Nukes – Part 5

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1. Introduction

This paper will be a 2021 update on (1) Small Modular Reactors (SMRs) from U.S. Reactor Manufacturers (RMs) that are at least somewhat likely to be built before 2030 (although not necessarily in the U.S.) and a near-commercial fusion power reactor that is at least somewhat likely to be built before 2040 (probably in the U.S.).

Since there are now five papers rather than listing them below, I will send you to my list of educational papers, a PDF on Energy Central that I update quarterly. This list has an index and uses sections. Section 25, "Nukes," has all of my prior Nukes papers, plus two more that are about Nukes, but not titled "Nukes…" This section also has descriptions of each paper and a link to the paper on Energy Central. I will update this list at the beginning of October, and this paper will be added to that section. If you've not used this list before – read the Introduction.

https://energycentral.com/c/ec/list-papers-posted-energy-central-subject-second-quarter-2021

Sections 2 through 4 below are each about a SMR, and section 5 is about the future possible fusion reactor.

2. NuScale

I covered the evolution of NuScale in Nukes 2 through Nukes 4. See list linked above.

Oregon-based NuScale has received U.S. Nuclear Regulatory Commission approval on its design which involves a smaller footprint, capacity and anticipated cost than traditional high-capacity nuclear power plants. The company is working with various partners to build its planned Carbon Free Power Plant project at the Idaho National Laboratory.[1]

NuScale Power has signed a memorandum of understanding (MOU) with Xcel Energy to explore feasibility of Xcel serving as its SMR plant operator.

NuScale Power today announced that recent private capital investments from a diverse base of strategic investors total $152 million, closing out NuScale's A-5 round of investments, and bringing the company's total funding year to date to approximately $192 million. Investments have been secured from GS Energy, Doosan Heavy Industry and Construction, IHI Corporation, Samsung C&T Corporation, Sargent & Lundy and Sarens. This announcement follows a $40 million investment from JGC Holdings Corporation earlier this year...[2]

In August 2020, NuScale made history as the first and only SMR to receive design approval from the U.S. Nuclear Regulatory Commission (NRC), and in July of 2021, the

[1] Rod Walton, Power Engineering, "Xcel Energy, NuScale considering utility to operate future SMR nuclear plants," Aug 18,2021, https://www.power-eng.com/nuclear/xcel-energy-considering-mou-to-operate-future-nuscale-smr-nuclear-plants/

[2] Business Wire via Yahoo Finance, "NuScale Power Secures Nearly $200 Million in Strategic Investments," Aug 3, 2021, https://ca.finance.yahoo.com/news/nuscale-power-secures-nearly-200-120000383.html

Commission published the proposed rule that would certify the NuScale design – a crucial step towards the construction and deployment of this SMR technology.

A Utah energy cooperative said it will reduce the number of small modular nuclear reactors it will build in Idaho from 12 to six for a first-of-a-kind project that is part of a federal effort to reduce greenhouse gasses that cause climate change.[3]

But Utah Associated Municipal Power Systems said the reactors will be more efficient than previously planned so the amount of power produced will only drop from 600 to 462 megawatts.

Cooperative spokesman LaVarr Webb told the Post Register in a story Friday that a plant with six reactors would be the right size for its members and outside utilities that want to join.

The project is part of an U.S. Department of Energy effort to reduce greenhouse gasses by using nuclear power to complement intermittent renewable energy.

The Energy Department late last year awarded the cooperative about $1.4 billion to help develop and build the commercial reactors at the Energy Department's 890-square-mile (2,300-square-kilometer) site in eastern Idaho that includes the Idaho National Laboratory…

"Before joining a next-generation, first-of-a-kind nuclear plant, utilities obviously want to be certain the plant is feasible and will be built," Webb said. "Now that we have made significant progress, including a large cost-share award from the Department of Energy, and NuScale has received design approval from the (Nuclear Regulatory Commission), we're seeing more and more utilities express interest in the plant."

Idaho Falls has committed to buying 5 megawatts of power from the reactors through the Carbon Free Power Project. The city had been committed to 10 megawatts but cut that in half in October amid concerns about financial risks.

"There is not much of a carbon-free future for many municipalities if we can't figure out some of this bridge technology to get us to some of these long-term solutions," Idaho Falls City Council member John Radford said at a July 8 meeting. "This project is something that can help keep this country on this trajectory to a carbon-free future and maybe a better existence for all of us."

Author's Comment: Per NuScale the schedule for above project is: "*The first NuScale Power Module™ will begin generating power in 2029, with the remaining modules coming online for full plant operation by 2030.*"

NuScale Power has announced the signing of a memorandum of understanding with the Grant County Public Utility District (Grant PUD) to evaluate the deployment of NuScale's advanced nuclear technology in central Washington State.[4]

[3] AP News, "Eastern Idaho nuclear project goes from 12 to six reactors" July 19, 2021, https://apnews.com/article/technology-science-business-environment-and-nature-climate-change-3737699443a50ebc3a24fccde562fd3f

[4] Nuclear Newswire, "NuScale to explore SMR deployment in central Washington," May 27, 2021, https://www.ans.org/news/article-2940/nuscale-to-explore-smr-deployment-in-central-washington/

Based in Ephrata, Wash., the Grant PUD is a public electric utility serving more than 40,000 retail power customers in Grant County. The utility's two Columbia River dams (Priest Rapids and Wanapum) and smaller hydropower projects have a generating capacity of more than 2,100 megawatts.

In its May 26 announcement, NuScale noted that its power plant design, the NuScale Power Module, is scalable in 77-MWe increments up to 924 MWe (12 units). "Modules can be added incrementally as regional load demands increase, offering the customer a new level of flexibility and reduced financial risk," NuScale said. "These qualities align well with Grant PUD's long-term objective of providing its customers with reliable, carbon-free energy."

Power hungry: According to a NuScale/Grant PUD frequently-asked-questions document, the utility projects that the demand for power will exceed its hydropower generation resources during seasonal peak times by 2026. "NuScale's small modular reactor technology, with its carbon-free, reliable power, provides a promising generation resource," the document states. "Grant PUD is excited to pursue this technology as it determines how it will serve the power needs of its growing customer base."

SMR developer NuScale Power and Prodigy Clean Energy have agreed to work together to advance their technologies as a baseload clean energy solution for coastal locations and island nations.[5]

This week NuScale and Prodigy sign memorandum of understanding (MOU) to support business development for a marine-deployed nuclear generating station powered by the NuScale small modular reactor (SMR). This is the second MOU between the two firms.

Prodigy Clean Energy is a Canadian company that designs and develops marine nuclear plants for safe, affordable and sustainable energy generation. It specializes in integrating commercial SMRs into marine power plant systems for coastal power generation.

Prodigy's SMR Marine Power Station would be shipyard-fabricated, and marine-transported to its deployment location, where it would be moored in place in sheltered and protected waters at the shoreline. Once berthed, the plant would be connected to the existing shore-side transmission system thus avoiding some of the significant capital costs associated with terrestrial nuclear power plant deployments…

3. GE-Hitachi BWRX-300

This design has not been as active as NuScale recently. Note that this design is covered in Nukes 3 and 4 papers – go to the list described and linked in the Introduction.

The big news may be that GE-Hitachi appear to be forming an alliances in Canada.

GE Hitachi Nuclear Energy (GEH) today announced the formation of GEH SMR Technologies Canada, Ltd. to support the deployment of the BWRX-300 Small Modular Reactor (SMR) in Canada.[6]

[5] By "djysrv", Neutron Bytes, "NuScale Launches Effort to Deploy Floating SMRs May 14, 2021, https://neutronbytes.com/2021/05/14/nuscale-launches-effort-to-deploy-floating-smrs/

[6] GE Press Release, "GE Hitachi Nuclear Energy Announces Formation of Canadian SMR Business," Feb 10, 2021, https://www.ge.com/news/press-releases/ge-hitachi-nuclear-energy-announces-formation-of-canadian-smr-business?_ga=2.34795937.1619241294.1630192580-1674769389.1629314314

Lisa McBride has been named Country Leader, Small Modular Reactors. In this role she will collaborate with Canadian customers, stakeholders, suppliers and partners in GEH's pursuit to bring the first grid-scale SMR to market by 2028.

"GE has been a pioneer in Canada's commercial nuclear energy industry since the 1950s and was part of a consortium that developed the country's first nuclear plant, the Nuclear Power Demonstration unit in 1962," said Jon Ball, Executive Vice President of Nuclear Products for GEH. "With the establishment of our Canadian SMR business we look forward to building on this legacy and bringing the world's first grid-scale SMR to Canada, positioning Ontario as a hub for SMR technology."

An independent report by PwC Canada, commissioned by GE Hitachi Nuclear Energy (GEH), estimates the potential economic benefits that would result from job creation, local supply-chain development, manufacturing, construction, operation and tax revenue generated by the deployment of BWRX-300 small modular reactors in Canada and the potential export of this technology worldwide.[7]

Authors Comment: PwC Canada is a leading Canadian Financial Consulting Firm. They are over 100 years old.

The independent report estimates that the construction and operation of the first BWRX-300 in Ontario is expected to generate approximately $2.3 billion in Gross Domestic Product (GDP), $1.9 billion in labour income and more than $750 million in federal, provincial and municipal tax revenue. The report estimates that each subsequent BWRX-300 deployed in Ontario and other provinces is expected to further generate more than $1.1 billion in GDP and more than $300 million in tax revenue...

The report estimates that each BWRX-300 that is constructed globally is expected to generate approximately $98 million in GDP for Canada and more than $45 million in total tax revenue through the purchase of Canadian machinery and equipment.

"GE's global market presence and reputation would be a key factor in promoting and developing Canada as an export base for SMRs around the world," the report said.

In addition to assessing areas including jobs, GDP, labour income and tax revenue associated with this technology, the report examined the potential for broader benefits including contribution to Canada's climate change commitments, promotion of diversity and inclusion, creation of opportunities for Indigenous communities, development of workers' skills and enhancement of technical excellence.

GE Hitachi Nuclear Energy (GEH), Global Nuclear Fuel-Americas (GNF-A) and Cameco Corporation (Cameco) have entered into a Memorandum of Understanding to explore several areas of cooperation to advance the commercialization and deployment of BWRX-300 small modular reactors (SMRs) in Canada and around the world.[8]

Author's Note: Cameco Corporation is a Canadian firm with Headquarters in Saskatoon, Saskatchewan, Canada. Regarding the statement below, CANDU reactors (Canada Deuterium Uranium) are a Canadian design that uses heavy water (water with

[7] GE Press Release, "Independent Report Highlights Economic Benefits of Deployment of GE Hitachi's SMR Technology in Canada," June 01, 2021, https://www.ge.com/news/press-releases/independent-report-highlights-economic-benefits-of-deployment-of-ge-hitachis-small?_ga=2.193117997.1619241294.1630192580-1674769389.1629314314

[8] GE Press Release, "GE Hitachi, Global Nuclear Fuel and Cameco to Examine Potential Collaboration to Support BWRX-300 SMR Deployment," July 06, 2021, https://www.ge.com/news/press-releases/ge-hitachi-global-nuclear-fuel-and-cameco-to-examine-potential-collaboration-to?_ga=2.3284528.1619241294.1630192580-1674769389.1629314314

deuterium instead of conventional hydrogen) for its coolant / moderator to enable the use of non-enriched uranium fuel. Several CANDU plants are still operating, and have continued to be incrementally upgraded, but no attempted future sales are seen. I believe that all other reactor designs use (at least) slightly enriched fuel, that is, uranium fuel with an enriched percentage of U-235 verses natural uranium.

Cameco supplies uranium, uranium refining and conversion services to the nuclear industry worldwide and is a leading manufacturer of fuel assemblies and reactor components for CANDU reactors.

"BWR and CANDU fuel types are closely related as both use similar cladding materials as well as ceramic, uranium dioxide fuel pellets so this type of collaboration offers the potential to extract significant synergies between the two fuel designs and manufacturing processes, enabling the expansion of Canada's local fuel supply chain capabilities," said Lisa McBride, Canada SMR Country Leader for GEH.

4. Holtec SMR-160

This design has not been as active as NuScale recently. Note that this design is covered in Nukes 3 and 4 papers – go to the list described and linked in the Introduction.

New news is below, the only major new news is that the Holtec SMR-160 is now in the NRC's Pre Application Review Stage:

The U.S. Nuclear Regulatory Commission (NRC) has a policy of encouraging early discussions (prior to submission of a license application) with potential applicants (such as utilities and reactor designers) to offer licensing guidance and to identify and resolve potential licensing issues early in the licensing process. Consistent with that policy, SMR, LLC, a Holtec International Company, has begun pre-licensing interactions with the NRC.[9]

Holtec International, a major supplier for the nuclear industry, is branching out to meet this need for carbon-free energy by designing a small modular reactor (SMR). In 2020, the company received $116 million in funding from the U.S. Department of Energy to develop and license its SMR-160 through the Advanced Reactor Demonstration Program…[10]

The SMR-160 is still a unique design, though. The reactor will be located underground, making it more secure and, in case of an accident, will use an automatically triggered system to cool the reactor that relies on gravity instead of any external equipment or pumps.

And that's not the only difference. Holtec International is a major supplier for the nuclear industry with over three decades of manufacturing experience, which the company is leveraging for its SMR.

"The SMR-160 is designed, literally, to be fabricated in the factory," said Tom Marcille, Holtec's vice president of reactor technologies and chief nuclear officer of the company's

[9] U.S. NRC, "Pre-Application Review of the SMR-160 Design," Nov 25, 2020, https://www.nrc.gov/reactors/new-reactors/smr/holtec/review.html

[10] Robbie Hayunga, The Nuclear Energy Institute, "Holtec Strives to Make Nuclear Innovation Look Simple With SMR-160," March 16, 2021, https://nei.org/news/2021/holtec-strives-nuclear-innovation-smr-160

SMR division. Holtec operates an advanced manufacturing facility in New Jersey, specifically designed to build next-generation reactors.

Holtec wants to use its established strengths in manufacturing to bring a new reactor to market. As part of this strategy, SMR-160 is also built to transfer used fuel into the company's own canister storage system.

But its integrated approach doesn't end with the design. Since Holtec is decommissioning the Oyster Creek nuclear plant only 55 miles away from its manufacturing facility in New Jersey, it has begun to look into building its SMR on the same site.

US-based Holtec said earlier this month that it was "pleased to observe" that the growing demand for clean and reliable base load energy was fueling interest in its SMR-160 small modular reactor (SMR). The SMR-160 is a 160MW light-water based pressurized SMR with a passive safety system.[11]

As an example of international interest in the SMR-160, Holtec noted the recent agreement with ÚJV Rež, part of the CEZ Group that is majority owned by the Czech government, for evaluation of the reactor for deployment in the Czech Republic. "Small modular reactors are being strongly considered as part of the Czech Republic's efforts to increase nuclear capacity," said Dr Rick Springman, Holtec's SVP of International Projects. "This agreement will provide for technical exchange and cooperation, focusing on the licensing pathway and project assessment for SMR-160 to provide the country with a safe and secure source of clean energy in the future."

Holtec has also joined a consortium with 15 major companies to establish the Moorside Clean Energy Hub in North West England. This includes a number of nuclear projects at Moorside, including a new UK-EPR pressurised water reactor together with "potentially a clutch of SMRs and other innovative technologies"…

These two announcements follow a previous agreement that Holtec established last year with Ukrainian nuclear utility to form a consortium partnership to lead the deployment of the SMR-160 in Ukraine. Discussions are also underway with top policy makers in India to deploy hundreds of SMR-160s throughout the subcontinent to generate geographically dispersed clean energy, Holtec said.

SMR-160 has completed phase 1 of the Vendor Design Review (VDR) process in Canada and the licensing process is underway with the US Nuclear Regulatory Commission.

5. National Ignition Facility (NIF) LIFE

NIF and LIFE are described in section 3 of "Distant Nuclear Fusion." Go to the list and section described and linked in the Introduction. LIFE is an abbreviation for Laser Inertial Fusion Energy. This was a fusion energy effort run at Lawrence Livermore National Laboratory between 2008 and 2013. LIFE conceptualized the technologies necessary to convert the laser-driven inertial confinement fusion concept being developed in the

[11] Nuclear Engineering International, "Holtec sees growing interest in its SMR-160," 29 Oct 2020, https://www.neimagazine.com/news/newsholtec-sees-growing-interest-in-its-smr-160-8207017/

National Ignition Facility (NIF) into a practical commercial power plant concept. This effort is described in detail in "Distant Nuclear Fusion."

The really big news is that NIF is moving much closer to theoretical break-even:

More than a decade ago, the world's most energetic laser started to unleash its blasts on tiny capsules of hydrogen isotopes, with managers promising it would soon demonstrate a route to limitless fusion energy.[12]

The National Ignition Facility (NIF) has taken a major leap toward that goal. Last week, a single laser shot sparked a fusion explosion from a peppercorn-size fuel capsule that produced eight times more energy than the facility had ever achieved: 1.35 megajoules (MJ)—roughly the kinetic energy of a car traveling at 160 kilometers per hour. That was also 70% of the energy of the laser pulse that triggered it, making it tantalizingly close to "ignition": a fusion shot producing an excess of energy.

"After many years at 3% of ignition, this is super-exciting," says Mark Herrmann, head of the fusion program at Lawrence Livermore National Laboratory, which operates NIF.

NIF's latest shot "proves that a small amount of energy, imploding a small amount of mass, can get fusion. It's a wonderful result for the field," says physicist Michael Campbell, director of the Laboratory for Laser Energetics (LLE) at the University of Rochester.

"It's a remarkable achievement," adds plasma physicist Steven Rose, co-director of the Centre for Inertial Fusion Studies at Imperial College London. "It's made me feel very cheerful. … It feels like a breakthrough."

And it is none too soon, as years of slow progress have raised questions about whether laser-powered fusion has a practical future. Now, according to LLE Chief Scientist Riccardo Betti, researchers need to ask: "What is the maximum fusion yield you can get out of NIF? That's the real question."

Fusion, which powers stars, forces small atomic nuclei to meld together into larger ones, releasing large amounts of energy. Extremely hard to achieve on Earth because of the heat and pressure required to join nuclei, fusion continues to attract scientific and commercial interest because it promises copious energy, with little environmental impact…

NIF's approach, known as inertial confinement fusion, uses a giant laser housed in a facility the size of several U.S. football fields to produce 192 beams that are focused on a target in a brief, powerful pulse—1.9 MJ over about 20 nanoseconds. The aim is to get as much of that energy as possible into the target capsule, a diminutive sphere filled with the hydrogen isotopes deuterium and tritium mounted inside a cylinder of gold the size of a pencil eraser. The gold vaporizes, producing a pulse of x-rays that implodes the capsule, driving the fusion fuel into a tiny ball hot and dense enough to ignite fusion. In theory, if such tiny fusion blasts could be triggered at a rate of about 10 per second, a power plant could harvest energy from the high-speed neutrons produced to generate electricity.

[12] Daniel Clery, Science, "With explosive new result, laser-powered fusion effort nears 'ignition'," Aug. 17, 2021, https://www.sciencemag.org/news/2021/08/explosive-new-result-laser-powered-fusion-effort-nears-ignition

Author's comment: NIF's lasers are very inefficient, so getting from theoretical break-even (described above) to practical break-even will be a hill too high for it to climb. That is why LIFE was created – it uses much more efficient solid-state lasers (a.k.a. laser diodes). This is among many other changes that were made to increase efficiency and practicality for the LIFE design. Read "Distant Nuclear Fusion" for more details.