REPORT WITH RECOMMENDATIONS

Industrial Waste Heat Recovery Project

An Initiative of the Hamilton Chamber of Commerce

Funded by

TAF The Atmospheric Fund

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ENGINEERING W Booth School of Engineering Practice and Technology McMaster University

ENBRIDGE Life Takes Energy

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ACKNOWLEDGEMENTS

The Atmospheric Fund
for investing in Hamilton's low carbon future

Mitacs Accelerate Program
for funding the project's graduate student researchers

Mitacs

PROJECT GOAL

Identify technically feasible and economically viable industrial waste heat diversion opportunities to drive competitiveness and reduce GHGs for businesses in Hamilton's Bayfront Area.

DESIRED LONG-TERM OUTCOMES

Use the report to unlock support (funding, enabling policies, infrastructure, relationships) needed to advance select opportunities and related activities, including systems implementation, education and training, research and development, across the study area and beyond.

THEORY OF CHANGE

Four project-specific enablers were identified to achieve a lasting impact:

Convene and Collaborate → **Research** → **Analyze** → **Recommend and Support**

These enablers guided the project and provided a framework to report on progress and evaluate performance. A special thank you to the team at Social Impact Advisors for their coaching.

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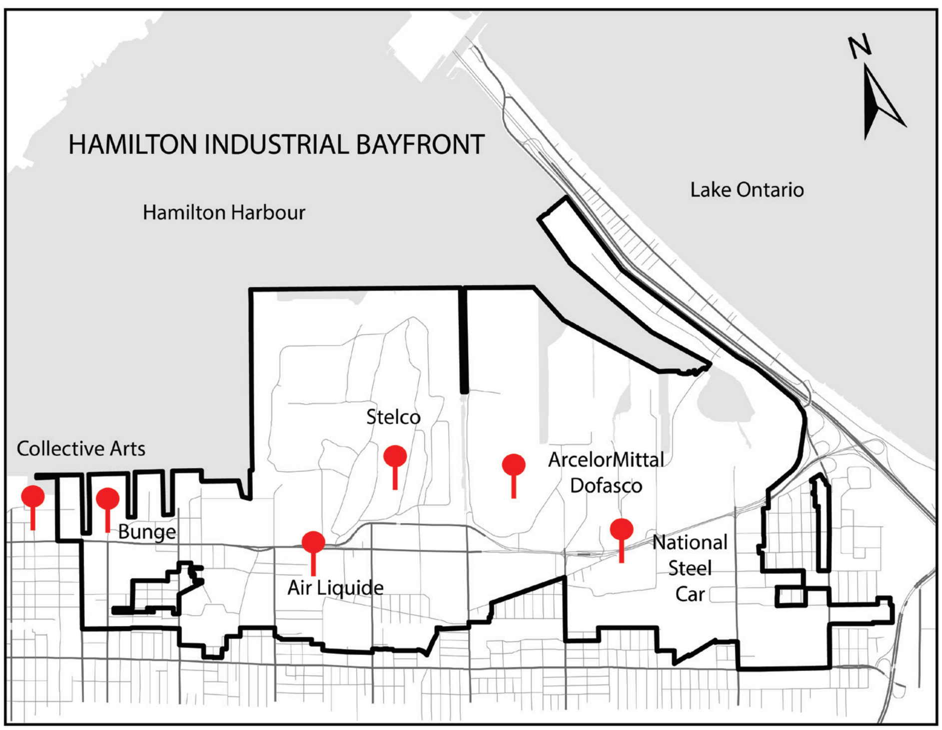
Study Area Map



EXECUTIVE SUMMARY

The Hamilton Chamber of Commerce received a two-year grant (2019-2020) from The Atmospheric Fund to identify opportunities to increase the recovery of waste heat among manufacturers operating in Hamilton's Bayfront Industrial Area. Additional funding was secured through Mitacs to assist with research costs.

This high level, introductory study was meant to contribute to an ongoing regional movement to drive improved energy utilization and reduce GHG emissions against the backdrop of a changing climate.

Hamilton — a prominent manufacturing centre and home to numerous energy-intensive industries — was seen as an ideal setting for this study. The community's goal to achieve carbon neutrality by 2050 provided an added degree of urgency.

Global research shows that upwards of 50% of energy consumed in industrial processes is lost as waste heat. Energy inefficiency in this sector is linked to increased fuel consumption and higher GHG emissions.

Findings and recommendations from this study are intended to inspire and inform future work to capitalize on Hamilton's industrial waste heat potential as a source of economic, social, and environmental benefit on the road to a low emissions future.

A related goal is to share learnings with other manufacturing centres in Ontario and beyond.

The broad sampling of opportunities found in this report are intended to spark conversations among stakeholders and lead to tangible actions, including the adoption of new and emerging waste heat technologies, investments in research and demonstration projects, development of waste heat monitoring systems, and the use of industrial waste heat as a source for district energy.

A key measure of long-term success will be reductions in GHGs from Hamilton area manufacturers reported by The Atmospheric Fund and other climate leaders.

Global research shows that upwards of 50% of energy consumed in industrial processes is lost as waste heat.

Study Background

By design, the study's geographic scope was limited to Hamilton's Bayfront Industrial Area, a well-established economic corridor stretching more than 9 kms along the shoreline of Hamilton Harbour. This area was chosen because of its concentration of energy intensive industries, including two steelmakers.

A defining feature of the study was the direct engagement of manufacturers in the area as essential partners in addressing challenges and opportunities related to energy efficiency in general and waste heat recovery in particular. This desire to work collaboratively with industry on issues related to sustainability is consistent with the values of the Hamilton Chamber of Commerce.

Fifteen select manufacturers were invited to take part in the study and six agreed to participate. These six manufacturers represent the diverse mix of industries operating in the area, including steelmaking, agribusiness, fabrication, and chemical refining. Certain practices and insights from these companies can be replicated at other sites.

In addition to manufacturers, the study engaged numerous organizations necessary to unlock Hamilton's industrial waste heat recovery potential. These organizations fell into four categories: municipal, community, academia, and subject matter specialists.

Structure

During the two-year span of the study, three voluntary groups were in place to assist:

Project Working Group:

This group reported through to the Hamilton Chamber of Commerce executive team and acted as a steering committee. It included representatives from Enbridge Gas Inc., HCE Energy Inc., Hamilton-Oshawa Port Authority, and McMaster University's W Booth School of Engineering Practice and Technology.

Project Advisory Panel:

This multidisciplinary panel met on two occasions (October 2019 and October 2020) to provide expert input on work in progress. Panellists were drawn from a variety of organizations across the public, private and not-for-profit sectors.

Project Tech Team:

This team met on a frequent basis to guide and support the technical aspects of the study, including energy and manufacturing systems, data collection and analyses, and GHG quantification.

These groups were supported by project facilitators from the Hamilton Chamber of Commerce.

Methodology

The study design featured a mix of qualitative and quantitative research. It also drew on the expertise of a variety of stakeholders directly and indirectly connected to the subject of industrial waste heat recovery and reuse. This community-based approach was selected as a means to gather input from multiple perspectives and build the local capacity needed to advance recommendations arising from the study.

The overall research design, though cumbersome at times, proved effective in engaging a wide range of people and organizations.

McMaster University's W Booth School of Engineering Practice and Technology was the lead research partner. The school operates under the Faculty of Engineering and excels in the delivery of experiential education in collaboration with community partners, including industry and municipalities.

During the first year of the project, two undergraduate students were contracted to carry out foundational research under the supervision of the Project Working Group.

During the second year, two graduate level engineering students were contracted to help identify and document select industrial waste heat recovery opportunities. These students worked as members of the Project Tech Team and under a McMaster University academic supervisor.

This community-based approach was selected as a means to gather input from multiple perspectives and build the local capacity needed to advance recommendations arising from the study.

Primary research applied to the six manufacturers included structured interviews, plant tours, completion of process-specific worksheets that were custom designed for this project, and sharing historical data and internal reports.

Primary research applied to the additional stakeholders, such as subject matter experts, included structured interviews and detailed documentation.

Secondary research involved literature searches to build foundational knowledge, fill data gaps, and identify best practices suited to local circumstances in Hamilton.

Deliverables

As planned, the study produced three deliverables:

1. An internal report that summarized the current state of waste heat recovery and reuse within the study area.
2. An internal report that matched select waste heat sources in the study area with potential sinks (uses) inside and outside the study area.
3. The present final report with recommendations available to the public.

Content of Final Report with Recommendations

The report you are reading includes content in the following sections:

1. *Summary of Current State Report:*
   This section features ten significant findings related to existing practices and plans within the study area that support GHG emission reductions and the expansion of waste heat recovery, and an overview of barriers and potential remedies related to waste heat recovery moving forward in Hamilton.
2. *Summary of Mapping Exercise Report:*
   This section details the methodology used to match potential waste heat sources and sinks, provides sample maps to help visualize thermal relationships, and offers a conceptual drawing of a potential District Energy System that would gather industrial waste heat from multiple sources across Hamilton's Bayfront Industrial Area to supply multiple users in the area and beyond.
3. *Overview of Select Waste Heat Recovery Opportunities Identified by Participating Companies:*
   This section presents a set of opportunities that arose from multiple interactions between the Project Tech Team and representatives with the six participating companies. Considerable effort was given to ensure that these forward-looking opportunities meet the basic test of "technical feasibility" and "economic viability" at a preliminary level. All parties agreed that further detailed discussions and analyses would be required as part of the post-study activities.
4. *Discussion of Thermal Distribution Networks:*
   This section addresses the need to transport industrial waste heat from sources to sinks efficiently and cost effectively. Key content includes a summary of best practices in District Energy, an overview of state-of-the-art Integrated Community Energy Systems, and the presentation of a "many to many" model designed to help manage risk.
5. *Overview of Enabling Resources:*
   This section summarizes highlights, takeaways, and next steps from in-depth discussions with five key stakeholder organizations ready to contribute in specific ways to advance waste heat recovery and district energy in Hamilton.
6. *Policy Discussion:*
   This section presents policy options designed to help maximize the diffusion of waste heat recovery technologies, particularly among companies in Hamilton and beyond. Also included is a set of policy recommendations for a post-study action plan.
7. *Recommendations:*
   The document ends with a set of recommendations that build on the findings of this study.
8. *Additional Content:*
   The report also includes insights on key partner organizations as well as descriptions of several technologies prevalent in waste heat recovery and reuse.

Key Findings

It is important to note that this localized study was limited to a small and diverse set of participating companies and stakeholders. Moreover, the study's design was weighted toward qualitative research and relied on data that the participants chose to provide. For these reasons, study findings cannot be generalized to a wider context. That said, the findings do provide initial insights and a starting point to advance industrial waste heat recovery in Hamilton and beyond.

Detailed findings are included throughout the report. Below are several takeaways:

- Study participants acknowledged that Hamilton-based manufacturers produce high levels of industrial GHG emissions tracked locally and regionally — e.g., more than 5 million tonnes of CO2 annually from the study area alone, equal to approximately 50% of the GTHA's overall industrial carbon emissions. They also pointed to the carbon-dependent nature of Hamilton's industrial make-up and the significant challenges and opportunities associated with de-carbonization.

- The study revealed that Hamilton is home to a variety of resources needed to help local manufacturers transition to a low emissions future, including a world class, research intensive university with energy expertise, an existing district energy system and related experience, a strong innovation eco-system, and a base of sophisticated companies.

- The study showed that waste heat recovery, distribution, and storage technologies are widely available to act on opportunities cited in this report. Discussions revealed that prices for many of these technologies continue to fall over time.

- Research confirmed that there is an abundant supply of industrial waste heat in the study area. The estimated recoverable waste heat generated by participating companies is approximately 4 million GJ/Yr., enough to heat roughly 45,000 homes for a year. The application of this waste heat could result in a carbon offset of approximately 200,000tCO2eq/Yr.

- Participants recognized that waste heat recovery is among a variety of tools that can be used to lower industrial GHG emissions, particularly with high heat manufacturers in Hamilton. For example, steelmakers employ heat at temperatures as high as 1,000°C and beyond. Waste heat from these processes can be applied internally for production purposes and/or externally for purposes such as district energy. Other available tools to reduce GHG emissions include alternative fuel sources such hydrogen and the electrification of additional manufacturing processes. Study participants expressed a keen interest to explore these transformational opportunities.

- To varying degrees, all the participating manufacturers are engaged in energy management initiatives to improve system wide efficiency and lower costs. The study showed that local companies are increasingly coupling energy efficiency with GHG reductions and the broader issue of climate change.

- The current scenario of relatively inexpensive fuel costs and low carbon pricing has helped maintain business-as-usual energy practices. Study participants recognized that the growing urgency of climate change could soon disrupt business-as-usual practices for a range of industries. According to research, this "new normal" could open the door to increased investments in waste heat recovery.

- Study participants recognized that policy measures, including financial incentives, will play a key role in advancing the adoption waste heat technologies and systems.

- The study revealed an important local challenge — identifying additional densely built "demand nodes" that could be recipients of industrial waste heat.

- Discussions with manufacturers revealed a number of barriers that would need to be addressed to trigger their participation in waste heat recovery projects, particularly those involving multiple partners. The two foremost barriers cited by manufacturers were the high costs for energy sharing infrastructure and the added complexity of collaboration.

General Conclusion

Waste heat recovery, coupled with district energy and other integrated community energy systems, can play a significant role in lowering Hamilton's industrial GHG emissions while contributing additional economic and social benefits.

A comprehensive implementation plan would need to engage and support local manufacturers, leverage community, academic and government resources, and deploy collaborative solutions that help de-risk investments in energy sharing.

Applying lessons learned from leading communities, including European best practices, and advocating for supportive policies, would be equally important.

The urgent need to address climate change while building a resilient, post-pandemic economy, provide an ideal platform to capitalize on Hamilton's industrial waste heat advantage.

The recommendations arising from this study provide the building blocks for action.

SUMMARY OF CURRENT STATE REPORT

The first key project deliverable was an internal report documenting the current state of waste heat recovery and reuse in Hamilton's Bayfront Industrial Area and various enabling factors (completed February 2020).

The development of the report was supervised by the Project Working Group and executed with the assistance of two student interns from McMaster University.

The aim was to gather information and insights from multiple sources to provide the Project Working Group with a foundational understanding of the subject and associated opportunities and challenges.

Primary sources included staff members from the six participating companies, representatives from a variety of organizations with knowledge of the subject (City of Hamilton, McMaster University, Environment Hamilton, Hamilton Industrial Environmental Association, Bay Area Climate Change Council, etc.), and external experts, including Markham District Energy.

The Project Advisory Panel also provided valuable information, particularly related to understanding energy systems, emissions, and industrial waste heat recovery from a uniquely Hamilton perspective.

Primary research also included a number of plant tours and meetings with company personnel (pre-pandemic).

Secondary research focused on documenting relevant experiences, practices, and policies from other communities.

The role of the Project Working Group was to analyze information gathered and glean insights to ensure the project was moving forward. Emphasis was given to viewing data through a local lens and identifying existing practices and plans that support GHG emission reductions.

Below are ten significant findings, in no particular order:

1. **Technological Advances Unlock New Possibilities**
   More than 20 years have passed since the publication of the most recent study examining waste heat recovery opportunities within Hamilton's Bayfront Industrial Area. Much has changed since that time, including the arrival of advanced technologies, such as high-efficiency heat pumps and lower-cost piping systems. This has reduced or eliminated barriers to the widespread adoption of waste heat recovery applications. It puts into play transformational initiatives, including long-distance thermal networks supported by industrial waste heat.

2. **Hamilton Industries Continue to Address GHG Emissions**
   According to The Atmospheric Fund, the industrial sector contributes 58% of Hamilton's total GHG emissions. That said, local industries — including two steelmakers — have reduced their overall aggregate emissions by approximately 40% since 2006.

   This is a result of many factors, including changes to Ontario's manufacturing landscape and myriad carbon reduction initiatives, such as waste heat recovery and reuse.

   The current state can be characterized by a movement among local manufacturers to adopt effective approaches to lowering GHGs that align with the expectations of financial markets, stakeholders, and society at large. This mindset has helped open the door to multi-sector collaboration, including the example of this project.

3. **Strong and Stable Manufacturing Base**
   Hamilton remains a leading manufacturing centre despite various challenges, including the offshoring of labour-intensive industries, globalization of supply chains, and automation. The city's official plan, zoning bylaws, and economic development strategy emphasize the enduring importance of manufacturing as a driver of local jobs and prosperity.

   Hamilton's Bayfront Industrial Area remains home to large- and small-scale manufacturers that offer reliable sources and uses of industrial waste heat. Moreover, the Hamilton-Oshawa Port Authority continues to broaden the diversity of its industrial tenants in Hamilton while investing in new infrastructure. The pathway leading to the area's industrial future is well established.

4. **Specialized Industries with Unique Challenges**
Many of Hamilton's leading industrial companies, including its two steelmakers, belong to the primary metals sector. They are energy-intensive companies that rely on carbon as an input. For example, producing steel from iron ore requires coal and coke as a reductant. This contributes to the steel industry being among the world's three most significant producers of carbon dioxide.

   Indeed, heat recovery is an essential strategy for the steel sector as it shifts to a low emissions future. Yet meeting its decarbonization targets will also require breakthrough innovations in steelmaking. Replacing carbon with hydrogen is one example. The increased adoption of electric arc furnace (EAF) technologies that expand the use of recycled scrap steel is another.

5. **Special Focus on Industrial Sector**
Numerous individuals and organizations in Hamilton are working to advance energy innovations to reduce GHGs, particularly in the areas of buildings and transportation. This project performs a complementary role by helping *industry* decarbonize through energy conservation measures and the offset of fossil fuels used for heating. Working together, the current state of local collaboration to address climate change is strong and effective.

Working together, the current state of local collaboration to address climate change is strong and effective.

6. **Local Manufacturers Invest in Initiatives to Address Climate Change**
Corporate investments, coupled with loans, grants, and subsidies from government and energy providers, enable local manufacturers to undertake projects in a range of areas that directly or indirectly reduce GHG emissions.

   GHG reductions are the result of energy conservation, efficiencies, and operational changes, and increased waste heat recovery.

   A survey of recent examples from Hamilton's Bayfront Industrial Area revealed tangible gains, including:

   - New piping infrastructure by Air Liquide and others to move liquids and gases among suppliers and consumers — lessons learned could be applied to building district energy infrastructure.
   - Companies clustering closer together within Hamilton's Bayfront Industrial Area to reduce transportation costs and leverage synergies — this helps strengthen the case for a thermal distribution grid.
   - Boiler upgrades and replacements, including waste heat recovery systems and increasing the use of otherwise lost by-product fuels — this provides significant GHG reductions.
   - Furnace updates and replacements — extends to the use of intelligent temperature control systems for improved energy conservation and advanced waste heat recovery systems.
   - Investments to reduce heat loss during distribution (improved insulation and steam traps, etc.) and end uses (smart control systems, recuperators, jacketed heat exchangers, etc.) — reducing heat loss helps lower fossil fuel use.

- Utilization of bio-carbon to reduce coal as an input requirement for coke production — i.e., a biomass substitute for coal.
- Use of industrial greenhouse gas emissions to produce high value algae and capture carbon — a state of the art innovation.

7. **Untapped Opportunities for Greater Impact**
   Research to document strengths within Hamilton's Bayfront Industrial Area related to energy use in general and waste heat recovery in particular pointed to several untapped opportunities, including the potential to:

   Enhance the 2 MW district energy system at Pier 10 by incorporating industrial waste heat as an input and expanding the distribution network to include additional customers.

   Build area-wide thermal infrastructure to enable energy capture, storage, upgrades, and sharing.

   Pilot new and emerging approaches to integrated energy systems that leverage synergies between thermal, electrical, and gas networks.

   Expand efforts to track and communicate area-wide progress in GHG reductions achieved through the actions of individual companies and inter-company collaboration — a special focus on waste heat recovery and reuse would fill an information gap.

8. **Waste Heat Recovery Under-Represented in Sustainability Plans**
   Stakeholder interviews, combined with online searches, revealed that all participating companies had developed energy plans with a view to conservation and cost savings. The larger companies have corporate sustainability plans that include an environmental component with goals in areas such as GHG reduction, waste reduction, water use reduction, and use of renewable energy.

   In most cases, waste heat recovery and reuse were not cited as a specific area of focus. Also absent were thermal grids and the application of district energy systems as tools to achieve sustainability goals through the offset of fossil fuels used to generate heat. Work to address these gaps at the company and the sector levels is a follow-on action from this project.

9. **Surplus Lands Present Opportunity to Use Industrial Waste Heat**
   In general, research showed that most land in the study area is being used for productive proposes ranging from manufacturing and storage to transportation and utilities. One area of opportunity is the surplus land owned by Stelco. This land became available as the company rationalized its operations at the Hamilton Works facility. The company's intentions for the land include attracting new users, such as warehouse, logistics, and fabrication operators — all well suited to utilize waste heat provided by Stelco and other nearby sources.

10. **Industrial Eco Park Concept is a Component of an Area Wide Vision**
    The Hamilton Industrial Environmental Association (HIEA) is promoting a vision to establish an Industrial Eco Park within Hamilton's Bayfront Industrial Area. According to the United Nations Industrial Development Organization, an Industrial Eco Park is "a community of businesses located on a common property in which businesses seek to achieve enhanced environmental, economic and social performance through collaboration in managing environmental and resource issues."

    One major benefit is the opportunity to share resources among companies, including utilizing one company's waste as an input to another company's manufacturing process. A Hamilton example is blast furnace slag from the iron-making process used to manufacture aggregate materials for the construction industry. This has the hallmarks of a "circular economy."

    HIEA has mapped more than a dozen resource sharing relationships among its 14 member companies. Waste heat sharing is not included in the current relationship map — could this be an opportunity moving forward? Another advantage of the Industrial Eco Park model is the potential for land use planning, including anticipating long-range infrastructure requirements. This could include thermal energy sharing infrastructure within the Industrial Eco Park planning process.

High-Level Assessment

Technical Feasibility:
Discussions with participating companies and related research revealed that technologies and systems required to increase the adoption of industrial waste heat recovery among Hamilton manufacturers are available. This extends to District Energy Systems, high-performance heat pumps, and thermal storage, to name a few. Hamilton-based manufacturers can also engage specialized expertise from the local community, including McMaster University's Faculty of Engineering (McMaster Institute for Energy Studies, W Booth School of Engineering Practice and Technology) and Mohawk College (Energy and Power Innovation Centre). The question of space required to install new equipment would need to be investigated on a case-by-case basis. Several of the larger companies participating in the project stated that technical feasibility studies had been conducted for specific projects. This could help accelerate implementation.

Economic Viability:
Costs and ROI related to implementing waste heat recovery projects were among the top issues raised by companies interviewed. For example, the need for a short payback period (1-3 years). Research by the project team identified a number of forces that are working together to help mitigate the cost barrier, and ideally, extend payback periods, including:

Costs and ROI related to implementing waste heat recovery projects were among the top issues raised by companies interviewed.

- Growing consensus on the need to lower industrial GHG emissions to address a changing climate.
- A heightened public expectation that industry is active in decarbonization.
- Increased adoption of carbon reduction targets by industry — for example, Canada's steel producers have set a goal to achieve net-zero CO2 emissions by 2050.
- Escalating federal price on carbon (from $50/tonne in 2022 to a projected $170/tonne in 2030).
- A growing number of government funding streams (grants, loans, subsidies, tax credits, etc.) available to industry to implement GHG reduction projects.
- Ongoing technical and funding support from Enbridge Gas and other energy providers to assist industry in demand side management.

These and other forces — including more stringent carbon reduction expectations up and down global supply chains and fluctuations in gas and electricity prices — will likely reframe how industry measures risk and assesses the economic viability of waste heat recovery projects and other decarbonization initiatives. In the end, economic viability will be determined by companies on a case-by-case basis.

Interviews with municipal and community stakeholders revealed a similar cost concern, in this case, the cost of infrastructure needed to transport waste heat. The potential to receive government infrastructure funding was raised as a possible solution, as were public-private partnership models.

Stakeholders responded well to the prospect of the Hamilton Chamber of Commerce being a policy and advocacy partner to help local stakeholders unlock government support for high potential projects.

GHG Reduction Potential:
Company interviews during this stage of the project began the process of identifying industrial waste heat recovery opportunities. A key selection criterion was how a given project might lead to direct and/or indirect GHG emission reductions. Larger companies were encouraged to "think big" and consider projects that might deliver community-wide benefits, for example, enabling disadvantaged neighbourhoods to access affordable district energy. Companies were free to select projects that best aligned with internal plans and priorities.

Refer to the Participating Companies section for a sampling of high potential waste heat recovery opportunities cited by the six manufacturers involved in this study.

BARRIERS AND REMEDIES

The present study, particularly discussions with Project Advisory Panel members and other local stakeholders, revealed a range of barriers to the broader adoption of industrial waste heat recovery and reuse. Study contributors, many drawing on their industrial and community experiences, talked about barriers in the context of Hamilton.

This reinforced the significant role that local conditions — geography, industrial base, urban form, existing thermal infrastructure, public policy — can play in determining the extent of waste heat utilization. Equally important, discussions also helped to identify potential remedies to these barriers.

Below are several leading examples:

Status Quo
Current market conditions in Ontario, especially fuel costs and carbon prices that remain relatively low in a global context, are helping maintain status quo energy practices in the industrial sector. Yet study participants agreed that several new drivers are challenging business-as-usual models. Most significant is climate change, and the need for low carbon energy solutions essential to meet GHG reduction targets

According to this study, one effective way to help lower barriers to increased industrial waste heat recovery is to place this work in the context of strategic leadership and corporate sustainability. This could initiate new business models that value waste heat recovery and district energy as priority actions in the transition to carbon neutrality.

Knowledge and Understanding
Technologies and systems in the fields of industrial waste heat recovery and district energy networks have evolved considerably in the past decade and new innovations — such as neighbourhood scale thermal grids and smart energy systems — are now being implemented in various parts of Canada.

Yet interactions with local stakeholders, including decision-makers, revealed gaps in knowledge and understanding. It will be difficult to close these gaps without enabling people to see new technologies in action and *experience* their impact on our daily lives.

Potential solutions raised include:

- Implement a high-profile demonstration project(s) to showcase new and emerging waste heat recovery, distribution, and end use applications.
- Engage regularly with key decision-makers on the supply side (industry) and demand side (developers) to share “what’s new” and how they can benefit.
- Provide modelling expertise to companies, and independent energy consultants, to simulate waste heat recovery systems and their positive impact on costs and quality.

Costs
Industry, in particular, views the costs commonly associated with waste heat recovery projects as a key barrier to implementation. High capital costs for specialized equipment, systems, and infrastructure are the greatest concern. This holds true for “cash strapped” municipalities and higher orders of government facing massive pandemic-induced deficits.

Potential solutions raised include:

- Engage experts to identify high impact waste heat recovery opportunities that lower company costs measured by energy utilization and life cycle analyses.
- Establish longer payback periods as a new business standard to remain ahead of climate policies and regulations.
- Access the full suite of incentive programs encouraging energy efficiency in general and waste heat recovery in particular.

Distance and Density

Hamilton has an abundance of energy intensive industries generally located within a 10 km by 5 km corridor along the Hamilton Harbour shoreline. That said, the current density of companies does not favourably compare to a compact, fit for purpose industrial campus. This presents a spatial barrier to acting on opportunities to easily share resources, including industrial waste heat. Distance is also a challenge when it comes to piping waste heat from Hamilton's Bayfront Industrial Area to potential users, especially homes, businesses, and institutions in lower city Hamilton. There are two issues. First, these thermal demand nodes are located 5-7 kms away from the industrial area. This adds to the cost and complexity of building and managing piping infrastructure. Second, the demand nodes — with the exception of Downtown Hamilton — may not be sufficiently dense to justify the cost of pipeline infrastructure.

Potential solutions raised include:

- Investigate global best practices in District Energy for proven technical solutions to the barriers of distance and density.
- Consider the cost-benefit advantages of beginning with a relatively small district energy system that serves a section of Hamilton's Bayfront Industrial Area and incorporates industrial waste heat as an energy source.
- Act on an expert recommendation cited in this report to conduct a detailed feasibility study on a potential industrial waste heat "trunk line" linking the Bayfront to the existing district energy system in Downtown Hamilton.

- Build small, standalone district energy systems (thermal grids) in select demand nodes with high growth potential (e.g., Hamilton West Harbour) that incorporate the potential for industrial waste heat sources at a future date.

- Explore the potential for a public-private partnership model to finance infrastructure — piping, nodes, etc.

Industrial Constraints
A common message from local manufacturers related to the paramount importance of production processes. Any potential project involving waste heat recovery and/or distribution (internal and/or external) must have no adverse impact on production. This constraint presents a barrier to implementation and should be addressed.

Any potential project involving waste heat recovery and/or distribution (internal and/or external) must have no adverse impact on production.

Potential solutions raised include:

- Focus on industrial waste heat sources removed from mission critical processes. Sample sources common across most industries are cooling towers, air compressors, and end of process flue stacks.

- Use modeling software to simulate waste heat recovery systems without affecting the actual process with a view to gain buy-in for proposed projects.

Risk Management
This was a significant concern cited by study participants from local industry, institutions, and government. The risk factors associated with participation in waste heat recovery projects and district energy initiatives can be grouped in several categories, including financial, administrative oversight, service reliability, and legal, among others. Risk management was particularly relevant to discussions on the potential use of a district energy system(s) to facilitate the distribution of waste heat streams among multiple sources and sinks in Hamilton's Bayfront Industrial Area and beyond. The two leading issues were costs (financing and sustaining a large, multi-partner initiative) and capacity (ensuring sufficient and reliable streams of industrial waste heat).

Potential solutions raised include:

- Pursue a "many to many" model that would maximize the number of waste heat suppliers and waste heat users connected to a shared distribution network.

- Engage a third-party administer to oversee the system.

- Develop an innovative financial model that would distribute risks and rewards across multiple partners.

- Ensure that industrial waste heat would be sourced from several heat streams contributing to the district energy system — i.e., build in redundancies.

- Ensure that industrial waste heat would be utilized by multiple users on the district energy system.

More information on this model is provided in the section titled Thermal Distribution Networks.

As global population and energy use grow, transitioning energy systems to reduce environmental impacts in ways that are affordable and reliable has never been more important. That is why Enbridge is targeting net-zero greenhouse gas emissions by 2050 in its operations and helping lead Ontario's clean energy transition.

Energy Conservation Programs

Enbridge has been delivering Demand Side Management (DSM) programs under Ontario Energy Board frameworks for nearly 25 years. Since 1995, the company has saved its customers 30 billion lifetime cubic meters of natural gas and 56.2 million tonnes of greenhouse gas emissions, the equivalent of taking 12.2 million cars off the road for a year.

Assistance for Hamilton Manufacturers

Enbridge has a strong presence in the Hamilton area. It has dedicated DSM advisors familiar with the many processes that power the local manufacturing sector.

Commercial/Industrial Program

Enbridge DSM Advisors work with customers and third-party providers to identify, evaluate, and help implement potential energy conservation initiatives. DSM programs for industrial manufacturers require customized solutions based on the unique nature of each manufacturing process. Customers can also qualify for a range of incentives for audits and implementing energy efficiency projects.

Large Volume Direct-Access Program

Through this program, high volume gas users, such as industrial operations, power generators, chemical plants, and petroleum refineries, have direct access to an incentive budget for energy efficiency projects in their facility. Customers work with Enbridge to develop an Energy Efficiency Plan which serves as a roadmap for driving their energy efficiency projects.

Significant Local Impact

From 2017 to 2019, Enbridge DSM Programs have provided nearly $900,000 in conservation incentives to Hamilton area industrial manufacturers. This has saved more than 12 million cubic meters of natural gas.

Sample waste heat recovery and reuse projects have targeted processes including combustion air pre-heating, steam and hot water generation, and HVAC systems.

Pilot Projects

Enbridge invests in DSM pilot projects focused on energy conservation and market innovation. Projects range from testing new energy efficient technologies to working with customers on the development of next generation DSM programs. Most recently, Enbridge utilized pilot budgets to help industrial manufacturers fund or subsidize steam plant optimization studies, training, and embedded energy managers.

Greening the Gas Supply

Enbridge is developing carbon-neutral gas sources, including renewable natural gas and hydrogen, to displace traditional natural gas and reduce emissions. Implementation of these technologies will leverage existing infrastructure, divert waste, stimulate regional economic development, and create local jobs.

Hydrogen

In 2018, Enbridge partnered with Cummins Inc. to build the first utility scale power-to-gas facility in North America, located in Markham Ontario. For the past two years, this facility has helped the IESO balance electricity supply and demand. The solution includes storing the province's surplus electrical energy using Enbridge's existing natural gas pipeline infrastructure. In 2021, Enbridge will leverage this

facility for a pilot hydrogen program that will blend hydrogen into a portion of its distribution system in Markham with no cost impacts to rate payers. The successful implementation of this project will support Enbridge in pursuing additional and larger scale hydrogen blending activities in other parts of its distribution system.

Renewable Natural Gas

Renewable natural gas (RNG) is a carbon-neutral, renewable fuel source created by capturing the methane emissions from anaerobic digesters, landfills, and wastewater treatment plants. This carbon neutral energy source made from waste can be injected into Enbridge's natural gas network. The by-product of anaerobic digestion (digestate) can also be converted into fertilizers that return nutrients to the soil. Known for its carbon offsetting advantage, RNG can manage waste, generate revenue, and reduce harmful emissions to fight climate change.

Continuing its investment in RNG, Enbridge recently announced a partnership with a Niagara area landfill operator to build the largest RNG plant in Ontario.

Enbridge has partnered with the City of Hamilton and City of Toronto to capture RNG from wastewater treatment and green bin organic waste, respectively. Continuing its investment in RNG, Enbridge recently announced a partnership with a Niagara area landfill operator to build the largest RNG plant in Ontario. The plant will capture landfill gas and is expected to generate enough green energy to heat 8,750 homes and reduce greenhouse gas emissions by 48,000 tonnes per year.

Transition to Tomorrow

Enbridge provides an affordable and reliable energy choice to over 140,000 Hamilton homes, businesses, and industries. In the past two years, it has invested more than $12 million to upgrade and enhance its Hamilton area systems. This investment, alongside ongoing collaboration with local industry and municipal partners, is helping build a climate resilient energy bridge to the future.

A key component of this project was to identify and map connections between industrial waste heat sources in the study area and potential users, inside *and* outside the area.

Project pre-work showed little evidence of thermal energy sharing at this time, suggesting potential untapped opportunities given appropriate conditions.

Several factors drove the mapping exercise, including the need to engage diverse stakeholders, develop preliminary visualization aids, and situate opportunities—particularly a proposed thermal distribution network — within a geospatial context.

A follow-on goal from this project is to inspire and inform industrial waste heat research, planning, and investment at an area level in Hamilton. Ideally, this would include selecting opportunities with the most significant potential for energy utilization and carbon emission reductions.

A "Mapping Exercise Report," an internal discussion document used by the project team to advance its work, was produced by Graduate Student Researchers from McMaster University's W Booth School of Engineering Practice and Technology. The Project Tech Team supervised this work. The following pages of this section provide a high-level summary.

Methodology

Early in the process, members of the Tech Team discussed the mapping exercise and decided on the following method:

- Focus on the six manufacturers from Hamilton's Bayfront Industrial Area that agreed to participate in the current study: Air Liquide, ArcelorMittal Dofasco, Bunge, Collective Arts Brewing, National Steel Car, and Stelco Hamilton Works.
- Start the process with high-level fact finding and analyses to identify potential waste heat recovery and reuse opportunities, and build rudimentary maps.
- Conduct individual meetings with participating companies to gather process-specific information and data pertaining to waste heat qualities, quantities, and flows.
- Use the meetings to establish and build relationships required for further planning and implementation.
- If needed, conduct secondary research to fill gaps in information.
- As needed, aggregate findings to protect company-specific information.
- Engage with prospective waste heat users in the broader community — e.g., new development nodes in the West Harbour area — to investigate opportunities to grow the demand side of the equation.

This method was implemented and proved effective. That said, the height of the COVID-19 restrictions in Hamilton (Spring 2020 through Fall 2020) made stakeholder outreach and engagement much more difficult. Meetings were postponed, tours cancelled, access denied. These responses were understandable given the severity of the health risks. Yet, in the end, each company came through with information, insights and data needed for the mapping exercise.

Implementation

The Project Tech Team, with the assistance of two Graduate Student Researchers, focused on the mapping exercise from January 2020 through August 2020. Key activities in the work plan included:

1. The Tech Team held weekly video calls to drive the process forward and respond to challenges and opportunities as they arose. This was particularly helpful in mitigating COVID-19's impact on the project.

2. The students enrolled in a graduate studies course at McMaster University's W Booth School of Engineering Practice and Technology that was established to support experiential education projects. During weekly classes, the students presented work in progress on the mapping exercise and benefited from faculty and peers' immediate feedback. Discovering how to apply the "Design Thinking Model" to the mapping exercise was a key learning outcome.

3. The Tech Team engaged experts in the field of smart energy systems — including Dr. Sophie Hosatte, Ph.D., CanmetENERGY; Dr. James Cotton, Ph.D., McMaster University; and, Peter Ronson, COO, Markham District Energy — to provide advice.

4. The Tech Team agreed on a standard waste heat classification system to be used in the mapping exercise. Temperature was the critical component, as noted here:

   High-Temperature: > 400°C
   (best applied to manufacturing processes and power generation)

   Medium-Temperature: 100°C–400°C
   (suited to manufacturing processes)

   Low-Temperature: < 100°C
   (appropriate for space heating and low-temperature thermal processes)

   Other elements of the classification system (state, pressure, chemical properties, flow rate, and reliability) were included in the Waste Heat Worksheet template used to gather information on each process studied in this project.

   The standard headings for the Waste Heat Worksheet related to waste heat classification were:

Significant Equipment Used	Age of Equipment	Date of Recent Retrofit	Thermal Efficiency of Equipment	State of Waste Heat (liquid, radiant, gaseous)
Properties of Waste Heat	Temperature of Waste Heat	Quantity of Waste Heat (GJ)	Availability (constant, intermittent)	Pressure and Flow Rate

5. The Tech Team engaged participating companies on multiple occasions to gather information and insights. The engagement process included six steps: i) Familiarization; ii) Information Gathering; iii) Analyses; iv) Discussion of Findings with Company; v) Refinement and Revisions; vi) Joint Agreement on opportunities to be cited in the final report.

6. The Tech Team used the above approach to document 12 manufacturing processes that generate industrial waste heat and contribute to GHG emissions: *

✔ Annealing ✔ Coke Making ✔ Conditioning ✔ Cooking	✔ Cooling ~ *process water* ✔ Drying ✔ Galvanizing ✔ Heating ~ *boilers, furnaces, kilns*	✔ Hot Rolling ~ *hot mill* ✔ Quenching ✔ Refining ✔ Sanitizing

* **NOTE:** As stated elsewhere in this report, many of these processes, such as materials heating and process cooling, are commonly used by numerous manufacturers throughout Hamilton's Bayfront Industrial Area. This opens the possibility of applying project findings and recommendations across several companies.

7. The Tech Team aggregated information from the participating companies to gain a high-level understanding of industrial waste heat from a **supply perspective**.

8. The Tech Team then turned its attention to understanding an emerging "waste heat story" from a **demand perspective**.

    - First, the team worked with companies to identify potential uses of waste heat within their fence lines. In most cases, this option pertained to high-temperature waste heat (> 400 C) best applied to high value production processes. These typically involve relatively short distances between a source and sink, enabling a manufacturer to extract the maximum value from its purchased fuels — this appealed to participating companies.

    - Second, the team spoke with participating companies that could potentially use waste heat supplied by another company(ies). For the most part, these opportunities focused on the supply of waste heat streams suited to space heating and select processes. As noted elsewhere in the present report, this arrangement presents several challenges, including energy security and reliability. In many cases, these concerns could be overcome using the proposed "many to many" model discussed later in this report.

    - Third, the team reached out to groups able to identify additional potential waste heat users inside the study area and beyond. These groups participated in interviews:

        Hamilton Industrial Environmental Association

        Hamilton Bayfront Industrial Strategy ~ City of Hamilton

        Hamilton Community Energy and Emissions Plan ~ City of Hamilton

        Pier 8 Development ~ City of Hamilton

        Barton-Tiffany Development ~ City of Hamilton

    The common takeaways from these discussions were:

    - Recognition that Hamilton's existing industrial waste heat supply exceeds demand.

    - Acknowledgement of the potential benefits derived from distributing waste heat across shared network(s).

    - Recognition of the key barriers to implementation, especially costs for shared infrastructure.

Select Preliminary Maps

Of the processes examined:

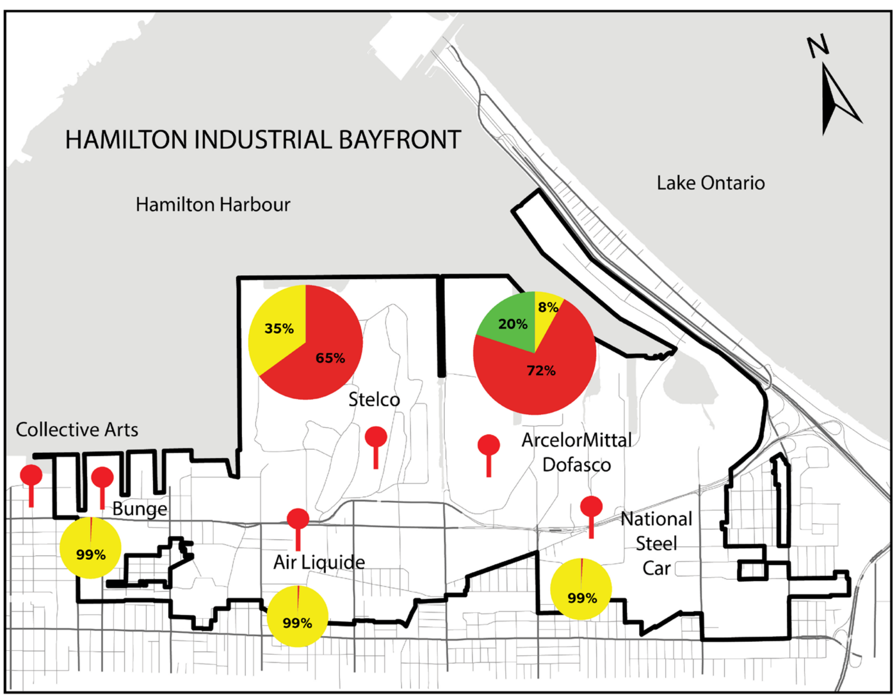
- Six produce medium- to high-grade waste heat at an average temperature of approximately 650°C, and a high of roughly 1,000°C (coke quenching). As noted, best uses for higher temperature sources are most often found within the company's fence line, and applied to preheating combustion gases, generating electrical power, etc. Together, these six processes produce approximately 8 million GJ of waste heat per year. **If 25% of it were applied to district energy, it could heat roughly 20,000 homes.**

- Nine produce low-grade waste heat at an average temperature of < 100°C, and a low of approximately 50°C (solvent extraction). The best potential uses for this waste heat are space heating and low-temperature processes — e.g., material cooking. **Together, these nine processes produce approximately 475,000 GJ per year of waste heat, enough to heat about 4,750 homes.**

Sample Findings

With significant assistance from the Graduate Student Researchers, the Tech Team developed various prototype maps using available data and insights. The aim was to initiate longer-term work to build a suite of visual aids that could be used to communicate the story of waste heat recovery and reuse in a Hamilton context. Challenges created by COVID-19 restrictions, particularly access to participating companies and related data, slowed progress. Nevertheless, valuable outcomes were achieved. Below are several examples produced using ArcGIS Online and other tools.

1. **Quality and Quantity of Waste Heat by Company**



In the map above, colour-coded pie charts are superimposed over the footprints of the participating companies. From a quality perspective:

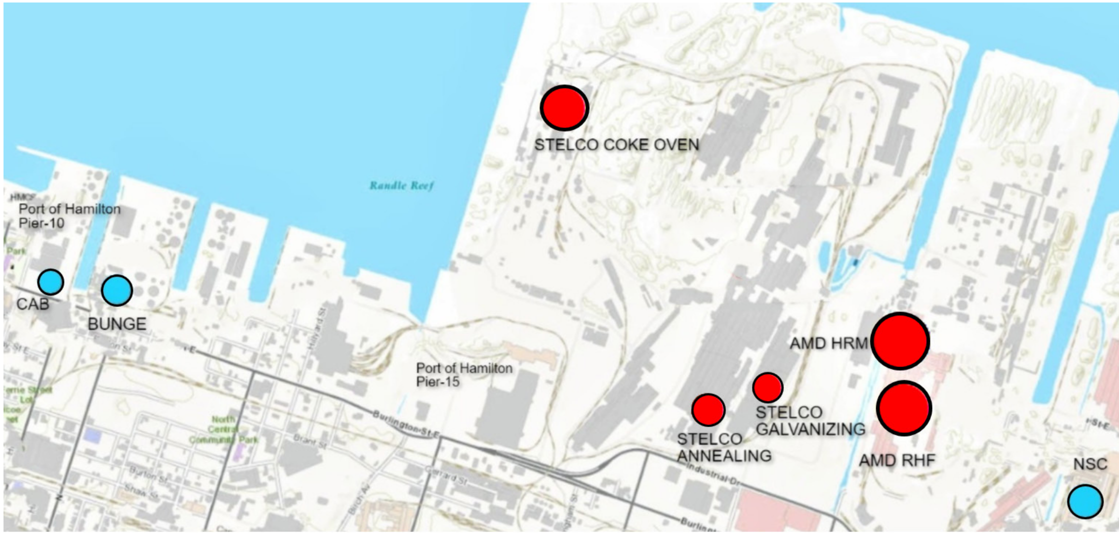
Red = High-Temp (> 400°C)

Green = Medium-Temp (100°C-400°C)

Yellow = Low-Temp (< 100°C)

A pie chart's circumference approximates the quantity of waste heat available at each company.

2. **Source-Sink Relationships** ~ Quantity Perspective



The above graphic plots waste heat sources (red circles) and potential waste heat sinks (blue circles) on a study area map. The circles' sizes provide a rough sense of supply (red) and demand (blue) among the participating companies. The largest waste heat source is the ArcelorMittal Hot Strip Mill. The largest potential sinks within the study area are National Steel Car and Bunge.

3. **Source-Sink Relationships** ~ Quality Perspective

The graphic above assigns temperature values to each source (diamond) and each potential sink (triangle) in the study area. It shows a full range of values from < 100°C to > 400°C.

4. Potential Demand Nodes

LEGEND

Major Sources of Industrial Waste Heat

Potential High Density Demand Nodes

This map plots potential demand nodes inside and outside the study area. A demand node is a building or cluster of buildings that have significant space heating requirements. These nodes (sinks) could become targeted destinations for industrial waste heat. A potential new demand node within the study area could be created through the re-development of surplus lands owned by Stelco. Outside the study area are several existing nodes (e.g., Downtown Hamilton, Ron Joyce Children's Health Centre, Hamilton General Hospital, etc.) and nodes in development (e.g., Pier 8, Baron-Tiffany Lands, etc.). The purpose of this map is to highlight the need to establish a large base of users over time that is sufficient to sustain a viable district energy system connected to industrial waste heat sources.

5. Current GHG Emissions

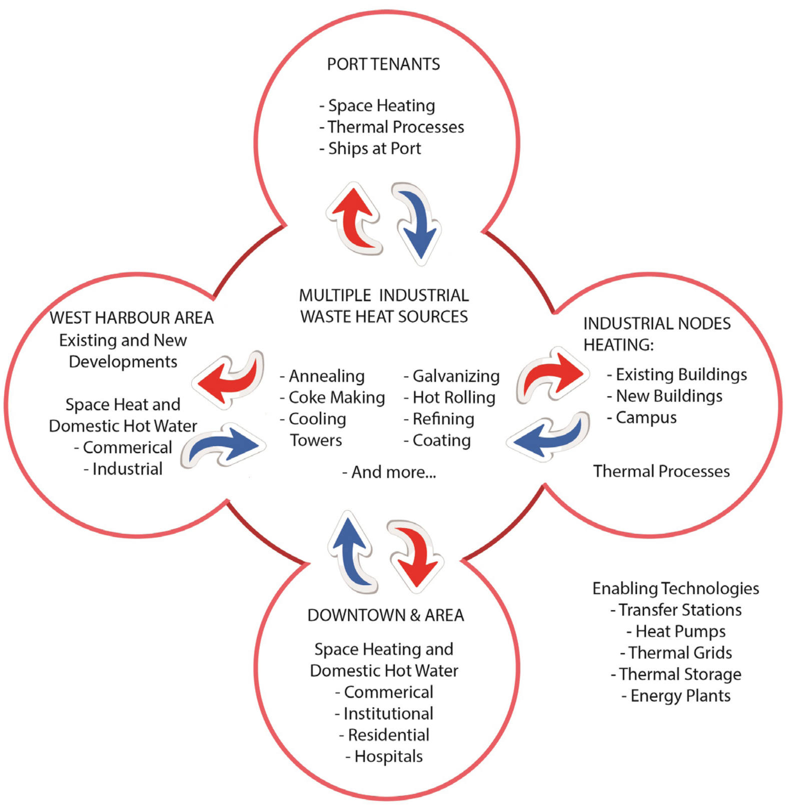
The map above employs cloud shapes to visually depict GHG emissions (tonnes per year) associated with the company-level processes featured in the study. It provides a helpful way to quickly compare and contrast emissions.

6. Potential GHG Offsets

The map above uses smaller size cloud shapes to show the potential GHG emission reductions that could result from acting on waste heat recovery opportunities cited in the present report.

Additional Visual AIDS

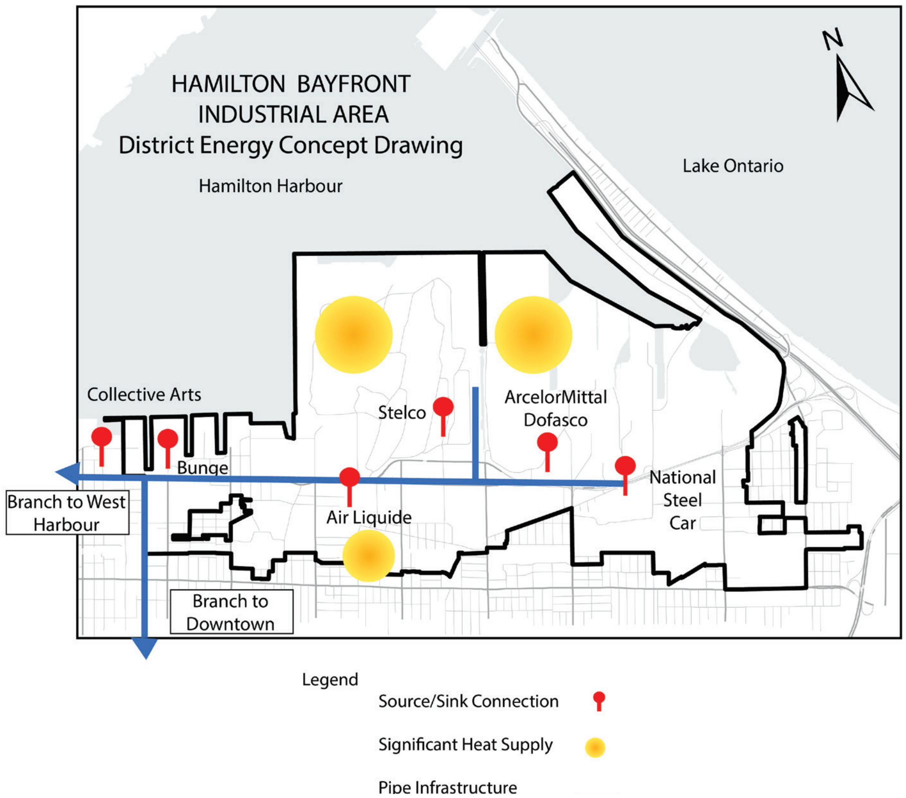
1. Source- Sink Infographic



The above infographic highlights the potential to distribute industrial waste heat from multiple sources to multiple demand nodes with significant space heating requirements.

2. **District Energy Concept Drawing**

This conceptual drawing helps envision the possibility of a District Energy System that would gather industrial waste heat from multiple sources across Hamilton's Bayfront Industrial Area to supply multiple users in the area and beyond.



Proposed Next Steps on Mapping Exercise

- Engage postsecondary faculty and students to build on the outcomes of this preliminary mapping exercise.
- Link with mapping systems and software used by The Atmospheric Fund and others to place Hamilton's Bayfront Industrial Area in a regional context.
- Link with mapping systems and software used by the Hamilton Community Energy and Emissions Plan (City of Hamilton) to connect industrial waste heat sources with potential users in the wider community.
- Work with the Hamilton Industrial Environmental Association and others to engage additional companies in the study area moving forward — e.g., Biox Corporation, Birla Carbon, Rain Carbon, and others.

PARTICIPATING COMPANIES

A SAMPLING OF POTENTIAL USES OF INDUSTRIAL WASTE HEAT INSIDE AND OUTSIDE THE COMPANY

Air Liquide

ArcelorMittal Dofasco

Bunge Hamilton

Collective Arts Brewing

National Steel Car

Stelco Hamilton Works

AIR LIQUIDE HAMILTON

Opportunity to Supply Waste Heat for External Uses

Encouraged by this TAF-funded project, Air Liquide Hamilton is keen to advance preliminary discussions now underway with HCE Energy Inc. and its partners related to contributing excess low-temperature waste heat to a growing district energy network serving Hamilton.

The waste heat would come from the Air Liquide plant in the form of warm cooling water. Industrial-scale heat pump technology, currently available in the market, would be used to "lift" the water temperature to meet the requirements of HCE Energy Inc. and its customers. Concurrently, lower temperature water from the heat pump would be returned to Air Liquide to help it meet internal cooling requirements, supplanting Air Liquide's need for evaporative cooling towers and their associated water and chemical use.

This source-sink combination has several compelling "win-win" features, including:

- Two willing partners equally committed to achieving a low carbon future.
- The proximity of the plant to an existing district energy network.
- Access to a constant, year-round supply of industrial waste heat suited to the requirements of district energy.
- Provision of return water to Air Liquide at a sufficiently low temperature needed to boost the plant's overall efficiency and increase throughput.

And as an added value, both the industrial process and its subsequent waste heat source and the heat pump technology central to this opportunity are powered by electricity provided by Ontario's "clean grid" — another step toward carbon-free thermal energy.

Key benefits identified by Air Liquide would include additional progress towards its global climate change goals, contributions to an expanding community energy system in Hamilton, and the potential to receive carbon emission credits.

From the perspective of HCE Energy Inc., this opportunity aligns with near term corporate goals to expand its district energy footprint by adopting next generation DE technologies — including heat pumps — and utilizing existing local sources of industrial waste heat. These potential outcomes would strengthen HCE Energy Inc.'s role as a climate change leader in Hamilton.

Moving forward, the partners would be looking for additional input from CanmetENERGY and other expert sources to help identify the type of heat pump technology best suited to this purpose and compliant with Canadian environmental standards.

Equally important would be an exploration into seasonal thermal energy storage potential, a key to providing year-round value. Assistance from ICE-Harvest, an R&D group headquartered at McMaster University and focused on integrated community energy, could help in this regard.

If implemented, this district energy solution would be unique in Canada and a potential model for replication

By the Numbers

- Available Waste Heat from Cooling Towers: 1,000,000 GJ/Yr.
- Enough Energy to Heat More Than 10,000 Homes
- Potential Net GHG Emissions Offsets: 51,000 CO_2e/Yr.
- Potential Carbon Emissions Benefit: $2.5 million CAD/Yr.

Notes/Assumptions

1. CW Circuit 1200 and CW Circuit 2000 are operating in tandem.
2. The net amount of waste heat available is kept conservative at 75% for the waste heat/GHG analysis.
3. 95% of the heat available from the CW is harnessable (considering the HX efficiency).
4. The total hours of Cooling Tower Operation are taken to be 8,760 hrs minus 10 days (240 hrs) for a maintenance window — i.e., 8,520 hrs.
5. The efficiency of a natural gas condensing boiler is assumed to be 95%. This is used to calculate the natural gas offset.
6. The resulting thermal energy is available at medium-low temperatures, i.e., HW supply @ 55°C and HW return @ 40°C. Heat pumps (COP of heating = 4) are used to generate the thermal energy.
7. According to Stats Canada, the average Canadian household consumes ≈ 100 gigajoules (GJ) of energy for use in the home.
8. The carbon emissions benefit has been calculated based on a carbon cost of $50 CAD/tCO2e in the year 2022.
9. All electricity is obtained from Ontario's Power Grid.

ARCELORMITTAL DOFASCO

Opportunity to Supply Waste Heat for Internal and External Uses

Background

ArcelorMittal Dofasco (AMD), a community-oriented manufacturer with a rich history of innovation, operates an integrated steel plant in Hamilton's Bayfront Industrial Area. Waste heat recovery and reuse are of strategic importance to the company on its path to a high efficiency, low carbon future.

A key area of focus for the company, and this project, is the hot strip mill.

AMD operates a modern seven stand hot strip mill that produces high quality hot rolled steel for its automotive, construction, tubular, and service centre customers. The mill also supplies the company's downstream operations, including cold rolling, galvanizing, and tinning lines. Globally, across the steel sector, hot strip mills process more gross tonnage than any other manufacturing process.

The hot strip mill transforms steel slabs from the continuous caster into hot band steel coils. From an energy use perspective, the hot mill is the most significant natural gas consumer onsite and a leading source of waste heat (low-temperature < 100°C through to high-temperature > 400°C).

The AMD hot rolling process begins by heating steel slabs in specially designed furnaces, fired by a combination of natural gas and by-product fuel, to a uniform temperature of approximately 1,200°C. In the furnace, the steel is heated above its recrystallization point, making it easier to shape.

The red-hot steel slab exits the furnace and enters a roughing mill. This mill exerts extreme pressure on the slab and, after multiple passes, considerably reduces its thickness while increasing its length. From there, the partially processed slab moves into the finishing mill stands. Here a series of rolls reduce the material to a desired thickness of between 12.7 mm and 1.5 mm. In the final step, the steel is wound into coils weighing as much as 30 tonnes each. Water plays an integral part in hot rolling, both in descaling and controlling temperatures through each step in the process.

AMD recognizes the potential for enhanced waste heat recovery in two distinct process areas: the reheat furnaces used to heat the incoming slabs, and the cooling towers used to cool massive volumes of recirculated cooling water.

Waste Heat from Reheat Furnaces

AMD operates two reheat furnaces in its hot strip mill. The furnaces have a combined production rate of approximately 4.8 million short tonnes/yr. Slabs that enter the furnaces are preferably hot charged; however, can be supplied at ambient temperature. They slowly move through a number of zones with multiple burners and are heated to a favourable rolling temperature of approximately 1,200°C in roughly 2.5 hours.

The furnaces are insulated and lined with refractory materials. Flue gas is the biggest contributor to heat loss. However, flue gas losses are relatively easy to recover compared to losses in other production processes.

Potential Use

The potential exists to recover significant industrial waste heat quantities and apply it to a new medium temperature (approximately 100°C) distributed energy circuit conceived for the surrounding area and ideally beyond.

General Method

Install a waste heat recovery system within or adjacent to the hot strip mill utilizing flue gases from the two reheat furnaces. Any system would need to meet design requirements, such as flue gas content, temperature, pressure drop, and corrosiveness. There are examples of such methods being used in a variety of industries to recover waste heat.

Energy would be recovered from the waste heat stream of the furnace flue gas and transformed into hot water for distribution to other users through a thermal network. The proposed system would consist of energy transfer stations and a thermal fluid to allow for heat transfer. The system could also benefit from thermal storage capacity — e.g., large, insulated surface tanks located on unused land.

Shared thermal infrastructure (pipes, control systems, etc.) would be required for the new distributed energy system, an ideal opportunity for public sector investments.

By the Numbers ~ approximate values for discussion purposes

- Recoverable Waste Heat in Flue Gases: 1.1 million GJ/Yr.
- Average Hot Water Recovery Temperature: 100°C
- Enough Energy to Heat More Than 11,000 Homes
- Potential Net GHG Emissions Offsets: 62,000 CO2e/Yr.
- Potential Carbon Emissions Benefit: $3.1 million CAD/Yr.

Notes and Assumptions

- Recoverable waste heat is estimated at 160 GJ per hour.
- Hours of availability are taken to be 7,000 hours per year.
- According to Stats Canada, the average Canadian household consumes ≈ 100 gigajoules (GJ) of energy for use in the home.
- The carbon emissions benefit has been calculated based on a carbon cost of $50 CAD/tCO2e in the year 2022.

Conclusion
This potential application of industrial waste heat from ArcelorMittal Dofasco could help lay the foundation for a new multi-source, medium temperature distributed energy system that would supply nearby users and the wider community.

Next Steps

- AMD to continue exploratory discussions with key stakeholders, notably HCE Energy Inc.
- If warranted, seek funding and expertise to conduct a formal feasibility study.

Waste Heat from Hot Mill Cooling Towers

As noted in the background section, high volumes of water are used throughout the strip mill process to remove scale (surface oxide), reduce friction, and control temperatures of both the steel and the equipment. Some of this water circulates within a closed loop and is cooled before being reused. Evaporative cooling towers are used to remove heat from the water before it is returned to the mill operation. This approach results in large quantities of low-temperature heat being rejected into the environment in the form of water vapor. This happens on a continuous basis when the hot strip mill is in operation (roughly 7,000 hrs./yr.).

Potential Uses
The potential exists to recover large quantities of low-grade waste heat from the cooling water circuit and use it as a heat stream for a low temperature distributed energy loop serving AMD and the surrounding area.

This use is common practice, particularly in Scandinavia and other regions of Europe. One example shared with AMD features Austrian steel company Amenhotep partnering with district energy provider Energie Graz to enhance the heat stream supplied to more than local 70,000 homes.

General Method
Replace the existing cooling towers with energy transfer systems capable of providing AMD with return water at the required temperature and supplying heated water to a closed-loop distributed energy system (DES). The energy transfer systems would employ heat pump technology to cool the AMD waters and heat the DES waters. This proposed low-temperature DES would likely operate in the range of 50-55°C and be well suited to new construction space heating applications. Site-specific heat pumps could also be added to achieve the temperature requirements of the individual users of the DES if higher hot water temperatures are required.

Shared thermal infrastructure (pipes, control systems, etc.) would also be required, an ideal opportunity for public sector investments.

By the Numbers ~ approximate values for discussion purposes

- Available Waste Heat in Cooling Water: 371,000 GJ/Yr.
- Average Hot Water Recovery Temperature: 55°C
- Enough Energy to Heat 3,700 Homes
- Potential Net GHG Emissions Offsets: 20,800 CO_2e/Yr.
- Potential Carbon Emissions Benefit: $1 million CAD/Yr.

Notes and Assumptions

- The waste heat available has been calculated based on a supply temperature of 33.5°C and an exit temp of 20.3°C with a water flow of 3,200 m^3/hr (All data 2019 Average Daily Medians).
- The energy capture per annum is based on the heat recovery efficiency of 30%.
- The total hours of cooling tower operation are taken to be 7,000 hours per year.
- According to Stats Canada, the average Canadian household consumes ≈ 100 gigajoules (GJ) of energy for use in the home
- The carbon emissions benefit has been calculated based on a carbon cost of $50 CAD/t$CO_2e$ in the year 2022.

Conclusion
This application could help build the foundation for a new distributed energy loop. Consideration could be given to exploring how this waste heat stream might complement the low-temperature "energy nodes" in development by the Integrated Community Energy and Harvesting Systems team led by Dr. Jim Cotton, Ph.D. at McMaster University.

Next Steps

- AMD to continue exploratory discussions with key stakeholders, notably HCE Energy Inc.
- If warranted, seek funding and expertise to conduct a formal feasibility study.

BUNGE HAMILTON

Internal and External Waste Heat Use Opportunities

Background

Bunge is a world leader in sourcing, processing, and supplying oilseed and grain products and ingredients. Bunge Hamilton, one of five Bunge crush facilities across Canada, processes oil and protein meal products from canola seeds and soya beans. The Hamilton plant is located on the Hamilton Harbour and operates 24/7 year-round. Plant operations span numerous processing steps, including thermal conditioning, cracking, flaking, cooking, mechanical extraction, solvent extraction, distillation, refining, bleaching, and deodorization. Ongoing investments in maintenance, technologies, and process improvements help ensure that the Hamilton plant, which dates from 1942, remains competitive.

Sustainability

Bunge Limited has a sustainability goal for its facilities of reducing energy consumption per tonne, GHG emissions per tonne, water use per tonne, and waste to landfills, all by 10%, as well as total waste generated by 20% by 2026 vs 2016 baselines. The Hamilton plant has already reached its goal of water use reduction per tonne and is working on energy and waste.

Energy Overview

The plant uses 150 psi steam produced from natural gas for many of its production processes, especially:

- *Thermal Conditioning*: Use of steam to heat and dry materials before processing
- *DTDC*: Use of steam in the process of Desolventizing, Toasting, Drying, and Cooling raw materials
- *Refining*: Use of steam to distill and deodorize oil

To produce steam, the plant operates five gas-fired boilers that range in age and efficiency. Boilers are shut down or turned down based on season and demand. The plant's ongoing efforts to lower energy use centre on two priorities: i) improving boiler efficiency and ii) maximizing the utilization of steam and hot water energy throughout the plant.

Bunge is replacing older boiler technology to further improve energy efficiency. Part of the investment is related to peak shaving to control rising electricity costs.

Investments in steam and hot water optimization include increasing insulation across the site and cconverting approximately 170 steam traps to a venturi style to reduce energy losses.

Recent heat recovery and steam conservation projects include:

1. Increasing the pressure of the flash steam system in the plant to offset high-pressure steam usage
2. Heat recovery from flash steam to preheat wastewater in the wastewater reboiler
3. Steam use reduction by installing new oil stripper units in the canola line and soya line to promote greater material contact with the steam

Additional Examples of Existing Waste Heat Recovery

- Oil-to-oil heat exchangers in the oil refining and bleaching process areas
- Air-to-air heat exchangers to preheat air before it enters the DTDC
- Oil-to-oil heat exchangers on all mineral oil systems
- Hexane liquid-vapor contactors for heat conservation in the distillation plant
- Recovered hot condensate from the process is routed back to the boiler house as boiler feed water, reducing the heat requirement to re-boil

- Tuned temp control loops throughout the plant to reduce excessive steam use and valve cycling

Additional Waste Heat Recovery Opportunities

- Waste heat from the hot oil (80°C) produced during the mechanical extraction process
- Waste heat from the condensate (95°C) exiting the cooker in the thermal conditioning process
- Waste heat from the hot cake (85°C) exiting the screw press during the mechanical extraction process

External Opportunities *
Bunge Hamilton is currently able to balance its thermal energy supply with energy demand. If excess waste heat were to become available for external applications, it would be of a low-grade quality in the temperature range of 50°C to 90°C. Input to a district energy system via a thermal microgrid would require addressing commercial issues, such as energy security, supply obligations, and being economically viable.

Given its ability to utilize lower temperature heat in its processes, Bunge Hamilton could be a recipient of thermal energy supplied by an industrial district energy system linked to various industrial waste heat sources and sinks across Hamilton's Bayfront Industrial Area. Utilizing a thermal microgrid would need to address the security of supply, reliability, and economic viability.

Next Steps

- Recognize Bunge Hamilton's track record in increasing energy efficiency through investments in waste heat recovery and other strategies.
- Continue to engage Bunge Hamilton in work facilitated by HCE Energy Inc. and others to explore the potential for district energy applications in Hamilton's Bayfront Industrial Area.

** Parties are not obligated to act on any of the proposed activities presented here to guide further discussion.*

COLLECTIVE ARTS BREWING

Opportunity to be a Recipient of Industrial Waste Heat

Collective Arts Brewing is a grassroots craft brewery that aims to fuse the creativity of craft beer with the inspired talents of emerging artists and musicians. The company features limited-edition works of art on its beer cans and labels, and works to make sure the liquid on the inside is as diverse and creative as the artists that they profile.

Sub-Processes
This innovative craft brewery operates various sub-processes that rely on dependable flows of saturated (dry) steam ~ i.e., steam that is in equilibrium with heated water.

These sub-processes include:

1. **Hot Jacketing** — a "jacket" fitted to the outside of a production vessel through which steam (roughly 90°C) is circulated to control the temperature of the contents inside the vessel uniformly.

2. **Keg Filling Line** — the use of steam (roughly 120°C) to thoroughly clean and disinfect reusable kegs before filling.

3. **Shrink Sleeve Steam Tunnel** — the use of steam to apply decorative labels to containers.

Hot water is also central to making craft beer. For example, during the Mash Mixing sub-process, the milled grains used to make beer are soaked in hot water (roughly 65°C) to convert the carbohydrates in the grains into a mixture of fermentable and non-fermentable sugars.

Total Steam and Hot Water Requirements: 7,000 GJ/Yr.

Partnering to Meet Growing Thermal Needs
Act on the opportunity to add a flow of industrial waste heat from adjacent companies to an existing district energy system that currently supplies steam and hot water to Collective Arts Brewing and other nearby customers.

Technology Requirements
Augment the existing system operated by HCE Energy Inc. to accommodate a feed(s) of excess waste heat in the form of hot water from one or more industrial sources.

By the Numbers

- Offset of $42,000/Yr. in Natural Gas purchases
- 400 tonnes of CO_2e/Yr. reduction
- Value of offset carbon: $20,000 CAD/Yr.

Notes/Assumptions

1. Natural gas valued at $6/GJ (delivered)

2. The carbon emissions benefit has been calculated based on a carbon cost of $50 CAD/t$CO_2e$ in the year 2022

Additional Opportunity
Use the enhanced HCE industrial district energy system to also supply thermal energy to meet Collective Arts Brewing's space heating requirements (production, warehousing, event, and office). This would eliminate the need for space heating units fuelled by natural gas, lower energy costs, and contribute to GHG reductions.

Next Step
Continue to work with community partners, notably HCE Energy Inc., to advance these opportunities.

** Parties are not obligated to act on any of the proposed activities presented here to guide further discussion.*

NATIONAL STEEL CAR

Opportunity to be a Recipient of Industrial Waste Heat

National Steel Car has designed, engineered, and manufactured a range of railcars in Hamilton for more than 100 years. It is the largest single-site rail car plant in North America. Its roofed facilities, including five integrated assembly lines, span more than 60 acres. Most of the steel used by the company to make its railcars is sourced locally.

Process: Heating production facilities

Description
The company has significant thermal requirements — especially between the months of November and April — for space and materials heating. The combined area of its production facilities, including the Main Building with ten zones and the Construction Building with three zones, is approximately 622,000 sq. ft. These facilities currently use Infrared Heaters (electromagnetic radiation) for space heating and Torpedo Heaters (forced air) for preheating materials used to fabricate railcars.

Quantities
Infrared Heaters: 180 | Torpedo Heaters: 132

Temperatures
Infrared Heaters: 60°C | Torpedo Heaters: 100-150°C

Production Space and Materials Heating Requirements
Approximately 309,000 GJ/Yr. (natural gas)

Tapping Into External Heat Sources *
National Steel Car is open to exploring the benefits of a proposed microthermal grid that would connect a number of local area manufacturers that produce waste heat (sources) with a variety of other companies and institutions that have a need for thermal energy (sinks). In this case, National Steel Car would "tap" into the grid for a reliable supply of thermal energy needed to meet its space and material heating requirements.

Proposed Method
A system for the area-wide distribution of thermal energy (water) would be established with waste heat coming from multiple sources and serving multiple sinks to reduce risk. The distribution system would use piping and smart monitoring systems to efficiently link the sources and the sinks. Heat pump technology would be used to match the temperature of the thermal energy supply to the sinks' needs. Support from multiple partners would be required.

By the Numbers

- Offset of $1.8 Million/Yr. in natural gas purchases.
- 15,000 tonnes of CO_2e/Yr. reduction.
- Value of offset carbon: $0.75 Million CAD/Yr.

Notes/Assumptions

1. Natural gas valued at $6/GJ (delivered).
2. The carbon emissions benefit has been calculated based on a carbon cost of $50 CAD/$tCO_2e$ in the year 2022.

Next Step
Continue to work with the Hamilton Chamber of Commerce, HCE Energy Inc., and other members of the Industrial Waste Heat Recovery Project to dig deeper into this emerging opportunity, including the potential to extend the scope to include space heating for office and related facilities.

** Parties are not obligated to act on any of the proposed activities presented here to guide further discussion.*

STELCO HAMILTON WORKS

Opportunities for Internal and External Uses

Stelco is a low cost, independent steelmaker with one of the newest and most technologically advanced integrated facilities in North America. The company produces flat-rolled value-added steels, including premium-quality coated, cold-rolled, and hot-rolled steel products. With first-rate gauge, crown, and shape control, as well as reliable uniformity of mechanical properties, its steel products are supplied to customers in the construction, automotive, and energy industries across Canada and the United States. The company operates two complementary facilities: **Lake Erie Work**s near Nanticoke, Ontario, and **Hamilton Work**s in Hamilton on the bayfront.

Commissioned in 1905 at Hamilton Harbour, Hamilton Works has evolved with the steel industry and its customers by developing and applying the sector's most modern technology and practices. Home to one of North America's premier zinc-coating lines, Hamilton Works' skilled employees produce world-leading galvanized and galvannealed sheet steel that serves important Canadian sectors such as the automotive, agriculture, and infrastructure industries. The 18-storey Z-Line is a world leader that annually produces 470,000 tons of product with excellent surface quality, corrosion resistance, and formability.

Galvanizing Line ~ *Internal Waste Heat Use Opportunity*

Description

Continuous strip galvanizing is the process of immersing steel in a bath of molten zinc to produce a multilayered, corrosion-resistant coating of zinc-iron alloy and zinc metal. This coating helps ensure quality and durability. The three-step process — surface preparation, galvanizing, and post-treatment — dates from the late 18th century but has progressed tremendously and continues to evolve.

Stelco Hamilton Works is home to Stelco's cold rolled and coated steel production facilities. The cold rolling mill receives hot-rolled coils from Stelco's Lake Erie Works to further process into finished products of the desired thickness, width, and mechanical properties.

The galvanizing lines at Stelco Hamilton Works (Z-Line and #3 Galv Line) receive the cold rolled coils and apply a zinc coating on the strip surface. These are continuous lines that consist of a series of surface preparation and coating application steps to produce galvanized or galvannealed products.

Heat treatment of the cold rolled steel moving through the lines is an essential part of the process. Two furnaces are in operation: A primary natural gas-fired radiant tube continuous annealing furnace used to prepare the steel for coating and a secondary electric induction annealing furnace used to treat the steel after exiting the zinc bath (galvanneal). The primary radiant tube furnace is a source of waste heat recovery.

Continuous Annealing Furnace

A multi-zone furnace is used to clean and modify the steel grain structure through heat treatment. This annealing process changes the properties of the steel, making it pliable and easier to form. Accurate temperature monitoring and control in each zone is essential to achieve process and quality standards. The furnace is fueled by natural gas.

Approximately 60% of the heat is transferred to the product. The primary heat loss areas are entry and exit openings, cooling water, walls, furnace components, and the flue gas stack. Of these, stack loss (waste combustion gases/flue gas) is the highest.

Potential Use

High-temperature flue gas can be used for direct or indirect heating and drying. Reuse of waste heat would be expected to raise energy utilization and reduce GHG emissions. Note: The GHG emission estimate for the Stelco Hamilton galvanizing line is approximately 18,400 tCO_2e/yr.

General Method

Use of heat exchange systems.

By the Numbers

- Production: 470,000 tonnes/yr.
- Furnace Operating Temp: 890°C
- Average Flue Gas Temp: 350°C
- Recoverable Waste Heat in Flue Gases: 155,000 GJ/Yr. ~ rough estimate
- Potential Net GHG Emission Offset: 8,700 CO_2e/Yr.
- Potential Carbon Emissions Benefit: $430,000 /CAD/Yr.

Notes and Assumptions

- The net GHG emission offset has been calculated based on a natural gas emission factor of 0.0561 tCO_2/GJ.
- The carbon emissions benefit has been calculated based on a carbon cost of $50 CAD/$tCO_2e$ in the year 2022.

Additional Opportunities
Waste heat recovery in other galvanizing line sub-processes could include:

- Molten Zinc Bath (460°C)
- Cooling Section of Line (450°C)
- Process Water Cooling Cycle (<100°C)

Next Steps
Stelco will continue to explore these internal opportunities, perhaps with faculty and students' assistance from the Faculty of Engineering at McMaster Engineering, and other educational facilities.

Coke Lines ~ *Internal and External Waste Heat Use Opportunities*

Description
These industrial ovens are used to carbonize metallurgical coal to produce coke, a central ingredient in blast furnace iron making. Stelco Hamilton currently operates one recovery coke making battery (#7 Battery) of 82 ovens. The battery, which last underwent a major rebuild in 1999, feeds the recently upgraded blast furnace at its Lake Erie plant. Surplus coke is sold to other companies.

Coke is produced by the heating of coal while controlling the ingress of air. The near absence of oxygen restricts combustion and the creation of CO_2. The heating releases moisture and volatiles in the coal, with a majority of the carbon remaining in the coke, thus reducing potential carbon emissions during this stage of coke production. The amount of CO_2 generated from coke ovens is less than 5% of that generated by the iron and steel industry.

The process is fuelled mainly by coke oven gas (COG) produced during the coke making process. The major components of COG are hydrogen (51%), methane (34%), carbon monoxide (10%), and ethylene (5%). Coke oven gas, when burned, contributes at most 10.8% CO_2 in the combustion products. The majority of the flue gas will be water vapor and nitrogen.

Each tonne of coal fed into a coke oven produces approximately 360 cubic meters of COG. About 40% of the produced gas is used for "under-firing/heating" the ovens, with the remaining 60% available as a fuel gas for other combustion purposes.

Direct GHG Emissions from Coke Making
The carbon held within the coke is not oxidized or released to the atmosphere and hence is not included in the GHG emission calculations for the project.

Indirect GHG Emissions from Coke-Making
These would come from the downstream burning of COGs and the use of coke in the iron making process in an integrated steel mill. The chemical interaction of coke and iron ore within blast furnaces creates significant amounts of CO_2. The Stelco Hamilton plant currently does not operate a blast furnace and hence does not contribute to this category of GHG emissions.

By the Numbers

- Coke Production: 600,000 tonnes/Yr.
- Temperatures: The coal is heated to approximately 1,100°C. The battery flue exhaust is about 350°C
- Available Waste Heat: 180,000 GJ/Yr. ~ rough estimate

Internal Uses

1. **Current**
   - Stelco Hamilton harnesses COG as a fuel source for its boiler operation used to produce process steam, reducing the burning of natural gas, and decreasing GHG emissions.
2. **Planned**
   - In the coming three to five years, Stelco Hamilton plans to commission a turbine generator system that would use steam to generate electricity. The steam would be produced in a boiler fueled by coke oven gas. This investment would represent a high-value use of COG that would otherwise be flared to the atmosphere.

External Uses
Given the quantity of waste heat produced in coke making, including low-grade streams, the potential exists to contribute excess amounts to a district energy system conceived for the Bayfront Area and beyond. This would require further investigation.

Other
The storage of surplus COG for later use would balance the fuel supply and demand (would need to overcome challenges associated with COG's corrosive nature).

Next Steps

- Stelco will continue to advance these internal opportunities, perhaps with faculty and students' assistance from the Faculty of Engineering at McMaster University and other educational facilities.
- Concerning potential external uses, Stelco will work with various stakeholders, notably HCE Energy Inc. and the Integrated Community Energy and Harvesting System team at McMaster University, to explore opportunities to contribute to a district energy system.
- Lessons learned and solutions could be replicated in similar processes across the Bayfront Industrial Area to increase the overall supply of low-grade waste heat required to support a robust district energy system.

Wet Coke Quenching ~ *Internal and External Waste Heat Use Opportunities*

Description
At the conclusion of the coke making process, red hot coke is cooled with the direct application of cooling water (coke quenching). A by-product of this 365/24/7 process (roughly once every twenty minutes) is steam, at atmospheric pressure, and a large basin of hot water. The potential exists to capture, clean, and store this heat for internal and external uses. This would be a way to increase the utilization of the coal used to produce the coke and the sensible heat of the coke itself.

Potential Uses

Internal

- The heat from the quenching tower process could be converted to electricity. Based on Stelco's coke production capacity, this could result in approximately 12.6 MW/hour of electricity to meet internal requirements. If applied externally, this could power roughly 8,000 homes.

- Hot water from the existing quenching process could be used to help meet local space heating requirements. Each push produces approximately 57 m3 of hot water, which could be transported to where it is needed. At a temperature of roughly 80°C, this amount of hot water could heat approximately 300 homes. This would reduce or eliminate the need for Carbon-based fuels for heating.

Key Technologies: Heat exchange system, thermal storage

External

Low-grade waste heat produced through wet quenching and not required by Stelco could be distributed through a district energy network serving users inside and outside the Bayfront Industrial Area.

Key Technologies: Heat exchange system, thermal storage, district energy infrastructure

By the Numbers

- Production: 30 tonnes of coke per "push" totaling approximately 660,000 tonnes per year (2019).
- Source Temperatures: 1050°C coke is quenched to 80°C.
- Available Waste Heat in Quench Water: 31,350 GJ/Yr. ~ enough to heat approximately 300 homes for a year.
- Available Waste Heat in Quenching: 1,000,000 GJ/Yr. ~ enough heat to generate 12.6 MW/hr. of electricity.

GHG Emissions
No GHGs are directly produced in the wet quenching process.

Total Potential GHG Reductions
No direct reductions; potential in-direct offsets related to reduced natural gas use across a district energy network would need to be calculated.

Next Steps

- Stelco will continue to advance these internal opportunities, perhaps with faculty and students' assistance from the Faculty of Engineering at McMaster University and other educational facilities.
- Concerning potential external uses, Stelco will work with various stakeholders, notably HCE Energy Inc. and the Integrated Community Energy and Harvesting System team at McMaster University, to

explore opportunities to contribute to a district energy system.

- Lessons learned and solutions could be replicated in similar processes across the Bayfront Industrial Area to increase the overall supply of low-grade waste heat required to support a robust district energy system.

- Parties will work together to explore funding opportunities.

Batch Annealing ~ *Internal Waste Heat Use Opportunities*

Description
A batch process whereby a stack of stationary coils (3-5) is subjected to a long heat-treating cycle to relieve the steel's internal stresses and make it less brittle. Waste heat from this process is high temperature and ideally suited to internal uses.

Potential Internal Uses

- Waste heat could be transferred from batches that are cooling down to batches that are heating up in the annealing process

- Waste heat could be used for electricity production using a downstream Organic Rankine Cycle

Key Technologies: Heat Exchangers, ORC System

By the Numbers

- Furnace Fuel: Natural gas

- Production: 200,000 tonnes/yr. capacity.

- Source Temperature: 650-700°C ~ high grade

- Potential Waste Heat Available: 55,000 GJ/Yr.

- Reference: Enough thermal energy to heat 550 Canadian homes for a year.

- Potential GHG Reductions: 3,000 tCO_2e/yr.

Next Steps
Stelco will continue to explore these internal opportunities, perhaps with faculty and students' assistance from the Faculty of Engineering at McMaster Engineering, and other educational facilities.

INDUSTRY INSIGHT: HCE ENERGY INC.

HCE Energy Inc. (HCE) was founded in 2002 by the City of Hamilton as a subsidiary of Hamilton Hydro Services Inc. It advanced energy resilience in the downtown core, established economies of scale, and encouraged urban renewal through compact development and reduced GHG emissions.

The first significant step was the development of an $11 million clean-burning, natural gas-fired facility in downtown Hamilton that in time would come to supply hot water heating, domestic hot water, and a source of standby electricity to a network of more than a dozen buildings (institutional, commercial, and multi-residential) through combined heat and power (CHP).

The downtown hub operates at approximately 80% thermal (hot) efficiency. Core components are:

- A natural gas-fired reciprocating engine CHP (Combined Heat & Power) produces up to 3.5 MW of electricity, with waste heat being utilized to produce 3.2 MW of heating capacity.
- Three natural gas-fired 4 MW hot water boilers provide additional thermal capacity.
- Electric chillers (centrifugal and absorption) connected to the system provide cooling capacity.
- Pumps distribute energy in water (hot and cold) across a network of insulated pipes.
- An Energy Transfer System (ETS) at each customer site provides heating and cooling energy in a closed loop.

Energy Conservation Programs

HCE's growing energy portfolio now extends beyond the downtown core system and includes:

McMaster Innovation Park:

A campus-style Integrated Community Energy System started in 2010 that includes a sustainable geothermal exchange system combined with conventional technology servicing 1/2 million square feet of innovation, research, and lab facilities. It also has a 600 kW CHP system that provides behind the meter resilient electricity to park tenants/businesses. The park is currently under expansion with a low carbon mandate that will be met by expanding the existing systems with energy sharing and thermal energy storage.

Hamilton-Oshawa Port Authority (Pier 10 Hamilton):

Industrial District Energy System (IDES) provides steam and hot water to adjacent industrial customers; also includes a 2 MW CHP system that provides electricity to the grid.

Various Locations in Hamilton and Beyond:

HCE began its green renewable electricity offerings in 2015 with the build-out of rooftop solar photovoltaic (PV) assets, including installations at 601 Burlington St. and 91 Eastport Dr. in Hamilton's Bayfront Industrial Area. The close to 4 MW of solar PV rooftop facilities has resulted in HCE achieving a reduction in GHG intensity by 34% from 2016 to 2019 in its electrical generation portfolio.

HCE's district energy system has replaced dozens of site-based, low-efficiency boilers resulting in area-wide GHG reductions.

Since commissioning in 2003, HCE has decreased its carbon emissions by more than 28,000 tonnes.

Planned GHG Reduction Practices

HCE Energy Inc. plans to act on viable opportunities arising from the current Industrial Waste Heat Recovery Project — e.g., exploring new district energy opportunities cited in the final report, expanding the industrial district energy system model now in use at Pier 10.

Uncommitted GHG Reduction Opportunities

- Expand the McMaster Innovation Park Campus Energy System to utilize McMaster Engineering's ICE-Harvest technology to provide the park with a low carbon energy future.
- Upgrade the downtown district energy hub (now nearing 20 years of service) to add features of next generation Integrated Community Energy Systems — i.e., industrial waste heat sources, geo-exchange, energy storage (electrical/thermal), and sharing, etc.
- Expand the downtown Hamilton district energy distribution networks.
- Grow renewable energy assets — i.e., photovoltaic, solar thermal, waste heat energy, etc.
- Improve efficiencies through AI and the development of "Smart Cities" initiatives.

THERMAL DISTRIBUTION NETWORKS

WASTE HEAT AND THE FUTURE OF DISTRICT ENERGY IN HAMILTON

A key goal of this study was to identify ways to capitalize on abundant sources of low-grade industrial waste heat in Hamilton.

This valuable resource, typically lower than 100°C, is best applied to heating spaces, providing domestic hot water, and operating low-temperature industrial processes.

Stakeholder interviews, secondary research, and team discussions underscored the opportunity to leverage local expertise in the design, operation, and maintenance of district energy systems.

This section answers several core questions, including:

1. How has district energy evolved in recent years?
2. What are the main ingredients of an integrated energy system?
3. How can industrial waste heat contribute to a district energy system?
4. What are the barriers and risks associated with district energy in the context of waste heat recovery?
5. How can these challenges be addressed, particularly in Hamilton?

District Energy Can Unlock the Value of Industrial Waste Heat

Similar to other communities worldwide, Hamilton's transition to a low emissions future must involve achieving greater efficiency across its energy systems and switching to renewable fuel sources.

Central to both these goals are modern district energy systems that utilize a diverse mix of low carbon energy streams, including industrial waste heat.

Hamilton is home to several industrial sectors regarded as ideal providers of waste heat for district energy. These sectors include steelmaking and chemical refining. The fact that these providers are clustered in and around Hamilton's Bayfront Industrial Area is an added benefit. The core challenge is transporting industrial waste heat from sources to sinks efficiently and cost effectively.

New technologies and methods developed and applied over the past century have led to District Energy Systems. These systems, which operate at lower temperatures, and as such can more easily accommodate renewable energy sources, can contribute to a comprehensive climate change strategy while offering a range of economic and social benefits at the local level and beyond.

As noted in this report, Hamilton has a well established and evolving district energy system operated by Hamilton Community Energy/HCE Energy (HCE), a wholly owned subsidiary of the City of Hamilton. This gives the community a tremendous advantage over most Canadian towns and cities.

Hamilton is also uniquely positioned to team up with local industry to drive energy efficiency, utilization, and innovation. This includes transporting industrial waste heat to local homes, businesses, and institutions. Moreover, there are limitless opportunities to involve expertise from Mohawk College and McMaster University, including specialists in the Institute for Energy Studies who are advancing Integrated Community Energy and Harvesting Systems (ICE-Harvest).

This trifecta (an established district energy provider, Hamilton's Bayfront Industrial Area, and a world-class research-focused university) is significant given that space heating and domestic hot water for buildings and residences represent more than 50% of Hamilton's overall greenhouse gas emissions.

District energy systems provide an energy distribution network and a path to allow for lower carbon impact energy sources. Now termed Net-Zero Ready, today's district energy systems have several defining features. Many operate at lower temperatures, often in the range of 55°C. This offers improved system-level efficiency and the opportunity to tap into lower temperature heat sources, including low-grade industrial waste heat once regarded as having little or no value. District energy systems accommodate switching to low carbon sources across a large footprint of buildings much easier and more economical than the retrofit of individual buildings.

Newer systems also use advanced pipes that are better insulated and able to distribute hot water, the principal heat carrier, over longer distances.

District energy systems accommodate switching to low carbon sources across a large footprint of buildings much easier and more economical than the retrofit of individual buildings.

HCE Energy Inc. pioneered Horizontal Directional Drilling in North America for District Energy. This method utilizes European sourced piping to overcome the high costs and difficulties associated with insulating systems in older municipalities. This opens opportunities to expand existing networks and develop new ones. Trends toward even lower infrastructure and operating costs are helping accelerate growth.

Modern low-temperature district energy systems work in lockstep with innovations that are lowering heating demand by constructing new, high-efficiency buildings and retrofitting older stock, creating new opportunities to reduce the carbon footprint of municipalities.

Perhaps the most significant step forward in district energy, particularly in the area of space heating, is the ongoing shift from fossil fuels to waste heat and renewables.

A fundamental change is the adoption of integrated energy systems that unlock synergies between a community's electrical, thermal, and gas networks. This takes the notion of conventional district energy — centralized, high-temperature, inflexible, and reliant on fossil fuels — and places it in the context of integrated community energy and smart energy systems.

An integrated, smart energy system is nimble and makes the best use of local assets and resources, as well as the advantages of a regional power grid.

Research for this project, including discussions with local stakeholders, show that an advanced, integrated system may include:

- Energy sharing.
- Electrical energy from multiple renewable sources, including wind, solar, and hydro. This "green electricity" can power industrial-scale heat pumps used to supply thermal energy to meet local space heating demand.
- Heat capture from geothermal sources.
- Heat storage, short-term and seasonal, using tanks, underground reservoirs, and geothermal applications.
- The use of alternative fuel sources, including biofuels and biomass.
- Thermal and electrical energy resiliency by decentralized combined heat and power (CHP) facilities.
- The ability to shift from one fuel source to another in a relatively straightforward manner.

A common denominator among these integrated energy microgrids is the ability to "harvest" thermal energy from multiple sources, ready it for space heating purposes, and distribute it to multiple users across a thermal network.

Implementation of smart energy systems combined with District Energy networks requires specialty infrastructure. Examples include CHP facilities, energy transfer centres, industrial-scale heat pumps, thermal storage, and a pipe network. These are proven technologies in common use across Europe, and to a growing extent, in North America.

In most cases, this enabling infrastructure is put in place in stages over several decades, often using a Master Plan as a blueprint for implementation.

Hamilton's Bayfront Industrial Strategy, now in development, could offer the means to embed smart energy systems and a thermal microgrid into a comprehensive renewal plan for the entire area. See the Enabling Resources section of this report for details.

Acting on this opportunity and others for energy sharing would require the cooperation of multiple stakeholders, significant investments, and in most instances, the involvement of a system administrator responsible for managing and operating the overall system.

Managing Risk
Study participants identified numerous risks associated with waste heat recovery projects that are outward-facing and reliant on some form of an external distribution system. The most commonly cited risks, in no particular order, are:

Supply Perspective

- High upfront costs and multiyear payback periods that are longer than usual.
- Concerns the project will not deliver on anticipated energy savings and GHG reductions.
- Loss of direct control given participation in multi-partner arrangements.
- Business uncertainty, particularly for foreign-owned companies exposed to global market conditions.

- Potential negative impacts on industrial processes that could disrupt throughput and affect quality.
- Long-term obligations, legal and otherwise, to consistently provide waste heat.
- Liability exposure for disruptions to flows of waste heat to external users.

Demand Perspective

- Entering into a nonconventional energy purchase agreement.
- Potential for service interruptions — i.e., threats to energy security.
- Reliance on equipment and technologies that are not in wide-spread use in Canada.
- Systems that could negatively affect the resale value of a property.

Distributor Perspective

- Securing finances to cover infrastructure design, build, and maintenance costs.
- Balancing thermal supply and demand — particularly ensuring a sufficient base of end-users to warrant new infrastructure investments.
- Delivering value to network suppliers and users.
- Generating sufficient financial returns to remain viable.
- Competition from conventional technologies and practices, and relatively inexpensive hydrocarbon-based fuels.
- Responding to changes in policies and regulations in areas including energy, building code, climate change, etc.

Many to Many Model

The Project Working Group understands the need for strategies to help manage these and other risks that represent potential barriers to capturing industrial waste heat and distributing it to users across a shared thermal network.

The proposed solution is a "many to many" model that would seek to engage numerous stakeholders with a common goal to share costs, mitigate risks, and unlock mutual rewards. This model recognizes the local context of pairing potential sources and sinks in Hamilton and the need to maximize participation on the supply *and* demand sides of the equation. In other words, spreading the risk among multiple suppliers and multiple users.

Suggested components of the proposed model include:

1. **Multiple Companies:**
   Maximize the number of companies and processes contributing waste heat to the overall system. This would help ensure a steady and reliable supply of thermal energy. The thermal distribution system would not be dependent on a single source.

2. **Diverse Streams:**
   Build a district energy system(s) that utilizes a variety of input streams in addition to industrial waste heat, for example, CHPs, renewables, etc. This would provide redundancy and help ensure capacity for future growth.

3. **System Administrator:**
   Address the need for a third-party entity responsible for managing and operating the overall system. The role could include coordinating an array of demand-supply relationships, overseeing

the system's design and operation, and accountability (financial, governance, etc.). This component would help address stakeholders' concerns related to implementing a "many to many" model.

4. **Repeatable Processes:**
   Tap into reliable sources of waste heat that are common across all industrial sectors. In Hamilton's Bayfront Industrial Area, this could include cooling towers used by most manufacturers to reject excess heat into the atmosphere. A focus on cooling towers could lead to a relatively simple and repeatable process for interacting with multiple companies in multiple industries. An added advantage of this approach is the benefit of engaging with companies without impacting internal processes. Stakeholder discussions indicate that this could help remove a significant barrier to company participation.

5. **Density of Users:**
   Heat demand density is the most important parameter for a district energy system's feasibility. The demand side of the "many to many" model would require compact user nodes — high-density developments, institutions, campuses — that support the economics of district energy systems "fueled" in part by industrial waste heat.

6. **Engaged Partners:**
   The "many to many" model has the potential to extend to partnerships that could help address complex challenges associated with district energy coupled with industrial waste heat recovery.

   One example could be a public-private partnership (government and industry) that works together to build essential thermal infrastructure — the "highway" needed to transport heat across Hamilton's Bayfront Industrial Area (an industrial loop) and from the Bayfront to downtown Hamilton (a commercial, institutional, and residential loop).

   Partnership could also be the key to research and development (McMaster University), specialized skills training (Mohawk College), policy and advocacy (Hamilton Chamber of Commerce), and planning and economic development (City of Hamilton), for example.

Interactions with local stakeholders who contributed to this project revealed numerous gaps in understanding the various economic, social, and environmental advantages of contemporary district energy systems.

In many cases, real and perceived implementation challenges — especially high infrastructure costs and potential risk exposures — crowded out discussions on the many well-documented benefits of district energy and waste heat recovery in the big picture contexts of energy utilization and climate change.

While acknowledging these challenges and pursuing solutions, it is also essential to seize opportunities. Stakeholders shared a number of strategies. Here are three for consideration moving forward:

1. **Education and Awareness:**
   Work on multiple fronts to explain what District Energy is, how it works, and the resulting benefits. District energy operates behind the scenes and below ground. It would be helpful to share the positive impact of this under-appreciated community resource. The same holds true for promoting industrial waste heat as a valuable asset with untapped potential. Building the case starts by telling the story.

2. **Decision Tools:**
   Help decision-makers compare the costs of district energy with the costs of conventional building-level solutions to space heating, cooling, and domestic hot water. When all real costs are factored in, including the capital, operations, and maintenance, a district energy scenario can often outperform a business-as-usual scenario, especially in the long term. Equally important is the need to help manufacturers measure the value of contributing their low-grade waste heat to a district energy system and the wider community. Calculators could layer in potential financial incentives, such as grants, loans, and subsidies.

3. **Targeted Advocacy:**
   Work with policymakers at all government levels to develop and implement coherent frameworks needed to accelerate the growth of district energy systems in Canadian communities. This could include loan guarantees and/or low-cost financing to build a district energy system, particularly those incorporating industrial waste heat sources. *See the policy section of this report for additional information.*

When all real costs are factored in, including the capital, operations, and maintenance, a district energy scenario can often outperform a business-as-usual scenario, especially in the long term.

TECH TALK: Industrial Heat Pumps

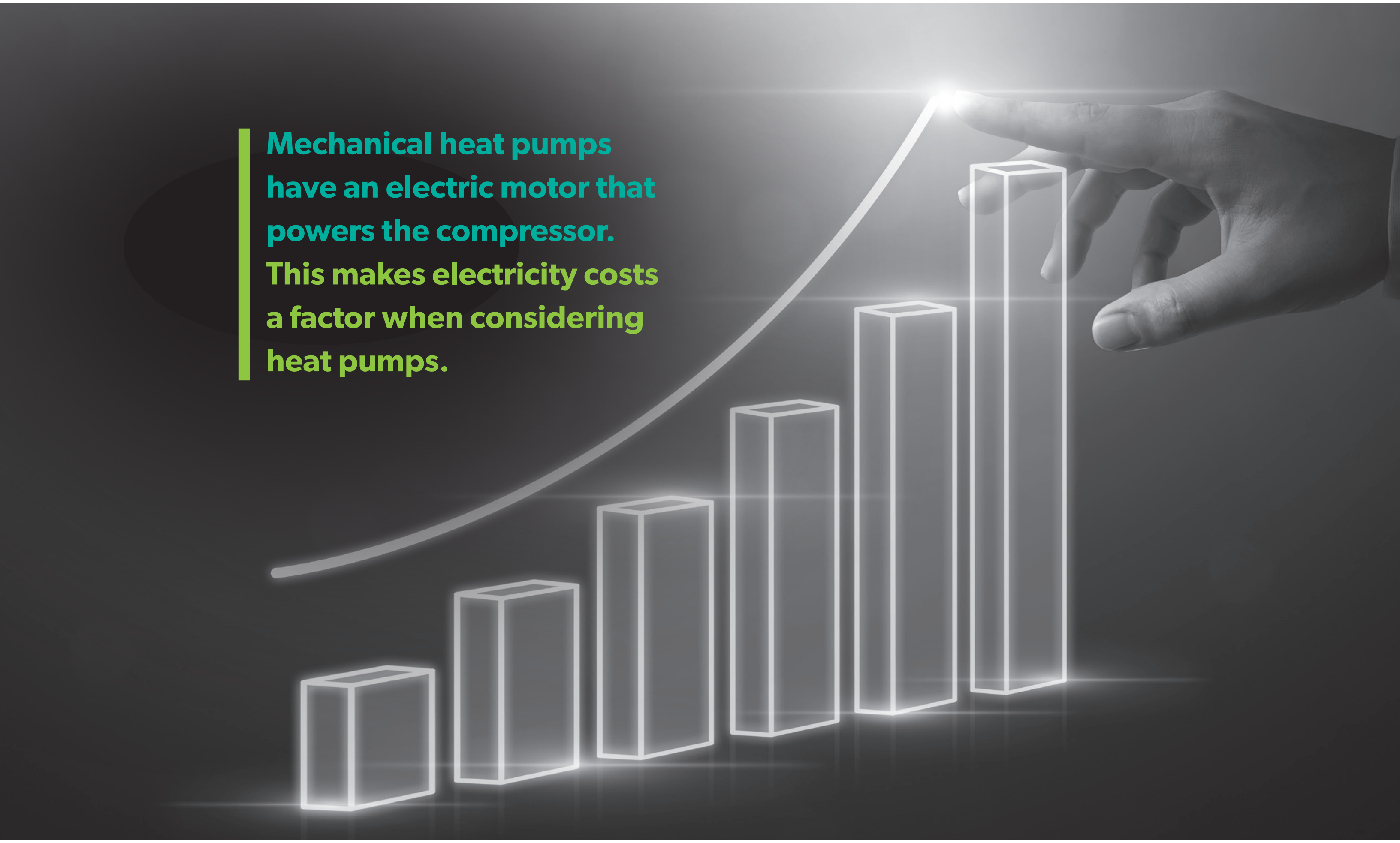
Technological innovation is helping drive complementary developments in district energy and industrial waste heat recovery. One leading example is the growing prevalence of industrial heat pumps worldwide.

Heat pumps are a class of active heat transfer equipment used to move and increase the temperature of a heat stream. An everyday example is an air conditioner which removes heat from one space (cooling) and transfers it to another.

Heat pumps can efficiently boost temperatures making them useful for home heating and similar applications. In an industrial waste heat application, the heat pump receives heat from a low-temperature waste heat source. The pump then lifts the temperature of the waste heat and delivers it as useful heat at the desired temperature.

A type commonly used in large-scale commercial settings is the mechanical heat pump. "Within a mechanical heat pump, the pressure of a refrigerant is increased with the use of a compressor. Due to this increase in pressure, the condensation temperature rises." *

The net effect is a marked temperature lift between the heat stream (water) entering the heat pump and exiting the heat pump. A modern mechanical heat pump, properly sized and equipped with an advanced refrigerant,



can lift the temperature of a waste heat stream from 25°C to 55°C, an ideal operating temperature for a District Energy System. In fact, heat pumps with a temperature lift capability approaching 95°C are available. It is important to note that energy efficiency decreases in higher temperature ranges.

Mechanical heat pumps have an electric motor that powers the compressor. This makes electricity costs a factor when considering heat pumps. Yet under the right circumstances, the cost of operating a heat pump will be less than the value of the energy saved in burning fossil fuels. Due to Ontario's "green grid," electricity used to power heat pumps in Hamilton would not contribute to GHG emissions.

A key recommendation of this report is to accelerate the local adoption of industrial heat pumps. It is proposed that specialists from CanmetENERGY be engaged in this work.

** Sourced from the website of De Kleijn Energy Consultants and Engineers, The Netherlands*

TECH TALK: Industrial Cooling Towers

Most manufacturers require a method to control the operating temperature of specific processes. This often means using water to absorb and remove unwanted heat. In many cases, companies pipe their heated cooling water to an evaporative cooling tower. This device, a mainstay across most industry sectors, is used to cool the water. The heat laden water interacts with cool air. The cool air promotes evaporation, and the resulting vapor is rejected into the atmosphere. This produces lower temperature water that can be used to cool a given process. While reliable and proven, evaporative cooling towers have a continuous loss of water that requires a blowdown of water and chemical additions to maintain quality, and a constant make-up of fresh water to offset losses through evaporation and blowdown.

Increasingly, industry is looking at alternative cooling methods that perform better than an evaporative cooling circuit and without the associated costs. This opens the door to waste heat recovery solutions and potential low-grade thermal energy streams for applications, such as space heating.

Evaporative cooling towers are ubiquitous across Hamilton's Bayfront Industrial Area. The possibility exists to collect waste heat from multiple cooling towers to form a combined stream connected to a district energy system. Assessing the merits of this opportunity would require research to produce an inventory of cooling towers that includes their locations and heat recovery potentials.

INDUSTRY INSIGHT: PORT OF HAMILTON

Operated by Hamilton-Oshawa Port Authority (HOPA), the Port of Hamilton is the largest port in Ontario and the western marine gateway to the Greater Toronto-Hamilton Area (GTHA). The Port of Hamilton is critical infrastructure for key Ontario industries, facilitating international trade flows and supporting domestic supply chains.

The Port of Hamilton is Southern Ontario's largest gateway for overseas exports of Ontario-grown corn, wheat and soybeans; imports of essential crop inputs used in Southern Ontario (urea ammonium nitrate, potash); raw material imports from the U.S. for steelmaking (iron ore and coal); finished steel used in GTHA automotive manufacturing, durable goods and construction projects; exports of large Ontario-manufactured components, factory equipment and machinery; and imports of liquid bulk petrochemical products, such as consumer gasoline and asphalt cement used in GTHA road construction.

HOPA is proud to participate in this waste heat project and believes that it has the potential to lead to significant greenhouse gas reductions. The port, operating with regard to its Sustainability and Environmental Policies, strives to continuously improve its environmental footprint and enhance how it operates sustainably within its communities.

Focus on Energy Conservation and GHG Emission Reductions

In late 2019, HOPA introduced four electric vehicle (EV) charging ports at its Hamilton headquarters. The stations are used daily by HOPA staff and other building tenants, and are also free for public use. Since introduction, the EV stations have been used more than 800 times and saved 4,360 kg of CO2.

HOPA works with Alectra Utilities on an ongoing basis to implement energy efficiency upgrades within port facilities. In 2018 and 2019, eight projects were completed to introduce high-efficiency lighting, reducing energy use by 1,733,000 kWh. Renovations to the port authority's Hamilton headquarters took advantage of the opportunity to improve the building envelope and mechanical services, including a new high-efficiency boiler and new insulation.

HOPA has also partnered with HCE Energy Inc. on projects to install rooftop solar panels on two port buildings, as well as an industrial district energy system at Pier 10. The system consists of a 2 MW natural gas engine that provides electrical power to the grid while supplying port tenants with steam and hot water. Energy sharing on a loop among users reduces overall emissions produced from equivalent numbers of conventional natural gas fueled boilers.

Utilization of Waste Heat

Port tenants explored a similar independent partnership in which an existing steam generator provided excess thermal capacity to an industrial neighbour. While this trial did not continue, it highlighted the important role a third-party intermediary could play in managing relationships among suppliers and users of thermal energy. HOPA recognizes it has a role to play in helping its tenants and customers achieve their decarbonization targets, including the International Maritime Organization's goal of reducing the GHG intensity of international shipping by 70% by 2050. The use of waste heat as an alternative to standalone heating units could add to HOPA's toolkit of options to improve environmental performance.

ENABLING RESOURCES

TO ADVANCE WASTE HEAT RECOVERY AND DISTRICT ENERGY IN HAMILTON

The Project Working Group engaged dozens of stakeholders to help inform and co-create this study.

Interviews and follow-on discussions revealed several complementary plans and initiatives.

They are presented here as "enabling resources" ready to contribute in specific ways to advance waste heat recovery and district energy in Hamilton.

Recommendation to Explore an Industrial Waste Heat Trunk Line

Integrated Community Energy & Harvesting System

Hamilton Bayfront Industrial Strategy

Hamilton Community Energy and Emissions Plan

Pier 8 and Barton-Tiffany Development

Background
Sustainability Solutions Group (SSG) — a collective of leading sustainability professionals — has been engaged by the City of Hamilton to provide consulting services in the development of its Community Energy and Emissions Plan.

In connection with this work, SSG engaged Farallon Consultants Limited to explore how industrial waste heat could be used to achieve the climate change goals of the City of Hamilton and the district energy system expansion goals of HCE Energy Inc.

The Hamilton Chamber of Commerce and others provided input into this preliminary exploration which has led to an internal report used by SSG for its energy modelling. The report can also help inform this project.

Essence of Report
In a very preliminary manner, the report looks at the potential merits of building a thermal "trunk line" that could connect numerous industrial waste heat sources in the bayfront area with district energy assets operated in and around downtown Hamilton by HCE Energy Inc. If implemented, this low-carbon heat stream could provide HCE Energy Inc. with additional options on how to enhance and/or expand its systems.

Report's Key Initial Conclusions

1. Industrial waste heat is available near downtown Hamilton in quantities and at temperatures that make it a very practical low-carbon source of heat for expanding the district energy systems of HCE Energy Inc.

2. A very high-level cost estimate suggests that the estimated differences in ongoing costs between the option of expanding the downtown energy system by building a business-as-usual natural gas boiler plant, and by building industrial waste heat recovery infrastructure is favourable enough to justify a feasibility study by a specialized engineering firm.

3. Waste heat in Hamilton's Bayfront Industrial Area is likely available at temperatures that are high enough to use Organic Rankine Cycle (ORC) turbines to generate both electricity and heat for district energy.

4. Large areas of Hamilton's downtown core (containing buildings that could be connected to district energy in the future) are located midway between the existing HCE Energy Centre on Bay Street and the sources of industrial waste heat. This is helpful since a trunk line from the industrial sites could be routed through this area of downtown Hamilton.

5. If electricity can be generated with ORC turbines, this electricity could be used for "cold ironing" ships in port as a means of reducing GHGs and air emissions from this source.

6. Although the district energy systems of HCE Energy Inc. could be expanded as high-temperature systems based on a conventional two-pipe distribution network, there are advantages to expanding the systems as three-pipe, hybrid networks. These advantages include the ability to connect older buildings that require higher temperature heat, the ability to recover waste heat from a wider range of sources, and the ability to remove waste heat from building cooling in the downtown core. The increase in the capital cost of providing the third pipe would likely be offset by the economic benefits it could provide.

The increase in the capital cost of providing the third pipe would likely be offset by the economic benefits it could provide.

7. Depending on the circumstances of industrial waste heat sources, potential benefits of using industrial waste heat for district energy could include:

- Increase redundancy and reliability to Hamilton's utility grids.
- Offset demand on Hamilton's utility grids.
- Help to offset risk and future cost of natural gas caused by carbon pricing.
- Create local jobs for both the construction and operation of district energy grid.
- Keep energy expenditures local and reinvested into the Hamilton community.

Next Steps

1. Ensure that Farallon's preliminary report is cited in the final City of Hamilton Community Energy and Emissions Plan.
2. Use the report to inform follow-on conversations on ways to leverage Hamilton's industrial waste heat advantage.
3. Support HCE Energy Inc. in efforts that it and/or others may undertake to launch a study(ies) by a professional engineering firm that builds on the Farallon report.

INTEGRATED COMMUNITY ENERGY & HARVESTING SYSTEMS (ICE-HARVEST)

Background
ICE-Harvest is a collaborative initiative focused on developing the community energy networks of the future through advancing the idea of integrating local distributed energy resources.

It is led by McMaster University, in cooperation with Carleton University, and in partnership with HCE Energy Inc., the GridSmartCity Cooperative, Siemens Canada, Enbridge Gas, Alectra Utilities, S2E Technologies, and GeoSource Energy.

The long-term goal is to increase community energy utilization and resiliency by:

- Transforming our communities into reactive micro thermal and electrical grids using advanced demand management and energy control systems.
- Harvesting and sharing unused energy otherwise wasted in energy intensive communities.
- Preventing turning off green power by using smart energy management and storage of heat, cooling, and electricity.

Integrated community energy solutions provide an alternative to centralized power and individual heating and chilling systems.

Efforts to-date by ICE-Harvest have resulted in a pilot facility at McMaster University, identification of potential node sites within communities across Ontario, optimization of the equipment that makes up the ICE-Harvest System, and exploring new ways to maximize thermal energy storage.

These outcomes have led to the development an operating system ready for use in a set of demonstration projects spanning select Ontario community, ideally including Hamilton.

Unique Operating System
At the heart of the operating system is a modular Energy Management Centre built to meet local requirements. A complete centre provides thermal energy generation, thermal energy storage, underground geothermal seasonal energy storage, electricity generation, and electricity storage. Connection to the electricity grid enables the centre to use centrally generated electricity to power heat pumps and battery storage during off peak times.

Each centre connects to micro thermal and micro electrical grids to power, heat, and cool connected buildings in an economically and environmentally sustainable fashion.

The integrated community energy and harvesting system captures waste heat from various sources, including industrial processes, and transfers it to buildings with heating dominant loads, such as large space heating and domestic hot water requirements.

ICE-Harvest supports significant GHG reductions through:

- Maximizing the utilization of locally available waste heat
- Maximizing the utilization of green electricity through smart energy management at the community level — e.g., use green electricity to power local energy storage and industrial scale heat pumps

Key Takeaways from our Discussions To-Date
The Project Tech Team engaged in several discussions with the ICE-Harvest Team, including team lead, James Cotton, Ph.D., McMaster University, focused on sharing insights and identifying opportunities to collaborate.

Highlights include:

- Recognition of a shared interest in a number of significant goals, including GHG reductions, waste heat recovery and reuse, energy sharing, thermal infrastructure, and utilizing existing assets to help meet future needs.
- Acknowledgement that in Ontario, peak thermal demand can be up to five times greater than peak electricity demand, hence the need for innovative ways to tackle our heating and cooling challenges.
- Considerable overlap of personnel and partner organizations, including McMaster University (Faculty of Engineering), HCE Energy Inc., and Enbridge.

In Ontario, peak thermal demand can be up to five times greater than peak electricity demand

- Demonstrated value in involving engineering students — especially grad, Ph.Ds., and post docs — in providing the capacity needed to advance this work.
- Agreement on the importance of identifying buildings clustered closely together to form "node" sites within communities that meet requirements for energy sharing, including proximity of waste heat sources and sinks — node sites would be able to use industrial waste heat as an energy input.
- Shared recognition of the untapped potential for harvesting vast amounts of low-grade waste heat rejected into the environment from industrial cooling towers — replacing industrial cooling towers with heat exchangers connected to a micro thermal network represents an effective way to capture a company's waste heat without affecting its processes (a solution to a barrier cited by many industrial firms). A focus on cooling towers would also provide a repeatable approach for working with companies across a range of industries.
- Agreement on the benefits of designing and building next generation thermal grids that are controllable and operate on lower temperature streams (< 50°C). This would open new opportunities to utilize greater quantities of low-grade waste heat from industry and other sources.
- Agreement on the role that industrial heat pumps can play in "lifting" the temperature of waste heat to meet the requirements of individual users — i.e., heat pumps located on users' sites provide flexibility within a shared system.

- Agreement on the growing importance of thermal storage (short-term and seasonal) to the future of waste heat recovery and reuse. Solutions could include insulated tanks, capped reservoirs, underground storage, etc. Consideration could be given to locating thermal storage facilities on unused lands in Hamilton's Bayfront Industrial Area.

- Recognition of ICE-Harvest Research Team's ability to offer specialized facilities and expertise to help accelerate the adoption of industrial waste heat recovery in Hamilton and beyond, including labs set-up to run experiments, thermal modelling technologies, and creating a digital twin of potential sites, etc.

Next Steps ~ *Proposed Activities **

1. Work together to identify a high potential, high profile demonstration project(s) in Hamilton that incorporates industrial waste heat recovery into the ICE-Harvest model.

2. Explore opportunities to jointly approach government to advance policy measures and funding programs that support ICE-Harvest and the shared goal of industrial waste heat recovery.

3. Utilize modeling expertise developed for ICE-Harvest (and other areas of specialization) to test the effectiveness of various waste heat recovery and reuse opportunities cited in this report.

4. Develop detailed designs of a local suite of investment-ready industrial waste heat projects in anticipation of potential funding opportunities.

5. Act on opportunities to build a repository of data (especially related to the Greater Hamilton Area) helpful in understanding the local energy landscape.

6. Consider a targeted project that would develop a detailed inventory of cooling towers across the Hamilton Bayfront Industrial Area.

7. Identify a short list of potential demonstration projects within the Bayfront Industrial Area that could help accelerate the wider adoption of waste heat recovery technologies, systems, and infrastructure.

8. Capitalize on Hamilton's unique ability to harness significant quantities of industrial waste heat to help meet the space heating (and cooling) requirements of large portions of downtown Hamilton and beyond.

9. Cite the interest among the local education institutions, and their research and development communities, to explore establishing an on-site presence within the Bayfront Area to work on a range of manufacturing challenges, including waste heat recovery and reuse.

10. Investigate the public-private partnership model — e.g., the IESO York Region Non-Wires Alternatives Demonstration Project.

** Parties are not obligated to act on any of the proposed activities presented here as a guide to further discussion. Given capacity constraints, parties recognize the need for additional resources to advance significant collaborative work.*

Background
The City of Hamilton is leading work to develop a comprehensive 45 + year vision, and related strategy and action plans, that will shape the future of the Hamilton Bayfront, home to a significant cluster of mixed industries near the shoreline of Hamilton Harbour.

The strategy development phase, which is now nearly complete, is an ideal time to embed energy innovations — including opportunities for industrial waste heat recovery and reuse — into key action planning documents and related policy frameworks.

Numerous meetings with city staff responsible for facilitating the strategy have indicated a strong interest in working together to achieve these mutually supportive aims.

Highlights of Discussions To-Date

- Promote the Bayfront Industrial Area as a source of pride, and a centre for employment and innovation.
- Support and expand the presence of mixed industries, including traditional and advanced manufacturing.
- Realize ongoing improvements, investments, and redevelopment — including the potential for institutional and commercial land uses.
- Proactively respond to the risks and opportunities posed by climate change.
- Consider ways to deepen the involvement of the private sector in realizing the vision of the Bayfront Strategy — e.g., the use of multi-level governance and public-private partnership models.

Next Steps

Recommendations to Promote Waste Heat Recovery
It is recommended that the Bayfront Strategy, accompanying action plans, and implementation work:

1. Place climate risks and opportunities among the drivers informing future planning and investments.
2. Point to the need for collective action to reduce industrial GHG emissions.
3. Support the efforts of leading industrial sectors — including the Canadian steelmaking sector — to achieve their net zero CO_2 targets by 2050.
4. Cite the opportunity to create an Industrial Eco Park (IEP) within the Bayfront Area that could be used to accelerate investments in common infrastructure, including waste heat recovery and distribution through a shared thermal grid.
5. Call for specific public policies needed to help unlock additional investments in industrial energy innovations in general and industrial waste heat recovery in particular.
6. Identify a short list of potential demonstration projects within the Bayfront Industrial Area that could help accelerate the wider adoption of waste heat recovery technologies, systems, and infrastructure.
7. Capitalize on Hamilton's unique ability to harness significant quantities of industrial waste heat to help meet the space heating (and cooling) requirements of large portions of downtown Hamilton and beyond.

8. Cite the interest among the local education institutions, and their research and development communities, to explore establishing an on-site presence within the Bayfront Area to work on a range of manufacturing challenges, including waste heat recovery and reuse.

9. Investigate the public-private partnership model — e.g., the IESO York Region Non-Wires Alternatives Demonstration Project.

HAMILTON COMMUNITY ENERGY AND EMISSIONS PLAN (CEEP)

Background
This is a long-term community plan led by the City of Hamilton that is on track to be presented to City Council in 2021. It is intended to help Hamilton meet its future energy needs while improving energy efficiency and reducing GHG emissions. The plan will set a path for Hamilton achieving net zero carbon emissions by 2050.

Shared Touch Points
Discussions with members of the Hamilton Community Energy and Emissions Plan team confirmed agreement on numerous shared touch points, including:

- Common focus on energy efficiency, conservation, and innovation as major contributors to decarbonization.
- Myriad energy-related advantages stemming from Hamilton being home to a significant manufacturing base clustered near a growing urban centre.
- Shared goal to engage manufacturers as potential suppliers of industrial waste heat as a thermal stream for district energy.
- Prospect of leveraging this business-led project spearheaded by the Hamilton Chamber of Commerce to help strengthen the role of local manufacturers in the overall aims of the Community Energy and Emissions Plan.
- Prospect of working closely with the City of Hamilton and its partners to identify and engage potential long-term users of industrial waste heat — e.g., municipal facilities, public housing developments, planned neighbourhoods, etc.
- Belief in working together to unlock potential investments that could enable thermal energy sharing from industrial sources to meet community needs — e.g., district energy for underserved neighbourhoods in transition, etc.

Next Steps

1. The Hamilton Community Energy and Emissions Plan will include industrial waste heat recovery — particularly from manufacturers operating in the Bayfront Area — among its short list of low-carbon actions to be modeled.

2. Parties will continue to work together to identify and assess opportunities to use district energy methods to connect industrial heat sources with heat sinks, including community hubs.

3. Parties will collaborate with a range of stakeholders to shape energy policy that includes enablers for industrial waste heat recovery and district energy distribution — e.g., grants, low-cost financing, etc.

4. Parties will identify potential demonstration projects that would help advance industrial waste heat recovery and reuse in Hamilton.

5. Parties will dig deeper into preliminary, high level analyses prepared to-date on the potential use of industrial waste heat as a thermal supply stream for Hamilton's district energy system.

PIER 8 AND BARTON-TIFFANY DEVELOPMENTS

Background
Two significant urban renewal projects within reach of the Hamilton Bayfront Industrial Area are potential large-scale sinks for industrial waste heat.

Pier 8, a former industrial pier on Hamilton Harbour at the foot of James Street North, is currently being redeveloped as a mixed-use waterfront community featuring approximately 1,600 residential units (mostly condo properties) and 13,000 square metres of commercial and industrial space.

This multiphase project, which includes nine large design blocks over five hectares, is expected to take more than a decade to complete. Waterfront Shores, a private development consortium, is leading the project.

The Barton-Tiffany lands, located near the West Harbour recreational area and north of the CN rail yards, is the site of a proposed development that would feature 500,000 sq ft of studio space for the film industry coupled with residential towers and a blend of commercial and institutional spaces. The goal is to see this municipally owned, 24-acre site sold to AEON Studio Group, a development consortium that would lead the multi-year project.

Key Discussion Takeaways
Members of the Project Tech Team discussed these projects with Chris Phillips, Manager of the Municipal Land Development Office, City of Hamilton. The discussion focused on opportunities for district energy supplied in full or in part by industrial waste heat.

Highlights:

- Recognition that the City of Hamilton has a long history of working with HCE Energy Inc., McMaster University, and others to explore innovative energy solutions (including district energy) in the context of Hamilton's waterfront and other significant properties.
- Recognition of the valuable role HCE Energy Inc. plays in facilitating energy-related partnerships in Hamilton — a local advantage in realizing new opportunities for energy sharing.
- Shared understanding that ongoing advances in waste heat recovery and district energy may make it possible to unlock new opportunities on the waterfront.
- Acknowledgement that both these projects are being led by the private sector. This lessens the ability of the City to influence significant decisions going forward.
- In the case of Pier 8, the City of Hamilton has not mandated specifications pertaining to energy supply and distribution technologies.
- Various factors will contribute to the ultimate mechanical requirements of the Pier 8 development, including:
    - Developers' preference for "predictable" and "repeatable" practices that mitigate risk and support their business models.
    - A general inclination among all parties to avoid the potential for complex negotiations and long-term, multi partner agreements.
    - The fluid nature of condo developments — many individual purchasers entering and leaving an umbrella corporation makes it difficult to implement long-term energy strategies.
- Working together to help overcome these and other barriers (real or perceived) will be important to the growth of district energy in Hamilton.
- The Pier 8 developer has indicated that it will seek certification from Energy Star Canada for multi-residential buildings. This could open the door for discussions on energy efficiency.

- Recognition that the Pier 8 development will proceed in phases over a number of years. This could make it possible to influence future energy decisions.
- The potential that the developers could add a high-rise tower (up to 45 storeys) could prompt interest in district energy solutions.
- The Barton-Tiffany studio district development may offer greater potential for district energy supplied by industrial waste heat in the shorter term.
- When built out, heating and cooling requirements would span approximately 500,000 sq ft of studio space, two residential towers, and multiple commercial and institutional properties.
- The key advantage of this development is its focus on large floor plate commercial and institutional spaces operating under single ownership over an extended period of time.
- In general, discussions regarding use of industrial waste heat from Hamilton's Bayfront Industrial Area would need to include the question of high infrastructure costs and who pays?

Next Steps

1. Meet with the Pier 8 developer (Waterfront Shores) to explore potential applications for district energy and related opportunities.
2. Meet with the Barton-Tiffany developer (Aeon Studio Group) to explore applications for district energy and related opportunities.
3. Act on the recommendation to strengthen the communication of the district energy value proposition, particularly targeting private developers.

POLICY DISCUSSION

POLICY DISCUSSION: MEASURES TO ENCOURAGE WASTE HEAT RECOVERY AND REUSE

At its core, waste heat diversion is a form of energy efficiency. There is an "energy efficiency gap" between existing energy use and optimal energy use (Jaffe et al, 82). Policy measures discussed below aim to minimize this gap through the diffusion of waste heat technology.

As noted in the EU's report, Heat Roadmap Europe, "the heating and cooling sector can be fully decarbonised based on technologies and approaches which already exist, are market-ready
and have successfully been implemented in Europe" (EU, 17). This suggests the nature of the problem is not based in a technology deficit.

Basic economic thinking would suggest that firms would want to minimize the energy efficiency gap themselves, as a matter of increasing efficiency and potentially lowering costs. However, as pointed out by Jaffe, Newell, and Stavins (2004), "market imperfections can lead to underinvestment in energy efficiency," which leaves the door open for corrective government policies to step in and help address this problem (Jaffe et al, 80).

This section outlines a number of policy measures that could overcome market imperfections and ultimately increase the uptake of waste heat recovery and reuse technologies among firms.

Policy Options
Policy measures typically fit into one of two informal categories: the carrot or the stick. Put simply, governments can implement policies that encourage certain actions (carrot) or discourage certain actions (stick). The policies discussed in this section fall into both categories, respectively. Analysis of which approach might work best for the problem at hand is provided.

Command & Control Regulation

Command and control regulation involves a stated command of what the regulated party must achieve and a penalty or sanction for non-compliance (OECD). An example of command and control regulation for technological implementation was the requirement to fit flue gas desulphurization to all new coal-fired power plants under U.S. Clean Air Act amendments of 1977. In the case of waste heat technology, a command and control approach could require firms to purchase and utilize a heat exchanger, as an example.

It should be noted that there are drawbacks to command and control measures. Namely, command and control regulation can be inefficient and inflexible. With technology mandates in particular, a firm cannot decide the best way to address the problem and the mandated solution may not be appropriate in the firm's individual context. Moreover, command and control regulation's one-size-fits-all approach can be inefficient, as it fails to achieve its goals at the least cost for society as a whole. Different firms will experience different costs to achieve an environmental end; and efficient policy would target actors whose abatement costs are lowest.

Market Based Instruments

Market based instruments (MBIs) are regulations that encourage certain behaviour through market signals, rather than through explicit directives (OECD). Examples of MBI policies include both carbon pricing and electric vehicle rebate programs. The former disincentivizes carbon intensive activities by increasing their cost, while the latter incentivizes technology adoption by reducing their cost. In both cases, it is up to the policy targets to decide how and if they wish to respond. In theory, properly designed and implemented MBIs ensure efficiency by providing incentives for action by actors who can achieve them most cheaply.

In the case of waste heat technology adoption, a number of MBI policies could be implemented. A price on carbon creates a market signal that incentivizes firms to minimize their efficiency gap, making waste heat technology adoption more appealing. Moreover, funding for waste heat technology, through a rebate or grant program, would also create a market signal that incentivizes firms to minimize their efficiency gap through adoption.

As it stands, Canada currently imposes a price on carbon. Since 2018, the federal carbon pollution pricing system placed a pollution price on fuel and a pollution price for industry. The carbon price is applied per tonne, increasing each year (Government of Canada). With this MBI in place, firms are incentivized to lower their emissions and fuel usage. In many cases, waste heat diversion reduces a firm's reliance on fuel, such as natural gas, making carbon pricing one form of market signal that impacts a firm's decision to adopt new technologies. Should this price continue to increase and remain in place for the long term, the price will impact a firm's cost-benefit analysis to waste heat adoption.

The Government of Ontario also works to create market signals toward energy efficiency and conservation through the Ontario Energy Board's *Demand Side Management Framework for Natural Gas Distributors*. The goal of Demand Side Management (DSM) is to reduce consumption of natural gas, which in turn, reduces customer bills and reduces carbon emissions. DSM initiatives exist to provide natural gas customers with programs that help them conserve energy, including grants for technology adoption (OEB, 1). Waste heat diversion technologies are eligible for DSM funding, generally consisting of economizers, recuperators, direct-contact condensing heat recovery for flue stacks, heat pumps, etc. Engineering feasibility studies, as well as energy assessments, are also eligible for DSM funding (Enbridge, 3). *See the Enbridge section of this report for details.*

Right now, distribution customers are responsible for financially supporting all DSM activities in Ontario. This means the incentives for energy conservation are covered by the distribution rates paid by customers (OEB, 15). Firms in Hamilton currently benefit from access to DSM incentives, through natural gas providers like Enbridge, but the available incentives may not be high enough to adequately incentivize firms to adopt energy efficiency technologies, considering the relative cost of waste heat technology adoption.

Existing DSM programs benefit from ongoing relationships with customers, fully established program set-ups, and internal expertise within natural gas distributors. To harness these strengths, an expansion of existing DSM program work could further reduce GHGs and improve efficiency for more users.

…an expansion of existing DSM program work could further reduce GHGs and improve efficiency for more users.

As noted, DSM incentives are currently funded through rate payers. Alignment between multiple sources of funding could allow distributors to expand their ongoing work in conservation and efficiency. Additional funding through the Province of Ontario to provide further incentives for DSM projects ought to be considered. The Ontario Energy Board's current DSM framework expires at the end of the 2021 program year. The OEB has initiated a consultation to consider the next framework.

The governments of Canada and Ontario, respectively, each have funding programs for climate action. The federal Low Carbon Economy Fund leverages investments in projects that support innovation and lowers GHGs (Government of Canada 2). The provincial Ontario Carbon Trust is an emission reduction fund that is planned to leverage private investment in clean technologies that are commercially viable (Government of Ontario). Neither of which explicitly fund waste heat diversion capital costs. By including waste heat technology capital costs as eligible costs for government funding and rebates, a direct market signal and incentive would be created to encourage the adoption of waste heat among industry.

Beyond government investment, an additional MBI policy option includes the creation of green bonds. Green bonds are "debt securities where the issue proceeds are utilized to fund projects with specific environmental benefits" (OFA). These bonds can incentivize waste heat diversion technology by providing private sector financing.

Since 2014, Ontario has released annual green bonds to help finance transit and other environmentally friendly projects across the province. In fact, Ontario is the largest issuer of Canadian dollar green bonds, totaling $5.25 billion (OFA). In Ontario, the selection of eligible projects is done by Ontario Financing Authority staff and the Green Bond Advisory Panel. While waste heat diversion projects would qualify for investment under the Ontario Green Bonds criteria, it should be noted, however, that projects are selected across the province, and not necessarily in Hamilton.

To this end, the City of Toronto established its own green bond regime in 2018, making it one of the first municipalities to establish a Green Debenture Program in Canada. The city's green bond regime issued and raised $300 million in 2018 and $200 million in 2019 for green capital projects within the city (Toronto). The City of Hamilton could replicate this policy measure and provide capital for local green projects, such as waste heat technology adoption, through the issuance of green city bonds.

Other ~ Procedural Simplicity

Beyond price signals, the perception of procedural simplicity can impact a firm's decision to adopt new technologies. A firm that perceives it will be difficult to navigate local municipal regulation and bylaws, may be dissuaded from adopting waste heat diversion technology. Waste heat diversion technologies can include sharing between or among different users. This raises the question of municipal easements and approvals for firms that decide to adopt the technology.

At the time of writing for this report, the City of Hamilton is working on its Hamilton Community Energy and Emissions Plan. This plan will focus on how to meet Hamilton's energy needs while "improving energy efficiency, reducing greenhouse gas emissions, and fostering local sustainable and community-supported energy solutions" (City of Hamilton).

The Project Tech Team met with city staff working on the Community Energy and Emissions Plan to discuss how waste heat can play a role in the city's stated goals. An energy plan that commits to reviewing municipal policy and procedure, to eliminate any barriers for increased resource sharing between properties, could improve the perception of procedural simplicity among firms considering waste heat adoption.

The City of Hamilton is also currently working on a Bayfront Industrial Area Strategy. This plan is meant to guide future improvements, investments, and redevelopment in the mixed industrial area on the shore of Hamilton Harbour. One of the stated goals of the Bayfront Strategy is to "improve the environmental conditions and image of the area" (City of Hamilton, B). The Project Tech Team also met with city staff working on Hamilton's Bayfront Industrial Area Strategy to discuss how waste heat can play a role in the city's stated goals.

An additional policy measure for simplicity to increase the uptake of waste heat technology includes leveraging city assets for waste heat technology installation, taking the onus off of individual firms. The United Nations Environmental Program assessed similarities among the 45 cities who lead the world in waste heat through district energy, in a report discussed below. Therein, UNEP noted that almost all 45 of the "champion cities" leveraged city assets, like land and public buildings, "for district energy installations or connections, including by providing anchor loads to alleviate load risk and facilitate investment" UNEP, 47). A formal review of city assets in Hamilton could serve this end.

Other ~ Data and Targets

Additional areas of policy, utilized by cities around the world that have seen measurable increases in waste heat technology, particularly for district energy purposes, include the collection of data and the setting of concrete targets.

More specifically, the UNEP report *Unlocking the Potential of Energy Efficiency and Renewable Energy* emphasizes the importance of data collection to inform a city's energy strategy. It explains that "a city needs to undertake a holistic study of municipal energy use and needs, from which it can identify goals and pathways for realizing specific socio-economic benefits, both now and into the future" (UNEP, 50). As mentioned, the City of Hamilton is undergoing this crucial step of data collection in its Community Energy and Emissions Plan.

Based on the data collected, a municipality can set concrete targets for uptake goals. In a review of the top 45 "champion cities" that use district energy found that "nearly all of the 45 local governments surveyed have established some type of district energy goal, and the majority have developed a district energy specific target" (UNEP, 51). This specific target coincides with additional overall GHG reduction targets. Examples of these district energy targets range from 200,000 residential connections to district energy by 2040 (Amsterdam, Netherlands), to using district heating in all new buildings and major renovations within the concession area for district heating (Bergen, Norway), to expanding the use of district cooling up to 20% of commercial buildings (Hong Kong, China). The use of stable targets reduces "the real and perceived risks to customers, heat suppliers, local authorities and owners of district energy systems — helping to develop long-term confidence in these systems" (UNEP, 57).

In cities where specific targets are set, they were supported by collaboration among the diverse local government departments relevant to land-use planning, including energy, waste, and buildings.

In fact, the UNEP report shows that "most of the 45 champion cities have established an administrative structure to coordinate these various bodies, for example through an interdepartmental committee, multi stakeholder partnership or designated Agency" (UNEP, 57). This evidence suggests the Hamilton Community Energy and Emissions Plan ought to include a specific, concrete target for district energy uptake in Hamilton. Moreover, the plan should establish a structure to ensure relevant municipal departments collaborate on the set target.

Recommendations and Rationale
Based on the discussions above, the following policy measures are recommended to address the energy efficiency gap and increase adoption of waste heat technology:

1. Implement a government funding program, at the federal or provincial level, dedicated to fully or partially offsetting the cost of waste heat diversion adoption among industrial companies.

2. Allow existing environmental funding opportunities, such as the Ontario Carbon Trust and the Low Carbon Economy Fund, to explicitly include waste heat technology capital costs as eligible costs for government funding and rebates.

3. Maintain a stable, predictable, increase in the price of carbon over time in Canada.

4. As part of the Community Energy and Emissions Plan and Bayfront Industrial Area Strategy, the City of Hamilton should review municipal policy and procedures to eliminate any barriers for increased resource sharing between properties; placing specific focus on regulations surrounding easements and the installation and maintenance of sharing infrastructure.

5. As part of the Community Energy and Emissions Plan and Bayfront Industrial Area Strategy, the City of Hamilton ought to commit to and set a specific, concrete target for district energy uptake in Hamilton and establish a structure to ensure relevant municipal departments collaborate on the set target.

6. The City of Hamilton should formally review how they could leverage city assets, like land and public buildings, for district energy installations or connections.

7. The City of Hamilton should review the green city bond framework used in other cities, like Toronto, and create a local green bond program to fund environmental capital projects, such as waste heat technology adoption, in the City of Hamilton.

8. As part of the Ontario Energy Board's next Demand Side Management (DSM) Framework for Natural Gas Distributors, consider additional funding through the Province of Ontario to provide further incentives for DSM projects, leveraging the existing program structure, relationships, and expertise.

9. Allow carbon credits for providing waste heat that in turn enables the offset of carbon-based fuels — the credits should accrue to the *supplier* of the energy not the user of the energy.

Allow carbon credits for providing waste heat that in turn enables the offset of carbon-based fuels.

It should be noted that these policy recommendations serve a number of important ends. The increase in waste heat diversion technology serves to:

1. Reduce fuel consumption, lower GHGs, and fight climate change.

2. Reduce costs for firms.

3. Improve firm efficiency.

4. Provide a competitive advantage to the region that cannot easily be replicated elsewhere without similar waste heat infrastructure, heat sources, and incentives.

Put simply, policy measures to encourage waste heat diversion offer environmental and economic benefits.

Sources

Jaffe, A. B., Newell, R. G., & Stavins, R. N. (2004).
Economics of Energy Efficiency. Encyclopedia of Energy, 2, 79-90.

Canada's Ecofiscal Commission (2016).
Choose Wisely: Options and Trade-offs in Recycling
Carbon Pricing Revenues.

Newell, R., Pizer, W. and Raimi, D. (2012).
Carbon Markets: Past, Present, and Future. Annual
Review of Resource Economics, 6(1), pp.191-215.

OECD. "Glossary of Statistical Terms."
OECD Statistics Portal, 2001.

Government of Canada. "Pricing carbon pollution from industry."
Canada's Climate Plan, 2019.

Government of Canada 2. "Pricing carbon pollution from industry."
Canada's Climate Plan, 2020.

Government of Ontario. "A Made-in-Ontario Environment Plan."
Protecting Our Environment. 2018.

City of Hamilton. "Community Energy Plan." Priority Projects. 2020.

EU, Paardekooper, S., Lund, R. S., Mathiesen, B. V., Chang, M., Petersen, U. R., Grundahl, L., David, A., Dahlbæk, J., Kapetanakis, I. A., Lund, H., Bertelsen, N., Hansen, K., Drysdale, D. W., & Persson, U. (2018). Heat Roadmap Europe 4: Quantifying the Impact of Low-Carbon Heating and Cooling Roadmaps. Aalborg Universitetsforlag.

UNEP. 'Unlocking the Potential of Energy Efficiency and Renewable Energy'.
DISTRICT ENERGY IN CITIES. 2015.

City of Toronto. 'Green Debenture Program'. 2020.

Ontario Financial Authority (OFA). 'Province of Ontario Green Bonds'.2020.

City of Hamilton, B. "Bayfront Industrial Area Strategy".
Planning a Community. 2020.

Ontario Energy Board (OEB). "Demand Side Management Framework for Natural Gas Distributors (2015-2020)". 2014.

RECOMMENDATIONS

PROJECT RECOMMENDATIONS

1. Form a voluntary committee tasked to advance the recommendations set out in this report — the Hamilton Chamber of Commerce should advise on a fit-for-purpose structure.

2. Leverage the partnership network established through this project to share the report highlights and recommendations with a range of audiences for the purpose of attracting interest, involvement, and investment. Existing communication channels, events and publications should be considered in the development of a communication plan.

3. Continue to interact with participating manufacturers with a view to advance the select waste heat recovery opportunities cited in this report.

4. Engage multiple stakeholders to develop a funding proposal for a local demonstration project(s) that would feature new and emerging technologies and systems, and highlight Hamilton's industrial waste heat advantage.

5. Help initiate professional engineering studies recommended in this report, including a study by a specialized firm to evaluate the feasibility of an industrial waste heat line running from Hamilton's Bayfront Industrial Area to the city's downtown centre.

6. Continue to secure specialized assistance from McMaster University (Faculty of Engineering, W Booth School of Engineering Practice and Technology, Institute for Energy Studies, etc.) to act on recommendations cited in this report related to research and development, modelling and mapping, education and training, etc.

7. Continue to work with stakeholders leading the development of Hamilton's Bayfront Industrial Strategy to advance the adoption of smart energy systems and related infrastructure necessary to capitalize on industrial waste heat recovery and reuse.

8. Continue to work with the team leading Hamilton's Community Energy and Emissions Plan to incorporate industrial waste recovery opportunities, particularly related to increasing local demand for district energy.

9. Work with the development sector — industrial, residential, and commercial — and members of its supply chains to promote the benefits of smart energy systems, including district energy.

10. Enlist the aid of the Hamilton Chamber of Commerce and other organizations to advance the policy recommendations set out in this report.

11. Work with the Hamilton Industrial Environmental Association and other sector organizations to engage additional companies across Hamilton's Bayfront Industrial Area to unlock waste heat recovery and reuse opportunities.

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