LeBreton Flats Wastewater Energy Transfer Study

OCAF Public

Ottawa Climate Action Fund

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Executive Summary

Envari Energy Solutions and Theia Partners were tasked with providing a low carbon heating and cooling solution for a new 600,000 ft2 residential development at the Library Parcel in LeBreton Flats, Ottawa, Ontario. OCAF provided funding for an enhanced study that would assess the potential for wastewater energy transfer (WET) to heat and cool additional development at and around LeBreton Flats.

The Interceptor Outfall Sewer (IOS) is the main trunk sewer carrying effluent that runs under the development site. Hourly sewer flow profiles were analysed and a consistent diurnal pattern was observed. The daily minimum flows were used to ensure the flow rate estimate would provide reliable energy transfer at all hours of the day. Diverted flow from the trunk sewer into the WET system can reliably meet or exceed 365L/s. This total diverted flow could support 6MW to 7.5MW of connected load, approximately three times the 2.25MW requirement for the proposed development at the Library Parcel. The WET technology is viable but reliable flow is the key variable.

In the Canadian market there are two suppliers of WET technologies; SHARC Energy Systems and HUBER Technology. Both SHARC and Huber technologies are suitable for the new development at the Library parcel.

To the immediate west of the parcel there is a City-owned diversion chamber which serves as a connection point to several sewers. The Interceptor Outfall Sewer (IOS), East-West Tunnel (EWT) of the combined sewage storage tunnel, and the Albert Storm Sewer (AST) all run under the north edge of the property. The WET technologies reviewed for his project rely on external heat exchangers. These systems divert a portion of the sewer flows into a wet well or pumping station, process the diverted sewage through an external heat exchanger, and then integrate the sewage back into the existing sewer. Both technologies require equipment to be installed in the wet well as well as inside the building's mechanical space.

The civil requirements for both systems require a wet well to temporarily store wastewater for use by the WET system. Once processed, the wastewater is integrated back into the sewer. Shoring in this location allows for approximately 30-metres of excavation to uncover both the IOS and EWT. Accessing both sewers in the area provides the WET system with redundancy for the periods when flow to this IOS is diverted. A 3-metre diameter wet well would be created between the two existing sewers down to a depth approximately 5-metres below the existing sewers to house the required pumps. A larger capacity WET system would see the same overall design concept for the wet well. The larger WET system would require additional shoring and excavation to create a larger wet well for the larger and/or additional pumps and screens.

Carbon modelling of the proposed development at the Library Parcel as well as the larger 7.5MW WET system was complete. The WET system provides significant greenhouse gas emission reductions and is estimated to reduce the proposed Library Parcel development's emissions by 1,163 tonnes of CO_2e yearly. The total development supported by the larger,

7.5MW, WET system is estimated to reduce greenhouse gas emissions by 4,091 tonnes of CO_2e yearly.

The civil costs are the primary driver for the project outcome. The cost estimate for the 3-metre diameter shoring and excavation required for the proposed development (2.5MW) were +/- $5M. The cost estimate for the larger 6-metre diameter shoring and excavation to support the larger WET system (6-7.5MW) were an additional +/-$1.5M. The economies of scale are significant with this civil work as a 30% increase in costs for the wet well could see a 200% increase in WET system capacity. Carbon savings are substantial for the additional capital cost investment required to support the larger WET system.

The conclusion of the proforma analysis indicates that at a scale of 7.5MW, the business begins to make financial sense, and the cost for the tenants is in line with fossil fuel based solutions. That said, the larger WET system only works if there are customers. Known customers are needed because debt can only be leveraged against revenue streams and revenue is small relative to the front-loaded capital costs in this business. Customers in this case are geographically constrained within a reasonable distance of the wet well as civil costs for pipe infrastructure are very high and in this area the landowners are the City of Ottawa and the NCC.

The City of Ottawa and the NCC are in the best possible position to make mandatory connections for future development to ensure customers for the larger system, thereby achieving the economies of scale for a financially viable scale. Only the City and the NCC can manage the scale and timing risk of when land in this area is developed. Without certainty on future customers, the developer of the wet well can only proceed with the smaller scale system. There will not be an economic means to expand this system in future.

Ultimately, OCAF could play a helpful role in advancing efforts to ensure that economies of scale can be realized and this important environmental opportunity is not missed. That could include pursuing options for external finance of the larger well or mandating future connections.

1 Background

Envari Energy Solutions and Theia Partners were tasked with providing a low carbon heating and cooling solution for new development at the Library Parcel in LeBreton Flats, Ottawa, Ontario. The initial base case study is intended to prove that it is viable and cost effective to build new development in Ottawa, a harsh winter climate, that utilises sewer-coupled heat-recovery chillers to meet its heating and cooling needs. The implementation of this type of system would eliminate the building's reliance on high greenhouse gas emitting fossil fuel-based heating.

Discussions with Ottawa Climate Action Fund, OCAF, outlined the desire for an enhanced study that would assess the potential for wastewater energy transfer (WET) to heat and cool additional development at and around LeBreton Flats.

The project team will conduct technical, financial and emissions analyses to assess the potential and feasibility for WET to be deployed at a larger scale – beyond the library parcel – thereby enhancing GHG reduction potential.

2 Sewer Flow & Capacity Analysis

Sewer flow in the Interceptor Outfall Sewer (IOS) at the proposed development area was estimated based on sewer level data in the Booth-Wellington regulator. This hourly data was collected by the City of Ottawa from July 2021 to July 2022.

2.1 Total Sewer Flow - Daily Profile

The hourly sewer flow profiles follow a consistent diurnal pattern. This pattern is shown in Figures 1 and 2. The total flow in the IOS trunk sewer is shown with the blue line.

When reviewing the data, the daily minimum flows were used to ensure the flow rate estimate would provide reliable energy transfer at all hours of the day. The two selected weeks in January and July illustrate the significant variation when comparing daily maximum and minimum flows.

It should be noted that building peak heating loads often occur in the early mornings which coincides with the lowest sewer flow rates. Conversely, building peak cooling loads often occur in the late afternoons which coincide with the largest sewer flow rates.

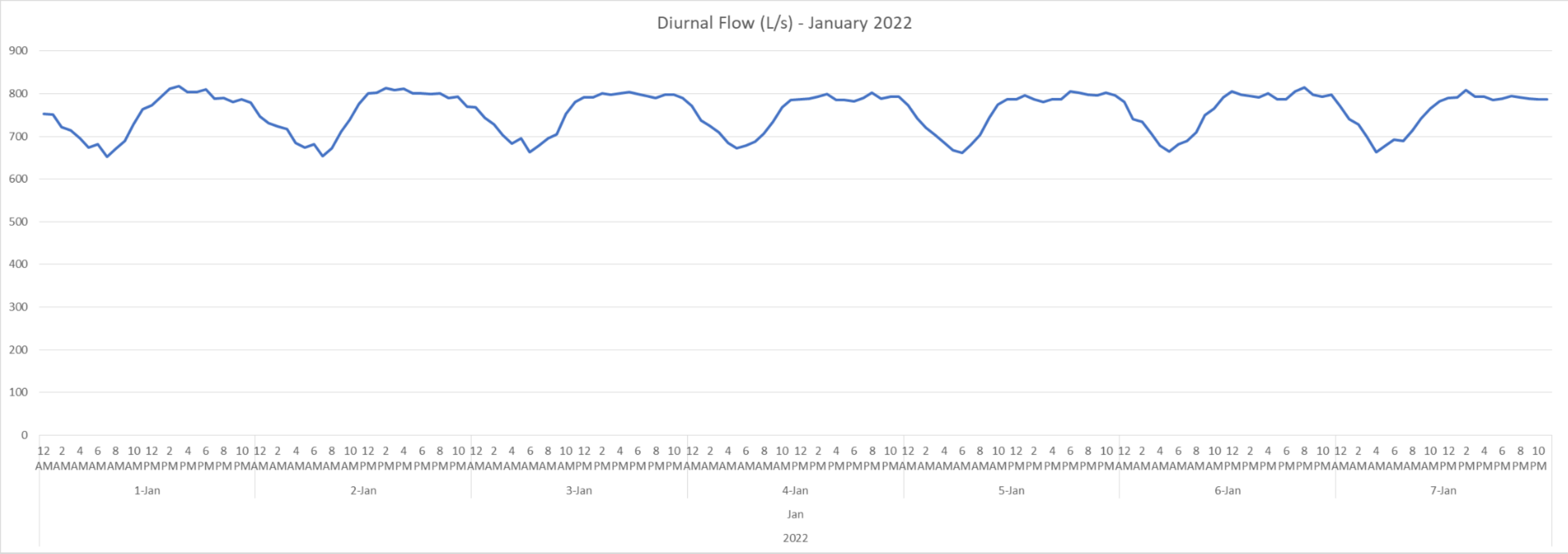


Figure 1: *Diurnal flow of the IOS trunk sewer between January 1st and 7th, 2022*

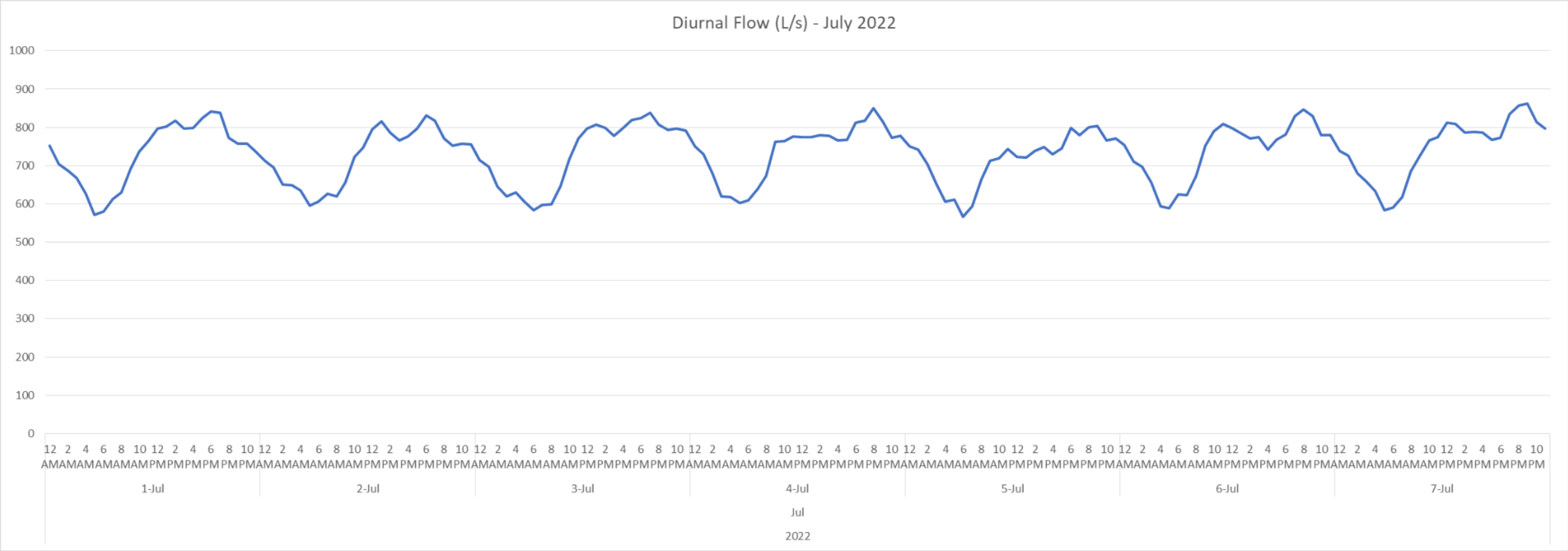


Figure 2: *Diurnal flow of the IOS trunk sewer between July 1*st and 7th, 2022

2.2 Total Sewer Flow - Yearly Profile

From the sewer level data, the flow that could be diverted to a WET system from the IOS trunk sewer with a 1.8m long side weir was estimated for various weir heights. Weir heights of 100mm, 125mm, and 150mm were compared to review the risk-benefit of a lower weir that produces more diverted flow but allows more debris (heavy solids) into the wet well.

The ‘Undiverted Flow’ that remains in the IOS trunk sewer due to the weir is illustrated in Figures 3 and 4. The dark blue area represents the amount of undiverted flow with a 100mm weir height. The small orange and grey areas represent the increase in undiverted flow if the taller weir heights were implemented instead of the 100mm.

The flow that is diverted by the weir represents the flow rate that could be utilised by a WET system. It is represented by the yellow and light blue areas of Figures 3 and 4. This diverted flow would serve the peak capacity of the proposed development and any remaining flow could be provided to additional development or a district energy system.

The current designs for the proposed development indicate that the peak capacity will require 140L/s of flow for the SHARC WET system or a flow rate of 250L/s for the HUBER ThermoWin WET system. The diverted flows that are required for the peak capacity of the proposed development are shown in Figures 3 and 4 as ‘Diverted - 665 Albert - SHARC’ and ‘Diverted - 665 Albert - HUBER’ respectively.

The ‘Diverted Additional Capacity SHARC’ and ‘Diverted Additional Capacity HUBER’ in Figures 3 and 4 represent the excess diverted flow that could be used to generate additional energy capacity if the WET system capacity were increased.

Figures 5 and 6 illustrate the diverted flows only. This representation of the data provides better clarity on the total flow that would be diverted to the proposed development at 665 Albert as well as the additional flow that could be used to generate additional capacity if the WET system was enlarged.

Figures 3 through 6 highlight a few key findings.

- The addition of a weir to prevent debris from entering the WET system greatly impacts the availability of diverted flow that can be used by a WET system. This diverted flow is much less than the total sewer flow and therefore caution should be used when prequalifying WET projects based on total sewer flows.
- The lower flow rate required by the SHARC WET system allows for a higher flow rate to be used in a larger capacity WET system serving additional development or a district energy system.
- There were five periods of time in the year of data where flow in the IOS was diverted into the Combined Sewage Storage Tunnel. These periods of no flow establish the requirement for redundancy to the WET system.

- Diverted flow can reliably meet or exceed 365L/s. This total diverted flow could support 6MW to 7.5MW of connected load, approximately three times the requirements for the proposed development at the Library Parcel.

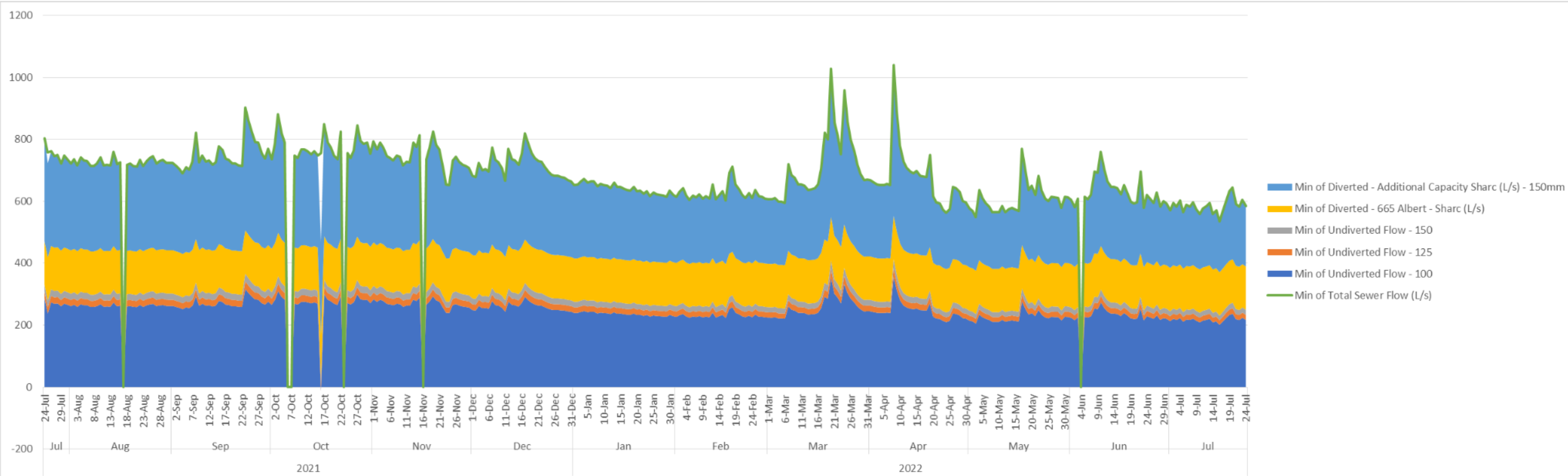


Figure 3: *Undiverted and diverted flows using the SHARC system*

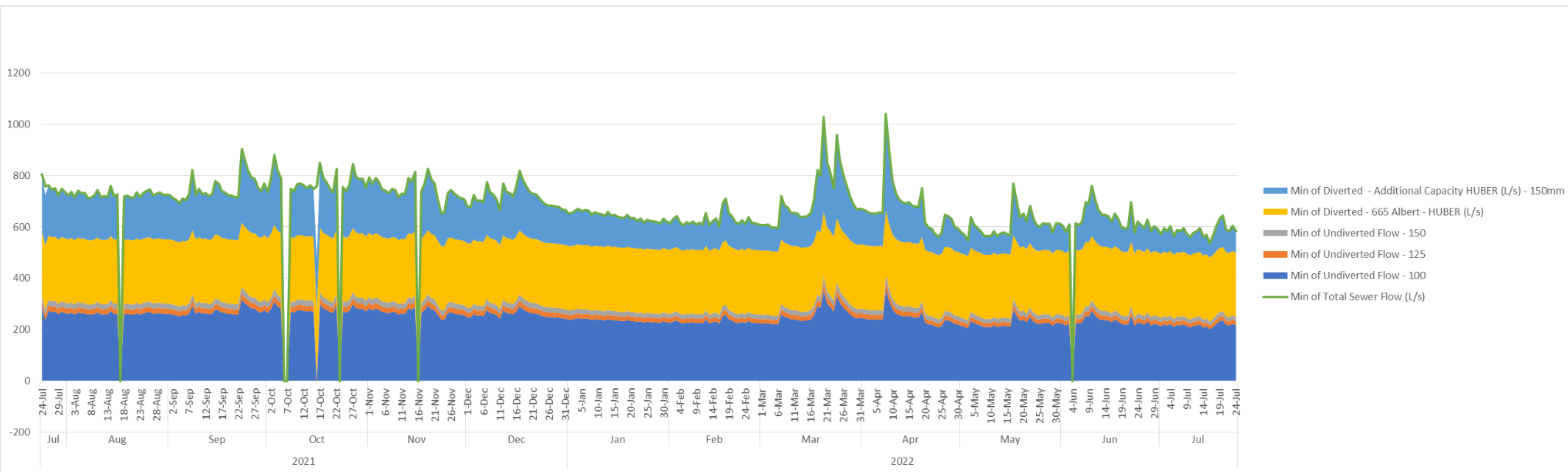


Figure 4: *Undiverted and diverted flows using the HUBER system*

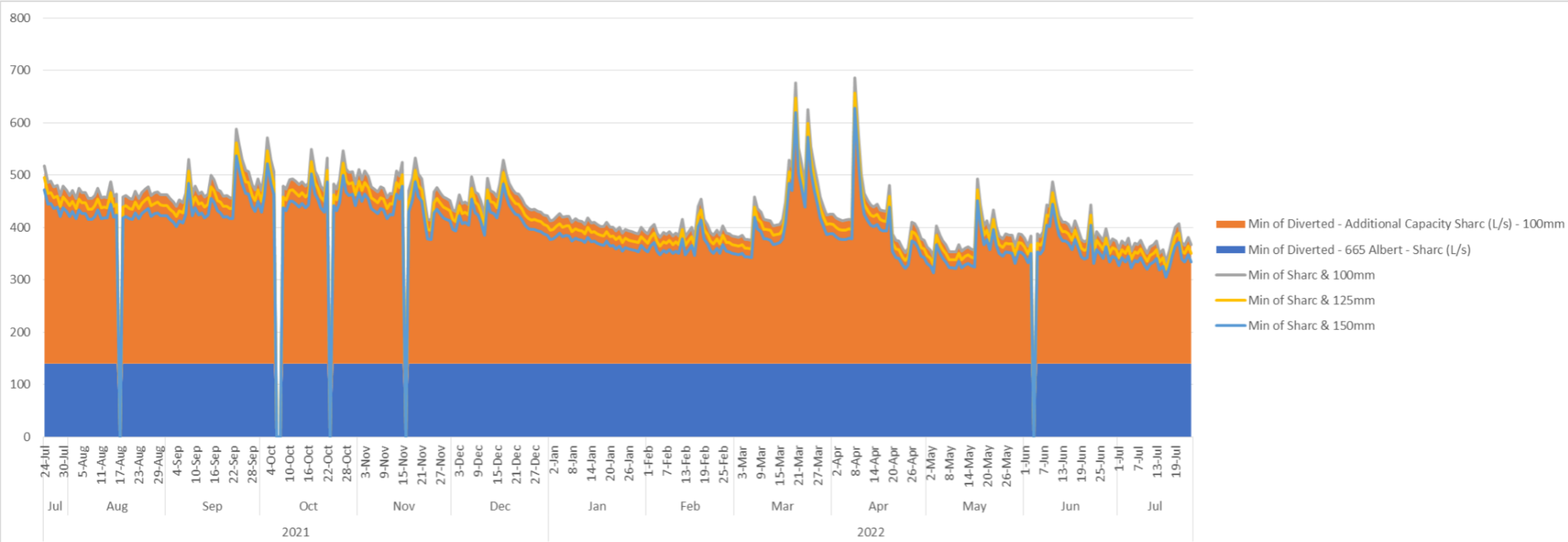


Figure 5: *Diverted flows using the SHARC system*

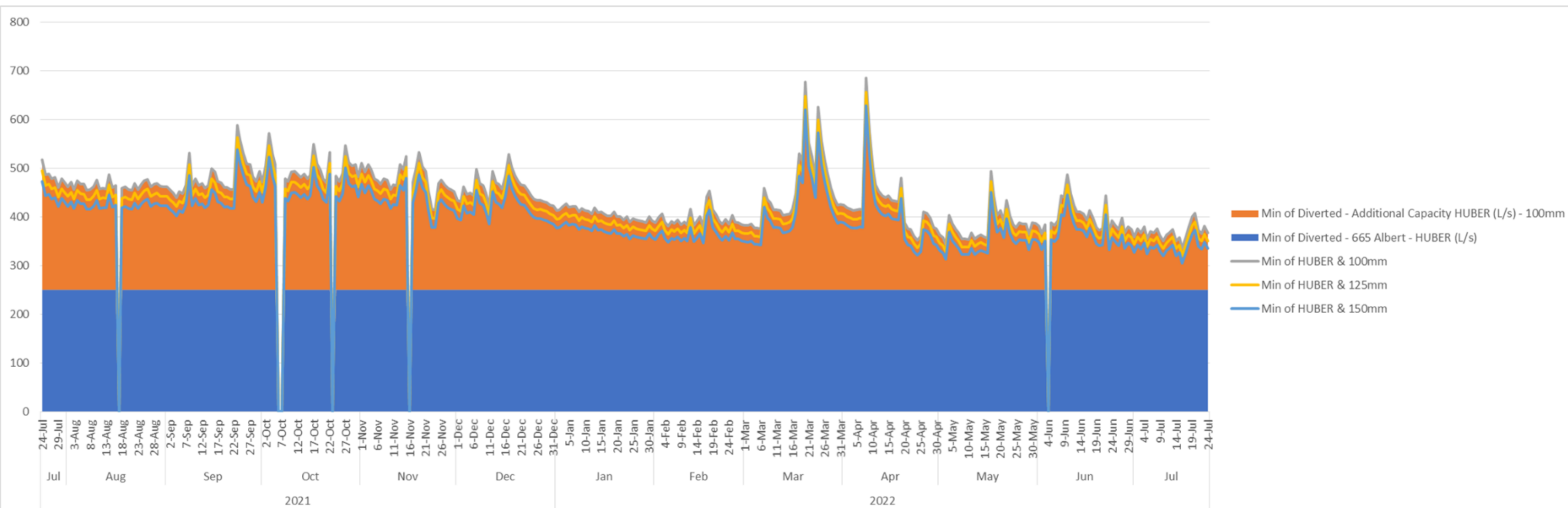


Figure 6: *Diverted flows using the HUBER system*

3 Technology Review

The project reviewed wastewater energy transfer (WET) systems that rely on external heat exchangers. These systems divert a portion of the sewer flows into a wet well or pumping station, process the diverted sewage through an external heat exchanger, and then integrate the sewage back into the existing sewer.

In the Canadian market there are two suppliers of WET technologies; SHARC Energy Systems and HUBER Technology.

3.1 SHARC Energy Systems

An overview of the SHARC Energy System and its technology are provided below.

- Sharc Energy Systems is a Canadian company represented by HTS in the Canadian Market.
- The SHARC Series of products is their industrial-sized product offering suitability for large buildings and district energy applications.
- Requires a wet-well or pumping station to introduce diverted sewer flows to the SHARC system.
- SHARC system macerates sewer flows to a slurry, passes the flow through a proprietary high-volume filter, then uses conventional wide-gapped flat plate heat exchangers to transfer energy to a building process loop.
- A counterflow piping and valve arrangement is used for periodic flushing of the heat exchanger.
- The filtered solids are integrated with the liquids and returned back to the existing sewer infrastructure.
- The SHARC process, operating in heating, is illustrated in Figure 7. The SHARC system can also operate to provide heat rejection from the building process loop when cooling is required.

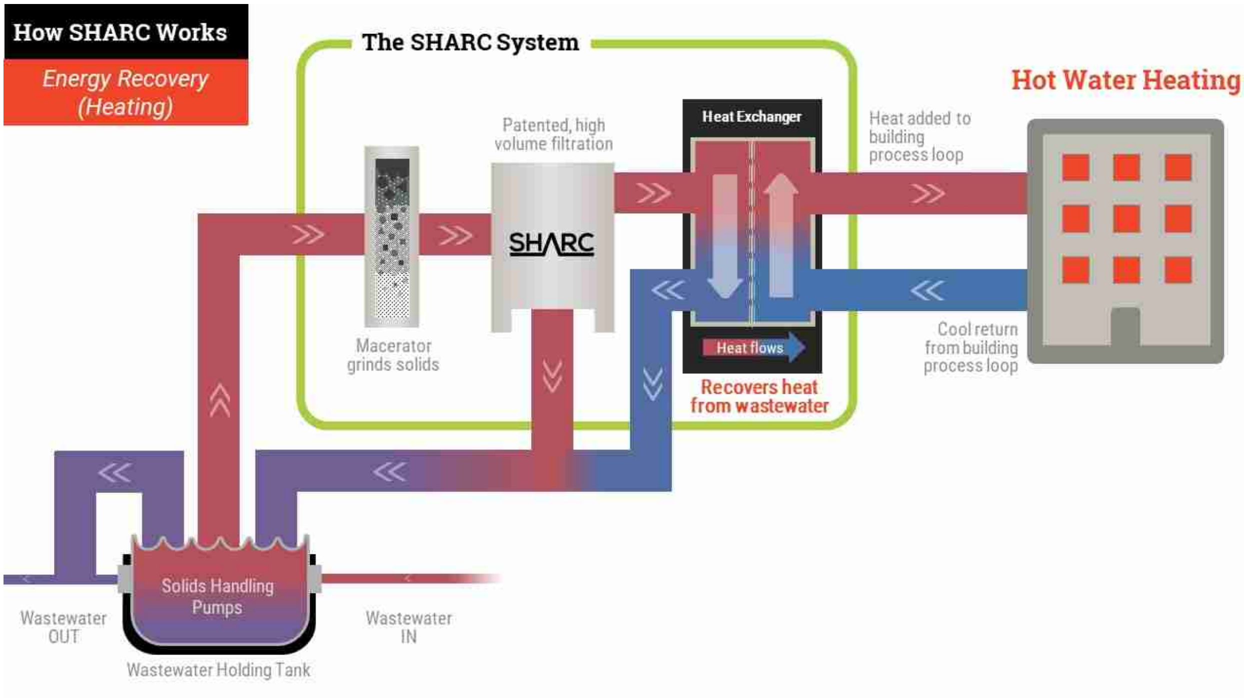


Figure 7: *SHARC System. Process schematic diagram of the SHARC System operating in heating.*[1]

- The building process loop that is tempered by SHARC is coupled with centralised heat recovery chillers or incremental heat pumps to provide finished heating and cooling to the occupied areas.

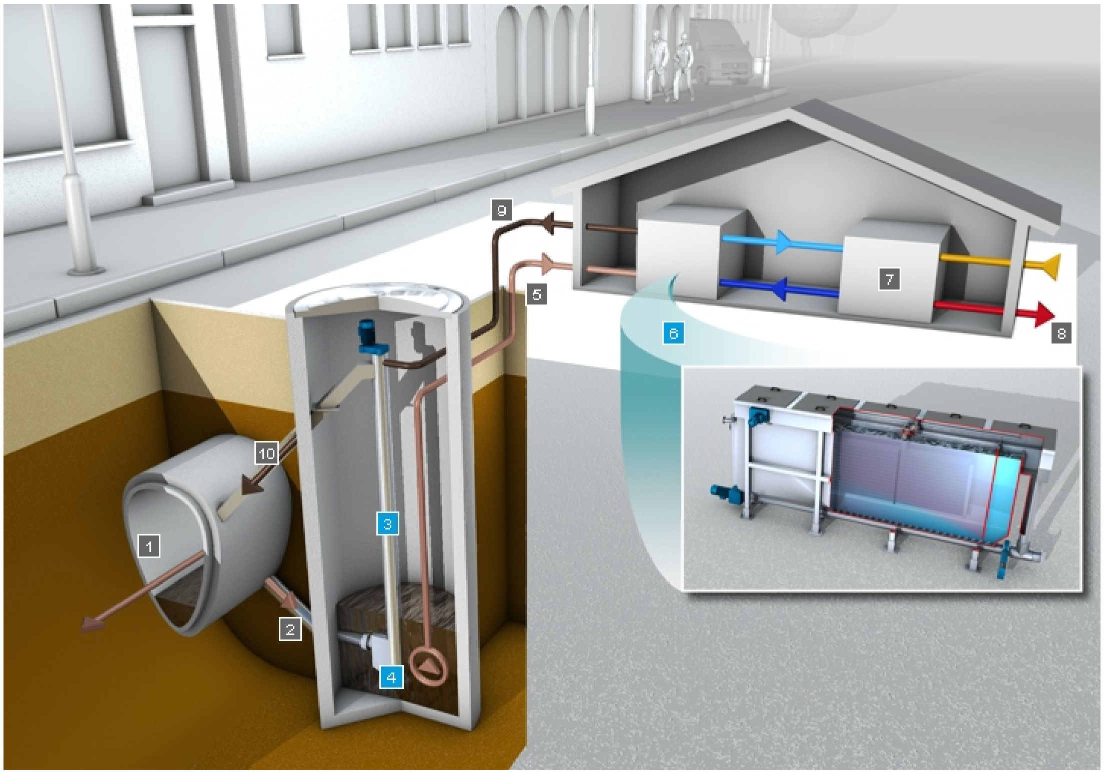
3.2 HUBER Technology

An overview of the Huber Technology system and its technology are provided below.

- HUBER is a German company that is licensed by Noventa Energy Partners in the Canadian Market.
- The HUBER ThermWin system is their industrial-sized product offerings suitable for large buildings and district energy applications. The ThermWin system consists of two major components, the ROTAMAT RoK4 pumping station screen and RoWin heat exchanger.
- Requires a wet-well or pumping station to introduce diverted sewer flows to the HUBER system.
- HUBER system screens the solids from the sewer flows, the screened wastewater is pumped through a proprietary heat exchanger to transfer energy to a building process loop. The screened solids are integrated with the liquids and returned back to the existing sewer infrastructure.
- A proprietary self-cleaning mechanism is used for periodic cleaning of the heat exchanger.

[1] SHARC Energy

- The HUBER Technologies process, operating in heating, is shown in Figure 8 below. The HUBER system can also operate to provide heat rejection from the building process loop when cooling is required.



The Systems Concept

1 sewer
2 sewage outflow
3 ROTAMAT® Pumping Stations Screen RoK 4
4 screen basket RoK 4
5 screened wastewater
6 compact HUBER Heat Exchanger RoWin
7 heat pump (+ heat storage tank)
8 heating water connection to consumers
9 cooled sewage return
10 screenings and sewage return into sewer

Figure 8: *HUBER Technologies System. Process schematic diagram of the HUBER Technologies System operating in heating*[2]

[2] HUBER Technology

- The building process loop that is tempered by HUBER is coupled with centralised heat recovery chillers or incremental heat pumps to provide finished heating and cooling to the occupied areas.

Both SHARC and Huber technologies are suitable for the Dream LeBreton project. In a qualitative comparison, SHARC's largest advantage is that it is a more efficient heat exchanger and therefore requires less total flow to exchange a given amount of heat. This is important in a flow-constrained environment. SHARC is also more compact and lighter, owing to the use of flat plate heat exchangers compared to Huber's shell-and-tube style exchange. However, Huber's system may be more operationally robust. The pumps in the Huber system are ubiquitous in the sewage industry globally and known to work well in the application. This compares to the use of a macerator on the SHARC system, which are prone to high levels of maintenance and clogging. The shell-and-tube heat exchange in the HUBER is also more forgiving with respect to clogging. Lastly, in a tall building application, where building operating pressures exceed 150psi, the SHARC system will require extra heat exchangers to serve as pressure breaks, whereas the HUBER system can be designed for higher pressures. This added equipment increases the cost to the overall system. The technology benefits from each manufacturer should be reviewed on a project-by-project basis to compare the options for WET technologies.

4 Peak Capacity Modelling & Thermal Storage

Energy modelling of the proposed Library Parcel development was used to determine capacity requirements for the proposed WET system. The peak heating and cooling energy requirement for the development was determined to be 2.25MW. Due to a high performing building envelope, the proposed development is very well balanced and the peak heating and cooling loads are the same.

Early design iterations of the proposed development made use of heat recovery chillers in a central plant to provide finished heating and cooling to the building. With this arrangement the design intent was to specify equipment capable of producing subzero temperatures using glycol as a working fluid, and creating ice to reduce summer peak requirements. This would allow a reduction in the Global Adjustment charge for the electricity cost, thereby reducing operating costs of the system. With glycol as a working fluid, the system requires an additional heat exchanger which reduces overall system efficiency below the minimum allowable level on this particular development. In current market conditions the cost increase on custom, large-scale, heat recovery heat pump chillers has climbed dramatically. Current costing on this equipment is approximately twice the cost of equipment procured in pre-pandemic years. Peak capacity and energy modelling for the proposed development using a central plant is shown in Figure 9.

Month	Power (kW)					Energy (kWh)						COP
	Load out Cooling	Load out Heating	Load out DHW	Sewer (source)	Load in Central plant	Load out Cooling	Load out Heating	Load out DHW	Sewer (heating source)	Sewer (rejection)	Load in Central plant	
January	55	2000	487	1846	610	15,628	739,747	157,839	729,326	0	208,100	4.4
February	55	1628	502	1551	474	13,875	615,494	146,816	619,751	0	175,801	4.4
March	854	1484	486	1381	431	23,784	489,814	157,285	518,375	5,184	151,657	4.4
April	1010	858	453	1072	302	47,025	272,407	142,029	310,234	17,465	104,937	4.4
May	1493	523	383	1644	414	197,449	95,158	124,056	97,075	151,313	88,059	4.7
June	1686	326	335	1883	450	340,888	17,554	105,048	9,557	332,278	96,375	4.8
July	1767	176	289	1991	471	401,393	8,001	93,596	1,113	422,861	107,431	4.7
August	1776	246	297	1997	473	384,698	12,649	96,365	5,134	397,374	105,086	4.7
September	1712	473	347	1910	457	230,776	69,657	108,799	63,996	195,699	86,819	4.7
October	1122	727	392	1231	310	64,008	224,908	126,825	250,697	32,031	96,743	4.3
November	289	1077	450	1100	344	15,839	391,301	140,957	425,970	175	126,913	4.3
December	55	1825	468	1652	543	15,318	592,524	151,747	602,566	0	173,395	4.4
Total						1,750,681	3,529,214	1,551,363	3,633,792	1,554,379	1,521,317	Mean
												4.5

Figure 9: Peak capacity and energy modelling for proposed development

The current design iteration for the proposed development will see the WET system provide the necessary heating and cooling to maintain an environmental loop serving the building. Distributed water-source heat pumps will be used in each suite and in the make up air unit to provide the final energy for heating and cooling. This arrangement eliminates the need for the additional heat exchanger however it also removes the ability to create subzero temperatures. The current design will not allow for thermal storage to reduce summer peak requirements.

5 Schematic Designs

5.1 Site Plan

The Library Parcel is located at 665 Albert Street at the intersection of Booth Street and Albert Street. To the immediate west of the parcel there is a City-owned diversion chamber which serves as a connection point to several sewers. The Interceptor Outfall Sewer (IOS), East-West Tunnel (EWT) of the combined sewage storage tunnel, and the Albert Storm Sewer (AST) all run under the north edge of the property. As shown in Figure 10 below, multiple locations on the parcel were reviewed for placement of the wet well. Option 1B (Green) and Option 4 (Red) were deemed most suitable for further review due to proximity to the building mechanical room as well as the size of wet well that could be installed.

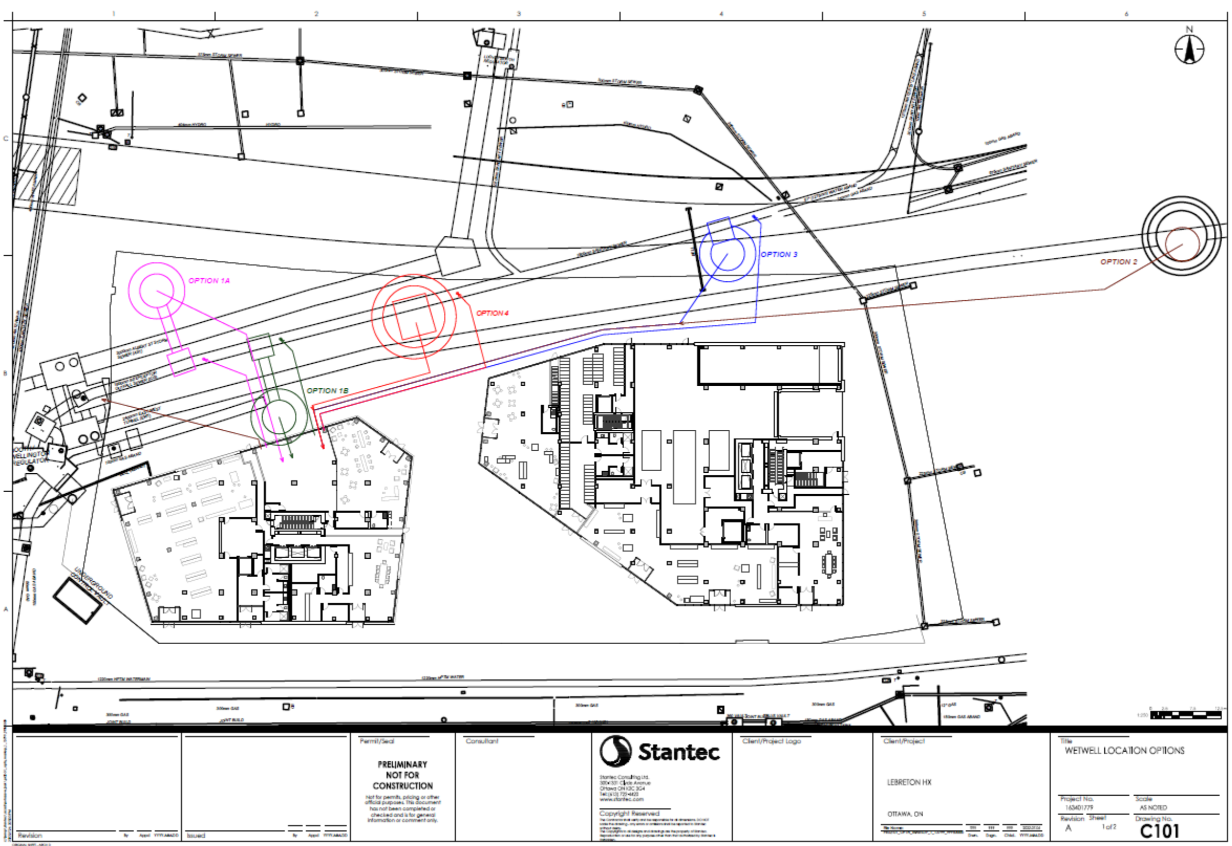


Figure 10: *Potential sites for the proposed wet well*

5.2 Mechanical

The mechanical systems for both technologies require equipment to be installed in the wet well as well as inside the building's mechanical space.

The overall mechanical process flow was described and illustrated in Section 2 of this report.

The preliminary interior mechanical layout drawing (M-1), system schematic (M-2), and wet well mechanical layout drawing (M-3) from HUBER Technologies for the proposed development at the Library Parcel are provided in Appendix A. The proposed system includes two RoK 4 screens installed in the wet well, five RoWin heat exchangers installed in the basement mechanical room, and a total of five heat pumps to serve the heating, cooling, and domestic hot water loads of the building.

A larger capacity WET system serving additional development or a district energy system would require additional pumping and screens in the wet well. The additional flow available is approximately three times that of the flow required for the proposed development at the Library Parcel. The increased pumping and screening requirements for the higher flows does not modify the design concept however it does increase the size and/or quantity of pumps and screens. This additional mechanical equipment leads to the need for a physically larger wet well to support the larger capacity WET system.

Since mechanical space in the proposed development for the Library Parcel is limited, only the space requirements for the additional mechanical equipment in the wet well have been reviewed. All mechanical room space requirements for additional heat exchanger and terminal or central plant equipment to make finished energy have not been included in this review.

5.3 Civil

The civil requirements for both systems require a wet well to temporarily store wastewater for use by the WET system. Once processed, the wastewater is integrated back into the sewer.

The civil design for the proposed development at the Library Parcel was prepared for the location identified as Option 4 on the site plan. Shoring in this location allows for approximately 30-metres of excavation to uncover both the IOS and EWT. Accessing both sewers in the area provides the WET system with redundancy for the periods when flow to this IOS is diverted. A rectangular inlet chamber would connect to both sewers. Actuated gates at the bottom of the inlet chamber would allow wastewater to flow from either sewer into the wet well. A 3-metre diameter wet well would be created between the two existing sewers down to a depth approximately 5-metres below the existing sewers to house the required pumps. See Figure 11 and Figure 12 on the following page for a representation of the proposed civil works.

A larger capacity WET system would see the same overall design concept for the inlet chamber and wet well. The larger WET system would require additional shoring and excavation to create a larger wet well for the larger and/or additional pumps and screens. Due to the location of the existing sewers an oval or rectangular wet well would be created.

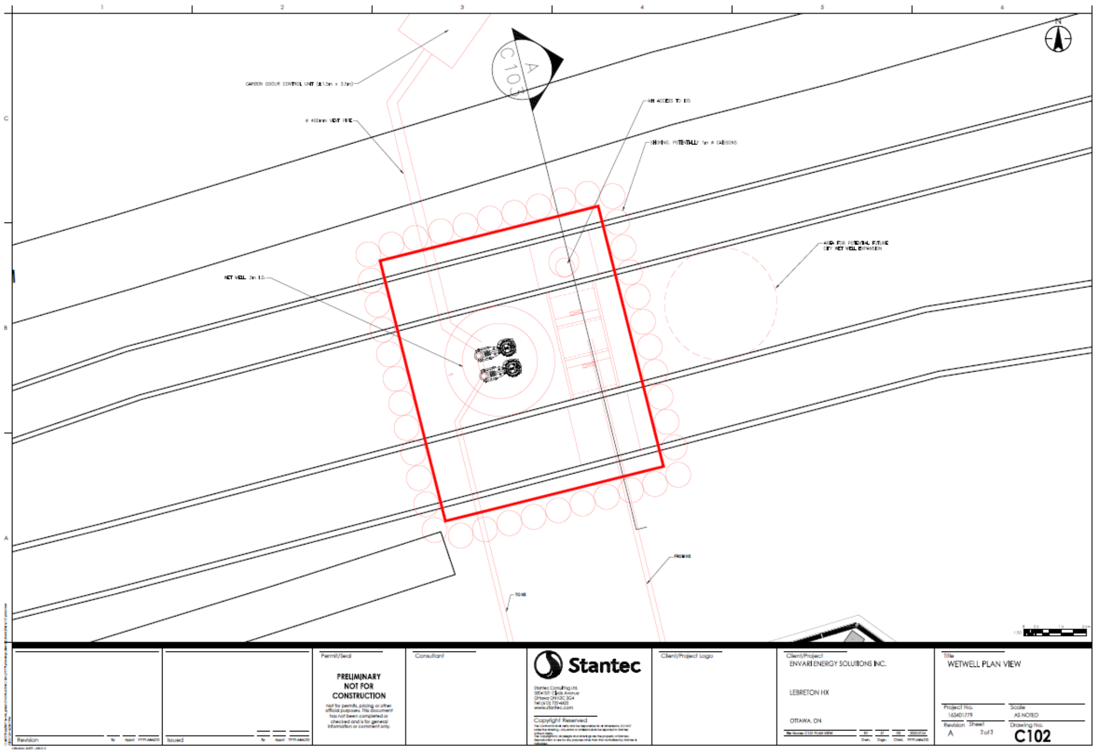


Figure 11: *Proposed location and shoring for wet well.*

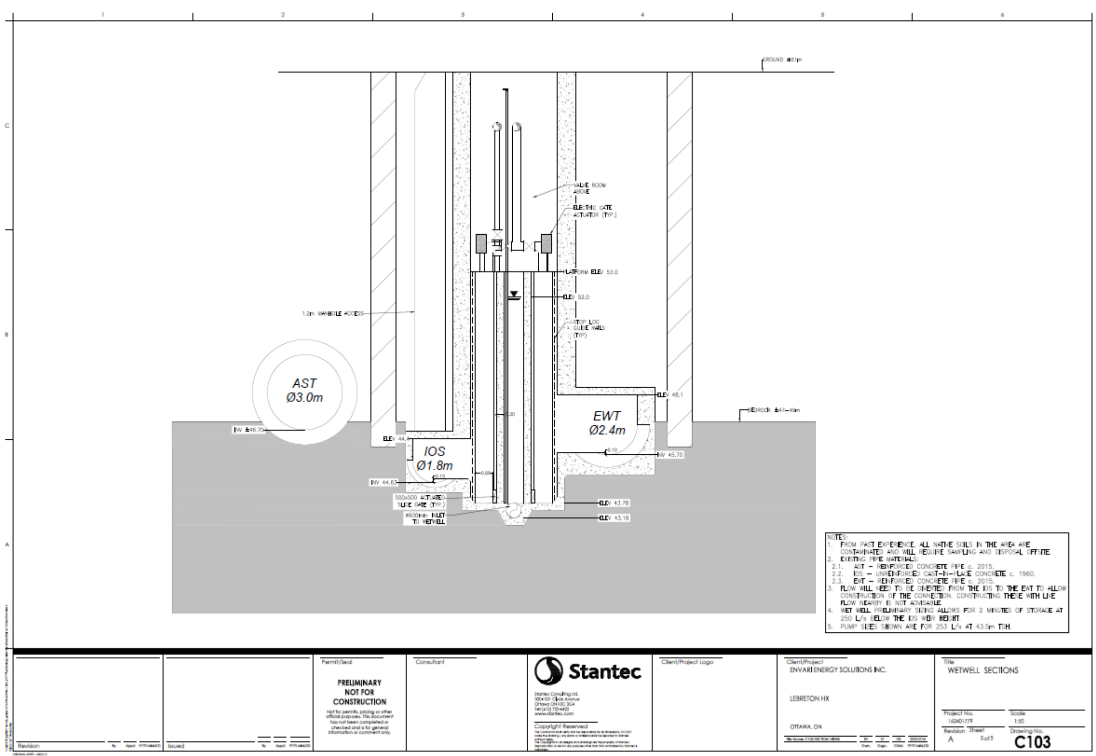


Figure 12: *Proposed inlet chamber for wet well.*

6 Carbon Modelling

Carbon modelling of the proposed development at the Library Parcel as well as the larger 7.5MW WET system was complete.

Greenhouse gas emission savings were determined by comparing business-as-usual (BAU) development against development supported by a WET system. In Ottawa, BAU would see the Customer's building served with gas boilers for heating and domestic hot water production, and a chiller coupled to a cooling tower for cooling.

It was beyond the scope of this study, but it would be interesting to compare the cost of the WET approach to other all-electric models to understand not only a comparison to BAU, but a comparison to a clean option. Each all-electric model would be very unique and have different inputs and efficiencies and therefore requires engineering work. For example, options for Dream are a geo-exchange system, and air-source heat pump system, resistance boilers, chillers and cooling towers. Our very high-level analysis indicates that the WET system, at the larger capacity, will outperform each of those options financially and in carbon in the long-term. However, the analysis is not thorough enough to report.

The WET system provides significant greenhouse gas emission reductions and is estimated to reduce the proposed development's emissions by 1,163 tonnes of CO_2e yearly.

The total development supported by the larger, 7.5MW, WET system is estimated to reduce greenhouse gas emissions by 4,091 tonnes of CO_2e yearly.

The carbon modelling assumptions and calculations are provided in Figure 13.

LeBreton Flats - High-Level Carbon Modelling

Carbon modelling and savings base don 7.5MW wastewater energy transfer

Proposed Connections

		2025	2028	2030
Project Phases		Dream	City/NCC - 1	City/NCC - 2
Gross Area (m2)				
Residential		54,882	56,275	56,275
Retail/Commercial		1,394		

Business as Usual (BAU) - Energy Intensity

These values come from a variety of sources and have been accepted in the BAU calculations for Zibi grants with Hydro Quebec, NRCan, FCM

Residential	Heating	80 kWh/m2/year
	Cooling	25 kWh/m2/year
	Domestic	45 kWh/m2/year
Retail	Heating	48 kWh/m2/year
	Cooling	72 kWh/m2/year
	Domestic	10 kWh/m2/year

BAU - Energy Use per Year

		2025	2028	2030
Heating	kWh	4,457,439	4,502,031	4,502,031
Cooling	kWh	1,472,379	1,406,885	1,406,885
DHW	KWh	2,483,620	2,532,392	2,532,392

Percent Improvement over Energy Code

Dream	30%		
City		0%	0%

Actual - Energy Use per Year

		2025	2028	2030
Heating	kWh	3,120,207	4,502,031	4,502,031
Cooling	kWh	1,030,665	1,406,885	1,406,885
DHW	kWh	2,483,620	2,532,392	2,532,392

COP per system

COP - Heating with Boiler	0.85
COP - WET cooling and heating	4.5
COP - WSHP for DHW	2.25
COP - chiller with cooling tower	4

Actual Energy Required

		2025	2028	2030
BAU	Gas (ekWh)	6,592,737	8,275,792	8,275,792
	m3 of Gas	635,870	798,200	798,200
	Electricity (kWh)	257,666	351,721	351,721
WET	Electricity (kWh)	2,026,247	2,438,600	2,438,600

Emission Factors

Natural Gas	1899.4	grams CO2e/m3
	0.0018994	tonnes CO2e/m3
Electricity	25	grams CO2e/kWh
	0.000025	tonnes CO2e/kWh

Emissions - BAU (tonnes CO2e)

	2025	2028	2030
Gas	1,207.7	1,516.1	1,516.1
Electricity	6.4	8.8	8.8
TOTAL	1,214.2	1,524.9	1,524.9

Emissions - Actual (tonnes CO2e)

	2025	2028	2030
Gas	-	-	-
Electricity	50.7	61.0	61.0
Total	50.7	61.0	61.0

Emissions Savings (tonnes CO2e)

	2025	2028	2030
Yearly tonnes CO2e per Phase	1,163.5	1,463.9	1,463.9
As percentage of BAU	-96%	-96%	-96%

TOTAL GHG emissions avoided perpetually from 2030 based on the 7.5MW WET system

4,091.3 tonnes C02e per year, 2030 onwards

Figure 13: Carbon modelling and greenhouse gas emission savings

7 Costing Estimate

The civil costs are the primary driver for the project outcome. An alternative approach to complete the civil works using a sinking shaft method was used to prepare the cost estimates for the proforma. The cost estimate for the 3-metre diameter shoring and excavation required for the proposed development (2.5MW) were +/- $5M.

The cost estimate for the larger 6-metre diameter shoring and excavation to support the larger WET system (6-7.5MW) were an additional +/-$1.5M.

The economies of scale are significant with this civil work as a 30% increase in costs for the wet well could see a 200% increase in WET system capacity.

8 Thermal Utility Review

The additional capacity (3.5-5MW) from a larger WET system could serve as a node in a larger 5th generation district energy system (meaning an ambient temperature 2-pipe loop, where the buildings all do some work). Envari and Theia are very interested in this district energy option, but mandatory connection and bankable market assessment would be necessary. It is likely that the City of Ottawa or NCC, as landlords in the area, would be necessary to impose the mandatory connection. The additional capacity could support 850 to 1200 new apartments.

The additional capacity would provide the partner, City of Ottawa or NCC, the ability to reject or accept heat up to the contracted capacity of 3.5-5MW. The temperature range and flow rates would be specified. The proforma comparison includes the heat exchange with the wastewater but does not include the building to house the heat exchangers. Terminal equipment or central plant equipment to make finished energy is not included.

Based on our experience at Zibi, we can also add a comment about the feasibility of a 4th generation district energy system (sending finished energy in a 4-pipe system) for this location and confirm that it will not be the most cost effective approach given geographical constraints for a “central plant” and the extremely high cost of civil at this time.

Envari also explored the potential for additional customers that are outside of the bounds of ownership of the NCC and the City of Ottawa. The “Good Companions” site, 670 Albert Street, is an opportunity and is slated for intensification for example, and a large landlord (under NDA) to the east of the site, and even a cursory examination of the Elisabeth Bruyere Hospital complex that sits above the flats. Given the civil costs of installing pipes today, the jurisdictional challenges with pipe rights of way, and the relative scale of the proposed WET system, it will be quite challenging to establish a district energy system in this area.

For clarity, we reiterate that both the NCC and the City of Ottawa must be willing participants to enable a district energy opportunity in order to fully exploit the 7.5 MW available in the IOS at this location.

9 Legal

In June 2022, the City of Ottawa and Theia Partners Inc. / Envari Holding Inc. entered into a Memorandum of Agreement (MOA) to formalise the commitment between the parties to pursue the design, construction, operation and maintenance of a Wastewater Energy Transfer (WET) System coupled to the City's infrastructure at the Dream Development located at 665 Albert Street, Ottawa, Ontario.

A Technical Advisory Committee was established in August 2022 to explore the preferred technical solutions and business terms regarding a proposed WET Project culminating in a Term Sheet. The Term Sheet outlines the detailed design and approvals on operations (gates, status, monitoring, etc.) as well as the billing processes and rate structures.

The City of Ottawa and Theia Partners Inc. / Envari Holding Inc. are aligned with their respective expectations and the City of Ottawa will not own or be responsible for any new infrastructure. Similarly, Theia Partners Inc. / Envari Holding Inc. cannot own the wastewater.

This legal work will only proceed if the City is given approval by City Council, and if the project proceeds financially with Dream LeBreton.

10 Additional Stakeholders

Envari and Theia have reached out to the following stakeholders to discuss their interest in the additional capacity from a larger WET system.

- Dream LeBreton is the developer of the Library Parcel and is a key stakeholder in the project as they would contract for the first 2.5MW of capacity.
- NCC and City of Ottawa, as landlords in the vicinity, could develop lands and make use of the additional capacity or mandate connections to future development by others. Discussions continue with both groups to explore their participation.
- Capital Sports Development was approached to discuss the new arena. Ultimately, the timing of that project would not align with the additional capacity from this larger wet well
- Zibi Community Utility consulted as a potential stakeholder
- Landlord (under NDA) , evaluated the feasibility of making use of the additional capacity. The civil costs and complexity to transport the additional capacity to Place de Ville eliminated them as a potential customer.

11 Business Case

11.1 Key Relationships in the Proforma

Envari/Theia (herein referred to as the Supplier) will develop and operate the wet well and the energy transfer between the sewer and the building. The Supplier carries all development costs and development risk. The Supplier is the entity who will enter into a Wastewater Energy Transfer agreement with the City of Ottawa, and will pay the City for the energy exchange. The Supplier will enter into an Energy Services Agreement with Dream (herein referred to as the Customer) to both supply thermal energy in winter and to dissipate thermal energy in summer. The Customer will pay the supplier a Connection Charge to join to the Supplier's system, and will continue to pay a monthly Capacity Charge for the ability to exchange energy.

It's important to recognize that the energy exchange to the sewer is not "finished" energy, meaning that the temperatures are not sufficient to heat and cool the buildings. Rather, heat pumps in the suites will be required to achieve the desired temperatures. This will involve the input of electricity at the suite, and must be factored into the total cost of thermal energy for the tenant. The Customer will own and operate all terminal equipment (heat pumps, air handlers, pumps etc). Therefore, none of these costs are included in the proforma for the Supplier. The Customer, in turn, will pass on a portion of Capacity Charge to the tenants. In a typical building the common element loads for domestic hot water production, common area heating and cooling, and corridor make-up air constitutes about 30% of the total load in a building, and the suites account for 70%. In our analysis we have used this as a way to apportion energy costs to the suites.

For the proforma (forward looking economic model), an assumption of the Connection Fee must be made, and the capital costs, O&M costs, and financing assumptions are input. Financing assumptions have been based on Theia's experience with the Zibi Community Utility, a recently developed district energy system. For modelling efficiency, the proforma models a sale in year 10 at a 13X EBITDA multiple. No such sale is actually contemplated, but the business is stabilised by this point, and the 13X multiple is supported by external evaluations of the Zibi district energy business.

The proforma will then solve for the Capacity Charge necessary to achieve an acceptable return. A quick calculation then allows for an analysis of the cost for each tenant, and a comparison can be made to business-as-usual (BAU). In Ottawa, BAU would see the Customer's building served with gas boilers for heating and domestic hot water production, and a chiller coupled to a cooling tower for cooling. Based on a database of precedent costs, a value of $100 per suite per month is the upper limit of the costs for BAU, although there is a significant range depending on the type of building. For costs beyond $100/suite/month, the Customer may have challenges renting units and may have issues with lenders as it pertains to the project's status of "affordable housing".

Several versions of the pro-forma, containing different assumptions have been run, to analyse the opportunity.

11.2 Proforma Results

The cost of constructing the civil infrastructure – building the wet well and the connection to the sewer – is the most important variable in the proforma, followed closely by the amount of ongoing revenue (Capacity Charges) that can be generated. The civil costs are not linear to the capacity of the wet well, but rather the smallest capacity wet well is only marginally cheaper than the largest wet well. We are able to identify that a 200% increase in capacity only increases the construction costs by about 30%. The business is not viable at the smaller scale for this reason, as the resulting costs are simply too high for the tenants. Increasing revenue is critical because debt-service is a challenge in this business as the capital cost is high and ongoing revenue is low. Without a healthy revenue flow, then sufficient debt cannot be raised, which leads to connection costs being too high for the Customer, and therefore the business becomes unviable at the small scale.

The conclusion of the proforma analysis indicates that at a scale of 7.5MW, the business begins to make financial sense, and the cost for the tenants is in line with BAU.

The challenge with this particular site is that the only certain development is Dream's LeBreton project, which will require approximately 2.5MW. Raising capital or debt to oversize the wet well would require certainty of future customers for the additional capacity. In the absence of this, the business is not viable.

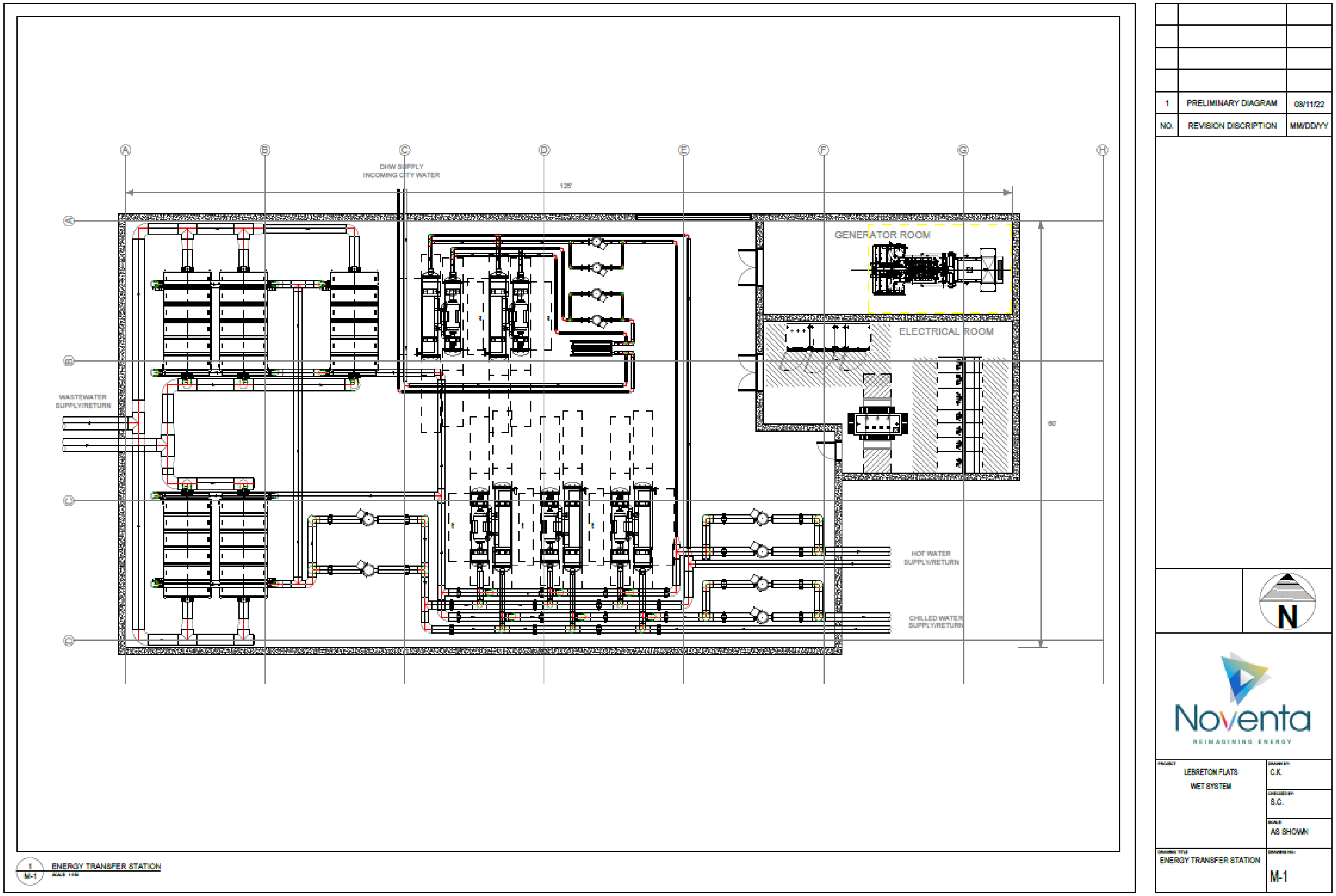
The project's proforma summary, Figure 14, comparing the base case WET system and the larger capacity WET system is shown on the following page. For clarity, these are the assumptions that were used for the development of the proforma are outlined below.

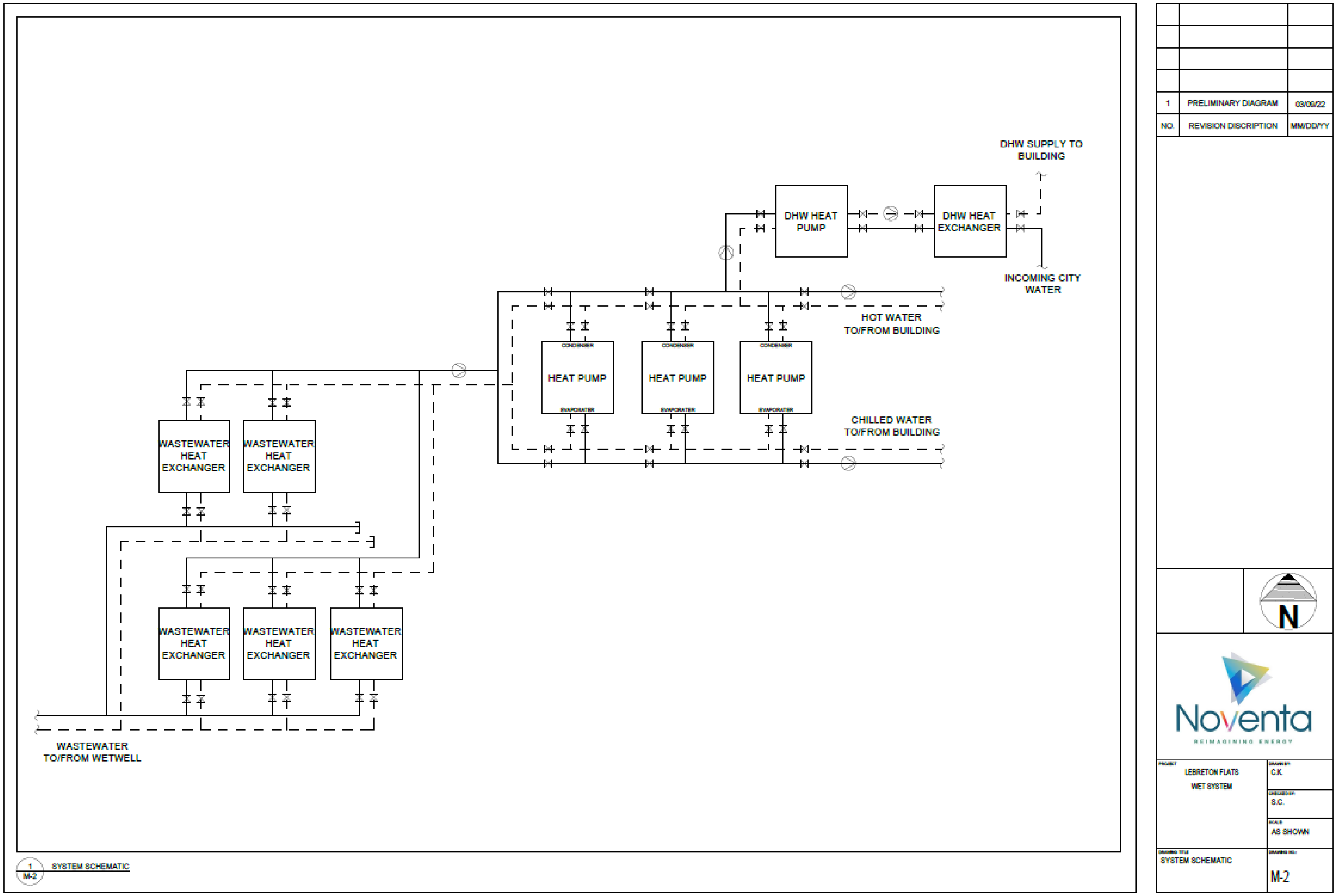
- Model 10 years of operation until 2035, fully stabilised
- Use inflation/discount/debt assumptions as per Zibi Community Utility analysis which are externally audited
- Model a disposition in 2035 based on 13X EBITDA multiple, less outstanding capital investment.
- Base case 2.5 MW – just Dream
- 2nd case 6MW - Dream, then City or NCC, or other for 1.75MW in 2028 and again in 2030
- 3rd case 7.5MW – Dream, then City or NCC, or other for 2.5MW in 2028 and 2030
- Dream pays full connection fee now. City or NCC pays the civil portion of the connection fee now, then the heat exchange portion at time of load.
- NOTE - the sample proforma for OCAF use most closely aligns with the second column from the left, although it has been updated with some additional recent costing information.

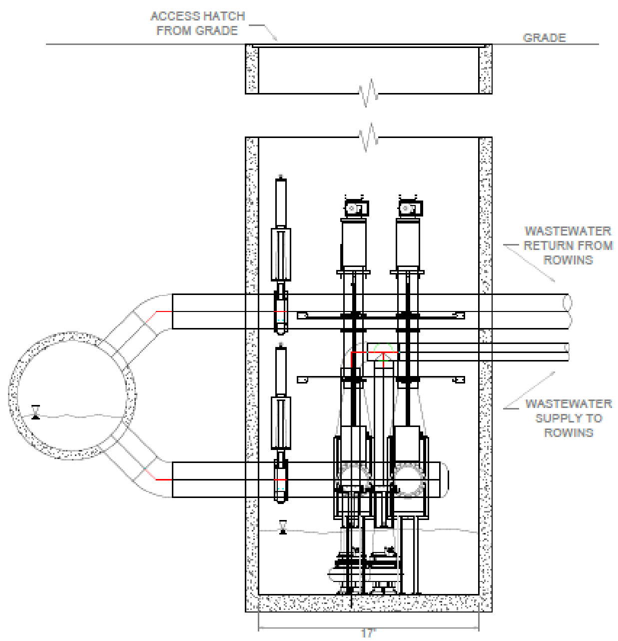
	2.5MW wet well (incl. conting)	6MW wet well (Other gets 3.5MW)	7.5MW wet well (Other gets 5 MW)	7.5MW wet well TARGET	NOTES on Target Outcome
Gross Development Costs	$18,039,950	$23,744,672	$25,018,007	$21,110,976	Find $3.7M through VE, Grants, better financing
Connect Fee per kW capacity	$2,181	$1,938	$1,851	$1,545	
Connection Fees Dream	$6,542,239	$4,846,103	$4,628,700	$4,240,340	at $7/MW
Connection Fees by Others (initial)		$ 3,015,353	$ 4,114,400	$ 3,769,191	
Connection Fees by Others (1st build)		$ 1,884,596	$ 2,571,500	$ 2,355,745	
Connection Fees by parcel builder (2nd build)		$ 1,884,596	$ 2,571,500	$ 2,355,745	
Capacity Charge ($/kW/month)	$ 41.09	$ 27.89	$ 23.45	$ 19.84	want this under $20
Capacity Charge ($ per year) DREAM	$ 1,232,700	$ 836,700	$ 703,500	$ 595,170	
Capacity Charge ($ per year) Other builder		$ 1,171,380	$ 1,407,000	$ 1,190,340	
Modelled Energy Use (kWh)	20,257,000	52,870,770	66,848,100	66,848,100	
Modelled Energy Use (GJ)	72,925	190,335	240,653	240,653	
Annual Cost per GJ	$ 16.90	$ 10.55	$ 8.77	$ 7.42	Only WET - must add "finishing" energy
# suites served	608	1,448	1,824	1,824	
Estimated Cost/Suite/Month	$ 118.27	$ 80.90	$ 67.50	$ 57.10	ideally - down to $50

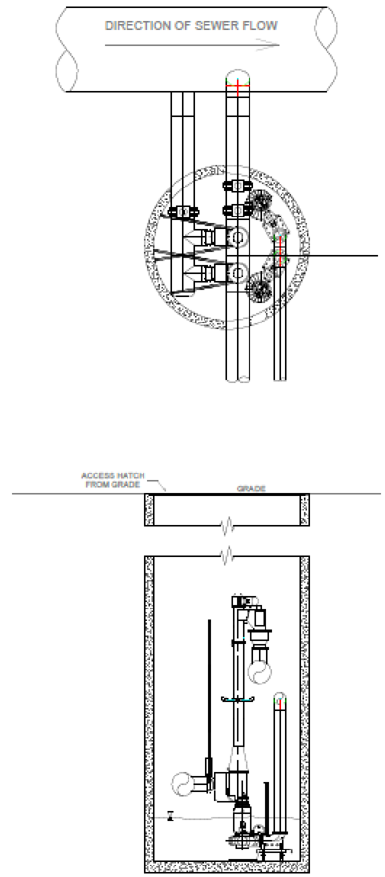
	2.5MW wet well (incl. conting)	6MW wet well (Other gets 3.5MW)	7.5MW wet well (Other gets 5 MW)	7.5MW wet well TARGET	NOTES on Target Outcome
Annual Cost per GJ (WET)	$ 16.90	$ 10.55	$ 8.77	$ 7.42	
Annual Cost to produce finished energy per	$ 6.54	$ 6.54	$ 6.54	$ 6.54	ssume heat pumps in suites and for DH\
Total Cost per GJ	$ 23.44	$ 17.09	$ 15.31	$ 13.96	Gas = $16.82/GJ today for heating
GHG Savings (perpetual tonnes CO2e)	1,164	3,213	4,091	4,091	anually - compared to BAU (gas)
# suites served	608	1,448	1,824	1,824	
Estimated Total Cost/Suite/Month	$ 164.03	$ 131.04	$ 117.83	$ 107.44	ideally - below $100

Figure 14: *Proforma summary comparing the base case WET system and the larger capacity WET system*


DHW SUPPLY
INCOMING CITY WATER
GENERATOR ROOM
ELECTRICAL ROOM
WASTEWATER SUPPLY/RETURN
HOT WATER SUPPLY/RETURN
CHILLED WATER SUPPLY/RETURN
ENERGY TRANSFER STATION
1 PRELIMINARY DIAGRAM 03/11/22
NO. REVISION DISCRIPTION MM/DD/YY
N
Noventa
REIMAGINING ENERGY
LEBRETON FLATS
WET SYSTEM
C.K.
S.C.
AS SHOWN
ENERGY TRANSFER STATION
M-1


DHW SUPPLY TO BUILDING
DHW HEAT PUMP
DHW HEAT EXCHANGER
INCOMING CITY WATER
HOT WATER TO/FROM BUILDING
HEAT PUMP
HEAT PUMP
HEAT PUMP
CHILLED WATER TO/FROM BUILDING
WASTEWATER HEAT EXCHANGER
WASTEWATER HEAT EXCHANGER
WASTEWATER HEAT EXCHANGER
WASTEWATER HEAT EXCHANGER
WASTEWATER HEAT EXCHANGER
WASTEWATER TO/FROM WETWELL
1 M-2 SYSTEM SCHEMATIC
1 PRELIMINARY DIAGRAM 03/09/22
NO. REVISION DISCRIPTION MM/DD/YY
N
Noventa
REIMAGINING ENERGY
LEBRETON FLATS WET SYSTEM
C.K.
S.C.
AS SHOWN
SYSTEM SCHEMATIC
M-2





NOTES:
1 WASTEWATER TO BE EXTRACTED FROM SEWER SLIGHTLY OFF CENTRE TO MAXIMIZE AVAILABLE WASTEWATER AND LIMIT AMOUNT OF SOLIDS EXTRACTED FROM SEWER.
2 ISOLATION VALVES TO BE INCLUDED ON BOTH PIPES BETWEEN THE WETWELL AND SEWER.
3 WETWELL STRUCTURE TO BE LOCATED UNDERGROUND WITH ACCESS HATCH AT GRADE.
4 SUMP PUMP TO BE INSTALLED ON GUARD RAIL FOR EASY REMOVAL FOR MAINTENANCE.
5 BACK FLUSHING VALVE TO BE INSTALLED AT INLET OF ROK4 IN THE UNLIKELY EVENT OF BLOCKAGE.

1 / M-3 WETWELL AND SEWER CONNECTION

2 / M-3 ENERGY TRANSFER STATION

NO.	REVISION DISCRIPTION	MM/DD/YY
1	PRELIMINARY DIAGRAM	03/11/22

Noventa
REIMAGINING ENERGY

LEBRETON FLATS WET SYSTEM	C.K.
	S.C.
	AS SHOWN
DRAWING TITLE: ENERGY TRANSFER STATION	M-3