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The primary goal of this project is to collect heat from wastewater in a sustainable way, that Utilities Kingston can then use to satisfy their client. To accomplish this, a wastewater heat recovery system has been designed that is compatible with pre-existing systems supplying Queen's university and several surrounding hospitals. The design uses a heat pump system to absorb thermal energy from wastewater and transfer it to clean lake water. This lake water is then used to raise the inlet water temperature being used at the central heating plant above its current ambient temperature. This in turn, increases the efficiency of the overall design and reduces the amount of greenhouse gases that the plant will emit. On top of reducing emissions, the design is expected to reduce energy consumption by up to 20% annually at the plant.

2050 [2].

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The main customers for the system are Queen’s university and Utlites Kingston. Queen’s will make use of the extra heat, and both customers may be involved œ p akÔ e

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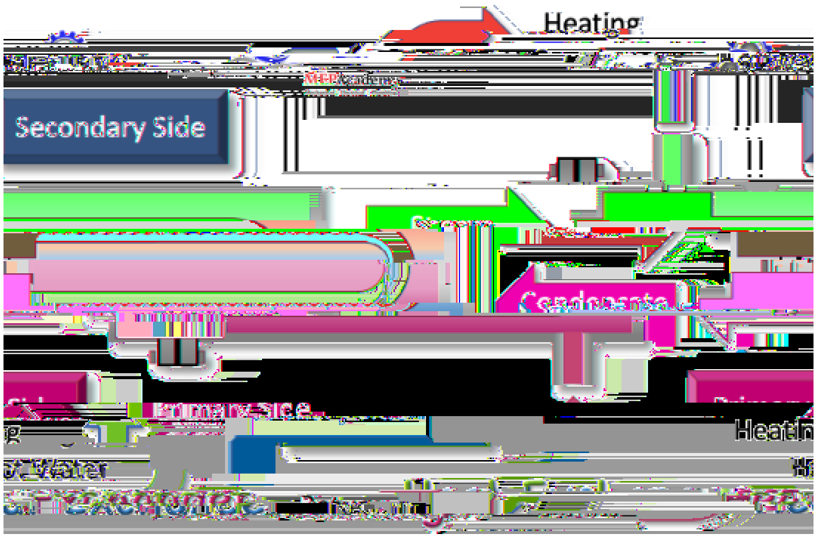
|---|---|
| Powder coating | Coating should be corrosion-resistant with a 10-year lifespan. |

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The second alternative that was considered was applying a commercial-scale heat exchanger system directly to the centralized wastewater line at the Utilities Kingston wastewater pumping station. This model is similar to other large scale heat recovery projects such as the WET system at Toronto Western and the SHARC system, implanted at the Trico LivingWell Retirement community in Calgary (among others). These systems involve a solids pump attached to the wastewater line, leading into a macerator, volume filter and then ran through a large-scale heat exchanger that diverts the energy into the buildings heating system. These systems are proven and have examples in-place that are successful in reducing energy requirements for heating. In Toronto Western's case, the system is projected to account for up to 90% of the hospitals needs [8].

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The goal of this heat pump design is to transfer heat to clean water extracted that is from Lake Ontario from a cold source. Heat will be extracted from the wastewater at the pump sta t on, performance. For this, a detailed analysis was conducted to determine system variables including fow rates, compressor e f ciency etc. More details on the heat pump schema t c, how it will operate with respect to the sources of water and refrigerant, and the types of models considering constraints can be found further in the report.

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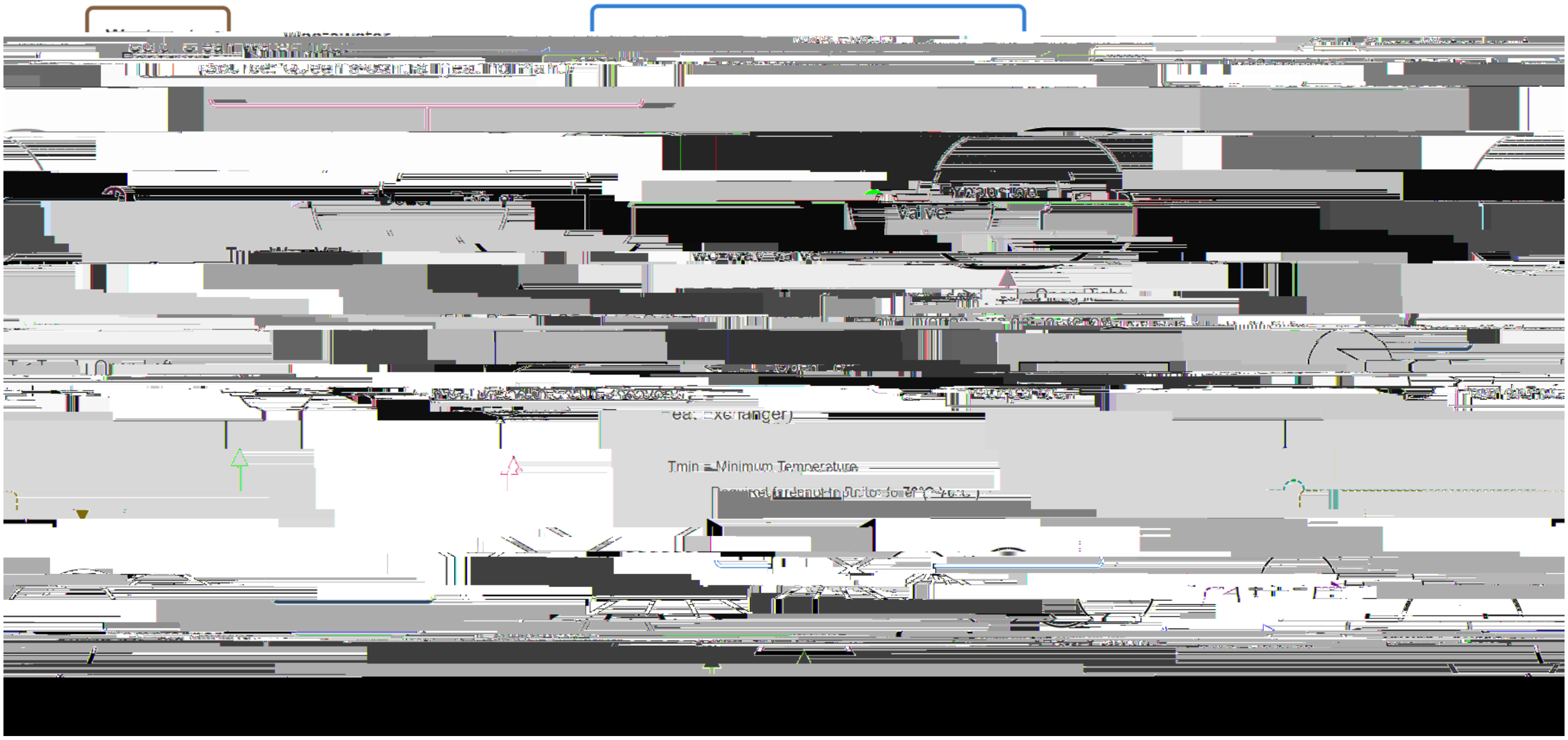


The fnal proposed design includes the use of a heat pump to transfer and extrapolate energy collected from wastewater to then be input into the cold, clean water line that is used to feed the boiler at Queen’s Central Hea t ng Plant. Currently, the boiler input is preheated by a heat exchanger and fow diverted from weekly washout. A two-way valve is used to ensure the heated clean water is of a su f cient grade to make a di f erence in the vaporiza t on process. If the output from the proposed system is not above the minimum boiler input temperature, then the valve and subsequent sensors will divert fow to the washout heat exchanger. Temperature sensors will also be located at the wastewater reservoir to ensure the system is inpu t ng the correct amount of mechanical work to achieve the desired grade. This system ensures that there is zero contact between wastewater and clean water sources, as well as allows for the connec t on of mul t ple inputs (during summer, lake-water can be connected to take advantage of its higher grade).

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The wastewater heat extrac t on and the heat pump compressor were modelled using OpenFOAM in order to con f rm the manual calcula t ons. These components were chosen because they are the main limits on the system's capacity. The heat exchanger used to extract heat from the wastewater is the main limit on how much energy can be extracted. This is because the wastewater pump sta t on output pipes

The compressor was simulated as a rota t ng disc, one meter in diameter, with average pressure inside calculated for various speeds.

Referring to , the shaded area is the Carnot cycle indica t ng the c hange of energy within the system in real-life situa t ons. In theory, the entropy in the low-pressure condi t ons will be maximized, to get the literal maximum e f ciency.

Based on Figure 9, when the pressure of R-134a can be manipulated to 1 bar in the expansion valve and compressed to 20 bar. The saturated temperature within such a pressure will be -27.53 and 67.43 respec t vely, sa t sfying the heat transfer.

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Based on the informa t on given, the daily wastewater f ow in the pumping sta t on is approximately 23,000 , with an average temperature around 16 . In this case, provided that the heat transfer sv M average Ǎ M Ǎ M Ǎ M Ǎ M ض

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|---|---|---|---|---|---|
| Unusual Smell (musty or rotting) | Possibly microorganisms or animals in pipe | 5 | 7 | 5 | 175 |
| Unusual Smell (burning) | Possibly due to serious electrical issues | 10 | 3 | 5 | 150 |
| Piping system failure | It is possibly due to the high pressure of fluid in the pipe, the corrosion, and potential ground movement | 10 | 5 | 3 | |

Heat recovery is most effective during colder months, but this is not an issue because Queen's university has a full student population during the fall and winter terms. The most significant downside of wastewater heating is installing the heat exchanger and pipe system underground. The installation has a high upfront cost for excavation and assembly, and maintenance may require repeated excavation. The summer term, when the system sees less use, provides enough time for inspection/maintenance. However, potential failures during the school year cannot be fixed immediately. Since the heat pump is not the main source of heating for Queen's and is instead used to increase the efficiency of the heating plant, failure would not disrupt university operation. Overall, the heat pump system would be worth the construction cost and help make Utilities Kingston and Queen's more energy efficient.

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[1] N. E. Selin, "Carbon Footprint," Encyclopedia Britannica, 23 September 2023. [Online]. Available: https://www.britannica.com/science/carbon-footprint.. [Accessed 16 October 2023].

[2] "Net-Zero Emissi˝A ne].

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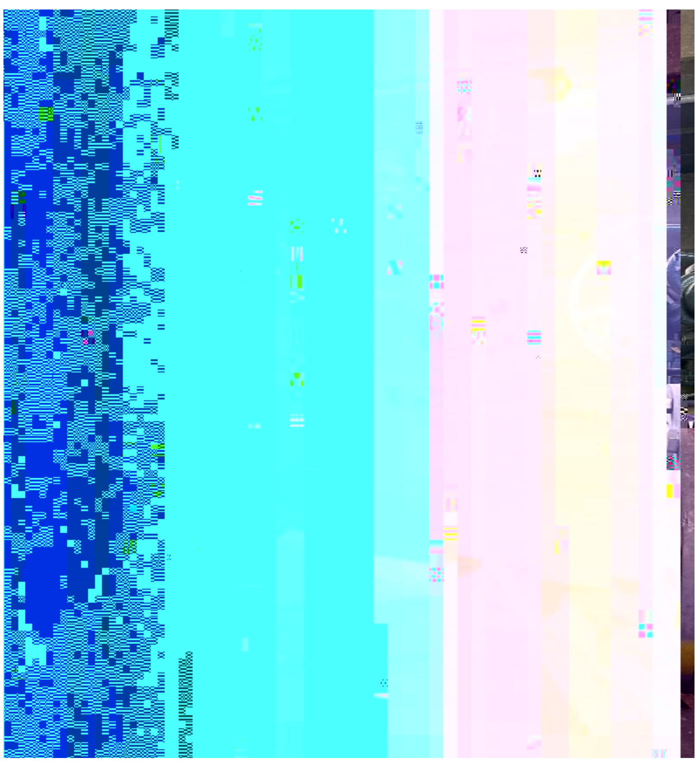

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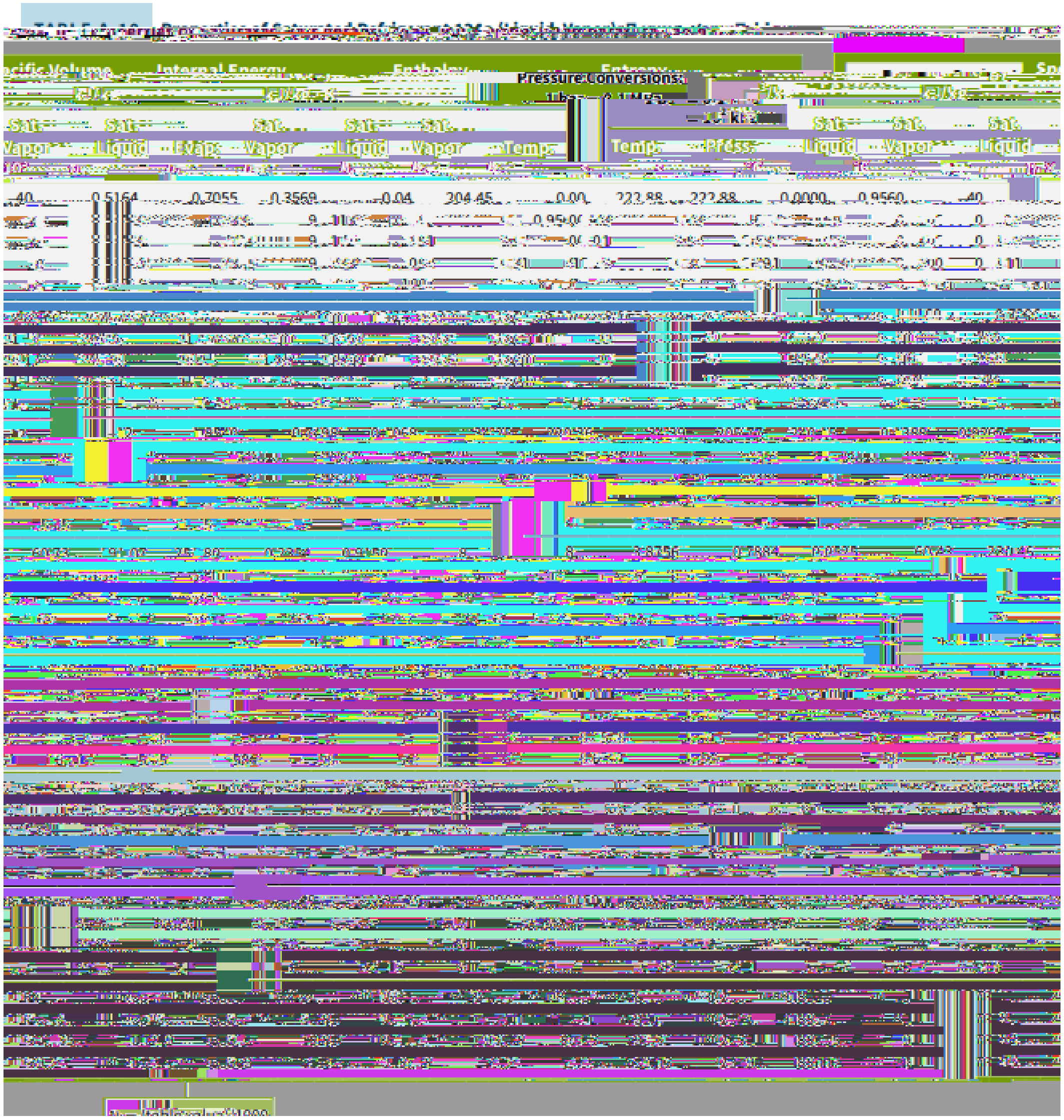

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This sign-off was originally submitted to the "Team 31: Sign-off Sheet: Technical Work and Deliverables completion" dropbox due December 5