Small Reactors with a Big Range of Use Cases

By Drew Robb

The UK recently completed a lengthy selection process for what could signal the revival of the nuclear industry. Great British Energy – Nuclear selected Rolls-Royce SMR as the preferred bidder to develop small modular reactors (SMRs), subject to final government approvals and contract signature.

"We are ending the no-nuclear status quo as part of our Plan for Change and are entering a golden age of nuclear with the biggest building programme in a generation," said Energy Secretary Ed Miliband. "Great British Energy - Nuclear has run a rigorous competition and will now work with the preferred bidder Rolls-Royce SMR to build the country's first ever small modular reactors – creating thousands of jobs and growing our regional economies while strengthening our energy security."

Traditional nuclear plants typically deliver 1 GW of power capacity. SMRs will be in the 30 MW to 300 MW range, though designs of only a few MW have also been proposed. The market will ultimately determine the optimum size. The intent is to utilize modular construction techniques to reduce build time to a few years, rather than the decade or more often required for a full-fledged nuclear facility.

This flexibility enables SMRs to be open to a great many use cases. Some may focus purely on power generation. Others may opt for a combined heat and power (CHP) model whereby they produce power as well as steam that can be used for district heating and in industrial processes.

Caption: The Westinghouse AP300 Small Modular Reactor provides 300MWe (900MWth). Courtesy of Westinghouse Electric.

How would nuclear CHP work? Nuclear energy is generated in a reactor. The heat from this reaction is used to boil water to turn it into steam that is fed through a turbine. As the turbine is connected to a generator, electricity is produced. As a secondary process, a fraction of the steam can be extracted from the steam turbine and siphoned off to heat homes, businesses, or provide steam for use in industry. Chemical, food processing, oil & gas, and other industries all need an abundant supply of steam or heat.

"Nuclear energy is vital for economic growth and delivering secure, reliable, home-generated power that is capable of meeting future demand, enabling net zero, and reducing the UK's dependence on importing fossil fuels," said GBN's Chair, Simon Bowen.

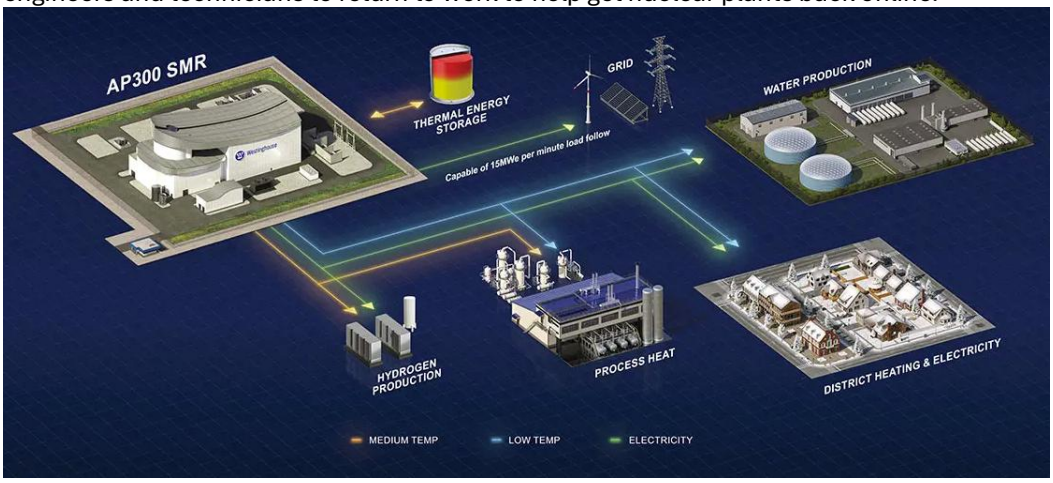
Nuclear Renaissance

The popular perception is that nuclear energy had its heyday in the sixties and seventies when production boomed. Overall output was thought to have dwindled following a series of disasters at Three Mile Island, Pennsylvania in 1979 and Chernobyl, Ukraine in 1986. Attempts made to reinvigorate the industry in the early 2000s came to an end following the Fukushima disaster in Japan in 2011. Japan, Germany, UK, USA, and others scheduled the closure of nuclear facilities. But appearances can be deceptive. Worldwide nuclear energy production rose from 1,500 TWh in 1987 to around 2,500 TWh today. It remains a major force in energy production across the globe. And it is about to get much bigger.

A major attraction of nuclear energy is that it is a carbon-free form of generation. With net zero goals falling miserably short in most nations, nuclear is seen as a great new hope. Hence, the sudden surge of attention. As well as its value in providing urgently needed power to the grid, AI-based data centers are opening up a new market for nuclear power. Morgan Stanley predicts that generative AI applications like ChatGPT could account for 75% of U.S. data center MWs by the end 2025. A similar story is likely to play out in the UK and across Europe. Data centers want power wherever they can get it. IT giants are investing massively:

- Amazon is providing financial backing for the deployment of 5 GW of new X-energy small modular reactor (SMR) projects by 2039 and has acquired a 1,200-acre data center campus that is directly connected to the 2.5 GW Susquehanna Steam Electric Station (a nuclear plant) in Pennsylvania. An existing 48 MW data center operating there currently will be expanded to 960 MW.
- Microsoft and Constellation Energy plan to invest more than $1.5 billion to recommence operations at the Third Mile Island nuclear plant in Pennsylvania by 2028 to power Microsoft AI data centers.
- Google and Kairos Power are developing 500 MW of molten salt nuclear reactors by 2035.

There is a three-pronged approach to the nuclear build out. New-build nuclear plants are in the works, but it will take many years for any to come to fruition. Decommissioned facilities are seen as a faster route to more power. U.S. plants like Palisades, Duane Arnold, and Three Mile Island are on the table for restart. There are even facilities that were never completed that could be scheduled for completion. Their advantage is that massive amounts of infrastructure investment already exist at these sites. Nuclear, after all, requires large concrete foundations as well as high-power transmission connections, the purchase of a lot of land, and the availability of an abundance of water. These elements are already present at many decommissioned sites. Further, a trained workforce can be found in the vicinity. Projects are finding willingness among retired nuclear engineers and technicians to return to work to help get nuclear plants back online.

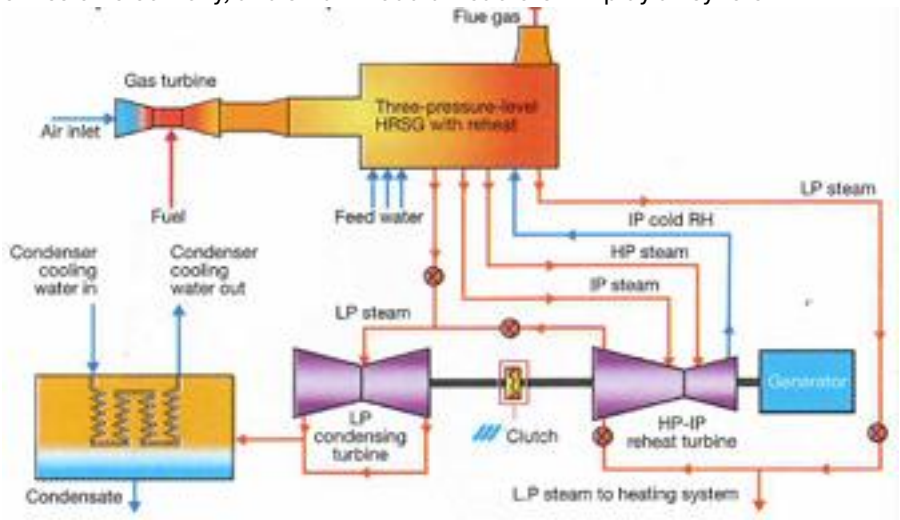


Caption: An SMR could provide power directly to the grid, as well as the energy needed for steam reforming hydrogen production, district heating, process steam, and other future applications like lithium-ion battery production (acid roasting). Courtesy of Westinghouse Electric.

SMRs for Faster Nuclear Power

SMRs are the third prong of the nuclear build out. Instead of a few massive nuclear facilities, a large series of SMRs could be located nearer to load sources and used for a wider range of applications. Amazon announced SMR deals with Energy Northwest in Washington state and Dominion Energy in Virginia. Data

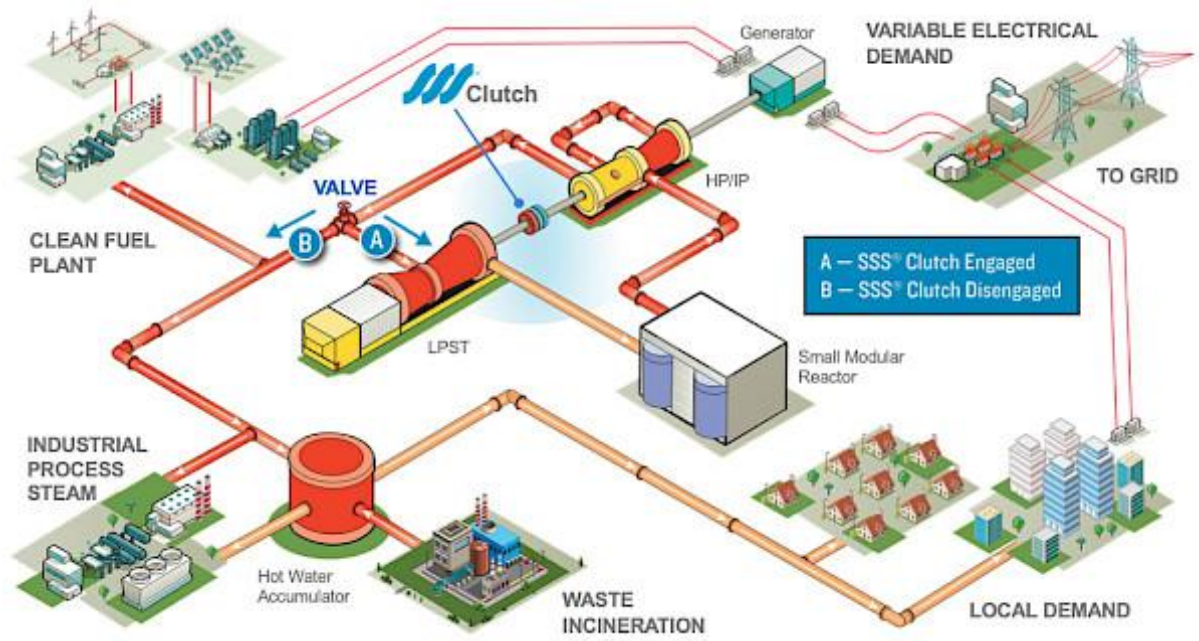
Center giant Switch of Las Vegas has developed a partnership with nuclear firm Oklo, which could result in 12 GW of nuclear energy between now and 2044. Switch gains PPAs for any resulting power.
“It is important to find the right mix of energy sources to deliver the uninterrupted power supply that data centers need to support AI,” said Faith Birol, Executive Director of the International Energy Agency (IEA). “According to our analysis, there is a role for established technologies such as renewables and natural gas, as well as emerging technologies like small modular nuclear reactors (SMRs) and advanced geothermal.”
IEA reports that there are plans to build up to 25 GW of SMR capacity associated with supplying the data center sector worldwide. The first projects are expected around the end of this decade. Holtec, for example, is working on the recommissioning of the Palisades Nuclear Facility. In parallel, it is adding SMRs to the site. “We plan to open the first two SMRs at Palisades by 2031,’ said Patrick O’Brien of Holtec.
Siemens Energy and Rolls-Royce have signed an SMR partnership. Siemens Energy will supply steam turbines and generators for Rolls-Royce Generation 3+ modular nuclear power plants, some as big as 470 MW.
"We are currently experiencing a global renaissance of nuclear energy,” said Karim Amin, a member of the Siemens Energy Executive Board. “Numerous countries are turning to nuclear technology to produce low-emission electricity, and small modular reactors will play a key role.”



Caption: SMRs could expand their scope by adding process steam to their repertoire. This can be accomplished by placing an SSS Clutch between the LP and HP/IP sections of the steam turbine.

SMRs for Flexibility

Some see SMRs as being the best way to add power to the grid in a reasonable time frame. Others are looking at how to expand their use cases. Applications might include energy storage, hydrogen steam reforming, process steam, district heating, or sea water desalination, and more. Hydrogen, for instance, has been held back due to the high cost of energy required for electrolysis. If a steam reforming plant was positioned beside an SMR, it could benefit from less costly and more efficient heat supply. The hydrogen could then be blended with natural gas at nearby power plants to lower the carbon footprint.
CHP is another use case. It could act a bargaining chip for communities quick to protest an SMR popping up in their vicinity. By promising cheap electricity or the delivery of cheap steam to the local utility to be used for district heating, residents might be willing to consider a new facility.
Certain industries might be keen to have an SMR nearby to provide process steam as well as power. Some might be willing to invest in CHP to provide a reliable source of steam and power. Oil and gas production or refining operations use steam in many ways including plastic polymerization. Car manufacturers use steam to dry paint on cars. Chemical plants need steam for enzymes, carbon black, paint, glassware, and rubber.
Flexible output from an SMR would not require any redesign to the reactor island but would necessitate a minor redesign of the steam turbine. By adding an SSS Clutch, the Low-Pressure (LP) section of the steam turbine can switch between electrical generation mode and supplying heat and steam. This concept is proven across many CHP plants and provides full utilization of steam and lower losses compared to other options.
“The flexibility of the steam turbine allows the reactor to operate at a continuous output, whilst the secondary island can switch between different operating modes,” said Morgan Hendry, President of SSS Clutch.



Caption: Possible use cases for the SSS Clutch in tandem with an SMR.

SSS Clutch has a track record in the nuclear industry dating back to the 1960s. Its main turning gear technology is being implemented at Hinkley Point C, which is currently under construction in the UK, and other projects including Flamanville in France, Akkuyu in Turkey, Eld Dabaa in Egypt, and Taishan in China.

“The SSS Nuclear Pinion Turning Gear clutch provides a fail-safe mechanism to rotate the large steam turbine shaft during the cool down phase to prevent distortion,” said Hendry.

Caption: A nuclear pinion turning gear with an SSS Clutch

Some SMR facilities might be flexible enough to base output on market rates. If electricity prices are high, the SMR can provide maximum power to the grid. If rates drop, steam for industrial processes might be more profitable. Alternatively, the plant could operate with a percentage of output to power and the rest to steam.