Coalition for Responsible Energy Development in New Brunswick

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Information regarding potential safety concerns and risks of the ARC-100 fuel

March 31, 2023

Background

- The Coalition for Responsible Energy Development in New Brunswick (CRED-NB) provides credible information to the public about energy development in New Brunswick.
- NB Power is proposing to develop a new nuclear reactor, the ARC-100, at its Point Lepreau site.
- A member of the public asked CRED-NB about the type of fuel that the ARC-100 will use, and if the intention is to reprocess the used ARC-100 fuel. Their questions arose after a presentation at which NB Power said there is no intention to reprocess the ARC-100 used fuel.
- This memo from CRED-NB discusses the ARC-100 design, the fuel for the design, "breeder" reactors, the plans for the used fuel, and risks and some implications for the New Brunswick public.

The ARC-100 design

- ARC is proposing a design for a fast reactor, cooled by liquid sodium metal and fueled by enriched uranium. The ARC-100 design is based on the second Experimental Breeder Reactor (EBR-II) that operated in a research facility in the U.S. The EBR-II was never designed or built for grid-scale commercial use and was never connected to a commercial electricity grid.
- A sodium-cooled fast reactor has never been successfully commercialized. In fact, five decades and more than $50 billion in development spending on attempts to commercialize a sodium-cooled fast reactor in several countries in the past have resulted not only in failure but also numerous dangerous fires and explosions due to the reactivity of the sodium coolant. [1]

The ARC-100 fuel

- The ARC-100 design requires a type of enriched uranium fuel called HALEU (High Assay Low-Enriched Uranium). HALEU is different from the natural (unenriched) uranium used by CANDU reactors, or the low-enriched uranium used by light-water reactors globally.

[1] B. Cochran, H.A. Feiveson, W. Patterson, G. Pshakin, M.V. Ramana, M. Schneider, T. Suzuki, F. von Hippel (2010). Fast Breeder Reactor Programs: History and Status. A research report of the International Panel on Fissile Materials. February, 128 pp. Available at: https://fissilematerials.org/library/rr08.pdf

- Enriched fuel has more of the kind of uranium in it (U-235) that can sustain a chain reaction. The fuel for current light-water reactors is enriched to no more than 5 percent. HALEU is enriched between 5 and 20 percent, the limit for civilian use. The ARC-100 design will use up to 15.5 percent enrichment.

- HALEU is considered permissible in commercial power reactors but raises nuclear weapons proliferation concerns because of the higher risk of using enriched uranium for nuclear explosions. A U.S. National Academies expert report states that expanding the global use of HALEU would potentially augment nuclear weapons proliferation and security risks. [2]

- The plan to use HALEU fuel raises several additional concerns. First, it will be a challenge to source the HALEU required for the ARC-100, given that the only current supply of this material is in Russia, and sanctions will likely make that Russian fuel unavailable in the foreseeable future.

- The U.S. has no capacity to manufacture HALEU fuel, although it is planning to ramp up to manufacture HALEU to supply the SMRs being developed in the U.S. It is unknown if HALEU will be available to fuel reactor projects in Canada in the coming decades.

- The ARC-100 product brochure [3] lists alternative sources of fuel instead of HALEU:
    - the waste created by light water reactors (which still contains about 95-97% of its energy potential, unfissioned);
    - the large, existing, global stockpile of depleted uranium-238;
    - the nuclear material removed from weapons, which currently creates a serious storage and security problem.

- The first source involves reprocessing, the second source implies that uranium-238 would be converted into plutonium-239, and the third source raises concerns related to importing this material into Canada.[4]

"Breeder" reactors

- A nuclear reactor can be what's called a "breeder." A breeder reactor breeds plutonium, it creates significantly more plutonium during fission than other types of reactors. The plutonium will continue to exist in the used fuel, after it is removed from the reactor.

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[2] National Academies of Sciences, Engineering, and Medicine (2022). "Merits and Viability of Different Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactors." Washington, DC: The National Academies Press. https://doi.org/10.17226/26500. Available at: http://nap.nationalacademies.org/26500

[3] "ARC-100: A Sustainable, Cost-Effective Energy Solution for the 21st Century" (ARC product brochure, no date) Available at: https://crednb.files.wordpress.com/2021/02/arc-100-product-brochure.pdf

[4] See "Weapons-Grade Plutonium Flown Across Southern Canada" in *Democracy Now*, Jan. 18, 2000, available at: https://www.democracynow.org/2000/1/18/headlines/weapons_grade_plutonium_flown_across_southern_canada

- The obvious reason to make a nuclear reactor a breeder is if the plan is to extract the significant quantities of plutonium from the used fuel through reprocessing, for re-use as new fuel in a reactor.

- A sodium fast reactor does not need to be a breeder. However, the ARC-100 is a "breeder" reactor. [5] [6] The ARC-100 is a breeder because the intent is to reprocess the used fuel.

Plans for the ARC-100 used fuel

- ARC has stated that their design is for a 20-year fuel cycle. They intend to load the ARC-100 with a 20-year supply of (HALEU) fuel and run the reactor for 60 years; the fuel would be loaded three times in total.

- In their February 2023 testimony to the Legislative Assembly of New Brunswick, ARC representatives stated that the ARC-100 would use a once-through fuel cycle, meaning that at the end of each fuel cycle, the used reactor fuel would be stored in a temporary facility, with the intent to store it permanently in a deep geological repository, should one be built.

- However in their February 2021 presentation to a committee of 16 nuclear experts with the US National Academies in Washington, ARC representatives stated the preferred long-term ARC-100 fuel cycle is to use pyroprocessing to recover plutonium and other transuranics to use as fresh fuel. They said the initial 20-year fuel irradiation cycle of the ARC-100 provides ample time for a deliberate planning and development program for reprocessing (what they call "recycling") the used fuel.[7]

- The ARC brochure (footnote 4) states: "Unlike conventional nuclear waste reprocessing technology, creating fuel for the ARC-100 does not involve separating pure plutonium suitable for direct use in nuclear weapons. Instead, it keeps the plutonium mixed with other long-lived radioisotopes so that it cannot be used directly in weapons."

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[5] For example on the NB Power website for SMRs, this document: https://smrnb.ca/wp-content/uploads/2021/04/Fact-Sheet_SMR-Waste-Levels.pdf states: "The ARC-100 is a fast breeder reactor, meaning it produces more fissionable fuel than it starts with... There is also the potential in the future for the ARC-100 to recycle its used fuel. If this were to happen, even more power is produced from a given amount of new fuel and a significant portion of the long lived more radiotoxic transuranics (also referred to as actinides) would be consumed."

[6] Statement by William Labbe, ARC president and CEO, on Feb. 14, 2023, in testimony to the Legislative Assembly of New Brunswick Standing Committee on Climate Change and Environmental Stewardship, "We operate on a different spectrum, because we are a fast breeder reactor ...." https://www.legnb.ca/en/webcasts/848 at 10:43 minutes.

[7] See slide 12 of the slide deck: "The ARC-100 Advanced SMR, February 2011, John Sackett, PhD, Senior VP and Chief Technology Officer, and Edward D. Arthur, PhD, VP Fuel Cycle Management & Safeguards, ARC Clean Energy," presentation on February 22, 2021, to the National Academies of Sciences, Engineering, and Medicine Committee on Merits and Viability of Different Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactors. Slide deck available at: https://www.nationalacademies.org/documents/embed/link/LF2255DA3DD1C41C0A42D3BEF0989ACAECE3053A6A9B/file/D0D53851D5988DF499DE2451F77DDA7C6DFD996AC5C9

- However, a 2009 report by non-proliferation experts from six US national laboratories concluded that pyroprocessing is about as susceptible to misuse for nuclear weapons as the original PUREX reprocessing technology used by the military. [8]

- More recently, a U.S. National Academies committee report in 2022 (reference in footnote 2) stated: "While these technologies may provide some benefit in delaying direct use of the materials, there was consensus among the committee members that none provided significant proliferation resistance at this time." (p. 221)

- The same expert report notes that due to the chemical reactivity of the sodium-bonded used fuel, that even for a once-through fuel cycle, processing would be required to remove the sodium so as to avoid adverse chemical reactions or explosions underground which could compromise the integrity of a final repository.

New risks for New Brunswick

- These issues related to the ARC-100 fuel will introduce new risks to New Brunswick that do not currently exist:

    - The use of HALEU fuel or alternative fuels made from nuclear weapons will require transporting this dangerous material through New Brunswick.

    - The evidence is clear that the long-term plan is to reprocess the ARC-100 used fuel to separate the plutonium, raising the well-known security and environmental risks associated with plutonium reprocessing. [9]

    - Even if the ARC-100 uses only a once-through fuel cycle without plutonium reprocessing, there will be environmental risks related to managing and/or conditioning the sodium-bonded used fuel.

    - The use of HALEU introduces an increased risk of accidental criticality, or uncontrolled chain reaction, of the used fuel, a risk virtually nonexistent with natural uranium CANDU fuel currently in use at Point Lepreau. [10]

[8] Brookhaven National Laboratory (2009). "Proliferation Risk Reduction Study of Alternative Spent Fuel Processing." BNL-90264-2009-CP. Available at: https://www.bnl.gov/isd/documents/70289.pdf

[9] See, for example: Von Hippel, F., Takubo, M., & Kang, J. (2019). *Plutonium: How Nuclear Power's Dream Fuel Became a Nightmare*. Springer Nature.

[10] Flowers Commission. (1976). *Royal Commission on Environmental Pollution, Sixth Report, Nuclear Power and the Environment*. See also: "A Review of Criticality Accidents, 2000 Revision," Los Alamos National Laboratory, LA 13638, Available at: https://www.nrc.gov/docs/ML0037/ML003731912.pdf

Implications of plutonium reprocessing in New Brunswick

- The heightened security and nuclear weapons proliferation risks involved with HALEU fuel and its alternatives, and especially with plutonium reprocessing, will necessarily lead to increased secrecy surrounding the ARC-100 project.

- Increased secrecy will mean reduced transparency and less information that can be shared, which will make it even more difficult for New Brunswickers to ask questions and make informed decisions about the role of nuclear power and the activities of nuclear operators in the province.

- Making plutonium an article of commerce - which will happen if plutonium-based fuel is used and sold commercially in Canada - raises serious concerns about what's referred to as a "plutonium economy" that has been described as "a terrible idea that refuses to die." [11]

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CRED-NB is active in a national campaign to ban plutonium reprocessing in Canada.
The campaign website has fact sheets and links to further information:

https://nuclearwastewatch.weebly.com/reprocessing.html

[11] See: J. Green (2020). The plutonium economy: a terrible idea that refuses to die. Nuclear Monitor, issue 884. Available at: https://wiseinternational.org/nuclear-monitor/884/plutonium-economy-terrible-idea-refuses-die