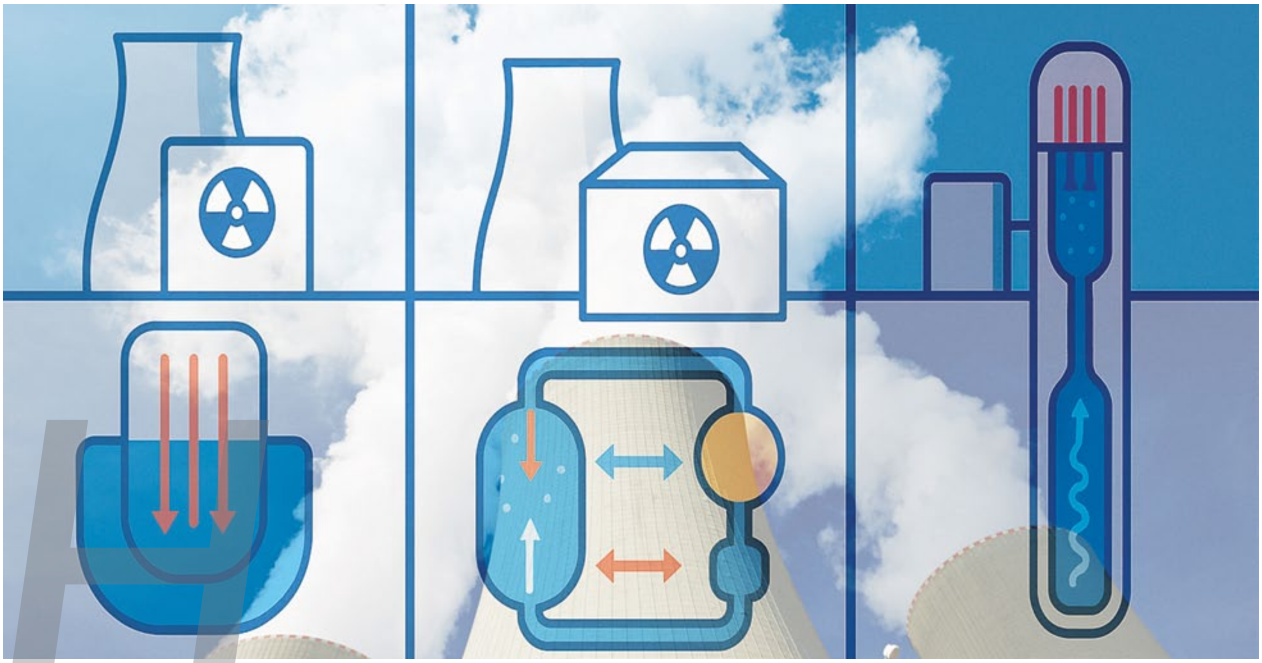
Is Nuke the Next Normal?

All SMRs utilise nuclear energy, but not all SMRs function the same way. Which one do you prefer?

By Raju Chellam



Here's a radiation report with a goofy twist: A doctor points out an X-ray to a group of interns during morning rounds. "As you can see, this patient is limping because his left fibula and tibia have hairline fractures." He then points to one intern: "Dan, what would you do in a case like this?" Taken aback at suddenly being arrowed, Dan blinks like a deer caught in the headlights. "Guess I would be limping too."

If that joke made you blink, these statistics should make you think: Investments in AI solutions and services are on track to generate a cumulative US$22.3 trillion in products and services by 2030. They will account for about 3.7% of the global GDP by then, according to the latest estimates from International Data Corp (IDC).

"Continuous business innovation through the use of AI, accelerated by growing use of AI Agents, is driving greater direct investments in infrastructure and software," says Rick Villars, IDC's vice president for worldwide research. "They are also generating substantial indirect spending across the tech delivery supply chain. Large cloud service providers are likewise investing heavily in infrastructure, reflecting the growing importance of complex AI ecosystems that support regional competitiveness and business expansion."

The rapid adoption of digitalisation and AI tech is significantly ramping up the demand for data centres (DCs) worldwide. To meet this growing demand, DC power requirements will triple by the end of the decade, reports McKinsey. For instance, the demand for DC power will jump from 3-4% of total power consumption currently in the US alone, to 11-12% by 2030.

MORE POWER PLEASE

The urge for power is driven by escalating compute and data needs, hampered by slower improvements in chip efficiency. The time required for CPUs to double their performance efficiency has extended from every

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two years to nearly every three years. Meeting the additional 50 gigawatts (GW) of DC capacity needed by 2030 will require more than US$500 billion in infrastructure investment.

"The power sector is rapidly becoming a protagonist in the AI story," McKinsey notes. "As the energy ecosystem grapples with meeting DCs' voracious need for power, it faces substantial constraints, including limitations on reliable power sources, sustainability, upstream infrastructure, power equipment within DCs, and electrical trade workers to build out facilities and infrastructure. Currently, the lead time to power new DCs in large markets such as Northern Virginia for instance in the US, can be more than three years."

Is there a possible solution to the energy problem? Yes, small modular reactor (SMR). This is a type of nuclear fission reactor designed to be smaller in size and power output, typically below 300 megawatts electric (MWe) compared to traditional large-scale nuclear reactors. They are modular because they can be prefabricated in a factory setting, transported to a site, and assembled relatively quickly.

The power required for DCs to run incremental AI-optimised servers will reach 500 terawatt-hours (TWh) per year in 2027, up 2.6 times the level in 2023. SMRs are emerging as a viable long-term solution to this looming power crisis. Gartner predicts the first SMR-powered DCs will become operational by 2030 and use sustainable power fully independent of utility power distribution grids.

"DCs require 24/7 power availability, which renewable power such as wind or solar cannot provide without some form of alternative supply during periods when not generating power," says Bob Johnson, a Gartner vice president analyst. "This is where nuclear energy comes in, offering reliable, low-carbon stability at predictable prices. SMRs promise these benefits, with the advantages of shorter approval and construction times, lower build and operating costs, and more siting options."

SMRs can potentially contribute significantly to improving energy security and managing energy costs while eliminating energy purchase emissions and enterprise carbon footprint, especially for power-hungry and energy-intensive industries like DCs. "Diversifying energy sources with SMRs will provide additional resilience against potential power outages and capacity issues," Johnson says. "Unlike traditional nuclear power plants, SMRs are designed to significantly lower costs while increasing safety, versatility, and efficient reuse or disposal of fuel."

MORE NUKE TYPES

All SMRs utilise nuclear energy but not all SMRs function the same way. Here are five main types:

- **LWR SMR:** Light Water Reactor SMRs utilise ordinary water as both the coolant and neutron moderator, operating within the thermal neutron spectrum. A prominent example is the NuScale Power Module. These reactors are an evolution of the conventional, large-scale pressurised water reactors (PWRs) and boiling water reactors (BWRs) already widely used in commercial nuclear energy generation. The key advantage of LWR-based SMRs lies in their reliance on well-established, regulatory-compliant technologies, offering a familiar licensing pathway and operational confidence. The cons: they require high-pressure containment systems and a reliable water source for cooling, which can limit deployment in water-scarce regions.
- **MSR SMR:** Molten Salt Reactors are distinct in that they may use molten salts both as the coolant and, in some designs, as the medium in which nuclear fuel is dissolved. Graphite often serves as the moderator for thermal MSR designs. One example is Terrestrial Energy's Integral Molten Salt Reactor (IMSR). MSRs offer low operating pressures, inherent safety features like passive cooling and freeze plugs, and the potential for high thermal efficiencies. The cons: managing corrosive salt chemistries and ensuring the long-term integrity of structural materials exposed to aggressive chemical and radiation environments.
- **SFR SMR:** Sodium-Cooled Fast Reactors operate without a moderator, utilising liquid sodium as the coolant and a fast neutron spectrum to sustain fission. Designs like the ARC-100 and GE-Hitachi's PRISM highlight the potential for high fuel utilisation and waste transmutation capabilities inherent to fast-spectrum operation. The

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advantages of SFRs include the ability to recycle spent fuel and reduce long-lived radioactive waste, with sodium providing excellent heat transfer properties. The cons: Sodium's high reactivity with air and water can increase design complexity and require strict containment and safety measures to prevent chemical hazards.

- **LFR SMR:** Lead-Cooled Fast Reactors are similar to SFRs. They operate on a fast neutron spectrum but utilise liquid lead or a lead-bismuth eutectic as the coolant. Examples include the SEALER reactor being developed in Sweden. The use of lead offers high thermal conductivity and stability under irradiation, while avoiding the fire and explosion risks associated with sodium. LFR reactors benefit from excellent shielding properties and can potentially operate for extended periods without refuelling. The cons: they must contend with heavy coolant mass, the corrosive nature of lead at elevated temperatures, and the engineering demands of maintaining the coolant in a molten state due to its high melting point.
- **HTGR SMR:** High-Temperature Gas-Cooled Reactors use inert helium gas as the coolant and graphite as the neutron moderator. The Xe-100 reactor from X-energy is a good example. These reactors achieve extremely high outlet temperatures, often in the range of 700°C to 900°C, making them suitable for applications beyond electricity generation, such as hydrogen production and industrial heat supply. The primary benefits are their high thermal efficiency and chemically inert coolant, which eliminates the risk of explosive reactions to air or water. The cons: complexity of manufacturing TRISO (Tristructural-Isotropic) particle fuel and the need for advanced heat exchanger designs to transfer the reactor's thermal output.

MORE NUKE WASTE

The flip side in all nuke scenarios? Foremost is the issue of what to do with nuclear waste. SMRs produce radioactive waste that must be carefully managed, although the actual quantity is surprisingly low. Potential solutions include reprocessing byproducts into usable fuel, making it significantly less radioactive and more easily disposable, or storing it in special underground facilities.

Another challenge is the time to develop SMRs and their initial high costs. "SMRs may not be generally available for 8-10 years," says Gartner's Johnson. "Early models will cost significantly more than competing power generation technologies. However, costs will come down with extensive use, just like they did with wind and solar power. SMRs will initially need financial incentives or subsidies to make them cost-competitive. Moreover, the SMR concept remains unproven and confined to research, with current projects limited to existing nuclear sites and no grid connections. Early projects will require sustained government support."

How should organisations evaluate SMRs? First, become familiar with what it will take to construct an SMR-based dedicated power station for a DC or cluster of DCs. Gartner recommends planning for future DC power options by including provisions for SMR deployment as a dedicated site power solution in long-term objectives.

Next, it is vital for organisations to regularly monitor SMR tech readiness, provider development activities and regulatory changes, to understand how they might impact future DC operations and energy sourcing. They should simultaneously assess the various SMR alternatives and the strengths and weaknesses of each.

Since we started with one wonky medical joke, let's end with another. The patient is being prepped for surgery to correct a fractured wrist when the doctor visits. "Do you have any questions before we take you to the OT?" the doctor asks. The patient thinks for a few seconds. "Just wondering, will I be able to play the piano after the operation?" The doctor replies, "Yes, of course." The patient smiles. "Great! I never could before."

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