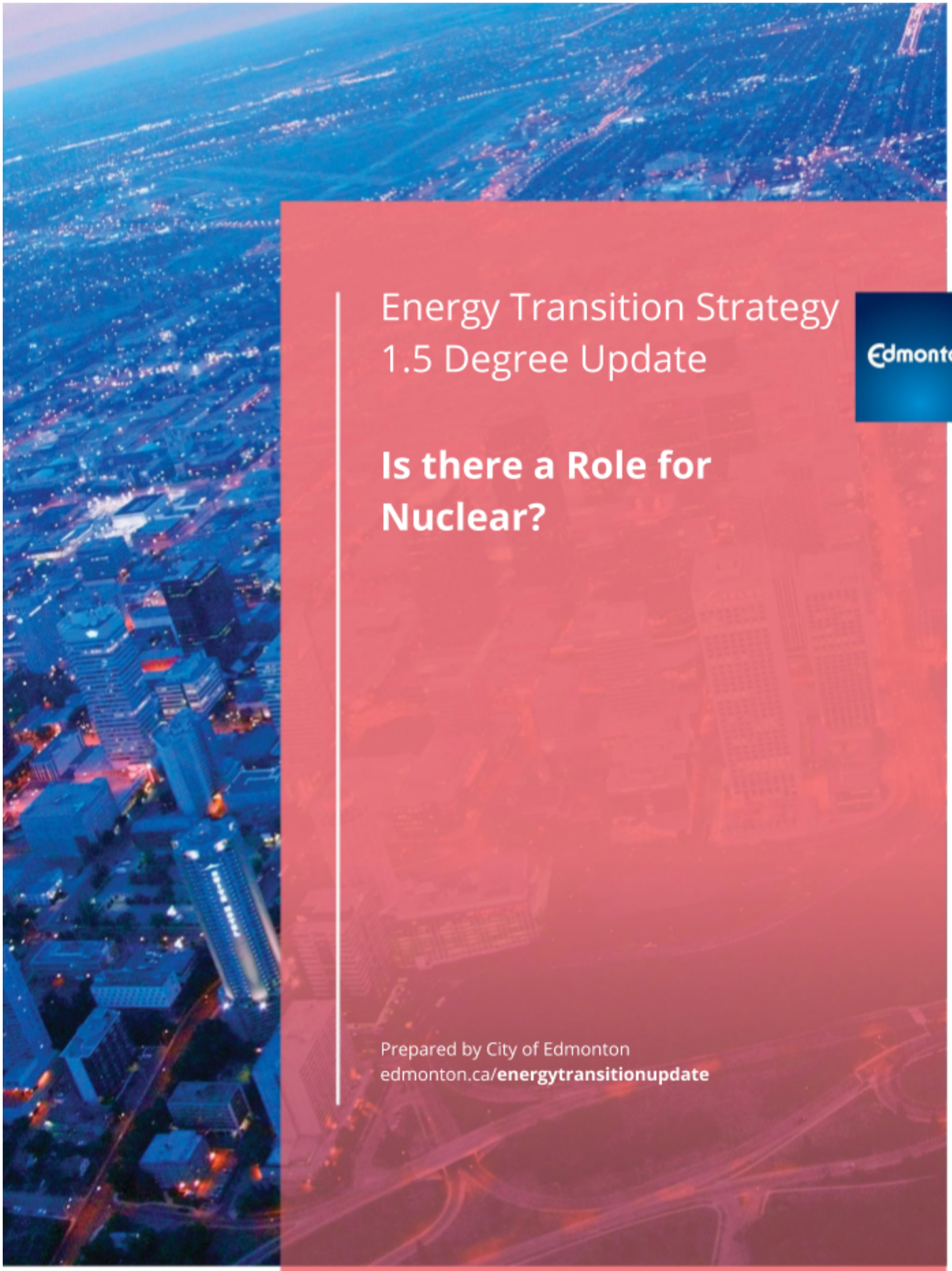

Energy Transition Strategy 1.5 Degree Update

Is there a Role for Nuclear?

Edmonton

Prepared by City of Edmonton
edmonton.ca/**energytransitionupdate**

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ISSUE IDENTIFICATION

On August 26th, 2019, City of Edmonton Council Declared a Climate Emergency and requested that City administration take steps to bring back a revised Community Energy Transition Strategy

On August 27th, 2019, City of Edmonton (the City) Council Declared a Climate Emergency and requested that City administration take steps to bring back a revised Community Energy Transition Strategy (CETS) by the end of third Quarter 2020 that aligns the current greenhouse gas (GHG) emissions targets and actions with the local carbon budget for City Council's approval. The requested work involved the City modelling a 2050 carbon neutral scenario which showed that even with interventions and aggressive adoption of renewable energy technologies, the City will not be able to reduce enough GHG emissions to stay within its carbon budget developed under a 1.5^{o}C scenario.

The objective of this policy brief is to examine the current status of nuclear fission and fusion technology and evaluate what role these technologies might play in Edmonton's Energy Transition. Nuclear fission is the common form of nuclear energy used currently. Nuclear fission is the process by which the nucleus of an atom (typically uranium) is split into two or more smaller atoms, while releasing energy. Nuclear fusion is effectively the reverse of this process, where two small atoms (typically hydrogen) are fused together and energy is released. Both processes are considered to be nuclear energy, but nuclear fission is substantially more advanced in the market.

NUCLEAR FISSION STATUS

Development of nuclear fission reactors in the 1950s originally focused on large, centralized plants, relying on the transmission system to transport the electricity to the demand centers. However, as the technology evolved reactor size is being reduced opening up new opportunities for novel uses of nuclear fission technology.

Small Modular Reactor Roadmap

To explore the status and opportunity for small modular nuclear fission technologies, Natural Resources Canada convened the Canadian Small Modular Reactor (SMR) Roadmap Steering Committee[1]. This committee evaluated the current state of nuclear energy technologies and provided recommendations for a roadmap for development and deployment of Small Modular Reactors (SMRs). The content provided within this briefing on SMRs and their status in Canada has entirely been sourced from the Canadian Small Modular Reactor (SMR) Roadmap Steering Committee.

This effort involved expert analysis, extensive engagement with industry and end users, and initial engagement with Indigenous communities and organizations. Five (5) expert groups were established to investigate questions related to technology, economics and finance, Indigenous and public engagement, waste management, and regulatory readiness.

"The earliest expected deployment of an SMR demonstration project in Canada was identified as 2026 in Ontario"

Through this work it was identified that there is currently no expected timelines for commercial SMR deployment in Alberta. Overall, the technology requires further demonstration and evaluation to validate the technical and economic considerations as well as significant targeted public engagement and regulatory development in Alberta specifically.

The earliest expected deployment of an SMR demonstration project in Canada was identified as 2026 in Ontario. It is important to note that in contrast to Alberta, Ontario has a long public and regulatory history with nuclear fission, being host to the majority of Canadian nuclear reactors. Without this regulatory history, the expectation for any deployment of SMR technology is very uncertain for Alberta.

To achieve any deployment of SMRs in Edmonton or the Metropolitan Region would require significant feasibility assessment, market demand evaluation, waste management service development, and regulatory development.

[1] Canadian Small Modular Reactor Roadmap Steering Committee (2018). *A Call to Action: A Canadian Roadmap for Small Modular Reactors.* Ottawa, Ontario, Canada.

Potential Benefits

The Economics and Finance Working Group of the SMR Roadmap Steering Committee studied the market potential for SMRs. They found that the domestic market potential is significant, with SMR's playing a key role for providing non-emitting electricity and heat in sectors currently reliant on fossil fuel based energy sources. Figure 1 highlights the sectors that could benefit from deployment of SMRs as identified by the Economics and Finance Working Group of the SMR Roadmap.

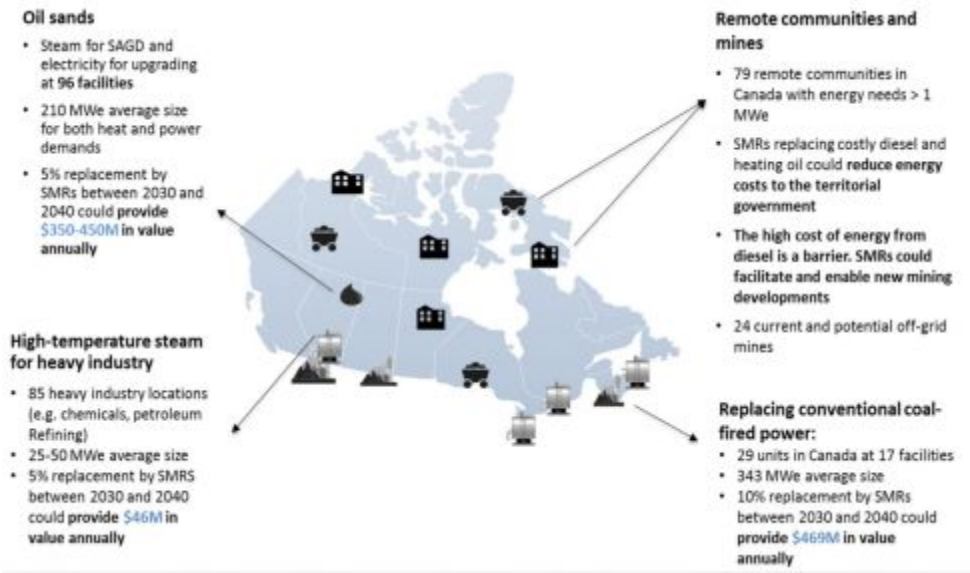

Figure 1: Potential domestic demand for SMR electricity and heat

For Edmonton, the largest opportunity for electricity and heat that could be supplied from SMRs comes from the heavy industrial sector in the Edmonton Metropolitan Region. SMRs represent a potential high quality source of electricity that can meet the heavy and dedicated loads needed in the heavy industrial sector within the Edmonton Metropolitan Region. Deployment of local, dedicated electricity generation near heavy industrial sites can reduce transmission costs and potentially create an economic benefit for these operations.

Heavy industry stakeholders involved in the Roadmap indicated no interest in developing in-house nuclear expertise or operating SMRs directly themselves - instead preferring a partnership with an experienced operator to license,

build, operate, own and sell heat and power as a service back to the host facility.

The full list of potential benefits for Canada, identified by the SMR Roadmap Steering Committee, is provided in Table 1.

Table 1: Potential Benefits for Establishing a Successful Small Modular Reactor industry in Canada.

Type of Benefit	Description
Economic Benefits	The creation of a new industrial sub-sector with an estimated 6,000 new jobs supporting a high-skill labour force, and adding up to an estimated $10 billion to Canada's GDP between 2030 and 2040.
	Anchoring cutting edge research in Canada in critical areas of innovation.
	Establishing Canada at the centre of a global export market, leading in the deployment and operation of SMRs internationally with the potential to capture value in an emerging global market estimated at $150 billion annually by 2040.
	Enhancing competitiveness in the mining sector with SMRs as a lower-cost source of low-carbon heat and power.
Geopolitical Benefits	Global leadership in SMR policy expertise as a strategic international engagement.
	Influence SMR regulatory practices internationally to assist in building an enabling framework for SMR deployment globally.
Social and Environmental Benefits	Contribute to meeting Canada's climate change commitments to enable key milestones in Canada's pathway to a low-carbon future.
	Unlocking regional growth opportunities, in technology development, new opportunities for

	uranium and fuel exports, and providing advanced manufacturing and nuclear supply chain services globally.
	Assist in building constructive relationships and a positive energy dialog to inform the full range of options available.

Potential Costs

The Economics and Finance Working Group of the SMR Roadmap Steering Committee also studied the levelized cost of electricity from on-grid SMRs, comparing them to natural gas, hydro, and wind costs. They found that SMRs can be a competitive option compared to these other available alternatives. Figures 2 and 3 compare the best and worst case scenarios for SMR levelized costs to these options. Under the worst case scenario the analysis still showed that SMRs could be competitive with other available options if demonstration projects prove successful.

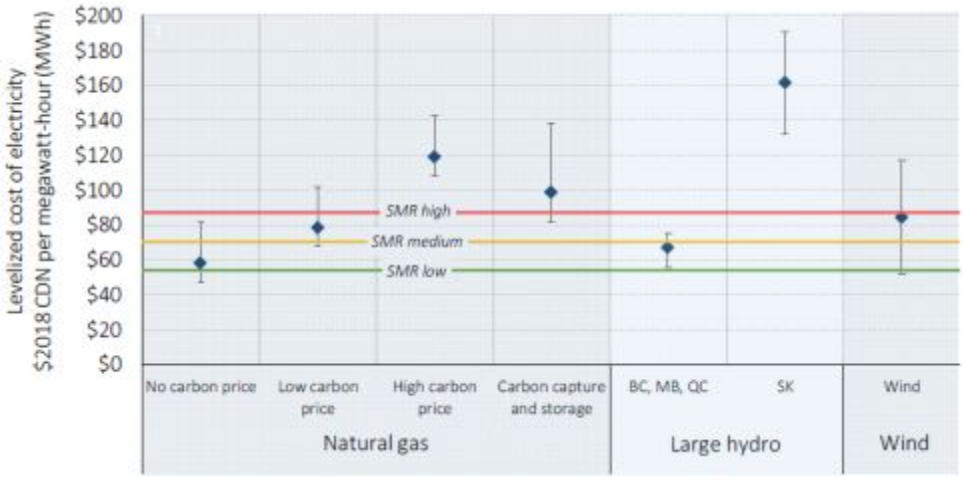

Figure 2: Comparison of levelized cost of electricity from on-grid SMRs with other options: Best Case scenario - 6% discount rate, high innovation

"It must be stressed that to establish Edmonton's role in the development of SMRs would require a significant government relations and public engagement effort as well as increased internal technical capacity."

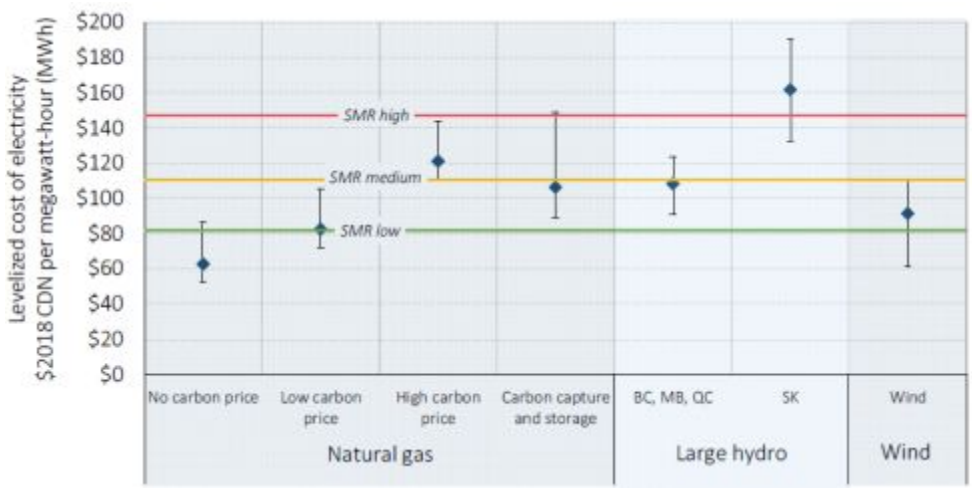

Figure 3: Comparison of levelized cost of electricity from on-grid SMRs with other options: Worst Case scenario - 9% discount rate, low innovation

Equity Considerations

For the development of nuclear fission technologies, the question of equity arises in the sharing of technical and financial risk, and ensuring the health and safety of all employees and those living in proximity to facilities throughout the lifecycle of handling nuclear fuel and waste.

Due to the potential for catastrophic failures, the public demands stringent regulatory oversight of nuclear fission developments that is currently absent in Alberta. This requires significant government investment to develop and establish effective regulatory requirements aligned with public expectations. Ultimately this necessitates a provincial commitment to establish a regulatory framework to guide nuclear fission deployment that addresses public concerns.

To ensure an equitable sharing of risks and benefits, the costs for the development of a nuclear regulatory framework should be borne by those entities that will financially benefit from their deployment; either through the reduction of electricity costs/improved productivity or through revenues earned from the sale of heat and electricity.

There is a history in the United States of America of citing nuclear facilities in marginalized, low income areas and nuclear reactor citing is therefore a primary prong of the environmental justice movement in that country. There

is a similar movement in civil society in Canada trying to ensure this does not happen. Civil society groups in Canada are often opposed to Canada for generational justice issues as well, suggesting that we are passing on the risk and the waste management issues to future generations.

Municipal Role in Fission Development

The SMR Roadmap does not identify any role or authority for municipalities to contribute to the demonstration and commercialization of SMRs. The recommendations provided by the roadmap highlight key roles for the Federal government, provincial governments, and the private sector but do not provide any role specific to municipalities.

In general, municipalities lack the technical and financial resources to adequately support SMR development alone. The roadmap is clear that the involvement of higher levels of government is required to effectively demonstrate and commercialize SMR technology.

While the Roadmap doesn't specify a municipal role, the City of Edmonton can demonstrate leadership and establish a role within the Canadian-wide effort. Table 2 provides those recommendations identified in the Roadmap that Edmonton could participate in, and highlights the potential role the City would serve.

Table 2: Select Recommendations within the SMR Roadmap with a potential role for the City of Edmonton.

Recommendation	Potential Edmonton Role
Federal government provides funding to cost-share one or more SMR demonstrations in Canada	Edmonton could be involved with an initial demonstration project; coordinating funding with the federal and provincial government, utilities, and the private sector.
Federal government to finalize Canada's Action Plan for SMRs	Edmonton could participate in finalization of the action plan, and build capacity for defining the municipal role within the roadmap.
Federal government should support engagement and early feasibility studies in jurisdictions that have indicated interest	Edmonton could seek support from the federal government to undertake local engagement and feasibility assessments to

	understand the role SMRs play in Edmonton's energy mix
Provinces to implement measures for incentivising first-commercial deployment of SMRs	Edmonton could advocate to the province for the need of such incentives (such as PPAs, feed-in tariffs, clean energy credits, or tax measures).
Provinces should develop public policy statements to include nuclear energy in climate change and clean energy planning and policies	Edmonton could include nuclear energy as a part of the future energy mix for Edmonton to meet net zero goals
Civil society to consider the Roadmaps key findings and recommendations	Edmonton can help facilitate civil society's consideration of the roadmaps findings, and provide engagement opportunities to identify local interest and opportunity in SMRs.

It must be stressed that to establish Edmonton's role in the development of SMRs would require a significant government relations and public engagement effort as well as increased internal capacity. Further effort would be required to define the capacity and resources necessary to establish Edmonton's role in SMR commercialization.

NUCLEAR FUSION STATUS

Nuclear fusion is a highly innovative technology that has yet to be proven technically. While the science of nuclear fusion reactions is generally understood, the mechanics and technology required for achieving and maintaining a fusion reaction remain elusive. There are two main approaches to achieving a fusion reaction under development, magnetic fusion energy (MFE) and inertial fusion energy (IFE). The developmental status of both technologies were explored by members of the Canadian Nuclear Society in their report Fusion 2030: Roadmap for Canada[2], which is the primary source relied upon for the information provided within this briefing.

Development of the MFE approach began in the late 1950s through international collaboration. The largest undertaking for MFE is the ITER project located in France. The project is estimated to cost $20+ billion, and is expected to be commissioned by the mid-2020s and demonstrate

[2] Canadian Nuclear Society (2016). *Fusion 2030: Roadmap for Canada*.

achievement of a fusion reaction by 2030. ITER has been funded by the EU, China, India, Japan, Korea, Russia and the United States.

Development of the IFE approach began in the mid-1970s, and has the benefit of using a simpler design that relies on laser technologies. Two main facilities have been built to achieve fusion via IFE; the National Ignition Facility (NIF) in the United States and the Laser MegaJoule (LMJ) in France. The NIF has already been successful at demonstrating fuel core ignition, but hasn't demonstrated full pellet ignition necessary for sustaining a fusion reaction.

Both approaches, If successful, have the potential to be a major breakthrough in energy production worldwide, and likely to unlock a major transformation of global energy systems. However, there remains a significant effort in developing the technology, with numerous technological risks and challenges to overcome to show that the technology is feasible.

Fusion 2030 Roadmap

The Fusion 2030 roadmap outlines an ambitious Canadian Fusion Program that would build capacity to establish a Canadian demonstration project by 2030 - but does not provide any expectations for commercial deployment beyond that. For that reason, Edmonton cannot consider any reductions from commercial deployment of nuclear fusion technology at this time. Figure 4 provides the steps identified within the Fusion 2030 Roadmap and the timelines necessary to establish a demonstration facility by 2030.

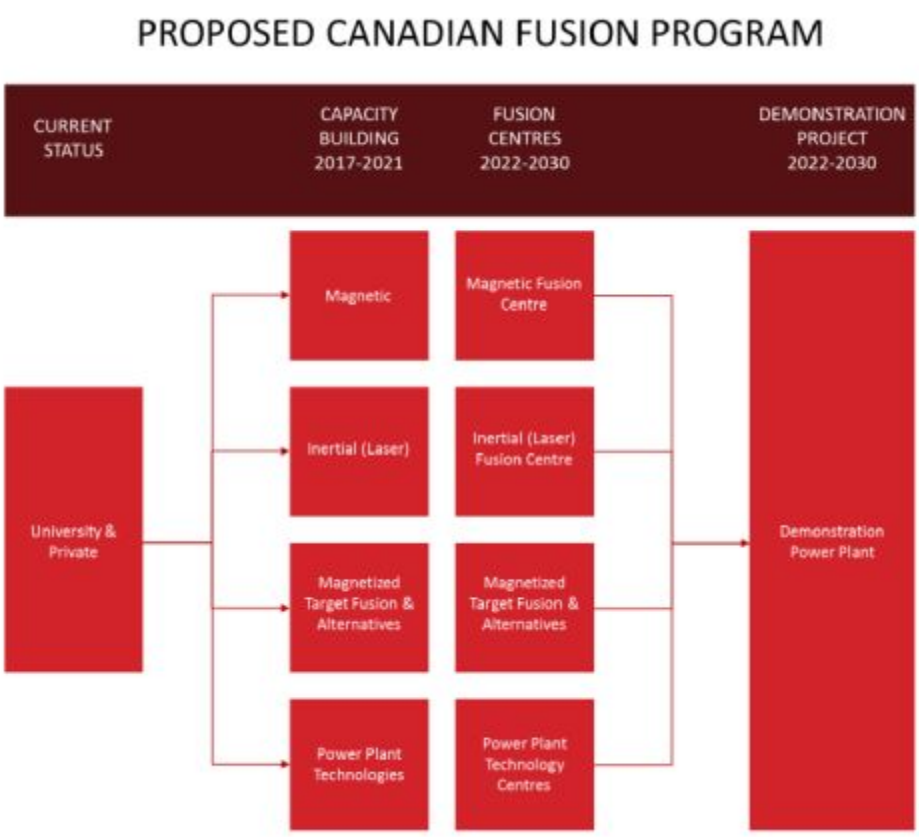

Figure 4: Necessary capacity building and facility development required for the establishment of a nuclear fusion demonstration power plant in Canada.

Potential Benefits

"any investment into [small modular reactors and fusion technology] should be considered highly risky"

Producing energy from nuclear fusion has a major potential to address growing energy demands without generating significant greenhouse gas emissions. Fusion is the energy source that powers the sun, a self-sustaining reaction that only produces helium as a byproduct (an element with limited and declining supply globally). This eliminates the concern with traditional fission plants and the nuclear waste byproducts that must be carefully managed.

Fusion also has benefits of potentially safer operations compared with fission technology. While the concern and technical challenge with fission reactions is controlling the reaction to avoid core meltdowns, the challenge for fusion is starting the reaction. If issues arise in managing the fission reaction it can be shut down relatively easily and without the risk of catastrophic failures.

Potential Costs

There are no current estimates of the cost for a commercial fusion reactor - this will not be known until there is successful demonstration of the technical ability to achieve a fusion reaction and further development of the economic viability of the resultant technology.

The Fusion 2030 Roadmap estimates that an initial investment by the federal government of approximated $125 million over five years matched by provincial support would be required to build capacity within Canada with the basic expertise and facilities in key areas that are advancing fusion energy. Further investment beyond the capacity building phase would be required to establish a demonstration project (likely requiring 10s of billions in investment).

Equity Considerations

For the development of nuclear fusion technologies, the question of equity arises in the sharing of technical and financial risks and benefits. Given the significant public investment required to further fusion technology development to achieve a commercial operation ($125 million matching funds from both federal and provincial governments as outlined in the Fusion 2030 Roadmap), there must be a clear case for how this investment of public funds will benefit the public either through reduced electricity costs, improved environmental performance, or improved business performance. There must be a clear commitment for the ultimate sharing of benefits between private developers and the public sector to ensure that the public investment into the technology is equitable.

There is currently no regulatory guidance for the development of a fusion power facility. To establish this requires significant government investment to develop and establish effective regulatory requirements aligned with public expectations. Ultimately this necessitates a provincial commitment to establish a regulatory framework to guide nuclear fusion deployment that ensures public concerns are addressed. To ensure an equitable sharing of risks and benefits, the costs for the development of a nuclear regulatory framework should be borne by those entities that will financially benefit from the technologies deployment; either through the reduction of electricity

costs/improved productivity or through revenues earned from the sale of heat and electricity.

Municipal Role in Fusion Development

Currently, there is no identified role or authority for municipalities to contribute to the development of nuclear fusion identified in the 2030 Fusion Roadmap. Given the lack of broad public knowledge about the opportunity, Edmonton could support fusion development by undertaking public education and engagement to raise awareness of this opportunity and gauge residents interest in supporting fusion technology development in Canada. This effort would require identifying and convening fusion experts, and building internal capacity to discuss and address technology concerns. This effort also does not provide any direct emissions reductions, which will be ultimately based on successful development of a commercial facility.

FORESEEABLE ISSUES AND MITIGATION STRATEGY

For both nuclear fission (in the form of SMRs) and nuclear fusion technologies their is major technical risk involved with demonstrating successful commercialization of these facilities broadly (with significantly higher technical risk associated with fusion technologies which remain unproven).

There are only two options for the City to mitigate this risk, 1) do not participate in the technical development of SMRs and fusion technology and allow leadership to be driven by the federal and provincial governments (this represents the status quo) or 2) develop the internal technical capacity and partnerships necessary to develop in house expertise to advocate for federal and provincial support towards the advancement of SMRs and fusion technology.

For the purpose of this policy brief, it is recommended that the City does not participate in the technological development of SMRs or fusion technologies. However, this approach would disadvantage Edmonton in the event that these technologies become commercially viable. Therefore, the City should remain open to attracting and retaining technical and support service businesses related to SMR or fusion technologies. Having such services established in Edmonton would be advantageous in the event that civil

society becomes more accepting and/or a technological breakthrough occurs. Even if the technologies advance as expected, they would still not be likely to be deployable within the 10-year planning horizon of the updated Energy Transition Strategy, and any support for these technologies would be for future climate action beyond 2030.

CONCLUSIONS WITH RECOMMENDED POLICY DIRECTIONS

There is an opportunity for Edmonton to become a hub for both SMR deployment and Fusion Energy development. Edmonton benefits from pre existing physics expertise at the University of Alberta, leadership in the development of artificial intelligence and nanotechnology, and a young and innovative population that are advantages for this development.

However, to take advantage of this opportunity would require a significant investment from the City of Edmonton, in partnership with both the federal and provincial governments. It would also require significant effort around education and marketing to gain the necessary social license to proceed with any specific development. This has not been an area where the City of Edmonton has historically engaged with provincial or federal governments, and therefore significant government relations efforts would be needed to realize this opportunity. These efforts would have to proceed swiftly if any nuclear technologies are to be deployed in the next 10 years and contribute to meeting Edmonton's 1.5 degree carbon budget.

Further, any investment into these efforts should be considered highly risky, and while there are tremendous benefits possible from demonstrating successful SMR deployment and fusion electricity production, commercial deployment of either technology in Edmonton or Alberta by 2030 is highly unlikely.

Based on this policy brief, the following policy statements are presented for the City's consideration.

1. While nuclear fission and fusion technologies have substantial potential benefits from their successful commercialization, due to the development status of the technology, the timelines for designing and

constructing these facilities, and the lack of social acceptability of the technologies, the City can not expect any reductions from deployment of these technologies within the Edmonton Community Energy Transition Strategy.

2. The City's energy transition strategy should continue to allow for the participation of any novel and disruptive technologies to contribute to efforts to reduce emissions when they become available.
3. The City should continue to rely on the leadership of the federal and provincial governments to advance these technologies.
4. The City should identify interest in nuclear fission and fusion technologies to the provincial and federal governments, leveraging the expertise of the University of Alberta, with the goal to establishing testing/demonstration facilities in Edmonton.
5. The City could provide policy statements that in principle support fusion development as a possible climate change mitigation action. This would be stated in terms of providing light touch support for burgeoning industry partners and associations.
6. The City could be a convener for civil society to explore the possibilities of nuclear in the energy mix as a viable mitigation solution.