a high level of variable generation capacity, including technical and economic details. Currently, Sweden already has a largely (67,7%) renewable grid with a large amount of pump-storage hydro capacity. It is neighbour to Norway that offers even more pump-storage hydro. And that apart from the fact that battery storage currently is in sharp cost decrease, and Sweden has an industry with a huge capacity of demand management. There is absolutely no reason that Sweden would need extremely expensive (more expensive than gas with CCS!) nuclear capacity for grid balance. In contrary, because of its relatively large unit-capacity of 300 MWe or 460 MWe, the mentioned SMRs threaten to disbalance the grid much more likely in cases of an unscheduled scram than any of the highly plannable and predictable variable generation ever would be able to do. Wind and solar are highly predictable and reliable on a 72-hour basis. Sweden has a highly recommended Swedish Meteorological and Hydrological Institute (SMHI) for that purpose.

33. Par. 3.4 – **Backup power** – the need for fossil or bio-fuel based back-up power undermines the claim that the project is fossil-free.

34. **Cooling water** – The environmental effects on the Baltic Sea ecosystem of ten degrees warmer outlet temperatures, especially under circumstances of increasing water and air temperatures due to climate change and the relative stagnant nature of the Baltic Sea itself, should be assessed in detail. Especially also cumulative effects in case the project is to function next to still operating old nuclear reactors in Ringhals.

35. **Time horizons for the EIA report** – Par. 8.1. states that the *Long term corresponds to the facility's operating time until decommissioning*. This is **an unacceptable limitation** to what needs to be assessed in an EIA. The EIA needs to investigate the full operation time of the project until it has been brought back to the original state of the landscape or the landscape has been handed over in another use. That means that **decommissioning** should be inherently part of the EIA. One of the large problems we face with historical nuclear projects is that decommissioning was not a part of the design process and that we are for that reason confronted with burgeoning decommissioning costs and efforts. But also **the full fuel chain, including final storage of radioactive waste**, should be included in the EIA. There is no other way to assess **potential burdens for future generations**.

**36. Ad 8.3. Assessment basis** – The Radiation Protection Regulation and ordinance, including the role and responsibilities of SSM, need a lot more attention than they are given here. What will be the role of SSM regulations, of WENRA guidance, of IAEA guidance? What will be the influence from foreign regulators having ruled over BWRX-300 and/or RR SMR projects? This paragraph is fully insufficient.

37. **Ad 9. The Consultation process** – This does not describe the obligatory consultation processes under Aarhus and the EU Nuclear Safety Directive. It should also include a description of the consultation processes for interested citizens in potentially impacted areas outside of Sweden. Especially Norway and Denmark should get extra attention, given their nearness to the project.

38. Greenpeace Nordic has commissioned a **report on the plans for SMRs at Ringhals by nuclear reactor expert Dipl. Phys. Oda Becker**, which can be found added hereunder (pages 10 – 38), and which is an integral part of this submission. We request the viewpoints expressed in this study to be included in the preparation of the EIA documentation.

# Critical Review of the Small Modular Reactors (SMRs) Rolls-Royce SMR and BWRX-300 - for Sweden

On behalf of Greenpeace Sweden

Dipl. Phys. Oda Becker

February 2026

## Content

## 1 Introduction

In June 2023, Sweden replaced its energy target of '100% renewable' electricity by 2040 with '100% fossil-free' electricity. Following the accident at Three Mile Island (1979), a referendum in 1980 decided that nuclear energy should be phased out by 2010. Six older reactors have been decommissioned by 2020. Six reactors at three sites are still in operation (Forsmark, Oskarshamn and Ringhals). Sweden's nuclear power plants generate around 30% of the country's electricity.

In November 2023, the government announced plans to build two large reactors by 2035 and the equivalent of 10 new reactors, including small modular reactors (SMRs), by 2045. Early February 2026, the Swedish government has announced several proposed measures to make it easier to establish new nuclear power in the country.[3] These include a new approval law, more possible locations for nuclear power on the coast, and increased government support for municipalities' feasibility studies.

The government has decided to submit a legislative proposal for amendments to the Environmental Code. The amendment - proposed to enter into force on 15 July 2026 - would remove the current bans and restrictions to exclude locations that could be suitable for new nuclear power without a case-by-case assessment.[4] The government has also proposed that SEK20 million (USD2.2 million) will be allocated annually until 2030 by the Swedish Environmental Protection Agency to municipalities that want to conduct feasibility studies for new nuclear power.[5]

The Swedish government received the first application for state aid in December 2025 from Videberg Kraft AB, a project company owned by Vattenfall AB and backed by a series of industrial firms via the Industrikraft i Sverige AB consortium.[6] The application is written in accordance with the framework for financing and risk sharing that is set out by the Government Bill on Financing and Risk Sharing in New Nuclear Power – a bill that was adopted by the Swedish Parliament in May 2025.

Negotiations regarding the conditions that will apply to the project will begin once the Swedish Government Offices have processed the application. When an agreement between the state and Videberg Kraft has been reached, the government may initiate the formal state aid process with the European Commission.[7]

Videberg Kraft is planning a project with either five BWRX-300 modular boiling water reactors (BWRs) from GE Vernova Hitachi, each with an electrical output of 300 MWe, or three modular pressurized water reactors (PWR) from Rolls-Royce, each with an electrical output of 470 MWe, which will provide a total output of approximately 1,500 MW. The decision on the final supplier is planned for 2026.

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3 WNN: Sweden proposes steps to facilitate new nuclear projects; 6 February 2026; https://www.world-nuclear-news.org/articles/sweden-proposes-steps-to-facilitate-new-nuclear-projects

4 The amendments mean that the ban on nuclear facilities in the coastal areas and archipelagos in Bohuslän from the border with Norway to Brofjorden, in Småland and Östergötland from Simpevarp to Arkösund and in Ångermanland from Storfjärden at the mouth of the Ångermanälven to Skagsudde and on Öland is lifted.

5 It had previously decided on a total of SEK15 million to municipalities during the years 2024 and 2025. It noted that 13 municipalities conducted pilot projects during 2024-2025, including preliminary studies on possible location.

6 Industrikraft has entered into an agreement with Vattenfall to acquire a 20 percent stake in Videberg Kraft.

7 Vattenfall: Videberg Kraft applies for state aid for investment in new nuclear power; 23 December 2025 https://group.vattenfall.com/press-and-media/newsroom/2025/vattenfall-videberg-kraft-applies-for-state-aid-for-investment-in-new-nuclear-power

Videberg Kraft assesses that the Ringhals NPP site is the most suitable location for the Project. They have applied to the Administrative County Board to revoke parts of the adjacent Natural Reserve, Biskopshagen, to expand the NPP location on the west side, towards the sea. For a Natural reserve to be (partly) revoked, there needs to be exceptional reasons according to Swedish law.
Greenpeace Sweden will submit a statement on this issue to the county administrative board to object to the exceptional reasons given for these reactors at this location. Greenpeace considers that a strong argument against these plans is to highlight various risks associated with the selected companies and their respective reactor designs, including at this site.
Greenpeace Sweden commissions Oda Becker to conduct a critical review of the proposed plans to build SMRs at the Ringhals nuclear power plant.
The study covers the following topics:

- Critical review of the prospects of SMRs in general and in Sweden in particular
- Critical review of the proposed reactor designs and their respective suppliers. It is also discussed whether it is likely that the reactors will be delivered within the time frame.
- Technical safety review of the respective reactor designs on the specific location, taking into account, for example, risk of flooding and extreme weather conditions.

To address these topics, following an introduction, Chapter 2 presents and discusses some general facts about SMRs. Chapters 3 and 4 describe and evaluate the two SMRs currently being considered in Sweden, the BWRX-300 and the Rolls-Royce SMR respectively. Chapter 5 provides the conclusions. An appendix outlines several aspects of the risks posed by climate change to nuclear reactors.

## 2 Small modular reactors – future development and use in Europe

The term 'small modular reactor' (SMR) was re-coined in 2010 in an attempt to relaunch a previously failed "renaissance" of nuclear energy in the early 2000s.The term SMR has become a widely used concept that is interpreted differently by various organizations. While it generally refers to reactors with a capacity of up to 300 MW, although some concepts (for example, the Rolls-Royce SMR with 470 MWe) exceed this arbitrary limit by quite a margin and cannot be considered "small".  Instead, the capacities of many designs are comparable with nuclear reactors built in the 20th century. The new European Industrial Alliance on SMRs[8] describes SMR as "compact nuclear power units that generate an electrical output of 10 to 500 MWe".
The term SMR can encompass a wide range of different reactor technologies, such as light-water reactors, high-temperature-gas-cooled reactors, molten salt reactors, and more.[9]

8 On 6 February 2024, the Commission announced the launch of the European Industrial Alliance on SMRs. The European Industrial Alliance on Small Modular Reactors (SMRs) aims to facilitate and accelerate the development, demonstration, and deployment of SMRs in Europe by the early 2030s. https://single-market-economy.ec.europa.eu/industry/industrial-alliances/european-industrial-alliance-small-modular-reactors_en#who-can-join-the-alliance-and-how

9 Each of these technologies implies the use of technology-specific supply chains and fuel-cycle arrangements, as well as distinct approaches to decommissioning and waste management.

### 2.1 Market introduction for SMRs far away

Most SMR concepts are in early development or licensing stages. The Rolls-Royce SMR, for example, has reached the third and final step of the UK's Generic Design Assessment (GDA). But it is still waiting for site license approval to begin construction. The French NUWARD concept is undergoing a redesign process aimed at increasing its electrical output to around 400 MWe, requiring licensing process restarts. Only Russia and China are operating, SMR prototypes with low performance indicators. The Argentinian CAREM-25, under construction since 2014, was abandoned in 2024. (WNIRS 2025) The Canadian project at Darlington, Ontario, represents the most advanced case, although only one of four originally planned BWRX-300 units received a construction license in May 2025.
The heterogeneity of SMR concepts will complicate their implementation in Europe, given the necessity of tailored regulation for different technologies and use cases, for example, emergency planning zones. According to the IAEA, there are more than 80 SMR designs and concepts globally. Most of them are in various developmental stages and only some are claimed to be near-term deployable. [10] Further, most concepts remain in early development stages. There are currently three SMRs in advanced stages of construction in China and Russia.
In Sweden, for example, besides the plan of construct SMRs at the Ringhals NPP site, Swedish reactor developer Blykalla began construction of the Advanced Testing Site for its lead-cooled SMR of Generation IV ("SEALER"), on the site of the Oskarshamn NPP in February 2025.[11]

### 2.2 SMR are not cheaper than large NPPs

It is often claimed that the cost overruns and schedule delays that have plagued large reactor projects will not be repeated with the SMRs. But the few SMRs that have been built paint a different picture. Significant construction delays are still the norm, and costs have continued to climb. The costs of SMRs are not lower than of large reactors like the EPR, but higher. That is why in the past people started to build large reactors instead of small ones. Reactors can only be built with subsidies or government money. A key belief for SMR proponents is that the new reactors will be economically competitive. But the experience with the initial SMRs that have been built shows that this is not true. There currently three operating SMRs worldwide—two in Russia and one in China. Costs for all three have been significantly higher than originally forecast.[12]
Economically, SMRs are unlikely to become competitive with existing reactors. A central promise of SMR concepts is the potential to benefit from industrial learning effects through serial production and standardization. However, this presupposes the repeated deployment of a limited number of standardized designs. The current SMR landscape is characterized by heterogeneous reactor concepts.
A recent cost calculation that takes into account economies of scale, economies of scope, and learning effects from the nuclear industry concludes that more than 1,000 SMRs would have to be manufactured before production would be cost-effective. It is therefore

10 IAEA: Small modular reactors; https://www.iaea.org/topics/small-modular-reactors

11 Nuklearforum Schweiz: Schweden Grundsteinlegung für Reaktortestanlage von Blykalla; 10. Februar 2025 https://www.nuklearforum.ch/de/news/schweden-grundsteinlegung-fuer-reaktortestanlage-von-blykalla/

12 Projected costs for the Russian SMRs climbed more than 300% from initial estimates. Likewise, it has been reported that the cost for China's Shidao Bay 1 SMR, a 150MW high-temperature gas-cooled reactor (HTGR), was triple initial cost projections.

unlikely that the existing cost disadvantages of SMRs will be offset by learning effects or economies of scale in the foreseeable future (PISTNER et al. 2021).
In practice, current deployment trajectories provide little evidence that such manufacturing volumes are achievable. There is substantial doubt about whether localized manufacturing facilities (and thus reduced costs) will materialize.[13] Historically, the nuclear industry has tended to increase rather than reduce costs.

### 2.3 SMR are not at all competitive with Renewables

The evidence from the cost estimates of SMR projects produced so far shows that they are not to be expected to produce economically competitive electricity. The Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) concluded that SMRs would be by far the most expensive way to generate power in the country;, the Levelized Cost of Energy (LCOE) for an SMR project starting to deliver power in 2030 was estimated at US$211–399/MWh; in comparison, solar PV and onshore wind were estimated at US$22.5–41/MWh and US$41–69/MWh respectively. When integration costs are included to account for the variability of wind and solar power, the cost of electricity was estimated to be in the range of US$58–84/MWh.[14] Which means the SMR´s cost per MWh are three to five times higher compared to solar and wind.
The Institute for Energy Economics and Financial Analysis **(**IEEFA) has taken a close look at the data available from the three SMRs currently in operation, as well as new information about projected costs from some of the leading SMR developers. IEEFA believe these findings should serve as a cautionary flag for all decision makers. The IEEFA recommends in particular that:

- **Regulators** should set restrictions to prevent delays and cost increases from being pushed onto ratepayers.
- **Utilities** that are considering SMRs should be required to compare the technology's uncertain costs and completion dates with the known costs and construction timetables of renewable alternatives.
- **Governments** should require that estimated SMR construction costs and schedules be publicly available so that utility ratepayers, taxpayers and investors are better assessing the magnitude of the SMR-related financial risks that they may be forced to bear.

Furthermore, it is important to consider the opportunity costs associated with promoting SMR projects. The funds invested in SMRs are no longer available for the construction of wind, solar and storage facilities. These carbon-free and lower-cost technologies can push the transition from fossil fuels forward significantly in the coming 10 years (when SMRs will still be looking for licensing approval and construction funding).

### 2.4 Questionable time claims

Another claim made by proponents of SMR concepts is the expectation of shorter time horizons, in particular shorter construction times. An evaluation of plants currently

13 Friess, F., Siddiqui, M. & Ramana, M. V. Small modular nuclear reactors for developing countries: Expectations and evidence. *PNAS Nexus* 5, pgag006 (2026).
14 Paul Graham, Jenny Hayward and James Foster, "GenCost: Cost of Building Australia's Future Electricity Needs", Commonwealth Scientific and Industrial Research Organisation, National Science Agency of Australia, 29 July 2025, see https://www.csiro.au/en/research/technology-space/energy/Electricity-transition/GenCost

planned, under construction or in operation does not confirm this assumption. On the contrary: planning, development and construction times usually exceed the original time horizons many times over.
In 2020, two SMR reactors based on the KLT-40S concept (so-called floating nuclear power plants) were commissioned in Russia. These reactors have been realized after 13 years of construction. The high-temperature reactor HTR-PM in China has been in commercial operation since 2023, after 11 years of construction.
GVH even claims it will be able to construct its BWRX-300 SMR in as little as 30-36 months. But nuclear industry experience is different, both in terms of past SMR development and construction efforts and the larger reactor projects, all of which have taken significantly longer than projected to begin commercial operation.
Many EU policymakers currently perceive SMRs as an additional promising option that could contribute to the EU's emission reduction targets. However, even under very optimistic assumptions for the speed of market introduction of SMRs, they will likely not contribute to these political objectives before the 2050 climate neutrality benchmark. Thus, betting on near-term SMR deployment for decarbonization binds limited political and administrative resources at EU and Member State level that could be better applied to existing cost-competitive technologies, namely, renewables and storage, to supply clean and affordable energy instead of waiting for a technology whose feasibility remains highly uncertain. Furthermore, the heterogeneous nature of proposed SMR concepts creates regulatory, industrial and governmental complexities that increase the uncertainty regarding future cost reductions and large-scale deployment.

### 2.5 Emergency Planning Zones

Theoretically, SMRs could potentially achieve safety advantages compared to power plants with a larger power output, as they have a lower radioactive inventory per reactor and aim for a higher safety level especially through an increased use of passive systems. In contrast, however, various SMR concepts also favor reduced regulatory requirements, for example, with regard to the required degree of redundancy or diversity in safety systems. Some developers even demand that current requirements be waived, for example in the area of internal accident management or with reduced emergency planning zones.
Questions regarding the necessity and sizing of the emergency planning zones (EPZ) for off-site emergency protection in SMR concepts remain open. EPZs are Zones around a nuclear reactor that are prepared to respond to an emergency. EPZs allow to pre-define the protective actions to mitigate the most likely consequences of a radiation emergency. According to IAEA, there are two EPZs: the Precautionary Action Zone (PAZ) with a suggested Radius of 3 to 5 km and Urgent Protective action planning Zone (UPZ) with a suggested radius of 15 to 30 km.
So far, in contrast to what is sometimes stated by SMR-developers, a need for planning zones that extend significantly beyond the plant site must be assumed for off-site emergency protection in SMRs. Special consideration is also necessary for SMRs are close to densely populated centers.

### 2.6 Regulations /Security and safeguards

The lack of a common definition of SMRs makes it difficult to develop new regulations or adapt existing ones. To strengthen nuclear safety, the Federal Office for the Safety of Nuclear Waste Management (BASE)[15] recommends adopting the IAEA's terminology, which defines "[…] SMRs as advanced reactors that produce electricity of up to 300 MW(e) per module [...]', which also '[...] have advanced engineered features, are deployable either as a single or multi-module plant, and are designed to be built in factories and shipped to utilities for installation as demand arises."[16] Note: Using this definition, the Rolls Royce SMR would not be classified as SMR. (BASE 2025)

The BASE highlights the development of national regulations must always be guided by the highest safety standards available. Similarly, nuclear safety must remain the top priority in efforts to standardize safety requirements for reactor designs and harmonize legal frameworks across European countries. National legal requirements should not be sidestepped or weakened. In particular, given their potential location near population centers, it is necessary to ensure a high level of nuclear safety. The concept of 'defence-in-depth' (DiD), as a basic principle for ensuring the safety of nuclear power plants, should be also used for SMRs.

When developing SMRs, security and nuclear material monitoring (safeguards) measures should be considered early on and thoroughly. To ensure security and non-proliferation, government agencies and SMR operators must establish an effective protection system that requires coordinated measures to ensure the physical protection of nuclear material and nuclear facilities. Member States and the EU must establish robust international regulatory frameworks to achieve the objectives set out in the strategy. Questions of security and protection against sabotage and terrorist attacks must be clarified. This will be particularly necessary for transportable modules. (BASE 2025).

Military actions against nuclear facilities, such as the Russian attacks on Ukrainian NPPs, pose a further danger that deserves special attention in the current global situation. Russia's attack on Ukraine has given rise to scenarios that were previously considered highly unlikely. The risk of catastrophic accidents has increased once again.

With the war in Ukraine, civilian nuclear facilities have become direct and indirect targets of armed conflict for the first time. Russia has made it clear that international rules prohibiting acts of war around nuclear power plants can only remain in force as long as all actors feel bound by them. In such cases, nuclear facilities become a particular threat. (BASE 2022)

It is more difficult to rule out armed conflict over a longer period of time. Even if the armed conflict does not take place on Sweden, the additional dangers must be taken into account, including: the use of remote-controlled drones loaded with explosives.

BASE calls on the European Commission to make nuclear safety and waste management issues cornerstones of its planned strategy for the development and use of SMRs in Europe. The Commission's measures should aim to ensure the highest level of safety for the operation, transport, waste disposal and decommissioning of SMRs, thereby minimizing the risks and costs for current and future generations in Europe. BASE therefore makes the following recommendations to the European Commission (BASE 2025):

- Adopting the IAEA definition for SMRs to provide conceptual clarity and remove definitional barriers to the development or adaptation of safety regulations.

15 a subordinate authority of the German Ministry of the Environment, performs supervisory and licensing functions and conducts research.

16 IAEA: Small Modular Reactors; https://www.iaea.org/topics/small-modular-reactors

- Ensuring that nuclear safety is given top priority in efforts to harmonize regulatory frameworks across all European countries and that national legal requirements are not sidestepped or weakened.
- Consideration of the concept of 'Defence in Depth' (DiD) in the development of the 'Safety-Safeguards-Security by Design' methodology for SMRs.
- Call on the IAEA to develop sound and appropriate regulations for the transport of SMRs.
- Supporting the development of an effective safeguards system that ensures the physical protection of nuclear material and nuclear facilities against sabotage and terror attacks and proliferation risks.

## 3 The BWRX-300

The BWRX-300 developed by GE Vernova Hitachi (GVH) is a boiling water reactor (BWR) with natural coolant circulation and passive safety systems, and an electrical output of 300 MWe.

### 3.1 Development history

GVH states that the BWRX-300 is the tenth generation of BWR designed by GVH and its predecessor organizations. The BWRX-300 design builds upon technology and methodologies used in its earlier designs, including the Advanced Boiling Water Reactor (ABWR), Simplified Boiling Water Reactor (SBWR) and the Economic Simplified Boiling Water Reactor (ESBWR). However, the development history of the BWRX-300 is not a story of success. The two predecessor types (SBWR and ESBWR) were never built. Only four reactors of the most recently built reactor type ABWR were constructed in Japan, and these have been out of operation for almost 15 years now. Its predecessors also included the reactor type (BWR-4) at the Fukushima site, where the catastrophic accident occurred in 2011.
In 2017, the development of the BWRX-300 based on the ESBWR design began. The ESBWR design has been licensed by the U.S. Nuclear Regulatory Commission (NRC) in 2014 and has an electrical output of 1,520 MWe. The changes from the ESBWR to the BWRX-300 are primarily due to the aim of reducing costs. According to the manufacturer, the cost reduction from the ESBWR to the BWRX-300 is approximately 60%. (ENCO 2022).

### 3.2 Licensing process and projects

***United States:*** In August 2022, the Tennessee Valley Authority (TVA) began planning for the possible deployment of a BWRX-300 at the Clinch River site. GVH submitted preliminary review documents of its BWRX-300 design to the U.S. NRC. The review was initiated by the NRC in December 2019 but had not been completed by February 06, 2026.[17] In May 2025, the TVA submitted a construction permit application to the US NRC to build a BWRX-300 at the Clinch River site.[18] TVA submitted a Preliminary Safety Analysis Report (PSAR) in 2025 to US NRC as part of a construction license application.

17 NRC: GEH BWRX-300, last update May 01, 2025. https://www.nrc.gov/reactors/new-reactors/advanced/who-were-working-with/pre-application-activities/bwrx-300
18 WNN: TVA submits first US BWRX-300 construction application; 20 May 2025. https://world-nuclear-news.org/articles/tva-submits-first-us-bwrx-300-construction-application

***Canada:*** In January 2023, GVH announced that Ontario Power Generation (OPG) had placed an order for a BWRX-300 reactor, which is expected to be commissioned by 2029.[19] In April 2025, the Canadian Nuclear Safety Commission (CNSC) has announced its decision to authorize OPG to construct a BWRX-300 reactor at the Darlington New Nuclear Project *(DNNP)* site in Clarington, Ontario.[20] OPG has been granted a license to construct by the CNSC. In January 2025, GVH said that early site preparation work at Darlington had been completed with construction of the first unit expected to commence by the end of 2029. According to OPG's website the goal is to complete construction of the first SMR by the end of this decade and connect to the grid by the end of 2030.[21]
***Great Britain***: In December 2025, GVH successfully completed a two-step Generic Design Assessment (GDA) for the BWRX-300 design. Currently, there are no plans to deploy the GVH BWRX-300 design in Great Britain, and no sites have been identified for its deployment. Should an organization wish to make plans to deploy the BWRX-300 design, the regulators would need to undertake a further period of detailed design assessment before safety-significant construction could begin and environmental permits could be issued. This assessment could be conducted on a generic basis with GVH, should the company choose to return to the GDA process to complete Step 3. Alternatively, it could be undertaken with a licensee or constructor as part of a site-specific development in Great Britain.[22]
**Poland:** GVH and Orlen Synthos Green Energy (OSGE) have signed an agreement to develop a detailed technical design of the BWRX-300 adapted to Polish regulations, safety standards and environmental conditions. Under the agreement, OSGE will invest in the development of a detailed BWRX-300 design to serve as a reference model for potential SMR projects in Poland. OSGE has made preparations for the deployment of BWRX-300 units at three different locations. It is expecting to complete the first unit near Wloclawek by 2032.[23]

### 3.3 General Design

The BWRX-300 primary containment extends below ground level. The reactor core is located inside the reactor pressure vessel (RPV) and houses 240 fuel assemblies and 57 control rods. It uses fuel assemblies (GNF2) that are already currently widely used globally.

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19 WNN: BWRX-300 completes Phases 1 & 2 of Canadian pre-licensing review; 15 March 2023. https://world-nuclear-news.org/Articles/BWRX-300-completes-Phases-1-2-of-Canadian-pre-lice

20 Canada: Commission authorizes Ontario Power Generation Inc. to construct 1 BWRX-300 reactor at the Darlington New Nuclear Project site; April 4, 2025. 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

21 OPG: OPG Ready to Begin Building North America's First Small Modular Reactor—Questions & Answers—When Will the SMRs Start Producing Power?, 8 May 2025, https://www.opg.com/story/opg-ready-to-begin-building-north-americas-first-smallmodular-reactor/

22 ONR: GE Vernova Hitachi's BWRX-300 completes Generic Design Assessment; December 2025; https://www.onr.org.uk/news/all-news/2025/12/ge-vernova-hitachi-bwrx-300-completes-gda

23 NUCNET:GE Vernova And OSGE Sign Polish Generic Design Agreement For BWRX-300; 25.02.2026; https://www.nucnet.org/news/ge-vernova-and-osge-sign-polish-generic-design-agreement-for-bwrx-300-2-3-2026

The operating pressure is 7.2 bar. The coolant inlet temperature is 270°C and the coolant outlet temperature is 287°C.

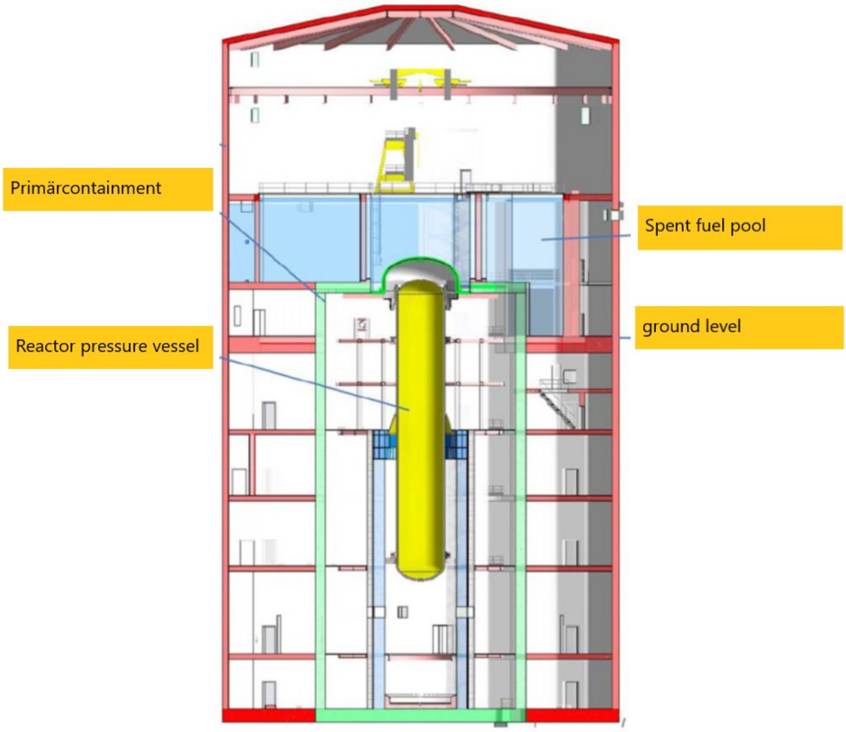



*Figure 1 Schematic illustration of the BWRX-300 (OSGE 2023)*

The spent fuel pool is located at ground level in the reactor building and has sufficient capacity for eight years' worth of spent fuel elements and for complete unloading of the reactor core.

The operation time of the BWRX-300 is at least 60 years. According to GVH, the operation time can be extended to 80 years, depending on operating history and system condition. (GEH 2023) The expected construction time is 30 to 36 months. The reactor has a modular design. The BWRX-300 is planned as a single unit.

The technology is still under development, so some challenges for the FOAK (=First-of-a-Kind) plant are unavoidable.

### 3.4 Key safety features

The management of severe accidents for the BWRX-300 is based on passive heat removal (through natural circulation) via the isolation condenser system (ICS) or the passive containment cooling system (PCCS). According to the manufacturer, neither core injection nor emergency power is required in the event of a loss-of-coolant accident (LOCA). The BWRX-300 design incorporates double reactor isolation valves (RIVs) in series which attach directly to the RPV. These valves are designed to close as part of the response to a LOCA. GVH claims the double RPV isolation valve configuration provides redundancy as each is capable of independently isolating a coolant pipe break.

A dry containment is used. Inerting the containment with nitrogen minimizes the risk of hydrogen explosions. It should withstand an earthquake with a PGA of 0.3g (SSE).

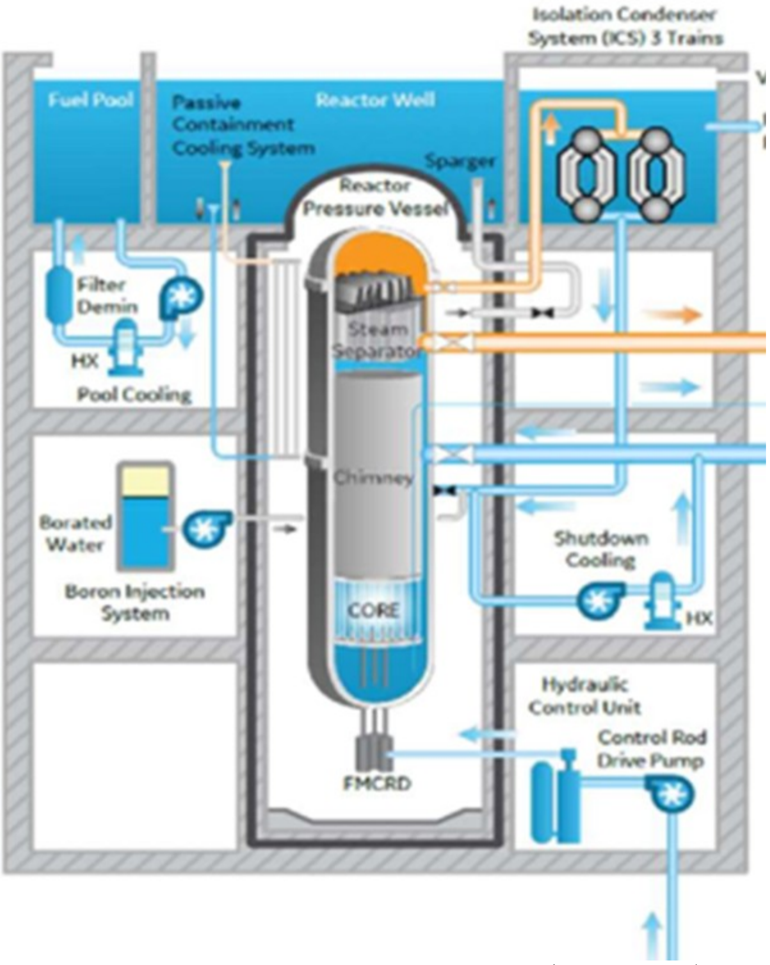



*Figure 2: Major Systems of the BWRX-300 (GEH 2023)*

Residual heat removal is ensured during primary circuit shutdown events via the **isolation condenser system (ICS)**. The heat is transferred to the IC pool, which is open to the atmosphere. The ICS is a natural circulation-driven safety system designed to provide emergency cooling of the reactor core, residual heat removal and overpressure protection of the RPV in the event of a loss of normal heat sink. The system consists of three identical and independent circuits, each consisting of: a pair of heat exchangers; an ICS pool above the containment in which the heat exchangers are immersed; steam supply and condensate return lines to/from the RPV, which supply both heat exchangers; for each supply/return line, a pair of RPV shut-off valves in series, which are integrated into the RPV, and a pair of parallel condensate return valves.

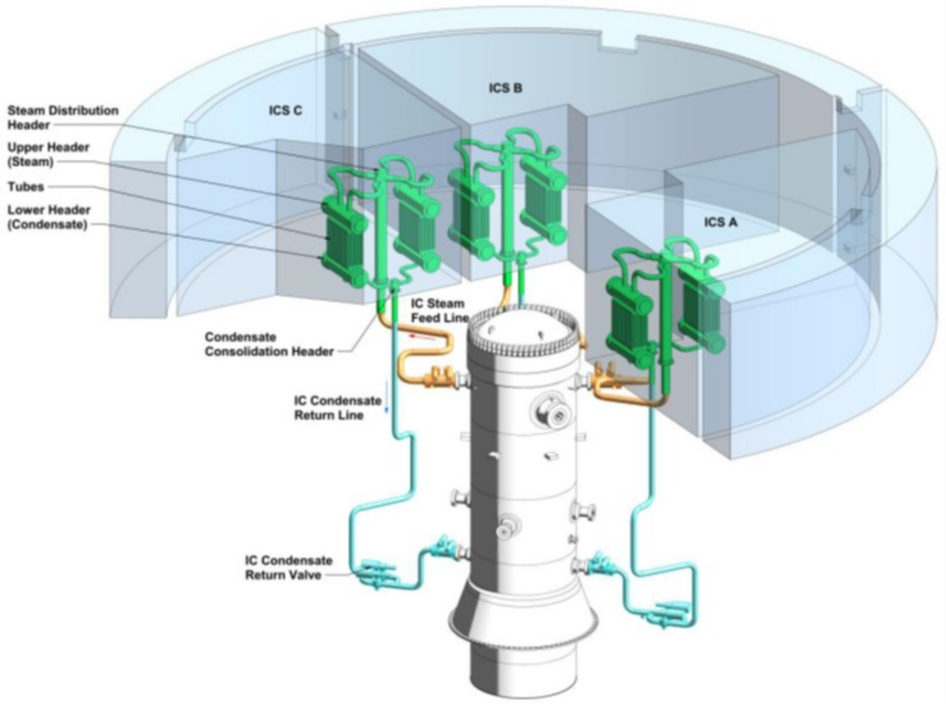



*Figure 3: Schematic diagram of the* ***isolation condenser system*** *(ICS) (GEH 2023)*

The ICS may be placed in service manually from the Main Control Room (MCR), automatically by the protection systems signal or by passive means if a loss of Direct Current (DC) power occurs (fail-safe).

Two ICS trains are required for LOCA mitigation (analysis assumes one ICS trains has a single failure). With two ICS trains in service, heat removal is sustained for seven days without operator action. All three ICS trains are credited for beyond design basis events. The heat rejection process continues for over seven days if the IC pool inventory is replenished. The ICS pools are located above ground and are not pressurized. Clean makeup water can be added directly to the ICS pools using readily available transportable sources such as a fire truck.

As a result of these innovations, the BWRX-300 design has eliminated safety relief valves and many of the active safety systems commonly installed on earlier generations of BWRs.

The **Passive Containment Cooling System (PCCS**) uses natural circulation to transfer heat from the containment building to a pool in order to maintain the pressure and temperature of the containment building within design limits in the event of accidents or failure of the active containment cooling system. The PCCS consists of several heat exchangers in the containment building which, in the event of a LOCA, transfer heat from the containment building to the water-filled reactor pool above the reactor pressure vessel (RPV). This is intended to ensure cooling for 72 hours without the need for measures of the personnel or AC power. PCCS operation does not require any sensors, controls, logic or electrically operated devices. Since there are no containment shut-off valves between the PCCS heat exchangers and the containment, the PCC is always in a 'standby' state. (WUA 2023)

### 3.5 Unproven reliability of passive safety systems

It is generally assumed that passive safety systems offer greater reliability than active safety systems. Natural circulation may be more reliable than a pump, but it is less clear how its reliability can be quantified. The forces that cause natural circulation depend on thermohydraulic factors that are not well understood and may be subject to significant uncertainties.
Passive systems can have a large intermediate state between the states "success" or "failure," which makes it difficult to integrate them into traditional safety analyses. Furthermore, a passive safety system may fail to perform its assigned function even in the absence of mechanical or electrical failure. This is because a passive safety system may rely on low-intensity phenomena (e.g., natural convection) that may be insufficient to perform its function under certain conditions. Such failures could occur if the phenomena involved are sensitive to system geometry (e.g., sensitivity to pressure losses), environmental parameters, and the discrepancy between design expectations and actual conditions, for example, due to external influences (climate, earthquakes, etc.).
The concept of "defense in depth" is the fundamental safety principle for nuclear power plants, even those that make extensive use of passive systems. The success of this safety concept is based on a sufficient degree of independence between the various safety levels. The BWRX-300 does not offer this independence between the safety levels.

### 3.6 Probabilistic safety analyses (PSA)

WENRA has published an analysis of the applicability of safety objectives for new reactors (WENRA 2013) to the safety assessment of SMRs (WENRA 2021b). It concludes that the safety objectives also apply to SMR concepts. The safety objectives include the practical exclusion of early and large releases in the event of a severe accident. According to the IAEA (2016), a situation can be considered practically eliminated if the occurrence of the event is either physically impossible or if the event can be considered extremely unlikely with a high degree of confidence. The term 'extremely unlikely' is not defined in more detail by the IAEA, nor is there currently an internationally accepted numerical definition.
GVH explained that the calculated core damage frequency (CDF) is smaller than $10^{-7}$ per year, the large release frequency (LRF) is smaller than $10^{-8}$ per year. To demonstrate the practical elimination of accident sequences that would lead to large early releases, GVH cites a general probabilistic value of less than $10^{-8}$/year for the BWRX-300 reactor type. The basis on which the probabilistic parameter estimates are based is not specified. The probabilistic value can only include the probability of internal events leading to large or early releases. Site-specific events that could potentially lead to severe accidents cannot be included, as assessments of site-specific hazards (natural hazards and man-made hazards, e.g. earthquakes, floods, explosions, aircraft crashes) are apparently not yet available. The contribution of the hazards mentioned to the risk of early or large releases can only be determined on the basis of detailed hazard analyses as part of a probabilistic safety analysis (PSA). It is not possible to prove the practical elimination of early and large releases solely by stating a probabilistic risk.
At this stage, it is not possible to assess whether accidents involving large or early releases can actually be practically eliminated for the BWRX-300.

### 3.7 Load-follow Operation

The BWRX-300 is primarily intended for base load operation. However, the BWRX-300 should also be capable of regulating the daily load to compensate for fluctuations in renewable energies. According to GVH, load following in the range of 50 to 100% of the output should be possible, with an output change of 0.5% per minute. (WUA 2023)
In general, operating a reactor in load following mode has technical disadvantages, as the plant components are exposed to numerous thermal stress cycles leading to faster ageing. (OECD/NEA 2011) Whether the observed and expected problems are reduced by the design of the BWRX-300 has not yet been proven and will have to be demonstrated in practice. In addition, load-follow operation has an economic disadvantage when the plants are operated at reduced power.
Load-following operation significantly impairs the operation of nuclear plants, as load reduction reduces profits. It also causes increased aging of components, thereby increasing operating costs. It should also be noted that insufficient maintenance and replacement of components can jeopardize the safety of the plant. In February 2026, the French operator EDF said it faces increased maintenance costs of around 1.5 million euros to 3.75 million euros a year as it has to reduce power at its reactors to respond to increased electricity supply of renewables.[24]

### 3.8 Standardization

The delays and cost overruns in nuclear projects are partly attributed to the large scale of on-site assembly work, which is said to be more efficiently organized in a factory. However, reactors always require extensive work on site, such as the power and water supply lines. For the BWRX-300, the ratio of factory to site activities is stated as 60 to 40. According to GVH, this is strongly influenced by the existence of a sea-based unloading facility at the site.
The main components of the BWRX-300 are to be manufactured in **specialized production facilities** and delivered to the site as prefabricated components ready for assembly. However, mass production would carry the risk of standardized errors. When manufacturing identical components, there is a risk that a design flaw will eventually occur in all plants whose components have passed through the production line in question. (THOMAS & SEQUENS 2023) This phenomenon was clearly evident in France in 2022, when a large number of reactors were shut down for safety reasons due to concerns about corrosion and cracking in stressed components. Although stress corrosion is a known phenomenon that had already occurred in other components of the French nuclear power plant fleet, this type of cracking was not expected in these plants. (ASN 2023; WNISR 2023)
Furthermore, even in industrial series production, there is a risk that components will not meet the required quality standards due to fraud and counterfeiting. (PISTNER et al. 2021) This has also already occurred on a large scale, e.g. in France. On 5 May 2016, the French Nuclear Safety Authority (ASNR) stated that ‘irregularities’ had been found in the manufacturing control records for around 400 components manufactured since 1965 at the Areva forging plant in Le Creusot, France.[25]

24 Reuters: France's EDF faces higher costs from electricity oversupply;16.02.2026; https://www.reuters.com/sustainability/climate-energy/frances-edf-faces-higher-costs-electricity-oversupply-2026-02-16/
25 NEI: Irregularities found at Areva’s Le Creusot forge; Nuclear Engineering International; 6 May 2016; https://www.neimagazine.com/news/newsirregularities-found-at-arevas-le-creusot-forge-4885947

### 3.9 Terror attacks

Many facilities in a modern industrial society are vulnerable to sabotage and terrorist attacks. Terrorist attacks or acts of sabotage can have a significant impact on nuclear facilities and thus also on the planned BWRX-300.

In terms of safety issues, SMRs, including the BWRX-300, offer no advantages over conventional nuclear power plants. The same concepts as for all nuclear power plants are required for the security concept. According to GVH, the **security concept** of the BWRX-300 is not disclosed to the public. The presentation therefore only contains general and partial information on the physical safety features. (GEH 2023)

- It is explained that all important facilities are located in areas where access is monitored and controlled. Most of the safety-relevant areas are located within the radiological control areas, which are not accessible during operation and are usually only entered during fuel element replacement.
- The safety concept and the physical separation of redundant systems, as well as simple passive safety systems, further support the physical safety of the facility, as several safety-relevant SSCs would have to be sabotaged in order to carry out effective radiological sabotage.
- Many components of safety-relevant systems are located below ground level, which reduces the risk of external threats.

Although part of the reactor is located below ground level (for cost reasons), the pools for the passive safety systems, which are essential for heat removal and the prevention of a serious accident, are located above ground level. The cooling pool for spent fuel elements is also located above ground level. The reduction in safety systems makes “successful” sabotage or terror attack easier. This is further facilitated by the factory manufacture of many components

The information provided by GVH clearly shows that the new reactor's **physical protection** requirements are largely based on previous requirements. However, an improvement of the previous physical protection system would be necessary for two reasons: Firstly, targeted terrorist attacks on nuclear facilities must also be considered possible in Europe. Secondly, it should be borne in mind in this context that kamikaze drones are used in a military context and could also be used by terror groups.

## 4 The Rolls-Royce (RR) SMR

The Rolls-Royce (RR) SMR is a single-module unit Pressurized Water Reactor (PWR) with an electrical output of 470 MWe. The Rolls-Royce SMR is being developed by the company Rolls-Royce in the United Kingdom (UK).

### 4.1 Licensing process and projects

On 10 June 2025, the British government announced that Rolls-Royce (RR) SMR had been selected as the UK's preferred bidder to build the country's first small modular reactors after a two-year competition. The British government pledged 2.5 billion pounds ($3.4 billion) for the SMR program over the next four years.[26] Rolls-Royce plans to build three SMRs with the state-owned company Great British Energy–Nuclear (GBE-N).

26 Reuters: Rolls-Royce denies report of IPO plans for small nuclear reactor unit; 30.08.2025; https://www.reuters.com/business/energy/rolls-royce-denies-report-ipo-plans-small-nuclear-reactor-unit-2025-08-30/

In November 2025, GBE-N has announced that the British government has selected Wylfa on the island of Anglesey in North Wales as the site for the UK's first RR SMR. The final contract with the SMR manufacturer and also the license are still pending. The initial project comprises three SMR units. GBE-N plans to start work at Wylfa in 2026. GBE-N's goal is for the SMRs to feed up to 1.5 GW into the grid from the mid-2030s onwards.[27]
Rolls-Royce SMR's technology has been selected by the **Czech Republic** to provide up to 3 GW of capacity in the country with nuclear power plant operator ČEZ, which has also taken a 20% stake in Rolls-Royce SMR.[28]

***Generic Design Assessment (GDA)***

The Environment Agency, the Office for Nuclear Regulation (ONR) and Natural Resources Wales (the regulators) have an assessment process - Generic Design Assessment (GDA) which enables them to scrutinize new nuclear power units designs before they are built in the UK. Step 1 of the Rolls-Royce SMR GDA (initiation) began on 3 April 2022. Step 2 of the GDA (fundamental assessment) began on 3 April 2023. Step 3 (detailed assessment) is ongoing. The assessment is likely to take about four years and is expected to be completed by 2026.

The GDA process focuses on the design of a generic nuclear power plant and is not site-specific. Due to its non-site-specific nature, the outcome of the GDA will be of limited use for Sweden, but it will enable potential critical issues to be considered. Some of the ONR's GDA assessments from Step 2 are briefly described in the following sections.

### 4.2 General Design

The RR SMR design is a small three-loop Pressurized ter Reactor (PWR) with design life of 60 years for non-replaceable components. The intended fuel is uranium dioxide (UO2). The reactor core consists of 121 fuel elements in a 17 x 17 configuration. The target burn-up is specified as 55-60 GWd/t, which is comparable to the values for large nuclear power plants.

The reactor is of a typical PWR design, including a steel Reactor Pressure Vessel (RPV) holding fuel assemblies, Steam Generators (SG), Reactor Coolant Pumps (RCP) and piping, all held within a steel containment. The reactor is equipped with a number of supporting systems for normal operation and a range of safety measures are present in the design to provide cooling, control criticality and contain radioactivity under fault conditions. Passive safety features are preferred to active components, reflecting the RR's design philosophy. One disadvantage of the RR SMR´s design is that the **forced circulation of the coolant** requires the use of active elements and has a negative impact on the reliability of the system.

The design of the RR SMR includes the following safety systems:

- Passive decay heat removal system (PDHRS)
- Passive containment cooling system (PCCS)
- Passive Emergency Core Cooling System (ECCS)
- Small Leak Injection System (SLIS)

The design includes passive reactor shutdown systems and passive core spray systems with only two redundancies (N+1). Furthermore, the concept of passive safety systems has not yet been tested in operation.

27 Nuklearforum Schweiz: Großbritannien: Wylfa wird Standort für erste SMRs von Rolls-Royce; 21.11.2025 https://www.nuklearforum.ch/de/news/grossbritannien-wylfa-wird-standort-fuer-erste-smrs-von-rolls-royce/

28 WNN: Rolls-Royce SMR and ÚJV Řež deepen collaboration, 28.11.2025; https://www.world-nuclear-news.org/articles/rolls-royce-smr-and-ujv-rez-deepen-collaboration

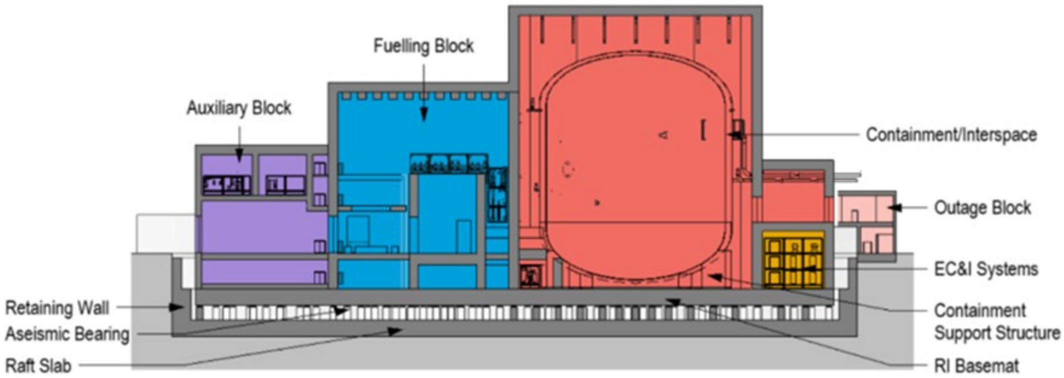



*Figure 4: Indicative Section Through Reactor Island Structures of the RR SMR* (ONR 2024c)

The RR SMR requires a site area of approximately 40,000 m³. The plant area is 10,000 m³. The RR SMR should operate in base load but **load following operation** in the range of 50–100% should also be possible (3–5% per min according to British grid code). This rate seems to be very fast compared to announced capability of other SMR designs. (see chapter 3.7) However, load-follow operation significantly impairs the operation of nuclear plants, as load reduction reduces profits and causes increased aging of components, thereby increasing operating costs.
An advantage of the RR SMR´s design is that it uses PWR technology, the most widely used concept for nuclear power plants. While the basic elements of the RR SMR reactor are typical of most PWR in operation today, there are some state-of-the-art innovations.
The RR SMR design adopts a primary circuit operating chemistry regime that differs from that of other operating PWRs in that reactivity control is achieved using control rods rather than through the addition of soluble boron to the primary coolant in normal operations.
The RR SMR uses a **boron-free primary circuit design**, in which toxic and corrosive boric acid has been removed from all operating systems. This reduces the power plant's overall water consumption and reduces wastewater generation. Boron-free operation also prevents dilution accidents.
Further work will need to be undertaken in Step 3 of GDA by the RR to develop the underlying evidence supporting the chemistry claims and arguments. Insufficient information was provided by the RR during Step 2 to form a judgement on the feasibility and implications of the shutdown chemistry approach. (ONR 2024b)
The reactor can be brought to a safe state for up to three days (72 h) without operator intervention in a design basis accident (DBA). However, this only applies to DBAs.

### 4.3 Management of Severe Accident

The Rolls-Royce SMR has several severe accident safety features. The design employs In-Vessel Retention (IVR) as its molten core (corium) cooling strategy. The corium is retained within the RPV and is cooled via ex-vessel cooling. Figure 5 shows a schematic diagram of the IVR.

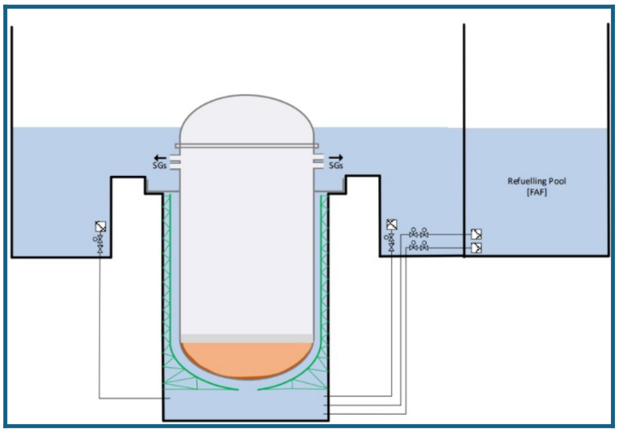


*Figure 5: Schematic Diagram of In-Vessel Retention* (ONR 2024a)

Steam generated from IVR and any released directly from the primary circuit is condensed by the Passive Containment Cooling (PCC) Heat Exchangers (HX) of the Local Ultimate Heat Sink (LUHS). The condensate then drains back into the Reactor Cavity via the containment sump. No containment spray is claimed during this mode. The containment sump is hydraulically connected to the Reactor Cavity during a severe accident, allowing the condensed water to be reused for IVR. The water which cools the containment atmosphere, which is on the inside of the PCC HX tubes, evaporates and exits the LUHS into the atmosphere.

Generally, during a severe accident in a PWR, there is potential for RPV failure whilst the reactor is still at high pressure. This can lead to high pressure melt ejection (HPME) of the corium from the RPV, which can challenge the containment. A decision has been made by the RR to include a severe accident depressurization function in order to avoid HPME. However, the design of this function is still in development.

Hydrogen generated during a severe accident could also pose a threat to the containment. The Rolls-Royce SMR design includes a Hydrogen Reduction System (HRS), consisting of Passive Autocatalytic Recombiners (PARs), located inside the containment.

ONR (2024a) concluded concerning severe accident management, that the RR has identified relevant severe accident phenomena that should be prevented/mitigated. The selected severe accidents sequences provide an adequate basis for the analysis provided during Step 2. However, the analysis has not been presented for assessment in Step 2.

It is explained that ONR (2024a) has confidence that the RR has a valid approach to demonstrate in Step 3 that the design practically eliminates sequences with the potential to lead to large or early releases. But further work is required. ONR highlighted that the justification for not installing a filtered containment venting system and containment leakage filtration is missing.

The Level 2 and 3 probabilistic safety analyses (PSA) have not been completed. ONR (2024e) concluded that there are limitations and gaps in various aspects of the PSA. According to RR, the calculated core damage frequency (CDF) and also the large release frequency (LRF) are smaller than $10^{-7}$ per year. (ONR 2024e)

The emergency planning zone (EPZ) for the RR SMR and the emergency preparedness measures will be determined later in the detailed design phase.

### 4.4 External hazards

A hazard shield, with various structures, systems and components (SSCs) located within it, formed from reinforced concrete walls and slabs, with the primary function to protect safety critical SSCs from external hazards including accidental and malicious aircraft impact. **Details of the layout are still being developed.**

*Figure 6: Extent of hazard shield shown in red (elevation on left (l), plan on right (r))* (ONR 2024c)

The reactor is designed to be protected from **external hazards** and the effects of ground movement. The design should withstand an earthquake with a PGA of more than 0.3g (SSE).

The hazard shield and reactor island are placed on a basement, which is supported by a seismic isolation system. The function of the seismic isolation system is to reduce the seismic demand to the majority of reactor island superstructures, including the reactor and spent fuel pool. The design employs low damping rubber bearings, and the proposals provide isolation in the horizontal direction only. Rolls-Royce SMR has contracted Skanska UK to deliver an aseismic bearing pedestal demonstrator for its SMR. These structural isolation devices are a key part of the factory-built nuclear power plant's design. Aseismic bearings are installed beneath the plant's nuclear island to decouple the reactor building from ground motion during an earthquake.[29]

High Extreme Ambient Temperatures (EAT) have the potential to increase heat loading on SSCs. Heating Ventilation and Air Conditioning (HVAC) and passive cooling systems have the function of protecting SSCs from excessive heating loadings, whether from internal or external sources. **The detailed design is ongoing.**

Several external hazards, e.g. extreme winds, lightning and Geomagnetically Induced Currents (GICs), have the potential to cause Loss Of Offsite Power (LOOP) and may also cause faults in electrical SSCs. Backup electrical supplies will be provided, including diesel generators. **Additional mitigations, such as diverse SSCs, may be provided but the detailed design for this is ongoing**.

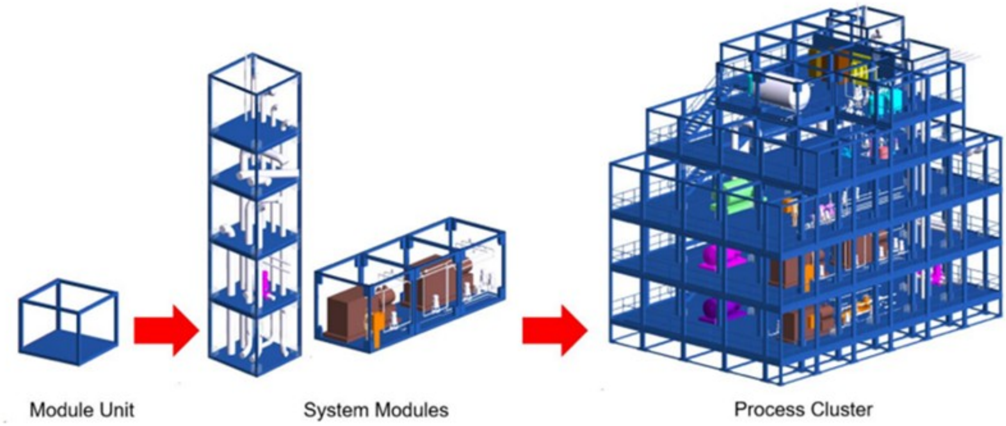
According to ONR (2024d), the technical quality of the RR's submissions has been to some specific shortfalls, e.g. **cliff edge methodology**. ONR has identified a number of challenges that the RR will need to address during Step 3, including the impact of the significant uncertainties that exist in estimating the effects of climate change.

29 WNN: Skanska to produce prototype aseismic bearing for Rolls-Royce SMR; 15 January 2026; https://www.world-nuclear-news.org/articles/skanska-to-produce-prototype-aseismic-bearing-for-rolls-royce-smr

According to ONR (2024d), for the GB NPPs the external hazards that pose the highest risk are typically seismic events and external flooding. The design of the RR SMR is 85% standardized and 15% site-specific.
It is explained that security measures are integrated into the plant design, e.g. entry and exit points of the buildings and structural resilience. According to ONR (2024f), the security features are not part of the early design. Security risks from sabotage of the plant and theft of nuclear material will only become apparent once the design has matured.

### 4.5 Modular design

Innovation comes in the form of its modular approach to construction which would see the majority of the power station built in factory conditions and assembled on site. The design is based on a modular construction with a high proportion of factory-made components in order to reduce construction time and costs. On-site activities are primarily limited to the assembly of **prefabricated**, pre-tested modules. According to RR, this concept minimizes the time required on site, as 90% of the manufacturing and assembly work is carried out under factory conditions.
The goal is an on-site construction time of around 500 days and a total construction time of four years, with two years for site preparation and another two years for construction and commissioning. The expected construction period does not apply for a FOAK plant.
The design includes road-transportable modules. The RPV diameter must not exceed 4.5 m to ensure that the British road transport height limit of 4.95 m is not exceeded.
The RR SMR design proposes the use of 'system modules'. According to RR, the benefit of this approach is that the modules can be assembled off-site and transported and installed upon delivery. This is a key feature of the RR SMR design that is a novel approach. The steel modules are also referred to as 'Mechanical Kit of Parts' (MKoP).
The design description explains the design of the 'process clusters' within the seismically isolated reactor island. It defines a process cluster as, 'the conglomeration of 'system modules' into discrete structural framing systems.' Figure 7 shows the terminology used for module combinations. The process clusters are anchored into the concrete structure at the base of the cluster only. For each process cluster, segregation concrete walls (barriers)




are provided.

*Figure 7: Assembly of Modules, System Modules and Process Clusters* (ONR 2024c)

At the time of ONR´s assessment during Step 2, the design is still under development. Also, the selection and location of internal hazards barriers within the process clusters is

not confirmed. Among others, ONR criticized the lack of any specific requirements for process clusters supporting the Main Control Room (MCR). ONR (2024c) has concluded based on its assessment: Further work is required to present a fully developed safety case.
According to Rolls-Royce its SMR is to be constructed using approximately 1,500 standard portable modules manufactured and tested in off-site factories.[30] Although RR has a plan and a preliminary concept for the modular construction method, according to the ONR there are still many questions and safety concerns regarding the assembly of the module on site. The necessary safety analyses have not been provided yet.
In addition, the safety concerns mentioned by ONR, there are some general concerns based on previous experience with standardized factory-made components (see chapter 3.8).
Above all, however, mass production would carry the risk of standardized errors. When manufacturing identical components, there is a risk that a design flaw will eventually occur in all plants whose components have passed through the production line in question. Furthermore, even in industrial series production, there is a risk that components will not meet the required quality standards due to fraud and counterfeiting.
According to RR, factory production allows for comprehensive quality control. While this is true, it also carries the potential for the same errors to occur in all standardized modules. In addition, quality-controlled components may be subject to damage during transport and installation.

## 5 Conclusions

Even as the evidence for the high costs and the long timeline for potential future construction becomes clearer, the industry, politicians, investors, and, last but not least, the media continue to portray SMRs as an indispensable and sure way to solve the climate emergency crisis.[2] An overview of SMRs in different countries shows that the reality about SMRs is far from the vision portrayed widely. One reason why these claims become more widely believed is the continued financial and political support offered to SMRs by multiple governments, some venture capitalists, and the nuclear industry itself.
Information about planned projects shows that the estimated costs for these projects also have skyrocketed. The cost increases for the BWRX-300 SMR project occurred before the design received licensing approval or construction begun. The Institute for Energy Economics and Financial Analysis (IEEFA) believes this should be a red flag for utilities, regulators and investors. The costs, already high, are likely to climb even higher.
The claim by SMR proponents that the reactors can be built quickly also stands in contrast to reality. Just as with the cost estimates, the rhetoric here does not correspond to reality. Long construction delays have been the norm, not the exception.
The hope held by SMR proponents that standardized factory production will reduce costs and construction time is highly questionable. However, this approach carries the potential for systemic flaws in reactors with identical standard designs. The potential risk that a problem identified in one SMR could affect the costs and possibly also the safety of other SMRs is not merely hypothetical. Due to the material and design choices made, the same problems have already occurred in many existing reactors worldwide. The measures required to address these systemic problems were both time-consuming and costly.
Based on current evidence and development status, SMRs are unlikely to provide a meaningful contribution to European energy system decarbonization within a relevant

30 RR SMR: Our technology, 2025; https://gda.rolls-royce-smr.com/our-technology

timeframe. Instead, continued attention towards their potential benefits will decelerate the necessary transformation of the energy system even further.

For Europe, the SMR hype stands in contrast with actual industry potential and various risks associated with SMRs. In February 2026, no SMR concept had been granted a construction license in the EU. The only SMR concept with ongoing construction activities outside of Russia and China, the BWRX-300 reactor in Canada, is yet to begin pouring concrete for the reactor housing. (WNISR 2025)

A recently published scientific publication critically assesses the prospects of SMRs in Europe. It finds that most SMR designs remain in early development, lack regulatory approval in the EU, and are unlikely to deliver electricity at scale before 2050. SMR concepts must still undergo an approval process in the EU. Once this step has been taken, additional site licensing, construction and commissioning steps will still be required. Electricity production from SMRs is unlikely to materialize at scale in the near term and remains decades away. If it occurs, it will come at very high costs. (BOELL 2026)

Measures and equipment for accident management similar to those for today's nuclear power plants are discussed in principle for SMR concepts. However, it cannot be conclusively determined at present whether such measures are going to be implemented in all SMR concepts, or whether some will not be implemented due to an expected higher reliability of other safety measures.

At this point in time, it is not yet possible to determine whether SMR designs will implement reliable accident management measures and equipment. Since the necessary regulatory framework does not yet exist, the safety level of SMRs cannot yet be conclusively assessed. Due to the presumed higher reliability of safety systems, manufacturers intend not to implement the safety features required for current nuclear power plants for cost reasons. This means that the risk posed by SMRs will likely continue to rise compared to modern nuclear power plants. It should be noted that external threats are continuing to increase, on the one hand due to climate change and on the other hand due to new weapons in the hands of terrorists (military drones).

The most significant design changes to the **BWRX-300** compared to its predecessor involve the removal of safety systems in order to achieve cost savings. However, it is not possible to reduce the number of safety systems without reducing the level of safety. At this stage, it is not yet possible to assess whether the respective licensing authorities will accept these design changes in the licensing process.

It is also noteworthy that the BWRX-300 is the only BWR among the advanced SMRs. Apart from two ABWRs, whose construction has been suspended in Japan, there are no other BWRs among the new construction NPP projects. This is also due to the fact that the BWR concept has been abandoned worldwide for safety reasons.

A key feature of the BWRX-300 is the use of passive safety systems (isolation condenser system (ICS) and passive containment cooling system (PCCS). It should be emphasized that the passive safety systems of the BWRX-300 have not yet been tested in operation. A passive safety system may not be able to perform its assigned function because it relies on low-intensity phenomena, which can be sensitive to environmental parameters or external influences (climate, earthquakes, etc.). Since the magnitude of the natural forces driving the operation of passive systems is relatively small, counteracting forces (e.g.

friction) can have a greater influence. The reliability of passive safety systems is therefore associated with greater uncertainties overall.
In contrast to the previous reactor type (ESBWR), the BWRX-300 is not equipped with a core catcher. It is assumed that the ICS provides sufficient cooling to make a core catcher unnecessary. However, it is not yet possible to conclusively assess whether this assumption is justified. In any case, the cost savings will lead to a reduction in safety. At this stage, it is not possible to assess whether accidents involving large or early releases can actually be practically eliminated for the BWRX-300.
For the BWRX-300, the level of protection against external hazards can only be assessed after the site-specific assessment has been conducted. The design of the BWRX-300 envisages that the primary containment is located below ground level. Whether this leads to additional external hazards, particularly from flooding events that are expected to occur more frequently and with greater intensity as a result of climate change, cannot be assessed at this time.
The licensing process for the BWRX-300 has not yet been completed in either the United States or Canada. To date, no European country has initiated the licensing process for this design.
The first reactor of this type is scheduled to go into operation in 2030 in Canada at the TVA site in Darlington. Whether this is really achievable cannot be said at this time, but based on the nuclear industry's experience to date, it is rather unlikely. Approval and construction in Sweden can or should presumably only begin after that, once the success and feasibility respectively of this project can be assessed.

Although the **Rolls-Royce SMR** is based on proven PWR technology, the overall modular concept and new production method are still new and therefore carry certain cost and schedule risks.
The RR SMR has a relatively high nominal output (470 MW) for an SMR. According to the IAEA classification, it would not belong to the category of SMRs. In addition, this reactor size could require extensive on-site assembly work. Therefore, it seems highly unrealistic to prefabricate 90% of the plant at the factory.
The RR SMR intends to use In-Vessel Retention (IVR) to prevent major radioactive releases in the event of a core meltdown accident. However, not all details have been worked out at this stage of the project. The safety concept cannot therefore be assessed as reliable at this stage, as it is still under development. There is no justification for omitting a filtered containment venting system. It remains to be demonstrated whether severe accidents that could lead to large or early radioactive releases are practically eliminated.
The RR SMR is said to have protection against external hazards. However, as the designs are not yet finalised, this cannot be assessed. In addition, the site assessment, which must be carried out, is also important for external hazards.
The approval process for the general design of the RR SMR is scheduled to be completed this year, but it is not yet clear whether this will be successful; many safety-related issues remain unresolved. Construction of three reactors is then scheduled to begin, with the reactors expected to start feeding electricity into the grid in the Mid-2030s.

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## 7 List of Figures

## Annex: Increasing risks associated with climate change

The main risk of nuclear power is the risk of severe accidents. On March 11, 2011, an earthquake measuring 9.0 on the Richter scale, and the subsequent tsunami caused a severe accident at the Fukushima 1 Dai-ichi NPP in Japan. Although this accident was caused by a tsunami, which is unrelated to climate change, this tragic event underscores the vulnerability of NPPs to extreme flooding. This potential hazard exists for the Ringhals NPP site.

There is no doubt that ongoing climate change poses an additional risk to nuclear power plants of all sizes. Many nuclear plants are built on coastlines where seawater is easily used as a coolant. Sea-level rise, shoreline erosion, coastal storms and heat waves – all potentially catastrophic phenomena associated with climate change – are expected to get more frequent as the Earth continues to warm.

### A.1 General Aspects

The IAEA distinguishes climate change related phenomena between Gradual Climate Changes (GCC) and Extreme Weather Events (EWE).

The main effects of Gradual Climate Change (GCC) are as follows:

Mean annual surface temperature: Even if the Paris Climate Convention is adhered to, temperature increases of well over +1.5 and +2°C must be expected on land. However, if we compare the emission paths necessary to achieve these goals with the ones actually adopted, we must continue to assume that climate scenarios will be much more extreme. (INRAG 2020)

Precipitation: Over the next few decades, it is very likely that the mean precipitation will increase in some regions. This leads to the fact that even without extreme precipitation intensities, extreme amounts of precipitation can occur due to the long duration of the rainfall.

Sea level rise: Driven by climate change, global mean sea level rose 11–16 cm in the twentieth century. Even with sharp, immediate cuts to carbon emissions, it could rise another 0.5 m this century. Under higher emissions scenarios, twenty first century rise may approach or in the extremes exceed 2 m in the case of early-onset Antarctic ice sheet instability. Other experts derive a possible non-linear rise in sea level of 1 m until 2060 from ice surface losses in Greenland, and a rise of another 1.4 m within the following decade, i.e. 2.4 m to about 2070. These are extreme values, but they are derived from observations, while the conservative IPCC data have been calculated from models known not to reflect melting processes sufficiently well. (INRAG 2020)

The main effects of Extreme Weather Events (EWE) are as follows:

Some types of extreme weather events are happening more often or are becoming more intense because of global warming.[31] More than 90 % of the natural disasters are related to weather. The dominant disasters are storms and flooding.

Temperature extremes: As global mean temperatures increase, there will be more frequent hot temperature extremes over most land areas on daily and seasonal timescales. Nonetheless, occasionally cold winter extremes will occur even in a warming world.

Precipitation extremes: It is likely that the frequency and intensity of heavy precipitation events will increase over land in the coming decades. It is likely that total atmospheric

31 Global warming also increases water vapor in the atmosphere, which can lead to more frequent heavy rain and snowstorms.

water vapor has increased several percent per decade over many regions of the Northern Hemisphere.
Higher average wind speeds brought on by changing climate can have some impact on NPPs. For plants near the coast, more persistent wind and fog can, over time, carry additional salt spray to those plants. Salt deposited in this way on exposed cables and metal parts will lead to faster corrosion and, potentially, to short circuits if the deposits are not cleaned regularly.
Sea level extremes: Driven primarily by an increase in mean sea level and by the drastically decreasing return periods of extreme events, a significant increase in the occurrence of future sea level extremes is projected by the end of the twenty-first century. Although sea level rise has not yet affected nuclear plants, in combination with storms could lead to site inundation.

### A.2 Impact of climate change on NPPs

Scientific evidence and recent catastrophes call into question whether nuclear reactors could function safely in our warming world. The climate change affects nuclear energy production in several ways, including

1. The efficiency of nuclear power plants decreases with increasing temperature.
2. Some sites may lose safety, with sea-level rise being of particular importance.
3. Extreme weather events threaten the safety of NPPs additionally.

The loss of efficiency of nuclear power plants as well as location issues are primarily associated with gradual climate changes (e.g. gradual warming), while safety issues are linked to extreme events. However, gradual climate change and extreme events are linked – rising sea levels, for example, also lead to extreme water levels during storms. Many acute safety threats from EWEs can be minimized by shutting down nuclear reactors until an event has passed, but this strategy leads to increasing outages as climate change and thus decrease the profits and increase the costs.
Flooding is one symptom of our warming world that could lead to nuclear disaster. The expected main effects of flooding on nuclear reactors are as follows:

- The presence of water in many areas of the plant may be a common cause of failure for safety related systems, such as the emergency power supply systems
- Considerable damage can also be caused to safety related structures, systems and components (SSCs) by the infiltration of water into internal areas of the plant, induced by high flood levels caused by the rise of the water table. Water pressure on walls and foundations may challenge their structural capacity. Note: This could be an issue for the BWRX-300, which is partly built under ground level.
- The dynamic effect of the water can be damaging to the structure and the foundations of the plant as well as the many systems and components located outside the plant.
- A flood may transport ice floes in very cold weather or debris of all types which may physically damage structures, obstruct water intakes or damage the water drainage system.
- The effects of flooding may jeopardize the implementation of safety related measures by operators and the emergency planning by making escape routes impassable and isolating the plant site in a possible emergency, with consequent difficulties in communication and supply.

However, given the current cost pressures, there is concern that many flood protection measures will not be fully implemented, as this would further increase the already high costs, thereby posing a risk of flooding.