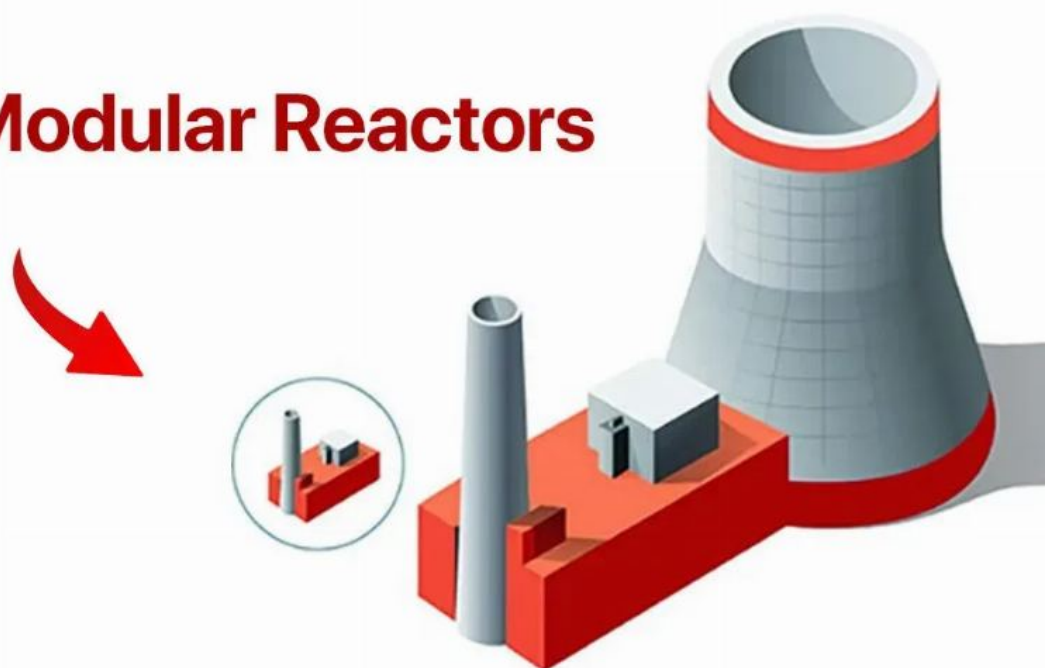


Small Modular Reactors India, Capacity, Types, UPSC Notes

July 10, 2026 • vajiramandravi.com



Small Modular Reactors



Small Modular Reactors are nuclear fission reactors with a power generation **capacity of up to 300 MW**. These types of nuclear reactors are characterised by their simplicity of design, factor-assembled production capacity, scalability, modularity, standardisation, cost-effective operation, short construction duration, etc. SMRs are an innovative solution that has the potential to reshape power generation and usage.

Nations around the world, including India, have committed to a Net Zero target for carbon emissions. In such a scenario, SMRs, despite having many practical challenges, can become a viable option for providing clean energy.

Small Modular Reactors Meaning

Based on power generation capacity, the International Atomic Energy Agency (IAEA) has defined **Small modular Reactors** as those nuclear power plants that produce electricity of up to 300 MW(e) per module, around one-third of the generation capacity of the traditional nuclear plants. The term SMR consists of **three terms** with independent meanings.

- **Small:** It is about the physical size of (SMRs) which is just **much smaller than conventional nuclear power reactors**.
- **Modular:** It is about making systems and components **factory-assembled and transported** as a unit to a location for installation.
- **Reactors:** It is about harnessing **nuclear fission** to generate heat to produce electrical energy.

Small Modular Reactors Working

The basic working principle of SMRs is similar to a typical nuclear fission reactor in controlled fission. Thus, there are three basic working steps of SMRs, being described below:

- **Heat generation:** Nuclear Power Plants generate heat through the **fission reaction** taking place in the reactor core, releasing in a controlled manner.
 - **A controlled rod** absorbs the extra neutron to maintain a controlled chain reaction and provide sustained energy.
- **Steam generation:** The Reactor's water coolant picks up heat from the reactor core. The coolant's pumps circulate this hot water through a steam generator, which converts water in a secondary loop into steam.
- **Mechanical energy to electrical energy:** Steam generated is used to derive turbines, which consequently convert to electrical energy.

Categories of Small Modular Reactors

As of now, only two SMR projects are in the operational stage globally - **Russia's Akademik Lomonosov plant** (a floating SMR) of **35 MW** capacity and **China's HTR-PM of 210 MW** capacity. Based on location, size, and coolant types, SMRs can be categorised into the following types:

- **Land-based water-cooled SMRs (PWRs):** These include water-cooled SMR designs of various configurations of LWR (Light Water Reactors) and PHWR (Pressurised Heavy Water Reactors).
 - **Example:** RITM-200N (project stage) in Russia.
- **Marine-based water-cooled SMRs (PWRs):** These include SMR designs for deployment in marine environments. This can be achieved in the form of floating units installed on barges or ships.
 - **Example:** **SMR KLT-40S**, a floating SMR in Russia.
- **High-temperature gas-cooled SMRs (HTGRs):** SMRs in this category can provide very high-temperature heat of more than 750°C, to be able to generate electricity at higher efficiency.
 - These SMRs can also be employed in many industrial applications and cogeneration.
 - **Example:** **HTR-PM (China)**
- **Liquid metal-cooled fast neutron spectrum SMRs (LMFRs):** They are based on fast neutron technology and use liquid metal coolants (sodium, lead, and lead-bismuth alloy) and Helium.
 - **Example:** **BREST** reactors (planned) in Russia
- **Molten Salt Reactor SMRs (MSRs):** They are based on molten fluoride or chloride salt coolants.
 - MSR based on both thermal neutron and fast neutron spectrums are in the development phase.
 - MSRs can sustain longer fuel cycles of several years.
- **Microreactors (MRs):** These are very small reactors that generate power **up to 10 MW(e)**.

- Various coolant options such as light water, molten salt, and liquid metal can be adopted by microreactors.

Small Modular Reactors Significance

SMR-based power plants offer unique advantages in terms of safety, efficiency, economics, and flexibility of operation.

- **Advanced safety features:** SMRs are designed to include several **passive safety features** to ensure lower risks for the uncontrolled release of radioactive materials into the environment, during any accident.
 - It has a relatively smaller **core damage frequency** and **source term** compared to **conventional** Nuclear Power Plants.
 - **Core damage frequency** is the likelihood that an accident can damage the nuclear fuel. **The source term** is a measure of radioactive contamination.
- **Economical and efficient:** Serial manufacturing models for SMRs can simplify plant design to reduce manufacturing costs. Moreover, off-site development of SMRs further reduces the cost.
 - **Brownfield project:** SMRs can be installed into an **existing grid or, a decommissioned thermal power plant**, as a discrete unit of power generation.
 - **SMRs overcome transportation limits:** 80% of SMR plants can be modularised and transported by road due to their smaller size, compared to only 20% for large reactors.
 - **Hybrid energy system:** SMRscan be paired with other sources of electric energy and increase the efficiency of renewable sources in a hybrid energy system.
- **Reduced fuel requirement:** Power plants based on SMRs require refueling every 3 to 7 years in comparison to between 1 and 2 years for conventional nuclear power plants.
 - SMRs are designed to operate for up to 30 years without the need for refueling.
 - Also, **SMRs are designed for low-enriched uranium.**
- **Decarbonising the power sector:** SMRs can play a meaningful role in reducing carbon emissions and can act as alternative sources of sustainable energy, better than conventional nuclear power plants.
 - It is also instrumental in attaining **Sustainable Development Goals** (SDGs) and helps to realise the goal of developing safe, clean, and affordable nuclear power options.

Challenges Associated with Small Modular Reactors

Along with their advantages and rising popularity, SMRs also face several regulatory, technical, and operational challenges.

- **Need for an efficient regulation regime:** The application of uniform regulation and safeguard standards across the world is crucial to the safe functioning of the overall ecosystem of SMRs.
- **Licensing challenge:** Newly developed SMR technologies may find it difficult to accommodate in the current **licensing regime.**
- **Radioactive Radiation:** SMRs are said to produce more radioactive waste than conventional ones, mainly in the form of spent fuel.
 - This can lead to serious health hazards, such as mutations in genetic material.

- **Potential nuclear disaster:** Nuclear power has faced opposition due to past nuclear hazards and potential disasters. In such a sceptical environment, convincing people to mainstream SMRs for decentralised power generation is a challenge.

Opportunities for India

The Indian Government has also acknowledged the advantages and opportunities of SMRs as a promising alternative to large reactors.

- **Carbon offsetting:** India has committed to achieve carbon neutrality by 2070. In such a scenario, various types of SMRs, such as microreactors, can be a viable option for offsetting carbon.
- **Utilisation of Decommissioned Power Plants:** Indian public sector units such as NTPC, and BHEL, etc. can use decommissioned areas for the installation of SMRs as a viable alternative to large-scale reactors.
- **Distributed Generation: Microreactors and other SMRs** can accelerate access to energy infrastructure in hilly and remote areas, such as the **Northeastern region**, to fulfill energy needs.
- **Nuclear-powered Submarine:** Modular reactors can be a key technology for the development of nuclear submarines such as **INS-Arihant**, thereby boosting India's Nuclear triad.

The Government has been developing a roadmap for studying the feasibility and effectiveness of the deployment of SMRs. A report published by NITI Aayog emphasises the successful deployment of SMR technology, leveraging private sector inclusion.

Small Modular Reactors UPSC PYQs

Question 1. With growing energy needs should India keep on expanding its nuclear energy programme? Discuss the facts and fears associated with nuclear energy. **(UPSC-Mains 2018)**

Question 2. The function of heavy water in a nuclear reactor is to **(UPSC-Prelims 2011)**

- (a) Slow down the speed of neutrons
- (b) Increase the speed of neutrons
- (c) Cool down the reactor
- (d) Stop the nuclear reaction

Answer: (a)

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