MINUTES

Commission to Investigate the Implementation of Next Generation Nuclear Reactor Technology in New Hampshire

November 6, 2023

Attendance:

Commission Members: Catherine Beahm, August B. Fromuth (remote), Daniel Goldner, Matthew Levander, Sen. Howard Pearl, David Shulock, Rep. Keith Ammon

Absent: Marc Brown, Rep. Michael Harrington, Christopher McLarnon

Public In-Person: Thomas Barrasso, Hon. Richard "Dick" Barry, Douglas Mailly, Rep. Alvin See

Public Remote: Arnie Alpert, Evan Cummings (Kairos), Paul Gunter, Chris Heck, Ryan McLeod (CNL), Nathan Raike (ISO-NE), Adam Schmidt (J. Grimbilas Strategic Solutions), John Tuthill, James Walker (NANO)

Meeting:

I. Call to Order

- The meeting was called to order by Representative Keith Ammon at 9:03 AM EST on November 6, 2023. The meeting was held in person at the New Hampshire Department of Environmental Services Office Building in Concord, NH with additional attendees participating via Zoom video conference.

II. Presentations

A. Presentation: Ryan McLeod, Chemical Technologist at Canadian Nuclear Laboratories. Topic: Nuclear Technology and Bitcoin Mining

1. Introduction

- Ryan McLeod works as a chemical technologist at Canadian Nuclear Laboratories (CNL), a nuclear research company owned by Atomic Energy of Canada Limited (AECL), which is itself owned by the government of Canada [1].
- He assembled a team and entered the Innovation for Nuclear contest hosted by the North American Young Generation in Nuclear (NAYGN) organization [2].
- The contest sought ideas on how nuclear power and small modular reactors (SMRs) could help meet the United Nations Sustainable Development Goals.
- Ryan's winning entry proposed using Bitcoin mining as a flexible electricity load to support the deployment of nuclear reactors by guaranteeing demand.

2. The Evolving Role of Nuclear Power

    - Many countries are concerned about having reliable, affordable, low-carbon emission energy sources to provide security for the electricity supply.
    - Nuclear power is seen as an obvious solution to help displace fossil fuels and meet sustainability targets.
    - Now is an opportune time to build more large-scale conventional nuclear reactors.
    - Also, there is a chance to deploy next-generation small modular nuclear reactors (SMRs) at underserved sites.
    - Canada is explicitly looking to expand nuclear generation capacity materially in the coming years.
    - The Canadian government is courting companies like NuScale, Moltex, ARC Clean Energy, and Ultra Safe Nuclear Corporation to build small modular reactors (SMRs) for remote communities and mines [3].
    - Meredith Angwin authored a book called "Shorting the Grid, “ highlighting the complex challenges grid managers face with renewables integration, which energy storage and demand response seek to solve [4].
    - Canadian Nuclear Laboratories has an internal modeling team examining the potential for pairing SMRs with intermittent renewables, energy storage, and other technologies into off-grid hybrid energy systems.

3. Potential Benefits of Integrating Bitcoin Mining with Nuclear Plants

    - Provides guaranteed electricity customers for purchasing nuclear plant output when online, regardless of whether transmission lines are ready to connect the facility to the wider grid.
    - Having financial certainty of a buyer in place improves investor confidence in capital-intensive new nuclear construction projects by contractually ensuring a revenue stream.
    - Recent trend of institutional investors expanding into the crypto asset class further enables major Bitcoin mining operations to serve as anchor customers for small modular reactor plant operators.
    - In addition to monetizing excess energy, Bitcoin mining serves as a financial incentive for miners to contribute extra computing resources to protect the security and integrity of the Bitcoin network.
    - This computing power enables other applications like verifiable timestamping important data, such as election results, in an immutable blockchain ledger.

4. How Bitcoin Cryptocurrency Mining Works

    - The underlying Bitcoin network protocol governs digital currency's total supply cap and the rate at which new coins enter circulation via an open-source algorithm.
    - Specialist Bitcoin mining computers validate transactions submitted to the network and organize them into "blocks" that form a chronological chain with complete history - this is the blockchain ledger.

- Miners perform intensive cryptographic computations at high energy loads and compete to close each new block, for which they earn newly minted Bitcoin as rewards.
- The latest generation custom Bitcoin mining machines optimize energy efficiency to use less electricity per unit of computational work performed.
- Efficiency is measured in joules consumed per terahash, where one terahash equals one trillion cryptographic hash calculations per second.

5. Real-World Examples of Bitcoin Mining Integrating with Nuclear Energy Infrastructure

    - Early off-grid Bitcoin mining operations powered by waste methane gas flare streams or landfill gas sites, avoiding the release of these harmful greenhouse gases.
    - Flexible mining data centers strategically sited directly at solar and wind renewable energy installations to serve as useful electricity load sinks during periods of excess intermittent production.
    - Some mining facilities implement complete immersion cooling infrastructure for computers to significantly reduce noise pollution and waste heat relative to traditional air-cooling methods.
    - TeraWulf [5] owns a mining operation behind the meter at the Talen Energy-owned Susquehanna nuclear plant to utilize non-grid-exported power.
    - NuScale [6] has an agreement with Standard Power [7] to provide up to 12 77MWe small modular reactor power modules to power a mining data center. Standard plans to build on a former coal generation site.

6. Pathways for Nuclear Plant Operators Looking to Integrate Bitcoin Mining

    - Companies like CleanSpark [8] provide Bitcoin mining solutions optimized for grid stability and reliability.
    - Cathedra Bitcoin [9], with facilities in New Hampshire, makes portable Bitcoin mining containers powered by flare gas engines and has firmware for optimizing mining computers.
    - Foreman Mining [10] sells fleet management software to monitor and control groups of mining machines remotely.
    - Hash Rate Index [11] and Braiins [12] offer data and tools to model mining profitability.
    - Turnkey self-contained Bitcoin mining data centers can be purchased pre-installed inside shipping containers for simple plug-and-play deployment.
    - Permanent custom-designed industrial-scale mining facilities can be constructed on the physical site of the nuclear plant to host computers long-term.
    - A vertically integrated business model can be adopted with the operator owning the entire Bitcoin mining operation.
    - Risks and rewards can be shared through partnerships, joint ventures, or hosting agreements with specialized external crypto-mining companies.
    - Fabiano Consulting [13] provides expert guidance on deploying Bitcoin mining to improve grid economics.

- New software platforms in development, such as Synota [14], can enable direct streaming of Bitcoin payments from mining operations to energy providers in real-time based on actual electricity consumption rather than the traditional monthly billing system.

7. Conclusion

- Bitcoin cryptocurrency mining operations are gaining more mainstream institutional credibility
- Integrating mining to provide grid balancing and a guaranteed customer base can accelerate the global adoption of clean nuclear energy to benefit humanity by displacing fossil fuel generation

8. Q&A:

- Q: Paul Gunter - Beyond Nuclear asked about the recent report by Iceberg Research, which examined the relationship between Standard Power and NuScale. He highlighted that NuScale had entered into a $37 billion sale agreement with Standard Power for 24 77-megawatt SMRs, even though these SMRs were still uncertified. He emphasized that the Iceberg Research report had damaged investor confidence and led to lawsuits by investors in NuScale related to Bitcoin development in Ohio and Pennsylvania. He offered to share the report with the New Hampshire Commission.
- A: Rep. Keith Ammon added that Iceberg Research is a short seller motivated to tank NuScale stock. He mentioned that NuScale had responded to the report, but the situation was still evolving.
- A: Ryan McLeod agreed with the concerns raised by Paul Gunter and mentioned that Standard Power would need to demonstrate its capability in building data centers to alleviate these concerns. He acknowledged that Bitcoin mining and nuclear power intersection was uncharted territory.
- Q: Paul Gunter - Beyond Nuclear also expressed concerns about NuScale's under-subscription with UAMPS in Utah for their project with Idaho National Labs. Given its involvement in Bitcoin mining and national media coverage, he emphasized the critical timing of these controversies for NuScale.
- A: Ryan McLeod added that building good relationships with communities and power brokers was essential when venturing into such projects.

B. Presentation: James Walker, CEO and Head of Reactor Development at NANO Nuclear Energy [15], gave a presentation on micro nuclear reactors.

1. Why Nuclear in New Hampshire?

- Renewables like solar and wind require a large amount of land and have intermittent power generation dependent on environmental conditions.
- Nuclear power provides consistent, high-capacity electricity production that is not hampered by intermittency issues, and nuclear plants can be located almost anywhere, not just in optimal sunlight or wind patterns.

- While small modular reactors (SMRs) seem interesting, microreactors have an even bigger untapped market potential.
- Microreactors can provide power for remote mines, oil & gas platforms situated offshore, military bases in remote locations, data centers requiring reliable energy, electric vehicle charging stations needing high capacity, and many other industrial processes located off the main grid.
- Microreactors can compete directly with diesel generators in terms of cost per megawatt as well as reliability.

2. NANO's Microreactor Development Approach

    - NANO asked technical teams to design microreactors capable of fitting inside standardized shipping containers so they can be transported anywhere using conventional transportation methods like trains, trucks, and ships.
    - The reactors should enable largely unmanned operation with passive cooling mechanisms for maximum safety.
    - They envision central monitoring and control of potentially hundreds of reactors from a main office, with just 1-2 security staff needed at each physical reactor site.
    - The reactors should require zero maintenance over targeted 10–15-year operational lifetimes between refueling cycles.

3. First Reactor Design with UC Berkeley Scientists

    - The design utilizes a solid core battery reactor with no moving coolant parts.
    - It relies on direct thermal conduction from the fuel rods to the reactor vessel wall and ambient air.
    - This represents the simplest possible reactor design that can be engineered.
    - It is capable of passively cooling itself even in the event that all mechanical systems fail simultaneously.
    - It operates at higher temperatures, enabling production of hydrogen through thermolysis.
    - It uses conventional fuel rods and technologies with a large historical operational data set.

4. Second Reactor Design with University of Cambridge Scientists

    - This design uses solar salt for cooling the reactor core.
    - It has only a few working parts, making it simple and reliable.
    - It is also engineered to passively cool itself even without active cooling pumps operating.
    - While it operates at a lower temperature than the Berkeley design, it can produce a higher thermal output over the reactor’s lifetime.

5. Business Model Benefits

    - NANO plans to lease the microreactors themselves as well as sell the power they produce using a contracting model, so customers would not face large upfront costs.

- Operation, refueling, decommissioning, and complete site cleanup would be handled entirely by NANO with no long-term liability for customers.
- This leasing framework makes adoption of the technology much easier for clients.

C. Presentation: Evan Cummings, Director of Business Development at Kairos Power [16].

1. Company Background and Overview

- Kairos Power is an energy engineering, design and manufacturing company that is singularly focused on developing one nuclear reactor technology called the Kairos Power Fluoride Salt Cooled High Temperature Reactor (KP-FHR).
- The company forecasts that 60% of US baseload natural gas power capacity and 40% of nuclear power capacity from existing light water reactors will retire by 2030-2040. This retirement of baseload plants presents an opportunity for advanced nuclear technology.
- The company was founded in 2016 and currently employs approximately 368 people, with 90% of the staff being engineering employees who are focused on the KP-FHR reactor design and commercialization efforts.
- Kairos Power has set a goal to achieve commercial deployment of the KP-FHR technology by the year 2030 or earlier if feasible.
- A key commercialization goal for the company is for the KP-FHR reactor to be cost-competitive with natural gas power plants in the U.S. electricity market without requiring any subsidies.

2. KP-FHR Technology Overview

- The KP-FHR is an innovative reactor design that combines two proven nuclear technologies:
    1. It utilizes a high temperature molten salt as the primary reactor coolant. The high temperature operation of up to 700°C enables high efficiency electricity generation.
    2. The reactor uses Tristructural-isotropic (TRISO) fuel, which provides enhanced stability, higher energy density, and improved safety performance compared to traditional uranium oxide nuclear fuel.

3. Strategic Development Approach

- Kairos Power is taking a strategic development approach that utilizes rapid learning cycles, vertical integration, and a series of large-scale design demonstrations in order to provide certainty regarding the technology performance, licensing, supply chain, constructability, and costs.
- The plan is to demonstrate the KP-FHR reactor technology at increasing scales, first with non-nuclear test prototype units called Engineering Test Units (ETUs). This will lead to the eventual construction of a 15-megawatt thermal (MWth) Hermes nuclear demonstration unit.
- Major infrastructure investments have been made to construct production facilities and laboratories in New Mexico, Tennessee, and Ohio to support the testing and demonstration plans.

4. Licensing Progress
    - A Construction Permit Application for the Hermes demonstration reactor was submitted to the U.S. Nuclear Regulatory Commission (NRC) in November 2021, following completion of extensive pre-application reviews and analysis by the NRC.
    - Kairos Power is the first advanced non-light water reactor developer to have obtained a firm 21-month review schedule from the NRC for a construction permit.
    - The company completed the final step required in the Construction Permit Application process on October 19, 2023. Approval to build the Hermes unit is expected from the NRC by the end of 2023.
5. U.S. Department of Energy (DOE) Partnership
    - Kairos Power was awarded $303 million through the DOE's Advanced Reactor Demonstration Program (ARDP) to construct the Hermes demonstration reactor at a site in Oak Ridge, Tennessee.
    - The ARDP award is a cost-shared award that specifically aims to reduce risks for advanced nuclear technology demonstrations.
    - Under the cost-share terms, Kairos Power will contribute an additional $326 million to the Hermes project, for a total budget of $629 million over 7 years.
    - Building and operating the demonstration reactor is projected to create 55+ full-time jobs and invest over $100 million into the East Tennessee regional economy.
    - This level of investment is prototypic of what would come in expansion to other states as well.
6. Industry Consortium Partnership
    - In 2022, Kairos Power formed the Kairos Power Operations, Manufacturing and Development Alliance (KP-OMADA) together with leading North American electric utility companies.
    - The industry consortium will collaborate on development, licensing, manufacturing, and eventual commercialization of the KP-FHR technology.
7. Q&A:
    - Q: Rep. Keith Ammon asked if molten salt from the Kairos reactor could be used for industrial heating applications as part of the business plan.
    - A: Evan Cummings (Kairos) answered that while their primary focus is on producing carbon-free electricity, they recognize industrial heat applications as an important potential opportunity to help decarbonize hard-to-decarbonize industries. This is on their roadmap for the future.
    - Q: Rep. Keith Ammon asked about the expected electrical output size of Kairos' planned commercial reactors.

- A: Evan Cummings stated that the output for their first commercial reactor design would be 140 megawatts electric per module. He added that the modularity of the design allows for economies of scale by locating multiple units together.
- Q: Paul Gunter (Beyond Nuclear) asked what the maximum projected modular design would be - how many 140MW reactor units could be co-located.
- A: Evan Cummings responded that the number of units would ultimately depend on customer demand and site constraints, but that the technology supports significant scalability.
- Q: Paul Gunter asked for confirmation that Kairos expects to receive a nuclear construction permit from the NRC by the end of 2023.
- A: Evan Cummings confirmed that they expect approval on a nuclear construction permit by the end of 2023.
- Q: Ryan McLeod asked if there are shared infrastructure capabilities between reactor modules to reduce costs with buildouts at scale.
- A: Evan Cummings confirmed that yes, there are opportunities for shared civil structures between units.

III. Commission Business

- Rep. Ammon informed the commission that statute requires one final meeting to be held by December 1st to approve the minutes from the current meeting and the final report. He has scheduled this meeting for Friday, December 1st at 1pm at the State House.
- Rep. Ammon asked if any commission members anticipated issues with attending that meeting, but no concerns were raised. He stated he will aim to provide a draft of the final report to commissioners before the December 1st final meeting. Commissioners can provide input on the draft report prior to the final meeting.
- Rep. Ammon brought up that Dartmouth's policy research shop will be using the commission's final report to have students conduct additional research projects related to financing and market conditions for potential SMR projects. The additional research could aid the Department of Energy.

IV. Discussion

- Former State Representative Dick Barry suggested the final report include some kind of cost-benefit analysis from companies currently working on SMR technology, to get a sense of the potential financial feasibility and benefits of pursuing SMR projects.
- In response to Dick Barry's suggestion, Dan Goldner from the PUC noted that many of the companies that presented to the commission had already provided estimated costs per megawatt hour for SMR technology, typically in the range of $60-80/MWh. He suggested summarizing this existing cost information in a table in the final report.
- Representative Alvin See asked if any businesses in New Hampshire that would be interested in using heat rather than electricity from potential SMR projects had been identified. Rep. Ammon responded that further investigation on heat utilization is still needed, and provided

examples of a cement plant and Concord's municipal steam heating system that potentially could utilize SMR heating in the future.

- In response, Rep. Alvin See stated he did not have any particular businesses in mind but noted that Concord's steam heating system alone is likely not large enough to be a viable project for SMR heating.
- Dan Goldner from the PUC brought up that the Berlin biomass plant had plans to provide heated water to warm sidewalks in Berlin. However, Rep. Alvin See noted that after the news from the previous week, those plans may now change, referring to the challenges facing the Berlin biomass plant.

V. Approval of Meeting Minutes

- The minutes from the October 10th commission meeting were presented and approved unanimously through a motion by Cathy Beahm, seconded by David Shulock. Two small amendments to the minutes were noted by Rep. Ammon. He also stated links to online webinars referenced in the minutes will be added for clarity.

VI. Adjournment

- Rep. Ammon requested a motion to adjourn the meeting. The motion was made by Sen. Howard Pearl and seconded by Dan Goldner. The meeting was adjourned by unanimous vote at 10:43 AM.

Submitted by Keith Ammon

References:

[1] https://www.cnl.ca/about-cnl/

[2] https://naygn.org/i4n/

[3] https://www.nrcan.gc.ca/our-natural-resources/energy-sources-distribution/nuclear-energy-and-uranium/canadian-small-modular-reactor-roadmap/21183

[4] https://meredithangwin.com/shorting-the-grid/

[5] https://terawulf.com

[6] https://nuscalepower.com

[7] https://standardpower.com

[8] https://www.cleanspark.com

[9] https://cathedra.com

[10] https://foremanmining.com

[11] https://hashrateindex.com/

[12] https://insights.braiins.com

[13] https://fabiano.consulting/

[14] https://www.synota.io/

[15] https://nanonuclearenergy.com/

[16] https://kairospower.com/