NATRIUM™ TECHNOLOGY. COMPETITIVE, FLEXIBLE AND READY

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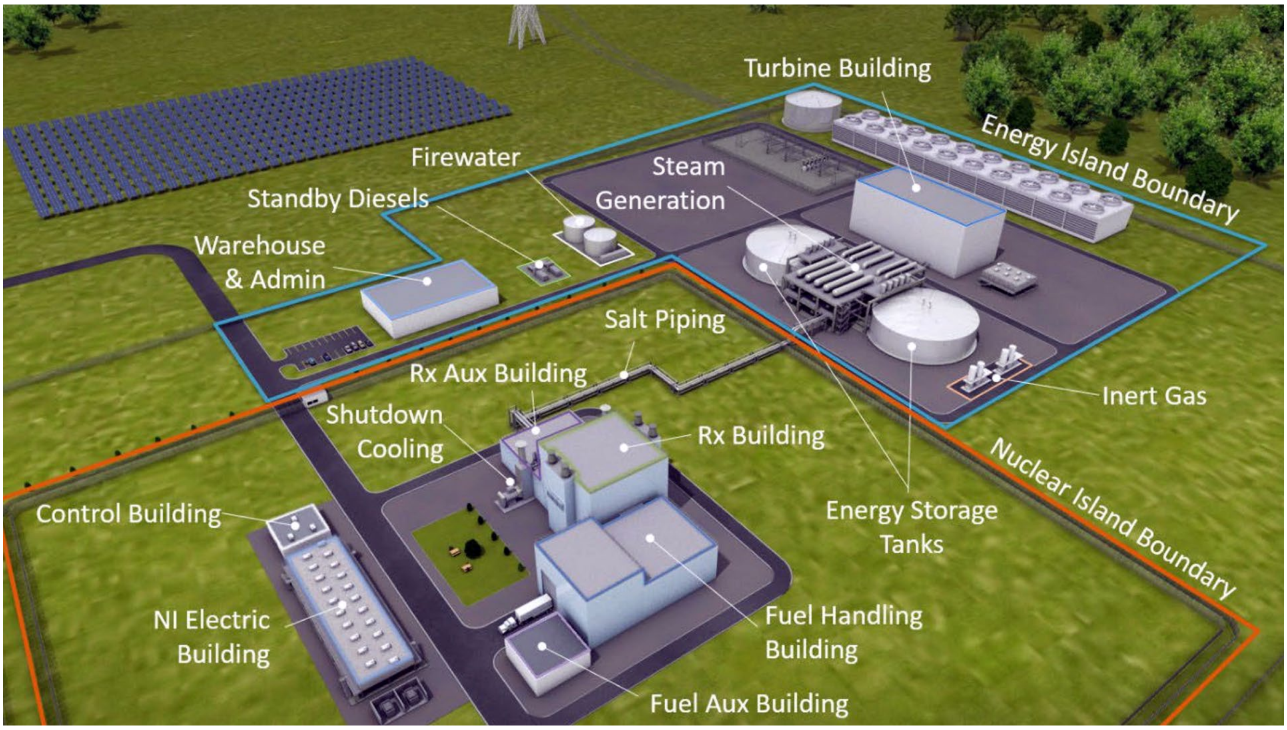

GE Hitachi Nuclear Energy (GEH) and TerraPower are collaborating on a new nuclear reactor, called Natrium™, which takes the best from our existing sodium fast reactor (SFR) designs, GEH's PRISM and TerraPower's Traveling Wave Reactor (TWR). The results of the GEH and TerraPower collaboration have been strong and this can be credited to our synergies and more importantly where we complement each other. While GEH is a nuclear reactor developer and services and fuel provider with more than 60 years of experience TerraPower, founded by Bill Gates, is an innovative developer with significant R&D capabilities and owners with goals regarding energy, climate change and poverty.

THE CHALLENGE

The international stage is becoming more focused on deep decarbonization of the energy sector, which includes attaining net-zero greenhouse gases. More and more countries and regions are prioritizing the need to produce dependable, clean power. Addressing climate change is an urgent global priority, requiring global action, national commitments, consistent policy and regulatory frameworks and the technological innovation and business partnership to realize these goals. GEH and TerraPower are committed to tackling the world's biggest challenges and believes that climate change is one of the most pressing issues we face today. The companies support the science and goals expressed in the Paris

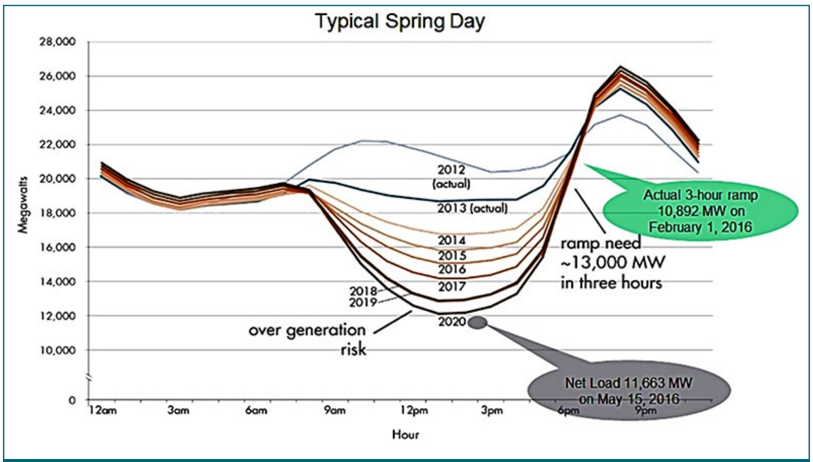

Figure 1.

Agreement to reduce global carbon emissions. Meeting the targets of the Paris Agreement requires investment in new and upgraded technologies.

According to International Energy Agency, in 2018 nuclear accounted for 10% of total global electricity generation but provided 29% of global low-carbon power generation, second only to hydro at 45%, and followed by wind and solar at 13% and 6% respectively. Over the past 50 years, the use of nuclear power has reduced CO_2 emissions by over 60 gigatons – nearly two years' worth of global energy-related emissions.[1] Meanwhile, renewables are the fastest growing source of new power generation capacity and electricity. BP's Statistical Review of World Energy (2020) found that renewables grew by 12.1%, which was its highest capacity increase ever while also being the largest for any fuel in 2019, at 41%. While this is a positive development for clean energy and addressing climate change, increased renewable penetration also creates some challenges.

RENEWABLE INSIGHTS FROM CALIFORNIA AND GERMANY

In the U.S. California leads the nation with 36% of its electricity coming from renewable sources with a goal of having 100% of its electricity come from renewable or carbon-free energy sources.[2] While this is excellent progress towards clean energy, it also comes with some growing pains. In 2013, the California Independent System Operator (CAISO) introduced a phrase to explain the challenges created with increased renewable penetration, "The Duck Curve"[3]. This shows that renewables are intermittent or variable resources, which can create oversupply risks, needs for flexible and responsive backup and even frequency control issues. In Figure 1, the net load is the difference between forecasted load and forecasted electricity production from variable generation resources, wind and solar, which shows the forecast variability. While wind also contributes, much of this daily variation is driven by solar. As the sun rises, shines, and sets, the net load inversely follows dipping through the morning to the "belly" of the duck and quickly ramping up in the evening for the "neck." In addition to this intra-day variation, solar energy also varies over the year as the sun's time and angles in the sky vary with the earth's axis angle and orbit around the sun.

Meanwhile, wind has its own types of variability. In addition to short term variations at the hourly and daily level, wind turbine generation performance varies throughout the year as a result of seasonal wind patterns. This can be seen in this chart for Germany as wind variations in January 2021, necessitated reinforcement by coal and gas[4]. Energiewende, Germany's "energy transition" to a low carbon energy supply is based on increasing renewables and the phasing out of clean nuclear energy before, coal and natural gas are retired. During this transition low periods of wind and solar have been primarily backed by fossil generation resulting in additional GHG emissions.

While nuclear, hydro, and renewables deliver 36.4% of the clean carbon-free global electricity, they provide only 15.7% of clean carbon-free global overall energy (including transportation and industrial needs)[5]. As the world addresses climate change these percentages will increase considerably, particularly with the electrification of transportation. As the most dependable source of CO_2-free, baseload and dispatchable power, nuclear energy must be a critical pillar in the transformation to a carbon-free future. Natrium technology is complementary to renewables and can help address some of the challenges of increased renewable penetration.

NATRIUM TECHNOLOGY

The GEH/TerraPower collaboration has transitioned through several gated phases with a design-to-cost focus while maintaining the simplicity inherent to the base technology of a pool type SFR. We established stakeholder and plant requirements, completed 24 key trade-off studies and 13 topical design reviews, leveraged energy storage technology from the concentrated solar power (CSP) industry, and determined the best initial configuration for a demonstration plant.

Together, we redefined what nuclear could be by eliminating nuclear "sprawl", the extent to which nuclear quality assurance and requirements apply, in order to reduce costs in many areas, and by designing a plant that will integrate with renewables as a dispatchable clean energy resource that can economically respond to the demand changes that renewables create. The result is the Natrium™ technology,

[1]IEA, Nuclear Power in a Clean Energy System, May 2019, https://www.iea.org/reports/nuclear-power-in-a-clean-energy-system

[2]CALIFORNIA CLEAN ENERGY ALMANAC 2020, Road to 100 Percent Clean Energy, https://www.energy.ca.gov/sites/default/files/2021-02/2020%20-%20CEC%20-%20CCEA%2002.04.21%20ADA.pdf

[3]CAISO – "What the duck curve tells us about managing a green grid", 2016, https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

[4]Energy-Charts, Net electricity generation in Germany in January 2021, https://energy-charts.info/charts/power/chart.htm?l=en&c=DE&interval=month&source=all&stacking=stacked_absolute_area&year=2021&month=01

[5]BP, Statistical Review of World Energy, 2020, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf

a 345 MWe/840 MWt reactor plant with simple nuclear systems that are "decoupled" from its flexible energy storage and power generation system. The reactor operates at 100% power 24 hours a day/7 days a week thereby reducing cycling of the nuclear island, while the energy island, consisting of molten salt energy storage, steam generation and steam turbine generator, absorbs grid demand variation by turbine output. While the reactor operates continuously at 100% thermal power the energy island plant design can flex up to 500 MWe for 5.5 hours, providing 2,750 MWhe of energy storage reserve when needed, ramp down to recharge storage (nominally to 100 MWe as necessary) or operate at 345 MWe continuously. As seen in Figure 2, the storage size and turbine output can be customized based on specific location and grid analysis without impact to the nuclear system due to decoupling.

Our collaborative work and design were recognized when Natrium was selected for a demonstration award by the U.S. Department of Energy (DOE) as one of two designs out of a broad field of entrants for the Advanced Reactor Demonstration Program (ARDP). Through this program, which involves site selection, plant design, licensing, procurement, construction and fuel fabrication, initial fuel core is scheduled to be loaded within seven years. The Natrium ARDP team is led by TerraPower and includes major partners GEH, Global Nuclear Fuels-Americas, LLC (GNF) and Bechtel Power Corporation (Bechtel) and is supported by utility partners, Energy Northwest, Duke Energy Carolinas, LLC (Duke Energy), and PacifiCorp (a Berkshire Hathaway Energy company) as well as national labs, universities, and others. At the end of the project, the Natrium demonstration unit will be an NRC-licensed grid-scale reactor entering commercial service complete with energy storage. In addition, all the infrastructure needed for further commercial deployments will have been established. The U.S. nuclear industry will be able to enrich and fabricate HALEU fuel, fabricate and qualify advanced reactor equipment and license, construct and operate highly competitive advanced reactors.

Heat Transport, Storage and Versatility

Natrium is far more versatile than current generation nuclear plants. There are three heat transport fluids—liquid metal sodium, molten nitrate salt and water/steam (Figure 2). In the primary system, the heat produced by the sodium-cooled nuclear core is transferred to a molten salt loop. The molten salt is drawn from a cold salt tank in the energy island, flows to the nuclear island, is heated by the reactor, and returns to the energy island to charge (fill) the hot salt tank. The steam generation system draws salt from the hot salt tank to generate superheated and re-superheated steam for conversion to electrical power by the steam turbine generator. This energy storage architecture contributes to the operation decoupling previously described.

Energy storage allows the reactor to operate at 100% power while the energy island ramps power up and down from ~100 to 500 MWe at 8%/minute to flexibly follow hourly electricity prices or provide other grid services. By shifting electricity generation to a time of higher price, annual revenues are increased, the extent of which will be location and policy dependent. In addition to collecting electricity and capacity payments, although limited now, there are possibilities for growing value through ancillary services such as frequency regulation, spinning reserves, voltage control, etc.

This operational flexibility of Natrium couples well with renewable energy, such as wind and solar. Natrium can store energy while solar and wind energy sources are generating electricity. When solar or wind power generation falls off, Natrium can leverage its stored energy to supply electricity to meet energy demand. This makes Natrium a natural part of energy markets targeting reduced carbon or net-zero carbon energy distributions. Wind and solar have very low variable cost with high capital cost, while not being dispatchable and are economically driven to sell power at any price when weather promotes high availability. The low variable cost and weather dependency can cause large hourly electricity price swings. Natrium is designed to capture this value by producing electricity during periods of low renewable availability. With this operational flexibility, Natrium can increase annual revenues compared to a plant without energy storage. Natrium's storage size and STG output can be customized to a "sweet spot" based on specific location and grid analysis, as shown in Figure 2. This strategy and our internal analysis are consistent with a recent LucidCatalyst report.

Key Safety Features

Natrium leverages the legacy of 40 reactor-years of EBR-II and FFTF operations in the U.S. These two predecessor reactors demonstrated that metallic-fueled SFRs can passively accommodate severe transients. The nuclear safety features have higher reliability due to low-pressure, always-on passive air cooling and inherent reactivity feedbacks that

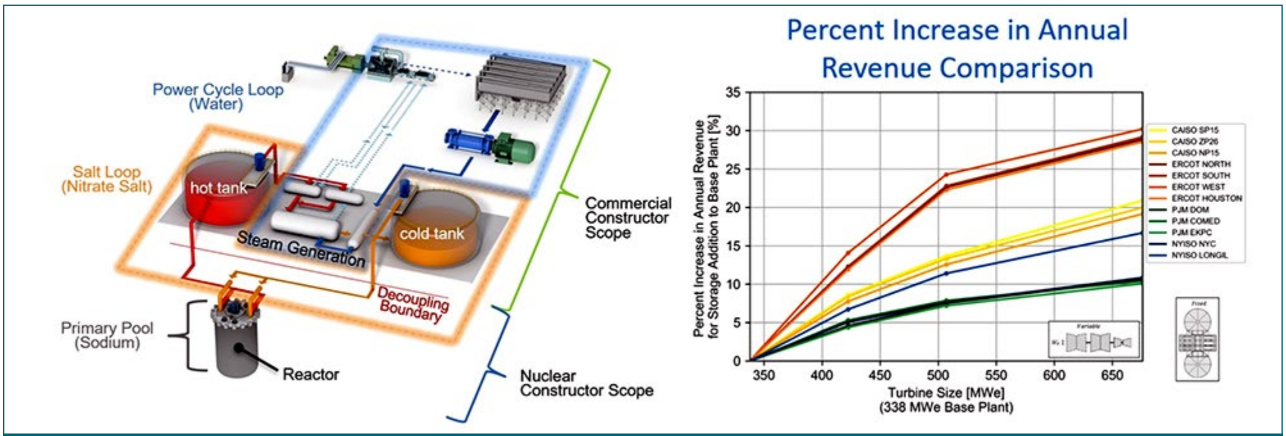

Figure 2.

naturally support a risk-informed performance-based approach to nuclear licensing.

With respect to decay heat removal, the high heat transfer of the reactor coolant, even under natural circulation, enables direct heat removal from the surface of the vessel without excessive reactor temperatures, which completely eliminates safety-related decay heat removal heat exchangers. The vessel, which is an existing cost, serves as the safety-related heat transfer surface area in Natrium's Reactor Air Cooling System (RAC). This is important for costs because the larger the footprint and complexity of nuclear safety-related components, the larger the buildings that house them.

These features eliminate the complex spiderweb of nuclear safety-related systems of past and current reactors which drive high costs. These attributes have especially positive impacts to the design response involving safeguards and security, station blackout coping time, and the size and scope of emergency planning. Given a station blackout, the plant automatically reaches a safe state. The underlying inherent safety of Natrium technology was proven by EBR-II and tests at Argonne National Laboratory in Idaho. Natrium's control rods insert by gravity automatically on the loss of power. Reactor cooling via passive RAC is always operating and will pick up the full shutdown cooling load should all normal heat removal pathways fail. Coping time is essentially unlimited, and the need for United States FLEX type equipment and emergency response personnel is eliminated by the inherent design. The NRC NUREG-1368[6], Pre-application Safety Evaluation Report for the PRISM Liquid Metal Reactor, concluded that "no obvious impediments to licensing the PRISM design had been identified." Given the similarities between Natrium and PRISM design, similar conclusions could be drawn (Figure 3).

Design-to-Cost

Natrium cost targets are derived from the business plan and previous cost estimate experience and are allocated to systems as well as fuel and operation and maintenance (O&M) cost accounts. Throughout the design process, the product cost model is refined with updated cost information and is used to project and accumulate product costs to use as a factor in evaluating design alternatives and to refine the design to meet cost targets. When cost targets are about to be or have been exceeded, designers work with the design to cost leader to develop an action plan to realign projected costs to an acceptable level, or to adjust target costs where necessary.

[6]NUREG-1368, "Preapplication Safety Evaluation Report for the Power Reactor Innovative Small Module (PRISM) Liquid-Metal Reactor." https://www.nrc.gov/docs/ML0634/ML063410561.pdf

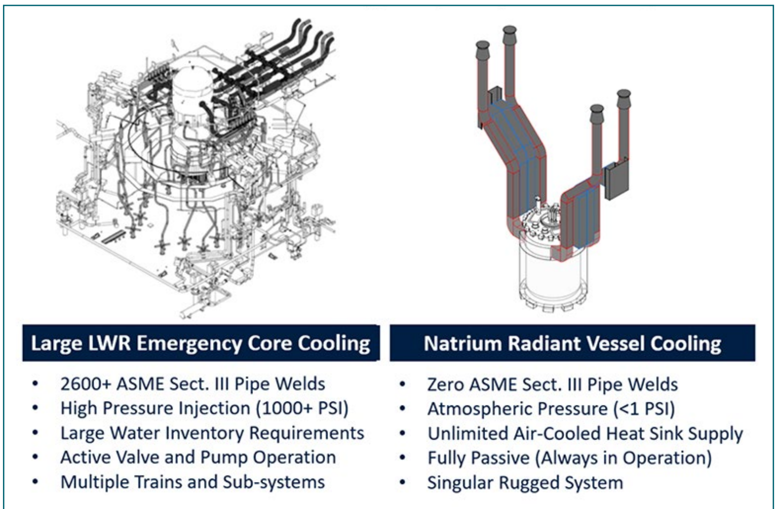

Figure 3.

The metallic fuel pool type SFR which forms the base of Natrium reactor technology has a much simpler safety profile. This creates an opportunity for cost reduction by permitting more streamlined architectures. Inherent properties of the fuel, coolant and pool design create a compact and simple safety envelope to reduce costs. The reactor buildings of most reactors use a monolithic arrangement in which the reactor is surrounded by a complex array of support and safety equipment. This makes the reactor building challenging and costly to build, since it becomes very large and filled with internal walls and equipment supports, all while being held to exacting nuclear standards. In contrast, Natrium takes full advantage of the simple and robust safety profile of its base technology to dramatically reduce the complexities associated with nuclear construction. The superior heat transfer characteristics of sodium and its low pressure permit compact equipment, unlike in systems cooled with pressurized water or gas. Safety functions are made integral to the reactor vessel, and support equipment is moved to separate structures with more flexible requirements, resulting in a vastly simplified reactor building design with an "open" floor plan (Figure 4). The most important nuclear systems are located and protected below ground while the vast majority of the nuclear island is above ground and can be designed and constructed to non-nuclear standards. The amount of nuclear seismic concrete is reduced by 80% compared to current GW scale Generation III+ LWRs. The resulting Natrium system is an entirely new class of nuclear power plant that can be rapidly deployed worldwide.

Decoupling

One of Natrium's key design philosophies is its "decoupling" approach to plant design. This approach is enabled by the inherently self-protecting reactor and the use of molten salt energy storage tanks. The nuclear island contains the reactor and the energy island contains the thermal energy storage tanks, steam generator and turbine. The nuclear island boundary conditions have been intentionally designed so its interface with the rest of the world does not impact its safety case. This is referred to as "regulatory decoupling". Similarly, steam generation and thermal energy storage operations (e.g. ramp rates) are relatively independent from reactor power operations due to the presence of molten salt energy storage tanks. This is referred to as "operations decoupling".

Decoupling enables the majority of the plant (i.e., the energy island) to be designed, constructed, and operated by a non-nuclear project team without being subject to nuclear regulations thereby reducing capital & operating costs. Nuclear operators focus on operating the nuclear heat source without the need for a skill set that includes operation of a steam

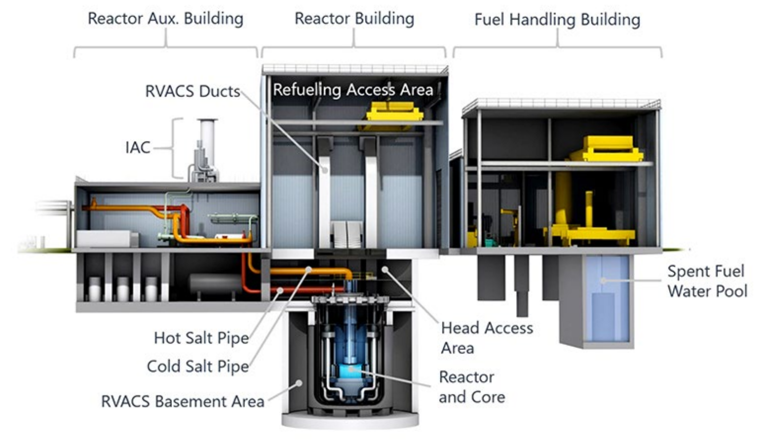

Figure 4.

electric plant. Operator training, quality, and maintenance programs between the two islands are separate, which reduces expenses by reducing spillover of nuclear practices into areas that do not need them. The energy island operators focus on following load demand, managing salt levels and turbine outputs without interference of nuclear issues. Decoupling also makes it straightforward to use Natrium for alternative applications, including process heat and hydrogen generation.

Readiness

Natrium has one of the highest technology readiness levels (TRLs) of any advanced non-light water Generation IV (GEN IV) reactor. Natrium draws from decades of design information, test data, lessons learned, and best practices from past operating SFRs. Worldwide, the base SFR technology has >400 years[7] of combined operating experience across numerous reactors.

Natrium plants will start-up with sodium-bonded U-Zr High Assay Low Enriched Uranium (HALEU, up to 20%) fuel based on 40 years of metallic fuel irradiation at EBR II and FFTF and more than a decade of recent fuel irradiation testing by TerraPower. Future improvements are planned for high burnup and high temperature fuel dramatically improving economics of once-through fuel cycle once testing/qualification is complete.

The molten salt energy storage technology employed by Natrium has already been demonstrated in concentrated solar power plants globally. Furthermore, with use of nitrate salt-heated steam generators derived from concentrated solar power instead of traditional sodium heated steam generators, Natrium has dramatically increased the strength of its supply chain.

Natrium Plant Parameters and Features

[7]World Nuclear Association, Advanced Nuclear Power Reactors, Sep 2020,www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/advanced-nuclear-power-reactors.aspx

Parameter	Value
Reactor Type/Reactor Coolant	Fast neutron spectrum/liquid metal sodium
Reactor Power	840 MWt/345 MWe net baseload equivalent
Power Output - Energy Island	345–500 MWe net, site dependent due to energy storage
Capacity Factor - Nuclear Island	92.5%
Thermal Efficiency	41 % net @ 84 mbar-abs condenser pressure
Load Following Capabilities	Ramp Rate 8%/minute and Turndown 20%
Reactor Operating Cycle	12-24 months
Reactor Coolant Operating Temperature	540°C
Primary Operating Pressure	~Atmospheric
Emergency Planning Zone	<400 m radius, i.e. site boundary

Table 1.

Design Feature	Advantages
High Energy, or Fast, Spectrum	Enables very high fuel utilization in once through fuel cycles or future used nuclear fuel recycling. If needed, can be called upon to recycle used nuclear fuel, extracting more energy from these assets by burning the long-lived transuranic isotopes and in turn optimizing the heat load and spacing, and reducing the burden, of the ultimate repository. Similarly, Natrium could be used to disposition depleted uranium or plutonium according to government policies.
Pool Reactor	Compact primary coolant boundary. Eliminates loss of coolant accidents. Allows for near atmospheric operating pressure. Inherently low driving force for radionuclide release. Easier to fabricate thin reactor vessel and easier to construct structures.
High Temperature	High thermal efficiency and reduced cooling water requirements. Suitable for coupling to thermal energy storage and process heat applications (district heating, desalination, hydrogen, etc.).
Sodium Coolant	Sodium, a liquid metal, has exceptional heat transfer leading to high power density. Mitigates radionuclide release. Corrosion practically non-existent, lowering staffing needs.
Nitrate Salt Coolant	Nitrate salt is well matched for use with sodium, as it: 1) has a large heat capacity facilitating energy storage; 2) minimizes liquid sodium inventory; 3) is virtually unaffected by radioactivity of the core; 4) supports temperatures that overlap sodium reactor operating temperatures quite well; and 5) allows use of existing steam generator designs while eliminating sodium-water reaction protection equipment.
Limited Excavation	Architecture enables vertical shaft excavation techniques that minimize engineered backfill and shorten construction schedule. Nearby structures can be built in parallel to the reactor building without awaiting backfill.

Table 2.

Tables 1 and 2 provide additional information about Natrium.

COMPETITIVE FLEXIBLE ADVANCED NUCLEAR PLANTS

In 2020 LucidCatalyst completed a study, "Cost & Performance Requirements for Flexible Advanced Nuclear Plants in Future U.S. Power Markets" for the U.S. DOE ARPA-E[8]. They modeled future scenarios in 2034 with combinations of 1) low and high renewables penetration, 2) at capacity pricing of $50 to $100/kW-yr, 3) with and without integrated thermal energy storage systems (ESSs), 4) modeled for four major deregulated U.S. Independent System Operators (ISOs) [ISO-New England (ISO-NE),the Pennsylvania, Jersey, Maryland Power Pool (PJM), the Midcontinent Independent System Operator (MISO), and CAISO].

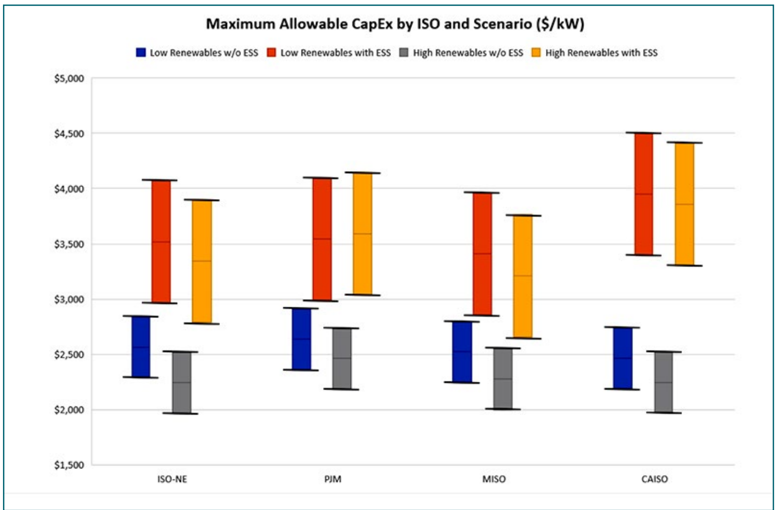

Figure 5.

As shown in the below chart, the data ranges from $1,965/kW to $4,503/kW and demonstrated that the "additional revenues from the 'nuclear + storage' plant justified extra allowable CapEx, ranging from $613/kW to $1,891/kW across the modeled scenarios and ISOs" (Figure 5).

The report also anticipates carbon pricing schemes being implemented in the U.S. by 2034, with proposals conservatively setting a CO_2 price of approximately $50/ton by 2034. Their modeling example for a specific load zone in PJM showed that a $25, $50, and $75/ton CO_2 price would increase the nuclear plant maximum allowable CapEx by $993/kW, $2,005/kW, or $3,018/kW, respectively.

LucidCatalyst concludes that, "Advanced reactor developers should be aware that while there are emerging market mechanisms to reward resources for enhancing grid flexibility and resiliency (and the operating reserve market is likely to expand), the primary revenue sources are energy sales and capacity payments. Average annual energy prices are also expected to fall due to increasing quantities of zero-marginal cost VRE [variable renewable energy]. Absent a CO_2 price, or premiums paid for emissions-free generation and capacity, advanced nuclear developers will need to design their plants to an average cost of below $2,989/kW." Natrium's CapEx target is compatible with this analysis and stands to be even more competitive based on the inclusion of energy storage and when ancillary services and CO_2 reduction are valued.

[8]LucidCatalyst, "Cost & Performance Requirements for Flexible Advanced Nuclear Plants in Future U.S. Power Markets": https://85583087-f90f-41ea-bc21-bf855ee12b35.filesusr.com/ugd/2fed7a_a1e392c51f4f497395a53dbb306e87fe.pdf

MEETING THE CHALLENGE

Natrium leverages the simplicity of SFRs, leans on over 400 years of combined global SFR operating experience, uses a fundamentally different decoupled approach, and embraces design-to-cost practices. The results are an innovative, flexible, economic reactor that is ready for deployment and can integrate with renewables. This achievement has already been recognized through Natrium's selection for a demonstration contract award by the U.S. DOE and interest from many customers. GEH and TerraPower look forward to delivering the Natrium DOE demonstration reactor followed by a fleet of commercial Natrium reactors that will bring immense value and flexibility side by side with renewables, as we help address global warming and air pollution concerns. Please visit NatriumPower.com to learn more.■