US-India Nuclear Cooperation and Small Modular Reactors

For Prelims: **Small modular reactor**, **Uranium**, **Fossil fuels**, **Artificial Intelligence** , **India-U.S. Nuclear Deal**, **Nuclear Non-Proliferation Treaty** , **International Atomic Energy Agency**

For Mains: Developments Related to India's Nuclear Energy, Ways to Enhance India's Nuclear Power Capacity.

Source: IE

Why in News?

Recent developments indicate a **revitalization of the civil nuclear deal between India and the United States (US)**, with **Holtec International's small modular reactor (SMR-300)** at the forefront.

- Holtec aims to collaborate with India to meet energy demands of India and advance clean energy goals by **utilising existing coal plant sites** for SMR deployment and exploring joint manufacturing, thereby aligning with **India's clean energy transition objectives.**

What is the SMR-300?

- **About:** The SMR-300 is an advanced pressurised **light-water reactor** that uses **low-enriched uranium fuel** to produce at least 300 megawatts (MWe) of electric power through **fission**.
- **Compact Design:** The SMR-300 requires significantly **less land** compared to traditional reactors, making it suitable for existing coal plant sites in India.
- **Support for Clean Energy Transition**: This technology is pivotal for India's clean energy goals, offering a competitive **alternative to fossil fuels** in the face of increasing energy demands, especially from technology sectors like **Artificial Intelligence** and **data centres.**
    - By developing SMRs, India aims to position itself as a **credible alternative in the global nuclear market,** competing against established players like Russia and China.
- **Challenges in Implementing SMR-300 in India:**
    - **Civil Liability for Nuclear Damage Act, 2010:** This legislation creates challenges for foreign nuclear suppliers by **placing liability primarily on equipment manufacturers.**
        - As a result, many potential partners are **hesitant to invest in India's nuclear sector** due to concerns about potential financial liabilities arising from accidents.
    - **Export Regulations:** The **US Atomic Energy Act of 1954** restricts US companies like Holtec from manufacturing nuclear equipment in India, complicating the potential for local production of SMR components.
    - **Legislative Limitations:** India's existing legislative framework **lacks the flexibility to amend liability laws,** hindering smoother collaboration with foreign entities.
    - **Future Prospects for SMR-300 in India:** Collaborating on SMR technology could enhance US-India ties, addressing both nations' technological constraints and labour cost challenges.

India-US Nuclear Deal

- The India-US Nuclear Deal **also known as the US-India Civil Nuclear Agreement,** was signed in 2008. This agreement stemmed from a joint statement made in 2005 by then Indian Prime Minister Manmohan Singh and US President George W. Bush.
  - The agreement aimed to facilitate **civil nuclear cooperation between the two countries,** marking a significant shift in US policy, which had previously **restricted nuclear trade with India** due to its non-signatory status to the **Nuclear Non-Proliferation Treaty (NPT).**
- The India-US nuclear deal, often referred to as the **"123 Agreement,"** allows US companies to supply **nuclear fuel and technology** for India's civilian nuclear energy program.
- As a part of India-US Nuclear Deal, India committed to allowing inspections from the **International Atomic Energy Agency (IAEA)** for its civilian nuclear program.
- **Benefits to India:** India gained eligibility to buy US **dual-use nuclear technology,** including materials and equipment for **uranium enrichment** and plutonium reprocessing.
  - The deal was expected to enhance India's energy security and help meet its growing energy demands through nuclear power.

What are Small Modular Reactors (SMRs)?

- **About:** According to the **IAEA**, small modular reactors (SMRs) are advanced nuclear reactors designed for enhanced safety and efficiency. Their power generation capacity typically ranges from **less than 30 MWe to over 300 MWe**.
- **Features:**
  - **Small**: Physically smaller than conventional nuclear power reactors, allowing for flexible deployment in various locations.
  - **Modular**: Designed for factory assembly, enabling transportation as a complete unit for easier installation.
  - **Reactors**: Utilise nuclear fission to generate heat for electricity production or direct applications.
- **Global Status of SMR Technology:** Globally, there are **over 80 SMR designs in various stages of development** and licensing, with some already operational. These designs fall into several categories.
  - **Land-based Water-Cooled SMRs**: Include designs like integral pressurised water reactors (PWRs) and boiling water reactors (BWRs) utilising mature technologies.
  - **Marine-Based Water-Cooled SMRs**: Designed for deployment in marine environments, such as floating units installed on barges or ships.
  - **High-Temperature Gas-Cooled SMRs (HTGRs)**: Capable of producing heat over **750 degrees Celsius**, making them efficient for electricity generation and various industrial applications.
  - **Liquid Metal-Cooled Fast Neutron Spectrum SMRs (LMFRs)**: Utilise fast neutron technology with coolants like sodium and lead.
  - **Molten Salt Reactor SMRs (MSRs)**: Employ molten fluoride or chloride salts as coolants, allowing for long fuel cycles and online refuelling capabilities.
  - **Microreactors (MRs)**: Extremely small SMRs designed to generate electrical power typically up to **10 MWe** using various coolants.

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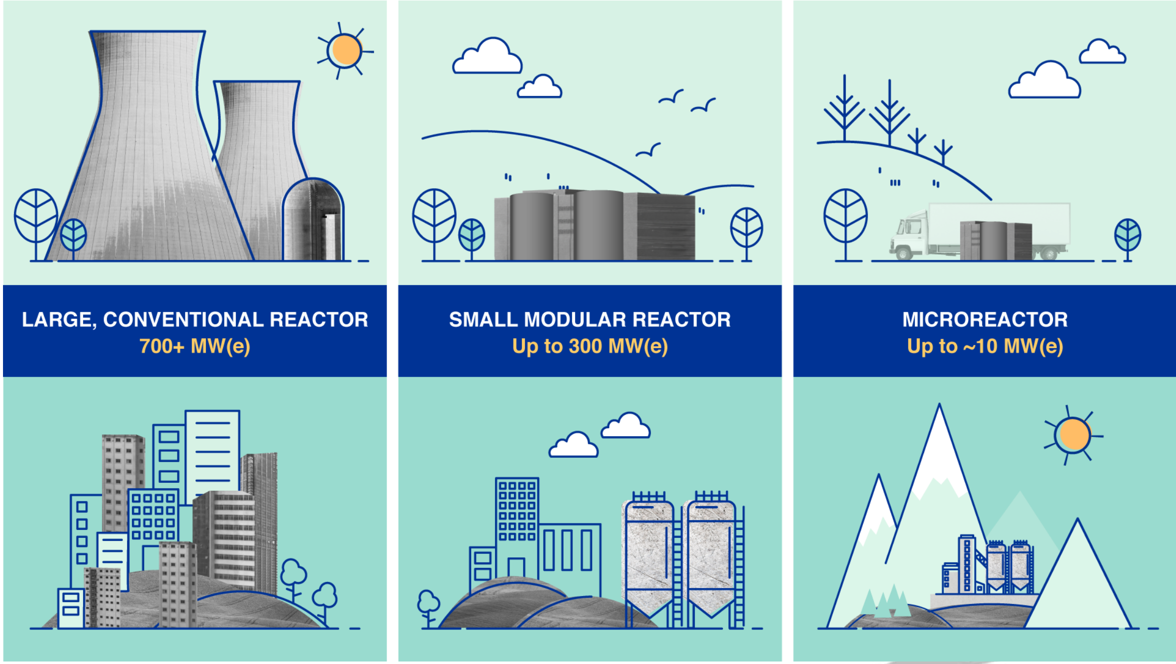

Note:

- As of now, two SMR projects have reached the operational stage globally. **Akademik Lomonosov floating power unit in Russia** and **high-temperature gas-cooled (HTGR) pebble-bed** in China.

What are the Benefits and Challenges of SMRs?

Benefits of SMRs	Challenges Associated with SMRs
SMRs can be **scaled up or down** to meet varying power needs. Can supplement existing power plants with **zero-emission fuel** or repurpose ageing thermal power stations.	Numerous SMR technologies have varying regulatory requirements. Prioritising the right technology and **improving Technology Readiness Levels (TRLs)** is crucial for large-scale deployment.
SMR-based power plants can refuel every 3 to 7 years, compared to 1 to 2 years for traditional plants, with some designed for up to 30 years without refuelling.	Supply chain issues are crucial for SMR competitiveness. More efforts are needed to build resilient global supply chains
SMRs utilise **passive safety features** that rely on physics to shut down and cool the reactor without **needing power or human intervention,** ensuring inherent safety.	SMRs generate **radioactive waste** requiring storage and disposal facilities, which can provoke socio-political resistance.
Can be integrated with renewable energy sources, providing low-carbon co-products. Mitigates fluctuations in energy supply on daily and seasonal bases.	Lack of experience with innovative designs complicates safety standard approval. Public opposition may arise from fears of nuclear disasters, necessitating effective awareness and engagement to address concerns.

What are the Challenges in India's SMR Development Aspirations?

- **Technological Disparities:** India's current nuclear technology, primarily based on **heavy water and natural uranium**, is increasingly out of sync with the globally dominant **light water reactors (LWRs).**
  - Transitioning to SMRs, which may utilise different fuel types, requires significant

technological adaptation and expertise development.

- **High External Costs:** While SMRs are designed to be economically feasible, the **associated costs of building safe reactors** and managing spent nuclear fuel can significantly **inflate project expenses,** complicating economic viability.
- **Regulatory Hurdles:** Existing nuclear regulatory frameworks are primarily designed for **large reactors,** necessitating updates to accommodate SMR-specific features.
  - The establishment of a comprehensive regulatory framework that addresses diverse SMR technologies and designs is crucial.
- **Public Acceptance and Safety Perceptions:** Lack of **public familiarity** with innovative SMR designs may lead to safety concerns and opposition due to fears of **nuclear disasters like Chernobyl Disaster.**
- **Human Resource Development:** Significant investment in infrastructure and manufacturing facilities is needed to support SMR deployment. India lacks a skilled workforce with expertise in SMR operations is essential for the technology's successful implementation and sustainability.

Way Forward

- India should construct SMR **prototypes to validate designs and operational reliability.** Aim for the first-of-a-kind SMR units to be operational by the early 2030s, facilitating the energy transition.
  - Review and update existing nuclear regulations to accommodate innovative SMR designs. Establish a comprehensive regulatory framework under the **Atomic Energy Regulatory Board** to ensure safety standards.
- Develop innovative financing models, including **green finance options,** to attract private investment and mitigate project risks.
- Identify skill gaps and implement training programs for SMR operations through **Bhabha Atomic Research Centre (BARC).**
- Develop strategies to strengthen nuclear supply chains for consistent SMR production. Integrate safeguards into SMR designs in collaboration with the **IAEA and other countries** to address non-proliferation concerns.

Drishti Mains Question:

What challenges does India face in transitioning to small modular reactor (SMR) technology, and what steps should the government take to promote their successful deployment?

UPSC Civil Services Examination, Previous Year Questions (PYQs)

Prelims

Q. The function of heavy water in a nuclear reactor is to (2011)

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

Ans: (a)

Mains

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