INNOVATION AWARD
International District Energy Association

District Heat Recovery (DHR) Plant
Toronto, Ontario, Canada

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Statement of Confidentiality

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Executive Summary – In 700 words or less, summarize the project/program, demonstrating the key aspects of what was done and the overall benefits:

Enwave is a leading provider of innovative, sustainable energy services. Enwave owns and operates district energy systems (DES) serving heating and cooling customers in downtown Toronto, Ontario, Canada. Enwave provides cooling to buildings year-around, servicing chilled water to downtown data centers and server rooms, running at or above a cooling load of 10,000 tons (or 120,000 MBH) all year-round. The “waste” heat from these customers was identified by Enwave as an opportunity to significantly reduce carbon emissions and further optimize their DES.

Enwave’s innovative District Heat Recovery (DHR) projects use the existing chilled water system as a heat source, capturing the waste heat through either locally or centrally located heat pumps. A localized heat pump would service the building in which it was installed, and a centralized hot water (HW) plant can serve many customers along the existing distribution line.

In comparison to a “standalone” heat pump installed in a building, which limits the heating capacity to the amount of waste heat/cooling load from the site, the district-connected heat recovery option allows customers to source as much low carbon waste heat as they desire, facilitating significant carbon impacts.

Enwave currently has two “central” plants which operate and employ DHR, including:

  **DHR Plant 1:** Three installed heat pumps connected to the DHR, adding a total of 16,500 MBH of low carbon capacity to this HW plant.
  **DHR Plant 2:** One installed heat pump connected to the DHR, adding a total of 3,000 MBH of capacity to this HW plant.

For these district-connected plants, chilled water returned from customers is the heat source, varying in temperature between 52°F and 56°F depending on season. The district-connected heat pumps in both plants produce 135-140 °F HW, while simultaneously producing useful cooling between 38 °F and 40 °F. The DHR can be used as baseload heating, where high-grade heating can be added to meet peak demand periods (usually by steam-to-HW), or as “full” heating, where heat pumps modulate in reaction to demand.

This concept has been applied successfully at both central heating water plants. A “local” plant is under construction at a customer site (a healthcare facility), where a 150-ton heat pump will produce at least 50% of the annual heating consumption of the site, with steam used for peak operation. Enwave is actively developing a project to increase district heat recovery at the Pearl Street Energy Centre through the construction of a building addition to house a 3,600 ton / 59,000 MBH high temperature (approximately 170 °F) district heat recovery plant that will reduce carbon emissions from the associated heating water network by up to 75%.

In 300 words or less, explain how the project/program is innovative and unique:

In order to reduce carbon emissions, electrification of heating is essential. In all but very specific energy markets, implementation of electric boilers to replace gas infrastructure is challenging both commercially (due to electrical utility costs) and technically (due to electrical utility constraints). Heat pumps, which leverage a heat source to multiply output and reduce electrical demand are an obvious
District Heat Recovery (DHR) Plant

solution, and water-source heat pumps are often the most practical option at scale. The challenge with heat pumps is aligning the heat source (typically a coincident local cooling load) with the heat load.

The DHR concept leverages the existing distributed and connected network of Enwave’s cooling customers to effectively share energy, and relieves the local customer from the limits and complexity of a standalone implementation. The central DHR plant allows Enwave to incorporate conventional and cutting-edge technologies at scale, and in combination with other heating sources ensure the maximum utilization of the asset to improve cost of production and to facilitate significant carbon reductions relative to conventional heating plants.

With supporting data, demonstrate the improved energy efficiency benefit offered by the project/program, in 250 words or less:

Using a heat pump system is more energy efficient than traditional natural gas boilers. Both energy efficiency and carbon intensity were analysed to compare natural gas boiler heating with Enwave’s DHR system. A 90% boiler efficiency was assumed for the comparable boiler plant. Energy efficiency was calculated using energy input (kWh) per energy output (mmBtu). For a 90% boiler plant:

\[
\text{KWh/mmBtu Efficiency} = \frac{1}{(90\text{% Boiler Efficiency}) \times 10^6 \text{ Btu/mmBtu}} \times 3412 \text{ Btu/kWh}
\]

\[= 326 \text{ ekWh/mmBtu output}\]

As shown in Table 1, the DHR operation at the both plants shows significantly improved energy efficiencies of 95.8 kWh / mmBTU (or 1.15 kW/ton) and 71 kWh / mmBTU (or 0.85 kW/ton), respectively, compared to the conventional natural gas boiler. The difference in efficiency between the two plants is largely driven by different heat pump types.

In addition, greenhouse gas (GHG) emissions from the two systems were also quantified using the annual energy generated from the DHR plants. The steam equivalent of the heat pump energy output was used to determine total GHG reductions resulting from the DHR project, which is a total of about 4,400 tCO2e per year and equal to about 95% reduction in GHG emissions compared to gas boilers.

Table 1: DHR System Efficiencies

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<thead>
<tr>
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<th>DHR Plant 1</th>
<th>DHR Plant 2</th>
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<tbody>
<tr>
<td><strong>Annual System Energy</strong></td>
<td>227,012 mmBtu</td>
<td>22,353 mmBtu</td>
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<tr>
<td><strong>Heating Energy from DHR</strong></td>
<td>60,158 mmBTU (27%)</td>
<td>9,746 mmBTU (44%)</td>
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<tr>
<td><strong>Heat Pump / DHR Efficiency</strong></td>
<td>71 kWh / mmBTU (4,274,239 kWh)</td>
<td>95.8 kWh / mmBTU (933.658 kWh)</td>
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<tr>
<td><strong>Boiler efficiency</strong></td>
<td>326 ekWh / mmBTU</td>
<td>326 ekWh / mmBTU</td>
</tr>
<tr>
<td><strong>% Improvement</strong></td>
<td>78%</td>
<td>71%</td>
</tr>
<tr>
<td><strong>GHG Emission Reductions</strong></td>
<td>3,777 tCO2e</td>
<td>605 tCO2e</td>
</tr>
</tbody>
</table>

Electricity Emission Intensity: 29 gCO2e / kWh (Electricity)
Boiler Emission Intensity: 64,850 gCO2e per mmBtu

There are additional DHR projects in the pipeline, some currently under construction and others development. This includes DHR within our plants and at Enwave’s customer sites. The heat pumps at customer sites will primarily be used to satisfy the respective building’s load. There is a combined GHG reduction of approximately 25,500 tCO2e per year, which equates to an approximate 95% reduction in emissions compared to a 90% natural gas boiler.
**District Heat Recovery (DHR) Plant**

*With supporting data and graphics, explain the financial advantages of this project / program in 250 words or less:*

The DHR utilizes the existing infrastructure to connect to the EDES. In order to illustrate the financial advantages of operating heat pumps over conventional gas boilers, the cost of operating heat pumps under both Ontario’s Class A (lower electricity rate) and Class B (higher electricity rate) electricity pricing structure were analyzed relative to the cost of natural gas.

To assess the financial advantages of DHR for Class A and Class B, the following assumptions were used:

- The electricity cost was based on 3rd party electricity forecast data,
- The heat pump plant can load shed using backup power or traditional heating sources during grid peaks, and
- Market natural gas costs (Enbridge “rate 6” in Ontario) with Federal benchmarks for carbon pricing, without accounting for rate escalation.

Figure 1 below shows the three predicted cost per energy output ($ / mmBtu) for heating water produced by natural gas boilers, heat pump (Class A), and heat pump (Class B). While the figure shows a marginal economic advantages per energy basis for heat pumps in Class B buildings, the project proves to have a significant cost advantage per energy basis for heat pumps in Class A buildings.

The gas boiler is exposed to the Federal benchmark for minimum carbon pricing that is established out to 2030, which causes the cost of gas boilers to steadily increase year over year. Heat pump operations permit reduced cost in 3 ways:

1. Reduced exposure to carbon pricing
2. Leveraging low cost electricity through Global Adjustment avoidance strategy, and;
3. “Free” cooling due to conversion of warm chilled water return to chilled water supply via the heat pump, which is a credit on Enwave’s cooling district.
In 250 words or less, please provide any additional information about the project/program (What challenges did you face? What plans do you have for the future? How did your customer base or community react?, etc.)

The two main challenges have been commercial availability of equipment and control of equipment. Ontario and other jurisdictions place limits on positive displacement refrigerant plants, and especially for a local DHR plant the operating costs of having attended operation would be challenging to overcome. We worked with our vendor partners to establish operating conditions that could satisfy heating requirements using conventional centrifugal chillers.

The second challenge related to control was ensuring that the DHR plants produced acceptable heating temperatures but also acceptable cooling temperatures. Since the DHR heat source is Enwave’s district cooling system, it was essential that the operation of the heat pumps would not negatively impact our cooling customers (for example, by way of a chilled water temperature excursion). Enwave overcame this challenge through working closely with equipment vendors to identify operating ranges, and incorporating significant monitoring elements in order to ensure an accurate understanding of conditions.

There is significant interest in the Toronto market from building owners to achieve their decarbonization targets. As a response to the demand, Enwave is developing a large central DHR plant at the existing PSEC, and developing operating procedures to further leverage existing assets (such as thermal storage) to increase utilization of DHR. Enwave is also actively working with several existing steam customers to integrate large local DHR plants within their existing buildings, and in new developments.
District Heat Recovery (DHR) Plant

1. Please provide 3 to 5 attachments as images, diagrams or photographs in jpeg format with identifying captions

Note: the following captions identify pictures sent in the accompanying attachment.

2. Graphical diagram of the Available Waste Heat in the CHW system.
3. Infographic of the District Waste Heat Recovery System
4. Picture of DHR Plant 2 heat pump installed