Thermal Networks and Nuclear Energy – Advancing the Dialogue towards Clean Heat Infrastructure for Canada

A Position Paper: Executive Summary

An Initiative of McMaster University's Institute for Energy Studies, the Boltzmann Institute and the Canadian Nuclear Association

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In Canada, about as much energy is used to heat buildings as is delivered as electricity for all purposes. Current plans for achieving net zero buildings include retrofitting the millions of existing buildings – to reduce energy demand – and converting heating systems to electric heat pumps, as part of a national *Electrify Everything* strategy to decarbonize multiple energy end-use sectors. However, completing the retrofits and providing sufficient peak electric power, during extended periods of extreme cold, for the millions of heat pumps may not prove feasible or affordable at the required scale by 2050. While much work is underway to mitigate the risks for the building-electrification pathway, an additional and complementary pathway merits consideration – Thermal Networks.

Thermal Networks (TNs) are District Energy systems, considered here as utilities implemented at-scale with the latest innovations. A Thermal Network (TN) is a system that harvests, produces, stores and distributes heat through a network of insulated, buried water pipes. TNs provide elegant, market-ready solutions to address affordability challenges facing decarbonization of building heating. While TNs today often use natural gas as their energy source, there are several options available to switch to clean heat sources. As they can harvest already available residual, clean heat from many sources that would otherwise be wasted, they can reduce the need for new clean energy generation. Through low-cost, short-term and seasonal heat storage, they allow economic delivery of a resilient building heating system in the face of highly variable heat demand during Canada's cold and unpredictable winters. TN utility models finance connections to buildings, with costs built into monthly customer charges, avoiding the burden of up-front investments by millions of individual owners.

A strategic case is presented for Thermal Networks to be an important contributor to affordable, clean heat infrastructure to service non-rural buildings across Canada. Over 200 existing district energy systems meet about 3% of Canada's total heat demand today – many European cold-climate countries are over 50% and growing. Analysis of Canada's population density suggests that ~70% of the population could be serviced by TNs, as an upper bound; we suggest that 50% be the minimum for initial pathway scoping, with a 70% ambition informed by the EU experience and ambitions. Key risks to TN deployments at scale include the need to secure Rights of Way in built urban areas and the need to minimize disruptions to urban infrastructure during installation. European experience with TNs - and Canada's past experience with the installation of natural gas networks - will be informative to the way ahead. The feasibility of achieving this level of TN penetration – with building electrification as a complementary pathway where TNs do not prove to be viable – will require coordinated planning of electricity grids, gas and thermal networks, including strategies to capture otherwise rejected heat, enabling policies, evidence-informed analysis and capacity building.

A critical opportunity for synergies between electricity grids and TNs occurs when they share Combined Heat and Power (CHP) generators and, for the decarbonization journey, non-emitting (clean) CHP generators. Two strategic benefits arise. One is a reduction in demand for additional clean

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heat generation, achieved through harvesting of the CHP heat. The second is that, by using large thermal storage to accept variable heat at the convenience of shared CHP generators, TNs provide grid services that help with grid modernization. Among other advantages, this will allow the grid to efficiently use a higher portion of variable renewables. As such, Thermal Network infrastructure can be viewed as an enabler of the electrification of other sectors.

Among the largest of clean CHP generators is nuclear energy. Canada is intending to significantly increase its nuclear energy capacity by 2050 – by as much as 3x today's capacity – a capacity growth essential for the Net Zero transition. To date, the primary focus for new nuclear capacity has been to harness its ability to produce clean baseload electricity to service both centralized provincial electricity grids and micro-grids. By harnessing the CHP capabilities of nuclear energy to also service TNs, Canada could leverage its strategic investment to help reduce the need for additional clean heat generation, thereby helping with affordability, while contributing to grid modernization that enables greater use of variable renewables.

There are two broad approaches for nuclear energy, in CHP mode, to service TNs. The first is for Nuclear Power Plants (NPPs), constructed to provide baseload electricity to service electricity grids, to be configured for CHP operations. Heat from CHP operations can be stored and transported via Thermal Corridors at distances upwards of ~100 km to provide heat to TNs accessible at these distances and with the capacity to receive the heat. The second is for Small or Micro Modular Reactors, operating in CHP mode, to be constructed as integral elements of TNs, with perhaps hundreds of these reactors providing CHP for TNs across Canada. Analysis suggests that nuclear energy could provide upwards of 25-50% of the nation's total TN heat supply, with large thermal energy storage making nuclear CHP plants dispatchable (for up to ~ 35% of electric power rating) to facilitate grid modernization. Several countries have either committed to nuclear energy to provide CHP for TNs or are exploring how best to do so. Canada can learn from these experiences.

Of course, the opportunity for nuclear energy to service TNs is predicated on the assumption that there will be TNs to receive nuclear generated heat. Joint planning of new nuclear capacity development in conjunction with coordinated planning of electricity grids and TNs is the critical first principle.

To move forward, the Position Paper proposes that Canadian governments collaborate to develop a Thermal Network Strategy aimed at identifying and supporting TN infrastructure investments for the social good and that recognizes the multiple benefits from having complementary and coordinated electricity and heat infrastructures. The recommendations below set out important measures for such a strategy, to efficiently and economically meet society's needs for heat, while providing a path to net zero GHG emissions. They are ordered in the sequence in which it is suggested they be progressed.

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R-1. Launch public education and consultation to expand public understanding of Thermal Networks and acceptance of distributed energy resources and nuclear within, or in close proximity to, urban areas so that the greatest use of both heat and power is achieved.

R-2. Recognize heat, also known as thermal energy, as a strategically important form of energy. Promote the conservation and re-use of heat as a key enabler of Canada's net zero transition.

R-3. Formally recognize Thermal Networks as part of Canada's energy critical infrastructure, essential to the health, safety, security and economic well-being of Canadians. Deploy Thermal Networks at scale to make residual and renewable heat resources affordable, reliable and accessible to nearly all non-rural buildings, when needed and with near zero GHG emissions.

R-4. Adopt a utility approach for Thermal Networks to eliminate barriers and provide options to support equitable, rapid decarbonization of building heating. Fund amortization of infrastructure and of building conversions through usage charges.

R-5. Integrate governance, planning and operation of electricity, gas, and Thermal Network infrastructures to create and leverage opportunities for synergies, greater efficiency and societal good in the energy sector transition in Canada by 2050.

R-6. Assess the business case to configure nuclear power plants, at all scales, for Combined Heat and Power (CHP) , where they can provide economic heat to Thermal Networks, maximize the benefits of nuclear power, and mitigate cost increases to both electricity and Thermal Network customers.

It is recognized that the recommended development of a Thermal Network Strategy and enabling policies that work for Canada will require near-term effort. Specific objectives include the following:

- **Indigenous voice:** Canada's Indigenous peoples must and will play a central role in Canada's energy system transition, through Indigenous knowledge informing environmental sustainability, as Rights Holders for much of the land on which much energy infrastructure is located, as equity holders in energy projects, as participants in Canada's energy workforce. Engagement with Indigenous peoples regarding the TN future for Canada is an immediate priority.
- **Socialize**: progress the socialization of the opportunity afforded for Thermal Networks to be an important contributor to Canada's clean heat infrastructure.

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- **Analyze**: develop the capacity to help inform an holistic evidence-based strategy by leveraging science-informed analysis and Indigenous knowledge, and in turn, bring this capacity to bear both to validate Position Paper findings and to progress understanding of the issues and policy choices needing early attention.
- **What next**: engage multiple stakeholders and Rights Holders across Canada's energy landscape to build towards a consensus, with commitments, on their contributions to the Strategy, with an agreed plan for What Next.

The full Position Paper can be accessed at:

https://www.eng.mcmaster.ca/mcmaster-institute-for-energy-studies/featured-publications/#thermal-networks-position-paper

The development of the Position Paper has been endorsed by McMaster University's Institute for Energy Studies, the Boltzmann Institute and the Canadian Nuclear Association, with the Paper's authors having relevant thermal networks, electric power and nuclear energy expertise. Senior representatives from sixteen other organizations – governmental, associations / think tanks, and the thermal, electrical and nuclear energy sectors – have been consulted and provided advice on the content of the Paper. Their involvement does not imply their endorsement of the Paper's findings and recommendations.

NOTE: This Position Paper neither comments on nor makes recommendations pertaining to existing or planned Thermal Network or nuclear energy projects in Canada.