NUCLEARENERGY INSIDER

# Small Modular Reactors: Opportunities for the US Supply Chain

The next generation of advanced nuclear reactors is less than a decade away from deployment. The U.S. Nuclear Regulatory Authority (NRC) will soon receive the first small modular reactor (SMR) design for certification amid expectations commissioning will begin in the mid-2020s.

This white paper examines the progress being made by developers and their supply chain partners towards commercialization, and the potential national and global markets for advanced nuclear reactors.

Featuring insights from:

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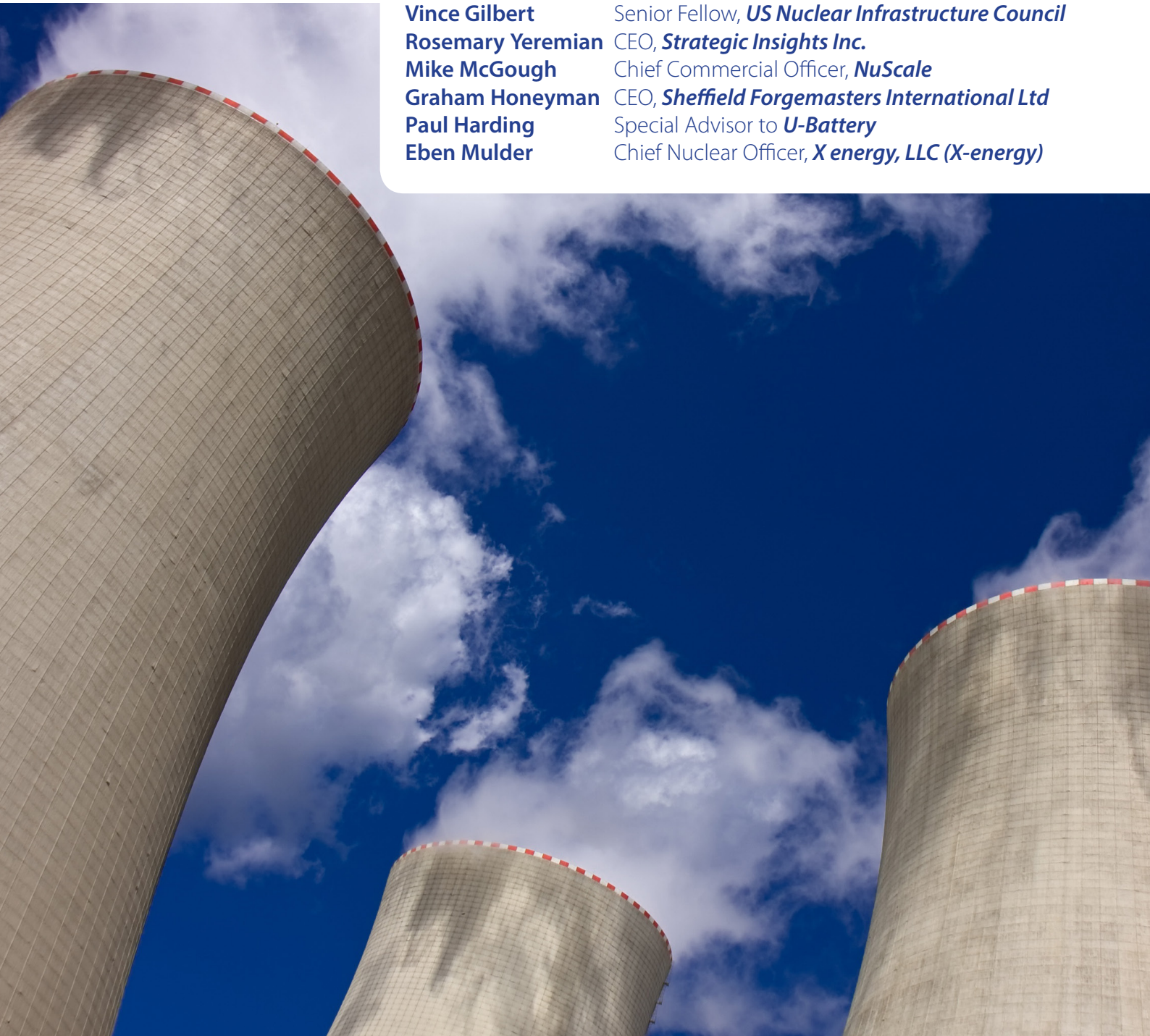
| **Vince Gilbert** | Senior Fellow, ***US Nuclear Infrastructure Council*** |
| **Rosemary Yeremian** | CEO, ***Strategic Insights Inc.*** |
| **Mike McGough** | Chief Commercial Officer, ***NuScale*** |
| **Graham Honeyman** | CEO, ***Sheffield Forgemasters International Ltd*** |
| **Paul Harding** | Special Advisor to ***U-Battery*** |
| **Eben Mulder** | Chief Nuclear Officer, ***X energy, LLC (X-energy)*** |



## Introduction

The U.S. Department of Energy (DoE) forecasts that electricity demand will rise by 22% by 2040 and four new civil nuclear plants are currently under construction. Georgia Power's two 1.3 GW PWRs near Waynesboro (Vogtle 3 and 4) will be the first new nuclear builds since 1996, while South Carolina Electric and Gas Company is also building two 1.3 GW PWRs at Jenkinsville (Summer 2 and 3).

However, the U.S. nuclear industry has come under sustained economic pressure due to cheap natural gas driving down wholesale prices. Nuclear operator profits have been drastically cut, resulting in a recent spate of premature closures. Despite modernization and digital upgrade programs, the Nuclear Energy Institute (NEI) has warned that further early shut downs are likely unless operating costs are reduced.

Globally, national governments face securing inexpensive energy supplies to meet increasing commercial and public demand. SMR technology is an attractive alternative to civil nuclear plants, which cost $7 billion-$10 billion and take around ten years to bring online. The cost of bringing an SMR design to market is around $2 billion – $3 billion, **with a manufacture-to-power-generation timeframe currently estimated at around three years.**

In a move to secure a future for nuclear power, U.S. government funding for advanced reactor research and development (R&D) increased from $133 million in 2015 to $141 million in 2016. SMR licensing funding rose from $55 million to $63 million, with NuScale on track to be the first SMR developer to submit its Integral Pressurized Water Reactor (IPWR) design to the NRC for certification.

SMR developers are reportedly evaluating sites in Oregon, Washington, Utah, Idaho, Arizona, Wyoming, Colorado and New Mexico. Further sites identified by companies that have yet to go public would bring the total number U.S.-based of projects to around 10 and, according to U.S. think tank Third Way, a raft of submissions is expected to follow for several projects including:

- B&W Company and Bechtel Power Corp in Charlotte, North Carolina
- General Atomics, San Diego, California
- Holtec, Jupiter, Florida
- Radix Power and Energy Corp, Setauket, New York
- Westinghouse, Fulton, Missouri

### Vince Gilbert, Senior Fellow, US Nuclear Infrastructure Council

There are several success paths to the commercialization of SMRs, but most lead through governments. Most companies developing the reactors do not have $2 billion-$3 billion to bring the design to market and governments will subsidize first-of-a-kind research and development, as well as licensing costs.

By providing the seed funding, governments establish public-private partnerships without assuming all the financial risks while benefiting from the advantage of investing in new technology. Revenue from supplier profits and export potential generate tax revenue for the government and jobs for the public sector.

There are challenges, including connecting electricity to the grid and obtaining a license, but SMRs offer an economic, safe and more flexible energy generation compared to [large-scale] civil nuclear power plants.

### Rosemary Yeremian, CEO of Strategic Insights Inc.

The global SMR market is moving forward faster than traditional nuclear industry and growth is in countries including Argentina, China and Russia rather than the nuclear power strongholds in North America or Europe. State financial support has been pivotal to driving the in-country development, design and construction of SMRs.

Companies seeking to enter the SMR supply chain in North America might encounter a more challenging environment from a commercialization perspective, as opportunities depend on a lot of factors including government support for building SMRs, licensing new designs and the availability of funding.

The issue is not a lack of technical expertise. There are several technically robust designs being developed. Rather, SMRs may face challenges in obtaining the financial support required over a long time horizon to see these designs licensed and successfully commercialized.

Got any questions? Put them to Vince and the USNIC team at the **7th Annual International SMR and Advanced Reactor Summit** (March 30-31, Atlanta).

**Click here to see the full speaker line-up, agenda and attendee list**

## NuScale

### *Mike McGough, Chief Commercial Officer*

*The 50MW IPWR Power Module will be deployed in clusters of 12 and Power cooperative Utah Associated Municipal Power Systems is scheduled to install NuScale's first commercial plant and be operational by 2026*

NuScale estimates the emerging global SMR market will be worth around $400 billion by 2035, with global demand approaching 1,100-1,500 modules. In the U.S. and UK, 12 projects have already been identified with potential for the deployment of 12-Power Module plants.

In the U.S., NuScale is eyeing potential customers around the country including in several western states where less than 5% of energy is derived from nuclear power and consumers are disproportionately reliant on energy from coal and natural gas plants, which are due to go offline in the next decade.

Compared to large civil nuclear plants, SMRs are quicker to fabricate, deploy commission and generate revenue while providing cheaper energy. NuScale's first Power Module plant will initially cost around $3 billion and take 40 months to construct and deploy, resulting in reduced capital outlay and faster time to generating a positive cash flow much earlier in the plant lifecycle.

NuScale is looking to the U.S., Europe and Asia as its main sources of suppliers. Although larger items including the turbines are likely to the sourced from a purpose-built factory, the focus is developing local supply chains. Total procurement cost estimates for plant components including 12 NuScale Power Modules and the associated turbine generators are more than $600 million.

In the UK, Sheffield Forgemasters International Ltd (SFIL), Nuclear Advanced Manufacturing Research Centre (Nuclear AMRC) and Ultra Electronics are already partners with NuScale and there is an opportunity for companies to form consortia that manufacture separately but deliver assembled components together.

NuScale reached out to potential U.S. and UK suppliers through a series of events that facilitated matching the reactor design with engineers. Now in the qualification process, NuScale will shortlist companies that meet its supplier criteria and expects it will announce the successful bids for building the Power Module in early 2018.

Supplier investment profiles will depend on their existing manufacturing capability. Firms already serving industries such as aerospace are likely to have the machines, equipment, material expertise and physical space that can be adapted to fabricate components for the IPWR.

## Sheffield Forgemasters International Ltd

*Graham Honeyman, CEO*

*UK-based SFIL has partnered with U.S. headquartered NuScale Power to develop manufacturing techniques for an IPWR SMR, scheduled for operations by 2026*

SFIL is manufacturing a large civil nuclear reactor vessel head to NuScale's design as part of a £4 million ($4.9 million) project funded by the UK government. NuScale is providing additional research and development funds in expectation that SFIL will manufacture the trial component by mid-2017.

In addition to NuScale, engineering companies including Westinghouse and Rolls Royce are developing SMR designs and will offer manufacturing and construction opportunities to supply-chain firms within the UK and U.S.

There is also export potential, as fast-growing BRICS and CIVET economies emerge and look to alternative energy sources which can enable localized power for the growth of domestically manufactured and produced goods.

It takes collaboration to develop these specialized components. SFIL has a strong technical team and a compelling record of work in civil nuclear manufacture, with 25 years of ASME Nuclear Materials Organization certification and NPT status that permits weld-fabrication of civil nuclear components.

SFIL entered the supply chain at an early stage to gain a market advantage and has worked with many civil nuclear specialists. It was approached by NuScale with specific technical proposals, which it responded to by detailing what it could offer as a manufacturer and fabricator of SMR components.

Although manufacturing a component for an SMR is a new venture for SFIL, the company's forging expertise and technical capability are strengthened by continued investment in technology R&D. This ensures a strong and sustainable manufacturing position for the future.

Investment in the latest generation of technical welding machinery will allow SFIL to operate at a high level of precision and enable it to produce the reactor vessel with the head welded into position. The investment necessary to cover labor and manufacturing costs is £7 million ($8.6 million), which SFIL has bid for under the UK government's SMR competition announced in March 2016.

Taking a longer-term view of investment could net very good returns, but the investment needs to be made at the beginning of the technology development and design process. SFIL will use the manufacture of the NuScale SMR design as a foundation on which to build expertise and experience so that it is prepared for the manufacture of the next set of SMRs.

## U-Battery

*Paul Harding, Special Advisor*

*U-Battery is a micro-modular nuclear reactor that will produce heat and electricity for a range of global energy needs. U-Battery uses existing, proven technology, powered by TRISO fuel. Each U-Battery will produce 10MW thermal or 4MW electricity.*

*Developed by a UK-based consortium comprising of Amec Foster Wheeler, Cammell Laird, Laing O'Rourke and URENCO, U-Battery will be a commercial and industrial product with a lifespan of 60 years.*

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The team is already well progressed towards the first-of-a-kind reactor and plan for the first U-Battery to be operational by the mid-2020s before moving onto commercial deployment and operation worldwide. As a micro-modular reactor, U-Battery is distinct from larger SMRs and is targeted primarily at the global markets for off-grid end users. These include:

• Heavy industry driven by energy intensive processes that consume heat and electricity, such as steel and cement manufacturing, as well as chemical production;

• Remote communities currently dependent on diesel or gas package plants for their energy supply, which are logistically difficult to supply and can be high cost compared to a grid based supply.

U-Battery can also be used as low-carbon backup power to large scale nuclear power plants and could also support specific processes, such as desalination and hydrogen production.

As a modular technology, U-Battery will be assembled as a complete product in a manufacturing facility, potentially in as little as six months, enabling export worldwide.

The consortium is already seeing strong market potential worldwide, including Canada, Poland and the UK. An independent assessment found that the global market for U-Battery could number more than 200 units by the mid-2030s.

The likely cost to build and develop U-Battery is less than £100 million. The consortium is currently undertaking Phase 1 design and development, which will be completed by the end of 2018, and encompasses the design and initial licensing processes to take U-Battery to an initial regulatory submission. The use of existing technology makes this a low cost, low risk development.

While purposely simple, U-Battery will require the manufacturing and assembly of a small number of specialist components developed by the supply chain. The team has already identified all the components needed, which include the reactor vessel, heat exchanger, turbines and generator, as well as the range of suppliers in the UK that could potential deliver each component.

Potential suppliers will inform the design to ensure its manufacturing viability and, as the requirements become clear, the consortium will seek to directly engage the supply chain and approach candidate firms.

## X-energy

### *Eben Mulder, Chief Nuclear Officer*

*The Xe-100 is a high temperature, gas-cooled pebble bed nuclear reactor. Each pebble is comprised of 25,000 TRISO particles with 170,000 pebbles packed into the pebble bed of the reactor. Each reactor, comprised of 600 tonnes of graphite, will consume 175 pebbles each day.*

*Each reactor will have 125MW thermal and 50MW electrical capacity, with a standard four-reactor plant generating 200MW of electricity once installed on a 10,000m$^2$ site.*

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X-energy is building the Xe-100 in the US, with the first reactor scheduled for deployment by 2030. Full commercialization is expected to follow two years later along a manufacturing timeline that produces ten reactors every two to three years. Bringing the first Xe-100 to market will cost $1bn, although costs are expected to decrease with subsequent production.

The Xe-100 has a range of applications, including military installations that require a safe and reliable energy supply independent of the grid. X-energy is also looking at water and chemical processing industries, and power facilities looking to replace coal with steam could also deploy the Xe-100 as it is compatible with the transmission and distribution infrastructure and generates steam above 540 degrees.

The global market also offers opportunities. Remote areas of northern Canada that depend on specific types of diesel, which is expensive to produce and deliver, have expressed interest in SMRs. Mining areas in South Africa would also benefit from the modular approach, which facilitates installing additional reactors to meet increasing demand.

The real market is the developing world, as delivering power to areas that have erratic and unreliable electricity and water supply would open up access to health, education and promote economic growth.

The DoE awarded X-energy $40 million to fund the reactor R&D program, which enabled outstanding fuel development including pebble pressing to be completed, as well as licensing support and furtherance of the reactor design. The grant lent X-energy credibility and although the reactor is still in the design phase, several firms have shown a serious interest in forging partnerships.

Burns and McDonnell Engineering Company Inc., an engineering and consultancy firm with in-house costing expertise and civil nuclear capability, compiled a cost study report that revealed 30% of X-energy's overall expenditure would be on construction. It took the opportunity to enter the SMR supply chain market and formalized a partnership.

X-energy has also partnered Southern Nuclear to move forward the deployment and commercialization of the Xe-100, and is collaborating with Idaho and Oak Ridge National Laboratories to facilitate NRC licensing of the fuel that X-energy is designing alongside the nuclear reactor.

## List of Acronyms

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| **ASME** | American Society of Mechanical Engineers |
| **BRICS** | Brazil, Russia, India, China and South Africa |
| **CIVETS** | Colombia, Indonesia, Vietnam, Egypt, Turkey and South Africa |
| **DoE** | Department OF Energy |
| **EPR** | European Pressurized Reactor |
| **IP** | Intellectual Property |
| **IPWR** | Integral Pressurized Water Reactor |
| **NPT** | National Pipe Tapered |
| **Nuclear AMRC** | Nuclear Advanced Manufacturing Research Centre |
| **NEI** | Nuclear Energy Institute |
| **NRC** | Nuclear Regulatory Authority |
| **PWR** | Pressurized Water Reactor |
| **R&D** | Research and Development |
| **SFIL** | Sheffield Forgemasters International Ltd |
| **SMR** | Small Modular Reactor |
| **USNIC** | US Nuclear Infrastructure Council |

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This whitepaper was produced in conjunction with…

The 7th Annual

# International SMR and Advanced Reactor Summit 2017

30-31 March • Atlanta, Georgia

*Develop commercial strategies for the global deployment of SMRs and Advanced Reactors*

**Just a few of the leading industry organisations you'll see at the event:**

- Assess the viability of financing SMRs and Advanced Reactors so you can best prepare to mitigate the financial risk tied to nuclear new builds.
- Hear from the leading global designers on their SMR and Advanced Reactor projects allowing you to consider which reactor best suits your commercial strategy.
- Realize the significant cost reduction potential for the construction, operation and maintenance of SMRs and Advanced Reactors which will be essential to remain cost-competitive in the energy market.
- Get to grips with the many potential applications of SMRs and Advanced Reactors, offering alternative revenue streams besides electricity generation and allowing operators to combat fluctuating market prices.

**Hear some of our speaker's thoughts on the 2017 event:**

"A strong focus on non-emitting, reliable, and resilient energy generation is a necessity in planning future energy systems around the world. The SMR Summit provides an excellent venue for interactions among international vendors, utilities, and decision makers that can make the dream of a low-carbon world a future reality. I am excited to be a part of that discussion!"

*Shannon Bragg-Sitton, INL*

"I'm greatly looking forward to understanding the opportunities ahead for SMR development at the conference, specifically where U.S. goods and services are featured."

*Michael Whalen, EXIM Bank of the United States.*

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