SNETP
Sustainable Nuclear Energy Technology Platform

The last decade has seen an increased interest in SMRs or small modular reactors. These small standardised reactors tackle the financial-burden currently observed in large nuclear projects. They also provide increased flexibility to balance the ever complex-to-manage electricity demand. SMRs offer new ways of producing and consuming nuclear energy, paving the way for industrial customers and emerging nuclear countries.

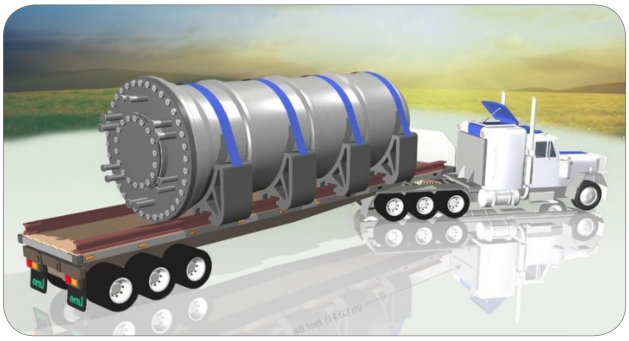
Nuclear Energy Factsheets

Small Modular reactors

In the early decades of today's nuclear sector, small units were the norm. Driven by the benefits of economies of scale, the nuclear industry has consequently up-scaled the size of reactor units: from the 50 MWe-range in the 1950s, reactors grew to the 1000-1600 MWe units that are common nowadays.

The concept of small reactors is being revived in the global context of reaching zero greenhouse gas emissions and decentralised energy sources. In addition, its modularity is an asset that boosts its competitiveness on the market.

Today what is commonly referred to as small modular reactors are advanced reactors with a power output ranging generally between 10 and 300 MW(e), which are designed to be built in factories and shipped to utilities for installation as demand arises [1].



SMR is not a product, it's an approach!

Several types of SMRs are being developed: the SMR concept encompasses a variety of different technologies. From evolutionary designs inspired by the wide operating fleet of water-cooled reactors to promising technologies of next-gen nuclear reactors, also known as Generation IV, more than 40 SMR designs have seen the light of day over the last 15 years.

Why have smaller units?

The SMR concept is an answer given by the nuclear industry to address the energy transition challenges.
SMRs tackle the financial-burden of large scale nuclear endeavours. They bear lower financial risk because lower upfront capital investment is required and the risk of delays during the construction phase is decreased.

Key features of SMRs are their modularity and scalability: vendors are developing standardised reactor modules designed to be manufactured directly on an assembly line. These modules allow for reduced construction activities once they are shipped on site. Thanks to this modular conception, SMRs offer the possibility to rapidly add generating capacity while the first unit(s) are already generating revenues.

A complementary solution to renewables

Nuclear energy has played a proven role in lowering the CO_2 emissions induced by the world electricity production. With CO_2 emissions comparable to renewables over the entire life cycle, SMRs can contribute to the decarbonation of the energy mix that is necessary to mitigate climate change.

As a general trend, SMRs aim at flexibility: most designs feature load-following and grid-balancing capabilities. Due to the increasing share of renewables in the energy mix, the electricity production may not be able to match the grid demand at all times. SMRs are designed as a mean to accommodate that production intermittency, which makes them an ideal low carbon partner of renewable energy sources.

A new business paradigm?

With their low energy output, SMRs are paving the way towards new markets: they are suitable for transmission grids which cannot cope with the concentrated large electrical outputs, as in emerging countries or remote regions of developed countries.

SMRs also offer alternatives for industrial energy customers (e.g. petrochemical industry) when comparing different energy sources. SMRs can provide heat in the form of steam, enabling process heat applications such as mining operations or even hydrogen production.

Bringing drinking water to regions in need

One promising process heat application for SMRs is seawater desalination. The size and features of SMRs are ideally suited to feed desalination plants, generating a growing interest in SMRs as a sustainable solution to water scarcity. This is particularly true in regions of Asia, Africa and the Middle East where access to drinkable water is becoming critical problem and slowing down the development of local populations.

The main SMR technologies

Diversity is the rule among small reactors. Floating power plants, nuclear «batteries» without the need for refuelling, and cogeneration plants are all examples of SMR concepts that are being studied. The following reactors are some of the flourishing SMR technologies.

Integral Pressurised Water Reactor (iPWR) are evolutionary designs inherited from the current and previous generations of water reactors. Powered by conventional fuel assemblies, iPWRs result from a system simplification and miniaturisation of the most common type of nuclear reactor. Although the system configuration is completely innovative, like in other reactor technologies, the iPWR benefits from a long operating experience, an established know-how and a mature technology.

In High Temperature Gas-cooled Reactors (HTGR), the usual water coolant is replaced by an inert gas (e.g. helium). Their higher operating temperature provides two advantages: it enhances the thermodynamic conversion of heat released by the nuclear chain reaction into electrical power and opens the door for new process heat applications, such as hydrogen production. Finally, HTGRs use a new type of fuel that is particularly robust, even under the worst accidental conditions: this makes HTGRs intrinsically safe.

Molten Salt Reactors (MSR) use liquid fuel in their conceptual formulation, instead of the solid fuel found in other reactors. This liquid fuel makes MSRs inherently safe thanks to their good thermal and neutronic properties. It also enables a more sustainable use of fuel resources: liquid fuel can be reprocessed and recycled more easily, a process that is even possible online for such reactors.
Although, in terms of safety, an MSR will face a combination of safety aspect to both the reactor technology and fuel reprocessing.

Liquid Metal Fast Reactors (LMFR) are powered by a chain reaction sustained by high energy neutrons. They use a liquid metal coolant – sodium, lead or lead-bismuth – which avoids the slowing down of neutrons occurring in conventional nuclear reactors. Thanks to these fast neutrons, fast reactors can induce fissions of transuranic elements that are high contributors to the radioactivity of nuclear waste. LMFRs are thus effectively able to convert nuclear waste into watts.

Passive safety

Despite the different technologies, most SMRs share a common approach to safety. The current generation of reactors achieved improved safety through complex engineered features and backup systems, planning for every imaginable scenario. SMRs on the other hand aim at inherent safety through simple and passive systems which rely on never-failing physical phenomena (e.g. gravity or natural convection) rather than mechanical components. This means SMRs do not need external power sources, such as grid electricity nor diesel generators, to perform the critical safety function of cooling down the reactor after shutdown.

When will we see SMRs?

Prototype SMRs have been under construction since the mid-2010s in Russia and China and are expected to produce power before 2020. In US, Northern America, and Argentina the first commercial units will become a reality in the mid-2020s.

SMRs are not just ideas on a sheet of paper anymore with first-of-a-kind units just around the corner…

REFERENCES

[1] International Atomic Energy Agency, "Advances in Small Modular Reactor Technology Developments", 2016

[2] IAEA Advanced Reactors Information System ARIS website (https://aris.iaea.org/), last consulted in May 2018.