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Infrastructure Canada
Communications
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Submitted by email: infc.info.infc@canada.ca

RE: Engagement Paper on the National Infrastructure Assessment – Energy Harvesting Infrastructure for Climate Action

McMaster University Institute for Energy Studies (MIES), in collaboration with the Integrated Community Energy and Harvesting systems' (ICE-Harvest) Energy Research Cooperative, is pleased to provide the Ministry of Infrastructure and Communities with feedback on its Engagement Paper on the National Infrastructure Assessment. MIES was founded in 1980 in the Faculty of Engineering as an interdisciplinary institute for the study of energy extraction, transformation, generation, transportation and end-use. The ICE-Harvest project is a research cooperative led by McMaster involving over 30 municipalities and 19 Industrial Partners, namely: HCE Energy Inc., GridSmartCity LDC Cooperative (Brantford Power, Burlington Hydro, Energy+, ENWIN, ERTH Power, Essex Power Lines, Halton Hills Hydro, Kingston Hydro, Kitchener Wilmot Hydro, Milton Hydro, Niagara Peninsula Energy, Oakville Enterprises Corp., Waterloo North Hydro, Welland Hydro-Electric Systems Corp.), Alectra Utilities, Enbridge Gas, s2e Technologies, Geosource Energy, and Siemens Canada Limited.

We recommend that the Ministry consider adopting Energy Harvesting Infrastructure as a cornerstone of its clean energy investment strategy, as energy harvesting is a locally available and carbon-free form of energy generation that epitomizes the government's goal of "*Powering our economy for clean energy systems and net-zero structures.*" Specifically, we propose that the Government of Canada develops a National Energy Harvesting Strategy aimed at identifying and supporting efficient energy harvesting infrastructure investments, and quickly scaling them to address the energy sector transition that will be required to achieve Canada's goal of becoming carbon neutral by 2050. Without energy harvesting we will continue to waste more energy than we actually use. The result is that as we decarbonize our heating systems, we will need to significantly increase carbon free generation, but more importantly, increase our peak electricity capacity and distribution infrastructure.

The Government of Canada has done a commendable job of ensuring the objectives of Canada's Climate Plan inform the priorities of all related ministry initiatives, as exemplified in the National Infrastructure Plan prioritizing clean energy infrastructure. Canada's Climate Plan also guides the

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Hydrogen and Small Modular Reactor (SMR) plans, as well as carbon pricing and specifically the climate change adaptation strategy. A National Energy Harvesting Strategy would also fall under this plan and be consistent with the government's priorities above. Among clean heat resources, wasted thermal energy from the commercial, institutional, and industrial sectors, as well as community cooling processes, is one of the most important untapped sources of carbon-free energy.

Over the past 4 years, the McMaster Institute for Energy Studies (MIES) has led the "Integrated Community Energy and Harvesting Systems (ICE-Harvest)" research initiative, which is co-sponsored both Provincially and Federally through the TargetGHG program. This program is conducted in partnership with Carleton University and the ICE-Harvest Energy Research Cooperative, which is comprised of 19 industry partners representing Ontario's various energy and utilities sectors. This research is funded by the Natural Sciences and Engineering Research Council of Canada [CRDPJ 401203143 - 2018] and the Ministry of Research and Innovation and Science (administered by the Ontario Centre of Excellence) [27851-2018], along with contributions from each partner. The above funding was preceded by a $3.8M infrastructure grant from the Canada Foundation for Innovation (CFI) and the Ontario Research Fund-Research Infrastructure to build a research-scale ICE-Harvest facility, formally known as the Research Facility for Integrated Building Energy Harvesting Systems (ReFIBES).

Using the Province of Ontario as a case study, this feedback presents a new perspective based on the ReFIBES pilot scale demonstration site that has been developed through an ongoing research program that validates the considerable potential of harvesting "waste" energy in typical cold-climate communities. Indeed, the scale of this "lost energy" is significant relative to the province's natural gas heating needs and represents a transformative opportunity for all of Canada.

Harvesting waste energy is often the lowest cost option compared to most other heating decarbonization approaches, as waste energy is a local resource; however, strategic investment in energy harvesting infrastructure is required to capture this abundant resource within our communities. The local storage of this wasted energy via short-term and seasonal thermal storage technologies can displace a significant proportion of the community's heating demands and provide a climate adaptation strategy that is resilient to major weather events, such as power losses due to freezing temperatures. With the incorporation of small emergency generators or renewable microgrid and storage for circulation pumps, local seasonal thermal storage can be used to heat buildings for weeks, providing further critical thermal resilience.

Our research program highlights the need to implement National/Regional Energy Harvesting Strategies on a global level, with an immediate focus on creating a National Inventory that catalogues waste heat sources and maps their proximity to heating loads—a requirement to utilize this local zero-emission heating source. Municipal initiatives have been undertaken to identify energy harvesting potential, such as the recent City of Hamilton Chamber of Commerce's industrial waste heat recovery project. However, this report highlighted the need for more tools

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and techniques to more accurately identify citywide energy harvesting potential. These locally identified gaps would be addressed by a National Inventory of waste heat sources. Until recently, the inability to harvest waste heat has been a lost opportunity to capitalize on a plentiful source of carbon-free energy; however, recent advancements in heat recovery heat pumps, thermal distribution networks, and thermal storage, along with the emergence of carbon pricing in many jurisdictions, have allowed this approach to emerge as a viable and highly appealing option for the present and for Canada's future.

Potential of Energy Harvesting

Waste heat from commercial, institutional, and industrial buildings, as well as from community cooling processes, is one of the most important yet untapped carbon-free energy resources. To illustrate, these waste heat sources plus curtailment of renewable electricity generation account for over 130 TWh each year in Ontario[1,2,3], which represents over 65% of the province's natural gas building heating energy demand. Notably, Canada Energy Systems Analysis Research (CESAR) estimates that Ontario's commercial, institutional, and industrial sectors incur approximately 94 TWh in end-use losses each year[4]. Figure 1 summarizes the lost energy opportunity in Ontario; the 21 TWh attributed to community cooling processes includes data centres, grocery stores, arenas, and building air conditioning systems.

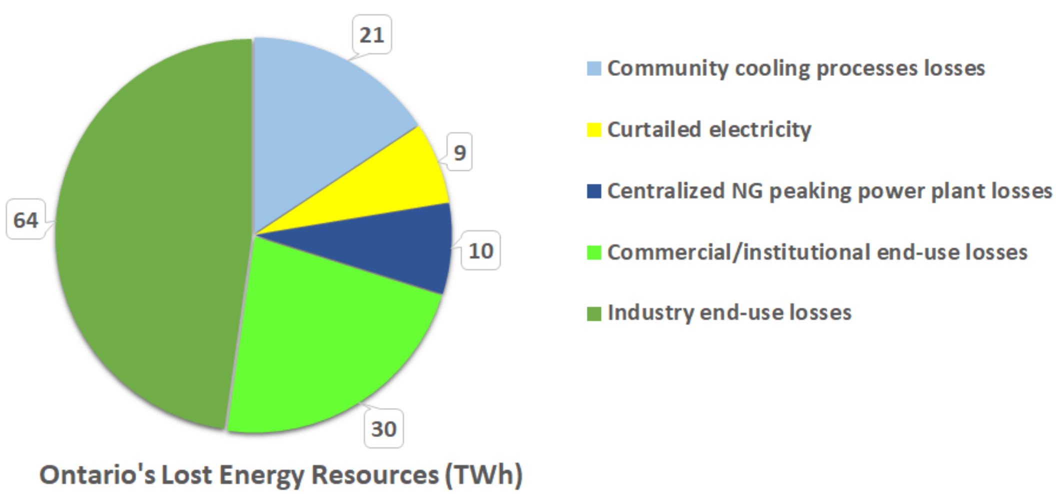

Figure 1. The potential harvestable lost energy in Ontario.

[1] Dandres, T., Vandromme, N., Obrekht, G., Wong, A., Nguyen, K.K., Lemieux, Y., Cheriet, M. & Samson, R. Consequences of future data center deployment in Canada on electricity generation and environmental impacts: A 2015–2030 Prospective Study. J. Ind. Ecol. 21, 1312-1322 (2017).

[2] Year-End Data (Independent Electricity System Operator (IESO), 2017); https://www.ieso.ca/Corporate-IESO/Media/Year-End-Data/2017

[3] Abdalla, A., Mohamed, S., Bucking, S. & Cotton, K.J. Modeling of thermal energy sharing in integrated energy communities with micro-thermal networks. Energy Build. ENB-D-21-00232 (2021)

[4] Sankey Diagrams Associated with Fuel and Electricity Production and Use in Canada (Canadian Energy Systems Analysis Research (CESAR), 2013); https://www.cesarnet.ca/visualization/sankey-diagrams-canadas-energy-systems

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The potential of energy harvesting is vast. While it is not economically viable to recover all waste energy, a large part is the lowest cost form of decarbonized heating for communities. A true accounting of this investment opportunity will require a National Waste Heat Inventory that catalogues waste heat sources and maps them to heating loads.

Energy Harvesting Synergies with Other Energy Sectors

Energy harvesting and sharing enabled by micro-thermal networks is an energy grid modernization strategy that can enable the integration of our siloed electricity, heating, and transportation networks. Peak electrical demand occurs on the hottest or coldest days of the year. By using local sources of “waste” heat to supply thermal energy, micro-thermal networks can reduce peak electrical demand while minimizing carbon emissions. Additionally, many electrical generators, such as hydrogen/biogas/natural gas-fueled generators and SMRs, produce more waste heat than electricity. Locating these generators within communities as distributed energy resources (DERs) creates an opportunity to harness this waste heat, thereby potentially doubling total energy utilization. This is significant, as it will be imperative to maximize fuel-energy-content use during the transition to alternative low-carbon and carbon-free sources of energy.

While the electrification of heating has been widely promoted as a decarbonization strategy, this approach could result in two to four times increase in the electrical generation, transmission, and distribution infrastructure to meet winter heating peaks in cold climate locations such as Canada. Another challenge relating to the electrification of heating is that sources of renewable generation, particularly solar, are not reliably available on cold winter nights when there is the largest heating demand. Additionally, smaller heating and cooling loads in spring and fall can result in an oversupply of solar and wind generation, which creates the need for curtailment to balance our siloed electrical grids. In 2017, curtailment or wastage from renewable wind and solar generation in Ontario accounted for 9 TWh, or 6% of all electricity consumed. This figure will only grow as more renewable generation is added to the electrical grid.[2]

The use of micro-thermal networks to distribute harvested waste energy, combined with short-term and seasonal thermal storage, can address these challenges. These technologies can meet thermal loads directly, while also reducing winter peak capacity electrical challenges associated with the electrification of heating. Additionally, through the use of high-efficiency electricity-driven heat pumps, otherwise curtailed spring and fall renewable generation can be stored in seasonal thermal storage and discharged to meet peak winter heating demands. Thus, micro-thermal networks and thermal storage are demand-responsive and support energy network integration by adding demand and harvesting when there is an oversupply of renewable generation, and by removing demand during periods of peak electrical demand. Furthermore, intelligently controlled micro-thermal networks are synergistic with the electrical grid, and they enhance the prevalence of renewable generation.

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Energy Harvesting Infrastructure is needed to leverage Industrial Symbiosis, which is when the by-product of one industrial facility can serve as a useful input to a different facility. Many manufacturing and process conversion facilities produce an abundance of waste heat that cannot be utilized internally, while other facilities have a large demand for low temperature-heat, such as greenhouses. Thus, it would be highly beneficial to co-locate and connect buildings that produce large amounts of waste heat with those that have high heat loads.

Energy Harvesting Infrastructure

- **Micro-Thermal networks** are needed to connect waste heat sources with heating loads. This is analogous to how an electrical grid is needed to connect renewable generators to electrical loads. There is an opportunity to use these micro-thermal networks to develop a novel prosumer and consumer model for thermal energy distribution. Micro-thermal networks typically take the form of hot or cold water pipes, similar to district energy systems, but can be controlled across a range of temperatures to manage electricity demand.
- **Thermal harvesting equipment** is required for harvesting waste energy streams. Heat exchangers and heat pumps are typically used for thermal energy harvesting. Heat pumps and electric boilers can also be used to harvest carbon-free electricity that would otherwise be curtailed.
- **Thermal storage** system (short-term water/phase-change materials tanks and seasonal storage pit, reservoir, or geothermal systems) infrastructure is needed to bridge the temporal mismatch between the availability of waste energy sources and load demands.
- **Bi-directional vehicle** infrastructure is required in high-energy-demand areas to support peak energy demand, and to function as electrical power quantity and frequency assets during the electrification and integration of our energy, heating, and transportation sectors.
- **Operation systems** such as controls and monitoring equipment are required to manage the multi-directional flow of energy from a variety of sources to multiple loads. As a grid modernization solution, these control systems could be linked with an electrical Distribution System Operator, and control in conjunction with other local DERs for the benefit of the local distribution grid.

Improving coordination among infrastructure owners and funders

A shift is required from siloed energy utility infrastructure to integrated energy system infrastructure to maximize local resource utilization, reduce all energy-sector-wide system costs, provide enhanced system-wide resilience, and reduce total carbon emissions. This shift will require several changes, including:

- updating federal and provincial regulations and competitive market rules with a regulatory regime that allows for cross-sectoral cooperation and innovation
- supporting the planning of regional integrated energy systems
- developing policies that discourage 'energy dumping' through atmospheric rejection devices in favour of harvesting this energy for community use
- co-locating waste-heat-producing facilities, such as manufacturing facilities, and heat-consuming facilities, such as greenhouses (which also addresses local food security)

Policy development, planning, design, and the operation of energy harvesting infrastructure will leverage advancements in data and technology, such as Digital Twins and Machine Learning, to "future proof" today's investments for a zero-carbon economy and provide resilience to extreme weather. Investments in digital infrastructure are key to the coordination of distributed energy resources (DERs) in real-time for the benefit of fully integrated energy grids.

Determining the best ways to fund and finance infrastructure
It is recommended that initial funding be provided for workforce and industry capacity-building pilot projects to enable the development and sharing of best practices for scaling up these systems quickly and economically. Next, low-cost financing (such as through the Canada Infrastructure Bank) should be made available for energy harvesting infrastructure projects that meet clear and achievable low-carbon performance requirements. To encourage both local and private sector investment, long-term regulatory and policy clarity is needed to minimize the risks associated with the high capital costs of long-life infrastructure (i.e., pipes with 50-100 year lifetimes).

Potentially, there could be targeted financial support for Municipally operated thermal utilities and infrastructure, as trust in the long-term viability of energy harvesting infrastructure is a key consideration in potential waste-heat providers and customers' decisions to transition from the status quo to a new energy service provider.

<u>Benefits to Canada</u>

Today, energy harvesting infrastructure can reduce GHG emissions by enabling more efficient fossil fuel use, and it can provide the necessary infrastructure for our transition to the carbon-free energy sector of the future. Ultimately, energy harvesting infrastructure is an ideal pathway to Canada's goal of developing technologies capable of producing an abundance of affordable clean energy as set out in the recently passed Bill C-12 – Canadian Net-Zero Emissions Accountability Act.

Furthermore, investments in energy harvesting would create local jobs, as personnel will be required to build and maintain this low-carbon infrastructure. Significantly, the money spent on energy utilities is cash that generally flows unidirectionally—that is, out of the community; in contrast, harvesting local resources keeps these utility payments within the community, in turn stimulating local economic development.

Energy harvesting infrastructure creates an opportunity to harness an unused resource that is already in our communities. In addition, investing in such infrastructure can reduce the centralized generation and electrical grid updates that are needed for the electrification of heating and transportation. This technology also has potential to increase the value proposition of other low-carbon investments (Hydrogen and SMR) by harvesting their otherwise wasted heat, while its demand responsiveness and ability to store otherwise curtailed carbon-free electricity enables it to support increased renewable electrical generation capacity.

Conclusion

Your efforts in creating this National Infrastructure Assessment are to be applauded. We believe that investment in energy harvesting infrastructure is critical to decarbonizing our energy sectors. To move this agenda forward, we propose the development of a National Energy Harvesting Strategy and immediately conducting an inventory of the potential of this untapped resource. Energy harvesting's focus on thermal storage and controllable micro-thermal networks provide the opportunity to lower peak energy demand through dynamic fuel switching and demand management, thus balancing energy supply and demand without having to expand our electricity infrastructure. While energy harvesting provides a strategic pathway to achieving a carbon-neutral future, charting this pathway will require a National Energy Harvesting Strategy and community energy integration policy to minimize lost energy that our society currently sees as waste. This energy is ubiquitous in our communities, and we need a strategy to harvest it.

We would like to thank you for this opportunity to share our perspective on the infrastructure requirements for Canada to achieve its 2050 Net-Zero Carbon Targets. We are currently developing a white paper on energy harvesting, which will include a discussion about infrastructure implications. We would be pleased to have the opportunity to speak with the federal government about this evolving technology. If you would like to follow up on this discussion, please contact Jim Cotton, Co-Director McMaster Institute for Energy Studies, McMaster University, cottonjs@mcmaster.ca .

Sincerely,

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