NUCLEAR: *closing the* FUEL CYCLE?

The dream of a new and improved solution for converting nuclear waste into energy could soon become reality. But challenges remain in bringing it to market. Will GE Hitachi Nuclear Energy succeed with its plan?

Report by Tony Ward and Brad Hartnett.

Support for nuclear power as a reliable, low-carbon energy solution has gained momentum in recent years. However, significant challenges remain in effectively managing nuclear waste and improving public acceptance of the industry in the aftermath of the catastrophic failure at Fukushima, which reignited anxiety about meltdowns.

New reactors currently being proposed could change that, by extracting more energy from spent nuclear fuel and making the resulting waste products much less radioactive. We have yet to see the first of these new recycling reactors built. But recent developments indicate that the dream of turning dangerous waste products into a safe, clean, low-carbon energy source could be a reality within 10-12 years. Prominent environmentalists including George Monbiot and Mark Lynas are among those who believe in the potential of these new technologies.[1]

Plutonium is created as a by-product in most nuclear reactors, leaving operators with a potentially dangerous asset or liability, depending on how you look at it. The UK has the world's largest stockpile of separated civilian plutonium: 91.2 tonnes, or over a third of the global civilian stockpile. On completion of nuclear fuel reprocessing over the next few years, this is expected to grow to 140 tonnes.[2] It is currently stored at the Sellafield site under strict controls, given its high security risk. Other countries with plutonium stockpiles include the US, Russia, France, South Korea and Japan.

We spoke with David Powell (VP European Sales) and Eric Loewen (Chief Consulting Engineer) of GE Hitachi Nuclear Energy (GEH) about the challenges they face in getting their new PRISM reactor to market, and how this technology could change the energy business.

How PRISM works

PRISM (Power Reactor Inherently Safe Module) is a small modular, sodium-cooled fast reactor that is designed to recycle used nuclear fuel to generate low-carbon electricity. It is an inherently safe design that could help to close the nuclear fuel cycle, decrease the amount of waste and reduce the time that waste has to be stored in a repository to a few hundred years. It is based on proven sodium reactor technology, developed and tested over 30 years in the US.

1. Monbiot and Lynas were among the signatories to an open letter to the UK Prime Minister endorsing PRISM technology in March 2012: www.monbiot.com/2012/03/15/a-letter-to-david-cameron, accessed 1 May 2014.

2. *Progress on approaches to the management of separated plutonium,* Nuclear Decommissioning Authority, January 2014, page 3, www.nda.gov.uk/documents/upload/Progress-on-approaches-to-the-management-of-separated-plutonium-position-paper-January-2014.pdf.

Eric Loewen explains the system's efficiency and environmental benefits: "Current fission reactors use just 1% of the energy in uranium. The new PRISM reactor is capable of extracting close to 99%. This could make mining and milling of resources massively more efficient, as well as maximizing the energy potential from spent fuel from existing reactors. Not only that, but the resulting waste is much more robust: after 300 years, the waste from PRISM would be less radioactive than, for example, the uranium ore mines in Australia or Canada."

On the fuel side, PRISM fuel could be recycled to completely consume and eliminate the plutonium, or it could be disposed of more easily as the spent fuel becomes virtually unusable for weapons proliferation purposes.

PRISM technology is based on a safe design that uses natural circulation from outside air to remove heat from the reactor vessel. In the case of Fukushima, the systems in place to remove heat were dependent on a separate electrical energy source, which was damaged in the event. In contrast, PRISM would permanently remove residual heat after the reactor is turned off.

PRISM is also designed to avoid seismic damage during earthquakes. Below-ground installation will lower radiation hazards and limit access points for increased security. As with other Small Modular Reactors (SMRs), PRISM's smaller and simpler design provides cost efficiencies unavailable to most large reactors.

Current development and next milestones

With the reactor having undergone extensive design work since 1981 and the potential for deploying the first plant in the UK by 2025, the prospect of near-unlimited and clean nuclear energy resources is tantalizingly close.

The technology has recently embarked on another phase of assessment with the UK's Nuclear Decommissioning Authority. A forthcoming hurdle is to get a green light from the UK Government to start the licensing process, after which the project can go forward through detailed design, construction and operation. Based on past projects, estimates on timings include up to six years for licensing and around three to four years for construction.[3]

"We'll be working closely with the Nuclear Decommissioning Authority (NDA) over the next 12-24 months to help them understand our technology, and why we believe it is safer and better for this particular application than any other option, so they can make a choice," says David Powell.

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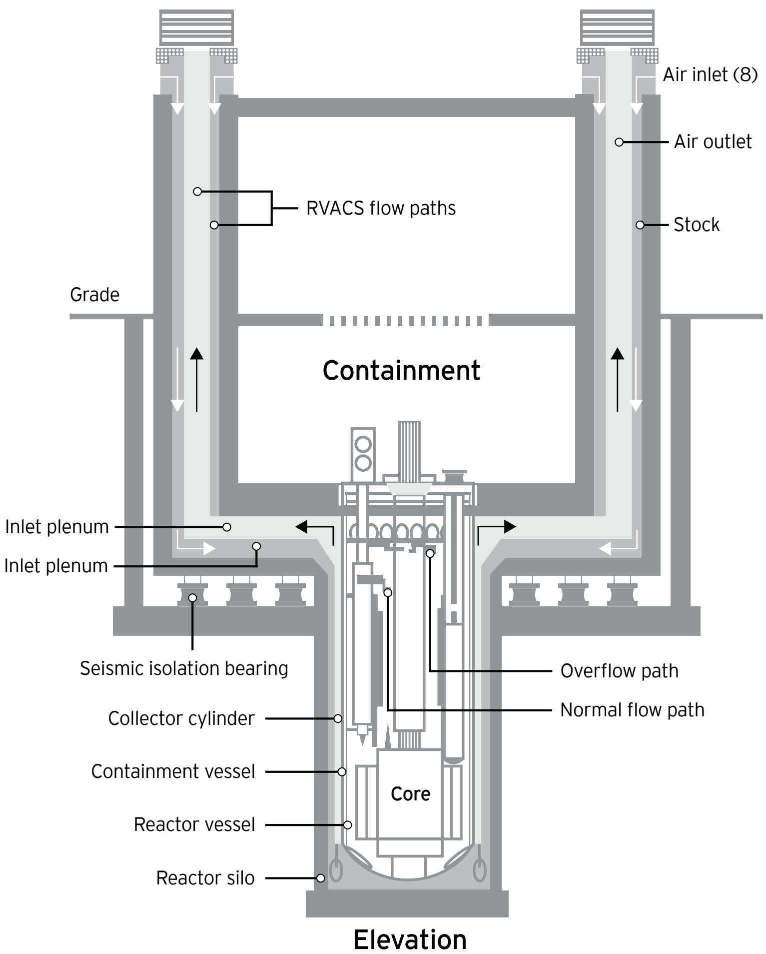
>
> **Eric Loewen,** GEH

Figure 1. PRISM's safety features



Source: GE Hitachi Nuclear Energy[4]

3. Construction of GEH's latest advanced boiling water reactor in Japan was completed in 38 months.

4. GEH, http://gehitachiprism.com/what-is-prism/how-prism-works/, accessed 12 March 2014.

Stability in the policy framework will be a key factor in getting PRISM to take hold in any market. Loewen is confident that the UK offers the required policy stability to introduce nuclear technology.

Overcoming barriers to commercialization

Loewen explains that in a PRISM reactor, the cladding around the fuel and the core structure is made from a ferritic stainless steel called HT-9.[5] Though used in the past, this type of steel is not currently available, so GEH would need to find a supplier willing to start manufacturing HT-9 again.

"The good news is that this presents a unique business opportunity for the UK to become the supply chain for ferritic stainless steel to other countries that are building fast reactors right now, such as India, China and possibly South Korea," says Loewen. "So while this is a supply risk for us, it also represents an opportunity for someone else."

Unlike many in its field, GEH has been building reactors continuously for the past 50 years, so Loewen is confident that its plant experience is current and risks are consequently low. Technical risks are well known and planned for: "PRISM's design incorporates the knowledge gained from 22 previous sodium-cooled reactors operating worldwide."

When asked about political risks, Powell says that there is strong cross-party support for nuclear in the UK, including support for dealing with plutonium, but adds that they will be keeping an eye on the UK's May 2015 general election. Loewen and Powell believe the PRISM project has the balance of environmental benefits, engineering quality and sound economics to survive a change of government.

Market potential for PRISM

While the UK decision is awaited, Asia clearly has interest in recycling technologies, for example in South Korea. India also has plans to deploy sodium reactors: "They are proud of their indigenous program for sodium-cooled reactors, and where India wants to take its technology is not unlike the PRISM approach," comments Loewen.

Meanwhile, Japan continues to revamp safety measures and is set to restart some of its idled nuclear plants in mid-2014. "The country needs to stabilize post-Fukushima," says Loewen. "But historically Japan's been at the forefront of sodium-cooled reactor technologies. It also has a history with nuclear fuel reprocessing. I see them coming back as a big player."

The US remains committed to disposing of, or reprocessing, its excess military plutonium, estimated at 61.5 tons.[7] But there is no regulatory environment at present to support a recycling solution in the US. The U.S. Department of Energy recently made a decision to shelve plans for a MOX recycling plant.[8] "What happens now is unclear," says Powell.

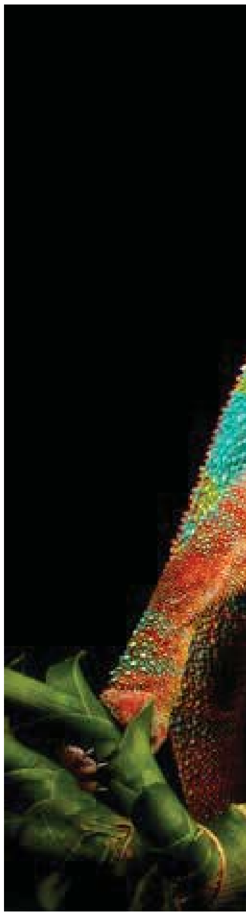
For the present, the issue of what to do with the waste in the US is unresolved. The Yucca Mountain repository site in Nevada has yet to receive clearance, as the Environmental Protection Agency (EPA) has set a requirement for a 1 million-year safe engineering design.

Closing the fuel cycle: PRISM versus MOX

The leading alternative solution for managing plutonium stockpiles is reprocessing it into mixed oxide (MOX) fuel, which is technically proven and accounts for around 2% of new nuclear fuel used today.[6]

PRISM's cost-effective fuel fabrication would hold a key advantage over building expensive MOX fuel plant infrastructure. In the US, the Department of Energy recently put its MOX Fuel Fabrication Facility in South Carolina on "cold standby" while it seeks other disposal or reprocessing solutions for its excess stocks of weapons-grade plutonium. The multibillion-dollar plant had faced spiraling construction costs and had gone well over budget.

PRISM potentially offers other key advantages over MOX, including robust proliferation resistance and reduced volumes of contaminated waste. PRISM is also focused on a dedicated purpose and simple market model: to produce electricity for the UK, rather than producing nuclear fuel that the Government would need to sell into a competitive market.



5. HT-9 was used in experimental Breed Reactor #2 and is proven.

6. World Nuclear Association, http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Fuel-Recycling/Mixed-Oxide-Fuel-MOX/, accessed 30 March 2014.
7. International Panel on Fissile Materials, http://fissilematerials.org/countries/united_states.html, accessed 30 March 2014.
8. US Department of Energy (DOE) funding for research into plutonium reprocessing was withdrawn in mid-March 2014, due to concerns about cost overruns for the MOX fuel. The DOE's multibillion-dollar MOX Fuel Fabrication Facility, on the Savannah River near Aiken, South Carolina, is now on "cold standby" as the DOE seeks other disposal or reprocessing solutions for its excess stocks of weapons-grade plutonium.

Impact on the nuclear industry

Nuclear fission has been part of the energy landscape for some 60 years. Through that time it has evolved rapidly, contributed significantly to global low-carbon electricity supply and created and sustained a high-tech industry. But the sector has also had to face a number of challenges, primarily focused on costs and safety.

Today's priorities for nuclear power are threefold:

- Control costs
- Mitigate the types of risk seen at Fukushima
- Do far more to minimize and resolve the legacy of waste that arises

SMRs, and PRISM in particular, show that the nuclear industry has had these priorities in mind for more than a generation. The technology is neither revolutionary nor unproven. What really marks PRISM out from other modular reactors is its ability to address the security challenges posed by growing stockpiles of plutonium.

If successfully deployed, PRISM potentially offers a new market for separating plutonium from spent fuel at existing nuclear plants. This could potentially reduce the ongoing costs of nuclear waste disposal. However, in the UK, we can't expect to see this feed through into reduced energy prices: nuclear will remain a relatively small part of the UK energy mix for decades to come.

Dr. David J. Powell

Vice President for nuclear power plant sales in Europe, GEH

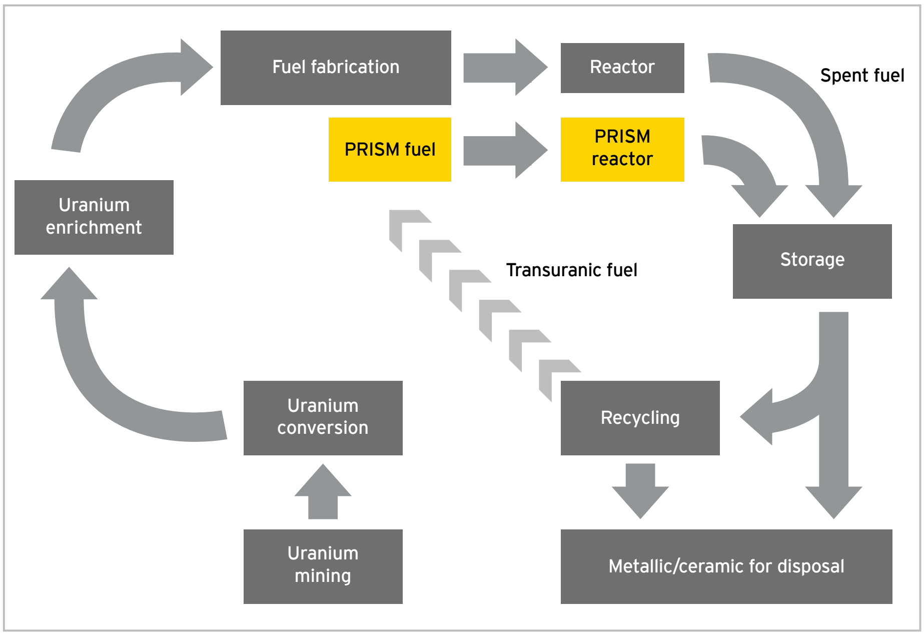
Dr. Powell leads GEH's efforts to deploy PRISM in the UK. He has nearly 30 years of experience in the nuclear industry, initially with British Nuclear Fuels plc and later with the Westinghouse Electric Company. David has held a number of senior positions developing and running nuclear businesses, including responsibility for Westinghouse's European fuel business and working in Tokyo, Japan, as President of BNFL/Westinghouse Japan. Dr. Powell received the 2012 Outstanding Contribution Award from the Young Generation Network (YGN) for his leadership and commitment to the industry.

Given the development, licensing and construction costs involved in delivering the first of any commercial-scale reactor design, PRISM crucially needs a lead sponsor – whether that is a utility looking for a reactor more suited to a geographically dispersed electricity system, or a country willing to commit to dealing with its plutonium and waste stockpile in a way that creates value rather than simply being a cost of historic programs.

Meanwhile, the tendency is to "kick the can down the road" – the costs of storage remain lower than building new permanent solutions. The UK will be considering this issue in the next few years and other countries will observe with interest.

Recycling solutions appear to be a "no-brainer" for the nuclear sector, promising an effective method of dealing with waste and a commercial upside. The long-term goal is to put more spent fuel into the recycling loop – rather than taking it from the reactor to storage, which is how most of the world's nuclear waste is currently managed.

Figure 2. PRISM complements a "closed" nuclear fuel cycle.



Source: EY

The NDA has already been persuaded that PRISM offers a credible alternative to the continued risk of the status quo. Over the next couple of years, the energy industry will be closely watching the NDA's decision-making process for managing plutonium stockpiles and its potential implications for PRISM licensing discussions.

Dr. Eric P. Loewen

Chief Consulting Engineer, GEH

Since 2006, Dr. Loewen has guided GEH's technical efforts for deployment of the PRISM integral fast reactor. His U.S. Navy service included Instructor at Nuclear Power School, and Quality Control Officer and Senior Reactor Operator in USS Long Beach (CGN-9). As Science and Technology Advisor to the Congress and aide to then-Senator Chuck Hagel, he integrated nuclear power into the U.S. Energy Policy Act 2005. From June 2011 to June 2012, Eric served as President of the American Nuclear Society (ANS).

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